The Thesis Committee for Benjamin Thomas Breeden III
Certifies that this is the approved version of the following thesis:

Observations on the osteology of *Scutellosaurus lawleri* Colbert, 1981 (Ornithischia: Thyreophora) on the basis on new specimens from the Lower Jurassic Kayenta Formation of Arizona

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

____
Timothy B. Rowe

____
Christopher J. Bell

____
Rowan C. Martindale

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by

Benjamin Thomas Breeden III, B.S.

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May, 2016

Observations on the osteology of *Scutellosaurus lawleri* Colbert, 1981 (Ornithischia: Thyreophora) on the basis on new specimens from the Lower Jurassic Kayenta Formation of Arizona

Benjamin Thomas Breeden III, M.S. Geo. Sci.

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Supervisor: Timothy B. Rowe

Scutellosaurus lawleri is a basal thyreophoran dinosaur from the Lower Jurassic Kayenta Formation, and it is the most abundantly known ornithischian dinosaur from the Lower Jurassic of North America. Despite its abundance in the fossil record, certain aspects of its anatomy have remained poorly understood due to the incomplete nature of the holotype, paratype, and referred specimens. I report here nearly 30 new specimens of *Scutellosaurus lawleri* collected along the Adeii Eechii Cliffs of northern Arizona between 1997 and 2000 by field parties from The University of Texas at Austin. Among this new material are two disarticulated associated skeletons, each preserving anatomy that is poorly known or not previously reported for the taxon, including the nasal, maxilla, lacrimal, postorbital, quadratojugal, squamosal, opisthotic, scapula, and ilium. These specimens have both been compressed taphonomically, making their removal from the surrounding matrix in their field jackets difficult without risk of damage to the fossil bone, so the specimens were CT scanned to aid with preparation. A phylogenetic analysis supports the position of *Scutellosaurus lawleri* as the basalmost member of Thyreophora. New autapomorphies identified include six premaxillary teeth, narrow and elongate frontals, a humerus substantially longer than the scapula, and neural spines of the proximal caudal vertebrae that are greater than 50% taller than the centra.

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INTRODUCTION

Scutellosaurus lawleri (Colbert, 1981) is an ornithischian dinosaur that was initially described based on two fragmentary skeletons collected from the Lower Jurassic Kayenta Formation of the Glen Canyon Group in northern Arizona. Following Colbert's initial description, some additional notes about the anatomy of *Scutellosaurus lawleri* were published on the basis of new material collected during the 1980s that included some elements of the skull that are absent from the holotype and paratype specimens (e.g., Clark & Fastovsky, 1986; Rosenbaum & Padian, 2000). Since then, fieldwork was conducted by several American institutions, and over the course of that work greater than 40 additional partial specimens of *Scutellosaurus lawleri* were collected. With this new material, it is the most abundantly known dinosaur from the Kayenta Formation. Several authors included *Scutellosaurus lawleri* in phylogenetic analyses of Ornithischia based primarily on the original description (e.g., Butler, Smith, & Norman, 2007; Butler, Upchurch, & Norman, 2008) and observations of some of the new undescribed material (Nesbitt, 2011; Boyd, 2012). A list of the phylogenetic definitions for the clades discussed in this thesis is provided in Table 1 and follows Butler *et al.* (2008).

Ornithischia is one of two major clades within Dinosauria, and as such, it is a comparatively popular and well-studied extinct taxon. Despite this popularity, the early evolutionary history of the clade remains poorly understood. Although it was once thought to be well-represented, primarily by isolated teeth and jaw fragments, throughout the Late Triassic (Chatterjee, 1984; Hunt, 1989; Hunt & Lucas, 1994; Heckert, 2002), recent taxonomic revisions (Parker *et al.* 2005; Irmis *et al.* 2007) reduced the number of verifiable Late Triassic ornithischian taxa to three: they are *Eocursor parvus* from the lower Elliot Formation of South Africa (Butler *et al.*, 2007), *Pisanosaurus mertii* (Casamiquela, 1967) from the Ischigualasto Formation of Argentina, and an unnamed heterodontosaurid (Báez & Marsicano, 2001) from Laguna Colorada Formation of Argentina.

Ornithischian fossils are thus rare and fragmentary from the Late Triassic (Figure 1A), and they remain relatively so until the Late Jurassic. Nevertheless, the group diversified and achieved a global distribution by at least the Early Jurassic (Figure 1B), with members of Heterodontosauridae (Crompton & Charig, 1962; Sereno, 2012), Neornithischia (Thulborn, 1970; Thulborn, 1972; Butler, 2005), and Thyreophora (Owen, 1861; Simmons, 1965; Colbert, 1981; Haubold, 1990; Dong, 2001; Norman, Butler, & Maidment, 2007) present in Lower Jurassic strata worldwide. A new basal ornithischian *Laquintasaura venezuelae* was reported from the Lower Jurassic La Quinta Formation in Venezuela by Barrett *et al.* (2014), but the phylogenetic affinities of that taxon are unclear.

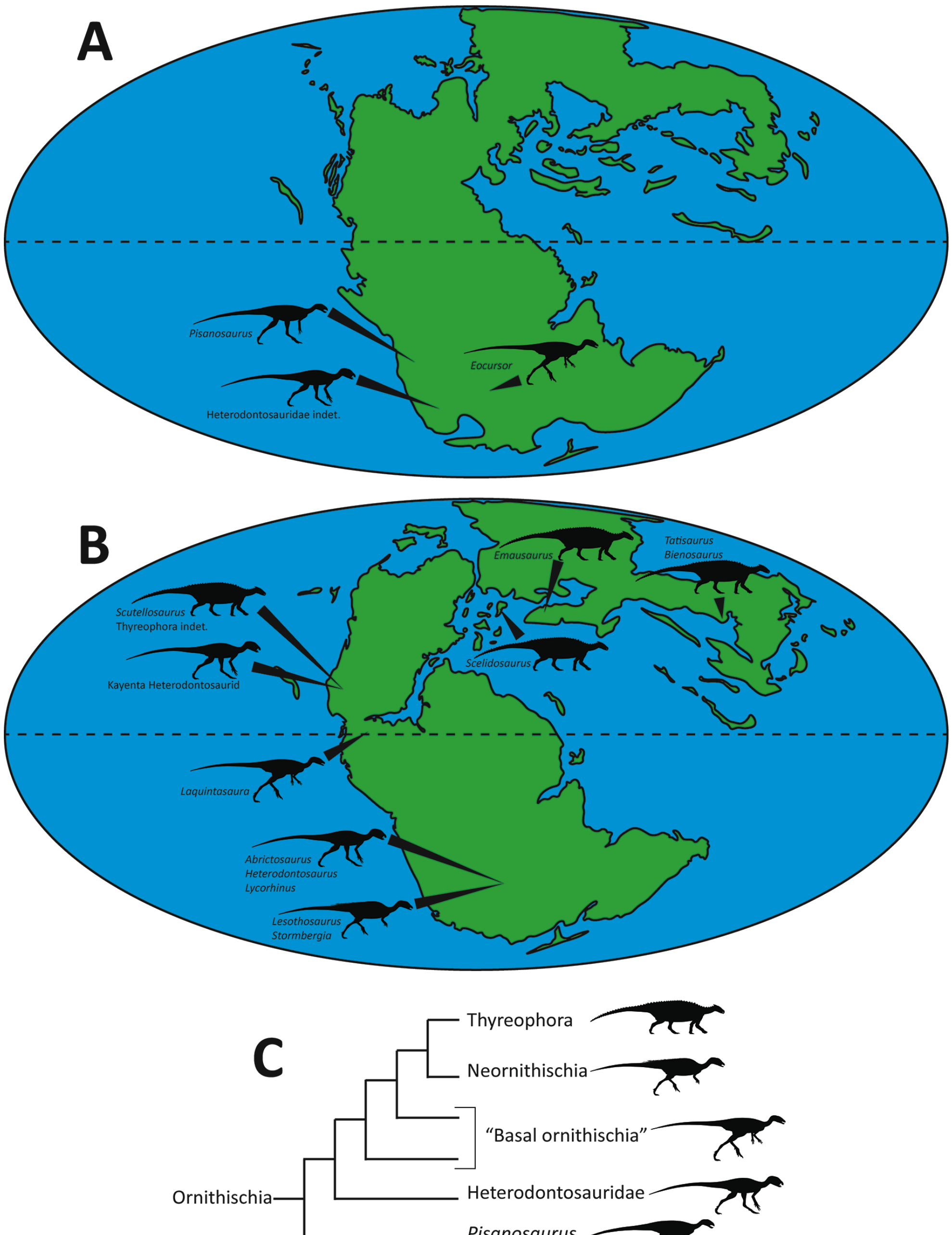

Figure 1. Paleogeographic distribution of reported ornithischian dinosaur taxa from the Late Triassic (A) and Early Jurassic (B) epochs. Generalized phylogeny following Butler *et al*. (2010) depicting the relationships of ornithischian taxa present during the Late Triassic and Early Jurassic (C). Maps modified from Blakey (2008). Black silhouettes by Scott Hartman and adapted from phylopic.org (http://creativecommons.org/licenses/by-sa/3.0/).

Table 1. Phylogenetic definitions for the clades discussed in this study (Modified from Butler *et al.,* 2008).

Clade Name	Phylogenetic Definition of Clade
Dinosauria	The most recent common ancestor of *Triceratops horridus* Marsh, 1889 and *Passer domesticus* (Linnaeus, 1758) and all of that ancestor's descendants.
Saurischia	All dinosaurs more closely related to *Passer domesticus* (Linnaeus, 1758) than to *Triceratops horridus* Marsh, 1889.
Ornithischia	All dinosaurs more closely related to *Triceratops horridus* Marsh, 1889 than to either *Passer domesticus* (Linnaeus, 1758), or *Saltasaurus loricatus* Bonaparte & Powell, 1980.
Genasauria	The most recent common ancestor of *Ankylosaurus magniventris* Brown 1908; *Stegosaurus stenops* Marsh, 1877a; *Parasaurolophus walkeri* Parks, 1922; *Triceratops horridus* Marsh, 1889; and *Pachycephalosaurus wyomingensis* (Gilmore, 1931) and all of that ancestor's descendants.
Thyreophora	All genasaurians more closely related to *Ankylosaurus magniventris* Brown, 1908 than to *Parasaurolophus walkeri* Parks, 1922, *Triceratops horridus* Marsh, 1889, or *Pachycephalosaurus wyomingensis* (Gilmore, 1931).
Eurypoda	The most recent common ancestor of *Ankylosaurus magniventris* Brown, 1908 and *Stegosaurus stenops* Marsh, 1877a and all of that ancestor's descendants.
Stegosauria	All ornithischian taxa more closely related to *Stegosaurus stenops* Marsh, 1877a than to *Ankylosaurus magniventris* Brown, 1908.
Ankylosauria	All ornithischian taxa more closely related to *Ankylosaurus magniventris* Brown, 1908 than to *Stegosaurus stenops* Marsh, 1877a.
Neornithischia	All genasaurian taxa more closely related to *Parasaurolophus walkeri* Parks, 1922 than to *Ankylosaurus magniventris* Brown, 1908 or *Stegosaurus stenops* Marsh, 1877a.

Within the Lower Jurassic Kayenta Formation, *Scutellosaurus lawleri* is the only ornithischian dinosaur that is relatively well known on the basis of several specimens (Colbert, 1981; Rosenbaum & Padian, 2000). An unnamed thyreophoran similar to *Scelidosaurus harrisonii* from the Lower Lias of England was reported from the Kayenta Formation by Padian (1989) but is only represented by isolated osteoderms, and an unnamed heterodontosaurid was reported by Attridge, Crompton, & Jenkins (1985) and was alluded to by Sereno (2012) but remains undescribed.

The phylogeny of Ornithischia only recently started to receive rigorous study. As noted by Butler *et al.* (2008), the majority of phylogenies of ornithischian dinosaurs published throughout the 1980s and 1990s (Norman, 1984; Cooper, 1985; Sereno, 1986, 1999) lacked crucial information for repeatability such as data matrices, specimen numbers, and tree-searching methods. They omitted fragmentary basal ornithischian taxa and/or assumed monophyly of major clades prior to analysis based upon coded supraspecific terminal taxa.

The monophyly of many groups within Ornithischia is well supported, with basal taxa, often consisting of only fragmentary material, taxa typically being the least stable members of these groups. Heterodontosauridae is a group whose position within Ornithischia is problematic. Heterodontosaurids were variably proposed as basal ornithopods (Sereno, 1999), the sister taxon to Marginocephalia (Xu *et al.*, 2006), the sister taxon to Cerapoda (Butler, 2005), and the basalmost clade within Ornithischia (Butler *et al.*, 2008). It remains a problematic group, and there is no consensus on its position; however, heterodontosaurids were also recovered as the basalmost clade within Ornithischia by Boyd (2012).

The global phylogeny of Ornithischia was recently tested with an emphasis on the relationships of basal taxa (Butler *et al.*, 2008). Many groups the authors considered universally accepted as monophyletic were coded as supraspecific taxa in their analysis because the authors claimed that the choice of exemplar taxa is not always obvious owing to a lack of consensus of relationships within these groups. Despite this argument, it was shown by others that the use of exemplar species as terminal taxa increases phylogenetic accuracy relative to the use of supraspecific terminal taxa (Wiens, 1998; Prendini, 2001). Assuming the monophyly of supraspecific terminal taxa effectively locked out purportedly basal taxa from these supraspecific taxa in their analysis. Additionally, certain taxa were excluded if their taxonomic validity was questionable, but the suspected heterodontosaurid BMNH A100 was included despite its uncertain taxonomic affinities and the incompleteness of the specimen.

The monophyly of Thyreophora is well supported. A split within Ornithischia between the unarmored bipedal ornithopods and a novel group comprising the quadrupedal armored ankylosaurs, stegosaurs, and ceratopsians was first proposed by Nopcsa (1915), who coined the name Thyreophora for the latter group. The name Thyreophora largely fell out of use in the literature until it was revived to the exclusion of ceratopsians by Norman (1984) and Sereno (1984) in the first cladistic reappraisals of Ornithischia. In nearly every phylogenetic analysis of ornithischian taxa that followed (e.g., Butler *et al.*, 2005; Butler *et al*., 2010; Boyd, 2012), *Scutellosaurus lawleri* was recovered as the basalmost thyreophoran taxon. Despite having first been described over 30 years ago, certain aspects of the anatomy of *Scutellosaurus lawleri* remained poorly understood, limited by sparse, fragmentary specimens.

The primary goal of this thesis is to provide a comprehensive inventory and examination of all specimens of *Scutellosaurus lawleri* collected from the Lower Jurassic Kayenta Formation in northern Arizona by field parties led by Timothy Rowe of the Vertebrate Paleontology Laboratory at The University of Texas at Austin (TMM) between 1997 and 2000. This period represents the only large-scale collection of vertebrate fossils from the Kayenta Formation in northern Arizona since parties from the UCMP collected during the early 1980s (Clark & Fastovsky, 1986). The TMM field collections resulted in the recovery of approximately 40 specimens of ornithischian dinosaurs. The majority of these new specimens can be referred to *Scutellosaurus lawleri*, but there is fragmentary evidence of other ornithischian taxa present in the Kayenta Formation among these specimens. These specimens are compared to the ornithischian material already described from the Kayenta Formation by Colbert (1981), Padian (1989), and Rosenbaum & Padian (2000).

The second goal is to review and provide additional comments on the specimens of *Scutellosaurus lawleri* already reported in the literature by Colbert (1981) and Rosenbaum & Padian (2000). These comments are based on novel, firsthand observations of the holotype and paratype specimens of *Scutellosaurus lawleri* reposited at the

Museum of Northern Arizona (MNA) in Flagstaff, AZ and referred specimens reposited at the University of California Museum of Paleontology (UCMP) in Berkeley, CA.

This work fills several important gaps in our knowledge of the skeleton of *Scutellosaurus lawleri* and addresses several controversial points in its interpretation. Until now, little of the skull was known. Over the last three years, mechanical preparation and computed tomographic scanning of several newly collected specimens at the Vertebrate Paleontology Laboratory at The University of Texas at Austin revealed far more of the skull than was previously known. This new information fills many unknowns in systematic analyses aimed at understanding basal ornithischian relationships. In addition, there is debate over the maturity at time of death of the published material (Padian, Horner, & de Ricolès, 2004). This survey of nearly all known material offers additional insight into the growth of *Scutellosaurus lawleri*, into the maturity at time of death of the various specimens, and into the general demographics of the known sample of *Scutellosaurus lawleri*.

Additionally, when *Scutellosaurus lawleri* was first described by Colbert (1981), the prevailing view of the age of the Kayenta Formation placed it in the Late Triassic, although that age was not historically accepted unanimously (e.g., Welles, 1954, Harshbarger, Repenning, & Irwin, 1957; Welles, 1970). Subsequent work based on uranium-lead ages of detrital zircons from matrix removed from field jackets of TMM specimens suggests that that the fauna from the Kayenta Formation is late Early Jurassic in age, offering a nuanced view of its position in the evolution of North American vertebrate faunas (Marsh, 2014).

Scutellosaurus lawleri once contributed to a widely held view that ornithischian dinosaurs achieved a global, cosmopolitan distribution before the end of the Triassic (Colbert, 1981; Sereno, 1997; Holtz, Chapman, & Lamanna, 2004). However, it now seems likely that ornithischians were absent from Triassic vertebrate faunas of North America (Parker *et al*., 2005; Nesbitt, Irmis, & Parker, 2007; Brusatte, *et al*., 2010; Langer *et al*., 2010) and that the ornithischian dinosaurs preserved within the Kayenta Formation including *Scutellosaurus lawleri* instead represent the oldest-known ornithischian dinosaurs to occupy North America following an end-Triassic extinction event that profoundly affected vertebrate faunas of the American Western Interior, if not a much wider area (Schaltegger *et al*., 2008; Nesbitt *et al*., 2009; Rowe, Sues, & Reisz, 2010).

When first described, *Scutellosaurus lawleri* was assigned to the Family Fabrosauridae and was suggested to be ancestral to the armored ornithischian dinosaurs, which include the stegosaurs and ankylosaurs (Colbert, 1981). A new systematic analysis of its position was conducted based on the new data on its skeletal structure. As detailed below, this analysis largely sustains the conclusions of previous phylogenetic analyses, that Fabrosauridae is a paraphyletic assemblage, and that *Scutellosaurus lawleri* occupies a basal position in the clade Thyreophora (e.g., Butler *et al.,* 2008*;* Boyd, 2012). Colbert's initial insight that *Scutellosaurus lawleri* was somehow involved in the early evolution of the armored dinosaurs (Colbert, 1981) is thus upheld, but recast in a modern phylogenetic context.

MATERIAL

All known material of *Scutellosaurus lawleri* was collected from the Lower Jurassic Kayenta Formation in northern Arizona on the Lands of the Navajo Nation (Figure 2) and remain the property of the Navajo Nation. With the exception of material at the University of California Museum of Paleontology, all specimens discussed here were collected under permits granted by the Navajo Nation Minerals Division to the Museum of Northern Arizona (MNA) and executed under the direction of Dr. Timothy Rowe between 1977-1981; and a permit to the Vertebrate Paleontology Laboratory of the University of Texas at Austin (TMM) executed by Dr. Timothy Rowe between 1997-2000, in collaboration with the Navajo EcoScouts. Under an agreement between the Navajo Nation, the Museum of Northern Arizona, and the Museum of Comparative Zoology of Harvard University (MCZ), a small representative collection of specimens from the Kayenta Formation that were collected under the MNA permits, in joint field work by the MCZ and MNA described below, was reposited at the MCZ. The specimens reposited at the MCZ have yet to be described. That work was funded by grants from the National Science Foundation (NSF) and from the National Geographic Society (NGS) to the late Dr. Farish A. Jenkins, Jr. of Harvard University.

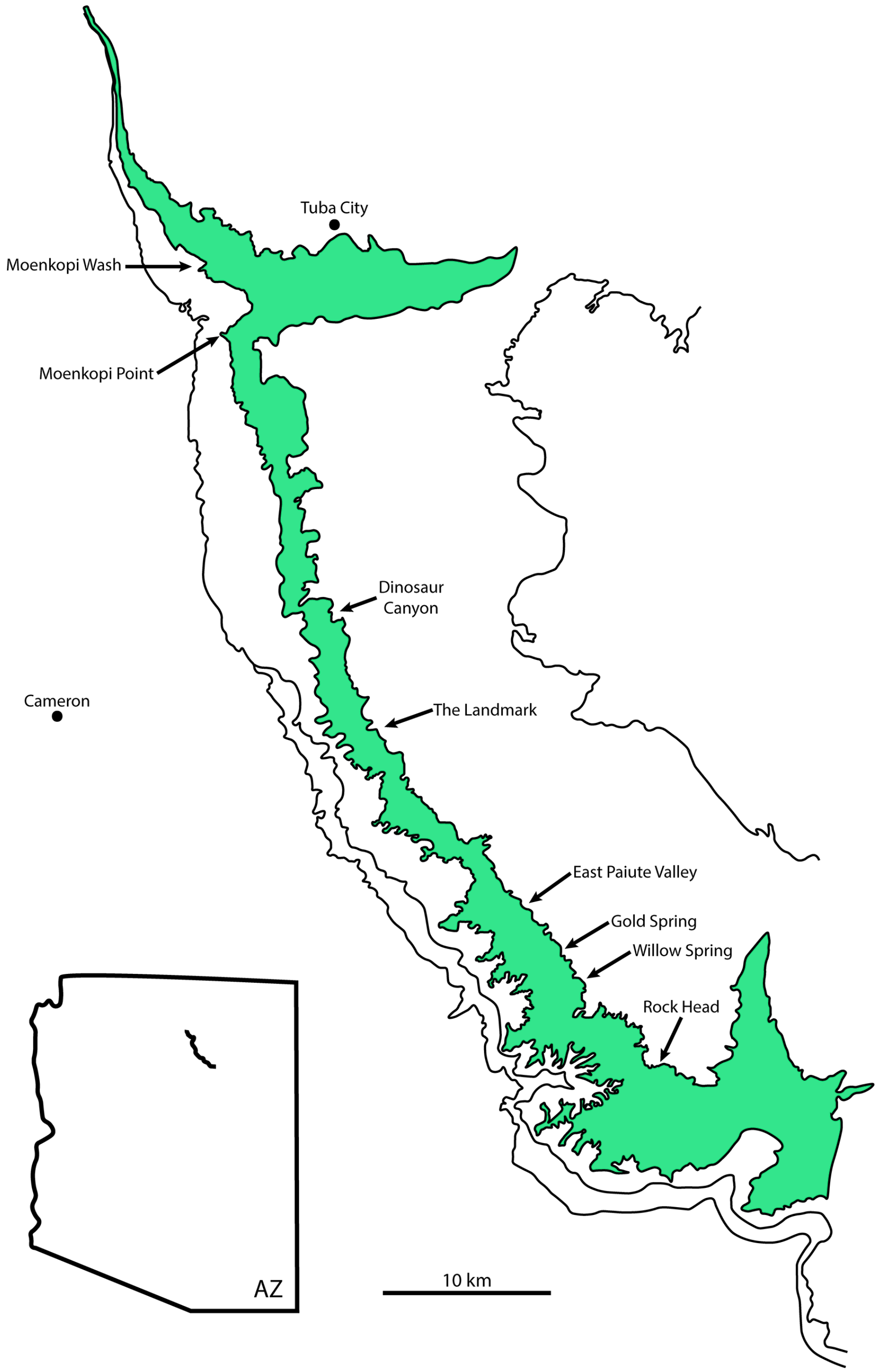

Figure 2. Map of the Adeii Eechii Cliffs in northern Arizona highlighting outcrop of the Lower Jurassic Kayenta Formation (shaded). Significant vertebrate fossil localities within the Kayenta Formation are noted. Modified from Clark & Fastovsky (1986).

The TMM specimens of ornithischian dinosaur fossils from the Lower Jurassic Kayenta Formation have remained largely unnoted in the literature nearly 20 years after their discovery and collection. Some elements from TMM 43687-16 (*Scutellosaurus lawleri*) and TMM 45608-1 (Thyreopohora indet.) were discussed and figured in a review of Jurassic vertebrate paleontology in Arizona by Tykoski (2005), and TMM 43687-16 was used to code characters for *Scutellosaurus lawleri* in a phylogenetic analysis of early archosaur relationships by Nesbitt (2011). TMM 43663-1 and TMM 43664-1 were also used by Boyd (2012) to code for *Scutellosaurus lawleri* in his phylogenetic analysis of ornithischian dinosaurs. Many of the ornithischian specimens collected by the TMM were collected as isolated fragments of associated material weathering out on the surface, sometimes in an assemblage of fragments from multiple taxa. In most cases, detailed field notes regarding the nature of the collection of these specimens are poor or absent, so it is not always clear from how wide of a surface area they were collected. In the absence of detailed field data, specimens collected under the same field number are considered "associated," and any isolated ornithischian elements collected from the same field number that could conceivably be referred to a single individual of *Scutellosaurus lawleri* on the basis of size and anatomy are considered to be from a single individual for ease of cataloging. In many cases, the referral of a fragmentary specimen to *Scutellosaurus lawleri* is supported primarily by the presence of one or more of the osteoderm morphotypes unique to *Scutellosaurus lawleri*. In some cases, osteoderms are absent in a specimen, but the material preserved is more morphologically similar to the holotype specimen of *Scutellosaurus lawleri* (MNA V175) than to any other taxon currently known from the Kayenta Formation. In the absence of unambiguous autapomorphies and osteoderms, these specimens are referred to cf. *Scutellosaurus*.

Field numbers are given in addition to specimen numbers where they are available. New specimens reported here are accessioned at the Vertebrate Paleontology Laboratory (TMM) at The University of Texas at Austin and are given specimen numbers that include a five-digit locality number followed by an individual specimen number and are reported here by locality. An abbreviated list of these specimens and their taxonomic identifications are provided in Appendix 1.

LOCALITY TMM 43647: HUMMINGBIRD CANYON

TMM 43647-6

This specimen (Field Number TR 97/08/F) was collected by Timothy B. Rowe in 1997 and comprises a small (~1 cm) trunk centrum and a single partial osteoderm. The specimen is referred to *Scutellosaurus lawleri* on the basis of the presence of a postcranial osteoderm.

TMM 43647-7

This specimen (Field Number TR/97/G) was collected by Timothy B. Rowe in 1997 and comprises badly crushed and weathered remains of an ornithischian dinosaur. Much of the material is too fragmentary for identification, but identifiable elements include a possible premaxilla fragment with a single visible tooth crown, a partial atlantal neural arch, at least six crushed partial trunk centra, a trunk rib fragment, three metapodial fragments, and at least five partial osteoderms. TMM 43647-7 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

LOCALITY TMM 43648: PAIUTE CANYON GENERAL

TMM 43648-13 (Figure 3)

TMM 43648-13 (Field number TR 97/43) comprises associated cranial and postcranial remains of a single individual of an ornithischian dinosaur. The specimen was collected at the Paiute Canyon General locality, TMM 43648, in association with tritylodontid fragments attributed to *Dinnebitodon* (TMM 43648-8). It comprises a nearly complete left frontal, a possible fragment of the parietal, two partial trunk neural arches, two partial trunk centra, a partial left scapula, a partial left humerus including complete proximal and distal ends, the ulnar condyle of the right humerus, the distal end of a metatarsal, and postcranial osteoderm fragments. TMM 43648-13 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

LOCALITY TMM 43656: GERALD'S TURTLE

TMM 43656-2

TMM 43656-2 (Field Number TR 97/41) comprises associated remains of a single individual of an ornithischian dinosaur. This material includes one sacral centrum, eight partial caudal vertebrae, a proximal fragment of a pedal phalanx, two nearly complete osteoderms, and several fragments of bone and osteoderm. TMM 43656-2 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43656-3

TMM 43656-3 (Field Number TR 97/40) was discovered by Timothy B. Rowe in 1997 and comprises mostly fragmentary remains of a single individual of *Scutellosaurus lawleri*, including a possible axis centrum; one complete and at least four partial trunk centra; a partial sacral centrum; several trunk rib fragments; three fragments of the left humerus including the proximal end, a midshaft fragment, and the ulnar condyle; nine partial osteoderms; and several other indeterminate fragments. TMM 43656-3 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43656-5

TMM 43656-5 (Field Numbers TR 97/40 and 97/42) comprises two partial vertebrae of *Scutellosaurus lawleri* that were collected in association with remains of *Kayentachelys* (TMM 43656-4). One of these vertebrae is represented by a trunk centrum and three fragments of its associated neural arch, and the other is a posterior cervical centrum. Both centra are taphonomically distorted and poorly preserved. TMM 43656-5 is referred to *Scutellosaurus lawleri* based on the presence of a rugose ventral keel on the cervical centrum.

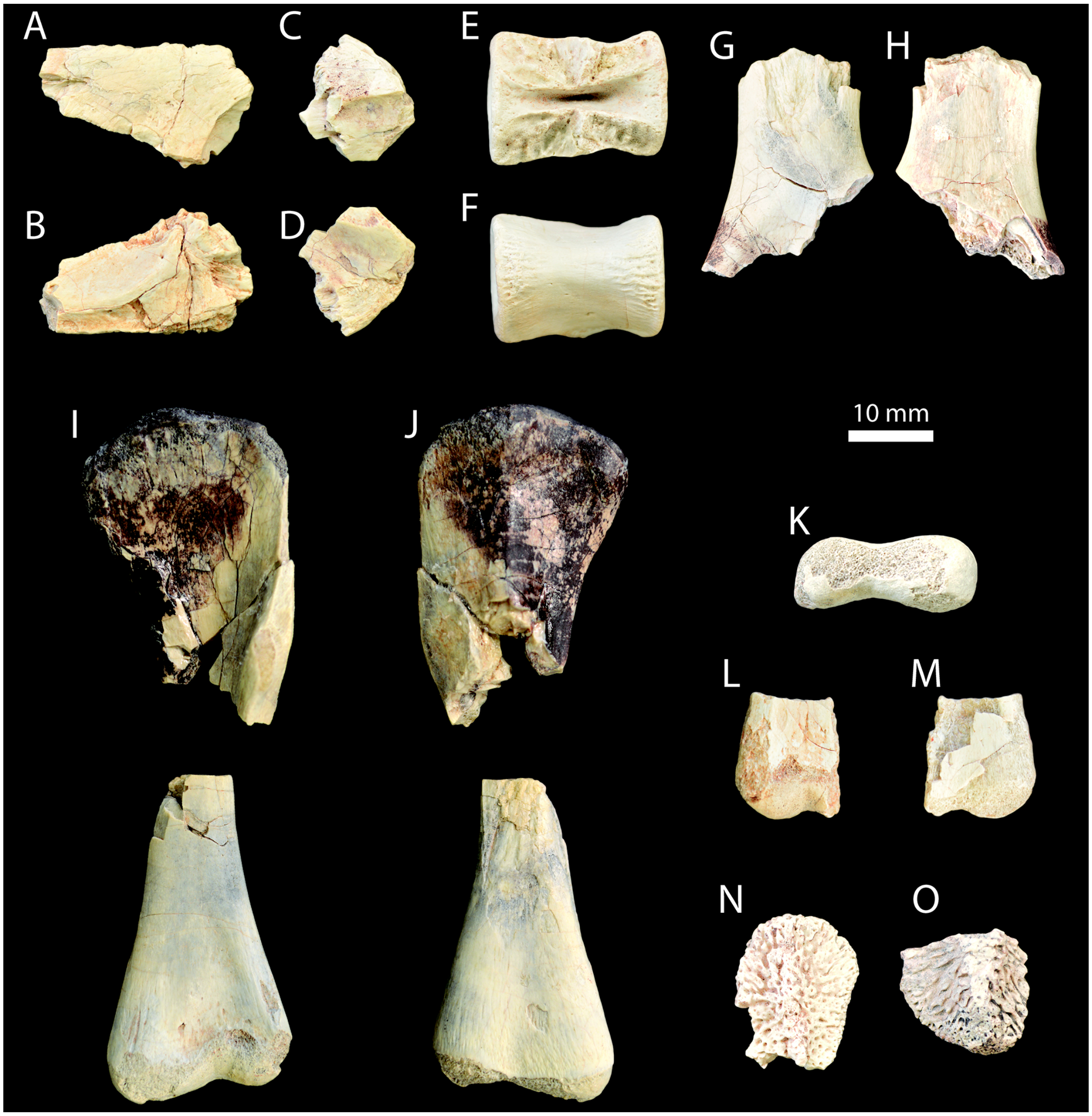

Figure 3. *Scutellosaurus lawleri*. TMM 43648-13. Left frontal in dorsal (A) and ventral (B) views; ?parietal in dorsal (C) and ventral (D) views; trunk centrum in dorsal (E) and ventral (F) views; left scapular fragment in lateral (G) and medial (H) views; left humerus in anterior (I), posterior (J), and distal (K) views; ulnar condyle of the right humerus in anterior (L) and posterior (M) views; and osteoderms (N-O) in dorsal view.

LOCALITY TMM 43661: ROCK HEAD TRITYLODONT

TMM 43661-1

This specimen (Field Number TR 97/02) was collected by Ronald Tykoski on 15 June 1997. It comprises two cervical centra, four trunk centra, at least two partial cervical neural arches, two sacral centra, a partial right scapula, several fragments of the right ilium, and several other indeterminate fragments from a single individual of an ornithischian dinosaur. The majority of the pieces of the specimen remain at least partially obscured by matrix. The scapula preserves the glenoid and some of the proximal surface for articulation with the coracoid. One piece of the ilium preserves the pubic peduncle and the proximal portion of the preacetabular process. The dorsal margin of the ilium is expanded to form a narrow mediolateral shelf, which is characteristic of *Scutellosaurus lawleri* (Butler, 2010). TMM 43661-1 is referred to *Scutellosaurus lawleri* based on the presence of a rugose ventral keel on the cervical centra and a mediolateral shelf on the dorsal margin of the preacetabular process of the ilium.

LOCALITY TMM 43663: EAST PAIUTE VALLEY NO. 1

TMM 43663-1

TMM 43663-1 (Field Number TR 97/49) comprises a partial associated skeleton of *Scutellosaurus lawleri*, including both cranial and postcranial remains. The specimen was discovered by Farish A. Jenkins, Jr. on 03 July 1997 and collected in a plaster jacket along with a bag of loose, weathered elements exposed at the surface. This specimen is referred to *Scutellosaurus lawleri* based on the presence of rugose ventral keels on the cervical vertebrae and postcranial osteoderms.

LOCALITY TMM 43664: EAST PAIUTE VALLEY NO. 2

TMM 43664-1

TMM 43664-1 (Field Number TR 97/48) comprises a partial associated skeleton of *Scutellosaurus lawleri*, including both cranial and postcranial remains. The specimen was discovered by Charles R. Schaff on 29 June 1997 and collected in a plaster jacket along with a bag of loose, weathered elements exposed at the surface. This specimen is referred to *Scutellosaurus lawleri* based on the presence of postcranial osteoderms and dorsal and ventral medial flanges on the preacetabular process of the ilium.

LOCALITY TMM 43669: GOLD SPRING WASH

TMM 43669-5

This specimen (Field Number TM-17-00) was collected from a talus slope by Ted Macrini on 01 June 2000. It consists of fragmentary associated cranial and postcranial remains from a single individual of an ornithischian dinosaur. It includes a small fragment of a dentary containing the root of a dentary tooth, several fragments of at least two trunk vertebrae, and ten partial osteoderms among other indeterminate fragments. TMM 43669-5 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43669-6

TMM 43669-6 was collected with TMM43669-5 by Ted Macrini on 01 June 2000 and shares a field number with it (TM-17-00). These specimens were cataloged separately, but it is not documented why. It consists of a cervical centrum, a caudal vertebra, and the right tibia of an ornithischian dinosaur. TMM 43669-6 is referred to *Scutellosaurus lawleri* based on the presence of a rugose ventral keel on the cervical centrum.

LOCALITY TMM 43670: TED'S TURTLE TOWN

TMM 43670-5

TMM 43670-5 (Field Number TR 00/16) comprises associated fragments of a single individual of an ornithischian dinosaur collected on 11 June 2000 by Elizabeth P. Gordon. Identifiable fragments include a partial dentary bearing three teeth, several partial vertebrae, a proximal left humerus, proximal and distal portions of the left femur, a distal right femur, a proximal right tibia, and a proximal left fibula. No unambiguous apomorphies are preserved, but the elements preserved are similar to the holotype and paratype specimen of *Scutellosaurus lawleri* (MNA V175 and MNA V1752), so TMM 43670-5 is referred to cf. *Scutellosaurus*.

TMM 43670-7 (Figure 4)

TMM 43670-7 (Field Number TR 00/17) comprises associated postcranial remains of a single individual of an ornithischian dinosaur collected on 12 June 2000 by Elizabeth P.

Gordon. The specimen came from a disturbed site showing signs of previous collection, likely by a crew from the MCZ. The best preserved elements from this material include the left femur and tibia, but badly weathered vertebrae, osteoderms, and other fragments also are present. TMM 43670-7 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

The femur lacks the medial portion of the head and is missing its distal end, so its length cannot be measured. The greater trochanter is confluent with the head of the femur. The anterior (lesser) trochanter is anteroposteriorly broad and projects approximately perpendicular to the head of the femur. The proximal point of the anterior trochanter sits 8 mm below the proximal point of the head of the femur and is separated from the greater trochanter laterally by a prominent notch. The pendant fourth trochanter is well preserved, with its distalmost point projecting 53 mm from the proximal end of the femur. The femur is mediolaterally crushed, giving it the appearance of being somewhat medially bowed in anterior view. In lateral view, the femur appears to be bowed anteriorly, but this too may be the result of taphonomic distortion. The tibia is 116 mm long, which is larger than the tibia of the holotype specimen of *Scutellosaurus lawleri* (MNA V175) and somewhat smaller than that of the paratype specimen (MNA V1752). Like the femur, the tibia also is taphonomically distorted. There is a fracture separating the proximal third from the distal two-thirds of the tibia, which gives the proximal end an artificial lateral kink relative to the rest of the tibia in anterior or posterior view. The distal end is anteroposteriorly compressed.

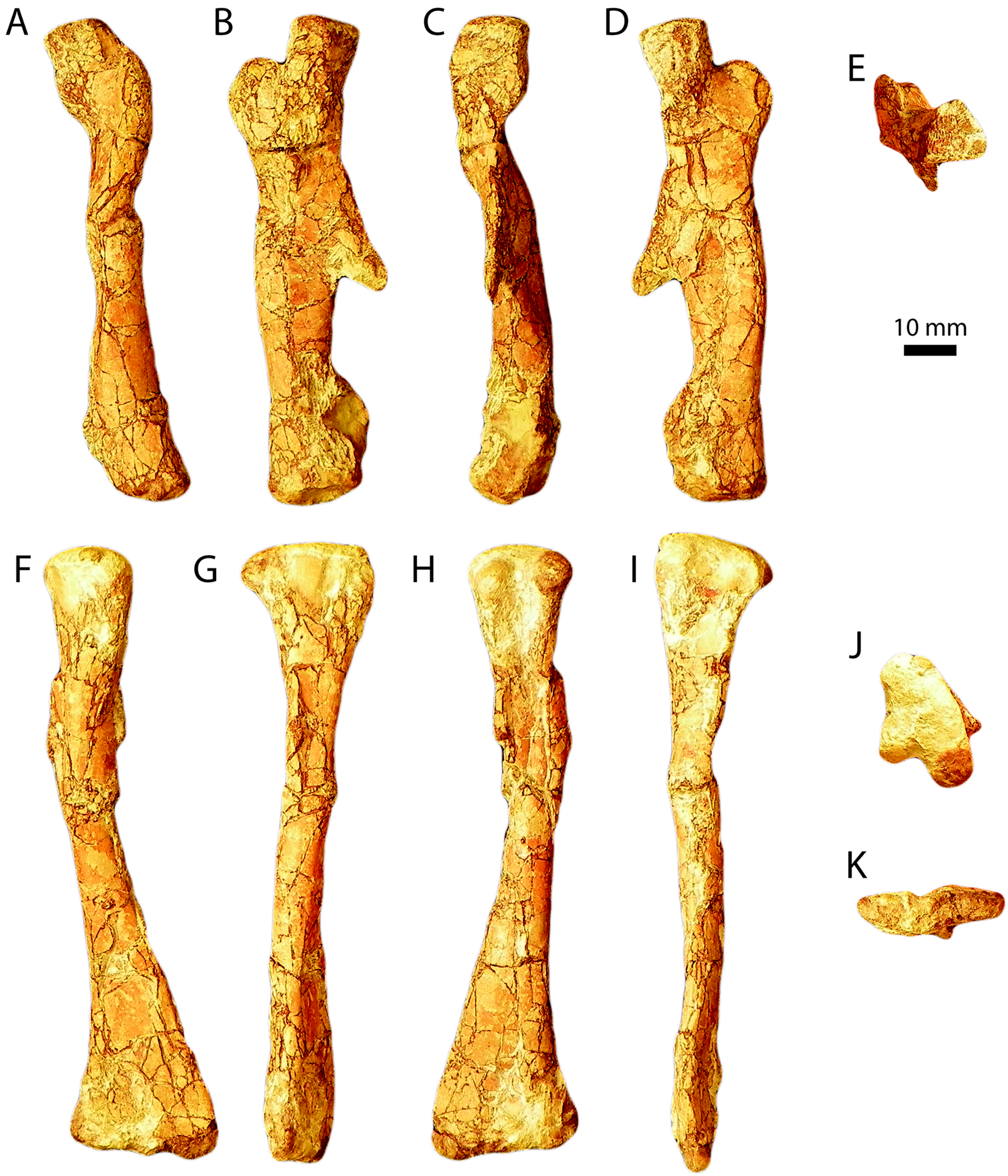

Figure 4. *Scutellosaurus lawleri*. TMM 43670-7. Left femur in anterior (A), lateral (B), posterior (C), medial (D), and proximal (E) views and left tibia in anterior (F), lateral (G), posterior (H), medial (I), proximal (J), and distal (K) views.

LOCALITY TMM 43687: GOLD SPRING GENERAL

TMM 43687-9 (Figure 5)

TMM 43687-9 (Field Number TR 98/04) comprises associated postcranial material from a single individual of an ornithischian dinosaur. Much of this material is coated in a thin rind of ironstone. The specimen consists of a partial possible sacral neural arch, a sacral centrum, a partial proximal caudal vertebra, a small rib fragment, the right femur missing its distal end, the left femur missing its proximal end, and two partial osteoderms. The fourth trochanter of the right femur is incomplete distally, and the left femur is anterolaterally compressed. TMM 43687-9 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43687-13

TMM 43687-13 was discovered by Gerald Grellet-Tinner and comprises associated long bone fragments. This includes a possible left distal tarsal 1, proximal and distal portions of left metatarsal II, a distal right metatarsal III, a partial left metatarsal V, and four other indeterminate long bone fragments. This specimen lacks any unambiguous autapomorphies and is referred to cf. *Scutellosaurus* on the basis of morphological similarity to the holotype and referred specimens of *Scutellosaurus lawleri.*

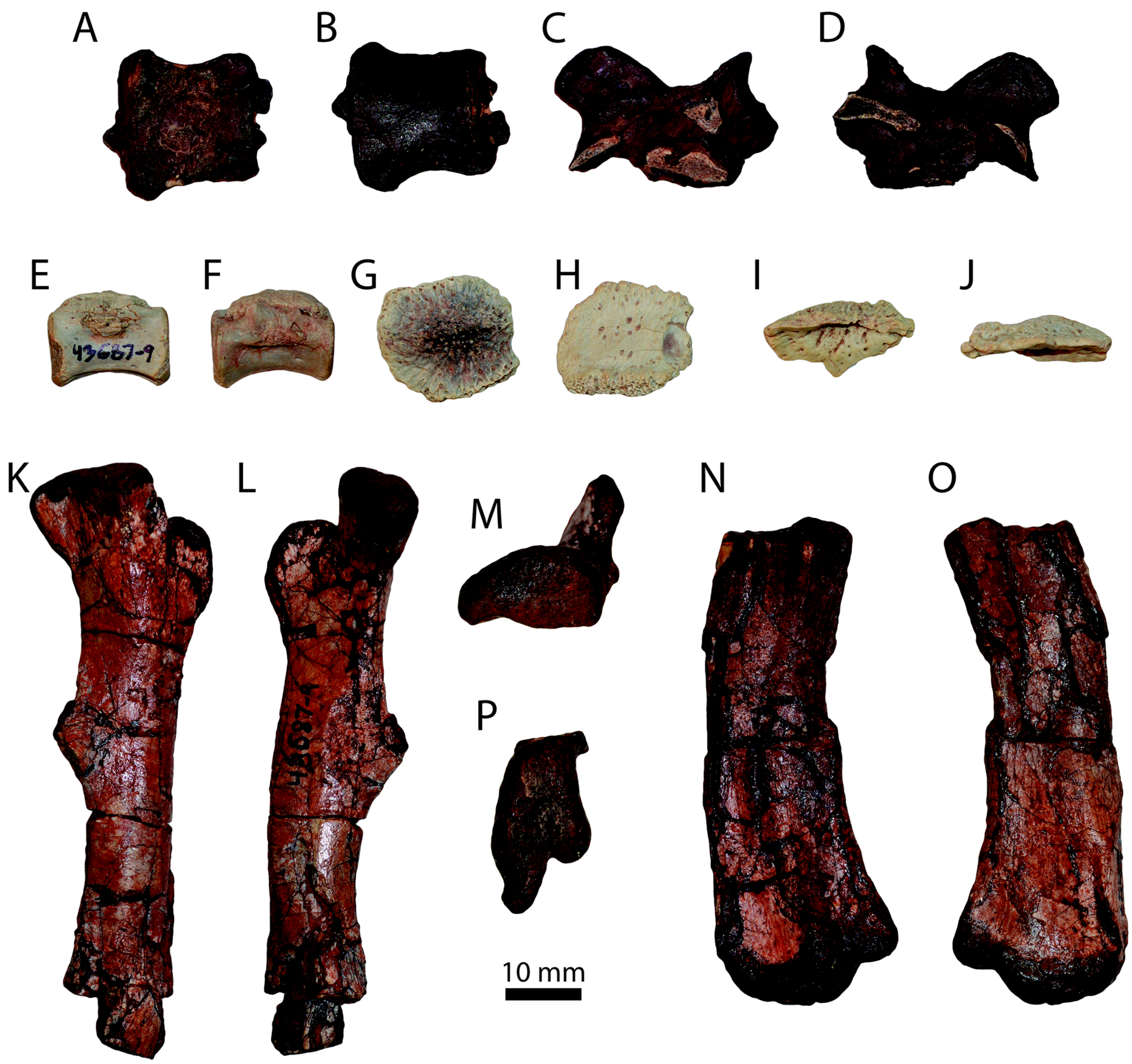

Figure 5. *Scutellosaurus lawleri*. TMM 43687-9. Sacral centrum in dorsal (A) and ventral (B) views; ?sacral neural arch (C-D); proximal caudal centrum in left (E) and right (F) lateral views; osteoderm in dorsal (G) and ventral (H) views; osteoderm in ventral (I) and lateral (J) views; right femur in lateral (K), medial (L), and proximal (M) views; and left femur in posterolateral (N), anteromedial (O), and distal (P) views.

TMM 43687-16 (Figure 6)

This specimen (Field Number TR 97/25) was collected by William W. Amaral with no date of discovery recorded. TMM 43687-16 comprises associated cranial and postcranial remains of a single individual of an ornithischian dinosaur. Many of these elements are covered in a thin ironstone rind. Tooth-bearing fragments of both maxillae of this specimen were previously reported by Tykoski (2005), and this specimen was also included in a phylogenetic analysis of archosaurs by Nesbitt (2011). A central portion of the parietal is present. Other probable cranial fragments are present, though most are too incomplete to identify confidently.

Portions of at least 11 trunk vertebrae, two sacral vertebrae, and one caudal vertebra are present. As in the holotype specimen, the neurocentral sutures are open and the neural arches are completely separated from the centra in the trunk and sacral vertebrae. The caudal vertebra is from the proximal portion of the caudal series, has a closed neurocentral suture, and prominent transverse processes. Several other fragments of neural arches and indeterminate centra also are preserved. Proximal and distal portions of the right humerus and the distal end of the left humerus are preserved. Of the hindlimb, the distal end of the left femur, fragments of at least two metatarsals, and fragments of at least four pedal phalanges are preserved. At least eight postcranial osteoderms are preserved. TMM 43687-16 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

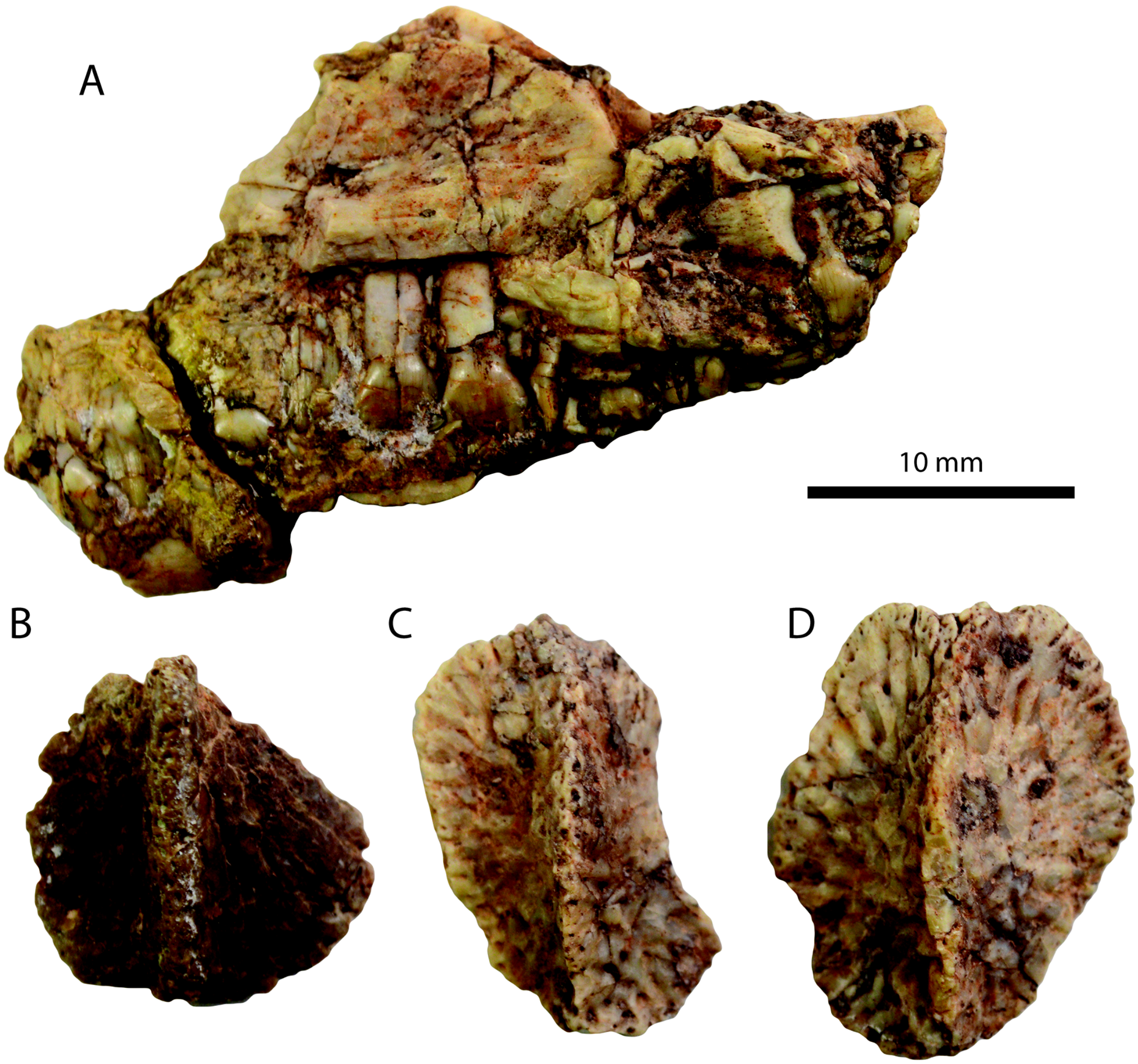

Figure 6. *Scutellosaurus lawleri*. TMM 43687-16. Maxillary fragment in lateral view (A) and postcranial osteoderms (B-D).

TMM 43687-17

This specimen (Field Number TR 97/51) was collected by Timothy B. Rowe in 1997 and comprises badly weathered postcranial remains from a single individual of an ornithischian dinosaur. It consists of a proximal left femur still largely obscured by matrix, two fragments of a proximal ?left fibula with much of the end obscured by matrix, three partial osteoderms, and other fragments. TMM 43687-17 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43687-22 (Figure 7)

This specimen was collected by Timothy B. Rowe with no date of discovery recorded. TMM 43687-22 comprises associated fragmentary postcranial remains of a single individual of an ornithischian dinosaur, including a cervical centrum, an anterior fragment of another cervical centrum, a trunk centrum, an isolated trunk(?) prezygapophysis, two partial anterior caudal vertebrae, one partial posterior caudal vertebra, a proximal right humerus, a proximal right radius(?), three fragments of the left ilium, a distal right femur, a proximal left tibia, a distal right tibia, proximal and distal fragments of a right metatarsal III, three rib fragments, a weathered osteoderm, and several other elements that await preparation. Although material is fragmentary and scarce, enough is present to warrant referring TMM 43687-22 to *Scutellosaurus lawleri.* The ventral keel of the cervical centrum is rugose. One fragment of the left ilium preserves an anterior portion of the acetabulum and the posterior end of the preacetabular process. Although the majority of the preacetabular process is absent in the left ilium of TMM 43687-22, distinct medial flanges on the dorsal and ventral margins are present. A postcranial osteoderm is preserved. The maximum widths of the distal femur and distal tibia indicate that this individual is somewhat larger than the paratype specimen of *Scutellosaurus lawleri* (MNA V1752) and may represent the largest individual specimen of *Scutellosaurus lawleri* currently reported. The cervical and trunk vertebrae of TMM 43687-22 lack the majority of their neural arches, but rather than separating along the neurocentral sutures as in other specimens, the neural arches are broken off slightly dorsal to the sutures, which appear at least partially closed. The systematic closure of neurocentral sutures has been tied to skeletal maturity in some archosaurs by Brochu (1996). Thus, in addition to being the largest individual, TMM 43687-22 also may represent the most skeletally mature individual specimen of *Scutellosaurus lawleri* currently reported.

TMM 43687-75

TMM 43687-75 comprises associated fragments of *Scutellosaurus lawleri*. The specimen was collected on 10 June 1998 from a disturbed locality that may have been initially discovered and abandoned by the MCZ. The individual is represented by at least four partial cervical vertebrae, five partial trunk vertebrae, six caudal vertebrae, ten neural arch fragments, a fragmentary left femur, a distal pedal phalanx, thirteen partial osteoderms, and several other unidentified fragments. This individual can be referred to

Scutellosaurus lawleri based on the presence of postcranial osteoderms and rugose ventral keels on the cervical centra. Remains of a smaller ornithischian dinosaur also were collected from this locality and are cataloged under the specimen number TMM 43687-123.

TMM 43687-81

TMM 43687-81 was discovered by Elizabeth P. Gordon on 29 May 2000 and comprises postcranial fragments of a single individual of *Scutellosaurus lawleri*. It includes a proximal trunk rib, a proximal right fibula, one nearly complete osteoderm, and several other fragments of osteoderm and bone. TMM 43687-81 is referred to *Scutellosaurus lawleri* based on the presence of postcranial osteoderms.

TMM 43687-112

This specimen was collected by Elizabeth P. Gordon on 01 June 2000 but not assigned a field number. It comprises fragments of a trunk vertebra, the distal end of the left metatarsal III, a distal pedal phalanx, a complete pedal phalanx that articulates with the distal phalanx fragment, and numerous fragments of osteoderms and other bone. TMM 43687-112 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

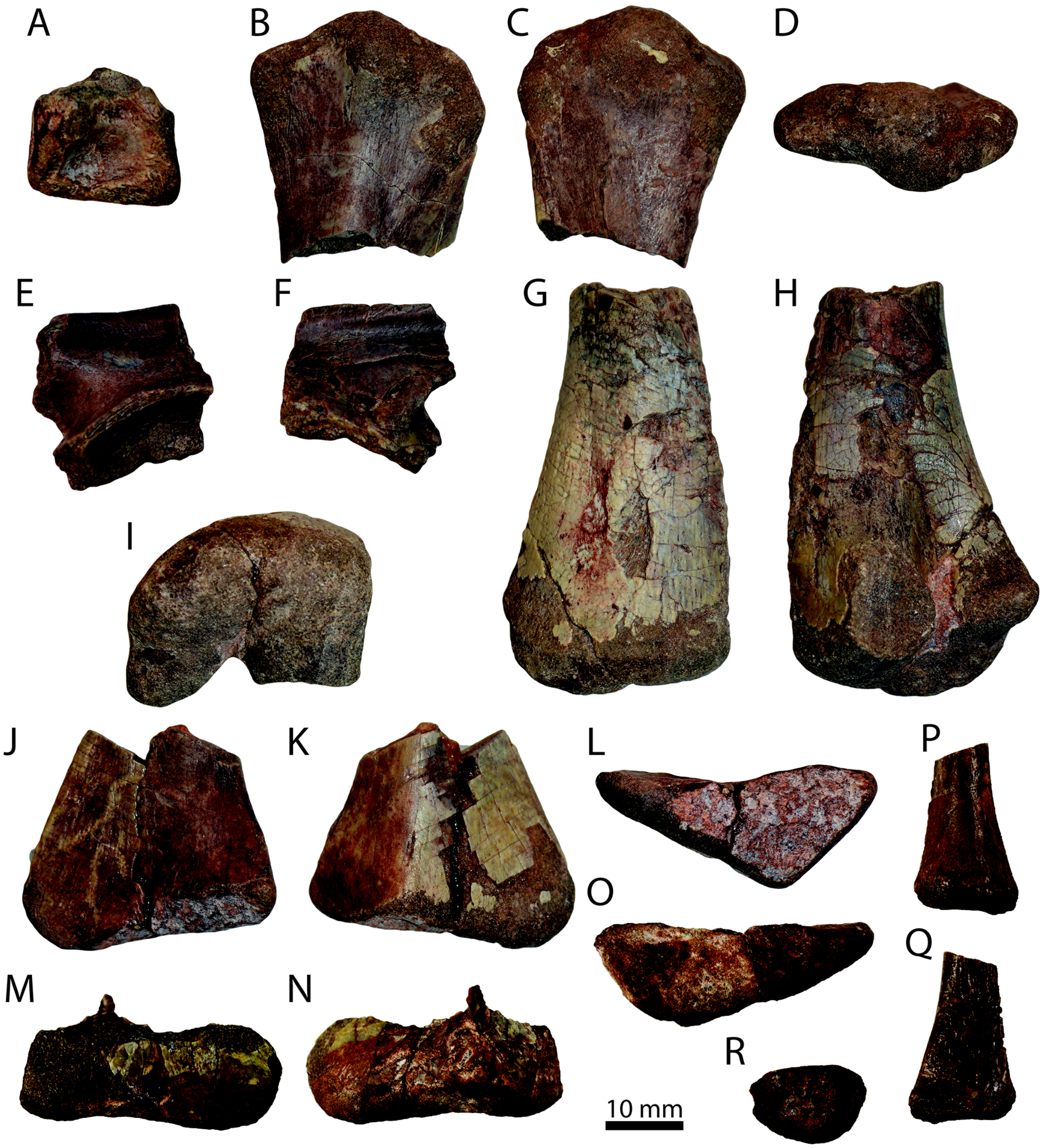

Figure 7. *Scutellosaurus lawleri*. TMM 43687-22. Cervical centrum in left lateral view (A), proximal right humerus in posterior (B), anterior (C), and proximal (D) views; preacetabular fragment of the left ilium in lateral (E) and medial (F) views; distal right femur in anterior (G), posterior (H), and distal (I) views; distal right tibia in anterior (J), posterior (K), and lateral (L) views; distal left tibia in anterior (M), posterior (N), and distal (O) views; distal fibula in anterior (P), posterior (Q), and distal (R) views.

TMM 43687-114

This specimen (Field Number RG-2-00) comprises small fragments of bone collected by Roger Gary on 08 June 2000 that may represent multiple taxa. Elements attributable to *Scutellosaurus lawleri* include a fragment of a trunk vertebra, a distal right metatarsal II, and a partial osteoderm. TMM 43687-114 is referred to *Scutellosaurus lawleri* on the basis of the presence of a postcranial osteoderm.

TMM 43687-115

This specimen was collected by Elizabeth P. Gordon on 01 June 2000 but not assigned a field number. It comprises one trunk centrum with fragments of its associated neural arch, a proximal portion of the left humerus, proximal and distal portions of the right humerus, a possible proximal metatarsal, a partial osteoderm, and numerous other fragments of an ornithischian dinosaur. It is referred to *Scutellosaurus lawleri* on the basis of the presence of a postcranial osteoderm.

TMM 43687-116

This specimen (Field Number JF-00-008) was discovered by Jonathan Franzosa during the summer of 2000 and comprises a partial trunk centrum, a distal left metatarsal IV, and 12 partial osteoderms. TMM 43687-116 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43687-121

This specimen was collected with no associated field data. It includes a ventral right quadrate, a proximal trunk rib, a distal pedal phalanx, and several partial osteoderms. TMM 43687-121 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43687-122

This specimen was discovered by Elizabeth P. Gordon on 01 June 2000 on a cow path near the *Eocaecilia* Quarry (Locality TMM 45609). It comprises one trunk centrum and an osteoderm from *Scutellosaurus lawleri*, both of which are coated with a rind of ironstone. These elements were collected in association with remains of *Kayentachelys aprix* (TMM 43687-25). TMM 43687-122 is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

TMM 43687-123

TMM 43687-123 comprises fragments of a small ornithischian dinosaur. This material was initially cataloged under the specimen number TMM 43687-75 but was separated because it clearly represents a smaller individual than the rest of the material preserved in that specimen. TMM 43687-123 preserves proximal and distal fragments of a right femur and a partial trunk centrum. The fourth trochanter is not preserved in the femur of this specimen. This specimen is referred to cf. *Scutellosaurus* on the basis of its morphological similarity to the holotype specimen of *Scutellosaurus lawleri* (MNA V175) and its association with TMM 43687-75, which is definitively referrable to *Scutellosaurus lawleri.*

TMM 43687-124

This specimen comprises 11 osteoderm fragments and was collected with no associated data. It is referred to *Scutellosaurus lawleri* on the basis of the presence of postcranial osteoderms.

LOCALITY TMM 43690: WILLOW SPRING GENERAL

TMM 43690-6

TMM 43690-6 (Field Number TM-32-00) was discovered on 16 June 2000 by Ted Macrini and includes a single fragmentary trunk centrum. Although no unambiguous autapomorphies are preserved, the centrum is morhphologically similar to those of the holotype of *Scutellosaurus lawleri* (MNA V175), so this specimen is referred to cf. *Scutellosaurus*.

LOCALITY TMM 43691: PAIUTE NORTH

TMM 43691-18

TMM 43691-18 (Field Number TM-21-00) was discovered by Ted Macrini on 05 June 2000 and comprises an isolated partial right scapula. Both proximal and distal margins are incomplete, but much of the glenoid is preserved. No unambiguous synapomorphies are preserved, but the scapula is similar in morphology to the holotype specimen of *Scutellosaurus lawleri* (MNA V175) and to referred specimens of *Scutellosaurus lawleri* (MNA V3133, TMM 4363-1, TMM 43664-1). A referral of *TMM 43691-18* to *Scutellosaurus lawleri* can not be justified on the basis of any unambiguous autapomorphies, and I refer it to cf. *Scutellosaurus*.

LOCALITY TMM 45608: GOLD SPRING SOUTH

TMM 45608-3

This specimen (Field Number PRO-20-00) comprises associated postcranial remains of a single individual and was discovered by Pamela R. Owen on 13 June 2000. It includes eight partial cervical centra, two partial centra that may be from a posterior cervical or an anterior trunk vertebra, five partial trunk centra, a nearly complete right humerus, a possible portion of an ulna or radius, several partial and complete osteoderms, and many other indeterminate fragments. TMM 45608-3 is referred to *Scutellosaurus lawleri* based on the presence of postcranial osteoderms and rugose ventral keels on the cervical centra.

LOCALITY TMM 45609: *EOCAECILIA* QUARRY

TMM 45609-4

TMM 45609-4 comprises isolated fragments of bone collected by Timothy B. Rowe to the south of the *Eocaecilia* microquarry on 27 May 1999. The majority of these fragments are too incomplete to identify, but a single nearly complete osteoderm of *Scutellosaurus lawleri* is present.

TMM 45609-5

TMM 45609-5 (Field Number TM-14-00) was collected by Ted Macrini on 31 May 2000 near the *Eocaecilia* microquarry and comprises one complete trunk centrum, one partial trunk centrum, a proximal left humerus, and several other indeterminate fragments from an ornithischian dinosaur. No unambiguous synapomorphies are preserved, so a referral to *Scutellosaurus lawleri* can not be justified. The preserved elements are morphologically similar to the holotype specimen of *Scutellosaurus lawleri* (MNA V175), and it is referred to cf. *Scutellosaurus*.

TMM 45609-6

This specimen (TM-3-00) was discovered by Timothy B. Rowe and collected by Ted Macrini on 29 May 2000 from a brown sandstone horizon that is stratigraphically higher than the "Blue Zone" that most of the other material was collected from at the TMM 45609 locality. This specimen preserves the intercentrum of the atlas, fragments of at least four cervical vertebrae, and an identified fragment of bone. Of the cervical vertebral fragments, one is a neural arch fragment preserving a parapophysis; two are the anterior ends of centra preserving the diapophyses; and one is a nearly complete vertebra preserving both diapophyses and parapophyses, the left prezygapophysis, and the right postzygapophysis, but the neural spine is missing. This specimen is noteworthy because the neurocentral suture of the nearly complete cervical vertebra appears at least partially closed, which is uncommon for presacral vertebrae in other specimens of *Scutellosaurus lawleri*. This specimen is referred to *Scutellosaurus lawleri* based on the presence of rugose ventral keels on the cervical centra. The unidentified fragment of bone can not definitively be attributed to *Scutellosaurus lawleri* but remains cataloged under the same specimen number as the vertebrae pending identification to the contrary.

LOCALITY TMM 47001: SOUTHWEST PAIUTE CANYON

TMM 47001-1

TMM 47001-1 (Field Number BBA-3-00) was discovered by Brian B. Andres on 30 May 2000 and comprises one complete and two partial trunk centra, at least two partial trunk neural arches, several trunk rib fragments including one complete proximal end, and other indeterminate fragments. No unambiguous apomorphies are preserved, but the preserved elements are morphologically similar to the same elements in the holotype specimen of *Scutellosaurus lawleri* (MNA V175) and are referred to cf. *Scutellosaurus* on the basis of this similarity.

UCMP SPECIMENS

The six referred specimens of *Scutellosaurus lawleri* reported by Rosenbaum & Padian (2000) are reposited at the University of California Museum of Paleontology (UCMP) and were collected from the Kayenta Formation along the Adeii Eechii Cliffs in northern Arizona between 1981 and 1983 by field parties led by James M. Clark. I elaborate on the original description of these six specimens by Rosenbaum & Padian (2000) on the basis of first-hand observation of the material, making comments on and corrections to their observations and interpretation of the material where needed. All six of these specimens were reported to have been collected from the same UCMP locality V85010 (Rosenbaum & Padian, 2000); however, only four of the six specimens were actually collected from that locality. The other two specimens UCMP 170829 and UCMP 130581 were collected from UCMP localities V85013 and V84235, respectively. Additionally, UCMP 130580 is occasionally incorrectly refered to as UCMP 130850 by Rosenbaum & Padian (2000) in their report of these referred specimens. UCMP 130850 is actually a specimen of the Paleocene mammal *Purgatorius unio* from Montana. Additional specimen-by-specimen comments are given by locality below.

UCMP 130580 (Figure 8)

A slightly smaller individual of *Scutellosaurus lawleri* than the holotype specimen (MNA V175). The majority of the elements preserved in the specimen were discussed and figured by Rosenbaum & Padian (2000), including portions of both frontals, a fragment of the parietal, a partial right jugal, the ventral ends of both quadrates, a nearly complete basioccipital, fragments of both dentaries, the atlas intercentrum, the odontoid process of the axis, an axis neural arch, five cervical centra, eight trunk centra, two sacral centra, eighteen caudal vertebrae, thirty fragmentary centra, several neural arch fragments, rib fragments, a complete sacral rib, portions of both scapulae, portions of both humeri, the proximal and distal ends of both ulnae, two carpals, a metacarpal III or IV, one complete manual phalanx, three partial manual phalanges, a manual distal phalanx, fragments of both ilia, a nearly complete left ischium, the shaft of the right ischium, fragments of both femora, a nearly complete right tibia, the proximal and distal ends of the left tibia, the proximal portions of both fibulae, the right astragalus (misidentified by Rosenbaum & Padian [2000] as the left astragalus), a possible distal tarsal 2, a proximal left and distal right metatarsal I, a distal left metatarsal II, a nearly complete right metatarsal III, a distal left metatarsal III, a complete right metatarsal IV, the proximal and distal ends of left metatarsal IV, three complete proximal pedal phalanges, five pedal phalangeal fragments, two pedal distal phalanges, several osteoderms, and other fragments unidentified by Rosenbaum & Padian (2000).

Thin sections of one radius, the right tibia, and an osteoderm were taken from UCMP 130580 in order to study the histology of the bones (Padian *et al.*, 2004; Main *et al.*, 2005). At least three lines of arrested growth in the right tibia and seven lines of arrested growth in the radius of UCMP 130580 were observed by Padian *et al*. (2004), who noted that growth appeared to be ceasing in both bones, which may indicate that UCMP 130580 was nearly fully grown. They concluded from the long-bone histology that *Scutellosaurus lawleri* grew slowly and may have reached adult size in two to three years. This conclusion conflicts with evidence of skeletal immaturity, such as the lack of fusion between the vertebral centra and their neural arches in the presacral vertebrae (Brochu, 1996) in UCMP 130580 and every other previously reported specimen of *Scutellosaurus lawleri* (Colbert, 1981; Rosenbaum & Padian, 2000).

Additional elements have been identified from UCMP 130580 since the specimen was originally reported by Rosenbaum & Padian (2000). A right surangular was identified in the specimen by Butler (2010). The surangular is a sigmoidal and transversely thin element that is generally convex on its lateral surface and concave on its medial surface. A well-developed anteroposteriorly-oriented ridge on the lateral surface of the surangular was noted by Butler (2010). This feature is shared with *Lesothosaurus*, *Emausaurus* and *Scelidosaurus*. Posterior to that ridge, the surangular extends posterodorsally where it contributes to the lateral wall of the retroarticular process. The dorsal margin of the anterior surangular is medially inflected, forming a prominent shelf that extends posteroventrally and curves back anteroventrally at its end. This shelf overhangs a deep cavity that is the contribution of the surangular to the dorsal margin of the adductor fossa. Surangular foramina are noted in *Heterodontosaurus tucki* (Norman *et al.*, 2011), *Lesothosaurus diagnosticus* (Sereno, 1991), and *Eocursor parvus* (Butler, 2010), but none can be identified in *Scutellosaurus lawleri* from this specimen.

An incomplete right postorbital lacking the ends of the anterior, posterior, and ventral processes has also been identified and is reported here. The description of the postorbitals from TMM 43663-1 and TMM 43664-1 below applies to this specimen.

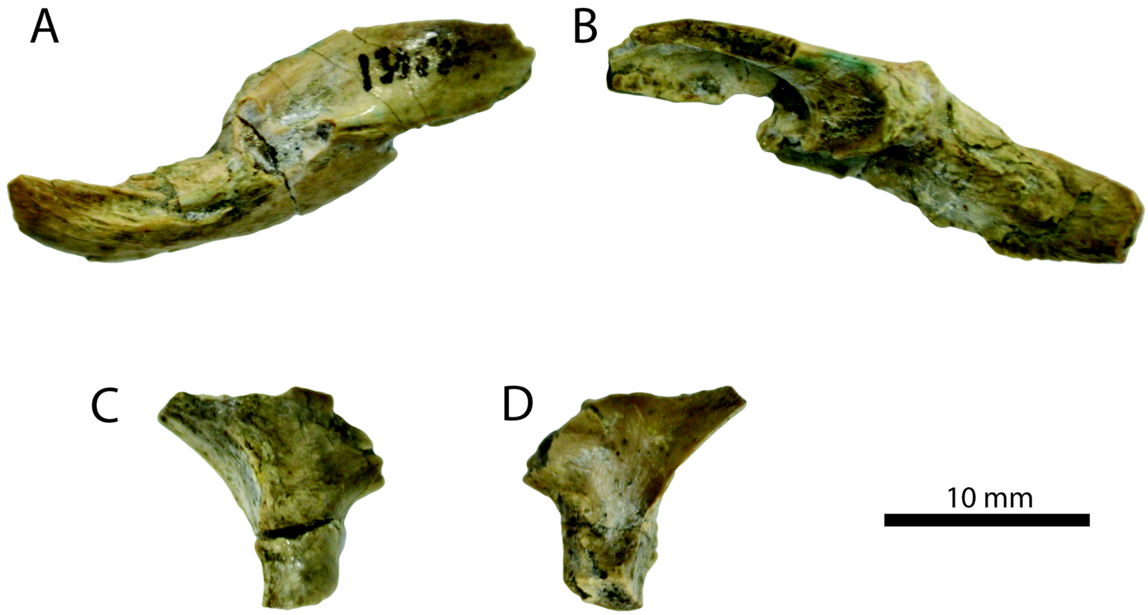

Figure 8. *Scutellosaurus lawleri*. UCMP 130580. Right surangular in lateral (A) and medial (B) views and right postorbital in lateral (C) and medial (D) views.

UCMP 170829

UCMP 170829 (Field number JMC 81-20) was discovered in October 1981 from UCMP Locality V85013 (Gold Springs 1) by James M. Clark. A distal radius, a small fragment of the ilium, the distorted distal end of a femur, and the proximal end of one fibula were reported by Rosenbaum & Padian (2000). In addition to the reported material, the specimen also preserves two cervical centra, two trunk centra, one sacral centrum, portions of both humeri, the right astragalus, and several other fragments of vertebrae and other bone.

UCMP 130581

UCMP 130581 (Field Number JMC 83-17) was discovered by Emily CoBabe on 10 June 1983 from UCMP Locality V84235 (Red Knob). It comprises partial vertebrae, rib fragments, a fragment of the left scapula including the glenoid fossa, a pedal phalanx, and several small fragments of bone and osteoderms. Of the vertebrae, two fragments of cervical centra, three proximal caudal centra, two caudal centra from the transition from proximal to distal, and a small fragment of distal caudal centrum are preserved.

UCMP 175166

UCMP 175166 (Field Number JMC 83-14) was discovered in June 1983 from UCMP Locality V85010 (Lower Blue) by James M. Clark. It comprises only a ventral left quadrate and a proximal right humerus.

UCMP 175167

UCMP 175167 (Field Number JMC 83-5) was discovered on 06 June 1983 from UCMP Locality V85010 (Lower Blue) by James M. Clark and preserves three badly distorted presacral centra and several other vertebral fragments.

UCMP 175168

This specimen (Field Number JMC 83-6) was discovered on 06 June 1983 from UCMP Locality V85010 (Lower Blue) by James M. Clark. A large portion of the left frontal from UCMP 175168 in their description of the skull was incorrectly reported by Rosenbaum and Padian (2000) when it is in fact a posterior fragment of the right frontal containing the anteromedial margin of the supratemporal fossa. In Table 1 of Rosenbaum & Padian (2000), the measurement of the dorsoventral thickness of the frontal of UCMP 175168 was mistakenly given under the specimen number UCMP 170829, which does not itself preserve a frontal. In addition to what was reported by Rosenbaum & Padian (2000), UCMP 175168 also preserves six partial presacral centra, two partial neural arches, an isolated neural spine, the anterior trochanter of the left femur, a badly weathered fragment of bone that may represent the proximal right tibia, two nearly complete osteoderms, and several other small fragments of indeterminate bone.

INSTITUTIONAL ABBREVIATIONS

BMNH, British Museum of Natural History, London, UK; MCZ, Museum of Comparative Zoology, Harvard, Massachusetts; MNA, Museum of Northern Arizona, Flagstaff, Arizona; PVL, Paleontología de Vertebrados Instituto Miguel Lillo, Tucumán, Argentina; SAM, Iziko South African Museum, Cape Town, South Africa; SGWG, Sektion Geologische Wissenschaften Greifswald, Ernst-Moritz Universität, Greifswald, Germany; TMM, Vertebrate Paleontology Laboratory, The University of Texas, Austin, Texas (Historical note: the Vertebrate Paleontology Laboratory (VPL) was for many years part of the Texas Memorial Museum and its specimens were cataloged using the TMM acronym; a recent administrative reorganization moved VPL to the Jackson School of Geosciences, but its specimen numbering system is unchanged and it retains the TMM acronym); UCMP, University of California Museum of Paleontology, Berkeley, California.

SYSTEMATIC PALAEONTOLOGY

DINOSAURIA OWEN, 1842

ORNITHISCHIA SEELEY, 1887

THYREOPHORA NOPCSA, 1915 SENSU SERENO, 1998

SCUTELLOSAURUS LAWLERI COLBERT, 1981

Holotype: MNA V175, a nearly complete associated skeleton comprising partial left and right premaxillae; partial left and right maxillae; possible nasal fragments; partial dentaries; five cervical centra; several partial and complete trunk neural arches and spines; five sacral vertebrae; and fifty-eight caudal vertebrae; several chevrons; several rib fragments; partial scapulae; partial coracoids; fragments of the ilia, ischia, and pubes; humeri, the right complete and the left missing a portion of the middle; distal right radius; proximal and distal left radius and ulna; two partial metacarpals; six manual phalanges; femora; tibiae; the left astragalus; the proximal right fibula and a fragmentary but nearly complete left fibula; probable distal tarsals; partial metatarsals and pedal phalanges; and greater than 300 osteoderms.

Paratype: MNA V1752, an incomplete associated skeleton larger than the holotype comprising four presacral centra; two sacral centra; forty-four caudal centra; fragments of the appendicular skeleton, including a complete right astragalocalcaneum; and fragments of osteoderms.

Referred specimens: MNA V3133, MNA 3137, UCMP 130580, UCMP 170829, UCMP 130581, UCMP 175166, UCMP 175167, UCMP 175168, MCZ 8592, MCZ 8799, MCZ 8801, TMM 43647-6, TMM 43647-7, TMM 43648-13, TMM 43656-2, TMM 43656-3, TMM 43656-5, TMM 43661-1, TMM 43663-1, TMM 43664-1, TMM 43669-5, TMM 43669-6, TMM 43670-5, TMM 43670-7, TMM 43687-9, TMM 43687-13, TMM 43687-16, TMM 43687-17, TMM 43687-22, TMM 43687-75, TMM 43687-81, TMM 43687-112, TMM 43687-114, TMM 43687-115, TMM 43687-116, TMM 43687-121, TMM 43687-122, TMM 43687-123, TMM 43687-124, TMM 43690-6, TMM 43691-18, TMM 45608-3, TMM 45609-4, TMM 45609-5, TMM 45609-6, TMM 47001-1.

Type locality and horizon: The holotype locality is Rock Head (MNA Loc. 219), Ward Terrace, Arizona, USA. The paratype locality is Gold Spring (MNA Loc. 291, MCZ Field Number 77 AR/4), Ward Terrace, Arizona, USA. All specimens of *Scutellosaurus lawleri* were collected from the Silty Facies of the Lower Jurassic Kayenta Formation of the Glen Canyon Group, along the Adeei Eechii Cliffs of northeastern Arizona in the Navajo Nation. General locality and collection data are given above where available for each of the TMM specimens.

Emended Diagnosis: A small (~1 m) bipedal thyreophoran ornithischian dinosaur distinguished by the presence of cervical centra that are deeply excavated laterally and possess ventral keels that are broad and rugose, dorsal and ventral margins of the preacetabular process of the ilium that are drawn out medially into distinct flanges that converge upon one another anteriorly, and an elongate tail comprising at least 58 caudal vertebrae. Although the presence of postcranial osteoderms is plesiomorphic with respect to other thyreophoran dinosaurs, *Scutellosaurus lawleri* has at least four unique osteoderm morphologies, all of which are heavily pitted and rugose. Morphotype A comprises asymmetrical broad, flat osteoderms with longitudinal keels. Morphotype B comprises asymmetrical osteoderms that possess two long sides sloping up to a ridge and are deeply concave ventrally such that each osteoderm maintains a uniform thickness. Morphotype C comprises symmetrical broad, flat osteoderms with two longitudinal ridges flanking the midline. Morphotype D and symmetrical narrow and long osteoderms.

Comments: The original diagnosis of *Scutellosaurus lawleri* was not based upon apomorphies, and many of the features included in the diagnosis by Colbert (1981) represent character states that are plesiomorphic with respect to other ornithischian taxa or are based upon incomplete data. The relatively long tail of *Scutellosaurus lawleri* was recognized by Colbert (1981) as diagnostic, and this feature was later quantified in an apomorphy-based context by Butler *et al*. (2008). The anteriorly converging dorsal and ventral flanges of the ilium were also identified as autapomorphic by Butler *et al*. (2008). *Scutellosaurus lawleri* was included in an investigation of osteological correlates for quadrupedality in ornithischian dinosaurs by Maidment & Barrett (2014) who proposed that *Scutellosaurus lawleri* was a biped based on the absences of an anteolateral process of the proximal ulna, a femur that is longer than the tibia, and a reduced fourth trochanter of the femur. This is in contrast to the interpretation of *Scutellosaurus lawleri* as a facultative quadruped by Colbert (1981). The presence of armor in *Scutellosaurus lawleri* was experimentally demonstrated not to impact the center of mass by Maidment, Henderson, & Barrett (2014), so it seems unlikely that the development of osteoderms in thyreophorans is what drove the evolution of obligate quadrupedality in eurypodans. Six osteoderm morphologies were proposed by Colbert (1981); however, several of his proposed categories grade into one another and are not significantly different, and osteoderm categories II-IV from Colbert (1981) were combined into Morphotype B in the present diagnosis. The arrangement of these osteoderms in life is unknown because no articulated specimen of *Scutellosaurus lawleri* has been discovered, but the asymmetrical osteoderms were probably arranged in lateral pairs anterior to the sacrum, and the symmetrical osteoderms were possibly arranged in four longitudinal rows flanking the tail in median dorsal, median ventral, and lateral rows in an arrangement similar to that observed in *Scelidosaurus harrisonii* (Norman, Witmer, & Weishampel, 2004b). The presence of osteoderms with two keels and symmetrical bases prompted Colbert (1981) to suggest that the parasaggital row of osteoderms flanking the back of the animal converged at some point posterior to the sacrum into a single row of osteoderms along the midline of the tail; however, the actual position of these osteoderms is uncertain.

METHODS

CT Methods

TMM 43663-1 and TMM 43664-1 were scanned by Matthew Colbert at the High-Resolution X-ray CT Facility at the University of Texas at Austin. Scanning was carried out on an Advanced Computed Tomography Imaging System (ACTIS) by North Star Imaging, Inc. The field jackets containing these specimens were split by Kenneth Bader into two smaller jackets each in order to accommodate the limited dimensions of the scanner. TMM 43663-1 was divided into a 'limb block' and a 'skull block,' and TMM 43664-1 was divided into a 'skull block' and a 'pelvis block'

The 'limb block' of TMM 43663-1 was scanned on 8 April 2014 in 1472 total image slices with a voxel size of 0.0957 mm. The 'skull block' of TMM 43663-1 was scanned on 28 April 2015 in 1785 total slices with a voxel size of 0.1169 mm. The 'pelvis block' of TMM 43664-1 was scanned together with the 'skull block' on 8 August 2014 in 1948 total image slices with a voxel size of 0.1715 mm. The 'skull block' of TMM 43664-1 was then re-scanned on 21 January 2015 in 1928 total slices with a voxel size of 0.124 mm. The 'pelvis block' of TMM 43664-1 was also re-scanned after additional preparation on 28 April 2015 together with the 'skull block' of TMM 43663-1 in 1785 total slices with a voxel size of 0.1169 mm.

Fossil bones from within each jacket were digitally isolated from the surrounding matrix when possible using the digital rendering software VGStudio MAX via a process that involves identifying each individual element, following it through the series of image slices, and tracing its outline in each slice. The result of this process is an isolated 3-dimensional digital rendering of each individual element. Digital data from these CT scans are reposited at the High-Resolution X-ray CT Facility at the University of Texas at Austin. Although all CT scans were useful in aiding the preparation of the physical specimens, only the CT scan of the 'skull block' of TMM 43664-1 significantly allowed for the visualization of anatomy not possible with the physical specimens. This CT scan also allowed for an approximate reconstruction of the skull of TMM 43664-1 from the disarticulated elements preserved (Figure 9). In many cases, the fossil bone itself proved more useful for description than CT scans, but the manual preparation of the bone was made possible by the scans.

Comparative Data

TMM 43663-1 and TMM 43664-1 are described in comparison to other specimens of *Scutellosaurus lawleri* on the basis of novel firsthand observations of the holotype (MNA V175), paratype (MNA V1752), and referred specimens (MNA V3133, MNA 3137, UCMP 130580, UCMP 170829, UCMP 130581, UCMP 175166, UCMP 175167, UCMP 175168) previously reported for the taxon and to other ornithischian dinosaurs on the basis of descriptions from the literature. Additionally, photographs of several taxa (*Pisanosaurus mertii*, *Eocursor parvus*, *Scelidosaurus harrisonii*, *Lesothosaurus diagnosticus*, *Stormbergia dangershoeki*, *Hypsilophodon foxii*) were graciously provided by Randall B. Irmis for the purposes of comparison. A complete list of taxa and relevant references used for comparison is provided in Table 2.

Table 2. List of ornithischian taxa used for comparison along with relevant references for each taxon.

Taxon	**References**
Ankylosauria	Vickaryous *et al*., 2004
Emausaurus ernsti	Haubold, 1990; Norman *et al*., 2004b
Eocursor parvus	Butler *et al*., 2007; Butler, 2010
Hexinlusaurus multidens	He & Cai, 1984; Barrett *et al*., 2005
Hesperosaurus mjosi	Carpenter *et al*., 2001
Heterodontosaurus tucki	Crompton & Charig, 1962; Sereno 2012; Norman *et al*., 2011; Galton, 2014
Hypsilophodon foxii	Galton, 1974; Norman, Sues, *et al*., 2004
Lesothosaurus diagnosticus	Thulborn, 1970; Thulborn, 1972; Sereno, 1991; Butler, 2005; Porro *et al*., 2015
Pisanosaurus mertii	Casamiquela, 1967; Bonaparte, 1976
Scelidosaurus harrisonii	Owen, 1861; Owen, 1863; Padian, 1989; Barrett, 2001; Norman *et al*., 2004b
Scutellosaurus lawleri	Colbert, 1981; Rosenbaum & Padian, 2000; Norman *et al*., 2004b
Stegosauria	Galton & Upchurch, 2004
Stormbergia dangershoeki	Butler, 2005

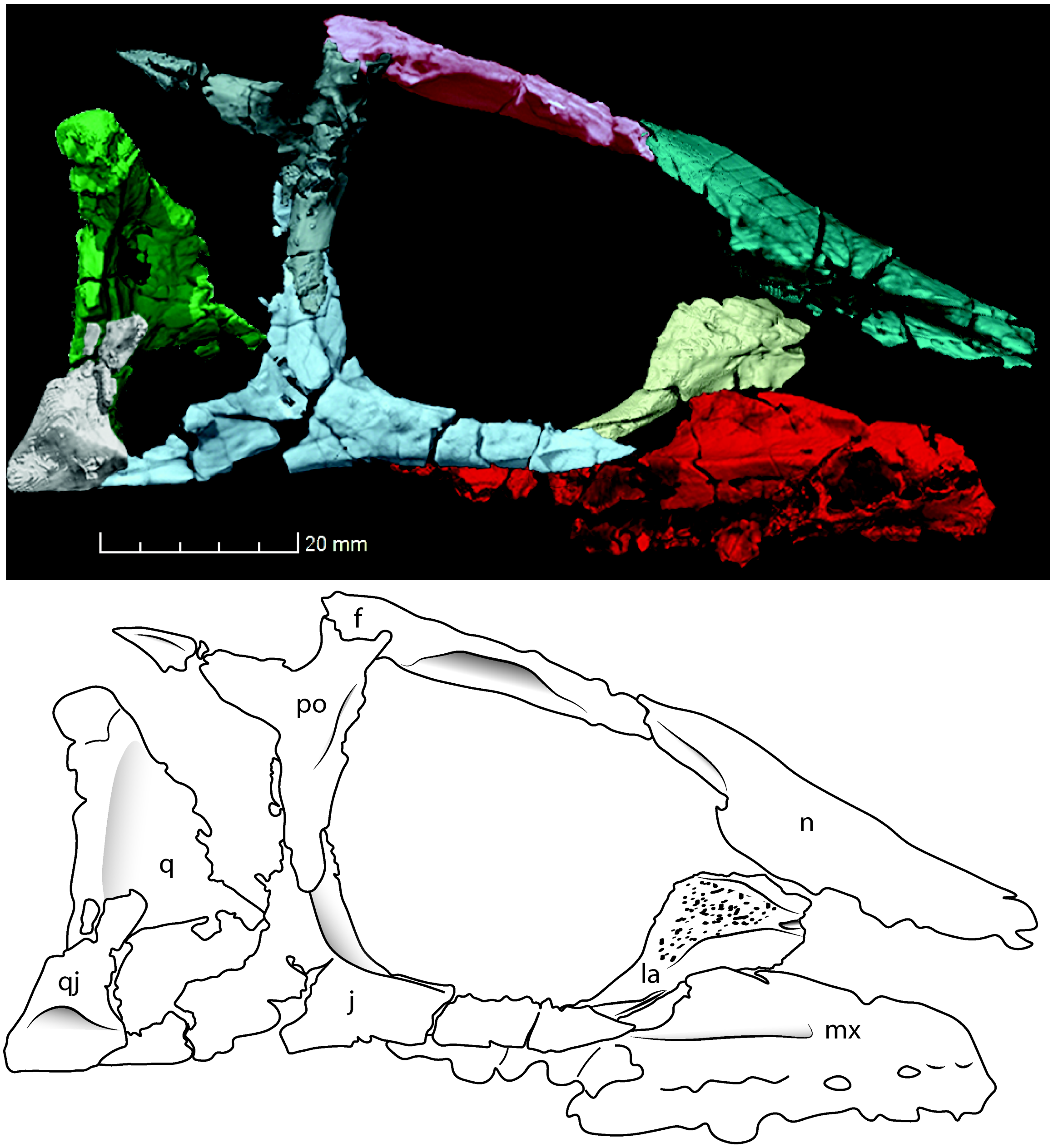

Figure 9. *Scutellosaurus lawleri*. 3D digital reconstruction of the skull from select cranial elements segmented from the CT scan of TMM 43664-1. Elements from the left side of the skull were reflected for this reconstruction. Abbreviations: f, frontal; j, jugal; la, lacrimal; mx, maxilla; n, nasal; po, postorbital; q, quadrate; qj, quadratojugal.

Cladistic Analysis

The new specimens TMM 43663-1 and TMM 43664-1 were added to the data matrix of Butler *et al*. (2010) in order to test the referral of these to specimens to *Scutellosaurus lawleri*. As described below, this referral was supported by phylogenetic analysis, and the new specimens were then used to re-diagnose *Scutellosaurus lawleri* on the basis of the new and more complete anatomical data that they provide.

In the data matrix of Butler *et al*. (2010), *Scutellosaurus lawleri* was coded on the basis of firsthand observations of the specimens MNA V175, MNA V1752, and UCMP 130580 as well as the key references by Colbert (1981) and Rosenbaum & Padian (2000). The autapomorphies of *Scutellosaurus lawleri* first identified by Butler *et al.* (2008) included a preacetabular process of the ilium in which the dorsal and ventral margins are drawn out medially into flanges that converge upon one another anteriorly as the process tapers to a point and an elongate tail comprising at least 59 caudal vertebrae.

The original data matrix was acquired from TreeBASE.org and manipulated using Mesquite Version 3.04 (Maddison & Maddison, 2015). The original matrix comprised 50 taxa and 227 characters. Adding TMM 43663-1 and TMM 43664-1 as separate operational taxonomic units (OTUs) to the matrix increased the number of OTUs included in the present analysis to 52. Phylogenetic analysis was performed using PAUP* Version 4.0a146 (Swofford, 2003) according to the same search settings described by Butler *et al.* (2010), to allow direct comparison with their results. All characters were weighted equally; five characters were treated as ordered (112, 135, 137, 138, 174); all branches with a minimum length of zero were collapsed ("amb"- option of Parsimony Settings > General); and multistate taxa were treated as polymorphisms. A heuristic search was conducted using 1,000 replicates and random stepwise addition. The maximum number of trees to be saved was not limited. *Euparkeria capensis*, *Marasuchus liloensis,* and *Herrerasaurus ischigualastensis* were defined as outgroup taxa. Transformation of characters was assessed under accelerated transformation (ACCTRAN).

OSTEOLOGICAL DESCRIPTION

The following comments on the anatomy of S*cutellosaurus lawleri* are primarily based on TMM 43663-1 and TMM 43664-1, but other specimens are referred to when appropriate in cases where they preserve aspects of the anatomy either missing or poorly preserved in TMM 43663-1 and TMM 43664-1.

CRANIAL SKELETON

Maxilla (Figure 6A; Figure 10)

A nearly complete but poorly preserved left maxilla is present in TMM 43664-1, and the ventral surface of the left maxilla is exposed in TMM 43663-1. Fragments of both maxillae are preserved in the holotype specimen of *Scutellosaurus lawleri*, but the overall morphology of the maxilla remains poorly understood. The left maxilla of TMM 43664-1 is preserved closely appressed to the left nasal, the right lacrimal, and a dorsal rib such that some of the medial surface of the posterior end of the maxilla is obscured from direct observation. No teeth are preserved in the maxilla of 43664-1, and the number of alveoli is not possible to discern as a result of the poor preservation of both the lateral and medial surfaces of the bone. Although the majority of the anatomy of the maxilla in TMM 43663-1 is poorly preserved, and the number of alveoli is not possible to discern as a result of the poor preservation, the specimen does preserve the anterior end of the maxilla. There appears to be a slight medial process at the anterior end of the maxilla for articulation with the premaxilla, which would overlap this process laterally. The maxilla of TMM 43664-1 is approximately triangular in cross-section like MNA V175 and the other basal thyreophoran dinosaurs *Emausaurus ernsti* and *Scelidosaurus harrisonii.* The maxilla of MNA V175 possesses well-developed resorption pits that sit lingual to the alveoli (Colbert, 1981), and these resorption pits are also present in the maxilla of TMM 43664-1.

Nasal (Figure 10)

A nearly complete left nasal that is missing fragments along its margins is preserved in TMM 43664-1. Possible fragments of the nasals closely appressed to the right maxilla of MNA V175 were described by Colbert (1981), but no significant anatomical data could be derived from that specimen, so the nasal of TMM 43664-1 is the best-preserved nasal known from *Scutellosaurus lawleri*. The nasal is a long and narrow plate that is transversely arched such that the ventral surface is concave. It is nearly flat in lateral view and subtriangular in dorsal view. The left and right nasals meet one another along a nearly straight butt joint. The anterolateral tip of the nasal overlies the dorsal process of the premaxilla. The lateral contacts of the nasal are not well preserved, but the lateral margin of the nasal would overlap the premaxilla and the maxilla. The contact between the nasal and the lacrimal is not preserved in TMM 43664-1, but it is narrow in the basal thyreophorans *Emausaurus* and *Scelidosaurus* as well as in heterodontosaurids and the basal neornithischian *Lesothosaurus*. The nasal is overall similar in morphology to the nasal of the basal stegosaur *Hesperosaurus mjosi*. The posterior margin of the nasal overlies the anterior tip of the frontal. There is a deep elliptical embayment along the posterolateral margin of the nasal where it is overlain by the prefrontal along a broad contact. The dorsal surface of the nasal is rough and cortically remodeled, and the ventral surface is relatively smooth.

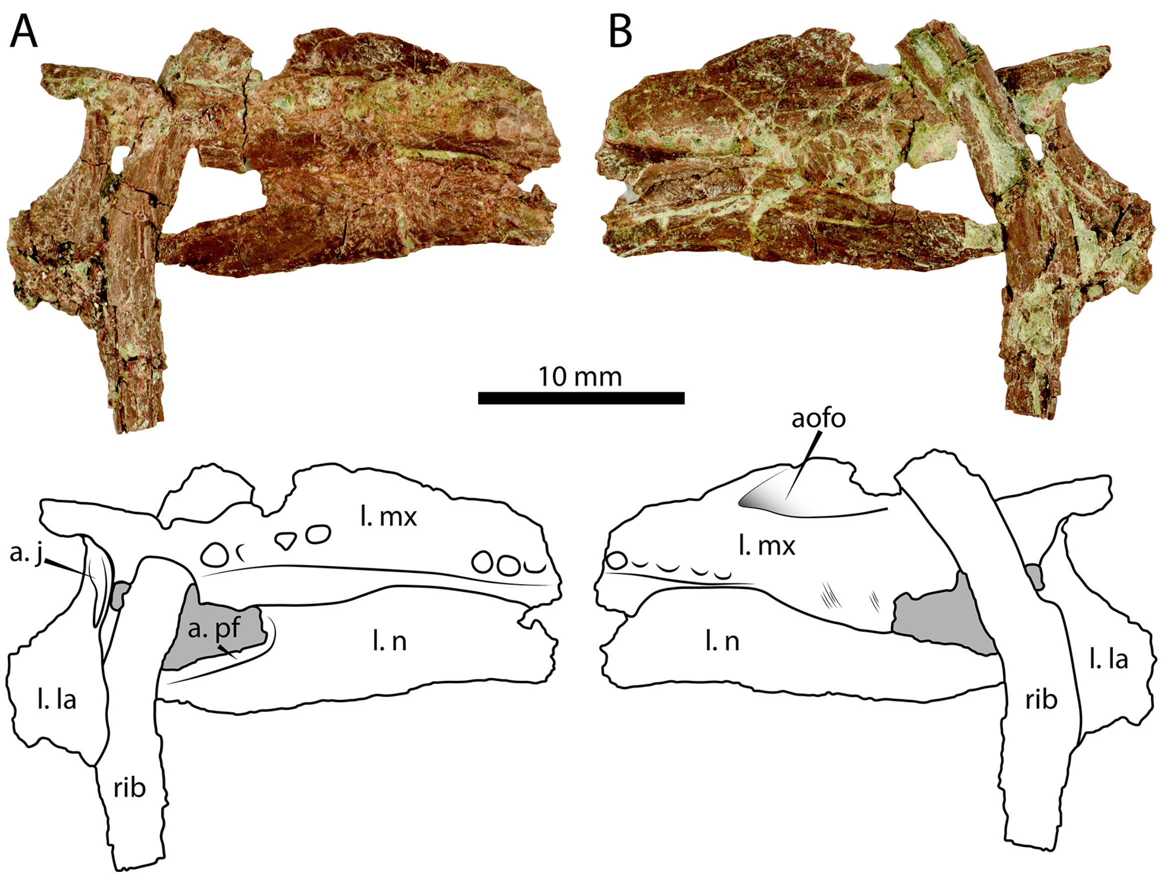

Figure 10 *Scutellosaurus lawleri*. TMM 43664-1. Block containing the left maxilla, left nasal, and left lacrimal. Abbreviations: aofo, antorbital fossa; a. ju, articulation with the jugal; a. pf, articulation with the prefrontal; l. la, left lacrimal; l. mx, left maxilla; l. n, left nasal; rib, rib.

Frontal (Figure 3A-B; Figure 11)

TMM 43663-1 preserves a nearly complete right frontal, and TMM-43664-1 preserves nearly complete left and right frontals. The frontals of *Scutellosaurus lawleri* were first reported in UCMP 130580 by Rosenbaum & Padian (2000), which preserves the posterior end of a left frontal and the anterior end of a right frontal. Although unnoted in the original description by Colbert (1981), a partial left frontal is also present in the holotype specimen of *Scutellosaurus lawleri*.

The frontal is a paired, roughly triangular element that contacts the nasal anteriorly, the other frontal medially, the postorbital laterally, and the parietal posteriorly. The frontal is overlain by the prefrontal along a shallow facet along the anterolateral margin. UCMP 130580 preserves the frontal-parietal suture, which is interdigitate but not fused (Rosenbaum & Padian, 2000). The midline surface is straight for articulation with the other frontal at the interfrontal suture. The anteroposterior length of the frontal exceeds the maximum transverse width, and it is transversely widest posteriorly and narrowest anteriorly. The frontal is broadly flat, but there is a smooth semicircular concavity on the ventrolateral surface of the bone where the frontal contributes to the dorsal margin of the orbit. The supratemporal fossa is present on the dorsal surface at the posterior margin of the frontal lateral to the sutural surface for articulation with the parietal. The supratemporal fenestra appears to be excluded from the posterior margin of the frontal by the parietal and postorbital. The right frontal of UCMP 130580 preserves a series of fine striations along its lateral margin posterior to the prefrontal facet. This series of striations has been interpreted as an osteological correlate for soft tissue (Maidment & Porro, 2009).

Parietal (Figure 3C-D)

A possible crushed fragment of the parietal is present in TMM 43664-1, but little new anatomical information can be derived from this specimen. The parietal is partially preserved in UCMP 130580 and is distinct in possessing a low sagittal ridge on the dorsal surface formed by arcuate depressions that meet much closer to the midline than in other early ornithischian dinosaurs (Butler, 2010).

Lacrimal (Figure 10; Figure 12)

TMM 43664-1 preserves left and right lacrimals, both of which are nearly complete. Much of the anterior margin of the right lacrimal is obscured by two partial teeth. The ventral margin of the left lacrimal is obscured by a partial dorsal rib, and much of the anterior end is crushed. The lacrimals are better visualized from the CT scan of the specimen. These are the first lacrimals reported for *Scutellosaurus lawleri*.

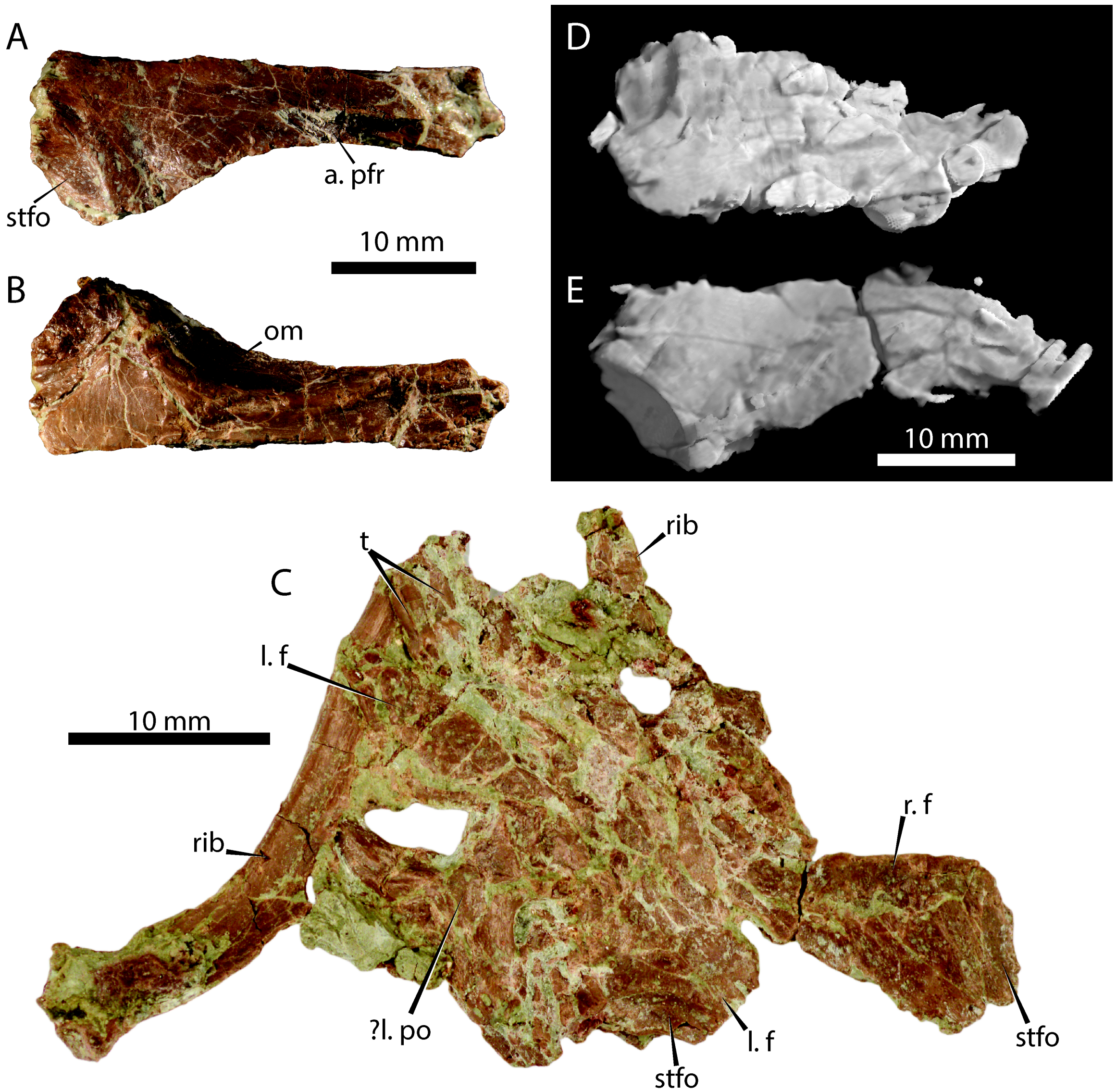

Figure 11. *Scutellosaurus lawleri*. Right frontal of TMM 43663-1 in dorsal (A) and ventral (B) views. Block from TMM 43664-1 containing both frontals (C). 3D digital rendering of the left (D) and right (E) frontals of TMM 43664-1 in dorsal view. Abbreviations: a. pfr, articulation with the prefrontal; l. f, left frontal; l. po, left postorbital; om, orbital margin; r. f, right frontal; rib, rib; stfo, supratemporal fossa.

The lacrimal is a transversely compressed subquadrangular element with a curved tapering posteroventral process, similar in morphology to *Emausaurus* (Haubold, 1990) and *Scelidosaurus* (BMNH R1111). The lacrimal forms much of the anterior margin of the orbit, and the posterior edge of the lacrimal is transversely broad with a prominent lacrimal foramen. The lateral surface is cortically remodeled anterodorsally, with a smooth depression anteroventrally marking the lacrimal contribution to the posterodorsal margin of the antorbital fossa. There is no evidence of an external antorbital fenestra in either lacrimal. Along the anterior margin between the raised rugose surface and the antorbital fossa is a distinct subtriangular notch for articulation with a slender process of the maxilla, as in *Lesothosaurus* (Sereno, 1991). The lateral surface of the posteroventral process of the lacrimal is overlain by the anterior process of the jugal along a scarf-joint articulation.

Jugal (Figure 13)

The jugal of *Scutellosaurus lawleri* was initially reported in UCMP 130580 by Rosenbaum & Padian (2000), which includes a nearly complete right jugal. The lateral surface of the jugal is cortically remodeled in this specimen. The cortical remodeling of individual cranial bones was hypothesized to be a synapomorphy of the proposed clade Ankylosauromorpha (*Scelidosaurus* + Ankylosauria) by Carpenter (2001), but its presence in *Scutellosaurus lawleri* establishes it as an unambiguous synapomorphy of Thyreophora (Butler *et al.*, 2008).

TMM 43663-1 preserves a nearly complete left jugal. Each of the three processes of the element is incomplete distally. TMM 43664-1 preserves a nearly complete right jugal that is best visualized in the CT scan of the specimen. The jugal is fractured in several places, but the distal ends of each of the three processes are relatively well preserved, unlike TMM 43663-1 and the UCMP specimens.

The description of the jugal as a triradiate inverted t-shaped element by Rosenbaum & Padian (2000) applies to the new specimens. The dorsal process is smooth on its medial surface, and there is a depression on its anterolateral surface that forms a scarf joint with the medial surface of the ventral process of the postorbital. The dorsal surface of the anterior process of the jugal forms a transversely broad shelf that defines the posteroventral margin of the orbit. The medial aspect of this shelf forms the pinched, dorsomedially-oriented peak noted by Rosenbaum & Padian (2000). The dorsal process has a distinct groove on the anterior aspect of the lateral surface for articulation with the ventral process of the postorbital, which would overlap the dorsal process of the jugal laterally to form a half-lap-joint articulation between the two elements. A fragment of another unidentified bone obscures the majority of the margin of the infratemporal fenestra formed by the posterior dorsal and dorsal posterior processes. As in UCMP 130580, the lateral surface is cortically remodeled. The general morphology of the jugal is overall similar to that of the jugal of *Emausaurus ernsti;* however, the ventral margin of the jugal is nearly straight in *Scutellosaurus*, whereas the anterior and posterior processes of the jugal of *Emausaurus* form an obtuse angle that is ventrally concave.

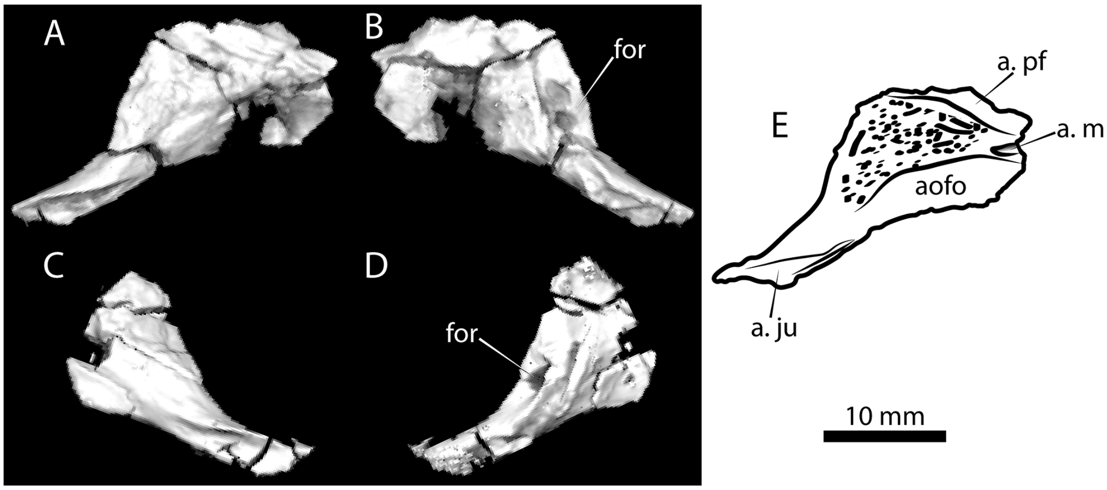

Figure 12. *Scutellosaurus lawleri*. TMM 43664-1. Right lacrimal in lateral (A, E) and medial (B) views. Left lacrimal in lateral (C) and medial (D) views. A-D are 3D digital renderings. Abbreviations: a. ju, articulation with the jugal; a. m, articulation with the maxilla; a. pf, articulation with the prefrontal; aofo, antorbital fossa; for, foramen.

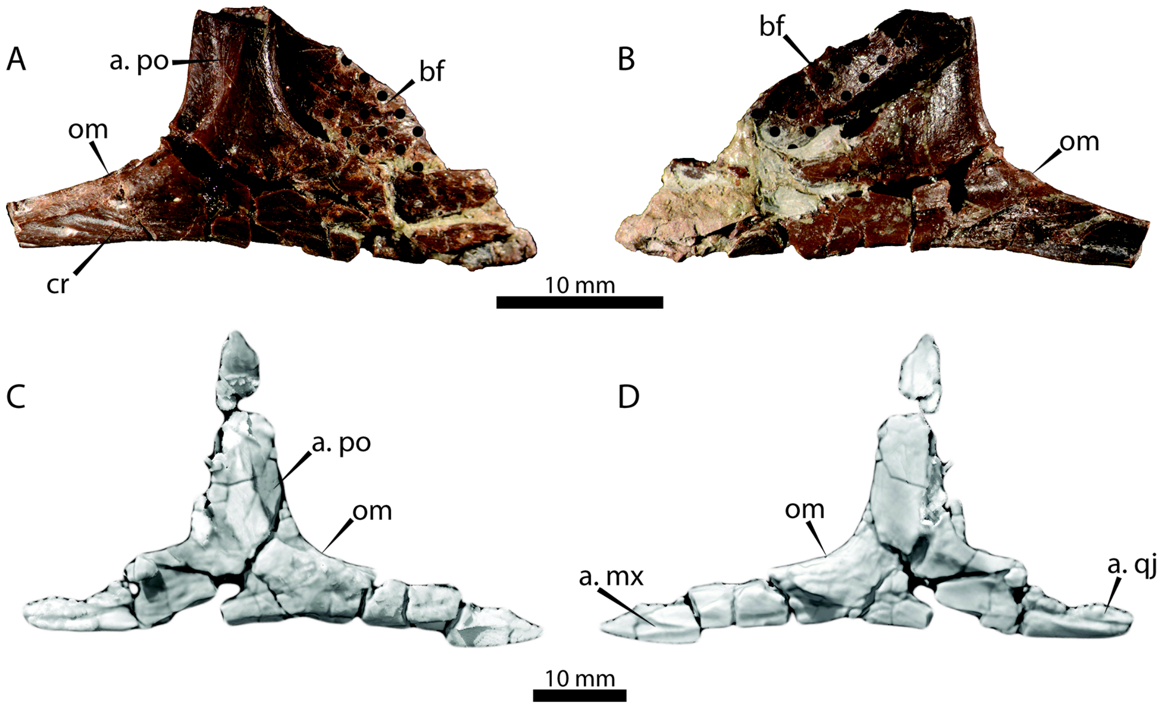

Figure 13. *Scutellosaurus lawleri*. Left jugal of TMM 43663-1 in lateral (A) and medial (B) views. 3D digital rendering of the right lacrimal of TMM 43664-1 in lateral (C) and medial (D) views. Abbreviations: a. mx, articulation with the maxilla; a. po, articulation with the postorbital; a. qj, articulation with the quadratojugal; bf, bone fragments; cr, cortical remodeling; om, orbital margin.

Postorbital (Figure 14)

Left and right postorbitals are preserved in both TMM 43663-1 and TMM 43664-1. In TMM 43663-1, the right postorbital is nearly complete but is missing much of its posterior process, and the left postorbital is nearly complete but badly fractured. In TMM 43664-1, the right postorbital is complete but fractured, and the left postorbital is badly distorted. The postorbital was not previously reported in published specimens of *Scutellosaurus lawleri*.

The postorbital is a transversely flat, triradiate element comprising anterior, posterior, and ventral processes. The ventral process is slender and tapers distally where it overlies the lateral surface of the dorsal process of the jugal along a scarf-joint articulation. The posterior process is slender and tapers distally where it articulates with the anterior process of the squamosal. The posterior margin of the ventral process is blade-like, and the anterior margin forms a ridge that is confluent with the ventral margin of the anterior process. This ridge defines the posterodorsal orbital margin. The anterior process is the shortest and most complex of these processes. Two medial cavities are present on the anterior process of the postorbital, one of which is ventral to the other. The dorsal cavity receives the posterolateral end of the frontal, where it forms a complex articulation. Posterior to that cavity is a small surface for articulation with the anterolateral parietal. The ventral cavity receives the laterosphenoid.

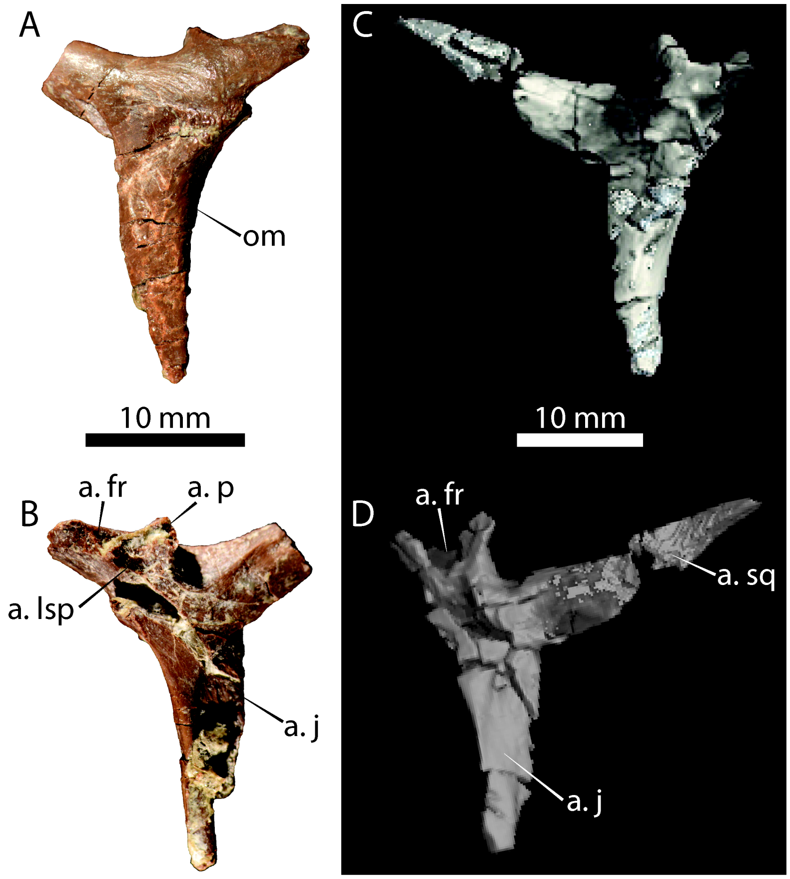

Figure 14. *Scutellosaurus lawleri*. Right postorbital of TMM 43663-1 in lateral (A) and medial (B) views. 3D digital rendering of the right postorbital of TMM 43664-1 in lateral (C) and medial (D) views. Abbreviations: a. fr, articulation with the frontal; a. j, articulation with the jugal; a. lsp, articulation with the laterosphenoid; a. p, articulation with the parietal; a. sq, articulation with the squamosal.

Squamosal (Figure 15)

A nearly complete isolated left squamosal is preserved in TMM 43663-1. Only the lateral surface of the squamosal could be prepared, so much of the medial surface remains obscured by matrix, and the CT scan of this specimen was insufficient to add any anatomical data regarding the medial surface. A possible fragment of the squamosal from MNA V175 was reported but not figured by Colbert (1981), and I could not locate this fragment among MNA V175 for personal observation. TMM 43633-1 thus preserves the first definitive squamosal of *Scutellosaurus lawleri*. The squamosal is a complex, triradiate element comprising anterior, prequadratic, and postquadratic processes. The lateral surface of the squamosal is deeply excavated. The anterior process curves ventrally and bifurcates into dorsal and ventral projections that flank the posterior process of the postorbital to form the upper temporal bar. The dorsal projection of the squamosal overlies the dorsolateral margin of the posterior process of the postorbital, and the ventral projection is overlain by the ventromedial margin of the posterior process of the postorbital. The prequadratic process is thin and incomplete ventrally, so it is unclear whether articulation between the squamosal and the dorsal process of the quadratojugal exists. The prequadratic process of the squamosal overlies the anterior margin of the quadrate, and the head of the quadrate articulates with the squamosal between the prequadratic and postquadratic processes. The postquadratic process is shorter than the anterior and prequadratic processes, and it is laterally swollen and rough. The postquadratic process overlies the paroccipital process of the otoccipital. The prequadratic process and the ventral projection of the anterior process of the squamosal contribute to the posterodorsal margin of the infratemporal fenestra.

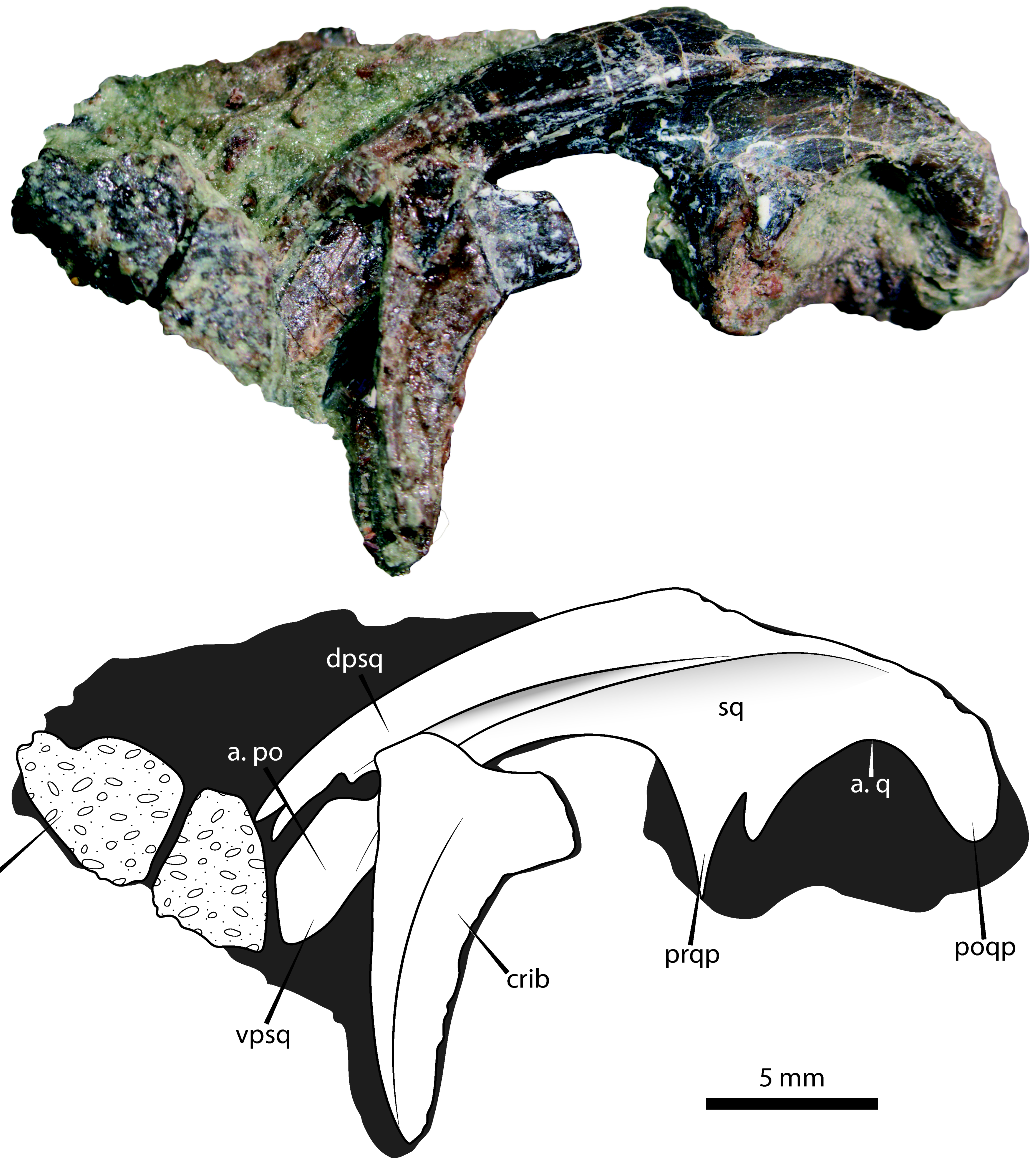

Figure 15. *Scutellosaurus lawleri*. TMM 43663-1. Block containing the left squamosal in lateral view. Abbreviations: a. po, articulation with the postorbital; a. q, articulation with the quadrate; crib, cervical rib; dpsq, dorsal process of the squamosal; ost, osteoderm; poqp, postquadratic process of the squamosal; prqp, prequadratic process of the squamosal; sq, squamosal; vpsq, ventral process of the squamosal.

Quadrate (Figure 16A-E)

A nearly complete left quadrate is preserved in TMM 43663-1, and a heavily fragmented but nearly complete right quadrate is preserved in TMM 43664-1. The quadrate of TMM 43664-1 is best visualized from the CT scan of this specimen. The quadrate comprises a dorsoventrally-oriented pillar-like body from which the thin pterygoid ramus and the short jugal ramus extend anteromedially and anterolaterally, respectively. The body of the quadrate arches somewhat anteriorly and medially. The dorsal body of the quadrate is concave along both its anterior and posterior surfaces. The jugal ramus is poorly preserved in both specimens, and there is no trace of a paraquadratic foramen. The ventral margin of this process would have been overlain laterally by the quadratojugal, which bears a prominent foramen on its medial surface. The pterygoid ramus is poorly preserved in TMM 43663-1 and is nearly complete but thin and extensively fragmented in TMM 43664-1. The pterygoid ramus is dorsoventrally tall and tapers anteriorly. The head of the quadrate bears a strong posterior facet and articulates with the squamosal between its prequadratic and postquadratic processes. The trochlear condyle for the lower jaw is well-developed, dorsoventrally broad, and bears distinct medial and lateral condyles. The medial condyle is larger than the lateral condyle. The lateral condyle is dorsally displaced relative to the medial condyle and tapers laterally where it curves somewhat anteriorly.

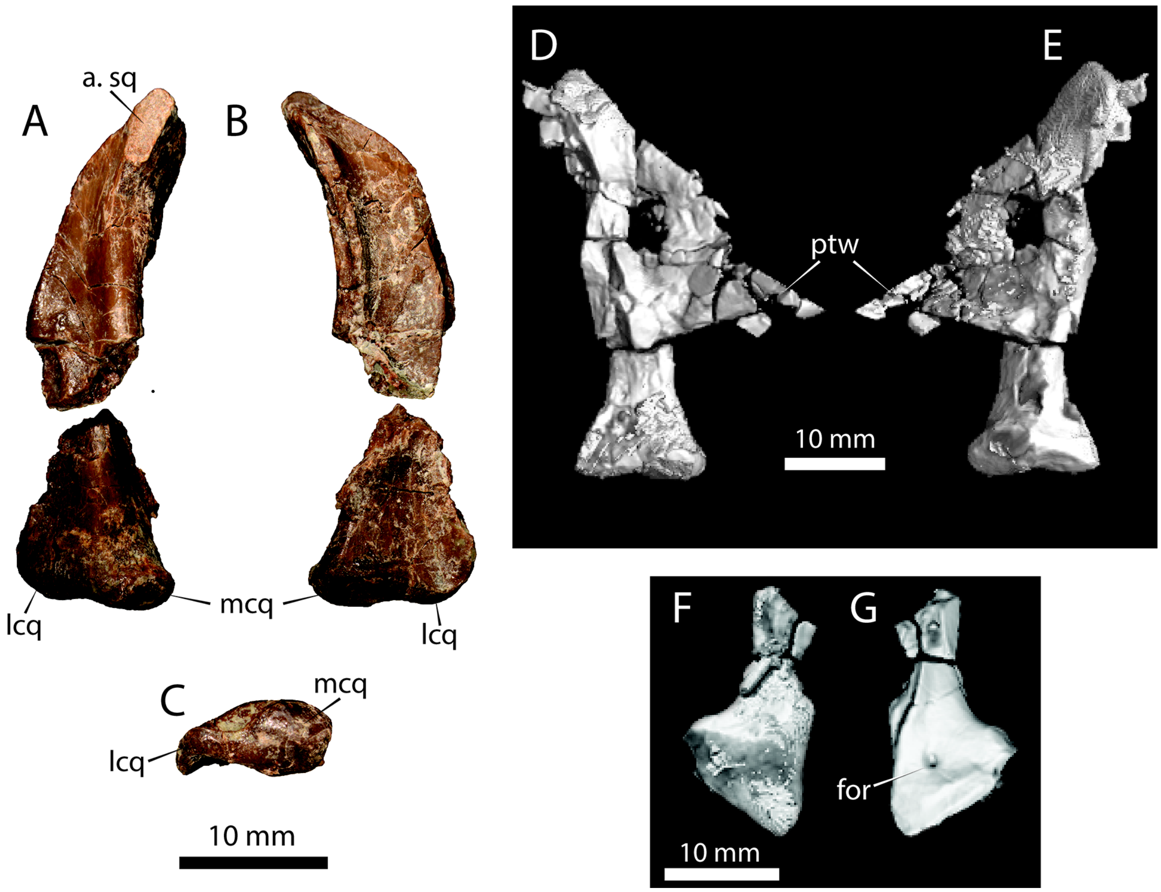

Figure 16. *Scutellosaurus lawleri*. Left quadrate of TMM 43663-1 in posterior (A), anterior (B), and ventral (C) views. 3D digital rendering of the right quadrate of TMM 43664-1 in anterior (D) and posterior (E) views. 3D digital rendering of the left quadratojugal of TMM 43664-1 in lateral (F) and medial (G) views. Abbreviations: a. sq, articulation with the squamosal; for, foramen; lcq, lateral condyle of the quadrate; mcq, medial condyle of the quadrate; ptw, pterygoid wing.

Quadratojugal (Figure 16F-G)

A nearly complete left quadratojugal is preserved in TMM 43664-1. This is the first specimen of *Scutellosaurus lawleri* in which the quadratojugal is reported. The quadratojugal is a paired L-shaped element with its long axis oriented dorsoventrally. It is transversely flat and overlaps the quadrate in lateral view, forming the dorsoventral margin of the infratemporal fenestra. The dorsal process of the quadratojugal tapers and may have articulated with the descending process of the squamosal, but the contact between these two elements is not preserved if it did exist. Much of the lateral surface of the quadratojugal is obscured by other elements and is visible only in the CT scan of the specimen. The medial surface of the quadratojugal is smooth and slightly concave and is pierced by a prominent foramen.

Supraoccipital (Figure 17A-C)

The supraoccipital is a single midline element that is preserved only in TMM 43663-1. The supraoccipital is subovoid and forms the dorsal margin of the foramen magnum. The anterior surface is smooth and concave with prominent facets along the ventrolateral margins for articulation with the dorsomedial margins of the paroccipital processes of the opisthotic. The anterodorsal margins would have contacts the parietal. A pronounced nuchal crest extends along the entire dorsoventral length of the posterior surface of the element, unlike the supraoccipital nuchal crest of *Lesothosaurus,* which is rounded and is only prominent dorsally (Porro *et al*., 2015). The supraoccipital nuchal crest is also weak in *Eocursor parvus* (Butler, 2010). On either side of the nuchal crest, the posterior surface is concave and pinched in, giving the element a Y-shape in dorsal view.

Opisthotic (Figure 17D-E)

The opisthotic is represented only by a single isolated right paroccipital process in TMM 43663-1. The paroccipital process extends laterally and is slightly expanded distally along its dorsoventral extent. It is approximately 1.3 times as wide transversely as it is dorsoventrally tall. The dorsomedial margin bears a facet for articulation with the supraoccipital. Lateral to this facet, the paroccipital process was overlain along its dorsal margin by the parietal. The posterior surface of the paroccipital process is concave such that the element gently arches anteriorly where the process would overlie the postquadratic process of the squamosal. The extent to which the paroccipital process contributed to the foramen magnum is unclear.

Dentary

Both dentaries are poorly preserved in TMM 43663-1. It is unclear how many alveoli are present in either dentary. The anterior end of each dentary is downturned, which is a synapomorphy of Thyreophora (Butler *et al.*, 2010). Better preserved dentaries and dentary teeth are present in MNA V175 and UCMP 130580, and little can be added to the description by Colbert (1981) here.

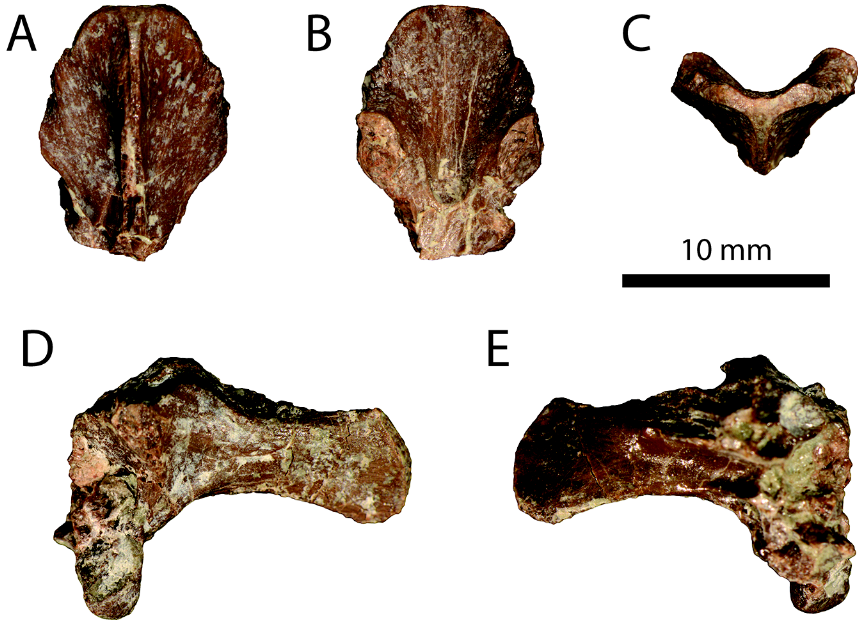

Figure 17. *Scutellosaurus lawleri*. TMM 43663-1. Supraoccipital in posterior (A), anterior (B), and dorsal (C) views. Right paroccipital process of the opisthotic in posterior (D) and anterior (E) views.

AXIAL SKELETON

The vertebral columns of both TMM 43663-1 and TMM 43664-1 are incomplete and restricted mostly to isolated and fragmentary centra and neural arches. Both specimens preserve cervical, trunk, sacral, and caudal vertebrae. Like the holotype, paratype, and referred specimens, the neurocentral sutures are open in all but the posterior caudal vertebrae in both specimens. In some cases, other TMM specimens preserve more complete and informative vertebrae than TMM 43663-1 and TMM 43664-1, and these are referenced where appropriate. Rib fragments are common in MNA V175 and UCMP 130580 but a lack of complete ribs rendered their anatomy poorly understood.

Cervical vertebrae (Figure 7A; Figure 15; Figure 18)

The odontoid process of the axis (developmentally the pleurocentrum of the atlas) is preserved in TMM 43664-1 and TMM 45609-6 and is unfused to the axis in both specimens. The atlas-axis complex of *Scutellosaurus lawleri* is poorly understood and has so far only been represented by an atlantal neural arch, the odontoid, and the atlas intercentrum of UCMP 130580. The odontoid is somewhat wider than it is long in dorsal view. The dorsal surface of the odontoid is broadly flat with a slight concavity along the midline of the element to accommodate the neural canal. The ventral surface is convex and rounded with a prominent lip anteriorly at its articulation with the dorsal surface of the atlas intercentrum. The anterior face of the odontoid is rounded and reniform in anterior view. The posterior margin of the odontoid is sinuous in dorsal and ventral views where it would articulate with the anterior centrum of the axis. The odontoid is transversely wider posteriorly than anteriorly.

Posterior to the atlas-axis complex, cervical centra are well known from *Scutellosaurus lawleri* from MNA V175 and UCMP 130580; however, the neurocentral sutures of the cervical vertebrae are completely open in both specimens, and no cervical centrum in either has its associated neural arch preserved. The cervical centra of *Scutellosaurus lawleri* are generally similar to those of other early ornithischian dinosaurs *Eocursor parvus* and *Lesothosaurus diagnosticus* in possessing deep lateral excavations that form a prominent ventral keel. *Scutellosaurus lawleri* is distinct from other early ornithischian dinosaurs in that this ventral keel is broad and extremely rugose (Colbert, 1981; Butler, 2010). TMM 43663-1 preserves a partial cervical centrum that exhibits a rugose ventral keel well. The best-preserved cervical vertebra of *Scutellosaurus lawleri* is from TMM 45609-6, which preserves a nearly complete anterior cervical vertebra with its neural arch still attached to the centrum. The vertebra is fragmented in several places but is held together by a hard iron-oxide matrix. The neurocentral suture is visible and was not completely closed at the time of death. The neurocentral suture is complex and approximates the contour of the ventral margin of the centrum in lateral view. In lateral view, the ventral margin of this vertebra is sinuous, and the posterior end of the centrum extends further ventrally than the anterior end does. The parapophysis is almost entirely contained by the centrum with a minor contribution from the neural arch dorsally along the neurocentral suture. The parapophysis is swollen and rounded and is positioned anteriorly flanking the lateral sides of the anterior central face such that the centrum appears subtriangular in anterior view. The centrum is round in posterior view. The diapophysis is positioned entirely on the neural arch just above the neurocentral suture and is offset dorsally and posteriorly from the parapophysis. The diapophysis is dorsoventrally shorter and extends somewhat farther laterally than the parapophysis. Neither the diapophysis nor the parapophysis lie upon a well-developed transverse process. The neural canal remains filled with matrix but is clearly expansive. The neural spine has broken off and is missing. The right prezygapophysis and left postzygapophysis are missing, and the remaining zygapophyses are poorly preserved. The prezygapophysis sits along a slender, anteromedially curving projection, and the postzygapophysis sits along a subtriangular posterolaterally oriented projection. It is unclear whether epipophyses were present.

A relatively well-preserved cervical rib is present in TMM 43663-1 closely appressed to the anterior left squamosal, but only the medial surface is visible. Cervical ribs are unknown in the type and published referred specimens of *Scutellosaurus lawleri*, making this the first reported cervical rib for the taxon. This rib closely resembles cervical rib 3 of *Hypsilophodon foxii* (Galton, 1974: fig. 19) and is from the right side of the body. The rib has two heads, with the tuberculum longer than the capitulum. The tuberculum is subrectangular in medial view, and the capitulum is subrounded. The medial surface of the rib is concave. Distally, the rib tapers and curves posterodorsally.

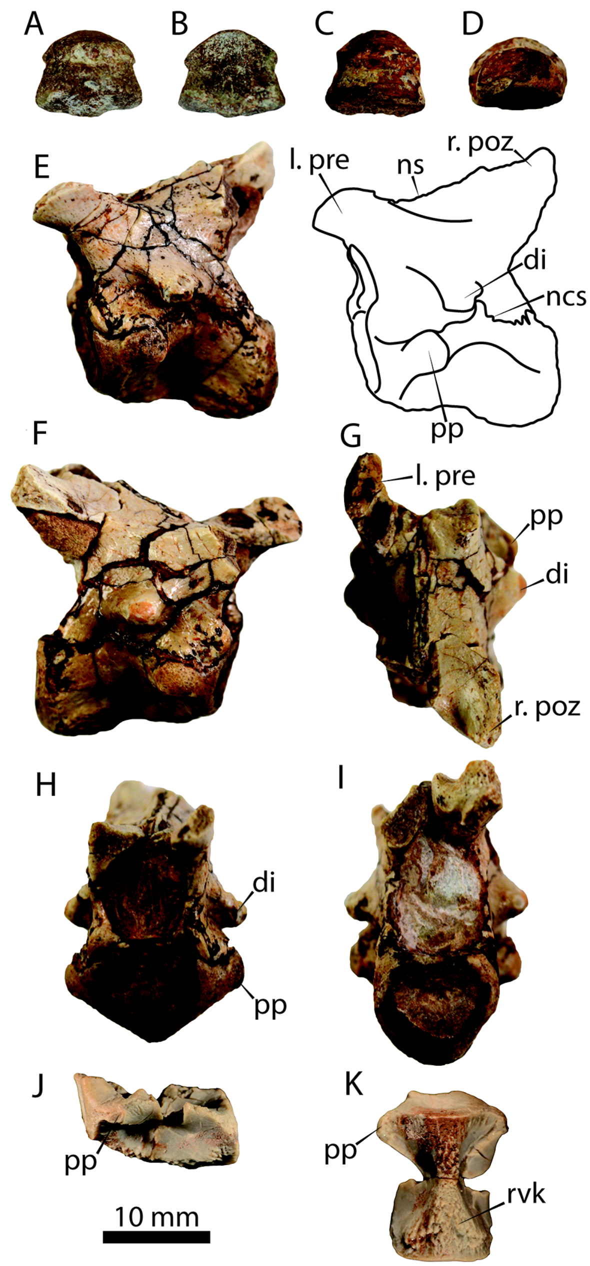

Figure 18. *Scutellosaurus lawleri*. Cervical vertebrae. Odontoid processes of TMM 43664-1 in ventral (A) and dorsal (B) views and TMM 45609-6 in ventral (C) and anterior (D) views. Cervical vertebra (TMM 45609-6) in left lateral (E), right lateral (F), dorsal (G), anterior (H) and posterior (I) views. Cervical centrum (TMM 43663-1) in left lateral (J) and ventral (K) views. Abbreviations: di, diapophysis; l. pre, left prezygapophysis; ncs, neurocentral suture; ns, neural spine; pp, parapophysis; r. poz, right postzygapophysis; rvk, rugose ventral keel.

Trunk vertebrae (Figure 3E-F)

The trunk vertebrae of the type specimens of *Scutellosaurus lawleri* were relatively well documented by Colbert (1981), and none of the TMM specimens preserve trunk vertebrae that are anatomically more informative than MNA V175. TMM 43687-75 preserves associated postcranial remains of a large individual of *Scutellosaurus lawleri* including a partial trunk vertebra with a complete centrum and some of its neural arch. The zygapophyses and neural spine of that vertebra are poorly preserved, but the neurocentral suture is at least partially closed. The closeure of the neurocentral suture in the trunk vertebrate of *Scutellosaurus lawleri* has only been reported in TMM 43687-22 and TMM 43687-75.

Trunk ribs are represented by numerous fragments in the type and published referred specimens of *Scutellosaurus lawleri*, and this is also the case with the specimens reported here, few of which preserve significant anatomical information. TMM 43664-1 preserves a fragmented nearly complete trunk rib from the left side of the body missing its distal end. Most of the lateral surface of the rib remains obscured by matrix. This rib possesses a well-developed capitulum and a reduced tuberculum, so it is probably from the posterior trunk region. The tuberculum projects dorsally as a short facet. The rib seems to widen before tapering distally, but this may be an artifact of preservation. The medial surface is concave with a groove extending distally.

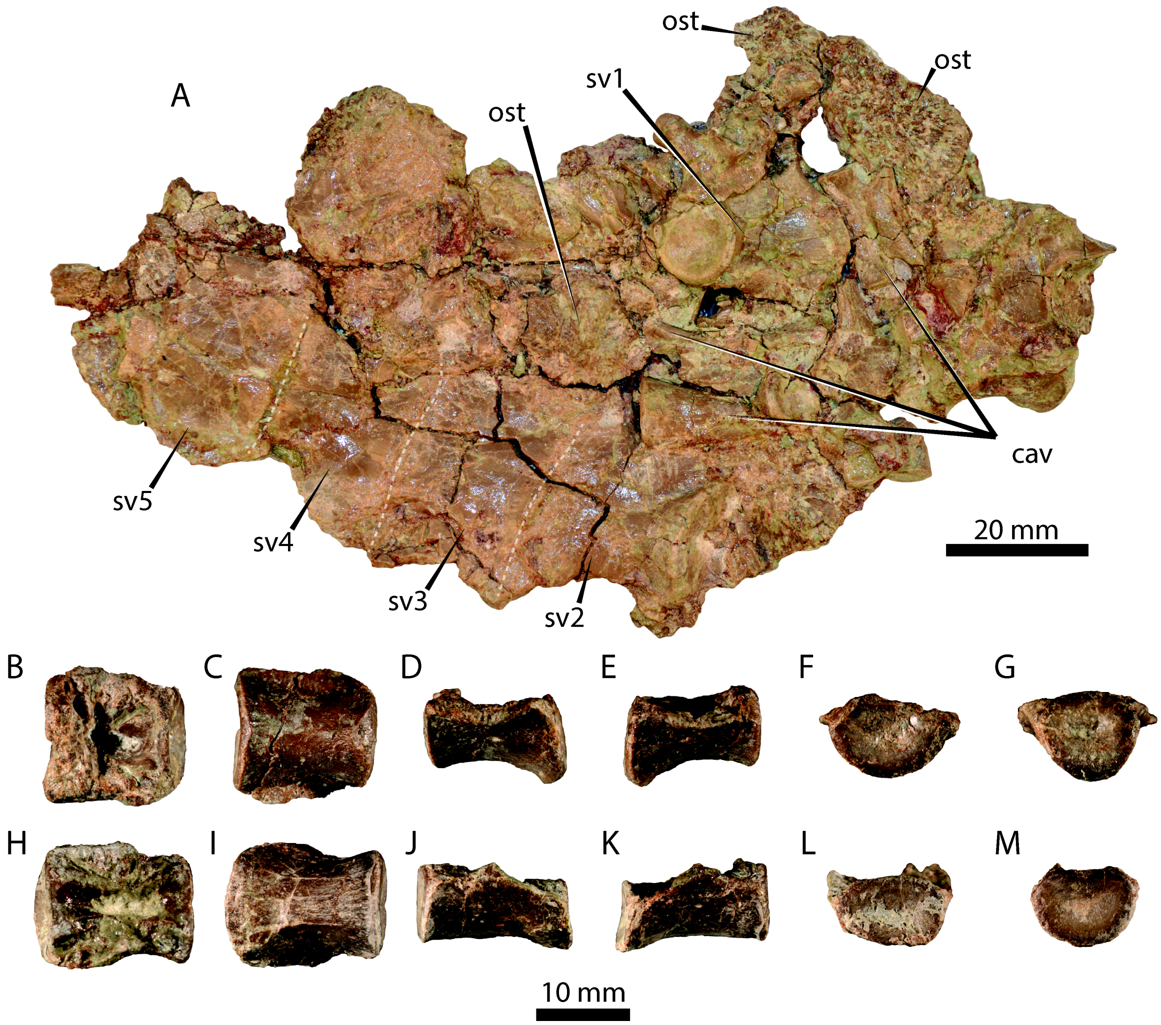

Figure 19. *Scutellosaurus lawleri*. Sacral vertebrae. Block from TMM 43664-1 containing sacral vertebrae (A). Sacral centra from TMM 43663-1 in dorsal (B, H), ventral (C, I), left lateral (D, J), right lateral (E, K), anterior (F, L), and posterior (G, M) views. Abbreviations: cav, caudal vertebra; ost, osteoderm; sv, sacral vertebra.

Sacral vertebrae (Figure 5A-D; Figure 19)

Sacral centra were reported from MNA V175, MNA V1752, and UCMP 130580 and are preserved in both TMM 43663-1 and TMM 43664-1. The holotype specimen (MNA V175) preserves five disarticulated sacral vertebrae lacking neural arches, and nothing can be added to the observations of Colbert (1981). TMM 43663-1 preserves two isolated cervical centra, and TMM 43664-1 preserves a complete sacral series comprising an isolated transitional dorsosacral centrum and articulated sacral centra 2 through 5 exposed in ventral view. No sacral neural arches are well preserved in either specimen. MNA V175 does not preserve a dorsosacral vertebrae, so it is possible that a sixth sacral vertebra was simply not preserved in TMM 43664-1. Five is the typical number of sacral vertebrae present in other early ornithischian dinosaurs; however, it is unclear whether this represents the plesiomorphic number of sacral vertebrae for all ornithischians owing to the poor preservation of the pelvis and sacrum of the basal taxa *Pisanosaurus mertii* and *Eocursor parvus*. Within Thyreophora, *Scelidosaurus harrisonii* and the basal stegosaur *Huayangosaurus taibaii* possess only four sacral vertebrae and more derived members of Stegosauria and Ankylosauria develop a synsacum. The basal neornithischians *Lesothosaurus diagnosticus*, *Stormbergia dangershoeki*, *Agilisaurus louderbacki*, and *Hexinlusaurus multidens* each possess five sacral vertebrae, and heterodontosaurids incorporate at least six vertebrae into the sacrum. In contrast, basal theropod and sauropodomorph saurischian dinosaurs typically possess only two or three sacral vertebrae (Langer & Benton, 2006). A well-preserved sacral rib is preserved in UCMP 130580, but the sacral ribs of TMM 43664-1 are poorly preserved.

Caudal vertebrae (Figure 5E-F)

Caudal vertebrae are widely known from nearly every specimen of *Scutellosaurus lawleri*, and the unusually high number of at least 59 caudal vertebrae is diagnostic of the taxon. Proximal (anterior) caudal vertebrae are distinct from distal (posterior) caudal vertebrae in possessing prominent transverse processes. These transverse processes decrease in size distally. Distal caudal vertebrae are the only vertebrae of *Scutellosaurus lawleri* that consistently possess complete closure of the neurocentral arch. MNA V175 preserves a nearly complete series of all caudal vertebrae, and nothing can be added to the observations of Colbert (1981). The holotype specimen (MNA V175) preserves 58 caudal vertebrae, which indicates that the tail comprised approximately 60 vertebrae. This number is higher than in other early ornithischian and basal thyreophoran dinosaurs and is considered an autapomorphic character state diagnostic of *Scutellosaurus lawleri* (Butler *et al.*, 2008).

PECTORAL GIRDLE

Scapula (Figure 3G-H; Figure 20)

Nearly complete scapulae are preserved in both TMM 43663-1 and TMM 43664-1. TMM 43663-1 preserves a complete mediolaterally crushed right scapula missing only small fragments of the posterior dorsal and ventral margins. Much of the anterior end of the scapula is obscured by small fragments of other bone, so length measurements are approximate. TMM 43664-1 preserves a complete mediolaterally crushed right scapula. A complete scapula is not known in any other specimen that is reported to date. Both scapulae are preserved in MNA V175 but lack their distal margins. MNA V1752 preserves two fragments of a scapula. UCMP 130580 preserves only fragments of left and right scapulae, precluding length measurements and character coding for the presence or absence of a distal expansion (Butler *et al.*, 2008).

The scapula is expanded dorsoventrally at both proximal and distal ends, giving it an asymmetrical, hourglass shape in lateral or medial view. The proximal expansion is defined by the acromion process dorsally and the glenoid cavity ventrally. The proximal margin is flat and transversely broad for articulation with the coracoid, which is not preserved in either TMM specimen. The distal expansion is greatest ventrally and is somewhat stronger overall than the proximal expansion. The margin of the distal expansion is gently convex with the ventral process extending farther than the dorsal process. The dorsal and ventral margins of the scapula are concave such that the shaft tapers proximally, reaching its narrowest height nearer to the proximal margin than the distal margin.

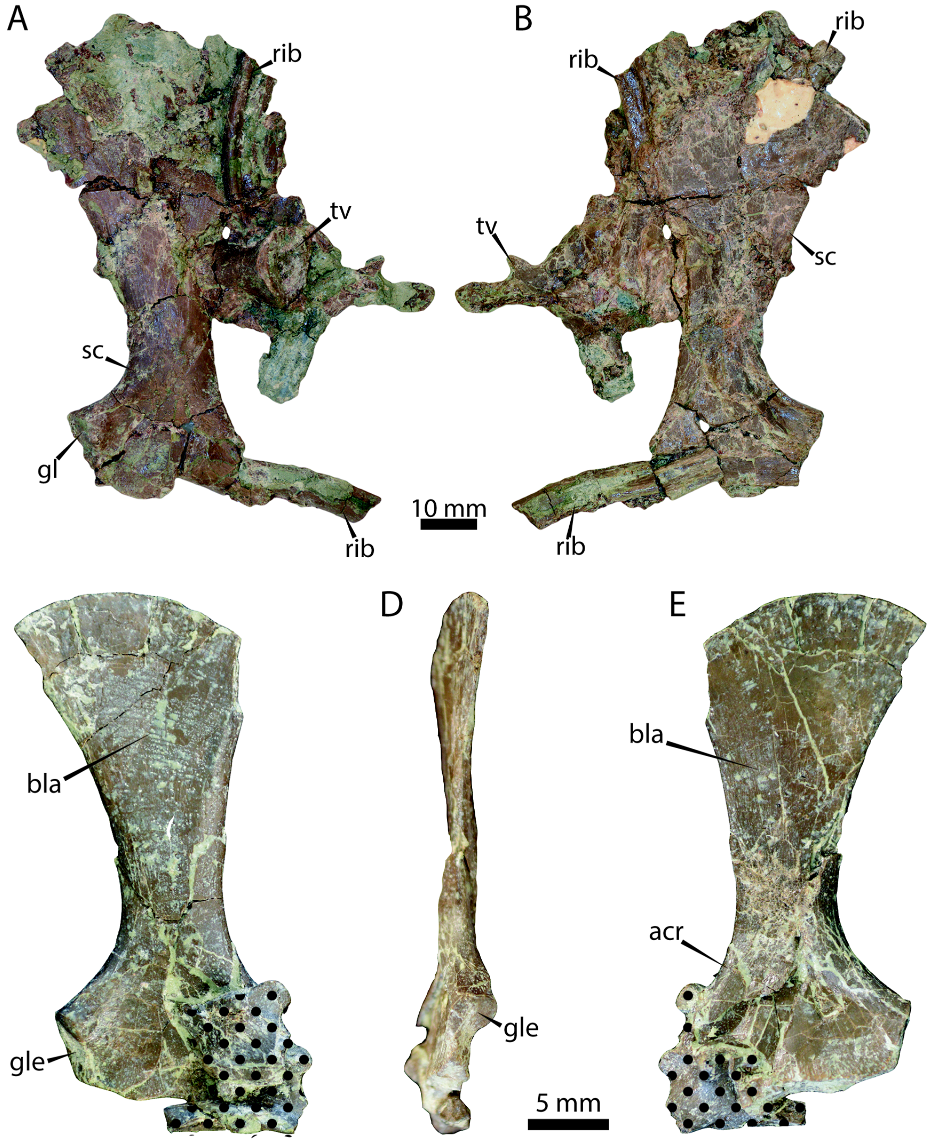

Figure 20. *Scutellosaurus lawleri*. Block containing right scapula of TMM 43664-1 in lateral (A) and medial (B) views. Right scapula of TMM 43663-1 in lateral (C), ventral (D), and medial (E) views. Stippled region indicates unidentified non-scapular bone fragments. Abbreviations: acr, acromion; bla, blade; gle, glenoid; rib, rib; sc, scapula; tv, trunk vertebra.

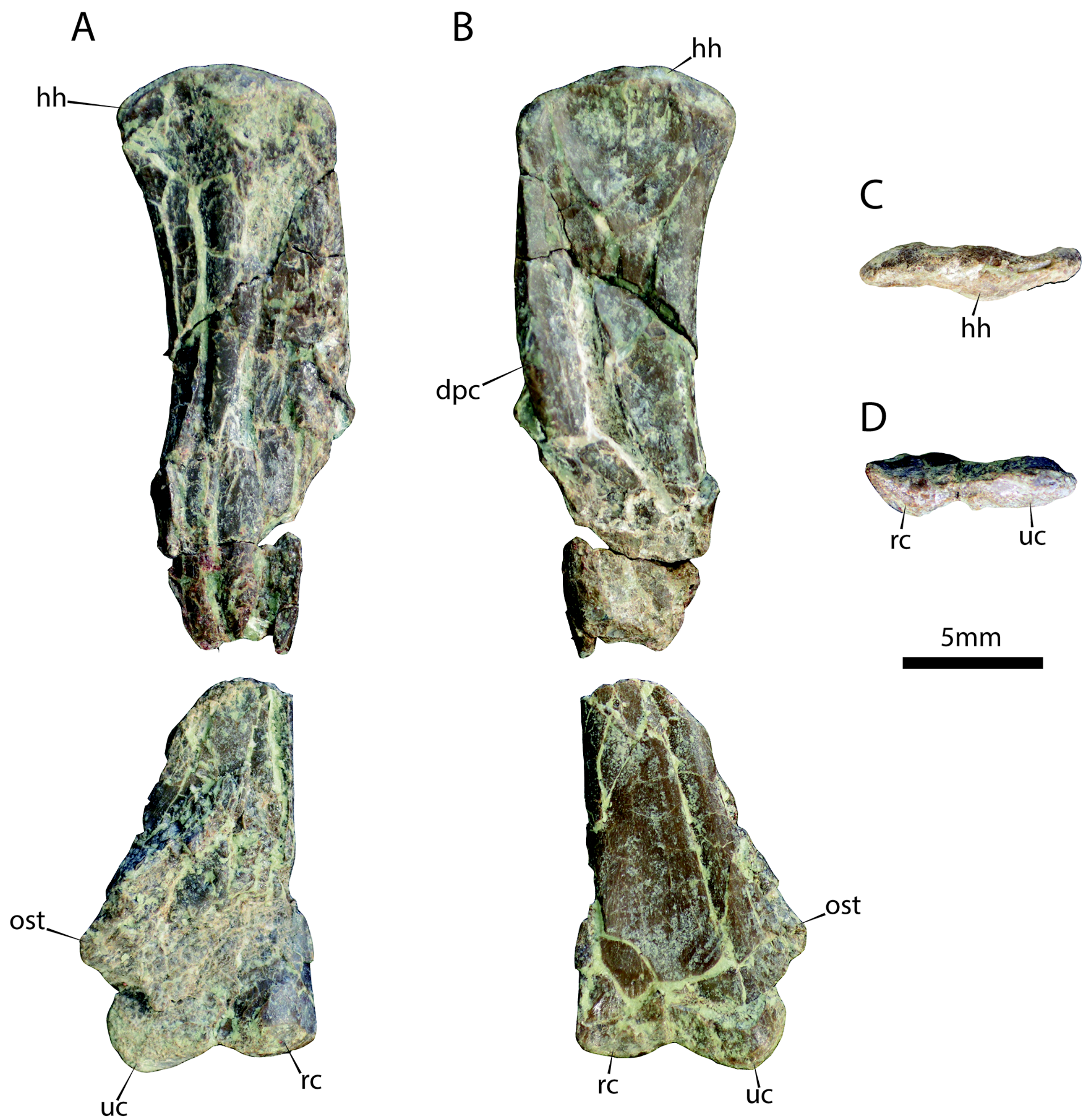

Figure 21. *Scutellosaurus lawleri*. TMM 43663-1. Right humerus in posterior (A), anterior (B), proximal (C), and distal (D) views. Abbreviations: dpc, deltopectoral crest; hh, head of the humerus; ost, osteoderm; rc, radial condyle; uc, ulnar condyle.

FORELIMB

Humerus (Figure 3I-M; Figure 7B-D; Figure 21)

TMM 43663-1 preserves a nearly complete right humerus in two pieces that have been anteroposteriorly compressed. The humerus is missing small fragments of the midshaft between the two preserved pieces, so its complete length cannot be measured, but the two pieces combined measure approximately 70.1 mm. The humerus is then at least 84% of the length of the femur, which is greater than the same ratio in most other basal ornithischian dinosaurs (Butler, 2010). It is also greater than the 73% ratio of the measurements of the humerus and femur given by Colbert (1981) in his description of the holotype specimen of *Scutellosaurus lawleri*. Rather than being explained by variation within the taxon, this appears to be the result of an inaccurate measurement of the holotype femur. Novel measurements of MNA V175 give a length of 84 mm for the femur, which is nearly 10 mm less than the measurement of 93.2 mm provided by Colbert. In anterior view, the humerus is straight along most of its length, but there is a prominent medial projection of the head of the humerus proximally. The medial projection is less pronounced than in *Eocursor parvus* but more pronounced than in other ornithischians such as *Heterodontosaurus tucki* and *Lesothosaurus diagnosticus*.

The head of the humerus is poorly developed. The proximal outline of the humerus is weakly sigmoidal, with the head of the humerus thicker medially than laterally. The lateral aspect of the head of the humerus tapers distally where it descends onto the small deltopectoral crest. A prominent tubercle is present at the apex of the deltopectoral crest in the holotype specimen (MNA V175) resulting from the attachment of the pectoralis muscle (Maidment & Barrett, 2011), but this tubercle is poorly preserved in TMM 43663-1. As with other early ornithischian dinosaurs, the distal humerus lacks entepicondyles and ectepicondyles. The lateral radial condyle and medial ulnar condyle form a trochlear surface at the distal end of the humerus. In distal view, the lateral aspect of the radial condyle tapers to a point anteriorly, and the ulnar condyle is ovoid.

PELVIC GIRDLE

Ilium (Figure 7E-F; Figure 22)

A nearly complete right ilium is preserved in TMM 43664-1. This ilium measures 116 mm long and is transversely crushed and fractured. The ilium of *Scutellosaurus lawleri* was previously reported by fragments in the holotype (MNA V175), UCMP 130580, and UCMP 170829. Much of the ventral margin of the ilium is obscured by other elements closely appressed to it including a dorsal rib, a possible metatarsal III, and several osteoderms. In dorsal view, the ilium is nearly straight, though this may be an artifact of the transverse taphonomic crushing rather than the actual morphology of the bone. The preacetabular process of the ilium is long, straight, and slender, comprising approximately 50% of the total length of the ilium. It tapers to a point anteriorly, similar to the preacetabular process of the ilium of *Scelidosaurus harrisonii* (BMNH R6704; Butler, 2005). The morphology of a fragment of UCMP 130580 identified as the anterior (preacetabular) process of the left ilium by Rosenbaum & Padian (2000) is inconsistent with the morphology of the preacetabular process of the ilium TMM 43664-1. The fragment from UCMP 130580 tapers anteriorly, where it expands and ends in a squared-off process and is ventrally concave in lateral view. In contrast, the ilium of TMM 43664-1 tapers to a point anteriorly and is straight in lateral view; however, it is possible that the preacetabular process is incomplete, and the squared-off process seen in UCMP 130580 is simply missing from TMM 43664-1. The dorsal margin of the ilium is transversely expanded into a medial flange, forming a shelf. The ventral margin of the preacetabular process is likewise expanded to form a medial flange, so the preacetabular process is C-shaped in cross section. The acetabular margin of the ilium is partially closed by a thin medioventral flange, similar to the condition seen in *Scelidosaurus harrisonii* (BMNH R6704; Butler, 2005).

HINDLIMB

Femur (Figure 4A-E; Figure 5K-O; Figure 7G-I; Figure 23)

The right femur of TMM 43663-1 is preserved but has been taphonomically distorted and fractured. The femur of TMM 43663-1 provides no new anatomical information, and nothing can be added to the description of the femur by Colbert (1981). MNA V175 contains both femora. The proximal and distal ends of the right femur of MNA V175 were preserved in association with one another, but the midshaft is badly crushed. The proximal right femur is preserved in a block containing parts of the right ilium, partial vertebrae, several osteoderms, and other bone fragments and the distal right femur is loose. The left femur is complete and is preserved in a block with portions of an ilium, a proximal pubis, and other bone fragments. Neither femur in the holotype preserves a complete fourth trochanter. MNA V1752 preserves both femora, which are nearly complete but lack their fourth trochanters, which were broken off and lost prior to collection.

The proximal end of the femur of TMM 43663-1 is compressed anteroposteriorly, and the distal end is compressed mediolaterally. The distal end of the femur appears to have been twisted counterclockwise relative to the proximal end in proximal view such that the distal condyles are oriented laterally, giving the femur an unnatural sinuous curve in anterior and posterior view. The femur is 83.3 mm long, but accurate linear measurements are precluded by distortion in the element. The greater trochanter is confluent with the head of the femur and is separated from the anterior trochanter by a prominent groove. The anterior trochanter is positioned somewhat medially to the greater trochanter. The proximal point of the anterior trochanter is oriented perpendicular to and approximately 8.7 mm below the proximal head of the femur. All but a distal fragment of the fourth trochanter is lost. The fourth trochanter is located entirely on the proximal half of the femur. The fibular condyle projects distally beyond the medial and lateral distal condyles, and the medial condyle has been taphonomically offset anteriorly from the fibular and lateral condyles.

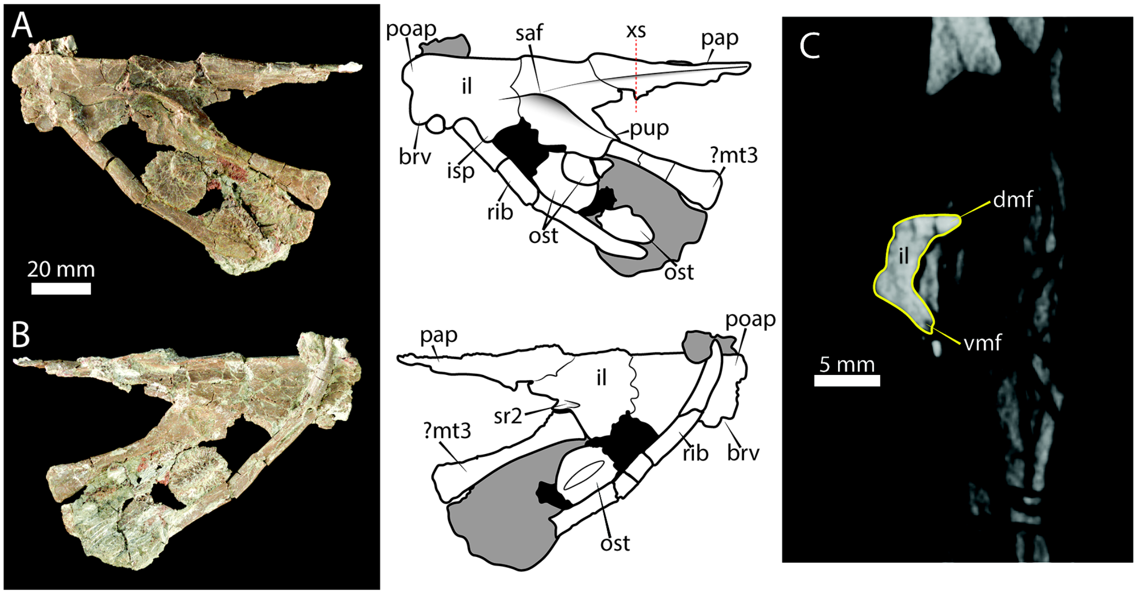

Figure 22. *Scutellosaurus lawleri*. TMM 43664-1. Block containing right ilium in lateral (A) and medial (views). CT image slice through the preacetabular process of the right ilium (C). Abbreviations: brv, brevis shelf; dmf, dorsal medial flange; il, ilium; isp, ischial peduncle; ?mt3, possible third metatarsal; ost, osteoderm; pap, preacetabular process; poap, postacetabular process; pup, pubic peduncle; rib, rib; saf, supraacetabular flange; sr2, point of attachment for sacral rib 2; vmf, ventral medial flange.

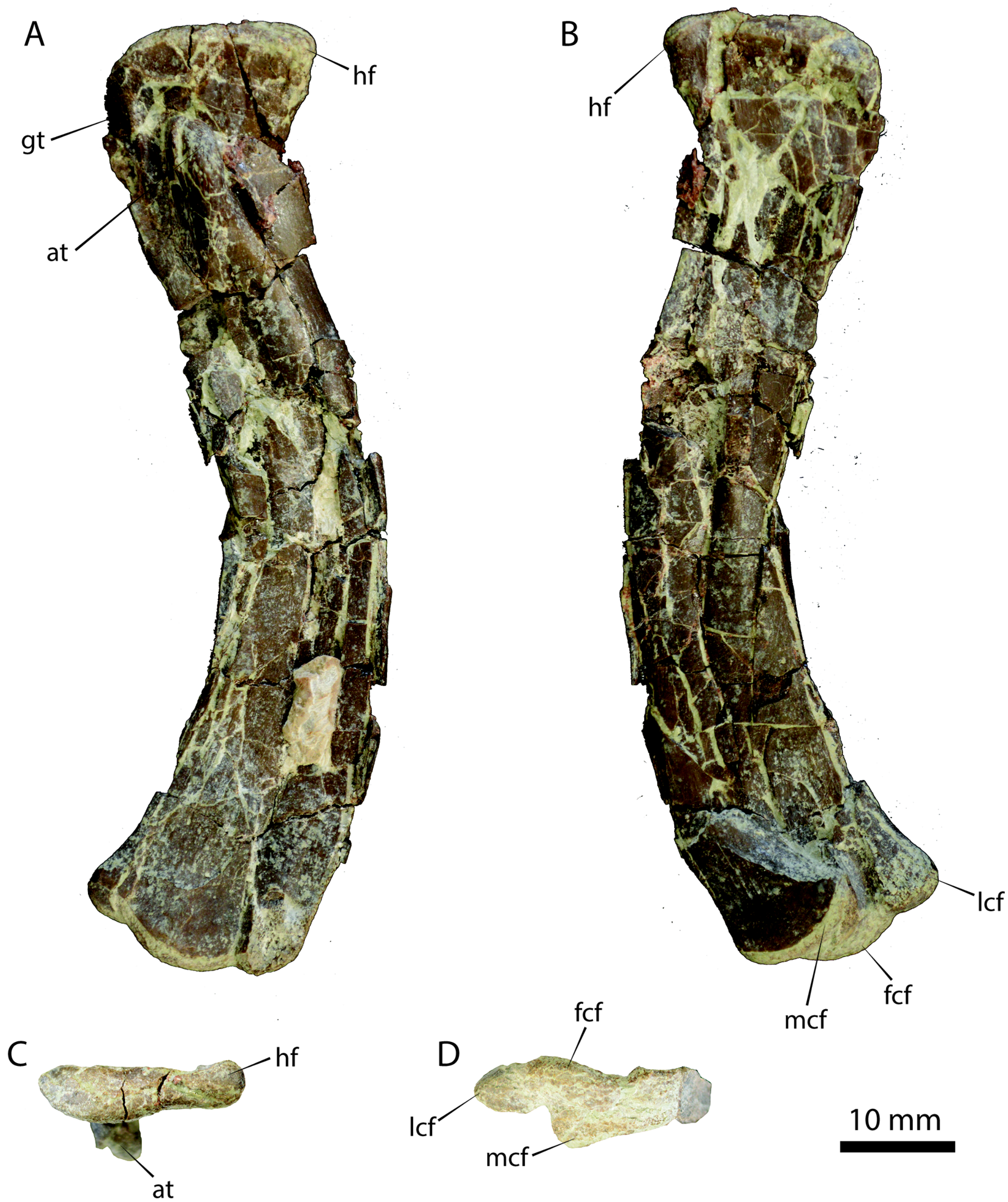

Figure 23. *Scutellosaurus lawleri*. TMM 43663-1. Right femur in posterior (A), anterior (B), proximal (C), and distal (D) views. Abbreviations: at, anterior trochanter; fcf, fibular condyle of the femur; gt, greater trochanter; hf, head of the femur; lcf, lateral condyle of the femur; and mcf, medial condyle of the femur.

Tibia (Figure 4F-K; Figure 7J-O; Figure 24A-C)

A partial right tibia missing the distal third of the bone is preserved in TMM 43663-1, but it has been taphonomically fractured and compressed mediolaterally. Little can be added to the description of the tibia by Colbert (1981), but it is worth noting that figure 28 of Colbert (1981) depicts the left tibia of MNA V175, not the right tibia as it is identified in the figure caption. The maximum proximal width of the tibia of TMM 43663-1 is 22.5 mm, which is approximately the same size as the holotype (MNA V175). The tibia is typical of early ornithischians and is similar to that of *Eocursor* (Butler, 2010) and *Lesothosaurus* (Thulborn, 1972). The proximal end of the tibia is expanded anteroposteriorly. The poorly developed cnemial crest projects anterolaterally and terminates posterolaterally at the *insisura tibialis*, which is a deep sulcus separating the cnemial crest from the fibular condyle (Butler, 2011). The fibular condyle projects posterolaterally and is positioned anterior to the medial condyle. A deep sulcus extends distally as a distinct ridge separating the medial and fibular condyles, as in *Lesothosaurus* and *Stormbergia* (Butler, 2005).

Fibula (Figure 7P-R; Figure 24D-I)

Proximal portions of both fibulae are preserved in TMM 43663-1 and TMM 43664-1. The proximal fibula is expanded anteroposteriorly, and the posterior margin of the proximal fibula extends slightly beyond the anterior margin in lateral view. The lateral surface of the proximal fibula is flat, and the medial surface is concave. Little can be added to the description of the fibulae of MNA V175 by Colbert (1981).

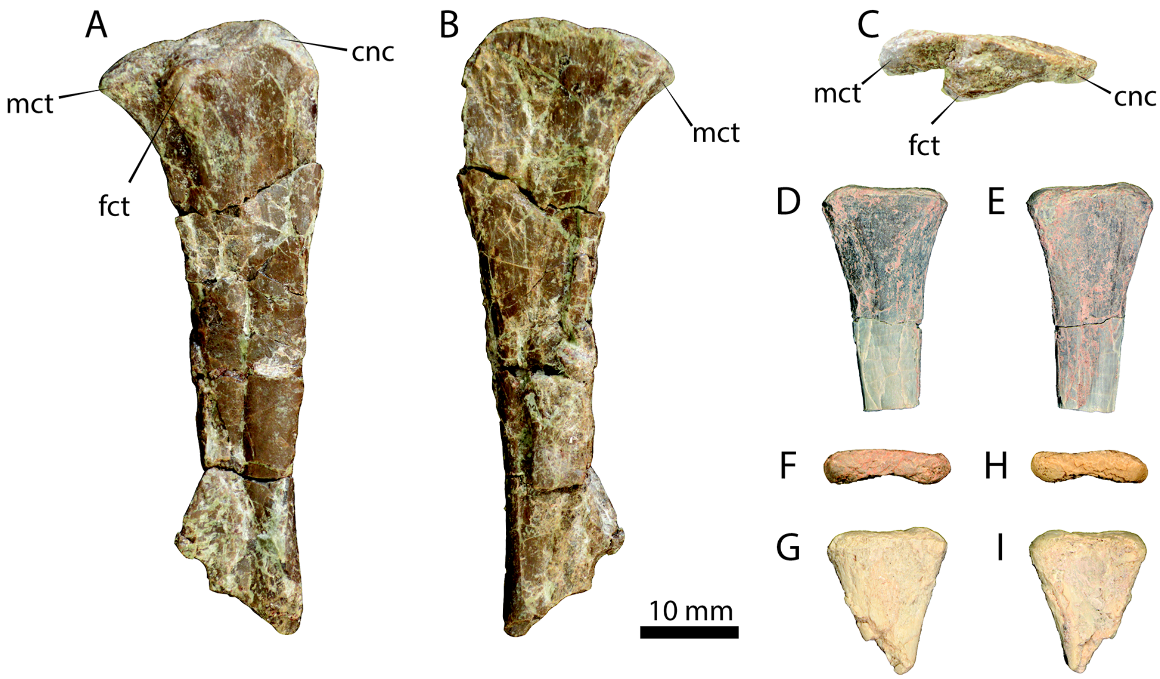

Figure 24. *Scutellosaurus lawleri*. TMM 43663-1. Proximal right tibia in lateral (A), medial (B), and proximal (C) views. Proximal right fibula in lateral (D), medial (E), and proximal (F) views. Proximal left fibula in lateral (G), proximal (H), and medial (I) views. Abbreviations: cnc, cnemial crest; fct, fibular condyle of the tibia; and mct, medial condyle of the tibia.

Astragalus (Figure 25)

A right astragalus is preserved in TMM 43663-1. The astragalus is proximodistally compressed taphonomically, but it is nearly complete. The astragalus is also preserved in MNA V175, MNA V1752, and UCMP 130580. The astragalus is a mediolaterally broad element that is concave proximally, forming an extensive, transversely wide trough for articulation with the medial malleolus of the tibia. Articulation between the fibula and the astragalus is greatly reduced. Anteromedially, there is a small foramen present. In dorsal view, the medial margin of the astragalus is rounded, and the lateral margin is concave where it articulates with the calcaneum. In most specimens of *Scutellosaurus lawleri*, the astragalus and calcaneum are not fused; however, the astragalus and calcaneum are fused in MNA V1752, which is among the largest individuals of *Scutellosaurus lawleri* currently known.

Metatarsals (Figure 26)

TMM 43663-1 includes complete right metatarsals III and IV. These are well preserved and relatively undistorted, though the proximal end of metatarsal III is dorsoventrally crushed. MNA V175 preserves only fragments of metatarsals I-IV. UCMP 130580 preserves fragmentary and complete metatarsals I-IV from both feet. As in UCMP 130580, metatarsal III of TMM 43663-1 is nearly straight, curving somewhat medially. The distal end is wider mediolaterally than dorsoventrally and forms a well-developed trochlear surface. Metatarsal IV is shorter and more medially curved than metatarsal III.

The ventral surface is gently concave. The proximal end is subtriangular in proximal view and subquadrangular. There are well-developed ligament pits present on the dorsal and ventral surfaces of the distal ends of both metatarsals.

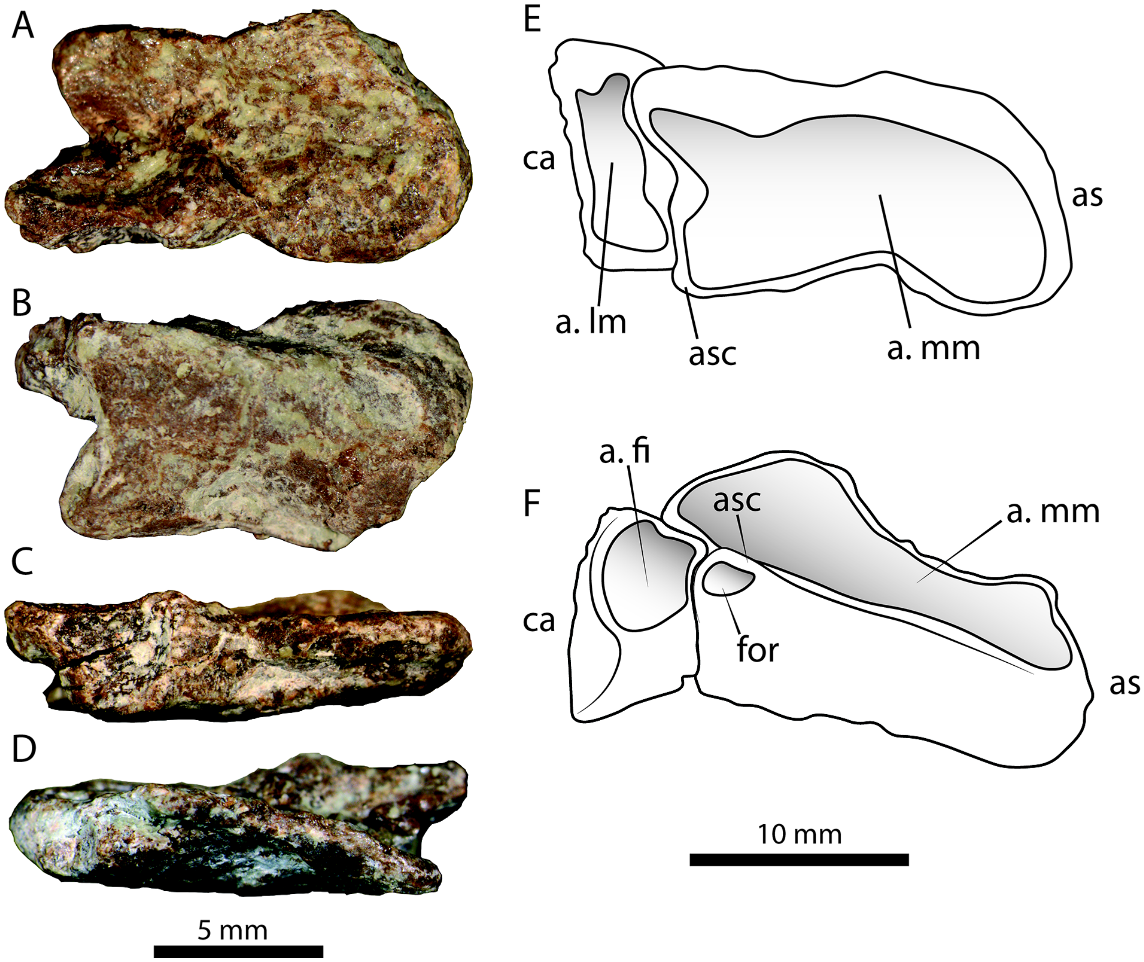

Figure 25. *Scutellosaurus lawleri*. Left astragalus of TMM 43663-1 in proximal (A), distal (B), anterior (C), and posterior (D) views. Left astragalocalcaneum of MNA V1752 in proximal (E) and anterior (F) views. Abbreviations: a. fi, articulation with the fibula; a. lm, articulation with the lateral malleolus of the tibia; a. mm, articulation with the medial malleolus of the tibia; as, astragalus; asc, ascending process of the astragalus; ca, calcaneum; for, foramen.

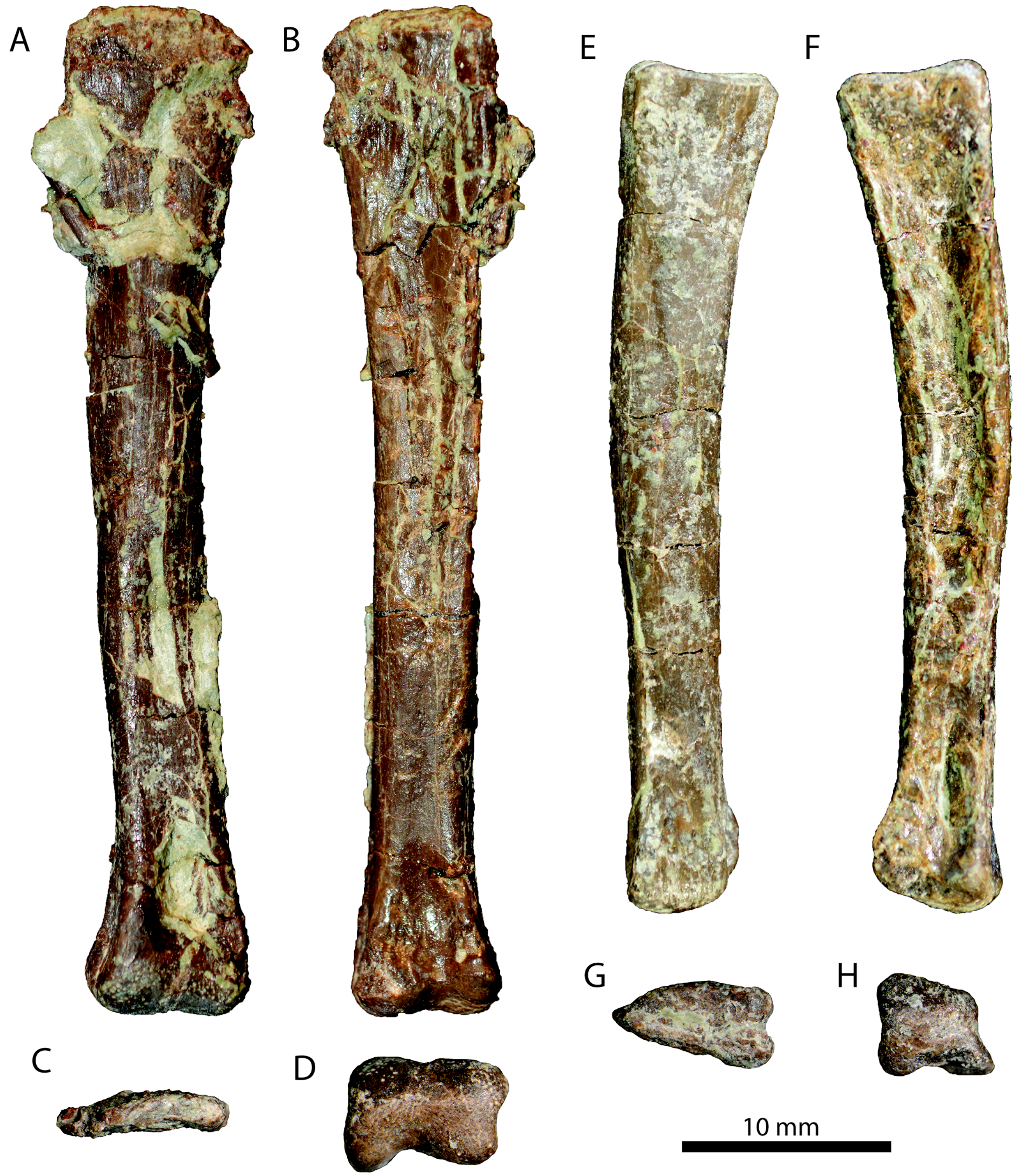

Figure 26. *Scutellosaurus lawleri*. TMM 43663-1. Right metatarsal III in dorsal (A), ventral (B), proximal (C), and distal (D) views. Right metatarsal IV in dorsal (E), ventral (F), proximal (G), and distal (H) views.

Pedal Phalanges (Figure 27)

Several complete and partial pedal phalanges are preserved, but none are preserved in articulation, so little information regarding the phalangeal formula can be discerned. The pedal phalangeal formula of the basal ornithischian *Lesothosuaurus diagnosticus* is probably 2-3-4-5-0 (Thulborn, 1972), and that of the basal thyreophoran *Scelidosaurus harrisonii* is 2-3-4-5-0 (Norman, Witmer, & Wieshampel; 2004b), so the holotype of *Scutellosaurus lawleri* was reconstructed with this formula as well by Colbert (1981). Two of the phalanges articulate with one another and may represent the proximal two phalanges from the right digit III. Two other phalanges can be articulated to one another and may represent phalanges 2 and 3 from right pedal digit IV. Each of the preserved pedal phalanges is similar in morphology to those in other early ornithischians including *Eocursor parvus*, *Lesothosaurus diagnosticus*, and *Stormbergia dangershoeki*. Each non-terminal pedal phalanx is longer than it is wide and is thinnest at the midshaft. The distal ends of the non-terminal pedal phalanges are spool-shaped and are transversely wider ventrally than dorsally.

One phalanx is a proximal pedal phalanx, possibly from digit III. Its proximal articular surface is weakly concave and subtriangular in proximal view. The distal end is spool-shaped, forming two articular condyles separated by a prominent groove that extends onto the dorsal and ventral surfaces of the distal half of the bone. The transverse width of the distal condyles is greater ventrally than dorsally.

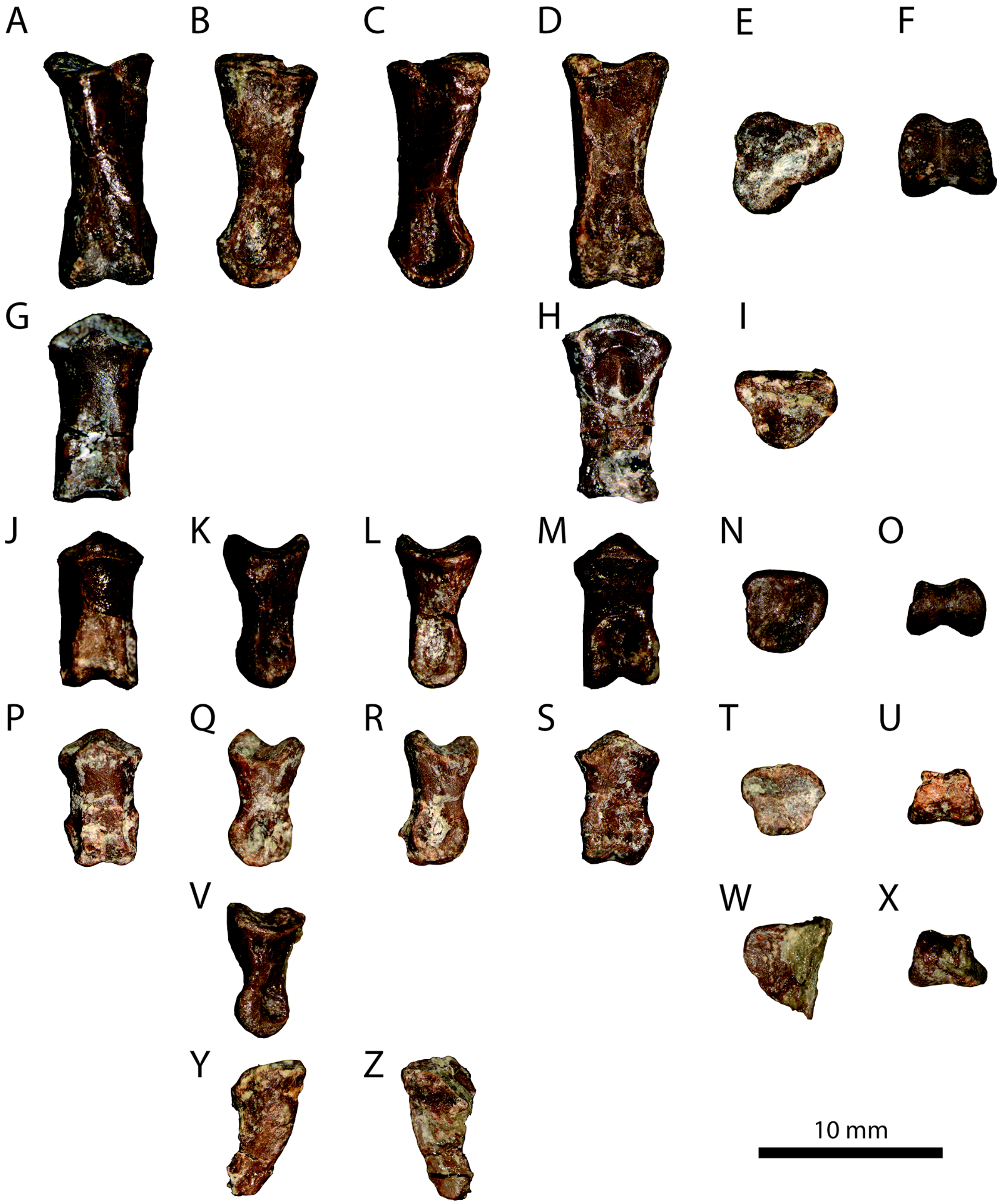

Figure 27. *Scutellosaurus lawleri*. TMM 43663-1. Pedal phalanges and unguals in dorsal (A, G, J, P), either lateral or medial (B, C, K, L, Q, R, V, Y, Z), ventral (D, H, M, S), proximal (E, I, N, T, W), and distal (F, O, U, X) views.

OSTEODERMS

Osteoderms are widely preserved among the TMM specimens of *Scutellosaurus lawleri*. The osteoderms of *Scutellosaurus lawleri* are discussed and figured in detail by Colbert (1981), but the categories of osteoderms proposed by Colbert are revised here in the diagnosis. The most commonly preserved osteoderms among the TMM specimens are from Morphotype A, which are asymmetrical broad, flat osteoderms with longitudinal keels (Figure 3N-O; Figure 5G-H; Figure 6B-D; Figure 28A-E). Morphotype B osteoderms, which possess two long sides sloping up to a ridge and are deeply concave ventrally such that each osteoderm maintains a uniform thickness, are uncommon but present among the TMM specimens (Figure 5I-J). A single Morphotype C was reported by Colbert (1981), and another is reported here from TMM 43664-1 (Figure 29F). These are broad, flat osteoderms with two longitudinal ridges flanking the midline. Rather than simply possessing two keels, this new osteoderm appears to be two Morphtoype A osteoderms sutured to one another. This osteoderm was preserved near the ilium and may support Colbert's hypothesis that two parasagittal dorsal rows of osteoderms converged upon one another posterior to the sacrum into a single row running along the dorsal midline of the tail. Few well-preserved Morphotype D osteoderms are present among the TMM specimens. These are symmetrical narrow and long osteoderms that flank the tail.

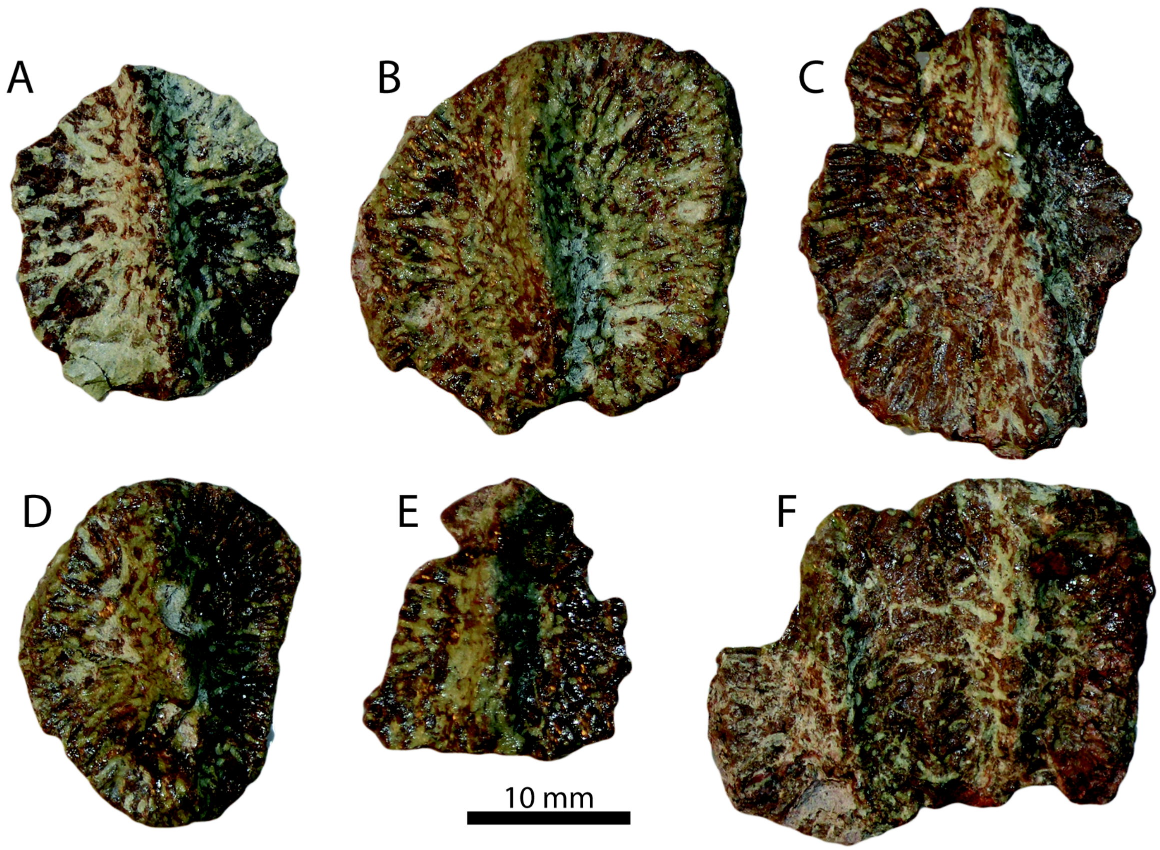

Figure 28. *Scutellosaurus lawleri*. TMM 43664-1. Morphotype A osteoderms in lateral view (A-E) and Morphotype C osteoderm in lateral view (F). Osteoderm morphologies are discussed in the diagnosis.

RESULTS OF PHYLOGENETIC ANALYSIS

The set of 3085 trees resulting from the search was filtered such that only the most parsimonious, minimum-length trees were saved, yielding 1136 most-parsimonious trees (MPTs). All MPTs have a length of 534 steps, a consistency index (CI) of 0.468, a retention index (RI) of 0.725, and a rescaled consistency index (RC) of 0.339. These results differ from those of Butler *et al.* (2010), whose analysis recovered 1137 MPTs (Length = 578 steps, CI = 0.51, RI = 0.72, RC = 0.37). A strict consensus of the MPTs recovered in the present analysis is presented in Figure 29. TMM 43663-1 and TMM 43664-1 both cluster in a polytomy with *Scutellosaurus lawleri* as coded by Butler *et al.* (2010), supporting the referral of these new specimens to *Scutellosaurus lawleri.* Aside from this, the overall topology of the recovered consensus tree does not differ from the strict component consensus presented by Butler *et al*. (2010).

Autapomorphies of *Scutellosaurus lawleri* recovered by the present analysis include narrow and elongate frontals in which the length is greater than twice the width (Character 64, State 1), six premaxillary teeth (Character 112, State 0), neural spines of the proximal caudal vertebrae that are greater than 50% taller than the centra (Character 142, State 1), an elongate tail comprising 59 or greater caudal vertebrae (Character 143, State 1), and a humerus that is substantially longer than the scapula (Character 149, State 1). In addition to these autapomorphies, TMM 43664-1 supports the identification as an autapomorphy of *Scutellosaurus lawleri* the preacetabular process of the ilium in which the dorsal and ventral margins are drawn out medially into flanges that converge upon one another anteriorly.

DISCUSSION

The are 27 character states unique to TMM 43663-1 and TMM 43664-1 which neither shares with the coding of *Scutellosaurus lawleri* from Butler *et al*. (2010). This is a result of missing data in the previously published specimens. These 27 character states are summarized and discussed below, because these character states represent new morphological data for *Scutellosaurus lawleri*. A complete list of the phylogenetic characters and the data matrix used for the present analysis are provided in Appendices 2 and 3, respectively. In the following discussion, the clade of (*Scutellosaurus lawleri* + TMM 43663-1 + TMM 43664-1) is treated as the single taxon *Scutellosaurus lawleri* Colbert, 1981. The character numbers below correspond to those used in the character list provided in Appendix 2, and character states of *Scutellosaurus lawleri* are bolded in each character discussed.

1) Skull proportions: **0. Pre-orbital skull length more than 45% of basal skull length**; 1. Pre-orbital length less than 40% of basal skull length.

   Although no specimen of *Scutellosaurus lawleri* preserves a complete articulated skull, enough cranial material is present in TMM 43664-1 for a tentative reconstruction of the skull to be generated from CT scans of the specimen, which allows this character to be coded. Based on this reconstruction, the pre-orbital skull length is greater than 45% of the basal skull length in *Scutellosaurus lawleri*. That represents a plesiomorphic state for all taxa included in the present analysis.

19) Deep elliptic fossa present along sutural line of the nasals**: 0. Absent**; 1. Present.

TMM 43664-1 preserves a complete left nasal, which lacks a deep fossa along the medial sutural line. The distribution of this character among many other early ornithischian dinosaurs (*Pisanosaurus mertii, Eocursor parvus, Lesothosaurus diagnosticus)* is unknown, but this character is present in the outgroup taxon *Herrerasaurus ischigualastensis, Heterodontosaurus tucki,* and some basal neornithischian dinosaurs (*Agilisaurus louderbacki*, *Hexinlusaurus multidens*). In contrast, this character is absent in the basal thyreopohoran dinosaur *Scelidosaurus harrisonii*, Ankylosauria, and Stegosauria. Butler *et al.* (2008) identified the absence of this character as a synapomorphy of Thyreophora under ACCTRAN optimization (the character state was unknown in that analysis for the basal thyreophoran dinosaurs *Scutellosaurus lawleri* and *Emausaurus ernsti*). I recover the absence of the character as an unambiguous synapomorphy of Thyreophora.

49) Postorbital, orbital margin: **0. Relatively smooth curve**; 1. Prominent and distinct projection into orbit.

Both TMM 43663-1 and TMM 43664-1 preserve postorbitals. In both specimens, the orbital margin is a smooth curve, allowing this character to be coded for *Scutellosaurus lawleri.* This character state is plesiomorphic for all taxa included in the present analysis.

50) Postorbital: **0. T-shaped**; 1. Triangular and plate-like.

Both TMM 43663-1 and TMM 43664-1 preserve T-shaped postorbitals comprising long tapering ventral (jugal) and posterior (squamosal) processes and a short c-shaped medial process that primarily articulates with the frontal. This character state is plesiomorphic for all taxa included in the present analysis.

51) Postorbital–parietal contact: **0. Absent, or very narrow**; 1. Broad.

Both TMM 43663-1 and TMM 43664-1 preserve postorbitals, allowing this character to be coded for *Scutellosaurus lawleri*. The short medial process of the postorbital of *Scutellosaurus lawleri* primarily articulates with the frontal, leaving contact with the parietal narrow if such contact was present at all. The absence of this character is plesiomorphic for all taxa included in the present analysis, and the derived state of a broad postorbital-parietal contact is present only within Pachycephalosauria.

52) Contact between dorsal process of quadratojugal and descending process of the bsquamosal: **0. Present**; 1. Absent.

Although neither TMM 43663-1 or TMM 43664-1 preserves a complete quadratojugal and squamosal, enough is present of each element to tentatively code the contact between the two as being present. The quadratojugal of TMM 43664-1 is dorsoventrally elongated and appears to be missing much of the dorsal process, and the squamosal of TMM 43663-1 has a long tapering ventral process that is incompletely preserved. This character is present in the other basal thyreophoran taxa *Emausaurus ernsti* and *Scelidosaurus harrisonii*, and the morphology of these elements in *Scutellosaurus lawleri* is overall very similar to the same elements in *Emausaurus ernsti*. Therefore, this character is tentatively scored as being present in *Scutellosaurus lawleri.*

53) Quadratojugal, shape: 0. L-shaped, with elongate anterior process; **1. Subrectangular with long axis vertical, short, deep anterior process**.

TMM 43664-1 preserves a nearly complete quadratojugal, which is vertically elongate with a short anterior process. The quadratojugal of the outgroup taxa *Euparkeria capensis* and *Herrerasaurus ischigualastensis* is L-shaped with a long anterior process, and all ornithischian dinosaurs that can be coded for this character possess a subrectangular quadratojugal with a long vertical axis.

54) Quadratojugal, ventral margin: **0. Approaches the mandibular condyle of the quadrate**; 1. Well-removed from the mandibular condyle of the quadrate.

Although neither TMM 43663-1 nor TMM 43664-1 preserve the quadrate and quadratojugal in life position, it appears that the ventral margin of the quadratojugal of TMM 43644-1 retains the plesiomorphic condition of approaching the mandibular condyle of the quadrate.

55) Quadratojugal, orientation: **0. Faces laterally**; 1. Faces posterolaterally.

The quadratojugal of TMM 43664-1 is a flat element that retains the plesiomorphic condition of being oriented to face laterally. This condition is retained by all thyreophoran dinosaur taxa except for Ankylosauria.

56) Quadratojugal, transverse width: **0. Mediolaterally flattened**; 1. Transversely expanded and triangular in coronal section.

The quadratojugal of TMM 43664-1 is a flat, mediolaterally compressed element. This character state is plesiomorphic for all taxa included in the present analysis.

59) Quadrate shaft: **0. Anteriorly convex in lateral view**; 1. Reduced in anteroposterior width and straight in lateral view.

Both TMM 43663-1 and TMM 43664-1 preserve nearly complete quadrates, which are anteriorly convex in lateral view. This character state is plesiomorphic for all taxa included in the present analysis.

71) Postorbital–squamosal bar: **0. Bar-shaped**; 1. Broad, flattened.

TMM 43663-1 preserves both postorbitals and one squamosal. Although these are not preserved in articulation, the posterior process of the postorbital and the anterior process of the squamosal are both elongate and taper to a point. These processes would articulate with on another via a scarf joint, forming a bar. This character state is plesiomorphic for all taxa included in the present analysis.

72) Postorbital–squamosal tubercle row: **0. Absent**; 1. Present.

The postorbitals and squamosal of TMM 43663-1 lack a tubercle row, which is plesiomorphic for all taxa included in the present analysis.

73) Enlarged tubercle row on the posterior squamosal: **0. Absent**; 1. Present.

As noted for Character 72, the squamosal of TMM 43663-1 lack tubercles, which is plesiomorphic for all taxa included in the present analysis.

75) Paroccipital processes: **0. Extend laterally and are slightly expanded distally**; 1. Distal end pendent and ventrally extending.

TMM 43663-1 preserves an isolated paroccipital process of the opisthotic, which extends laterally and is slightly expanded distally. This character state is plesiomorphic for all taxa included in the present analysis, and is retained by heterodontosaurids and most thyreophoran taxa, and the distal end of the paraoccipital process extends ventrally in many neornithischian taxa.

76) Paroccipital processes, proportions: **0. Short and deep (height ≥ 1/2 length)**; 1. Elongate and narrow.

The paroccipital process preserved in TMM 43663-1 retains the plesiomorphic condition of being short and deep. All other taxa included in the present analysis retain this plesiomorphic state with the exception of some marginocephalian neornithischian taxa.

140) Posterior sacral ribs are considerably longer than anterior sacral ribs: **0. Absent**; 1. Present.

TMM 43664-1 preserves a series of sacral vertebrate in articulation (interpreted as sacral vertebrae 2 through 4 in this study), and the sacral ribs are all approximately the same length. This condition is plesiomorphic for all taxa included in the present analysis.

142) Proximal caudal neural spines: 0. Height the same or up to 50% taller than the centrum; **1. More than 50% taller than the centrum**.

Although the holotype (MNA V175) and paratype (MNA V1752) specimens of *Scutellosaurus lawleri* each preserve nearly complete vertebral columns, the majority of the vertebrae in both specimens either lack their neural spines or their neural arches altogether. This is also true of TMM 43663-1 and TMM 43664-1.

Most of the vertebrae in both specimens are poorly preserved, but one proximal caudal vertebra of TMM 43664-1 preserves both the centrum and neural spine in articulation. The posterior end of the neural spine does appear to be taphonomically displaced, precluding precise linear measurements, but even accounting for displacement, the height of the neural spine still seems to exceed the height of the centrum by at least 50%. As noted above, this character state is recovered as an autapomorphy of *Scutellosaurus lawleri*. Among thyreophoran dinosaurs, Stegosauria also possesses neural spines that exceed the height of the centrum by at least 50%. As *Scelidosaurus harrisonii* and Ankylosauria both lack this condition, it is recovered as homoplastic between *Scutellosaurus lawleri* and Stegosauria in the present analysis.

144) Chevron shape: **0. Rod-shaped, often with slight distal expansion**; 1. Strongly asymmetrically expanded distally, width greater than length in mid caudal vertebrae.

No well-preserved chevrons have yet been reported for *Scutellosaurus lawleri,* but isolated fragments of chevrons are present in TMM 43664-1 and retain the rod-shaped condition that is plesiomorphic for all taxa included in the present analysis.

149) Proportions of humerus and scapula: 0. Scapula longer or subequal to the humerus; **1. Humerus substantially longer than the scapula**.

No specimens of *Scutellosaurus lawleri* preserved both a complete humerus and scapula. MNA V175 preserves both left and right scapulae and humeri, but the distal ends of the scapulae are incomplete, precluding the determination of relative length ratios between the two elements. TMM 43663-1 preserves a complete right scapula and proximal and distal ends of a nearly complete right humerus. Though precise linear measurements of the humerus are not possible because it is not complete, the combined length of the two preserved halves is approximately 70 mm, and the scapula measures 48.8 mm long, making the humerus at least 143% of the length of the scapula. This condition is recovered as an autapomorphy of *Scutellosaurus lawleri* in the present study.

150) Scapula blade, length relative to minimum width: **0. Relatively short and broad, length is five to eight times minimum width**; 1. Elongate and strap-like, length is at least nine times the minimum width.

TMM 43663-1 and TMM 43664-1 both preserve complete scapulae that are short and broad. The outgroup taxon *Herrerasaurus ischigualastensis* and the basal ornithischian clade Heterodontosauridae possess elongate, strap-like scapulae, and the majority of genasaurian taxa reverse to the possession of a short and broad scapula. This reversal was recovered as a synapomorphy of Genasauria by Butler *et al.* (2008) under ACCTRAN optimization, because the character can not be coded for the basalmost genasaurian *Eocursor parvus*.

152) Scapula, blade-shape: **0. Strongly expanded distally**; 1. Weakly expanded, near parallel-sided.

Although many published specimens of *Scutellosaurus lawleri* preserve scapulae (MNA V175, MNA V175, UCMP 130580), TMM 43663-1 and TMM 43664-1 are the first specimens to preserve scapulae with complete distal ends. In both specimens, the distal end of the scapula is strongly expaned. The outgroup taxa *Euparkeria capensis* and *Herrerasaurus ischigualastensis* both possess a weakly expanded scapula, and nearly all ornithischian taxa including *Scutellosaurus lawleri* possess a scapula that is strongly expanded distally. This feature was identified as a synapomorphy of Ornithischia by Butler *et al.* (2008) under ACCTRAN optimization, because the scapula is not preserved in the basalmost ornithischian taxon *Pisanosaurus mertii*.

166) Preacetabular process, length: 0. Less than 50% of the length of the ilium; **1. More than 50% of the length of the ilium**.

The ilium of *Scutellosaurus lawleri* is known from fragments in MNA V175 and UCMP 130580, but TMM 43664-1 is the first specimen to preserve a nearly complete ilium. The total length of the ilium is 117 mm, and the preacetabular process of the ilium is long and straight, measuring 60 mm in length (51% of the total length). This condition is shared with eurypodan thyreophorans, but the character can not be coded for the basal thyreophoran *Emausaurus ernsti*, and the basal thyreophoran *Scelidosaurus harrisonii* has a preacetabular process that is less than 50% of the total length of the ilium. In the present analysis, this condition is recovered as a synapomorphy of Thyreophora, and its absence in *Scelidosaurus harrisonii* is considered a reversal.

168) Dorsal margin of preacetabular process and dorsal margin of ilium above acetabulum: 0. Narrow, not transversely expanded; **1. Dorsal margin is transversely expanded to form a narrow shelf**.

The dorsal margin of the preacetabular process of the ilium of TMM 43664-1 is transversely expanded to form a narrow medial shelf. This feature is recovered as a synapomorphy of Thyreophora. In *Scutellosaurus lawleri*, the ventral margin of the preacetabular process is also expanded medially, which is autapomorphic for this taxon (Butler *et al*., 2008).

175) Medioventral acetabular flange of ilium, partially closes the acetabulum: **0. Present**; 1. Absent.

The acetabulum is partially closed by a thin medioventral flange of the ilium in TMM 43664-1. This feature is plesiomorphic for all taxa included in the present analysis and is retained by *Scutellosaurus lawleri* and all other thyreophoran taxa.

176) Supraacetabular ‘crest’ or ‘flange’: **0. Present**; 1. Absent.

A supraacetabular crest is present in the ilium of TMM 43664-1. This condition is plesiomorphic for all dinosauriform taxa included in the present analysis and is retained by *Scutellosaurus lawleri* and all other thyreophoran taxa.

178) Pubic peduncle of ilium: **0. Large, elongate, robust**; 1. Reduced in size, shorter in length than ischial peduncle.

The pubic peduncle of the ilium of TMM 43664-1 is elongate and projects dorsoventrally. This condition is plesiomorphic for all taxa included in the present analysis and is retained by *Scutellosaurus lawleri* and all other thyreophoran taxa.

207) Fibular facet on the lateral margin of the proximal surface of the astragalus: 0. Large; **1. Reduced to small articulation.**

The astragalus is preserved in TMM 43663-1 and is also present in MNA V175, MNA V1752, and UCMP 130580. The contribution of the fibula to the ankle joint is reduced in ornithischian dinosaurs such that the proximal surfaces of both the astragalus and calcaneum form a mediolaterally continuous trough to receive the medial and lateral malleoli of the tibia, respectively, and contact between the distal fibula and tarsus is restricted almost entirely to a facet on the calcaneum that lies anterior to the prominent facet for the lateral malleolus of the tibia.

208) Calcaneum, proximal surface: 0. Facet for tibia absent**; 1. Well-developed facet for tibia present.**

The calcaneum is not preserved in any TMM specimen, but a complete fused astragalocalcaneum is preserved but unreported in MNA V1752. The astragalus and calcaneum are isolated in all other specimens of *Scutellosaurus lawleri*. The proximal surfaces of both the astragalus and calcaneum form a continuous mediolateral trough to receive the medial and lateral malleoli of the tibia, respectively. Anterior to this trough, the calcaneum possesses a facet to receive the distal fibula, and contact between the distal fibula and the astragalus is reduced. This condition is plesiomorphic with respect to other ornithischian dinosaurs.

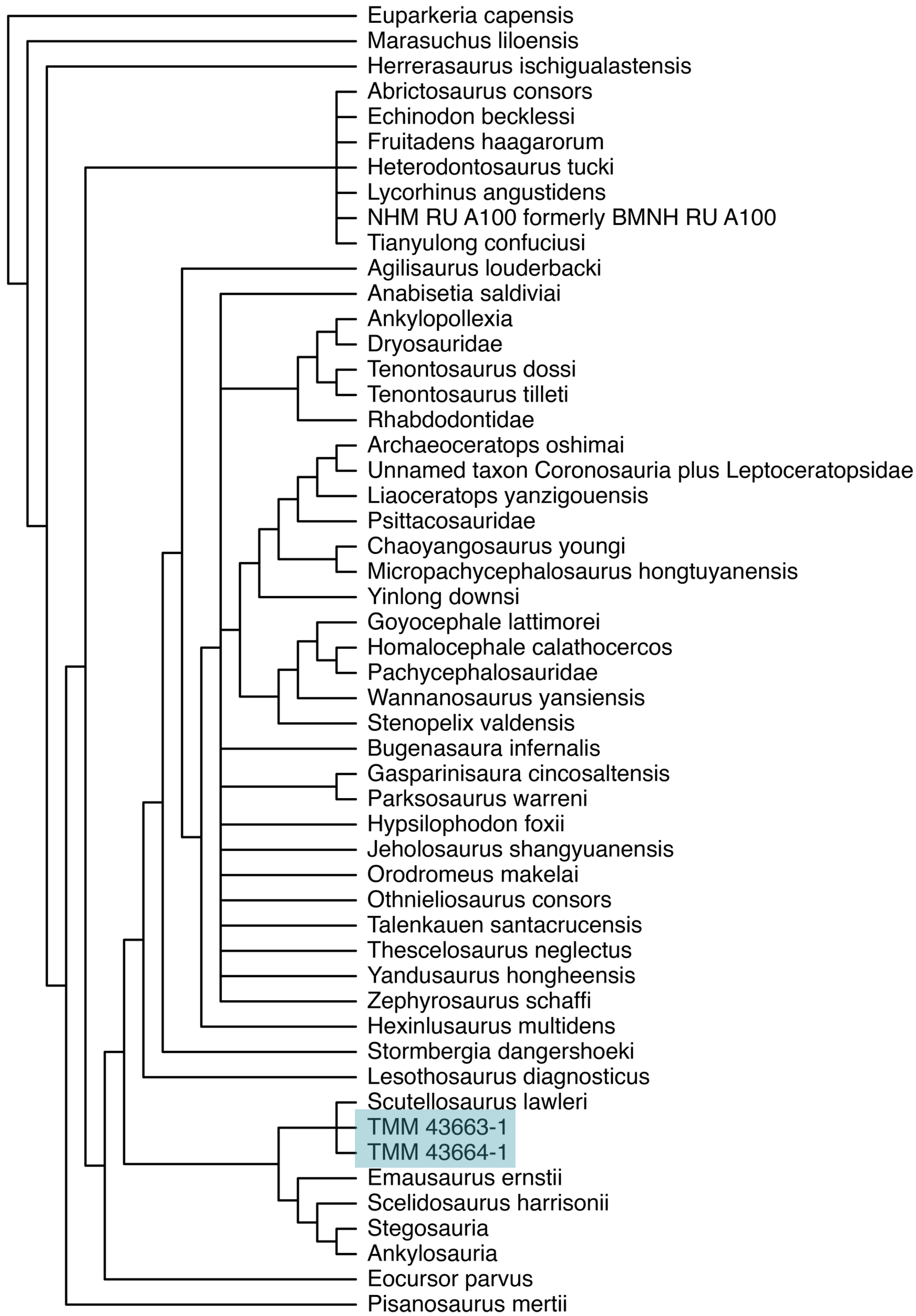

Figure 29. Strict consensus of 1136 most parsimonious trees (Length = 578 steps, CI = 0.51, RI = 0.72, RC = 0.37).

CONCLUSIONS

The description of nearly 30 new specimens of *Scutellosaurus lawleri* makes it the most abundantly known dinosaurian taxon from the Lower Jurassic Kayenta Formation and one of the most abundantly known ornithischian dinosaurs from the Lower Jurassic worldwide. Despite this abundance, certain aspects of its anatomy remain relatively poorly understood; however, the new specimens TMM 43663-1 and TMM 43664-1 allows for several skeletal elements to be described for the taxon for the first time. Nearly all new ornithischian material from the Kayenta Formation can be referred to *Scutellosaurus lawleri*, and all of these specimens are reported here. In addition to these new specimens of *Scutellosaurus lawleri*, there is evidence for the presence of other ornithischian taxa present in the Kayenta Formation. *Scelidosaurus*-like osteoderms similar to those described by Padian (1989) were reported from TMM collections by Tykoski (2005), and these osteoderms are unlike those of *Scutellosaurus lawleri* in that they are not heavily vascularized and do not maintain uniform thickness, so there are at least two thyreophoran taxa present in the Kayenta Formation. In addition to thyreophoran taxa and the unnamed heterodontosaurid reported by Attridge *et al.* (1985), there is evidence for the presence of at least one other ornithischian taxon in the Kayenta Formation in the TMM collections, and that material will be reported separately. At present, no thyreophoran taxa have been reported from the southern hemisphere, and no neornithischian taxa have been reported from the northern hemisphere. Heterodontosaurids are geographically widespread during the Early Jurassic (Sereno,

2012) as are both sauropodomorph (Barrett, 2009; Rowe *et al*., 2010; Sertich & Loewen, 2010) and theropod (Raath, 1980; Welles, 1984; Rowe, 1989; Tykoski, 1998; Smith *et al*., 2007) saurischian dinosaurs, so the apparent absences of thyreophorans from the northern hemisphere and neornithischians from the southern hemispehere in Lower Jurassic strata is puzzling.

Phylogenetic analysis following the methods of Butler *et al*. (2010) confirms both the referral of the two most complete specimens reported here (TMM 43663-1 and TMM 43664-1) to *Scutellosaurus lawleri* and the position of *Scutellosaurus lawleri* as the basalmost member of Thyreophora. Autapomorphies previously identified for *Scutellosaurus lawleri* by Butler *et al*. (2008) include dorsal and ventral margins of the preacetabular process of the ilium that are drawn out medially into distinct flanges which converge upon one another anteriorly, and an elongate tail comprising at least 58 caudal vertebrae. Two new autapomorphies of *Scutellosaurus lawleri* are added from the character matrix of Butler *et al*. (2010) on the basis of new specimens described here. They are the presence of narrow, elongate frontals at least twice as long as they are wide, and a humerus that is longer than the scapula. Additionally, the broad rugose ventral keels of the cervical centra and various osteoderm morphologies discussed in the diagnosis of the taxon in this study seem to be unique to *Scutellosaurus lawleri*. The description of two new specimens preserving much of the skull of *Scutellosaurus lawleri* warrants a re-diagnosis of the taxon, which will require a thorough phylogenetic analysis focused on thyreophoran relationships.

APPENDICES

Appendix 1: List of TMM Specimens discussed in the text

Locality	Specimen number	Identification
TMM 43647: Hummingbird Canyon	TMM 43647-6	*Scutellosaurus lawleri*
	TMM 43647-7	*Scutellosaurus lawleri*
TMM 43648: Paiute Canyon General	TMM 43648-13	*Scutellosaurus lawleri*
TMM 43656: Gerald's Turtle	TMM 43656-2	*Scutellosaurus lawleri*
	TMM 43656-3	*Scutellosaurus lawleri*
	TMM 43656-5	*Scutellosaurus lawleri*
TMM 43661: Rock Head Tritylodont	TMM 43661-1	*Scutellosaurus lawleri*
TMM 43663: East Paiute Valley No. 1	TMM 43663-1	*Scutellosaurus lawleri*
TMM 43664: East Paiute Valley No. 2	TMM 43664-1	*Scutellosaurus lawleri*
TMM 43669: Gold Spring Wash	TMM 43669-5	*Scutellosaurus lawleri*
	TMM 43669-6	*Scutellosaurus lawleri*
TMM 43670: Ted's Turtle Town	TMM 43670-5	cf. *Scutellosaurus*
	TMM 43670-7	*Scutellosaurus lawleri*
TMM 43687: Gold Spring General	TMM 43687-9	*Scutellosaurus lawleri*
	TMM 43687-13	cf. *Scutellosaurus*
	TMM 43687-16	*Scutellosaurus lawleri*
	TMM 43687-17	*Scutellosaurus lawleri*
	TMM 43687-22	*Scutellosaurus lawleri*
	TMM 43687-75	*Scutellosaurus lawleri*
	TMM 43687-81	*Scutellosaurus lawleri*
	TMM 43687-112	*Scutellosaurus lawleri*
	TMM 43687-114	*Scutellosaurus lawleri*
	TMM 43687-115	*Scutellosaurus lawleri*
	TMM 43687-116	*Scutellosaurus lawleri*
	TMM 43687-121	*Scutellosaurus lawleri*
	TMM 43687-122	*Scutellosaurus lawleri*
	TMM 43687-123	cf. *Scutellosaurus*
	TMM 43687-124	*Scutellosaurus lawleri*
TMM 43690: Willow Spring General	TMM 43690-6	cf. *Scutellosaurus*
TMM 43691: Paiute North	TMM 43691-18	cf. *Scutellosaurus*
TMM 45608: Gold Spring South	TMM 45608-3	*Scutellosaurus lawleri*
TMM 45609: *Eocaecilia* Quarry	TMM 45609-4	*Scutellosaurus lawleri*
	TMM 45609-5	cf. *Scutellosaurus*
	TMM 45609-6	*Scutellosaurus lawleri*
TMM 47001: Southwest Paiute Canyon	TMM 47001-1	cf. *Scutellosaurus*

Appendix 2: Phylogenetic characters (Modified from Butler *et al*., 2010)

1) Skull proportions: 0. Preorbital skull length more than 45% of basal skull length; 1. Preorbital length less than 40% of basal skull length.

2) Skull length (rostral–quadrate): 0. 10% or less of body length; 1. 13% or more of body length (modified following Xu *et al*. 2006).

3) Neomorphic rostral bone, anterior to premaxilla: 0. Absent; 1. Present.

4) Rostral bone, anteriorly keeled and ventrally pointed: 0. Absent; 1. Present.

5) Rostral bone, ventrolateral processes: 0. Rudimentary; 1. Well-developed.

6) Premaxilla, edentulous anterior region: 0. Absent, first premaxillary tooth is positioned adjacent to the symphysis; 1. Present, first premaxillary tooth is inset the width of one or more crowns.

7) Premaxilla, posterolateral process, length: 0. Does not contact lacrimal; 1. Contacts the lacrimal, excludes maxilla–nasal contact.

8) Oral margin of the premaxilla: 0. Narial portion of the body of the premaxilla slopes steeply from the external naris to the oral margin; 1. Ventral premaxilla flares laterally to form a partial floor of the narial fossa.

9) Position of the ventral (oral) margin of the premaxilla: 0. Level with the maxillary tooth row; 1. Deflected ventral to maxillary tooth row.

10) Premaxillary foramen: 0. Absent; 1. Present.

11) Premaxillary palate: 0. Strongly arched, forming a deep, concave palate; 1. Horizontal or only gently arched.

12) Overlap of the dorsal process of the premaxilla onto the nasal: 0. Present; 1. Absent.

13) Fossa-like depression positioned on the premaxilla–maxilla boundary: 0. Absent; 1. Present.

14) Premaxilla–maxilla diastema: 0. Absent, maxillary teeth continue to anterior end of maxilla; 1. Present, substantial diastema of at least one crowns length between maxillary and premaxillary teeth.

15) Form of diastema; 0. Flat; 1. Arched ‘subnarial gap’ between the premaxilla and maxilla.

16) Narial fossa surrounding external nares on lateral surface of premaxilla, position of ventral margin of fossa relative to the ventral margin of the premaxilla: 0. Closely approaches the ventral margin of the premaxilla; 1. Separated by a broad flat margin from the ventral margin of the premaxilla

17) External nares, position of the ventral margin: 0. Below the ventral margin of the orbits; 1. Above the ventral margin of the orbits.

18) External naris size: 0. Small, entirely overlies the premaxilla; 1. Enlarged, extends posteriorly to overlie the maxilla.

19) Deep elliptic fossa present along sutural line of the nasals: 0. Absent; 1. Present.

20) Internal antorbital fenestra size: 0. Large, generally at least 15% of the skull length; 1. Very much reduced, less than 10% of skull length, or absent.

21) External antorbital fenestra: 0. Present; 1. Absent.

22) External antorbital fenestra, shape: 0. Triangular; 1. Oval or circular.

23) Additional opening(s) anteriorly within the antorbital fossa: 0. Absent; 1. Present.

24) Maxilla, prominent anterolateral boss articulates with the medial premaxilla: 0. Absent; 1. Present.

25) Maxilla, accessory anterior process: 0. Absent; 1. Present.

26) Maxilla, buccal emargination: 0. Absent; 1. Present.

27) Eminence on the rim of the buccal emargination of the maxilla near the junction with the jugal: 0. Absent; 1. Present.

28) Slot in maxilla for lacrimal: 0. Absent; 1. Present.

29) Accessory ossification(s) in the orbit (palpebral/supraorbital): 0. Absent; 1. Present.

30) Palpebral/supraorbital: 0. Free, projects into orbit from contact with lacrimal/prefrontal; 1. Incorporated into orbital margin.

31) Palpebral, shape in dorsal view: 0. Rod-shaped; 1. Plate-like with wide base.

32) Palpebral/supraorbital, number: 0. One; 1. Two; 2. Three.

33) Free palpebral, length, relative to anteroposterior width of orbit: 0. Does not traverse entire width of orbit; 1. Traverses entire width of orbit.

34) Exclusion of the jugal from the posteroventral margin of the external antorbital fenestra by lacrimal–maxilla contact: 0. Absent; 1. Present.

35) Anterior ramus of jugal, proportions: 0. Deeper than wide, but not as deep as the posterior ramus of the jugal; 1. Wider than deep; 2. Deeper than the posterior ramus of the jugal.

36) Widening of the skull across the jugals, chord from frontal orbital margin to extremity of jugal is more than minimum interorbital width: 0. Absent; 1. Present, skull has a triangular shape in dorsal view.

37) Position of maximum widening of the skull: 0. Beneath the jugal–postorbital bar; 1. Posteriorly, beneath the infratemporal fenestra.

38) Jugal (or jugal–epijugal) ridge dividing the lateral surface of the jugal into two planes: 0. Absent; 1. Present.

39) Epijugal: 0. Absent; 1. Present.

40) Jugal boss: 0. Absent; 1. Present.

41) Node-like ornamentation on jugal, mostly on, or ventral to, the jugal–postorbital bar: 0. Absent; 1. Present.

42) Jugal–postorbital bar, width broader than laterotemporal fenestra: 0. Absent; 1. Present.

43) Jugal–postorbital joint: 0. Elongate scarf joint; 1. Short butt joint.

44) Jugal, form of postorbital process: 0. Not expanded dorsally; 1. Dorsal portion of postorbital process is expanded posteriorly.

45) Jugal–squamosal contact above infratemporal fenestra: 0. Absent; 1. Present.

46) Jugal posterior ramus, forked: 0. Absent; 1. Present.

47) Jugal, posterior ramus: 0. Forms anterior and ventral margin of infratemporal fenestra; 1. Forms part of posterior margin, expands towards squamosal.

48) Jugal–quadratojugal contact: 0. Overlapping; 1. Tongue-and-groove.

49) Postorbital, orbital margin: 0. Relatively smooth curve; 1. Prominent and distinct projection into orbit.

50) Postorbital: 0. T-shaped; 1. Triangular and plate-like.

51) Postorbital–parietal contact: 0. Absent, or very narrow; 1. Broad.

52) Contact between dorsal process of quadratojugal and descending process of the squamosal: 0. Present; 1. Absent.

53) Quadratojugal, shape: 0. L-shaped, with elongate anterior process; 1. Subrectangular with long axis vertical, short, deep anterior process.

54) Quadratojugal, ventral margin: 0. Approaches the mandibular condyle of the quadrate; 1. Well-removed from the mandibular condyle of the quadrate.

55) Quadratojugal, orientation: 0. Faces laterally; 1. Faces posterolaterally.

56) Quadratojugal, transverse width: 0. Mediolaterally flattened; 1. Transversely expanded and triangular in coronal section.

57) Prominent oval fossa on pterygoid ramus of quadrate: 0. Absent; 1. Present.

58) Quadrate lateral ramus: 0. Present; 1. Absent.

59) Quadrate shaft: 0. Anteriorly convex in lateral view; 1. Reduced in anteroposterior width and straight in lateral view.

60) Paraquadratic foramen or notch, size: 0. Absent or small, opens between quadratojugal and quadrate; 1. Large.

61) Paraquadratic foramen, orientation: 0. Posterolateral aspect of quadrate shaft; 1. Lateral aspect of quadrate or quadratojugal.

62) Paraquadratic foramen, position: 0. On quadrate-quadratojugal boundary; 1. Located within quadratojugal.

63) Quadrate mandibular articulation: 0. Quadrate condyles subequal in size; 1. Medial condyle is larger than lateral condyle; 2. Lateral condyle is larger than medial.

64) Paired frontals: 0. Short and broad; 1. Narrow and elongate (more than twice as long as wide).

65) Supratemporal fenestrae: 0. Open; 1. Closed.

66) Supratemporal fenestrae, anteroposteriorly elongated: 0. Absent, fenestrae are subcircular to oval in shape 1. Present.

67) Parietal septum, form: 0. Narrow and smooth; 1. Broad and rugose.

68) Parietosquamosal shelf: 0. Absent; 1. Present.

69) Parietosquamosal shelf, extended posteriorly as distinct frill: 0. Absent; 1. Present.

70) Composition of the posterior margin of the parietosquamosal shelf: 0. Parietal contributes only a small portion to the posterior margin;1. Parietal makes up at least 50% of the posterior margin.

71) Postorbital–squamosal bar: 0. Bar-shaped; 1. Broad, flattened.

72) Postorbital–squamosal tubercle row: 0. Absent; 1. Present.

73) Enlarged tubercle row on the posterior squamosal: 0. Absent; 1. Present.

74) Frontal and parietal dorsoventral thickness: 0. Thin; 1. Thick.

75) Paroccipital processes: 0. Extend laterally and are slightly expanded distally; 1. Distal end pendent and ventrally extending.

76) Paroccipital processes, proportions: 0. Short and deep (height $\geq$ 1/2 length); 1. Elongate and narrow.

77) Posttemporal foramen/fossa, position: 0. Totally enclosed with the paroccipital process; 1. Forms a notch in the dorsal margin of the paroccipital process, enclosed dorsally by the squamosal.

78) Supraoccipital, contribution to dorsal margin of foramen magnum: 0. Forms entire dorsal margin of foramen magnum; 1. Exoccipital with medial process that restricts the contribution of the supraoccipital.

79) Basioccipital, contribution to the border of the foramen magnum: 0. Present; 1. Absent, excluded by exoccipitals.

80) Basisphenoid: 0. Longer than, or subequal in length to, basioccipital; 1. Shorter than basioccipital.

81) Prootic–basisphenoid plate: 0. Absent; 1. Present.

82) Basal tubera, shape: 0. Knob-shaped; 1. Plate-shaped.

83) Basipterygoid processes, orientation: 0. Anteroventral; 1. Ventral; 2. Posteroventral.

84) Premaxilla–vomeral contact: 0. Present; 1. Absent, excluded by midline contact between maxillae.

85) Dorsoventrally deep (deeper than 50% of snout depth) median palatal keel formed of the vomers, pterygoids and palatines: 0. Absent; 1. Present.

86) Pterygovomerine keel, length: 0. Less than 50% of palate length; 1. More than 50% of palate length.

87) Pterygoid–maxilla contact at posterior end of tooth row: 0. Absent; 1. Present.

88) Pterygoquadrate rami, posterior projection of ventral margin: 0. Weak; 1. Pronounced.

89) Cortical remodeling of surface of skull dermal bone: 0. Absent; 1. Present.

90) Predentary: 0. Absent; 1. Present.

91) Predentary size: 0. Short, posterior premaxillary teeth oppose anterior dentary teeth; 1. Roughly equal in length to the premaxilla, premaxillary teeth only oppose predentary.

92) Predentary, rostral end in dorsal view: 0. Rounded; 1. Pointed.

93) Predentary, oral margin: 0. Relatively smooth; 1. Denticulate.

94) Tip of predentary in lateral view: 0. Does not project above the main body of predentary; 1. Strongly upturned relative to main body of predentary.

95) Predentary, ventral process: 0. Single; 1. Bilobate.

96) Predentary, ventral process: 0. Present, well-developed; 1. Very reduced or absent.

97) Dentary symphysis: 0. V-shaped; 1. Spout shaped.

98) Dentary tooth row (and edentulous anterior portion) in lateral view: 0. Straight; 1. Anterior end downturned.

99) Dorsal and ventral margins of the dentary: 0. Converge anteriorly; 1. Subparallel.

100) Ventral flange on dentary: 0. Absent; 1. Present.

101) Coronoid process: 0. Absent or weak, posterodorsally oblique, depth of mandible at coronoid is less than 140% depth of mandible beneath tooth row; 1. Well-developed, distinctly elevated, depth of mandible at coronoid is more than 180% depth of mandible beneath tooth row.

102) Anterodorsal margin of coronoid process formed by posterodorsal process of dentary: 0. Absent; 1. Present.

103) Coronoid process, position: 0. Posterior to dentition; 1. Lateral to dentition.

104) External mandibular fenestra, situated on dentary-surangular-angular boundary: 0. Present; 1. Absent.

105) Small fenestra positioned dorsally on the surangular-dentary joint: 0. Absent; 1. Present.

106) Ridge or process on lateral surface of surangular, anterior to jaw suture: 0. Absent; 1. Present, anteroposteriorly extended ridge; 2. Present, dorsally directed finger-like process.

107) Retroarticular process: 0. Elongate; 1. Rudimentary or absent.

108) Node-like ornamentation of the dentary and angular: 0. Absent; 1. Present.

109) Level of jaw joint: 0. Level with tooth row, or weakly depressed ventrally; 1. Strongly depressed ventrally, more than 40% of the height of the quadrate is below the level of the maxilla.

110) Mandibular osteoderm: 0. Absent; 1. Present.

111) Premaxillary teeth: 0. Present; 1. Absent, premaxilla edentulous.

112) Premaxillary teeth, number: 0. Six; 1. Five; 2. Four; 3. Three; 4. Two; 5. One.

113) Premaxillary teeth, crown expanded above root: 0. Crown is unexpanded mesiodistally above root, no distinction between root and crown is observable; 1. Crown is at least moderately expanded above root.

114) Premaxillary teeth increase in size posteriorly: 0. Absent, all premaxillary teeth subequal in size; 1. Present, posterior premaxillary teeth are significantly larger in size than anterior teeth.

115) Maxillary and dentary crowns, shape: 0. Apicobasally tall and blade-like; 1. Apicobasally short and sub-triangular; 2. Diamond-shaped.

116) Maxillary/dentary teeth, marginal ornamentations: 0. Fine serrations set at right angles to the margin of the tooth; 1. Coarse serrations (denticles) angle upwards at 45 degrees from the margin of the tooth.

117) Enamel on maxillary/dentary teeth: 0. Symmetrical; 1. Asymmetrical.

118) Apicobasally extending ridges on maxillary/dentary teeth: 0. Absent; 1. Present.

119) Apicobasally extending ridges on lingual/labial surfaces of maxillary/dentary crowns confluent with marginal denticles: 0. Absent; 1. Present.

120) Prominent primary ridge on labial side of maxillary teeth: 0. Absent; 1. Present.

121) Prominent primary ridge on lingual side of dentary teeth: 0. Absent; 1. Present.

122) Position of maxillary/dentary primary ridge: 0. Centre of the crown surface, giving the crown a relatively symmetrical shape in lingual/labial view; 1. Offset, giving crown asymmetrical appearance.

123) At least moderately developed labiolingual expansion of crown (‘cingulum’) on maxillary/dentary teeth: 0. Present; 1. Absent.

124) Heterodont dentary dentition: 0. No substantial heterodonty is present in dentary dentition; 1. Single, enlarged, caniform anterior dentary tooth, crown is not mesiodistally expanded above root; 2. Anterior dentary teeth are strongly recurved and caniform, but have crowns expanded mesiodistally above their roots and are not enlarged relative to other dentary teeth.

125) Peg-like tooth located anteriorly within dentary, lacks denticles, strongly reduced in size: 0. Absent; 1. Present.

126) Alveolar foramina (‘special foramina’) medial to maxillary/dentary tooth rows: 0. Present; 1. Absent.

127) Recurvature in maxillary and dentary teeth: 0. Present; 1. Absent.

128) Overlap of adjacent crowns in maxillary and dentary teeth: 0. Absent; 1. Present.

129) Crown is mesiodistally expanded above root in cheek teeth: 0. Absent; 1. Present.

130) Position of maximum apicobasal crown height in dentary/maxillary tooth rows: 0. Anterior portion of tooth row; 1. Central portion of tooth rows; 2. Caudal portion of tooth rows.

131) Close-packing and quicker replacement eliminates spaces between alveolar border and crowns of adjacent functional teeth: 0. Absent; 1. Present.

132) Fusion between the intercentum of the atlas and the neural arches: 0. Absent; 1. Present.

133) Epipophyses on anterior (postaxial) cervical vertebrae phicoelous; 1. At least slightly opisthocoelous.

135) Cervical vertebra number: 0. Seven/eight; 1. Nine; 2. Ten or more.

136) Articulation between the zygapophyses of dorsal vertebrae: 0. Flat; 1. Tongue-and-groove.

137) Dorsal vertebrae, number: 0. 12–13; 1. 15; 2. 16 or more.

138) Sacral vertebrae, number: 0. Two; 1. Three; 2. Four/five; 3. Six or more.

139) Sacrum, accessory articulation with pubis: 0. Absent; 1. Present.

140) Posterior sacral ribs are considerably longer than anterior sacral ribs: 0. Absent; 1. Present.

141) Anterior caudal vertebrae, length of transverse processes relative to neural spine height: 0. Subequal; 1. Longer than neural spine.

142) Proximal caudal neural spines: 0. Height the same or up to 50% taller than the centrum; 1. More than 50% taller than the centrum.

143) Elongate tail (59 or more caudal vertebrae): 0. Absent; 1. Present.

144) Chevron shape: 0. Rod-shaped, often with slight distal expansion; 1. Strongly asymmetrically expanded distally, width greater than length in mid caudal vertebrae.

145) Sternal segments of the anterior dorsal ribs: 0. Unossified; 1. Ossified.

146) Gastralia: 0. Present; 1. Absent.

147) Ossified clavicles: 0. Absent; 1. Present.

148) Sternal plates, shape: 0. Absent; 1. Kidney-shaped; 2. Shafted or hatchet-shaped (rod-like posterolateral process, expanded anterior end).

149) Proportions of humerus and scapula: 0. Scapula longer or subequal to the humerus; 1. Humerus substantially longer than the scapula.

150) Scapula blade, length relative to minimum width: 0. Relatively short and broad, length is 5-8 times minimum width; 1. Elongate and strap-like, length is at least 9 times the minimum width.

151) Scapula acromion shape: 0. Weakly developed or absent; 1. Well-developed spine-like.

152) Scapula, blade-shape: 0. Strongly expanded distally; 1. Weakly expanded, near parallel-sided.

153) Humeral length: 0. More than 60% of femoral length; 1. Less than 60% of femoral length.

154) Deltopectoral crest development: 0. Well-developed, projects anteriorly as a distinct flange; 1. Rudimentary, is at most a thickening on the anterolateralmargin of the humerus.

155) Humeral shaft form, in anterior or posterior view: 0. Relatively straight; 1. Strongly bowed laterally along length.

156) Longest manual phalanx as percentage of length of humerus: 0. Less than 10%; 1. More than 15%.

157) Metacarpals with block-like proximal ends: 0. Absent; 1. Present.

158) Metacarpals 1 and 5: 0. Substantially shorter in length than metacarpal 3; 1. Subequal in length to metacarpal 3.

159) Penultimate phalanx of the second and third fingers: 0. Shorter than first phalanx; 1. Longer than the first phalanx.

160) Manual digit 3, number of phalanges: 0. Four; 1. Three or fewer.

161) Manual digits 2–4: 0. First phalanx relatively short compared to second phalanx; 1. First phalanx more than twice the length of the second phalanx.

162) Extensor pits on the dorsal surface of the distal end of metacarpals and manual phalanges: 0. Absent or poorly developed; 1. Deep, well-developed.

163) Manual unguals strongly recurved with prominent flexor tubercle: 0. Absent; 1. Present.

164) Acetabulum: 0. At least a small perforation; 1. Completely closed.

165) Preacetabular process, shape / length: 0. Short, tab-shaped, distal end is posterior to pubic peduncle; 1. Elongate, strap-shaped, distal end is anterior to pubic peduncle.

166) Preacetabular process, length: 0. Less than 50% of the length of the ilium; 1. More than 50% of the length of the ilium.

167) Preacetabular process, lateral deflection: 0. 10–20 degrees from midline; 1. More than 30 degrees.

168) Dorsal margin of preacetabular process and dorsal margin of ilium above acetabulum: 0. Narrow, not transversely expanded; 1. Dorsal margin is transversely expanded to form a narrow shelf.

169) In dorsal view, preacetabular process of the ilium expands mediolaterally towards its distal end: 0. Absent; 1. Present.

170) Dorsal margin of the ilium in lateral view: 0. Relatively straight or slightly convex; 1. Sinuous, postacetabular process is strongly upturned.

171) Subtriangular process extending medially from the dorsal margin of the iliac blade: 0. Absent; 1. Present.

172) Subtriangular process, form and position: 0. Short and tab-like, above acetabulum; 1. Elongate and flange-like, on postacetabular process.

173) Brevis shelf & fossa: 0. Fossa faces ventrolaterally and shelf is near vertical and visible in lateral view along entire length, creating a deep postacetabular portion; 1. Fossa faces ventrally and posterior of shelf portion cannot be seen in lateral view.

174) Length of the postacetabular process as a percentage of the total length of the ilium: 0. 20% or less; 1. 25-35%; 2. More than 35%.

175) Medioventral acetabular flange of ilium, partially closes the acetabulum: 0. Present; 1. Absent.

176) Supra-acetabular ‘crest’ or ‘flange’: 0. Present; 1. Absent.

177) Ischial peduncle of the ilium: 0. Projects ventrally; 1. Broadly swollen, projects ventrolaterally.

178) Pubic peduncle of ilium: 0. Large, elongate, robust; 1. Reduced in size, shorter in length than ischial peduncle.

179) Pubic process of ischium, shape: 0. Transversely compressed; 1. Dorsoventrally compressed.

180) Ischium, shape of shaft: 0. Relatively straight; 1. Gently curved along length.

181) Ischial shaft, cross-section: 0. Compressed mediolaterally; 1. Subcircular and bar-like.

182) Ischial shaft: 0. Expands weakly, or is parallel-sided, distally; 1. Distally expanded into a distinct ‘foot’; 2. Tapers distally.

183) Groove on the dorsal margin of the ischium: 0. Absent; 1. Present.

184) Tab-shaped obturator process on ischium: 0. Absent; 1. Present.

185) Ischial symphysis, length: 0. Ischium forms a median symphysis with the opposing blade along at least 50% of its length; 1. Ischial symphysis present distally only.

186) Pubis, orientation: 0. Anteroventral; 1. Rotated posteroventrally to lie alongside the ischium (opisthopubic).

187) Shaft of pubis (postpubis), shape in cross-section: 0. Blade-shaped; 1. Rod-shaped.

188) Shaft of pubis (postpubis), length: 0. Approximately equal in length to the ischium; 1. Reduced, extends for half or less the length of the ischium.

189) Reduction of postpubic shaft: 0. Postpubic shaft extends for around half the length of ischium; 1. Postpubic shaft is very short or absent.

190) Body of pubis, size: 0. Relatively large, makes substantial contribution to the margin of the acetabulum; 1. Reduced in size, rudimentary, nearly excluded from the acetabulum.

191) Body of the pubis, massive and dorsolaterally rotated so that obturator foramen is obscured in lateral view: 0. Absent; 1. Present.

192) Prepubic process: 0. Absent; 1. Present.

193) Prepubic process: 0. Compressed mediolaterally, dorsoventral height exceeds mediolateral width; 1. Rod-like, mediolateral width exceeds dorsoventral height.

194) Prepubic process, length: 0. Stub-like and poorly developed, extends only a short distance anterior to the pubic peduncle of the ilium; 1. Elongated into distinct anterior process.

195) Prepubic process, extends beyond distal end of preacetabular process of ilium: 0. Absent; 1. Present.

196) Extent of pubic symphysis: 0. Elongate; 1. Restricted to distal end of pubic blade, or absent.

197) Femoral shape in medial/lateral view: 0. Bowed anteriorly along length; 1. Straight.

198) Femoral head: 0. Confluent with greater trochanter, fossa trochanteris is groove-like; 1. Fossa trochanteris is modified into distinct constriction separating head and greater trochanter.

199) ‘Anterior’ or ‘lesser’ trochanter, morphology: 0. Absent; 1. Trochanteric shelf ending in a small, pointed, spike; 2. Broadened, prominent, ‘wing’ or ‘blade’ shaped, sub-equal in anteroposterior width to greater trochanter; 3. Reduced anteroposterior width, closely appressed to the expanded greater trochanter.

200) Level of most proximal point of anterior trochanter relative to level of proximal femoral head: 0. Anterior trochanter is positioned distally on the shaft, and separated from ‘dorsolateral’ trochanter/greater trochanter by deep notch visible in medial view; 1. Anterior trochanter positioned proximally, approaches level of proximal surface of femoral head, closely appressed to ‘dorsolateral’/greater trochanter (no notch visible in medial view).

201) Fourth trochanter of femur, shape: 0. Low eminence, or absent; 1. Prominent ridge; 2. Pendent.

202) Fourth trochanter, position: 0. Located entirely on proximal half of femur; 1. Positioned at midlength, or distal to midlength.

203) Anterior (extensor) intercondylar groove on distal end of femur: 0. Absent; 1. Present.

204) Posterior (flexor) intercondylar groove of the femur: 0. Fully open; 1. Medial condyle inflated laterally, partially covers opening of flexor groove.

205) Lateral condyle of distal femur, position and size in ventral view: 0. Positioned relatively laterally, and slightly narrower in width than the medial condyle; 1. Strongly inset medially, reduced in width relative to medial condyle.

206) Distal tibia: 0. Subquadrate, posterolateral process is not substantially developed; 1. Elongate posterolateral process, backs fibula.

207) Fibular facet on the lateral margin of the proximal surface of the astragalus: 0. Large; 1. Reduced to small articulation.

208) Calcaneum, proximal surface: 0. Facet for tibia absent; 1. Well-developed facet for tibia present.

209) Medial distal tarsal: 0. Articulates distally with metatarsal 3 only; 1. Articulates distally with metatarsals 2 and 3

210) Metatarsal arrangement: 0. Compact, closely appressed to one another along 50-70% of their length, spread distally; 1. Contact each other only at proximal ends, spread strongly outwards distally.

211) Digit 1: 0. Metatarsal 1 robust and well-developed, distal end of phalanx 1-1 projects beyond the distal end of metatarsal 2; 1. Metatarsal 1 reduced & proximally splint like, end of phalanx 1-1 does not extend beyond the end of

metatarsal 2; 2. Metatarsal 1 reduced to a vestigial splint or absent, does not bear digits.

212) Pedal digit 4 phalangeal number: 0. Five; 1. Four or fewer.

213) Metatarsal 5, length: 0. More than 50% of metatarsal 3; 1. Less than 25% of metatarsal 3.

214) Metatarsal 5: 0. Bears digits; 1. Lacks digits.

215) Pedal unguals, shape: 0. Tapering, narrow, pointed, claw-like; 1. Wide, blunt, hoof-like.

216) Epaxial ossified tendons present along vertebral column: 0. Absent; 1. Present.

217) Ossified hypaxial tendons, present on caudal vertebrae: 0. Absent; 1. Present.

218) Ossified tendons, arrangement: 0. Longitudinally arranged; 1. Basket-like arrangement of fusiform tendons in caudal region; 2. Double-layered lattice.

219) Parasagittal row of dermal osteoderms on the dorsum of the body: 0. Absent; 1. Present.

220) Lateral row of keeled dermal osteoderms on the dorsum of the body: 0. Absent; 1. Present.

221) U-shaped cervical / pectoral collars composed of contiguous keeled osteoderms: 0. Absent; 1. Present.

222) Wear facets on teeth: 0. Absent or sporadically developed; 1. Systematic development of wear facets along the entire tooth row.

223) Head of humerus is separated from prominent medial tubercle on proximal surface by a groove: 0. Absent; 1. Present.

224) Pendent fourth trochanter, rod-like with subparallel anterior and posterior surfaces: 0. Absent; 1. Present.

225) Fibula, distal end is strongly reduced and splint-like: 0. Absent; 1. Present.

226) Astragalus and calcaneum are indistinguishably fused to one another: 0. Absent; 1. Present

227) Maximum expansion of distal tibia relative to proximal: Distal tibia is considerably less expanded than proximal 0; Maximum expansion of distal tibia is subequal to that of proximal tibia 1.

Appendix 3: Taxon and character matrix (Modified from Butler *et al.*, 2010)

(A=0&1; B=1&2; C=2&3; D=3&4; E=0&2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Abrictosaurus consors	0	0	0	?	?	1	0	0	1	1	?	?	0	1	1	0	0	0	?	1
Agilisaurus louderbacki	0	0	0	?	?	1	0	0	0	1	1	0	0	0	?	0	0	0	1	1
Anabisetia saldiviai	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Ankylopollexia	0	0	0	?	?	1	1	1	1	0	1	0	0	?	?	0	0	1	0	1
Ankylosauria	0	0	0	?	?	1	0	0	0	1	1	0	0	0	?	0	0	0	0	1
Archaeoceratops oshimai	0	1	1	1	1	1	0	0	0	0	?	0	0	1	0	1	0	0	0	1
Bugenasaura infernalis	?	?	0	?	?	0	?	0	?	?	1	?	?	?	?	0	0	0	0	1
Chaoyangosaurus youngi	1	?	1	0	0	1	?	0	0	?	0	?	0	0	?	1	1	0	?	1
Dryosauridae	0	0	0	?	?	1	1	1	1	0	1	1	0	?	?	0	0	1	0	1
Echinodon becklessi	?	?	0	?	?	?	?	0	?	?	1	?	?	?	?	0	?	?	?	?
Emausaurus ernstii	0	?	0	?	?	?	0	0	0	?	1	0	0	0	?	0	0	0	?	1
Eocursor parvus	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Euparkeria capensis	0	0	0	?	?	0	0	0	0	0	0	0	0	0	?	0	0	0	0	0
Fruitadens haagarorum	?	?	0	?	?	1	?	0	?	?	1	?	?	1	1	?	?	?	?	?
Gasparinisaura cincosaltensis	0	0	?	?	?	?	?	?	?	?	?	?	?	1	0	?	?	?	?	1
Goyocephale lattimorei	?	0	0	?	?	?	0	0	1	?	1	0	0	1	1	0	0	0	0	1
Herrerasaurus ischigualastensis	0	0	0	?	?	0	0	0	0	0	0	0	0	0	?	1	1	0	1	0
Heterodontosaurus tucki	0	0	0	?	?	1	1	0	1	1	1	1	0	1	1	0	0	0	1	1
Hexinlusaurus multidens	?	0	0	?	?	?	0	?	?	?	?	?	?	?	?	?	?	0	1	1
Homalocephale calathocercos	?	0	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	1
Hypsilophodon foxii	0	0	0	?	?	1	0	0	1	1	1	0	1	1	0	0	0	0	1	1
Jeholosaurus shangyuanensis	0	0	0	?	?	?	?	0	0	?	?	0	1	0	?	0	0	0	1	1
Lesothosaurus diagnosticus	0	0	0	?	?	1	0	0	0	1	1	0	0	0	?	0	0	0	?	1
Liaoceratops yanzigouensis	0	?	1	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0	0	1
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	0	1	1	?	?	?	?	1
Marasuchus liloensis	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Micropachycephalosaurus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
NHM RU A100	?	?	0	?	?	1	?	0	?	?	1	?	0	1	1	0	0	?	?	1
Orodromeus makelai	0	0	0	?	?	1	0	0	0	1	1	?	1	0	?	0	0	0	1	1
Othnieliosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Pachycephalosauridae	0	0	0	?	?	1	0	0	1	1	1	0	0	1	A	0	0	0	0	1
Parksosaurus warreni	0	0	?	?	?	?	0	?	?	?	?	?	?	1	0	?	?	?	0	1
Pisanosaurus mertii	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	1	1	1	0	0	1	1	0	0	1	0	0	0	?	?	1	1	0	0	1
Rhabdodontidae	0	0	0	?	?	1	0	0	1	0	1	0	0	?	?	0	0	0	0	1
Scelidosaurus harrisonii	0	0	0	?	?	1	0	0	?	?	?	0	?	0	?	?	?	?	0	1
Scutellosaurus lawleri	?	?	?	-	-	?	?	0	?	1	1	?	?	?	?	0	0	?	?	?
Stegosauria	0	0	0	?	?	1	0	0	0	1	1	0	A	0	?	0	0	0	0	1
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Talenkauen santacrucensis	?	0	0	?	?	1	0	1	?	?	1	?	0	1	0	0	0	0	?	1
Tenontosaurus dossi	0	0	0	?	?	?	1	1	1	0	1	0	0	1	0	0	0	1	0	1
Tenontosaurus tilleti	0	0	0	?	?	1	1	1	1	0	1	0	0	?	?	0	0	1	0	1
Thescelosaurus neglectus	?	0	?	?	?	?	?	?	?	?	?	?	?	1	0	?	?	?	?	?
Tianyulong confuciusi	0	0	0	?	?	1	0	0	1	?	?	0	0	1	1	0	0	0	?	1
TMM 43663-1	?	?	?	-	-	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
TMM 43664-1	0	?	?	-	-	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?
Coronosauria + Leptoceratopsidae	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	1
Wannanosaurus yansiensis	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	1
Yinlong downsi	1	1	1	0	1	1	?	0	0	1	0	?	?	0	?	0	0	0	1	1
Zephyrosaurus schaffi	?	?	0	?	?	1	?	0	1	1	1	0	?	1	0	0	0	0	?	1

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Abrictosaurus consors	0	0	?	?	0	1	0	0	1	0	0	0	0	0	?	0	?	?	?	?
Agilisaurus louderbacki	0	0	0	?	0	1	0	?	1	0	1	1	1	0	0	0	?	0	0	0
Anabisetia saldiviai	?	?	?	?	?	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Ankylopollexia	0	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	?	0	0	0
Ankylosauria	1	?	0	0	0	1	0	0	1	1	?	2	?	?	1	0	?	0	0	0
Archaeoceratops oshimai	0	0	0	?	?	1	0	0	1	0	1	0	0	0	2	1	1	1	1	0
Bugenasaura infernalis	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0	0	?	0	0	0
Chaoyangosaurus youngi	?	?	?	?	0	1	1	?	?	?	?	?	?	?	2	1	0	0	0	0
Dryosauridae	0	1	0	0	1	1	0	1	1	0	0	0	1	0	0	0	?	0	0	0
Echinodon becklessi	?	?	?	?	0	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	?	0	0	0
Eocursor parvus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Euparkeria capensis	0	0	0	0	0	0	0	0	0	?	?	?	?	0	0	0	?	0	0	0
Fruitadens haagarorum	0	?	?	0	0	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Gasparinisaura cincosaltensis	0	1	0	?	?	1	0	0	1	0	0	0	0	1	0	0	?	0	0	0
Goyocephale lattimorei	?	?	?	?	0	1	0	0	1	1	?	1	?	?	0	0	?	?	0	0
Herrerasaurus ischigualastensis	0	1	0	0	0	0	0	0	0	?	?	?	?	0	0	0	?	0	0	0
Heterodontosaurus tucki	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	?	0	0	1
Hexinlusaurus multidens	0	0	0	?	?	1	0	?	1	0	0	0	0	1	0	0	?	0	0	0
Homalocephale calathocercos	1	?	?	?	?	1	0	0	1	1	?	1	?	?	0	0	?	0	0	0
Hypsilophodon foxii	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	?	0	0	0
Jeholosaurus shangyuanensis	0	0	0	?	0	1	0	0	1	0	?	0	?	1	0	0	?	0	0	0
Lesothosaurus diagnosticus	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	?	0	0	0
Liaoceratops yanzigouensis	0	0	0	?	0	1	1	0	?	?	?	?	?	0	2	1	1	1	0	0
Lycorhinus angustidens	0	0	?	?	0	1	0	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Micropachycephalosaurus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
NHM RU A100	0	0	?	0	0	1	0	0	?	?	?	?	?	?	?	0	?	0	?	?
Orodromeus makelai	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	?	0	0	1
Othnieliosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Pachycephalosauridae	1	?	?	?	0	1	0	0	1	1	?	1	?	?	0	0	?	0	0	0
Parksosaurus warreni	0	1	0	?	?	1	0	0	1	0	?	0	?	1	0	0	?	0	0	0
Pisanosaurus mertii	?	?	?	?	?	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	?	?	0	0	0	1	1	0	1	0	1	0	0	?	2	1	0	1	0	0
Rhabdodontidae	0	1	0	0	0	1	0	0	?	?	?	?	?	1	0	0	?	0	0	0
Scelidosaurus harrisonii	0	1	0	0	0	1	0	0	1	1	?	2	?	0	1	0	?	0	0	0
Scutellosaurus lawleri	?	?	?	?	?	1	0	?	?	?	?	?	?	?	1	0	-	0	0	0
Stegosauria	0	0	0	0	0	1	0	0	1	1	?	2	?	0	1	0	?	0	0	0
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Talenkauen santacrucensis	0	?	?	?	0	1	0	0	?	?	?	?	?	?	?	?	?	?	?	?
Tenontosaurus dossi	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	?	0	0	0
Tenontosaurus tilleti	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	?	0	0	0
Thescelosaurus neglectus	?	?	?	0	0	1	?	?	1	0	0	0	0	?	0	0	?	0	0	0
Tianyulong confuciusi	0	0	0	0	?	1	0	?	?	?	?	?	?	0	0	?	?	?	?	0
TMM 43663-1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	1	?	?	0	?	0
TMM 43664-1	?	?	?	?	?	1	0	?	?	?	?	?	?	?	1	?	?	0	?	0
Coronosauria + Leptoceratopsidae	0	1	0	0	0	1	0	0	1	0	1	0	0	0	2	1	1	1	1	0
Wannanosaurus yansiensis	?	?	?	?	?	?	?	?	1	1	?	1	?	?	0	0	?	0	0	0
Yandusaurus hongheensis	0	0	0	0	0	1	0	0	?	?	?	?	?	?	0	0	?	0	0	0
Yinlong downsi	0	1	0	?	?	1	0	?	1	0	0	0	0	0	2	1	0	1	0	0
Zephyrosaurus schaffi	0	?	?	1	0	1	0	?	1	0	1	0	0	?	0	0	?	0	0	1

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Abrictosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?	?	?	?	?
Agilisaurus louderbacki	0	0	0	0	0	0	0	0	0	0	0	?	1	0	0	0	1	0	0	0
Anabisetia saldiviai	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Ankylopollexia	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	A
Ankylosauria	0	1	1	0	0	0	0	0	0	0	0	?	1	?	1	0	0	1	0	0
Archaeoceratops oshimai	1	1	0	1	?	0	0	0	0	1	0	?	1	0	1	1	?	0	1	0
Bugenasaura infernalis	0	0	0	0	0	0	0	?	0	0	0	1	1	0	0	0	?	0	0	0
Chaoyangosaurus youngi	1	?	?	?	?	0	0	0	?	?	?	?	1	0	0	0	?	0	?	0
Dryosauridae	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	1
Echinodon becklessi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	?	0	0	0
Eocursor parvus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Euparkeria capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fruitadens haagarorum	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Gasparinisaura cincosaltensis	0	0	0	0	0	0	0	0	0	0	?	0	1	1	0	0	?	0	0	0
Goyocephale lattimorei	1	1	1	0	0	0	0	0	0	?	1	?	1	?	0	0	?	?	?	?
Herrerasaurus ischigualastensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterodontosaurus tucki	0	0	1	0	0	?	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Hexinlusaurus multidens	0	0	0	0	0	0	0	0	0	0	0	?	1	0	0	0	?	0	0	0
Homalocephale calathocercos	1	1	1	0	0	0	0	0	0	?	1	1	1	0	0	0	0	0	0	0
Hypsilophodon foxii	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
Jeholosaurus shangyuanensis	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
Lesothosaurus diagnosticus	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Liaoceratops yanzigouensis	0	1	0	1	1	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Micropachycephalosaurus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?
NHM RU A100	0	0	?	0	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Orodromeus makelai	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0
Othnieliosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Pachycephalosauridae	1	1	1	0	0	0	0	0	0	?	1	1	1	0	0	0	0	0	0	0
Parksosaurus warreni	0	0	0	1	?	0	0	?	0	0	0	?	1	1	0	0	?	0	0	0
Pisanosaurus mertii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Rhabdodontidae	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Scelidosaurus harrisonii	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Scutellosaurus lawleri	0	0	0	0	0	1	0	0	?	?	?	0	1	?	?	?	0	0	?	?
Stegosauria	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Talenkauen santacrucensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Tenontosaurus dossi	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	1
Tenontosaurus tilleti	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	1
Thescelosaurus neglectus	0	0	0	0	0	0	0	?	0	0	0	?	?	?	?	?	?	?	?	?
Tianyulong confuciusi	0	?	?	?	?	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?
TMM 43663-1	0	0	0	0	0	1	0	0	0	0	0	?	?	?	?	?	0	?	0	?
TMM 43664-1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	?	?	0	?
Coronosauria + Leptoceratopsidae	0	1	0	1	1	0	0	0	0	1	0	1	1	0	1	1	0	0	1	0
Wannanosaurus yansiensis	1	0	1	0	0	0	0	0	0	?	0	?	1	?	0	?	?	?	?	?
Yandusaurus hongheensis	0	0	0	0	0	0	0	?	?	?	?	?	?	?	?	?	?	0	?	?
Yinlong downsi	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	?	0	0	0
Zephyrosaurus schaffi	0	0	0	0	0	?	0	?	1	0	0	?	?	0	?	?	1	0	0	?

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Abrictosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Agilisaurus louderbacki	0	0	1	0	0	0	0	0	?	?	0	0	0	0	1	0	?	0	0	0
Anabisetia saldiviai	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Ankylopollexia	1	0	0	0	0	0	0	0	?	?	0	0	0	0	1	0	1	1	0	0
Ankylosauria	0	0	1	0	1	?	1	0	?	?	1	0	0	0	0	0	?	0	0	1
Archaeoceratops oshimai	0	0	2	0	0	1	0	1	1	1	0	0	0	0	0	1	?	0	1	?
Bugenasaura infernalis	?	0	0	0	0	0	0	0	?	?	0	0	0	0	?	?	?	?	?	?
Chaoyangosaurus youngi	0	0	2	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?
Dryosauridae	1	?	0	0	0	0	0	0	?	?	0	0	0	0	1	0	1	1	0	0
Echinodon becklessi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	0	0	?	0	0	0	0	0	?	?	0	0	0	0	?	?	?	?	0	0
Eocursor parvus	?	?	?	?	0	0	0	0	?	?	?	?	?	?	?	?	?	?	?	?
Euparkeria capensis	0	0	1	0	0	0	0	0	?	?	0	0	0	0	0	0	1	0	0	0
Fruitadens haagarorum	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Gasparinisaura cincosaltensis	?	0	?	?	0	0	?	0	?	?	0	0	0	0	0	0	0	0	0	?
Goyocephale lattimorei	?	?	?	0	0	0	0	1	0	0	1	1	1	1	1	0	?	?	?	?
Herrerasaurus ischigualastensis	0	0	1	0	0	0	0	0	?	?	0	0	0	0	0	0	1	0	0	?
Heterodontosaurus tucki	0	0	2	0	0	0	0	0	?	?	0	0	0	0	0	0	0	0	0	0
Hexinlusaurus multidens	0	0	?	0	0	0	0	0	?	?	0	0	0	0	1	?	?	?	?	?
Homalocephale calathocercos	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	0	?	0	0	0
Hypsilophodon foxii	1	1	0	1	0	0	0	0	?	?	0	0	0	0	1	0	0	0	0	0
Jeholosaurus shangyuanensis	1	1	0	1	0	0	0	0	?	?	0	0	0	0	1	0	?	?	?	0
Lesothosaurus diagnosticus	0	0	0	0	0	0	0	0	?	?	0	0	0	0	0	0	0	0	0	0
Liaoceratops yanzigouensis	0	0	2	0	0	1	0	1	1	1	0	0	0	0	0	1	?	0	1	0
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0
Micropachycephalosaurus	?	?	2	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
NHM RU A100	?	?	?	?	0	0	0	?	?	?	?	?	?	0	?	?	?	?	?	?
Orodromeus makelai	0	0	0	1	0	0	0	0	?	?	0	0	0	0	1	0	0	0	0	0
Othnieliosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Pachycephalosauridae	0	0	0	0	1	?	1	1	0	0	1	1	1	1	1	0	?	A	0	0
Parksosaurus warreni	?	0	0	?	0	0	0	0	?	?	?	?	0	0	?	?	?	?	?	?
Pisanosaurus mertii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	0	0	2	0	0	0	0	1	0	1	0	0	0	0	0	A	0	0	0	0
Rhabdodontidae	?	0	2	0	0	0	0	0	?	?	0	0	0	0	1	0	1	0	0	0
Scelidosaurus harrisonii	0	0	1	0	0	0	0	0	?	?	0	0	0	0	0	0	?	0	0	1
Scutellosaurus lawleri	?	?	1	1	0	0	?	?	?	?	?	?	?	0	?	?	?	?	0	?
Stegosauria	0	0	1	0	0	0	0	0	?	?	0	0	0	0	A	0	1	0	0	1
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Talenkauen santacrucensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Tenontosaurus dossi	1	1	0	0	0	0	0	0	?	?	0	0	0	0	1	0	1	1	0	?
Tenontosaurus tilleti	1	1	0	0	0	0	0	0	?	?	0	0	0	0	1	0	1	1	0	0
Thescelosaurus neglectus	?	?	?	0	0	0	0	0	?	?	0	0	0	0	?	0	1	1	0	0
Tianyulong confuciusi	?	?	2	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
TMM 43663-1	?	?	1	1	0	0	?	?	?	?	0	0	0	?	0	0	?	?	?	?
TMM 43664-1	?	?	1	1	0	0	?	?	?	?	0	?	?	0	?	?	?	?	?	?
Coronosauria + Leptoceratopsidae	0	0	2	0	0	1	0	1	1	1	0	0	0	0	0	1	?	0	1	0
Wannanosaurus yansiensis	?	?	?	?	0	0	0	1	0	0	1	1	0	1	1	0	?	?	?	?
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Yinlong downsi	0	0	2	0	0	1	0	1	0	1	0	1	1	0	1	0	0	?	0	0
Zephyrosaurus schaffi	?	?	0	1	0	0	0	0	?	?	0	0	?	0	1	0	0	0	0	0

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Abrictosaurus consors	?	?	?	?	?	?	?	?	0	1	1	0	0	0	?	1	0	0	0	0
Agilisaurus louderbacki	0	0	?	?	0	?	0	0	0	1	0	?	0	0	0	0	1	0	0	0
Anabisetia saldiviai	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	1	0
Ankylopollexia	0	0	2	0	0	?	0	0	0	1	1	0	1	0	1	0	1	0	1	0
Ankylosauria	0	0	0	0	1	1	0	0	1	1	0	0	0	0	?	1	1	1	0	0
Archaeoceratops oshimai	?	0	1	?	0	?	?	?	0	1	1	1	0	1	0	0	1	0	0	0
Bugenasaura infernalis	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?	0	0	0
Chaoyangosaurus youngi	?	0	?	?	0	?	0	?	0	1	1	1	0	1	?	0	1	0	0	0
Dryosauridae	0	0	1	0	0	?	0	0	0	1	1	0	1	0	1	0	1	0	0	0
Echinodon becklessi	?	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	0	0	0	0
Emausaurus ernstii	?	0	0	?	?	?	?	?	1	?	0	?	?	?	?	?	1	1	0	0
Eocursor parvus	?	0	0	?	?	?	?	?	?	?	?	?	?	?	?	?	1	0	0	0
Euparkeria capensis	0	0	0	0	0	?	0	0	0	0	?	?	?	?	?	?	0	0	0	0
Fruitadens haagarorum	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	0	0	0
Gasparinisaura cincosaltensis	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?	0	0	0
Goyocephale lattimorei	?	1	?	?	?	?	0	?	0	?	0	?	?	?	?	?	0	0	0	0
Herrerasaurus ischigualastensis	0	0	0	?	0	?	0	0	0	0	?	?	?	?	?	?	0	0	0	0
Heterodontosaurus tucki	0	0	0	0	0	?	0	0	0	1	1	0	0	0	?	1	0	0	0	0
Hexinlusaurus multidens	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	1	0	0	0
Homalocephale calathocercos	1	1	0	?	0	?	?	1	0	?	?	?	?	?	?	?	?	?	?	?
Hypsilophodon foxii	0	0	1	0	0	?	0	0	0	1	1	1	0	0	0	0	1	0	0	0
Jeholosaurus shangyuanensis	?	0	0	1	0	?	?	?	0	1	1	1	0	0	0	0	1	0	0	0
Lesothosaurus diagnosticus	0	0	0	?	0	?	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Liaoceratops yanzigouensis	0	0	1	?	0	?	0	0	0	1	1	0	0	1	0	0	1	0	0	1
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	0	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Micropachycephalosaurus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	0	0
NHM RU A100	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	0	0	0	0
Orodromeus makelai	0	0	0	?	?	?	?	?	0	1	?	?	?	0	?	0	1	0	0	0
Othnieliosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Pachycephalosauridae	1	1	0	1	0	?	A	1	0	1	0	?	?	?	?	?	0	0	0	0
Parksosaurus warreni	?	0	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?	0	0	0
Pisanosaurus mertii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	0	0
Psittacosauridae	0	0	0	1	0	?	1	0	0	1	1	A	0	0	0	0	1	0	0	1
Rhabdodontidae	?	0	1	?	?	?	?	?	0	1	1	0	0	0	1	0	1	0	1	0
Scelidosaurus harrisonii	0	0	1	?	1	0	0	0	1	?	0	?	?	?	?	?	1	1	0	0
Scutellosaurus lawleri	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	?	?	1	0	0
Stegosauria	0	0	0	0	1	?	0	0	0	1	0	0	0	0	0	0	1	1	0	0
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Talenkauen santacrucensis	?	?	?	?	?	?	?	?	0	1	1	1	0	?	1	0	1	0	0	0
Tenontosaurus dossi	?	0	?	?	0	?	0	?	0	1	1	0	1	0	0	0	1	0	1	0
Tenontosaurus tilleti	0	0	1	?	0	?	0	0	0	1	1	0	1	0	0	0	1	0	1	0
Thescelosaurus neglectus	0	0	1	?	?	?	?	?	0	1	?	?	?	?	?	?	1	0	0	0
Tianyulong confuciusi	?	?	?	?	?	?	?	?	?	1	1	?	0	0	?	?	?	0	1	0
TMM 43663-1	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	?	?	1	0	0
TMM 43664-1	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	?	?	?	?	?
Coronosauria + Leptoceratopsidae	0	0	B	1	0	?	1	0	0	1	1	1	0	1	1	0	1	0	?	0
Wannanosaurus yansiensis	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	0	0	0	0
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?	?	?	?
Yinlong downsi	1	1	2	?	?	?	?	0	0	1	0	1	0	0	1	0	1	0	0	0
Zephyrosaurus schaffi	0	0	1	?	?	?	?	?	0	?	?	?	?	?	?	?	?	?	?	?

	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Abrictosaurus consors	1	1	0	0	0	?	0	0	?	0	0	3	0	0	1	1	?	0	?	0
Agilisaurus louderbacki	1	1	0	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	?	0
Anabisetia saldiviai	1	?	?	?	?	?	?	?	?	0	?	?	?	?	1	1	?	1	1	0
Ankylopollexia	1	1	1	1	1	0	0	0	1	0	1	?	?	?	2	1	1	1	0	1
Ankylosauria	0	1	0	1	0	0	0	0	0	1	0	?	1	0	1	1	0	0	?	0
Archaeoceratops oshimai	1	1	1	1	0	1	1	1	0	0	0	3	1	0	1	1	?	?	?	1
Bugenasaura infernalis	1	1	0	1	1	2	0	0	?	0	0	1	1	0	1	1	1	1	1	0
Chaoyangosaurus youngi	?	1	0	1	0	0	1	1	0	0	0	4	1	0	1	1	1	0	?	0
Dryosauridae	1	1	1	1	0	0	0	0	0	0	1	?	?	?	2	1	1	1	0	1
Echinodon becklessi	?	?	0	?	?	?	?	0	?	?	0	D	?	?	1	1	0	0	?	0
Emausaurus ernstii	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	?	0
Eocursor parvus	0	1	0	0	0	1	0	0	0	0	?	?	?	?	1	1	?	0	?	?
Euparkeria capensis	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	?	0
Fruitadens haagarorum	?	?	0	?	?	?	?	?	?	?	0	3	1	0	1	1	0	0	?	0
Gasparinisaura cincosaltensis	1	1	0	1	1	0	0	0	1	0	?	?	?	?	1	1	1	1	1	1
Goyocephale lattimorei	1	1	0	1	0	?	0	1	?	0	0	3	1	1	1	1	1	A	A	0
Herrerasaurus ischigualastensis	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	?	0
Heterodontosaurus tucki	1	1	0	0	0	0	0	0	1	0	0	3	0	1	1	1	1	1	0	1
Hexinlusaurus multidens	1	1	0	?	?	?	?	0	0	0	?	?	?	?	1	1	0	1	0	0
Homalocephale calathocercos	?	?	?	?	?	?	?	?	0	?	?	?	?	?	1	1	?	1	1	0
Hypsilophodon foxii	1	1	0	1	1	0	0	0	1	0	0	1	1	0	1	1	1	1	A	0
Jeholosaurus shangyuanensis	1	1	0	1	0	0	0	0	0	0	0	0	?	0	1	1	?	1	1	0
Lesothosaurus diagnosticus	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	?	0
Liaoceratops yanzigouensis	1	1	1	1	0	0	1	1	0	0	0	3	1	0	1	1	1	1	1	1
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	1	1	?	0	?	0
Marasuchus liloensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Micropachycephalosaurus	1	1	0	?	?	?	?	?	?	0	?	?	?	?	1	1	1	0	?	?
NHM RU A100	?	?	?	?	?	?	?	?	?	0	0	3	0	1	1	1	?	0	?	0
Orodromeus makelai	1	1	0	1	1	0	0	0	0	0	0	1	1	0	1	1	0	0	?	0
Othnieliosaurus consors	?	?	?	?	?	?	?	0	?	0	?	?	?	?	1	1	1	0	?	0
Pachycephalosauridae	1	1	0	1	0	0	0	1	0	0	0	3	A	A	1	1	?	A	A	0
Parksosaurus warreni	1	1	0	?	?	?	0	0	1	0	?	?	?	?	1	1	1	?	1	0
Pisanosaurus mertii	?	1	0	?	0	0	0	0	0	0	?	?	?	?	1	?	?	0	?	0
Psittacosauridae	1	1	1	A	A	0	0	0	0	0	1	?	?	?	1	1	1	1	1	1
Rhabdodontidae	1	1	1	?	?	0	0	0	0	0	1	?	?	?	2	1	1	1	1	0
Scelidosaurus harrisonii	0	1	0	1	0	1	0	0	0	1	0	1	1	0	1	1	0	0	?	0
Scutellosaurus lawleri	0	?	?	?	?	1	?	0	?	0	0	0	?	0	1	1	0	0	?	0
Stegosauria	1	1	0	0	0	0	0	0	0	0	A	?	1	0	1	1	0	0	?	0
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Talenkauen santacrucensis	1	1	?	?	?	?	?	0	?	0	0	1	?	?	?	1	?	?	1	0
Tenontosaurus dossi	1	1	1	?	?	?	0	0	0	0	0	?	?	?	2	1	1	1	0	0
Tenontosaurus tilleti	1	1	1	1	1	2	0	0	0	0	1	?	?	?	2	1	1	1	0	0
Thescelosaurus neglectus	1	1	0	1	1	2	0	0	?	0	0	?	1	?	1	1	0	?	1	0
Tianyulong confuciusi	1	1	0	0	0	0	?	0	0	0	0	5	0	1	1	?	?	0	?	0
TMM 43663-1	?	?	?	?	?	?	?	0	?	0	?	?	?	?	?	1	0	0	?	0
TMM 43664-1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	1	0	0	?	0
Coronosauria + Leptoceratopsidae	1	1	1	1	0	1	1	0	0	0	A	4	1	0	1	1	1	1	1	1
Wannanosaurus yansiensis	1	1	0	1	0	0	0	0	?	0	?	?	?	?	1	1	1	0	?	?
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	1	1	1	?	1	0
Yinlong downsi	1	1	0	0	1	0	1	1	0	0	0	3	1	0	0	1	?	1	1	0
Zephyrosaurus schaffi	?	?	?	?	?	?	?	?	?	?	0	1	1	0	1	1	1	?	1	0

	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
Abrictosaurus consors	?	?	0	0	1	?	1	1	1	1	0	?	?	?	?	?	?	?	?	0
Agilisaurus louderbacki	0	?	0	2	0	0	1	1	1	1	0	0	1	0	1	0	1	2	0	0
Anabisetia saldiviai	?	?	?	?	?	?	1	1	1	?	?	?	?	?	?	?	?	?	?	?
Ankylopollexia	1	0	1	0	0	0	1	1	1	1	1	0	1	1	B	0	2	C	?	0
Ankylosauria	0	?	0	0	0	0	1	1	1	1	0	1	1	0	0	0	?	B	0	0
Archaeoceratops oshimai	?	1	0	0	0	?	1	1	1	1	1	?	?	?	?	1	0	3	1	0
Bugenasaura infernalis	1	0	0	0	0	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?
Chaoyangosaurus youngi	0	?	0	0	0	0	1	1	1	1	0	?	?	0	?	?	?	?	?	?
Dryosauridae	1	0	1	0	0	0	1	1	1	1	0	?	1	1	1	0	1	3	1	0
Echinodon becklessi	0	?	0	0	?	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	0	?	0	0	0	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?
Eocursor parvus	0	?	0	0	?	0	1	?	1	1	0	?	?	0	?	0	?	2	?	?
Euparkeria capensis	0	?	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Fruitadens haagarorum	0	?	0	1	1	0	1	1	1	1	0	?	?	0	?	?	?	3	?	?
Gasparinisaura cincosaltensis	?	?	0	0	0	?	1	1	1	1	0	0	?	0	?	?	?	3	1	0
Goyocephale lattimorei	0	?	0	1	?	?	1	1	1	?	0	0	?	?	?	1	?	3	?	1
Herrerasaurus ischigualastensis	0	?	1	0	0	1	0	0	0	0	0	0	0	0	2	0	1	0	0	0
Heterodontosaurus tucki	1	A	1	1	1	1	1	1	0	1	1	?	0	0	1	?	0	3	?	0
Hexinlusaurus multidens	0	?	0	?	0	0	1	1	1	1	0	0	1	0	1	0	1	2	0	0
Homalocephale calathocercos	?	?	0	?	?	?	1	1	1	1	0	?	?	?	?	1	?	3	1	1
Hypsilophodon foxii	1	0	0	0	0	0	1	1	1	1	0	0	1	0	1	0	1	3	1	0
Jeholosaurus shangyuanensis	0	?	0	0	0	?	1	1	1	1	0	0	1	0	1	0	?	?	?	?
Lesothosaurus diagnosticus	0	?	0	0	0	0	1	1	1	1	0	0	0	0	?	0	?	2	0	?
Liaoceratops yanzigouensis	1	1	0	0	0	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?
Lycorhinus angustidens	?	?	0	?	?	1	1	1	1	1	0	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	?	?	?	?	?	?	?	?	?	?	?	0	1	0	?	0	?	0	0	0
Micropachycephalosaurus	0	?	0	0	0	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?
NHM RU A100	?	?	0	1	1	1	1	1	1	1	0	?	?	?	?	?	?	?	?	?
Orodromeus makelai	0	?	0	0	0	0	1	1	1	1	0	0	1	0	1	0	1	3	1	0
Othnieliosaurus consors	0	?	0	?	?	?	1	?	1	?	0	?	?	0	?	0	1	3	?	0
Pachycephalosauridae	0	?	0	B	?	0	A	1	1	1	0	?	?	?	?	1	?	3	?	1
Parksosaurus warreni	0	?	0	0	0	0	1	1	1	1	0	?	?	?	?	0	2	3	?	0
Pisanosaurus mertii	0	?	?	0	0	?	1	1	1	1	0	?	?	0	?	?	?	?	?	?
Psittacosauridae	1	0	0	0	0	0	1	1	1	1	0	0	1	0	A	0	0	3	1	0
Rhabdodontidae	1	0	1	0	0	0	1	1	1	1	0	?	1	1	?	0	?	3	?	0
Scelidosaurus harrisonii	0	?	0	0	0	0	1	1	1	1	0	0	0	0	0	0	2	2	0	0
Scutellosaurus lawleri	0	?	0	?	0	0	1	1	1	1	0	0	?	0	1	0	1	2	?	?
Stegosauria	0	?	0	0	0	0	1	1	1	1	0	1	1	0	E	0	E	2	0	0
Stenopelix valdensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	3	?	?
Stormbergia dangershoeki	?	?	?	?	?	?	?	?	?	?	?	0	?	0	?	0	1	2	0	0
Talenkauen santacrucensis	?	?	?	0	?	?	1	1	1	1	0	?	0	0	1	0	2	?	?	?
Tenontosaurus dossi	1	0	1	0	0	0	1	1	1	1	0	?	0	1	2	0	?	3	?	0
Tenontosaurus tilleti	1	0	1	0	0	0	1	1	1	1	0	0	0	1	2	0	2	3	1	0
Thescelosaurus neglectus	1	0	0	0	0	0	1	1	1	?	?	?	?	0	?	0	2	3	1	0
Tianyulong confuciusi	?	?	0	1	0	?	1	0	1	2	0	?	?	?	?	?	?	?	?	?
TMM 43663-1	0	?	?	?	?	0	1	1	1	?	0	?	?	0	?	0	?	?	?	?
TMM 43664-1	?	?	?	?	?	0	1	1	1	?	0	0	?	0	?	0	?	2	?	0
Coronosauria + Leptoceratopsidae	1	1	0	0	0	0	1	1	1	1	1	?	1	0	2	?	0	3	?	0
Wannanosaurus yansiensis	0	?	0	1	0	?	1	1	1	1	0	?	?	0	?	?	?	?	?	?
Yandusaurus hongheensis	?	?	0	?	?	?	1	1	1	1	0	?	?	0	?	0	?	?	?	?
Yinlong downsi	?	?	0	0	0	?	1	1	1	1	0	?	0	?	?	?	?	?	?	?
Zephyrosaurus schaffi	0	?	0	0	?	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?

	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
Abrictosaurus consors	?	?	?	?	?	?	?	?	0	?	1	0	0	0	0	?	1	0	?	?
Agilisaurus louderbacki	0	0	0	0	0	1	0	?	1	0	1	0	1	0	0	?	?	?	?	?
Anabisetia saldiviai	?	?	?	?	?	?	?	?	0	0	1	0	0	1	0	0	0	0	0	?
Ankylopollexia	0	1	0	0	0	1	0	B	0	0	A	0	0	0	0	0	0	0	0	1
Ankylosauria	0	0	0	0	0	1	0	1	0	0	?	1	0	0	0	?	0	1	0	1
Archaeoceratops oshimai	0	?	?	0	?	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Bugenasaura infernalis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Chaoyangosaurus youngi	?	?	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	?	?	?
Dryosauridae	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	?	?	?	?	?
Echinodon becklessi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	1	?	?
Eocursor parvus	?	?	?	?	?	?	?	?	0	0	1	0	0	0	0	?	?	0	1	?
Euparkeria capensis	0	0	0	0	0	?	1	0	0	0	1	1	0	0	0	?	0	0	?	?
Fruitadens haagarorum	?	?	?	?	?	?	?	?	?	?	?	?	0	0	0	1	?	?	?	?
Gasparinisaura cincosaltensis	0	?	?	1	?	1	0	?	?	?	0	0	?	0	0	?	?	?	?	?
Goyocephale lattimorei	?	?	?	?	0	1	?	2	?	?	?	?	1	1	1	?	?	?	?	?
Herrerasaurus ischigualastensis	0	0	0	0	0	?	?	?	?	1	1	1	0	0	0	1	1	0	1	0
Heterodontosaurus tucki	0	0	0	0	0	1	0	?	0	1	1	0	0	0	0	1	1	0	1	0
Hexinlusaurus multidens	0	0	0	0	0	1	0	?	1	0	1	0	0	0	0	0	0	0	0	0
Homalocephale calathocercos	1	?	?	0	0	1	?	2	?	?	?	?	?	?	?	?	?	?	?	?
Hypsilophodon foxii	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Jeholosaurus shangyuanensis	0	?	?	0	?	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Lesothosaurus diagnosticus	?	?	?	?	?	?	?	?	0	0	1	0	1	0	0	0	0	0	0	?
Liaoceratops yanzigouensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	0	0	?	0	?	?	?	?	?	?	?	?	0	0	0	?	?	?	?	?
Micropachycephalosaurus	?	?	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
NHM RU A100	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Orodromeus makelai	0	0	?	0	?	1	0	1	0	0	1	0	?	0	0	0	0	0	0	0
Othnieliosaurus consors	0	0	?	0	1	1	0	1	0	0	1	0	0	0	0	?	?	?	?	?
Pachycephalosauridae	1	?	?	0	0	1	?	2	0	1	1	0	1	1	1	?	?	?	?	?
Parksosaurus warreni	0	?	0	1	1	1	?	1	0	0	0	0	0	0	0	?	?	?	?	?
Pisanosaurus mertii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	0	?	0	0	0	1	1	1	0	A	1	0	0	0	0	0	0	0	0	0
Rhabdodontidae	0	1	?	0	?	1	0	?	?	0	0	0	?	0	0	?	?	?	?	?
Scelidosaurus harrisonii	0	0	0	0	0	1	0	?	0	0	1	0	0	0	0	?	?	?	?	?
Scutellosaurus lawleri	0	?	1	?	?	?	?	?	?	?	1	?	0	0	0	?	0	0	?	?
Stegosauria	0	1	0	0	0	1	0	?	0	0	1	1	0	0	0	?	0	1	0	1
Stenopelix valdensis	0	?	?	0	?	1	?	?	?	1	?	0	?	?	?	?	?	?	?	?
Stormbergia dangershoeki	0	0	?	?	?	?	?	?	0	0	1	0	?	?	0	?	?	?	?	?
Talenkauen santacrucensis	?	?	?	?	?	1	0	?	0	0	1	0	0	1	0	?	?	?	?	?
Tenontosaurus dossi	0	1	1	0	?	1	0	1	0	0	0	0	0	0	0	0	0	0	?	?
Tenontosaurus tilleti	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Thescelosaurus neglectus	0	1	?	0	1	1	0	?	0	0	1	0	0	0	0	0	0	0	0	0
Tianyulong confuciusi	?	?	?	?	?	?	?	?	?	?	1	?	?	0	0	?	?	?	?	?
TMM 43663-1	0	1	?	?	?	?	?	?	1	0	?	0	0	0	0	?	?	?	?	?
TMM 43664-1	0	?	?	0	?	?	?	?	?	0	?	0	?	?	?	?	?	?	?	?
Coronosauria + Leptoceratopsidae	0	?	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0
Wannanosaurus yansiensis	?	?	?	?	?	?	?	?	?	?	?	?	1	1	1	?	?	?	?	?
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	0	0	1	0	?	0	0	?	?	?	?	?
Yinlong downsi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Zephyrosaurus schaffi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
Abrictosaurus consors	0	1	?	0	1	0	0	0	0	0	0	?	1	1	?	1	0	0	?	?
Agilisaurus louderbacki	?	?	?	0	1	0	0	0	0	0	0	?	0	1	0	0	0	1	0	0
Anabisetia saldiviai	?	0	0	0	1	1	0	0	0	0	0	?	1	1	1	1	1	1	0	0
Ankylopollexia	1	0	0	0	1	0	0	0	0	A	0	?	1	1	1	1	1	1	1	0
Ankylosauria	0	0	0	1	1	1	1	1	0	0	0	?	0	0	0	0	0	0	1	0
Archaeoceratops oshimai	?	?	?	0	1	0	0	0	0	0	0	?	1	2	1	1	1	1	0	?
Bugenasaura infernalis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Chaoyangosaurus youngi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Dryosauridae	?	?	?	0	1	0	0	0	0	1	0	?	1	1	1	1	1	1	1	0
Echinodon becklessi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Eocursor parvus	0	1	?	0	1	?	0	0	0	0	0	?	1	1	1	0	0	0	0	0
Euparkeria capensis	?	0	?	1	0	0	0	0	0	0	0	?	?	2	0	1	0	0	0	0
Fruitadens haagarorum	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Gasparinisaura cincosaltensis	?	?	?	0	1	0	0	0	0	1	0	?	1	1	1	1	1	1	0	0
Goyocephale lattimorei	?	?	?	0	1	0	1	1	1	0	1	0	1	2	1	1	?	?	?	?
Herrerasaurus ischigualastensis	0	1	1	0	0	0	0	0	0	0	0	?	0	1	0	0	0	0	0	0
Heterodontosaurus tucki	0	1	1	0	1	0	0	0	0	0	0	?	1	1	1	1	0	0	0	0
Hexinlusaurus multidens	0	0	0	0	1	0	0	0	0	0	0	?	1	1	0	1	0	1	0	0
Homalocephale calathocercos	?	?	?	0	1	0	1	1	1	0	1	1	1	2	1	1	1	1	1	1
Hypsilophodon foxii	0	0	0	0	1	0	0	0	0	0	0	?	1	2	1	1	1	1	0	0
Jeholosaurus shangyuanensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Lesothosaurus diagnosticus	0	0	0	0	1	0	0	0	0	0	0	?	0	1	0	0	0	0	0	0
Liaoceratops yanzigouensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	?	?	?	1	0	0	0	0	0	1	0	?	?	2	0	0	0	0	0	0
Micropachycephalosaurus	?	?	?	0	1	0	0	0	0	?	?	?	?	?	?	1	?	?	?	?
NHM RU A100	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Orodromeus makelai	0	0	0	0	1	0	0	0	0	0	0	?	1	2	1	1	1	1	0	0
Othnieliosaurus consors	?	?	?	0	1	0	0	0	0	0	0	?	1	1	1	1	1	1	0	0
Pachycephalosauridae	?	?	?	0	1	0	1	1	1	0	1	1	1	2	1	1	1	1	1	1
Parksosaurus warreni	?	?	?	0	1	0	0	0	0	0	0	?	?	?	?	1	?	?	0	0
Pisanosaurus mertii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	0	0	0	0	1	0	0	0	0	0	0	?	1	2	1	1	1	1	0	0
Rhabdodontidae	?	?	?	0	1	0	0	1	0	0	0	?	?	1	1	1	0	1	1	0
Scelidosaurus harrisonii	?	?	?	0	1	0	0	1	0	0	0	?	0	0	0	0	0	0	0	0
Scutellosaurus lawleri	0	0	0	0	1	?	0	?	0	0	0	?	?	1	?	?	?	?	0	0
Stegosauria	0	0	0	0	1	1	1	1	0	0	0	?	0	0	0	0	0	0	0	0
Stenopelix valdensis	?	?	?	0	1	0	0	1	0	0	0	?	1	1	1	1	0	1	1	0
Stormbergia dangershoeki	?	?	?	0	1	0	0	0	0	0	0	?	0	1	0	0	0	0	0	0
Talenkauen santacrucensis	?	?	?	0	1	0	0	0	0	1	0	?	1	1	1	1	?	1	?	?
Tenontosaurus dossi	?	0	0	0	1	0	0	0	0	1	0	?	1	1	1	1	1	1	0	0
Tenontosaurus tilleti	1	0	0	0	1	0	0	0	0	1	0	?	1	1	1	1	1	1	0	0
Thescelosaurus neglectus	0	0	0	0	1	0	0	0	0	1	0	?	1	1	1	1	0	1	0	0
Tianyulong confuciusi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0
TMM 43663-1	?	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
TMM 43664-1	?	0	?	0	1	1	0	1	0	0	0	?	0	?	0	0	0	0	?	?
Coronosauria + Leptoceratopsidae	1	0	0	0	1	0	0	0	0	1	0	?	1	2	1	1	1	1	1	0
Wannanosaurus yansiensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Yinlong downsi	?	?	0	0	1	0	0	0	0	0	0	?	1	1	1	1	0	?	?	?
Zephyrosaurus schaffi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
Abrictosaurus consors	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?	2	?
Agilisaurus louderbacki	0	0	1	1	0	1	1	0	?	0	0	1	0	1	0	1	0	0	2	0
Anabisetia saldiviai	0	1	0	1	1	1	1	0	?	0	0	1	0	1	1	1	0	1	3	1
Ankylopollexia	1	1	0	1	1	1	1	1	0	0	0	1	0	1	1	1	1	1	C	1
Ankylosauria	0	E	0	0	1	1	1	1	A	1	1	1	0	0	0	1	1	0	?	?
Archaeoceratops oshimai	0	0	0	0	1	1	1	1	1	0	0	1	1	1	0	1	?	1	3	1
Bugenasaura infernalis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Chaoyangosaurus youngi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Dryosauridae	1	1	0	1	1	1	1	0	?	0	0	1	0	1	1	1	0	1	3	1
Echinodon becklessi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Eocursor parvus	0	0	1	0	0	1	1	0	?	0	0	1	0	0	0	1	0	0	2	0
Euparkeria capensis	0	0	0	0	0	0	0	0	?	0	0	0	?	?	?	0	0	0	0	?
Fruitadens haagarorum	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	0	2	1
Gasparinisaura cincosaltensis	0	0	0	1	1	1	1	0	?	0	0	1	1	1	1	1	0	1	3	1
Goyocephale lattimorei	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Herrerasaurus ischigualastensis	1	0	0	0	0	0	0	0	?	0	0	0	?	?	?	0	0	0	1	0
Heterodontosaurus tucki	0	0	0	0	?	1	1	0	?	0	0	1	0	0	0	1	0	0	2	1
Hexinlusaurus multidens	0	0	0	1	1	1	1	0	?	0	0	1	1	1	1	1	0	0	2	0
Homalocephale calathocercos	0	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	0	1	3	1
Hypsilophodon foxii	0	0	0	1	1	1	1	0	?	0	0	1	1	1	1	1	0	1	3	1
Jeholosaurus shangyuanensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	1	3	1
Lesothosaurus diagnosticus	0	0	1	0	0	1	1	0	?	0	0	1	0	0	0	1	0	0	2	0
Liaoceratops yanzigouensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	0	0	0	0	0	0	0	0	?	0	0	0	?	?	?	0	0	0	1	0
Micropachycephalosaurus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	1	3	1
NHM RU A100	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Orodromeus makelai	0	0	0	1	1	1	1	0	?	0	0	1	1	1	1	1	0	1	3	1
Othnieliosaurus consors	0	0	0	1	1	1	1	0	?	0	0	1	1	1	1	1	0	1	3	1
Pachycephalosauridae	0	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	0	1	3	1
Parksosaurus warreni	0	0	0	1	1	1	1	?	?	0	0	1	1	1	1	1	0	1	3	1
Pisanosaurus mertii	?	?	?	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?	?	?
Psittacosauridae	0	0	0	0	1	1	1	1	1	0	0	1	1	1	0	1	0	1	3	1
Rhabdodontidae	1	0	0	0	1	?	?	?	?	?	?	?	?	?	?	?	1	1	3	1
Scelidosaurus harrisonii	0	0	0	0	1	1	1	0	?	0	1	1	0	0	0	1	0	0	2	0
Scutellosaurus lawleri	0	0	0	0	0	1	1	0	?	0	0	1	0	?	?	1	0	0	2	0
Stegosauria	0	2	0	0	1	1	1	0	?	0	A	1	0	1	0	1	1	0	?	?
Stenopelix valdensis	0	0	0	0	1	1	?	?	?	0	0	1	1	1	A	1	0	1	C	1
Stormbergia dangershoeki	0	0	A	1	1	1	1	0	?	0	0	1	0	0	0	1	0	0	2	0
Talenkauen santacrucensis	?	?	?	?	?	1	1	?	?	0	0	1	0	1	1	1	?	1	3	1
Tenontosaurus dossi	0	1	0	1	1	1	1	0	?	0	0	1	0	1	1	1	?	1	3	1
Tenontosaurus tilleti	0	1	0	1	1	1	1	1	0	0	0	1	0	1	1	1	1	1	3	1
Thescelosaurus neglectus	0	0	0	1	1	1	1	0	?	0	0	1	1	1	1	1	0	1	3	1
Tianyulong confuciusi	0	0	1	0	?	1	1	1	0	?	?	?	?	?	?	1	0	?	?	?
TMM 43663-1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	0	2	0
TMM 43664-1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Coronosauria + Leptoceratopsidae	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0	1	0	1	3	1
Wannanosaurus yansiensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?	?	?
Yandusaurus hongheensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Yinlong downsi	0	?	?	?	?	1	1	1	0	0	0	1	?	1	0	1	0	?	2	1
Zephyrosaurus schaffi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
Abrictosaurus consors	2	0	0	?	?	1	?	?	?	0	1	0	1	1	0	?	?	?	0	0
Agilisaurus louderbacki	2	0	0	0	0	1	1	1	0	0	1	0	1	1	0	1	0	0	0	0
Anabisetia saldiviai	2	0	1	0	1	1	1	1	?	0	1	?	1	1	0	1	?	0	0	0
Ankylopollexia	2	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	0	2	0	0
Ankylosauria	0	1	0	0	0	1	1	1	?	1	2	1	1	1	1	1	0	0	1	1
Archaeoceratops oshimai	?	?	?	?	?	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0
Bugenasaura infernalis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Chaoyangosaurus youngi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Dryosauridae	2	0	1	1	1	1	1	1	1	0	2	0	1	1	0	1	0	0	0	0
Echinodon becklessi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Emausaurus ernstii	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0	?	?	?	1	1
Eocursor parvus	2	0	0	0	0	1	?	?	?	0	?	?	?	?	?	1	?	?	0	0
Euparkeria capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	?	1	?
Fruitadens haagarorum	2	0	0	0	0	1	1	1	?	?	?	?	?	?	?	?	?	?	?	?
Gasparinisaura cincosaltensis	2	0	0	0	0	1	1	1	1	0	2	0	1	1	0	1	1	0	0	0
Goyocephale lattimorei	?	?	?	?	?	1	?	?	1	?	?	?	?	?	0	1	1	1	0	0
Herrerasaurus ischigualastensis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	?	0	0
Heterodontosaurus tucki	2	0	0	0	0	1	?	?	0	0	1	0	1	1	0	1	0	0	0	0
Hexinlusaurus multidens	2	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	0	0	0
Homalocephale calathocercos	1	0	?	0	?	1	1	?	1	0	?	?	?	?	?	1	1	1	0	0
Hypsilophodon foxii	2	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	1	0	0	0
Jeholosaurus shangyuanensis	2	0	0	0	0	1	1	1	1	0	1	0	1	1	0	?	?	?	0	0
Lesothosaurus diagnosticus	2	0	0	0	0	1	1	1	0	0	1	?	1	1	0	1	0	0	0	0
Liaoceratops yanzigouensis	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Lycorhinus angustidens	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Marasuchus liloensis	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	?	0	?
Micropachycephalosaurus	?	0	?	?	?	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?
NHM RU A100	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Orodromeus makelai	2	0	0	0	A	1	1	1	1	0	0	0	1	1	0	1	?	0	0	0
Othnieliosaurus consors	2	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	?	0	0	0
Pachycephalosauridae	1	0	?	0	?	?	?	?	?	?	?	?	?	?	?	1	1	1	0	0
Parksosaurus warreni	2	1	0	0	?	1	?	?	?	0	0	0	1	1	0	1	1	0	0	0
Pisanosaurus mertii	?	?	?	?	?	0	?	0	?	0	?	?	?	?	0	?	?	?	0	0
Psittacosauridae	2	0	1	0	0	1	1	1	0	0	0	0	1	1	0	1	0	0	0	0
Rhabdodontidae	2	1	1	1	?	1	1	1	?	?	?	?	?	?	?	1	1	?	0	0
Scelidosaurus harrisonii	2	1	0	0	0	1	1	1	0	0	0	0	1	1	1	1	0	0	1	1
Scutellosaurus lawleri	2	0	0	0	0	1	1	1	?	0	?	?	?	?	0	1	?	?	1	1
Stegosauria	0	1	0	0	0	1	1	1	?	1	2	1	1	1	1	A	0	0	1	1
Stenopelix valdensis	?	?	?	?	?	1	?	?	?	0	0	0	1	1	0	1	0	0	0	0
Stormbergia dangershoeki	2	0	0	0	0	1	1	1	?	0	1	?	1	1	0	1	?	?	0	0
Talenkauen santacrucensis	2	?	?	?	?	1	1	1	?	0	0	0	?	1	0	1	?	0	0	0
Tenontosaurus dossi	2	1	1	1	1	1	1	1	?	0	0	0	1	1	0	1	1	0	0	0
Tenontosaurus tilleti	2	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	1	0	0	0
Thescelosaurus neglectus	2	1	0	0	0	1	1	1	1	0	0	0	1	1	0	1	1	0	0	0
Tianyulong confuciusi	?	?	1	0	0	1	?	?	?	0	1	?	?	?	0	1	1	0	0	0
TMM 43663-1	2	0	0	0	0	1	?	?	?	0	?	?	?	?	0	?	?	?	1	1
TMM 43664-1	?	?	?	?	?	?	1	?	?	?	?	?	?	?	0	?	?	?	1	1
Coronosauria + Leptoceratopsidae	2	0	1	0	0	1	1	1	1	0	0	0	1	1	A	1	0	0	0	0
Wannanosaurus yansiensis	1	0	?	0	?	1	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Yandusaurus hongheensis	?	?	0	0	0	?	?	?	?	?	?	?	?	?	0	?	?	?	?	?
Yinlong downsi	2	0	?	?	?	?	?	?	?	?	?	?	?	?	0	?	?	?	0	0
Zephyrosaurus schaffi	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

	221	222	223	224	225	226	227
Abrictosaurus consors	0	1	?	1	1	?	?
Agilisaurus louderbacki	0	1	0	0	0	0	1
Anabisetia saldiviai	0	?	0	0	?	0	?
Ankylopollexia	0	1	0	0	0	0	1
Ankylosauria	1	A	0	?	0	?	1
Archaeoceratops oshimai	0	1	?	?	?	0	?
Bugenasaura infernalis	?	?	?	?	?	?	?
Chaoyangosaurus youngi	?	1	?	?	?	?	?
Dryosauridae	0	1	0	0	0	0	1
Echinodon becklessi	?	?	?	?	?	?	?
Emausaurus ernstii	?	0	?	?	?	?	?
Eocursor parvus	0	0	0	0	0	?	1
Euparkeria capensis	0	0	0	?	0	0	0
Fruitadens haagarorum	?	0	1	1	1	1	0
Gasparinisaura cincosaltensis	0	?	0	0	0	0	1
Goyocephale lattimorei	0	1	0	?	?	?	?
Herrerasaurus ischigualastensis	0	0	1	?	0	0	0
Heterodontosaurus tucki	0	1	1	1	1	1	0
Hexinlusaurus multidens	0	0	0	0	0	0	1
Homalocephale calathocercos	0	1	?	0	1	0	?
Hypsilophodon foxii	0	1	0	0	0	0	1
Jeholosaurus shangyuanensis	0	?	?	0	0	0	1
Lesothosaurus diagnosticus	0	1	0	0	0	0	1
Liaoceratops yanzigouensis	?	1	?	?	?	?	?
Lycorhinus angustidens	?	1	?	?	?	?	?
Marasuchus liloensis	0	0	0	?	0	0	0
Micropachycephalosaurus	?	0	?	0	?	?	?
NHM RU A100	?	1	?	?	?	?	?
Orodromeus makelai	0	1	0	0	0	1	?
Othnieliosaurus consors	0	?	0	0	0	0	1
Pachycephalosauridae	0	1	0	0	1	?	1
Parksosaurus warreni	0	1	?	0	0	0	1
Pisanosaurus mertii	0	1	?	?	0	0	0
Psittacosauridae	0	1	0	0	0	0	1
Rhabdodontidae	0	1	0	0	0	0	1
Scelidosaurus harrisonii	1	1	0	0	0	0	1
Scutellosaurus lawleri	0	0	0	0	0	0	1
Stegosauria	0	0	0	?	0	0	1
Stenopelix valdensis	0	?	?	?	0	0	1
Stormbergia dangershoeki	0	?	?	0	0	0	1
Talenkauen santacrucensis	0	?	?	0	0	?	?
Tenontosaurus dossi	0	1	0	0	0	0	1
Tenontosaurus tilleti	0	1	0	0	0	0	1
Thescelosaurus neglectus	0	1	0	0	0	0	1
Tianyulong confuciusi	0	0	?	?	?	?	?
TMM 43663-1	0	0	0	0	0	0	?
TMM 43664-1	0	0	?	?	0	?	?
Coronosauria + Leptoceratopsidae	0	1	0	0	0	0	1
Wannanosaurus yansiensis	0	0	0	0	1	?	0
Yandusaurus hongheensis	?	1	0	?	?	?	?
Yinlong downsi	0	?	?	0	?	?	?
Zephyrosaurus schaffi	?	1	?	?	?	?	?

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Vita

Benjamin Thomas Breeden III was born in Baltimore, Maryland in 1988. He graduated from Century High School in Eldersburg, Maryland in 2006. After briefly attending Carroll Community College in Westminster, Maryland as a percussion performance major, he transferred to the University of Maryland, College Park in 2008 to study geology. Benn received his B.S. in Geology in 2011, graduating with high honors. As an undergraduate, he held several internship and studentship positions through the Department of Paleobiology at the Smithsonian National Museum of Natural History in Washington, DC. During this period, he also worked as an undergraduate researcher in the Stable Isotope Laboratory in the Department of Geology at the University of Maryland. Upon graduating, he continued to work in the Stable Isotope Laboratory as a research assistant in the Paleoclimate CoLaboratory until 2013. Benn matriculated at The University of Texas at Austin as a graduate student in the Jackson School of Geosciences in the autumn of 2013. In August 2015, Benn became a PhD student in the Department of Geology & Geophysics at the University of Utah, studying terrestrial biological and geochemical changes across the Triassic-Jurassic boundary on the Colorado Plateau. Benn remains an avid percussionist.

bennbreeden29@gmail.com

This thesis was typed by Benjamin Thomas Breeden III