Sauropoda from the Kelameili Region of the Junggar Basin, Xinjiang Autonomous Region

Zhiming Dong
(*Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica*)

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Translated by Will Downs
Department of Geology
Bilby Research Center
Northern Arizona University
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Abstract

This is a short report describing sauropod material collected from the Kelameili region of the Junggar Basin in 1983 by the Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica, Xinjiang Paleontological Research Team. Specimens were recovered from the Middle to Late Jurassic Wucaiwan and Shishugou fms. and are identified as *Bellusaurus sui* gen. et sp. nov. and *Tienshanosaurus* sp.

Introduction

In 1983 the Xinjiang Paleontological Expedition from the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Academia Sinica, conducted research at the southern foot of the Kelameili Mountains in the northeastern border of the Junggar Basin at north latitude 45°6' and east longitude 89°5', where a collection of dinosaurs were recovered from Jurassic sediments. A discussion of the regional stratigraphy relating to the fossil localities has been conducted by Zhao (1980). This text is a report on the Sauropoda collected from the region.

I. Sauropoda from the Dinosaur Valley Quarry (Locality 83003).

In 1954 a vertebrate locality was discovered by a Kelameili regional petroleum exploration team of the Xinjiang Petroleum Administrative Office who named the fossiliferous region "Dinosaur Valley." Later, in the early 1960s, the Regional Museum of the Uygur Autonomous Region collected an incomplete skeleton that was regrettably lost later due to the ten years of political turmoil in China. The current research was conducted under the guidance of colleague Xiling Peng from the Xinjiang Petroleum Office in the northern Xinjiang oil fields who led the team to the productive localities in Dinosaur Valley, where systematic excavations were made at locality 83003 for over one month.

Quarry 83003 principally produces sauropod dinosaurs. Approximately 17 individuals were collected although none was complete, and adequate cranial material was minimal, which caused a difficulty in the diagnosis. The size and morphology of the specimens indicate that the assemblage consists of a group of conspecific small and/or possibly juvenile sauropods that are equivalent in both size and age. The teeth are spoon shaped, allowing their assignment to the family Bothrosauropodoidea and approaching the subfamily Euhelopodinae. On the principle that the distance between species is reflected in morphological differentiation, and relatively tighter morphological similarity reflects a closer relationship, a skeleton was reconstructed from the material collected at quarry 83003 based upon euhelopodine characters including cranial morphology, vertebral count, and others.[*] This text is a description of two reconstructed skeletons designated as a type IVPP V8299 and referred specimen V8300.

[*] This reconstruction is housed in the exhibit gallery of the Xinjiang Mineral Resource Office.

II. Description.

Saurischia
Sauropoda
Bothrosauropodoidea
Brachiosauridae
Bellursaurinae Subfam.nov.

Diagnosis: As for genus.

***Bellusaurus* Gen. nov.**

Diagnosis: As for species.

***Bellusaurus sui* sp. nov.**

(Plate VI, Fig. 5)

Etymology: "Bellus" is of Latin derivation indicating small, delicate, and beautiful. As the sauropods from Dinosaur Valley, Kelameili region, are small and lightly built, they are erected as *Bellusaurus*. Species nomenclature is erected in honor of Senior Preparator Youling Sui, one of the premier restorers of dinosaurs. *Bellusaurus* is the last restoration undertaken by Mr. Sui.

Diagnosis: Small in size, spoon-shaped teeth, gracile body structure, height of skull moderate, neck slightly longer than body, and longest cervical vertebra is 1.5 times longer than the dorsals.

Cervical vertebrae are opisthocoelous with robust centra, well-developed pleurocoels, and planar ventral surfaces that lack ventral keels. Neural arches and spines are low; neural spines are vertical plates and appear “pseudospinus.” Cervical spines are unbifid. Dorsal vertebrae are also opisthocoelous with solid centra. Degree of prezygapophyseal development is standard, pleurocoels are well developed, neural arches and spines are equivalent in height, and spines are unbifid. Sacrum is composed of four vertebrae with the anterior three sacral neural arches and spines fused. The fourth neural arch and spine is disassociated. A sacricostal lobe is absent. Anterior caudals are procoelus. First caudal displays fan-shaped diapophyses. Central caudals are amphicoelous with flattened, club-shaped neural spines. Posterior caudals are gently amphicoelous; haemal arch structure is simple and unbifurcated.

Each element in the pectoral girdle is robust. The scapula is long and thin, the coracoid is subrounded, and the sternum is quadrate. Anterior limbs are shorter than posterior limbs and all limb shafts are strongly elliptical. The pelvic girdle is typically sauropodomorph. The ischial body is high, the pubic process is well developed, such that pubic fusion is in opposition and less “apron” like than more primitive forms.

Locality and age: Dinosaur Valley, Kelameili, Junggar Basin. Middle to Late Jurassic Wucaiwan Fm.

Specimens: Type (IVPP V8299) includes fragmentary cranial elements and teeth. Referred specimen (V8300) consists of a composite skeleton, minimal cranial elements and a portion of caudal vertebrae.

Description: Four cranial elements are preserved: the supraoccipital, a complete right exoccipital, a basisphenoid and a partial right maxilla. It is not possible to conduct cranial reconstruction on the basis of these few pieces. The size of the supraoccipital is comparable to that on *Shunosaurus*, and hence a 17.8 cm skull length is estimated for *Bellusaurus*, a figure compatible with the length of the three cervical vertebrae.

The central occipital region of the supraoccipital is the largest cranial element collected. It is butterfly shaped with a swollen crest in the center of the sellae region. This morphology also resembles that of *Shunosaurus*. The winged region is shaped like butterfly wings with a dorsal margin that contacts the parietal; dorsolaterally there is a posterior convex arm that accommodates the squamosal, the ventrolateral margin contacts a projecting arm dorsal to the occipital, and the ventral margin is a round and smooth notch that forms the roof of the foramen magnum.

A deep pearl shaped fossa lies medially on the supraoccipital. The smooth and glossy medial wall represents the posterior wall of the braincase. A tuberosity is present on each side at the winged region to facilitate articulation with the exoccipital.

The exoccipital (Fig. 2B, Pl. IV, Fig. 1) is situated at the ventrolateral region of the occiput to form the lateral walls of the foramen magnum. This triradiate-shaped element is morphologically similar to the *Camarasaurus* exoccipital illustrated by Ostrom (1966, Pl. III A). The largest lateral angle is represented by the paroccipital process. Within the Sauropoda the paroccipital process is generally rather small. This element is laterally flattened with a rounded flattened terminus. The anterolateral side of this terminus articulates with the posterior margin of the quadrate. The dorsal angular process of this element is irregular, broadened transversely, and fuses with the supraoccipital. The ventral sides of the angular processes fuse with the basioccipital to form the lateral walls of the foramen magnum. Two small foramina lie ventrally by the suture line with the paroccipital process. The anterior foramen may represent cranial nerve X while the posterior may represent cranial nerves XI-XII. Berman and McIntosh (1978) described the skull of *Diplodocus* in which they suggested cranial nerves IX-XI and the fenestra ovalis were confluent and lay within the "original opisthotic, which was bounded by the exoccipital posteriorly and the proötic anteriorly." Ventral to these foramina are two openings for cranial nerve XII. On the exoccipital of *Bellusaurus* only two foramina are recognized that may represent cranial nerve XII.

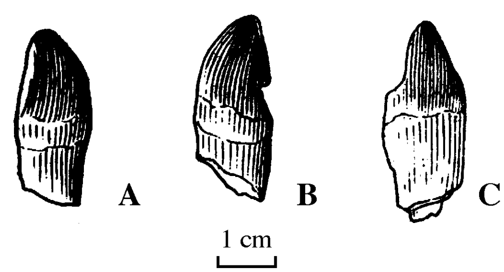


Figure 1. Teeth of *Bellusaurus sui* gen. et sp. nov.
A. Lingual; B. Lateral; C. Worn tooth.

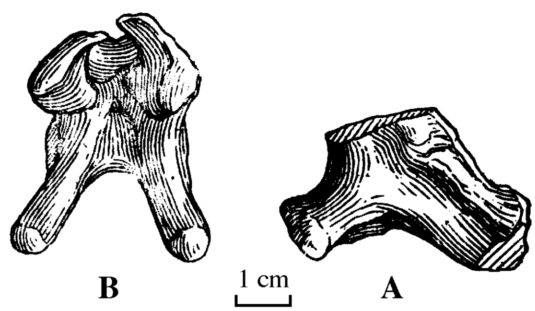


Figure 2. *Bellusaurus sui* gen. et sp. nov.
A. Basisphenoid; B. Exoccipital

The basisphenoid fuses with the basioccipital to form the base of the cranium. It bifurcates in accordance with the pterygoid processes, which appear to be derived from the sphenoidal foot, extending ventrally to compose basipterygoid processes. The body of this element is rectangular. At the anterior margin there is a thin bony ridge, the parasphenoid, but on this specimen the parasphenoid has been broken and is only preserved as a remnant fragment. On the dorsal margin of this element there is a semicircular and deep concavity, the medial wall of which is flat and smooth. This constitutes the anterior component of the braincase. At the posterior margin of the basisphenoid are two robust tuberosities to facilitate the articulation with the anterior processes of the basioccipital. The anterior margins of the angularly shaped basipterygoid processes are sharp while their posterior margins are rounded such that in cross-section they are nearly triangular. The ventral ends are flattened to form an articular surface for the dorsal pterygoid flanges.

A portion of a right maxilla 3.5 cm long and containing seven teeth is preserved. Three of the teeth lack crowns due to occlusal wear, while the remaining four consist of newly erupted tooth crowns. It is difficult to estimate the total length of the maxilla, but data derived from the Euhelopodinae indicate that the tooth count may reach 15-16. Minimally, *Bellusaurus* should possess 10 teeth with an estimated length of approximately 8.5 cm.

A broken remnant that lies on the dorsal margin of the maxilla represents an ascending branch or the nasal lamina, such that the anterolateral side defines the external nares and its posterior margin is the preorbital fossa. Based upon the configuration of the remnant branch on the maxilla, it is inferred that the external nares of *Bellusaurus* were positioned anteriorly, unlike the posteriorly positioned nares of *Diplodocus* and *Brachiosaurus* and more similar to *Shunosaurus* and *Omeisaurus*.

Dentition: In addition to the seven teeth contained in the maxilla are six isolated teeth which are all basically similar morphologically. The maxillary dentition is aligned in tight proximity. A thin layer of purple enamel caps the tooth crown. Individual teeth maintain a shallow spoon-shaped surface lingually with a small swollen medial ridge. The inception of this ridge lies at the base of the convex surface and extends to the tooth's apex. The apex is slightly recurved posteriorly. At the anterior margin there are small enamel tuberosities that are quite unlike the sharper denticles of a theropod dentition. The tooth crown is expanded at the base, contracts at its midpoint, tapers to a point, and begins to recurve posteriorly. Morphological development is asymmetrical. The labial surface of the crown is uniformly convex. Tooth morphology is simple, resembling that of *Pleurocoelus*. Most sauropods display a lingually recurved dentition. Rich and Molnar (1983) applied the computational method of Osborn and Mook (1921) to determine a curvature rate that ranges between 55 and15°. On *Bellusaurus* this curvature is approximately 13°.

No articulated vertebral columns were recovered from excavation site 83003, with the exception of five cervicals. Hence, it is difficult to determine the dorsal vertebral count. The cervical vertebrae of *Bellusaurus* resembles those of *Pleurocoelus.* Compared to those found in Asia, they approach *Datousaurus* in the subfamily Euhelopodinae, which is a Middle Jurassic taxon that displays relatively autopomorphic characters such as relatively long cervical vertebrae that may number 14-16. Consequently, during the time of skeletal reconstruction, careful consideration was given to the morphology and the geologic age such that the vertebral column was reconstructed with 13 cervicals, 13 dorsals, 4 sacrals, and 50 ± 3 caudals. Confirmation of this hypothetical vertebral formula must await the recovery of more complete material.

Two distinct morphotypes of cervical vertebrae may be recognized. Anterior cervicals have short centra that increase in length, with low neural arches and spines that increase in height, and shallow pleurocoels that gradually increase in depth and length. Posterior cervical centra, on the contrary, gradually decrease in length, increase in height, and possess neural arches and spines that systematically and gradually increase in height. The vertically oriented plate-shaped neural spine begins to transform into a transversely broadened form. This type of cervical morphological transformation is clearly expressed in the genera *Datousaurus, Mamenchisaurus, Omeisaurus,* and *Camarasaurus.* During the reconstruction process of *Bellusaurus* the cervical vertebrae were aligned in this relatively standard order based upon their morphological variation.

At excavation site 83003, 57 cervical vertebrae were recovered, but a representative atlas was absent. A complete axis, however, was recovered. Descriptions of additional cervical vertebrae that generally conform to two morphotypes will be given later in the text. Cervical vertebrae III, VIII, and XIII of *Bellusaurus* have been selected for description and illustration.

The features of the axis are basically complete (Fig. 3, Plate I, Fig. 1). The centrum is shallowly opisthocoelous, anterior zygopophyses are flattened, and there is a corroded remnant of an odontoid process. Pleurocoels are deep, long, square in shape, and lack a median septum.

From the lateral aspect the body of the centrum is rectangular. Ventrally there is a distinct but extremely weak medial keel. Two lateral marginal laminae are conspicuous. The posterior centrum is slightly broader than the anterior end. The postzygopophyses are concave and rounded to form a hemispherical shape. Anteroventrally and anterior to the pleurocoels lie flat, lozenge-shaped articular surfaces that constitute the parapophyses.

The neural arch is low. On each side of the arch anterodorsally is a small elliptical node that forms a small process. These two nodes are the prezygopophyses facilitating articulation with the atlas neural arch. On each side posteroventral to the prezygopophysis is a small mastoid-shaped process that extends ventrolaterally. These are the diapophyses that are each weakly derived from two laminae: the infraprodiapophysial lamina and the anterodiapophysial lamina. These two supporting laminal ridges increase in length and ascend with the diapophyses along the vertebral column, which is standard morphological development, and this, accordingly, allows an accurate estimation when determining the positions of cervical vertebrae.

The neural spine resembles those on *Datousaurus* and *Omeisaurus,* which are formed as a vertical ridge that gradually increases in breadth posteriorly. At the posterior end it bifurcates into two posterolateral angularly shaped processes. Two elliptically shaped nodes are present as articular surfaces that lie at the ventrolateral surface of these processes. These two processes intersect anteriorly at the posterodorsal end of the dorsal spine. Ventral to their intersection is a deep triangular depression identified as the postspinal cavity. This cavity varies in morphology along the cervical vertebrae by increasing in height, gradually becoming shallower, and finally becoming lost.

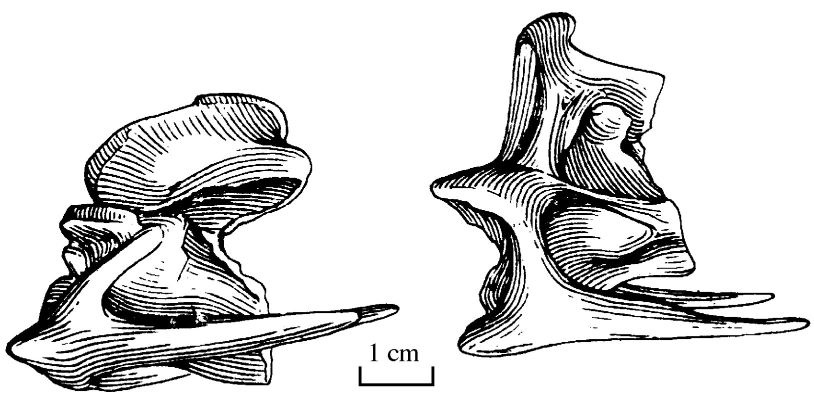


Figure 3. (A.) Axis and (B.) cervical vertebra III of *Bellusaurus sui* gen. et sp. nov.

Cervical vertebra III (Fig. 3, and Pl. I, Fig. 2) is opisthocoelous. Anterior processes are more well developed than on the axis. The well-developed prezygopophyses are hemispherical in shape. A circular lamina lies between the anterior processes and the vertebral centrum, a character that is rather similar to and relatively conspicuous on the genus *Pleurocoelus (Astrodon).* Pleurocoels are well developed; a medial septum is placed obliquely to divide each pleurocoel into anterior and posterior fossae, the anterior being relatively small and shallow and the posterior large and deep. These characteristic pleurocoels appear to be regular features on the posterior cervicals as well. Along the cervical column they increase in length and depth and accordingly the septum's angle of obliquity, and relative position, change with the increase in length. On both *Camarasaurus* and *Mamenchisaurus* the cervical pleurocoels frequently contain two or three oblique septa to form multiple secondary pleurocoels. Pleurocoel development is recognized as a derived character. *Bellusaurus* generally maintains two subvertical pleurocoels up to cervical XI. Posterior to this there is only a single deep pleurocoel per side.

The ventral side of the third cervical centrum is flat and has lost the median keel. A circular lamina, or ridge, lies between the centrum and the prezygopophyses, clearly demarcating the two.

At each lateral margin of the circular lamina lies a large flattened node or parapophysis that extends ventrolaterally.

The neural arch is low with horn-like prezygopophyses extending anterodorsally, and elliptically shaped articular surfaces lying anterodorsally. Dorsal laminae run from the base of the zygopophyseal articular surfaces posterior to the neural arch where they intersect at the anterior margin of the neural spine, the base of which is then formed into a triangular depression, or anterospinal cavity. This cavity becomes higher and shallower along the cervical column and is finally lost at cervical X. At the lateral sides of the neural spine are shallow and elongate depressions that lie on the dorsal sides of the diapophyses. These are the supradiapophysis cavities, which ascend and gradually migrate posteriorly along the vertebral column. Postzygopophyses are similar to those on the axis except for a shallow depression posterior to the diapophyses and anterior to the postzygopophyses which constitutes the postdiapophysis cavity.

The diapophyses are each supported by three laminae, the anterior two of which are similar to those on the axis. The first extend from the ventral prezygopophyses posteriorly to form the anteroventral margin, or laminae, of the diapophyses. The second initiate anterior to the postzygopophyses and ventral to the postdiapophysis cavity, where they extend from the base of the neural arch to support the posteroventral sides of the diapophyses. These are referred to as the infradiapophysial laminae. The third constitute the postdiapophysial laminae, which originate anterior to the posterior margins of the postzygopophyses and extend to the posterior margin of the diapophyses, but these laminae are still not very conspicuous on cervical III. The positions of these three laminae vary along the cervical column, as do their degree of development. The degree of laminae development also differs between sauropod taxa. The developmental sequence may be traced easily from primitive morphotypes to derived genera. These features are also significant characters for determination of a taxon’s geologic age.

The neural spine of cervical III differs from that of the axis. It is a low vertical plate with a wide dorsal surface that has migrated to the center of the vertebral body. The basal anterior margin is the anterospinal cavity, while the basal posterior margin is the postspinal cavity. Both sides of the neural spine’s posterior margin are supported by dorsal laminae from the postzygopophyses. These two laminae increase in height and become more vertical in succession along the vertebral column.

Cervical vertebra VIII is the longest in the column, but apart from its size, its morphology is similar to that of cervical III. The parapophyses ascend highly; there is a pleurocoel posterior with a nearly perpendicular septum within it. The sizes of the two sub-pleurocoels are nearly equivalent, and they nearly penetrate the centrum medially with only a thin osseous septum separating them.

The neural arch has become tall. The pre- and postzygopophyses lie nearly on the same plane and are morphologically similar to cervical III. The neural spine has become tall, but its length has become shortened. Two dorsal laminae on the prezygopophyses extend to the anterolateral margin of the dorsal spine. The apex of the dorsal spine has become slightly inflated, and at its anterior face there is a tuberosity.

Cervical vertebra XIII displays a shortened and heightened opisthocoelous centrum with a deep and circular posterior sulcus, and a shortened medial section. Well-developed crescentic anterior processes are present; pleurocoels are well developed and extremely deep but the oblique septum is nearly lost. The anterior pleurocoel is deeper than the posterior pleurocoel. A well-developed but extremely weak median keel is present on the ventral side of the centrum. Parapophyses lie anterior to the pleurocoels.

The most conspicuous character of cervical XIII is the morphological transformation of the neural arch and spine. The arch is heightened while the spine has been broadened. Diapophyses are triangular, extend horizontally like two butterfly wings, and are supported by three laminae. Prezygopophyses lie anteromedial to the diapophyses, each with an elliptical articular surface that is inclined medially. Postzygopophyses are raised and positioned posterolateral to the neural spine. The high and broadened neural spine causes the postspinal cavity to become enlarged. Both sides of the neural spine have incipient medial folding. On the dorsal vertebrae this folding causes the neural spine to become club shaped. Two dorsal laminae on the anterior articular surfaces become the lateral laminae of the neural spine. Because there is a lateromedial fold on the dorsal spine, a medial depression has begun to develop along the lateral lamina. The posterior articular surfaces are elliptical. At their ventral intersection is a triangular node that constitutes the hypophyses. The length of this shortened cervical approaches the length of the dorsal vertebrae.

The top of the cervical neural spine has become slightly convex with no traces of bifurcation. This character is present along the column posteriorly to the last cervical and anterior dorsal vertebrae. Spinal cavities are not very well developed, which indicates that *Bellusaurus* was a relatively agile sauropod.

Cervical ribs are short and trichocephalous, with a conical anterior process. The capitular and tubercular pedicels are nearly equivalent in size on the first few cervical vertebrae and ascend posteriorly following the diapophyses along the vertebral column. The capitulum and tuberculum also increase in length posteriorly as does the angle between the two. Distal ends of the cervical ribs are gracile and sharp. Among the Sauropoda these ribs frequently increase in length, particularly within the long-necked taxa such as *Mamenchisaurus*, where they may attain 2.5 m. In this case the posterior end of a cervical rib will frequently fuse to the anterior process of the next cervical rib behind it. *Bellusaurus* displays short and disassociated cervical ribs, expressing a similarity in style to the Theropoda and Prosauropoda, or being primitive in nature.

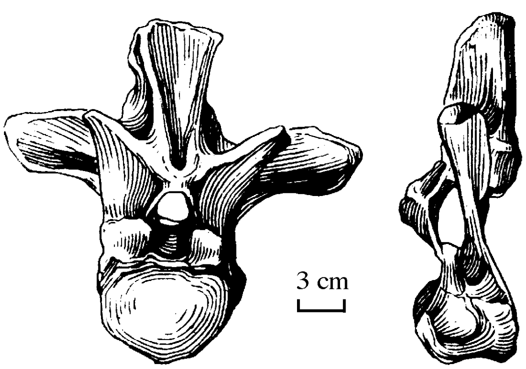


Figure 4. First dorsal vertebra of *Bellusaurus sui* gen. et sp. nov.

It is frequently difficult to distinguish between the morphology of cervical and dorsal vertebrae in their transition phase, and this is generally determined by whether or not the rib heads are trichocephalous. Additional indicators of dorsal vertebra I (Fig. 4) include the position of the parapophyses in addition to the position for the articulation with the scapular girdle. Dorsal vertebrae differ according to their position in the series. Similarly they may be discriminated into anterior and posterior morphologies: several anterior dorsal vertebrae still retain the cervical morphology with transversely broadened neural spines, planar extended diapophyses, anterior diapophyseal laminae, and posterodorsal laminae positioned nearly in the same plane. The neural spine is inclined posteriorly, there is a relatively deep posterior spinal cavity, and anterior and posterior zygopophyses are separated with obliquely inclined surfaces. The posterior dorsal vertebrae generally commence at number V or VI. The neural arches and spines become high and straight, the neural spine narrows transversely, the lateral face is reduced medially and is folded, the postzygopophyses have shifted posterior to the neural spine, both pair of zygopophyses become closer together, diapophyses become raised and triangular, the ventral diapophyseal laminae shift to the ventral surface, and the parapophyses shift to the base of the neural arch and ventral to the prezygopophyses.

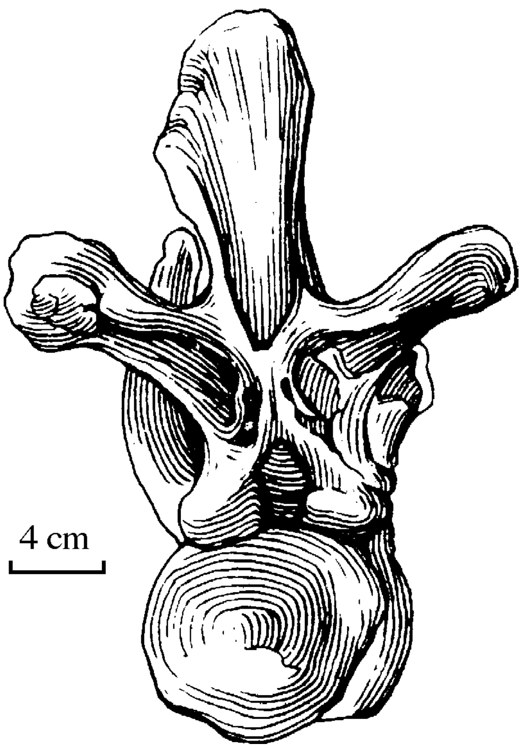


Figure 5. Dorsal vertebra XII of *Bellusaurus sui* gen. et sp. nov.

Dorsal vertebra I has an opisthocoelous centrum, nearly equivalent in length and height, a moderately developed anterior process, a shortened medial section, and well-developed pleurocoels that are long and elliptically shaped. The neural arch is high with a large neural canal; the neural spine is narrow and high with a flattened dorsal apex. The spine is not bifid. The diapophyses are well developed being both horizontal and laterally extended. The well-developed diapophyses are supported by three laminar ridges (Fig. 4). Prezygopophyses are straight but the articular faces are medially inclined. Zygopophyseal laminae extend dorsally and are composed of two lateral laminae that intersect and lead to the top of the neural spine. The anterospinal cavity is shallow and nearly lost. The intersection between the postzygopophyseal articular surfaces is a small, projected V-shaped ridge or hypophysis. Dorsal vertebra XII (Fig. 5, and Pl. I, Fig. 3) has a gently opisthocoelous centrum nearly equivalent in height and length with an undeveloped anterior process. Deep and rounded pleurocoels are dorsolaterally positioned. The entire centrum is slightly compressed, changing its contour into an ellipse.

The neural arch is high with a large and rounded neural canal. Prezygopophyses have come closer and intersect. The articular faces are inclined in opposition to form a single crescentically shaped articular fossa. Parapophyses are located ventral to the prezygopophyses and constitute wing-shaped, horn-like processes. Diapophyses are dorsolaterally extended. The trilaminae-supported diapophyses are trifacial, or triangular in cross-section. Postzygopophyses also intersect to form a V-shaped articular face. The neural spine is club-shaped and has become straight and high with a retracted anterior surface and a large swollen dorsal tuberosity. Laterally, a medial fold forms a perpendicular cavity. The postspinal cavity has become lost.

Dorsal ribs are simple in structure and dichocephalous. They ascend with the diapophyses along the vertebral column. The angle between the capitulum and tuberculum increases. The dorsal ribs of *Bellusaurus* differ from more derived sauropods in having relatively rounded distal ends which more closely approach prosauropods in morphology.

Not a single complete sacrum was collected from quarry 83003. Only two fused sacral vertebrae were recovered during excavation and preparation of specimens, in addition to six isolated sacral vertebrae, and a portion of fused sacral neural arches and spines. The sacral region of *Bellusaurus* is determined to be composed of four vertebrae, based upon the three aforementioned fused sacral neural spines and the number of medial rib tuberosities on the iliac blades (reconstruction of the sacrum is figured in Fig. 6 and Pl. II, Figs. 1, 2).

Sacral vertebrae are amphiplatyan with enlarged proximal and distal ends. Centra are slightly longer than high, lack pleurocoels, and ventrally display a thickly swollen keel. Four of these vertebrae are determined to be co-ossified based upon both articular surfaces. Sacral diapophyses and ribs are fused to form plank-shaped sacricostal lobes with expanded medial and lateral ends and twisted shafts. This morphology resembles both *Vulcanodon* and *Shunosaurus*.

The distal ends of these lobes are not mutually connected, such that they have still not formed into the yoke-like sacricostal structure that is so well developed on *Camarasaurus*, *Mamenchisaurus*, and *Omeisaurus* in the later periods.

Three fused neural spines are preserved and appear as a flattened plate. Dorsally there are distinct depressed clefts allowing the individual spines to be distinguished. Laterally there are six parallel vertical laminae, each nearly equivalent in size. The anterior sides of these laminae constitute prezygopophyseal dorsal laminae, while the posterior side extends to form the dorsal laminae of the postzygopophyses. Sacral spine IV is isolated and club shaped. This resembles the first caudal vertebra.

The caudal vertebral count is not clear, but the several genera within the characteristically Asian subfamily Euhelopodinae, such as *Euhelopus, Mamenchisaurus, Omeisaurus* and others all have shorter tails than their contemporaneous counterparts in North America such as *Camarasaurus* and *Apatosaurus*. 50 ± 3 caudals are estimated for *Bellusaurus*. Whether or not this count is accurate must await later verification.

Three morphotypes may be recognized among the caudal vertebrae: Proximal caudals are designated from 1 to13 with procoelus centra. Depth of the procoel cavity begins to gradually shallow from caudal II. Pleurocoels are absent, and there are remnants of club-shaped diapophyses. These diapophyses gradually diminish and become lost anteroposteriorly. Remnant caudal ribs are fan shaped and fused to the first four anterior centra. The caudal neural spine is club shaped. Medial caudals display platycoelous centra, lack pleurocoels, are constricted at their center with expanded anterior and posterior ends, and are nearly equivalent in height and length. Posteriorly the lengths of the centra increase and neural spines become plate shaped, lower, and inclined posteriorly with robust apexes. The distal caudals display long, gently platycoelous centra. Neural spines increase in length and are small, vertically directed, club-shaped projections that are inclined posteriorly.

More detailed descriptions and illustrations for each of the aforementioned sections are provided below:

Caudal vertebra I (Pl. I, Fig. 7) is gently procoelous with an elliptical centrum that is slightly higher than long, lacks pleurocoels, and is constricted medially. Diapophyses are present dorsally with remnant fused caudal ribs that extend from the base of the neural spine ventrally to the centrum. Neural spine is high and club shaped with a slightly swollen apex. Anteriorly there are laminar ridges.

Caudal vertebra XV is gently platycoelous with a centrum length that is slightly greater than its height. Two vertical laminae lie on each side and the medial section has become constricted. The structure of the centrum resembles prosauropods. The neural spine is thick and plate shaped, inclined posteriorly, and has a slightly swollen apex.

Caudal vertebra XLIII (Pl. IV, Fig. 10) is simple in structure with a gently platycoelous centrum that is longer than high. The neural spine has become altered to a vertical but posteriorly inclined position and appears like a small club-shaped spike.

Haemal arches were rare in quarry 83003. Those that were completely preserved have, like prosauropods, a simple structure. No bifurcated morphologies are noted.

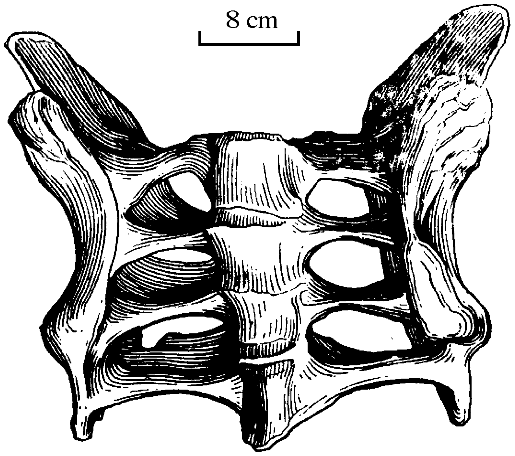


Figure 6. Sacral reconstruction of *Bellusaurus sui* gen. et sp. nov. (ventral view).

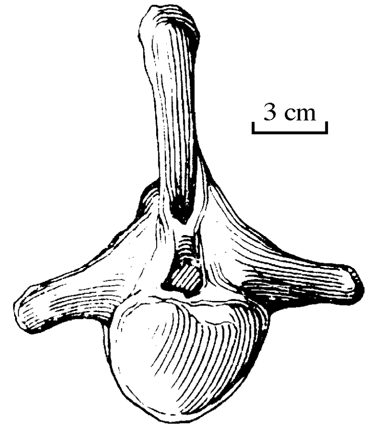


Figure 7. Second caudal vertebra of *Bellusaurus sui* gen. et sp. nov.

Pectoral girdle and anterior limbs.

Elements of the pectoral girdle are relatively numerous and preserved relatively completely. Morphologies are similar although there are size discrepancies. Clavicles, however, are absent. Described are the scapula, coracoid, and sternum.

Twenty-seven scapulae were collected; among them seventeen were from the left side and ten were from the right. It is from these data that the number of individuals represented in the quarry is determined to be seventeen. The type specimen is completely preserved with a length of 48 cm. This is nearly the length of the femur. This element is thick with a broadened and relatively thin distal blade that curves inward toward the body. The medial side is flat but is swollen laterally in the center. The anterior margin is thin. At the proximal end the element is expanded. Laterally there is a transversely directed elliptical depression that is posteriorly thickened to fuse with the coracoid and create the glenoid cavity. The superior margin, which fuses with the coracoid, is relatively straight. Compared to more derived sauropods in later periods, this scapula is relatively primitive, once again approaching the morphology of prosauropods (Fig. 8, and Pl. IV, Figs. 3, 4).

Five coracoids were collected; among them three are from the left side and relatively complete, while the remaining two are from the right side and damaged. This element is subrounded and plate-shaped, laterally convex and medially concave. The margins are thin with the dorsal margin that fuses with the scapula being relatively straight. At the ventromedial side (posterior margin) there is a thickened and deep depression that unites with the scapula to create a semicircular articular fossa, or the glenoid.

There is only a single thin and nearly square element, presumed to be a sternal plate, represented in the entire collection. Laterally it is slightly convex and medially gently concave. A thick articular surface lies dorsally. The four edges of the element are irregular. Romer (1956) presumed that the sternal margins were cartilaginous. The distal margin is slightly damaged but it is estimated that the length and breadth are rather equivalent.

Representing the anterior appendages are twenty-nine humeri, twelve radii, seven ulnae, a suspicious carpal, a number of metacarpals, and digits.

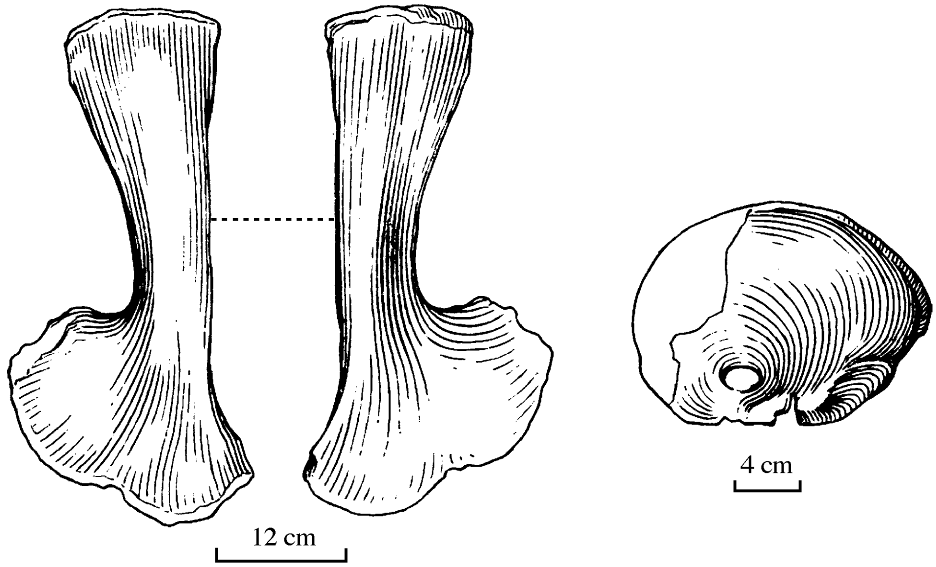


Figure 8. Scapula and coracoid of *Bellusaurus sui* gen. et sp. nov.

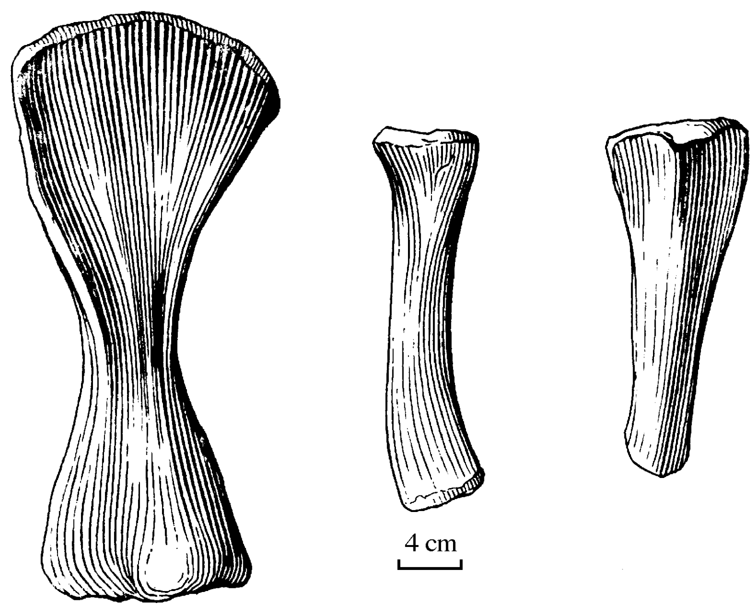


Figure 9. Humerus, radius, and ulna of *Bellusaurus sui* gen. et sp. nov.

The humerus (Fig. 9, and Pl. IV, Fig. 5) has a straight shaft that is subrounded in cross-section. Both ends are expanded. The proximal end is broad and thick with a triangular dorsal articular surface. The humeral head is robustly swollen. Laterally there is an expanded triangular ridge that curves dorsally to form the deltopectoral crest. Anteriorly there are two shallow depressions or fossae for the brachialis musculature. On the anconel side there is a swollen ridge that attenuates one-third down the shaft. Distally, there is a robust swelling between the ulnar (medial) and radial (lateral) condyles. A small ectepicondyle is present dorsolaterally and the trochlea is a glossy depression. Humeral length is 35.5 cm.

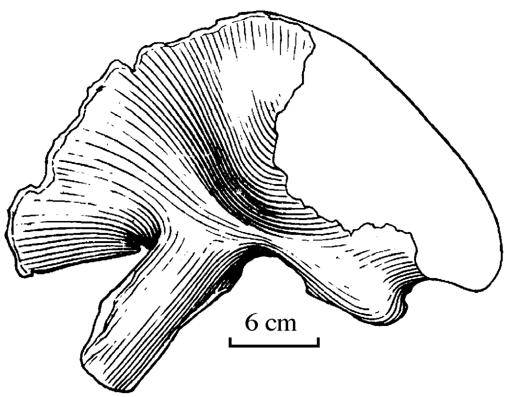
The ulna (Fig. 9, and Pl. IV, Fig. 6) is straight with a robustly swollen and triangular proximal end. A thickly swollen tuberosity is present on the articular surface. Three laminae from the proximal end extend distally to attenuate halfway down the shaft where it becomes circular. An olecranon process is not well developed. An inclined depression lies dorsomedially to accomodate the radius. The distal end is a slightly expanded articular surface. Its length is 27 cm.

The radius (Fig. 9, and Pl. IV, Fig. 7) is slightly shorter than the ulna with a length of 25.5 cm. It is relatively straight with expanded proximal and distal ends that are nearly equivalent in size. The shaft is strongly elliptical. The articular surfaces at both ends have a medial depression that form a cavity.

One strongly elliptical piece of bone appears to be a carpal. On *Shunosaurus* two of these elements are present with the medial carpal slightly smaller than the lateral, and both being irregular in morphology. The strongly elliptical piece from quarry 83003 is also irregular in morphology.

Pelvic girdle and posterior limbs.

Quarry 83003 produced five ilia, eleven ischia, and nine pubi. These three pieces of the pelvic girdle are clearly typical for the Sauropoda as they are long and platelike. Elements of the same type are nearly equivalent in size and morphology.



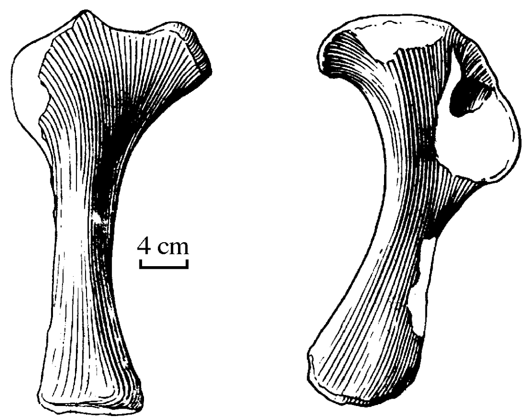


Figure 10. Ilium of *Bellusaurus sui* gen. et sp. nov.

Figure 11. Pubis and ischium of *Bellusaurus sui* gen. et sp. nov.

The ilium (Fig. 10, and Pl. 3, Fig. 2) is fan shaped with a well-developed anterior lobe that extends anterolaterally. A posterior process is not well developed. The lateral side of the fan-shaped iliac blade is slightly medially depressed. A well-developed pubic peduncle extends anteroventrally; however, it differs from those on *Camarasaurus, Omeisaurus,* and *Shunosaurus* by displaying an anterior side that is relatively flat instead of being convexly projected. Posteriorly (acetabular surface) it is slightly concave. The entire peduncle is plate shaped. An ischial process is undeveloped, and there remains only a long rounded node. Dorsal to the acetabulum there is a small swelling running along the acetabular margin and ascending to form a crest. On the medial side of the ilium are three nodes to facilitate the fusion with the sacricostal lobes. Between each node lies a vertical laminar septum.

The plate-shaped pubis (Fig. 11, and Pl. III, Fig. 3) resembles that on *Camarasaurus.* The anterolateral margin is thick, a lateral convex swelling is present, the posterior margin is thin, and the shaft is relatively broad. A long tuberosity is present on the proximal articular surface to facilitate the fusion with the pubic peduncle of the ilium. The pubic plate thins posteriorly and begins to curve laterally to become arc-like and form the anterolateral margin of the acetabulum. A large oblique and long obturator foramen lies posterolaterally and is open on several of the pubi, but on others with broken margins the obturator foramen appears to be enclosed (Pl. III, Fig. 3).

The distal end of the pubis is broadened with a medial thick swollen ridge that forms the pubic symphysis. This style of fusion in opposition, rather than a more apron like form, is characteristic of later sauropods.

The ischium (Fig. 11, and Pl. III, Fig. 4) is simple in structure and shorter than the pubis. This element is convex laterally but planar medially. The proximal end consists of a crescentically depressed margin that comprises two separate articular surfaces; the dorsal of these fuses with the ischial peduncle on the ilium while the ventral articular surface fuses with the pubic peduncle and forms the posterior wall of the acetabulum. The distal end of the ischium is not inflated. and medially there is an extremely rugged surface for fusion with the opposing ischium. Berman and McIntosh (1978) recognized two categories of ischial fusion: the *Diplodocus* style and the *Camarasaurus* style. *Bellusaurus* relates to the latter.

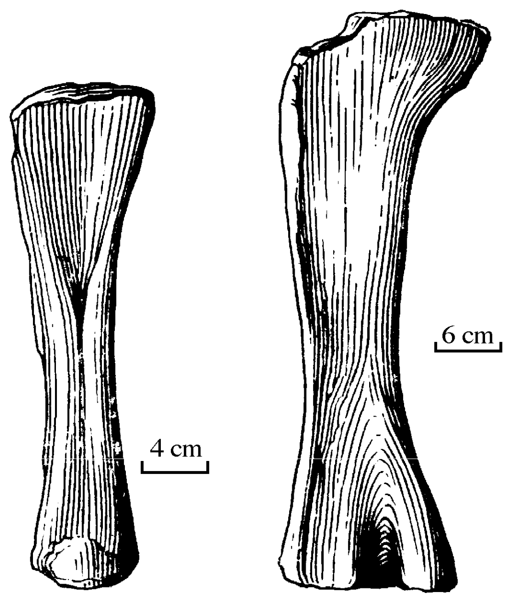


Figure 12. Femur and tibia of *Bellusaurus sui* gen. et sp. nov.

The size and morphology of all the femora collected (Fig. 12, and Pl. II, Figs. 3, 4) are basically consistent, being straight with a strongly elliptical shaft and a length of 55 cm. The femur head is semicircular, extends medially, but lacks a conspicuous neck. The fourth trochanter is situated on the middle of the shaft posteromedially as a robust 9-cm-long swelling. Medially this trochanter facilitates the caudifemoralis longus; laterally there is a shallow groove for the adductor. The distal end is inflated with the medial (tibial) condyle, subcircular in shape and larger than the lateral (fibial) condyle. A relatively deep intercondylar fossa lies between the two. On the lateral side of the lateral condyle lies a shallow vertical groove that separates this prominent condyle from a dorsal condyle. A vertically directed and deep troclea lies anterior between the lateral and medial condyles.

The tibia (Fig. 12, and Pl. III, Fig. 5) is straight and robust with a length of 39.5 cm. The proximal end is inflated in an elliptical shape with a central surficial cavity that articulates with the tibial condyle of the femur. The cnemial crest lies anterolaterally at the fibular surface, projects sharply forward, and attenuates one-third of the way down the shaft. On the medial side of this crest is a wide vertical depression with projected nodes on both sides that facilitate the abutment of the proximal concave end of the fibula. The inflated proximal end of the tibia gradually becomes gracile and straight ventrally to the distal end where it then secondarily becomes thickened. A deep cavity lies on the distal end for the articulation with the astragalus. A large crescentically shaped calcaneal process lies on the lateral side of the astragalar cavity, though a calcaneum has yet to be found associated with a sauropod. On later sauropods this process is exceptionally well developed.

The fibula (Pl. III, Fig. 6) is long with two inflated ends. The proximal end is slightly larger than the distal end. The bone is simple in structure and strongly elliptical in cross-section. It is slightly shorter than the tibia.

Only a single astragalus was recovered from quarry 83003. From a lateral aspect it is triangular; dorsally it appears asymmetrically conical. On the lateral side is a high swelling, but an ascending process is undeveloped. A shallow vertical depression lies at the tibial surface. A sharp process projects off the medial side. The morphology of the entire element is typical for sauropods.

III. Discussion and Diagnosis.

The size and morphological characters of the specimens derived from quarry 83003 undoubtedly express the conspecific nature of the assemblage, but the question arises whether these small sauropods represent juveniles or adults. As juveniles, if the morphological characters are not stable, this would affect their practical utilization for taxonomic assignment.

The sauropods in this quarry were subjected to hydraulic transportation prior to burial. A large portion of the material is abraded. Analysis of sedimentary characteristics suggests that the bones were deposited in a relatively tranquil flow. Water velocity could not have been excessive. The degeneration of these animals' corpses occurred after decomposition and prior to burial. Numerous skeletons were dispersed following individual degeneration, as represented by the scattering of cranial elements and the detachment of neural arches and spines from dorsal vertebral centra. This also suggests the light degree of osseous fusion. Juvenile characteristics of dinosaurs have been noted by Galton (1982), whose study would suggest that the group of small sauropods in quarry 83003 were juveniles that were subjected to a single catastrophic condition resulting in a mass death assemblage.

The class Reptilia undergoes variable and continuous lifelong growth. Several taxa display differential growth rates with a large proportional discrepancy between juveniles and adults. Consequently, at the time of taxonomic diagnosis careful consideration must be made upon character differences within the juvenile phase. Developmental stages of the Dinosauria, and particularly research upon juveniles, is extremely depauperate. Gilmore (1925) conducted a detailed description of a nearly complete juvenile *Camarasaurus* skeleton and suggested that there were no large morphological discrepancies between juveniles and adults. Galton (1982) conducted skeletal comparisons between stegosaur juveniles and adults and cited twelve character differences. These characters were principally expressed in the degree of skeletal fusion, suture fusion, and morphological development of long-bone articular surfaces. Mook (1921) and Cong, Zhou, and Zhang, (1983) conducted studies of extant crocodillians and suggested that within the process of ontogenetic development, the early stage (hatchling) displays a relatively large morphological discrepancy which later gradually diminishes. This is predominantly expressed in the differential growth of the skull, as the post-cranial skeleton does not differ greatly. Hence, diagnoses and taxonomic assignment of the sauropod data from quarry 83003 are made feasible by the practical application of presumably stable post-cranial characters.

In 1984, locality 84004 was discovered at an equivalent stratigraphic level but 200 km distant from locality 83003 within the Junggar Basin. This locality produced a small sauropod consisting of a femur, tibia, and four vertebrae from the Shisugou Fm. The morphology and size of this specimen are completely consistent with *Bellusaurus* from locality 83003 at Jiangjungebi. This discovery provides further evidence justifying the character stability of *Bellusaurus*, and further indicates the presence of a small adult sauropod species that lived gregariously in the Jurassic of the northeast Junggar Basin. *Bellusaurus sui* gen. et sp. nov. is reliably erected upon the basis of its post-cranial elements.

Sauropod phylogeny is based upon the structure of the skull, with two superfamilies based upon tooth morphology: the spoon-shaped Bothrosauropodidea and pencil-shaped Homosauropodidea. A majority of workers agrees with this convenient and practical principle of classification, despite the usage of several different familial ranking names utilized by others (Young, 1958; Romer, 1956; Steel, 1970).

The sauropods derived from locality 83003 possess spoon-shaped teeth, which reliably assign them to the Bothrosauropodidea. Steele (1970) recognizes three subfamilies within the Brachiosauridae: the Cetiosaurinae, Camarasaurinae, and Euhelopodinae.

The Cetiosaurinae are relatively primitive sauropods which display amphiplatyan vertebrae and undeveloped pleurocoels. This excludes *Bellusaurus* which possesses opisthocoelous cervical and dorsal vertebrae with well-developed pleurocoels.

The Camarasaurinae possess short cervical vertebrae with high bifid neural spines, and presacral vertebral centra with a honeycombed internal structure. This also excludes *Bellusaurus*.

The Euhelopodinae, erected by Romer in 1956, is represented by several Asian Late Jurassic and Early Cretaceous large sauropods: *Tienshanosaurus*, *Euhelopus*, *Omeisaurus*, and *Mamenchisaurus*. The most significant character of this subfamily is a long neck, with cervical vertebrae attaining 17-19 in number, being two and one-half times the length of the dorsal vertebrae, possessing low cervical neural spines which become bifid dorsally but not deeply concave, and presacral centra are internally honeycombed. The sauropods from locality 83003 are excluded from this family due to the large discrepancies of the latter characters, despite their similarity among characters such as relatively long cervicals and low cervical spines. Consequently, it is necessary to erect a new subfamily, the Bellusaurinae subfam. nov. Characters for this family include: relatively small size, spoon-shaped dentition, opisthocoelous presacral vertebrae, cervical centra one and one-half times the length of dorsals, low pseudospinus neural spines, unbifid cervical and dorsal spines, well-developed pleurocoels, and solidly constructed presacral vertebrae.

The author of this paper conducted observations on bothrosauropod material collected from the Early Cretaceous of Maryland in 1887 that was named by Marsh as *Pleurocoelus* (*Astrodon*). Juvenile individual USMN 4968 displays dentition and dorsal vertebrae extremely similar to *Bellusaurus*, only the teeth are slightly more robust, and cervical pleurocoels are oval and lack a medial septum. Consequently, it is believed here that the Bellusaurinae contain two genera: *Bellusaurus* and *Pleurocoelus*. These evolved independently and their relationship to sauropod evolution would require a much longer discussion, or a topic for a separate paper.

IV. Sauropods of the Wucaiwan Region.

In 1983, IVPP conducted exploration of the Wucaiwan region, in the western Kelameili Mountains of Xinjiang, and discovered a large sauropod in the central section of the Shishugou Fm. Initially the specimen was preserved relatively intact, but due to the long period of surficial exposure, became deeply weathered, such that by the time of discovery only four relatively well-preserved cervical vertebrae and seventeen articulated caudal vertebrae were collected. Cervical vertebrae indicate this specimen to be a massive individual with an estimated length of 14-15 m.

Description

Sauropoda
Bothrosauropodidea
Euhelopodinae
***Tienshanosaurus* sp.**

Diagnosis: Euhelopodid-style cervical vertebrae with long and opisthocoelous centra, ventrally flat and lacking keels, neural spines are low, or pseudospinus, large and long cervical ribs.

Age and locality: Early Late Jurassic Shishugou Fm., Wucaiwan, Kelameili, Junggar Basin.

Specimen: Four cervical vertebrae with attached ribs, and caudal region with seventeen articulated vertebrae associated with haemal arches. Specimen number IVPP V8301.

Description: A string of cervical vertebrae was exposed on the surface, allowing a sequential identification. However, due to a long period of erosional weathering, it was not possible to collect a complete specimen, and the four specimens that were recovered were damaged. These four cervicals are articulated with a length of 207 cm. The third in the series is the longest. These are inferred to be numbers seven through ten, or the longest in the cervical sequence. Centra are large and long, opisthocoelous, and ventrally relatively flat. Pleurocoels are well developed. Neural arches and spines are low with the low neural spine appearing pseudospinus. There is no indication that the dorsal spines were bifid. These characters align the specimen with the Euhelopodinae. Cervical ribs are trichocephalous and linked to each other proximally and distally. At both sides of the cervicals they comprise vertically long laminae.

Seventeen relatively well-preserved, articulated caudal vertebrae are present. The centra are amphiplatyan. Neural spines are plate-shaped and posteriorly obliquely inclined. These represent the central caudal region and resemble the general sauropod condition.

Diagnosis and Discussion.

Specimen V8301 displays cervical vertebrae typical of the Euhelopodinae, with spines similar to those on *Omeisaurus.* *Tienshanosaurus chitaiensis* is a well-known sauropod described from the Jurassic of the Junggar Basin (Young, 1937), although its precise locality is vague. C.C. Young's original description indicates that it should have been derived from Baigudui, north of Qitai. The specimen's mode of preservation and coloration is consistent with other specimens derived from the Shishugou Fm. When C.C. Young conducted research upon Chinese sauropods in 1958, he concluded that *Tienshanosaurus* was Late Jurassic in age, but north of Qitai the middle Late Jurassic Shishugou Fm. is exposed at two localities (Zhao, 1984): the first is 15 km north of Jiangjunmiao and the second is in the vicinity of the Shaqiuhe River, by Wucaiwan, at the foot of the Kelameili Mts. The current specimen V8301 was derived from the Shishugou Fm. near Wucaiwan and is comparable to the type specimen of *Tianshanosaurus* in being typically large. However, due to the scarcity of data, the current specimen is merely assigned to an indeterminate species of the same genus. More advanced diagnosis must await further discoveries of new data.

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