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NEW BRACHIOSAUR MATERIAL FROM THE LATE JURASSIC OF UTAH AND COLORADO

James A. Jensen

Abstract.—Little is known about the Brachiosauridae, which includes some of the largest known sauropods, such as the genus Brachiosaurus, discovered in western Colorado by Elmer S. Riggs in 1900. Additional diagnostic material, previously unknown in the western hemisphere, is reported from three comparatively recent quarries: the Jensen/Jensen Quarry in eastern Utah and the Dry Mesa and Potter Creek quarries on the Uncompahgre Upwarp in western Colorado. An unknown, well-preserved, articulated sauropod atlas/axis, seven cervical vertebras, and an interesting flora were associated with the Potter Creek Quarry brachiosaur material. Taphonomic factors in that quarry are noted. The Jensen/Jensen and Dry Mesa deposits occur in basal sediments of the Brushy Basin Member of the Morrison Formation, and the Potter Creek Quarry in an intermediate section of that member.

No complete, articulated skeleton of the sauropod genus Brachiosaurus has been reported from North America. However, an incomplete skeleton was collected in Colorado in 1901, and disarticulated bones of the genus have been found in at least four other localities. Elements described here, not previously reported from the western hemisphere, include a partial scapula, a distal cervical vertebra, a radius, a metacarpal, and a humerus. The radius, metacarpal, and humerus appear to represent a novel species but will not be described here as such.

In 1900 the type-species of the genus Brachiosaurus was collected by Elmer S. Riggs, of the Field Columbian Museum, Chicago, who discovered a partial skeleton of this remarkable sauropod near Grand Junction, Colorado. This skeleton possessed the previously unknown feature of front legs equal in length to the rear (Fig. 1), which elevated the base of the neck and thorax far above any spinal inclination previously reported in sauropods. Riggs (1903) appropriately named it Brachiosaurus altithorax. He recovered approximately 20 bones, including seven articulated presacral and two caudal vertebras, a sacrum and the right ilium, a left coracoid, right humerus, right femur (Fig. 1), and four ribs. The femur and humerus were greatly compressed, with the distal end of the latter being partially destroyed by surface erosion (Fig. 1). This material is now preserved in the Field Museum of Natural History, Chicago.

A decade later a second discovery of brachiosaur bones was collected by a German paleontologist, Janensch, in Tendaguru, Tanzania, formerly East Africa. He recovered a fairly complete skeleton that he named B. brancai (Janensch 1914); the restored skeleton is now mounted in the Museum für Naturkunde in East Berlin, East Germany. Subsequent work by British expeditions, and possibly other European institutions, recovered other brachiosaur materials from Tanzania, but for more than 50 years no additional brachiosaur remains were scientifically reported from the western hemisphere.

Circa 1943 a brachiosaur skeleton in an advanced state of erosion was discovered on the Uncompahgre Upwarp in western Colorado by the late Daniel E. Jones and his wife, Vivian, of Delta, Colorado. The humerus (Figs. 2B, 3A–D, 4B) was collected and donated to the U.S. National Museum in Washington, D.C., but was never described. The discovery site, approximately 70 km SSE of the Riggs locality, was named the Potter Creek Quarry. Its stratigraphic position is approximately in the middle of the Brushy Basin Member of the Morrison Formation. I worked there two seasons (1971, 1975), collecting five disarticulated elements of a large sauropod (? B. altithorax), bones of a second, smaller sauropod genus, and teeth of an unknown theropod. The brachiosaur elements collected include part of the discovery humerus (Figs. 3E, 5A–D, 6B), a medial
dorsal vertebra (Figs. 3D, 4A–A₃), an incomplete left ilium (Fig. 3A–A₃), and a left radius and metacarpal (Figs. 3B, 5E–E₁). Materials of the smaller, indeterminate sauropod include the broken fragments of an articulated vertebral series from the atlas/axis to the seventh cervical vertebra. This series was found intact but excavated in fragments by the Jones family and given to me. I was able to reassemble an articulated atlas/axis and third cervical
vertebra (Fig. 10A–E) from this broken material because of its excellent preservation. A detailed study of some of this material is in progress, but a preliminary examination reveals it to be from a mature sauropod. The elements noted here are much too short and small for any described brachiosaurid.

In 1960 I discovered a dinosaur bone deposit in basal Brushy Basin Member sediments of the Morrison Formation near
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Jensen, Utah. This deposit (the Jensen/Jensen Quarry) is located south of the Green River, a few miles from the Dinosaur National Monument Quarry. Two years' work (1962, 1966) in this quarry (Figs. 11, 13) produced several brachiosaur elements including a rib 2.75 m (9 ft) long (Fig. 6B), a distal cervical vertebra, the proximal half of a scapula, and a coracoid. Many worthless slivers and fragments of shattered brachiosaur cervical vertebrae were encountered. Because the coracoid associated with the scapula does not appear to match the coracoid of *B. altithorax*, the specific identity of the elements is presently in question. When fully prepared, the material may represent an undescribed species; but an insufficient number of elements duplicating those of the type-species presently precludes such a determination. Additional, well-preserved brachiosaur material, cited in the Uncompahgre fauna (Jensen 1985), is described here from the Potter Creek Quarry.

Fig. 3. Potter Creek Quarry brachiosaur: A–A₂, left ilium (dorsal border, ischiadic peduncle restored); B, radius; C, metacarpal; D, fourth or fifth dorsal vertebra; E, left humerus. Abbreviations: dc, deltoid crest; ms, muscle fossa.
Fig. 4. Dorsal vertebrae: A–A₂. Potter Creek Quarry brachiosaur, fourth or fifth dorsal vertebra, right lateral view; B–B₂, *Dystylosaurus edwini*, type (B), anterior (B₁), posterior (B₂), right lateral views, probably anterior dorsal; C, *Ultrasaurus macintoshi*, type posterior dorsal vertebra, 1.45 m tall, left lateral view.
Fig. 5. Potter Creek Quarry: A–D, brachiosaur humerus. A, proximal end; B, mid-shaft section; C, detail of bulbous deltoid crest; D, anterior, distal end; E, metacarpal MC I, mesial view; E₁, same, lateral view. Abbreviations: dr, deltoid ridge; ms, muscle fossa/scar.
Fig. 6. A. Scapulocoracoid referred to *Ultrasaurus macintoshi*, prone figure 6'3" tall. B. Jensen/Jensen Quarry brachiosaur rib, Dry Mesa Quarry *Ultrasaurus* scapulocoracid, Potter Creek Quarry brachiosaur left humerus. All three elements cast in fiberglass resin.
This material is much better preserved than that of the type of *B. altithorax* (Riggs 1903) and justifies some revision of the generic diagnosis (see Systematic Paleontology).

In 1972 I opened a quarry near Dry Mesa (Dry Mesa Quarry) in basal Brushy Basin.
Fig. 8. A, Proximal end of brachiosaur femur, proximal end 5'6" in circumference, from Recapture Member of the Morrison Formation; B, Supersaurus vivianae, right lateral view of mid-cervical vertebra; C, mid-cervical vertebra, Supersaurus vivianae right lateral view (restoration seen in Fig. 7). Abbreviations: acx, anterior convexity; bns, bifurcate neural spine; idl, infradiagonal lamina; poc, posterior concavity; pp, parapophysis; prdl, prediapophysial lamina; prz, prezygapophysis; pz, postzygapophysis; sdl, supradiagonal lamina; tp, transverse process; vl, ventral lamina.

Member sediments on the NE monocline of the Uncompahgre Upwarp in western Colorado. This quarry (Fig. 13) lies approximately 20 km NW of the Potter Creek Quarry but is on a significantly lower horizon. A decade of work in it produced many tons of dinosaur-related materials including bones of several unusually large sauropods (Jensen 1985), some of which appear to be brachiosaurid. Among the large elements recovered was a (?) mid-cervical vertebra more than 1 m in length (Figs. 7A–B, 8C), which, having a bifurcate
Fig. 9. Scapula (coracoid) profiles of eight sauropod genera: A, Haplocanthosaurus; B, Supersaurus vivianae; C, Cetiosaurus; D, Diplodocus; E, Camarasaurus; F, Apatosaurus; G, Supersaurus; H, Brachiosaurus; I, Ultrasaurus. Not to scale.
Fig. 10. Potter Creek Quarry, unidentified sauropod atlas/axis with intercentrum third cervical vertebra: A, superior view; B, inferior view; C, anterior view; D, right lateral view; E, posterior view. Abbreviations: at, atlas; ax, axis; crf, cervical rib fragment; ctp, collapsed transverse process; dp, diapophysis; ira, incorrectly restored area (x x in dotted lines); n, neurapophysis; pp, parapophysis.

spine, was readily identifiable as unrelated to *Brachiosaurus*. Because of its huge size, however, an error was made in referring it to *Ultrassaurus macintoshi* Jensen (1985), in the Brachiosauridae. To mitigate this error, I here remove the vertebra, BYU 5003, from Brachiosauridae and provisionally refer it to the Diplodocidae. This referral is based on two factors: principally, a bifurcate neural spine, and, secondly, the fact that two unusually large scapulocoracoids (Figs. 9B, 9G), found in the same (Dry Mesa) quarry, were referable to the Diplodocidae. One of these (BYU 5500, Fig. 9B) is the holotype of *Supersaurus vivianae* Jensen (1985). A large rib (Figs. 1F, 8B), though broken into many sections, appears to have been more than 3 m (over 10 ft) long.
In 1979 a scapulocoracoid, 2.70 m (8'10") long (Figs. 6A–B, 9I) was collected in the Dry Mesa Quarry. This scapula, BYU 5000, is readily referable to the Brachiosauridae (Fig. 9H) and is the holotype of *Ultrasaurus macintoshi* Jensen, 1985.
In 1985 I found the proximal third of an extremely large sauropod femur (Figs. 8A, 12A) in a uranium miner's front yard in southern Utah. The head of this femur is 1.67 m (5'6'') in circumference and was collected from the Recapture Creek Member of the Morrison Formation in Utah near the Arizona border. It is the largest bone I have ever seen; it is also the first dinosaur bone reported from the Recapture Member of the Morrison Formation and is herein pictured in Figure 8A. The proximal end of a sauropod femur is generally

Fig. 12. Profiles of various sauropod femora: A, brachiosaurid, Recapture Creek Member, Morrison Formation; B, apatosaur; C, Diplodocus; D, unidentified, Dry Mesa Quarry. Abbreviations: alam, alamosaur; amph, amphicoelias; apato, apatosaur; brach, brachiosaur; camar, camarasaur; diplo, Diplodocus; haplo, haplocahtsaur. All scale bars equal 0.5 m.
not significantly diagnostic, but in profile (Fig. 12A) this specimen resembles the Upper Cretaceous *Alamosaurus* (Fig. 12 alam.) more than it does profiles of Jurassic sauropods (Fig. 12). In the latter group it bears the greatest resemblance to the profile of *Brachiosaurus* (Fig. 12 brach.) and is here referred to that family.

**Systematic Paleontology**

Suborder Sauropodomorpha

Infraorder Sauropoda

*Brachiosauridae*

*Brachiosaurus* Riggs 1903

**Revised generic diagnosis.**—Humerus and femur of subequal length; humerus with deltoid crest located one-third of total shaft length down from proximal end; neural arches moderately elevated, all neural spines single, not bifid, increasing in height anteriorly from sacrum to mid-dorsal region, short transverse processes on first presacral vertebra increasing in length on each vertebra to the mid-dorsal section, dorsal centra with well-developed pleurocoels, hyposphene-hypantrum articulation well developed; height of first two presacral vertebrae shorter than the preceding series, with length of centra short, length of the third to seventh presacral centra equal to half the vertebra's total height, measured from ventral border of anterior convexity to spinal apex; dorsal rib heads pneumatic; sacrum with five ilium-supporting vertebrae, width of sacrum approximately equal to length, with short sacral spines and five ossified centra; anterior caudal vertebrae with short neural spines, moderately developed caudal ribs, and no pleurocoels.

**Referred specimens.**—BYU 9754: mid-dorsal vertebra, partial left ilium, left radius, one right metacarpal, left humerus, and various rib sections, all associated.

**Species Indeterminate**

**Horizon and Locality.**—An intermediate horizon of the Brushy Basin Member, Morrison Formation, Late Jurassic Period; Potter Creek Quarry, T49N, R12W, SW 1/4, Sec 5, Montrose County, Colorado.

**Collector.**—J. A. Jensen.

**Description.**—Mid-dorsal vertebra. The height of the vertebra is comparatively greater than that of the type with a proportion of centrum length to total vertebral height of 3 to 7, compared to a proportion of 3.7 to 7.2 in the type (Riggs 1904). The supraprezygopophyseal laminae are not parallel, as in *B. altithorax*, but conjoined midway up the neural spine, forming a robust pre-spinal lamina that transversely increases in width dorsally (Figs. 3D, 4A). Both diaphyses are missing, leaving the length of the transverse processes unknown. A moderately developed hyposphene-hypantrum articulation contrasts with the unusually developed intervertebral articulations in *B. altithorax*. An elongate centrum has well-developed pleurocoels. The apex of the neural spine is expanded into a robust 90-degree, transverse, gablelike metapophyseal cap (Fig. 4A). The neural arch is constricted around its base (Fig. 4A–A) rather than being anteroposteriorly long as in *Ulausaurus* Jensen, 1985 (Fig. 4C), or long and broad as in *Dystylosaurus* Jensen, 1985 (Fig. 4B–B).

The inner and outer distal condyles of the humerus are anteriorly prominent (Fig. 5D). The rugose crest of the deltoid ridge is bulbous, comparatively short (Fig. 5B–C), and centered one-third of the total shaft length below the proximal end. A prominent, deep muscle fossa with a transverse, crenulated, lower margin (Fig. 5A) occurs in the upper part of the broad, anterior valley, adjacent to the deltoid ridge.

A metacarpal (Fig. 5E–E), probably right, MC III, has a laterally expanded distal end.

The radius (Fig. 3B), with few distinguishing features, is tentatively identified as the left.

The anterior iliac process is massive and shorter than that of *B. altithorax*. The dorso-posterior third of the ilium, including the ischiadic peduncle, is missing and is conservatively restored here after several Tendaguru brachiosaur ilia in the British Museum (Natural History) (McIntosh 1980, personal communication). The pubic peduncle is long and thin, viewed laterally, forming a weak anterior acetabular arch.

**Discussion.**—A deep muscle fossa with a crenulated lower margin (Fig. 5A ms) occurs on the humerus in the upper part of a broad valley adjacent to the deltoid ridge, marking the terminal insertion of a large adductor
cle. This may have been the “antero-superior muscle” identified in *Camarasaurus supremus* by Osborn and Mook (1921), or the M. pectoralis, or an equivalent of the M. deltoideus, said to terminate on or near the delto-roid ridge in ornithischian dinosaurs (Romer 1927). This fossa is not known to be equally prominent in other sauropod genera.

The long, comparatively weak pubic peduncle of the ilium suggests the anterior end of the ilia may have been rotated ventrally around a transverse acetabular axis, similar to the 20-degree iliac rotation seen in the sauropod *Cathetosaurus lewisi* Jensen (in press). In that genus a ventral rotation of the anterior iliac processes placed a stronger, well-butressed section of the ilia above the head of the femur. This rotation, not reported in other sauropod genera, allowed *C. lewisi* to elevate the anterior body, neck, front limbs, and thorax to a bipedal stance. A similar iliac rotation in brachiosaurs would have compensated for an elevated thorax due to their unusually long front limbs (Riggs 1903). In non-bipedal sauropods, such as the Apatosauridae, Diplodocidae, and Camarasauridae, elevation of the anterior body would have obliged the weakest cross section of the pubic peduncle to carry a major amount of body weight.

**UNIDENTIFIED SAUROPOD.** It is concluded here that the atlas/axis and articulated third cervical vertebrae (Fig. 10) belong to an unidentified sauropod. This determination is strengthened by the allochthonous nature of the deposit in which three families were represented; however, only mild evidence of strong, fluctuating currents, such as heavy cross-bedded sands, grits, bone abrasion, and rip-up mudclasts, was encountered during extensive excavations in the area.

An allochthonous deposit of dinosaur bones usually contains the remains of one skeleton, representing the one-time death-site burial of an individual (Dodson et al. 1980), characteristically isolated from the disruptive hydraulic forces of active channel environments. Allochthonous deposits, on the other hand, are composed of disarticulated parts of various vertebrates collected by active hydraulic forces sweeping a drainage area during an indefinite, extended period of time.

Correcting an earlier, inaccurate report on the Potter Creek fauna (Dodson et al. 1980), which listed one taxon and the pattern of bone occurrence as “isolated skeletal parts,” the Potter Creek faunal list includes at least three families: two sauropodmorphs; *Brachiosaurus* sp., and an unidentified smaller sauropod; and an unusually large theropod, possibly *Tortosaurus* Galton and Jensen (1979), or a large allosaurid. Furthermore, the pattern of bone occurrence is associated and articulated, rather than “isolated,” as reported, and the locality produced elements of a well-preserved flora consisting of various undescribed reproductive structures.

**TAPHONOMY.**—The huge brachiosaur ilium was partially destroyed, broken diagonally through its thickest section and separated from the dorsoposterior section, which was never found. This damage was not the result of levee overwash, stream abrasion, large-animal turbation, postburial pressure and faulting, nor scavengers, since no teeth marks were found in any of the bones. Also, the uncrushed, articulated, unidentified, smaller-sauropod cervical series was found adjacent to the broken ilium, undamaged by the force(s) partially destroying that huge element. The ilium was apparently broken elsewhere, the parts separated, with only one being transported to the site. Unusually strong hydraulic pressure would have been required to move such a heavy, irregular shape, but no evidence of high-energy fluvial activity was present in the surrounding sediments and so no explanation of this enigma is readily apparent.

When I first visited the locality, a considerable amount of shattered dinosaur bone, obviously belonging to a large individual, was lying on the slope below the deposit. The Jones family informed me that more was present when they discovered the site many years earlier. This lead to the conclusion that the major portion of a brachiosaur skeleton was present before erosion.

**FLORA.**—Considerable fossil plant material was present in an area adjacent to the quarry horizon in the form of reproductive structures. Cycadophyta seeds were common, from the family Cycadales (Chandler 1966), on fragments of macroporophyll, including the micropyle of fertile embryos. I collected approximately one liter of these organs, as well as immature seeds of *Behuninia joannei* (Chandler 1966) and mature seeds of the Cycadophyta *Jensensispermum* redmondii
Other reproductive structures included a cone of the gymnosperm Coniferales, family Taxodineae, Sequoia sp., seeds of the genus Carpolithus Linnaeus incertae sedis (Chandler 1966), and many megasporophyll fragments. This fossil plant material, a faunal list, and the information on taphonomy were available but not published in the first taphonomic report on the quarry (Dodson et al. 1980).

ACKNOWLEDGMENTS

The Daniel E. “Eddie” Jones family of Delta, Colorado, were responsible, circa 1943, for the first new brachiosaur bones found in the western hemisphere since the discovery of the type species of Brachiosaurus by E. S. Riggs in Colorado in 1900. Other brachiosaur bones described here, particularly those from the dry Mesa Quarry, are also the result of their extensive explorations on the Uncompahgre Upwarp in western Colorado. I thank Dr. John S. McIntosh for his encouraging support, Dr. Samuel P. Wells and Dr. James R. Jensen for criticizing the manuscript, and Dr. Stephen L. Wood, editor, Great Basin Naturalist, for his continuing support that has enabled me to continue publication of the results of 23 years of collecting new dinosaurs.

LITERATURE CITED


