New Sauropod Dinosaur Specimens Found Near Moab, Utah, and the Sauropod Fauna of the Morrison Formation

by John R. Foster

Sauropod dinosaurs are among the most interesting animals that lived during the Mesozoic. The mass of even the moderate-sized members of this group surpasses anything on land today, and indeed the average sauropod was larger than just about any land animal on Earth before or since their reign. Perhaps nowhere are sauropods better represented than in the Morrison Formation of the Rocky Mountain region. The formation is approximately 150 million years old and represents the period of the apex of sauropod diversity during dinosaur times. Although other groups of animals in the Morrison Formation had more member species, or were more numerically abundant, or were more the animals of our nightmares, with large teeth and claws, none of these exceeded the sauropods in ecological importance nor in awesome size. The sauropods dominated the vertebrate biomass of the time, and as plant-eaters, they were thus the most important dinosaurs in transfering energy from the primary producers of the ecosystem (plants) to the secondary consumers (carnivores). Without big sauropods, there likely would be no monsters like *Allosaurus* or *Torvosaurus.*

The skeletons of sauropods are also rather beautiful in design. With the very robust limbs built to support bulks up to nearly 100 metric tons, and with the vertebral columns structured to reduce weight every way possible, almost no other animal skeletons in history look quite like that of a large sauropod.

But who are the sauropods of the Morrison Formation? The first three genera of sauropods found in this unit were, not surprisingly, those that have proven to be the most abundant; *Camarasaurus*, *Diplodocus*, and *Apatosaurus* constitute the "big three" of sauropod dinosaurs in the Morrison Formation. They are far more common as fossils than are the other types of sauropods of this age in North America.

Camarasaurus is the most abundant dinosaur found in the Morrison Formation and occurs at many sites throughout the Rocky Mountain region. In fact, it occurs in every state with Morrison Formation exposure except Arizona. Although less popularly known than many of its contemporaries, *Camarasaurus* is numerically the most common dinosaur and has the most completely known skeleton of any sauropod in the formation. An articulated juvenile specimen from Dinosaur National Monument in Utah, about 1/3 average adult size, is one of the most complete dinosaurs in the world.

As sauropods go, most *Camarasaurus* specimens are unremarkable in size; the average adult length and live weight are only about 45–50 feet and 14–18 tons. One very large species from the top of the formation near Cañon City, Colorado, however, reached weights of nearly 47 tons and was probably the largest animal of the time. *Camarasaurus* is distinguished by its large, round skull with robust jaws and thick spoon-shaped teeth.

Apatosaurus is the second most abundant sauropod found in the formation. It is known from a number of quarries and occurs in every state in which the Morrison Formation is exposed (including Arizona). A large, 70-foot, 30-ton animal, *Apatosaurus* was one of the first dinosaurs found in the

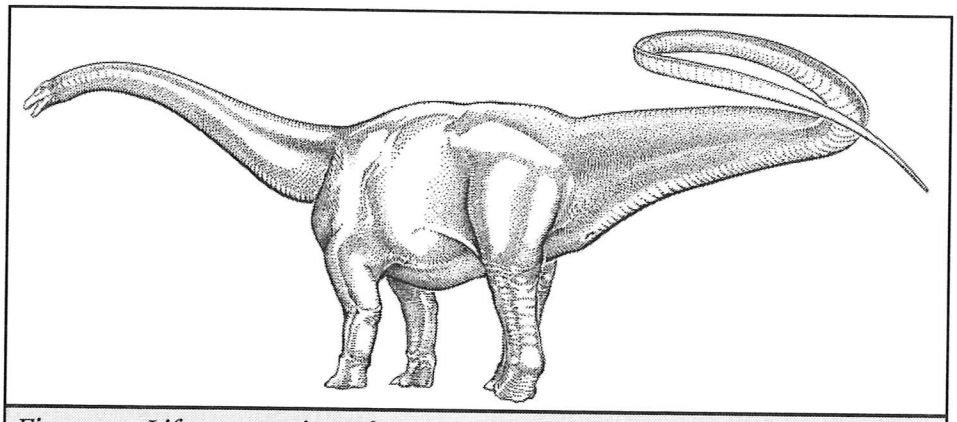


Figure 1. Life restoration of Apatosaurus. (Drawing by Donna Sloan) All pictures for this article provided by the author, John R. Foster.

formation near Morrison, Colorado, back in 1877 (Fig. 1). The adult femur of this sauropod is more than six feet long, and the distinguishing characters of the animal include a thick, flexible neck, a wide but relatively flat skull with pencil-like teeth only at the fronts of the jaws, a very long tail, and very robust limb bones. *Apatosaurus excelsus* and *A. louisae*, although of similar length, were distinctly different in weight, at approximately 24 and 34 tons, respectively.

Diplodocus is the third of the common sauropods of the Morrison Formation and is similar in overall size to *Apatosaurus*, but it is much more slender (Fig. 2, see cover). In fact, both *Diplodocus* and *Apatosaurus* were approximately 70–80 feet long, but *Diplodocus* only weighed a little over 12 tons. Both had long, low skulls with pencil-like teeth at the front of the jaw, and they were closely related, but *Diplodocus* had a narrower skull, narrower neck vertebrae, more slender limbs, and more elongate tail vertebrae.

Diplodocus was first found near Cañon City, but has since been identified from many quarries in the Morrison Formation, including the Dry Mesa Quarry southwest of Delta, Colorado, the Howe Quarry in northcentral Wyoming, Dinosaur National Monument in Utah, and several sites at Como Bluff, Wyoming, northwest of Laramie. The *Diplodocus* mounted at the Denver Museum of Nature and Science is from Dinosaur National Monument, in Utah.

Barosaurus is a rare genus in the Morrison Formation. It was first found about 10 miles north of Rapid City, South Dakota, in 1889 and was worked at that time by O. C. Marsh and his assistant, Yale graduate J. B. Hatcher. Marsh named the animal in 1890, but it wasn't until 1898 that he sent another assistant, George Wieland, to collect the rest of the skeleton. This Wieland did mostly alone, working well into the fall when, as he put it in 1920, "cold and dust storms made excavation difficult."

Barosaurus is very similar to *Diplodocus* in size, shape, and build, but has much more elongate cervical vertebrae (perhaps as much as 50% longer relative to centrum diameter) and shorter caudal vertebrae. *Barosaurus* was about the same length and weight as *Diplodocus* but is represented by only one-eighth as many specimens. It is known from two sites in the Black Hills of South Dakota, as well as the quarry at Dinosaur National Monument and several others.

Brachiosaurus was first found on July 4, 1900, by H. W. Menke, a member of the field crew of Elmer Riggs, about four miles from downtown Grand Junction, Colorado, at what is now called Riggs Hill. Riggs was with the Field Museum in Chicago and is known for demonstrating, among other things, that the animal known for some time as *Brontosaurus* is, in fact, the same as *Apatosaurus*. At the time of the discovery in 1900, his crew was working on a *Camarasaurus* several miles away, but they managed to get the new specimen out of the ground that same year. He named the new sauropod *Brachiosaurus* (the "arm-lizard") in a paper in 1903, because among its distinguishing characters was the fact that its forelimbs were slightly longer than the hindlimbs (the reverse was true in all other sauropods).

Brachiosaurus is a very large animal with femur and humerus bones each nearly seven feet long, ribs about 8–10 feet long, a long neck, and relatively short tail. With the long front legs and a back that swept upward towards the long neck, the animal was similar to a 43-ton reptilian giraffe. It probably fed in the tree tops above the other animals of the time, and it is rather rare in the Morrison Formation, known only from a handful of sites. The late Jim Jensen of Brigham Young University probably excavated more of the Morrison *Brachiosaurus* specimens than anyone else, locating partial skeletons at

the Dry Mesa and Potter Creek quarries southwest of Delta, Colorado, and at the Jensen-Jensen Quarry near Dinosaur National Monument, Utah. *Brachiosaurus* was later found in what is now Tanzania in southern Africa and in Portugal, both in deposits similar in age to the Morrison Formation.

Haplocanthosaurus is also a less abundant sauropod in the Morrison Formation. It was first found near Cañon City, Colorado, and named in a paper in 1903. It is of moderate size and weight (about 10 tons) and is relatively unspecialized. The skull has not yet been found, as far as we know. The vertebrae of *Haplocanthosaurus*, in some ways, are roughly similar to those of *Camarasaurus*, although it is not directly related to that genus. *Haplocanthosaurus* is known mostly from the lower levels of the Morrison Formation and a recent find from the Salt Wash Member near Vernal, Utah includes a nearly complete haplocanthosaurid skeleton.

Supersaurus is a very large diplodocid sauropod from the Dry Mesa Quarry on the Uncompahgre Plateau of Colorado. It is rather similar to *Barosaurus* in most respects, but the mid-caudal vertebrae *may* be more similar to *Apatosaurus*. It was probably more than 100 feet in length and close to 40 tons in weight.

Seismosaurus is another large (~40 ton) diplodocid sauropod known from a single specimen from the Morrison Formation in New Mexico. Most of the elements known from this animal are from the posterior half of the skeleton, and it has been referred to as a species of *Diplodocus* by some workers.

Amphicoelias was a large diplodocid, quite similar to *Diplodocus*, and was named by E. D. Cope from Garden Park, Colorado. There are two named species: *A. altus*, based on two dorsal vertebrae, a femur, and an ulna; and *A. fragilimus*, based on a fragment of neural spine so large that sauropod expert Jack McIntosh has calculated that if scaled to the proportions of a *Diplodocus* (as seems reasonable) just the femur of the animal would be 3 meters long! Whether or not *Amphicoelias* is a type of sauropod truly distinct from *Diplodocus* remains to be seen, however.

Ultrasaurus is no longer considered a valid taxon. It was another very large sauropod from Dry Mesa Quarry, named by Jim Jensen as a brachiosaurid in 1985. The type specimen of this animal, a single dorsal vertebra, has since been shown to belong to the type specimen of the diplodocid *Supersaurus*. Material referred to *Ultrasaurus*, including a scapula and caudal vertebra, was later determined by Jensen or other workers to in fact belong to *Brachiosaurus* or *Supersaurus*.

Dystylosaurus is yet another large sauropod from Dry Mesa, described as a brachiosaurid. Brian Curtice and Ken Stadtman suggested in a recent paper that this single dorsal type specimen is not brachiosaurid at all and also may be part of the *Supersaurus* skeleton from the same quarry.

Dyslocosaurus is possibly from the Morrison Formation of eastern Wyoming (the locality records are not very good) and appears to be a diplodocid. It consists of the lower half of a hind limb and is unique in having a foot comprising five unguals (blunt claws, in sauropods). Other sauropods have just three of these claws on the hind foot. Unfortunately, there is little else in *Dyslocosaurus* to distinguish it from other diplodocids, and it is even possible (though perhaps not likely) that it is from another formation.

Cathetosaurus consists of most of a skeleton and was excavated by Jim Jensen in the Cactus Park region of western Colorado. It has since been shown by Jack McIntosh and others to be an old individual of *Camarasaurus*.

Dystrophaeus was found very low in the Morrison Formation (so low, in fact, that some workers don't even include it in the Morrison) back in 1859. It appears to be a rather primitive sauropod, and its type locality south of Moab, Utah, was relocated by Fran Barnes about 130 years after the specimen was originally collected.

The first six, well known sauropod genera of the Morrison Formation (*Camarasaurus*, *Apatosaurus*, *Diplodocus*, *Barosaurus*, *Brachiosaurus*, and *Haplocanthosaurus*) are all known from multiple partial to complete skeletons, and their validities are well established. The less well known taxa (*Supersaurus*, *Seismosaurus*, *Amphicoelias*, *Dystylosaurus*, *Dyslocosaurus*, *Cathetosaurus*, *Dystrophaeus*, and *Ultrasaurus*) are each known from isolated partial skeletons down to single bones and are all far less proven. Of these less well known genera, however, *Supersaurus* is probably the most well established and likely to be valid,

and *Ultrasaurus* and *Cathetosaurus* are the most solidly shown to be junior synonyms of other genera. *Dystylosaurus* and *Dyslocosaurus* are each too poorly known to really have any idea *what* they were, and I'm not yet totally convinced that *Amphicoelias* and *Seismosaurus* aren't just very large individuals of *Diplodocus*. We will need more complete skeletons of animals that can be referred to these genera to be sure.

Moab Area Sauropods

Although the area around Moab, Utah, contains abundant exposures of the Morrison Formation, and although these outcrops have produced a number of dinosaur footprint localities, associated partial skeletons of dinosaurs have thus far proven rare. And major quarries have not yet been found. The Mill Canyon site has produced many bones out of a channel sandstone, but these are nearly all fragmentary, at least on the surface. In recent years, however, two associated sauropod specimens have been found in the area, and these are briefly discussed here.

Camarasaurus

The first specimen is DOLM 515, a sauropod referred to as *Camarasaurus* sp. on display at the Dan O'Laurie Museum of Moab. It was found in the Brushy Basin Member of the Morrison Formation near the base of the southwest slope of the La Sal Mountains, south of Moab. The rock in which it was found appears to be a very light tan to white medium- to fine-grained sandstone.

DOLM 515 consists of three dorsal centra, three partial sacral centra and a large, separate piece of fused sacral ribs, one caudosacral, two fused sacral neural spines, a partial ilium, ilium fragment, several small rib fragments, and ten caudal centra (caudals 1-9 and 20?) (Figs. 3 and 4). The posterior dorsal centra are approximately 24–27cm in diameter, have deep pleurocoels, are opisthocoelous, and have had the neural arches and spines broken off. The sacral vertebrae and caudosacral are fused and approximately 28cm diameter but also have lost their sacral ribs and spines. The two fused sacral neural spines are narrow and rounded along their top surface. The partial ilium appears to be the posterior portion of a left, including the ischiac peduncle and posterior edge of the blade. The piece of fused sacral ribs that is separate from the sacral vertebrae includes the surface for attachment of the ilium (iliac bar), although it cannot be determined whether this piece is a left or right. From this piece it appears the ilium was not fused to the sacrum in this individual. Caudals 1-9 all consist mostly of just the centra; the caudal ribs, neural spines, and in most cases, the neural arches are broken off. In vertebrae where part of the neural arch is still preserved, it is always the left side. The left sides of the centra are also generally better preserved than the right. The caudals range in diameter from approximately 25cm for caudal 1 down to about 17cm for caudal 9. The caudal centra are smooth and rounded on their ventral surface, and the lateral surfaces lack pleurocoels. Caudal 1 does have an unusual, very shallow, rounded indentation on its right lateral surface, but this is not deep enough to be considered a true pleurocoel. The caudal ribs of caudals 1–9 are all simple. Caudal 20? is 10cm in diameter and just over 12cm long.

DOLM 515 matches specimens of *Camarasaurus* in all its characteristics (Gilmore, 1925; Osborn and Mook, 1921), and several aspects of its morphology rule out most other sauropod taxa of the Morrison Formation. The dorsal centra of DOLM 515 are relatively short anteroposteriorly, not elongate as in *Brachiosaurus* (Riggs, 1903); the neural spines of the sacral vertebrae are relatively narrow and rounded on top, unlike the tall, squared off, and

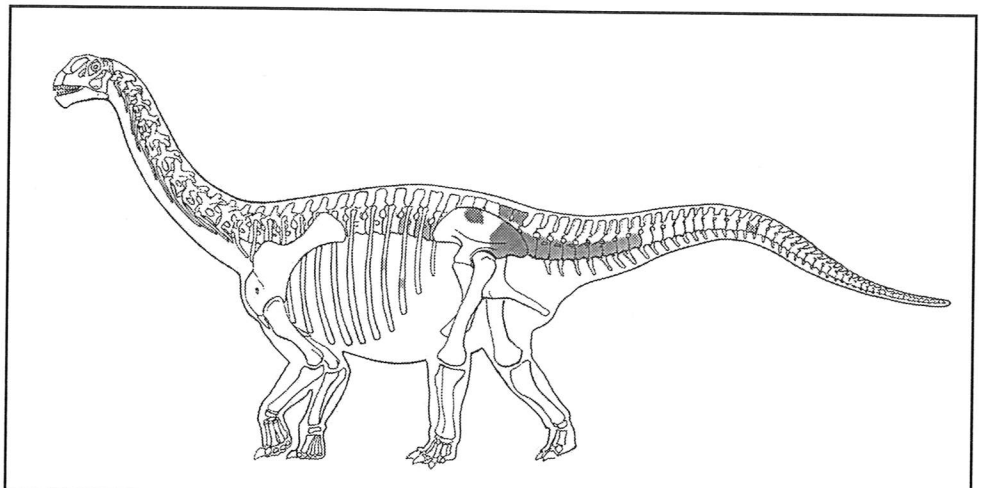


Figure 3. Skeletal reconstruction of *Camarasaurus*. Skeletal elements represented by DOLM 515 are shaded.

wide neural spines of diplodocids; the mid-caudal vertebra is not elongate as in diplodocids; the chevrons facets of the caudal centra do not appear to be as large as in *Haplocanthosaurus* (Hatcher, 1903); the ventral surfaces of the anterior caudal centra are rounded, not keeled as in *Apatosaurus*, nor grooved as in *Diplodocus* and *Barosaurus*; the caudal central lack pleurocoels, unlike *Diplodocus* and *Barosaurus*; and the anterior caudal ribs are simple, not wing-like as in diplodocids (Hatcher 1901; McIntosh, 1990).

Apatosaurus

The second specimen is ARCH 3151, a sauropod referred to *Apatosaurus* sp. It was found in a hard, blue-green mudstone high in the Brushy Basin Member of the Morrison Formation within Arches National Park. ARCH 3151 consists of nine caudal centra (approximate numbers: 2, 3, 5, 7, 9, 10, 11, 14, and 20), a pubis, and many other fragments (Fig. 5). The caudal centra range from 29cm to 15cm in diameter, and most are missing their caudal ribs, neural arches, and neural spines. The right sides of the centra are generally preserved better than the left. The anterior centra in particular tend to be taller than wide. The pubis is missing some of the proximal end, but the shaft and distal end are mostly intact; this pubis is 79cm long.

ARCH 3151 can be identified as *Apatosaurus* based on several characters: the absence of pleurocoels in the caudal centra and the lack of a ventral groove in these bones both rule out the other diplodocids *Diplodocus* and *Barosaurus*; the distinct ventral keel on the anterior caudal centra distinguishes ARCH 3151 from *Camarasaurus*, *Haplocanthosaurus*, and *Brachiosaurus* (in fact, the ventral keel is unique to *Apatosaurus* among Morrison sauropods); the pubis is robust; and the anterior caudal centra also have an unusual posterior surface in which the lower half is slightly convex and the upper half is slightly concave. This type of centrum surface was described in *Apatosaurus* by Gilmore (1936).

Perhaps the most significant aspect of specimen ARCH 3151 is the stratigraphic level at which it was found. Although much of the material was collected from the surface, several bones were removed from their in situ position, and thus the stratigraphic level of the quarry could be determined. The Brushy Basin Member of the Morrison Formation at this site is approximately 75m thick, and the *Apatosaurus* specimen was found about 13m below the top contact of the Brushy Basin with the Cedar Mountain Formation. ARCH 3151's relative position within the Brushy Basin Member, compared to other sites, suggests that it could be the stratigraphically highest occurrence of *Apatosaurus* in the Morrison Formation. Although such long distance correlations can be difficult, comparing its relative position within the formation to the section along the Front Range of Colorado indicates that the Arches specimen may be from a level near and perhaps above that of Cope's Quarry 8 at Garden Park (Turner and Peterson, 1999). Cope's Quarry 8 yielded the very large sauropod

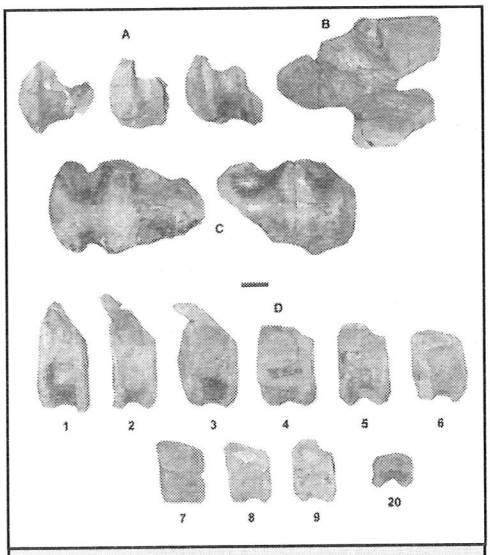


Figure 4. DOLM 515, Camarasaurus sp. from the Morrison Formation on the southwestern slope of the La Sal Mountains. A) Three dorsal centra in left lateral view; B) Posterior portion of ilium in medial? view; C) Sacral vertebrae in ventral view; D) Centra of caudal vertebrae in left lateral view (approximate positions numbered). Scale bar = 10cm.

Camarasaurus supremus but was at a level even higher than the Cope's Nipple pits. In fact, if the relative stratigraphic position of the Arches *Apatosaurus* is accurate, among sauropods only *Amphicoelias altus* from Cope's Quarry 12 (the highest quarry in the formation) would be from higher in the Morrison than ARCH 3151. If we compare the stratigraphic position of the Arches quarry just to major, nearby quarries in the Brushy Basin Member, its relative position is clearly well above that of sites such as the Carnegie Quarry at Dinosaur National Monument, the Cleveland-Lloyd Quarry, the Mygatt-Moore Quarry, and the Dry Mesa Quarry.

Among sauropods from high in the Morrison, however, ARCH 3151 is unlike the very large *Amphicoelias altus* and *Camarasaurus supremus* in

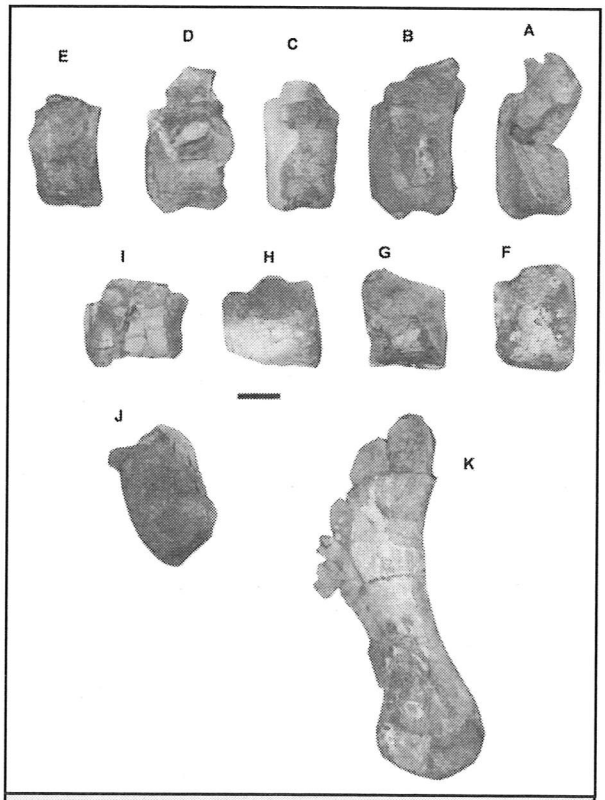
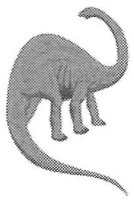


Figure 5. ARCH 3151, *Apatosaurus* sp. from near the top of the Brushy Basin Member of the Morrison Formation in Arches National Park. A–F) Centra of caudal vertebrae in right lateral view. A) Caudal 2; B) Caudal 3; C) Caudal 5; D) Caudal 7; E) Caudal 9; F) Caudal 10; G) Caudal 11; H) Caudal 14; I) Caudal 20; J) Caudal 5 in anterior view showing ventral keel of centrum (left dorsolateral portion of centrum missing); K) Right pubis. All vertebral positions approximate. Scale bar = 10cm.

that it is not remarkably big; ARCH 3151 is similar in size to most adult specimens of *Apatosaurus* from quarries lower in the formation. Still, as apparently the geologically youngest (and thus last) example of *Apatosaurus* that we currently have, this specimen may yet reveal more about the apatosaur line during the latter days of Morrison times.

Acknowledgments

Thanks to Rusty Salmon and the crew at the Museum of Moab for permission to study DOLM 515. I also thank Laura Joss, Superintendent of Arches National Park, for permission to illustrate ARCH 3151. The permitting, excavation, and curation of the Arches specimen was facilitated by former Chief Ranger Jim Webster along with Charlie Schelz, Vicki Webster and others at Arches. The dig was a cooperative project between the National Park Service, the Museum of Western Colorado, and the Utah Museum of Natural History. Jim Kirkland was key in initiating the project, helped with the excavation, and was enthusiastic at all stages. A final thanks to Mike Getty, Scott Madsen, and the volunteers and students from the UMNH and MWC for their teamwork in the field.



References

1. Gilmore, C. W. 1925. A nearly complete articulated skeleton of *Camarasaurus*, a saurischian dinosaur from the Dinosaur National Monument, Utah. *Memoirs of the Carnegie Museum* 10(3):347–384.
2. Gilmore, C. W. 1936. Osteology of *Apatosaurus*, with special reference to specimens in the Carnegie Museum. *Memoirs of the Carnegie Museum* 11:175–300.
3. Hatcher, J. B. 1901. *Diplodocus* (Marsh): its osteology, taxonomy, and probable habits, with a restoration of the skeleton. *Memoirs of the Carnegie Museum* 1(1):1–63.
4. Hatcher, J. B. 1903. Osteology of *Haplocanthosaurus*, with description of a new species, and remarks on the probable habits of the Sauropoda and the age and origin of the Atlantosaurus Beds. *Memoirs of the Carnegie Museum* 2(1):1–72.
5. McIntosh, J. S. 1990. Species determination in sauropod dinosaurs with tentative suggestions for their classification. *In* Carpenter, K. and Currie, P. J., eds., *Dinosaur Systematics: Perspectives and Approaches*, Cambridge University Press, p. 53–69.
6. Osborn, H. F., and Mook, C. C. 1921. *Camarasaurus*, *Amphicoelias*, and other sauropods of Cope. *Memoirs of the American Museum of Natural History* 3:247–287.
7. Riggs, E. S. 1903. *Brachiosaurus altithorax*, the largest known dinosaur. *American Journal of Science* (ser. 4) 15:299–306.
8. Turner, C. E., and Peterson, F. 1999. Biostratigraphy of dinosaurs in the Upper Jurassic Morrison Formation of the Western Interior, USA. *In* Gillette, D. D., ed., *Vertebrate Paleontology in Utah*, Utah Geological Survey Miscellaneous Publication 99-1, 77–114.

John Foster is Curator of Paleontology at the Museum of Western Colorado. His research focuses on the terrestial vertebrate paleoecology of the Jurassic of western North America, particularly in the Morrison Formation.