VOLUMINA JURASSICA, 2014, XII (2): 197–210
DOI: 10.5604/17313708 .1130144

Haplocanthosaurus (Saurischia: Sauropoda) from the lower Morrison Formation (Upper Jurassic) near Snowmass, Colorado

John R. FOSTER[1], Mathew J. WEDEL[2]

Key words: *Haplocanthosaurus*, sauropod, Late Jurassic, Morrison Formation.

Abstract. A small sauropod dinosaur collected from the Rocky Mountains of central Colorado (north of the Elk Range, Pitkin County) is assigned to the rare genus *Haplocanthosaurus*. The specimen, MWC 8028, consists of four dorsal centra, five partial ribs, the sacrum, five caudal vertebrae, three chevrons, five partial neural spines and many fragments and is from the lower third of the Upper Jurassic Morrison Formation. The dorsal vertebrae are procamerate, and on the sacral vertebrae the neural arch peduncles are vertically elongate and the neural spines are strongly reclined. The only sauropod from the Morrison Formation that shares these characters is *Haplocanthosaurus* and based on those characters MWC 8028 is referred to *Haplocanthosaurus*. This is at most the tenth specimen and the seventh locality for this sauropod, all within the Morrison Formation.

INTRODUCTION

Haplocanthosaurus is one of the rarest sauropods of the Upper Jurassic Morrison Formation of the western United States. This sauropod was first described as *Haplocanthus* from specimens collected at the Marsh-Felch Quarry at Garden Park, Fremont County, Colorado, around the turn of the last century (Hatcher, 1903a). Hatcher (1903b) revised the name to *Haplocanthosaurus* several months later because he mistakenly believed *Haplocanthus* was preoccupied. *Haplocanthus* was technically correct until a 1991 ICZN ruling (ICZN, 1991) that established *Haplocanthosaurus* as the correct name due to widespread use, based on a proposal by Lucas and Hunt (1989). Hatcher (1903c) provided a detailed description of the osteology of *Haplocanthosaurus* based on the Marsh-Felch Quarry specimens. CM 572, the genus holotype, was named as *H. priscus*, and CM 879, also from the Marsh-Felch Quarry, was designated the holotype of the species *H. utterbacki*, although this latter specimen has generally been regarded as a juvenile and a subjective synonym of *H. priscus* (McIntosh, 1990a; Upchurch *et al*., 2004). McIntosh and Williams (1988) named *H. delfsi* on the basis of a partial skeleton about 50% larger than the *H. priscus* type material. *Haplocanthosaurus delfsi* was also found in the Garden Park area but in the Cleveland Museum Quarry south of the Marsh-Felch Quarry.

Whereas common sauropods from the Morrison Formation such as *Camarasaurus*, *Diplodocus*, and *Apatosaurus* (Dodson *et al*., 1980) are known from specimens representing minimum numbers of individuals (MNI) ranging from approximately 100 to more than 170 (Foster, 2001, 2003), *Haplocanthosaurus* is known from fewer than a dozen (and possibly as few as four) specimens, most represented by a handful of elements. By far the best preserved and most complete specimen of a haplocanthosaurid, FHPR 1106, was excavated from west of Dinosaur National Monument in

[1] Museum of Moab, 118 East Center St., Moab, UT 84532 USA; email: director@moabmuseum.org
[2] College of Osteopathic Medicine of the Pacific and College of Podiatric Medicine, Western University of Health Sciences, 309 East 2nd St., Pomona, CA 91766, USA

1999. Any occurrences of these rare and relatively small sauropods are of interest, especially given their apparent restriction to the lower half or so of the Morrison Formation.

ABBREVIATIONS

CM – Carnegie Museum of Natural History, Pittsburgh; CMNH – Cleveland Museum of Natural History, Cleveland, Ohio; DINO – Dinosaur National Monument, Jensen, Utah; FHPR – Utah Field House of Natural History Museum, Vernal, Utah; FMNH – Field Museum of Natural History, Chicago, Illinois; MWC – Museum of Western Colorado, Fruita, Colorado; SMM – Science Museum of Minnesota, St. Paul, Minnesota.

GEOLOGICAL SETTING

The present specimen was found by Mike Gordon, then a college student exploring his grandfather's land. In 2009, Gordon's mother, Jessica Bramson, contacted the Museum of Western Colorado and its crews investigated the site that June. Triebold Paleontology had previously worked the site briefly and determined that the material belonged to a sauropod but was not interested in working the site further. The Museum of Western Colorado collected the exposed bones and others in one jacket from July–September 2009. Excavations continued at the site each summer through 2013.

The Gordon-Bramson-Brothers Quarry is in the lower Morrison Formation, in a cut through a hogback made by Snowmass Creek in Pitkin County, Colorado (Figs 1, 2C). The town of Snowmass is approximately 1.6 km north of the quarry, downstream on Snowmass Creek. The strata are south-dipping (~35°), and the exposed formations range from Permian and Triassic through Late Cretaceous (Mancos Shale). Underlying the Morrison here are the Entrada Sandstone and the Curtis Formation, and overlying the Morrison is the Burro Canyon Formation (Mutschler, 1970; Freeman, 1972). To the south is the Elk Range.

The quarry is approximately 24.5 m above the base of the Morrison Formation (Fig. 2B). Locally, the Morrison is approximately 90 m thick (Mutschler, 1970; Freeman, 1972). This stratigraphic level, approximately 27% of the way up into the local Morrison section, is approximately equivalent to the middle Salt Wash Member of the Colorado Plateau (Turner, Peterson, 1999), although the lithology of the site

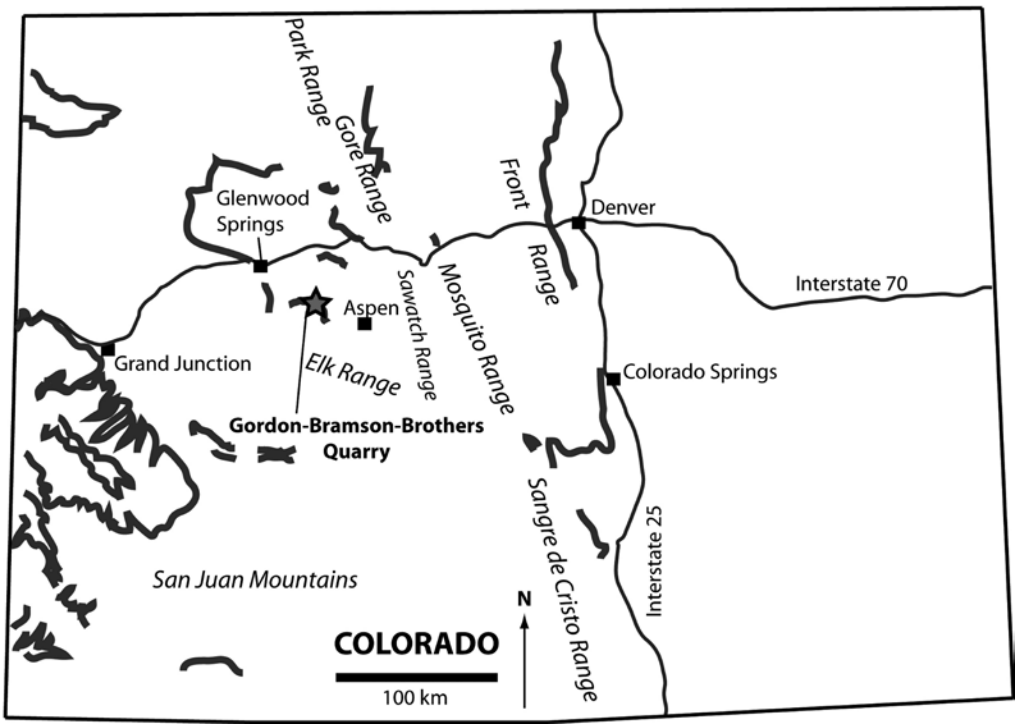

Fig. 1. Gordon-Bramson-Brothers Quarry locality map

Thick line indicates outcrops of the Morrison Formation; quarry indicated by star

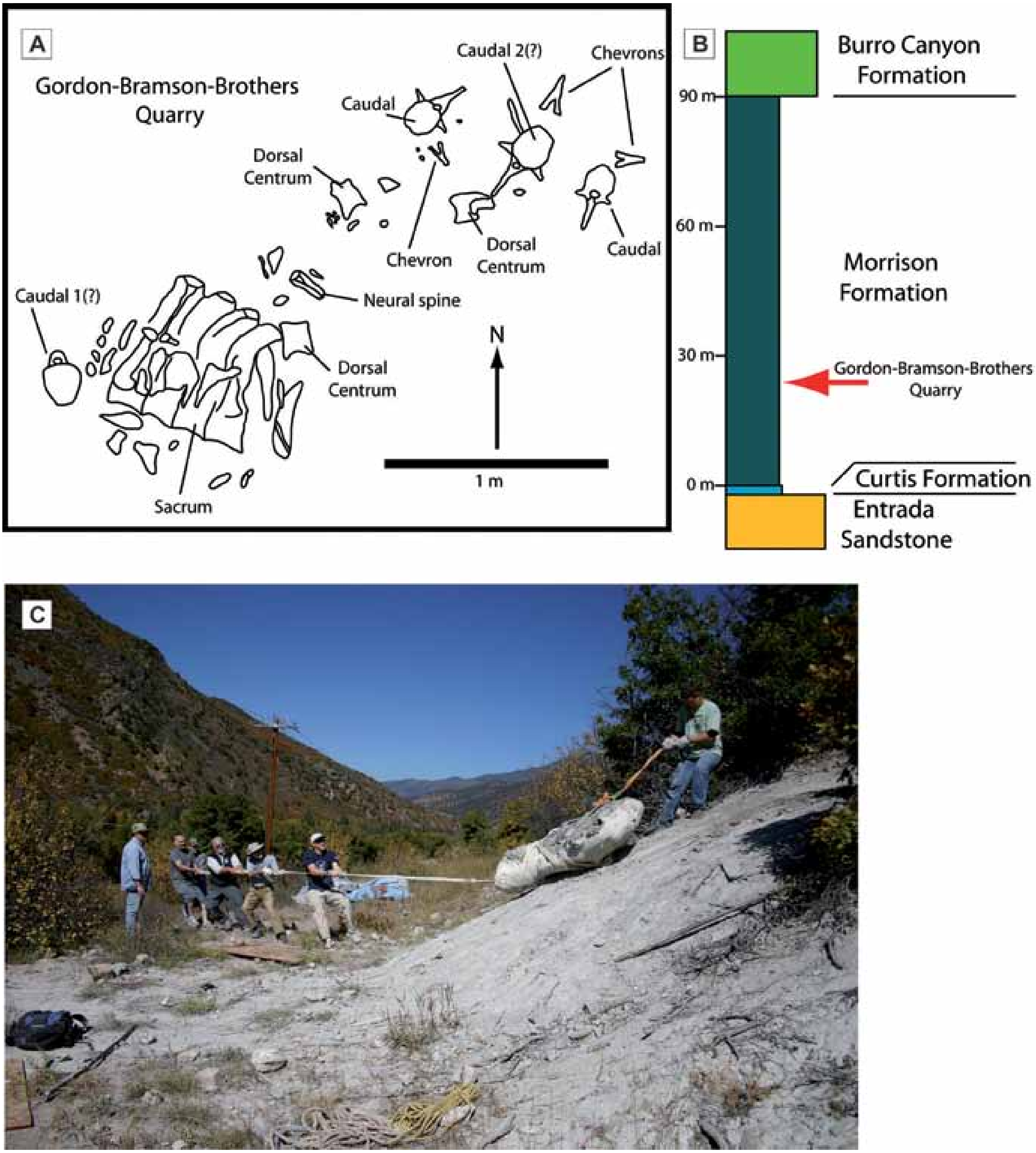

Fig. 2. Gordon-Bramson-Brothers Quarry

A. Quarry map showing association of anterior caudal and posterior dorsal vertebrae around the sacrum. **B.** Stratigraphic section showing position of the quarry within the Morrison Formation. **C.** Dragging field jacket containing the sacrum, one caudal, and two dorsal centra in September 2009. View looking north more closely matches the mudstone-limestone interbedding common in lower Morrison Formation outcrops of the Front Range area of Colorado. This stratigraphic level also puts the site at the approximate equivalent level (compared to respective local sections) as the Cabin Creek site near Gunnison (Bartleson, Jensen, 1988) and the Cleveland Museum's Delfs Quarry at Garden Park, the latter of which produced *Haplocanthosaurus delfsi* (McIntosh, Williams, 1988).

The Gordon-Bramson-Brothers Quarry is in a gray-green indurated mudstone and light gray siltstone, overlying a soft red mudstone. Below the quarry, from the base of the Morrison Formation up to within a few meters of the quarry stratigraphically, is an interval of interbedded gray mudstone and limestone beds, also noted by Mutschler (1970) elsewhere in the area in the lower Morrison Formation. The sauropod specimen described herein is an isolated and disarticulated, associated partial skeleton (Fig. 2A). Although the site is not yet fully excavated, the specimen is judged to represent a single individual because there are no duplicated elements nor are there any other dinosaur species in the deposit.

The specimen is highly fractured, most likely by Pleistocene frost-wedging at the site elevation of about 2,164 m and by root-wedging of a scrub-oak that was growing in the mudstone just above the specimen. Many of the pre-existing cracks in the specimen had matrix between them, and reassembly of the specimen was particularly challenging. Specimens deeper (down dip) in the quarry, including two of the caudal vertebrae, were in somewhat better condition but were still fractured.

SYSTEMATIC PALEONTOLOGY

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Sauropodomorpha Huene, 1932

Sauropoda Marsh, 1878

Neosauropoda Bonaparte, 1986

Haplocanthosaurus Hatcher, 1903

Haplocanthosaurus sp.

Figs. 3–7

Referred Specimen. – MWC 8028, fragmentary partial skeleton consisting of four dorsal centra, five partial ribs, the sacrum, five caudal vertebrae, three chevrons, five partial neural spines and many fragments.

Description. – The dorsal centra are thick-walled with procamerate pneumatic chambers (Fig. 3A–F); in the three best preserved vertebrae the lower borders of the lateral pneumatic fossae are preserved but the top of the centrum and all of the neural arch is missing. The dorsal centra are small (~15–16 cm diameter; see Table 1), and the lateral pneumatic fossae are anteroposteriorly elongated but shallow ventrally (Fig. 3B, D), with a thin medial septum; the ventral half of the centrum is solid in each vertebra. Although the dorsal elements are not complete, their

Table 1

Measurements of vertebrae in MWC 8028, *Haplocanthosaurus* sp.

Vertebra	Centrum height [mm]	Centrum width [mm]	Antero-posterior length [mm]	Total height (centrum and neural spine) [mm]
Dorsal A	150	100	130	–
Dorsal B	160	110	105	–
Dorsal C	–	–	~100	–
Dorsal D	–	85	110	–
Sacral 1 or 2	–	–	–	600
Sacral 4 or 5	165	~120	–	545
Caudal 1(?)	197	–	82	–
Caudal 2(?)	178	~150	60	420
Caudal 3 or 4(?)	157	148	84	–
Caudal 4 or 5(?)	155	–	90	–
Indet. caudal	195	–	~95	–

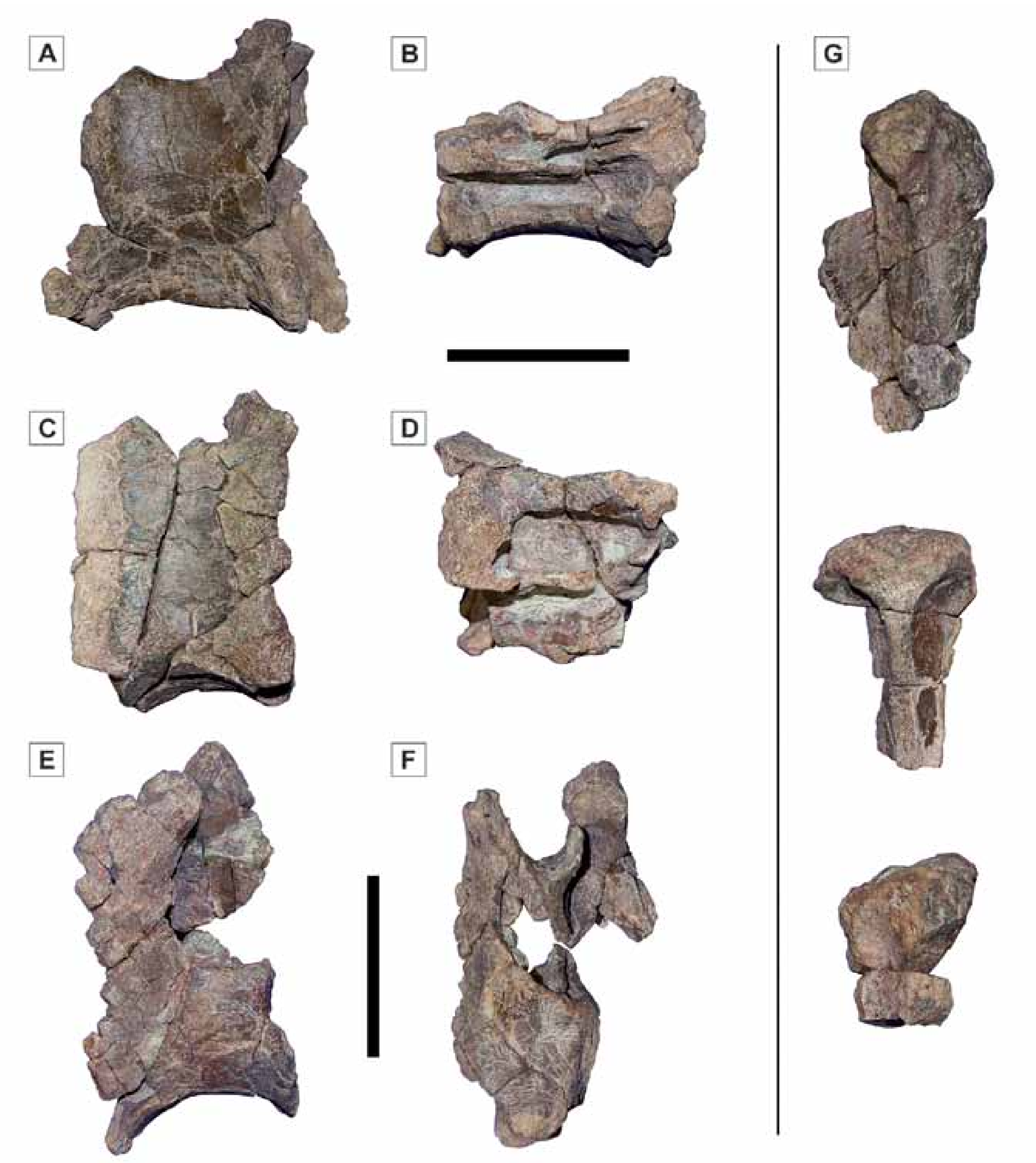

Fig. 3. MWC 8028, *Haplocanthosaurus* dorsal vertebrae

A. Lateral view of dorsal centrum with bottom edge of lateral pneumatic fossa preserved. **B.** Dorsal view of same centrum as in A, showing the median septum between the paired lateral fossae. **C.** Lateral view of dorsal centrum with smaller segment of the lateral pneumatic fossa margin preserved. **D.** Dorsal view of same centrum as in C, again showing the median septum and paired lateral fossae. **E.** Lateral view of dorsal centrum with partial pleurocoel preserved. **F.** Cross-sectional (posterior) view of same dorsal as in E. **G.** Dorsal neural spines in lateral (top) and anterior or posterior (center, bottom) views. Scale bars = 10 cm

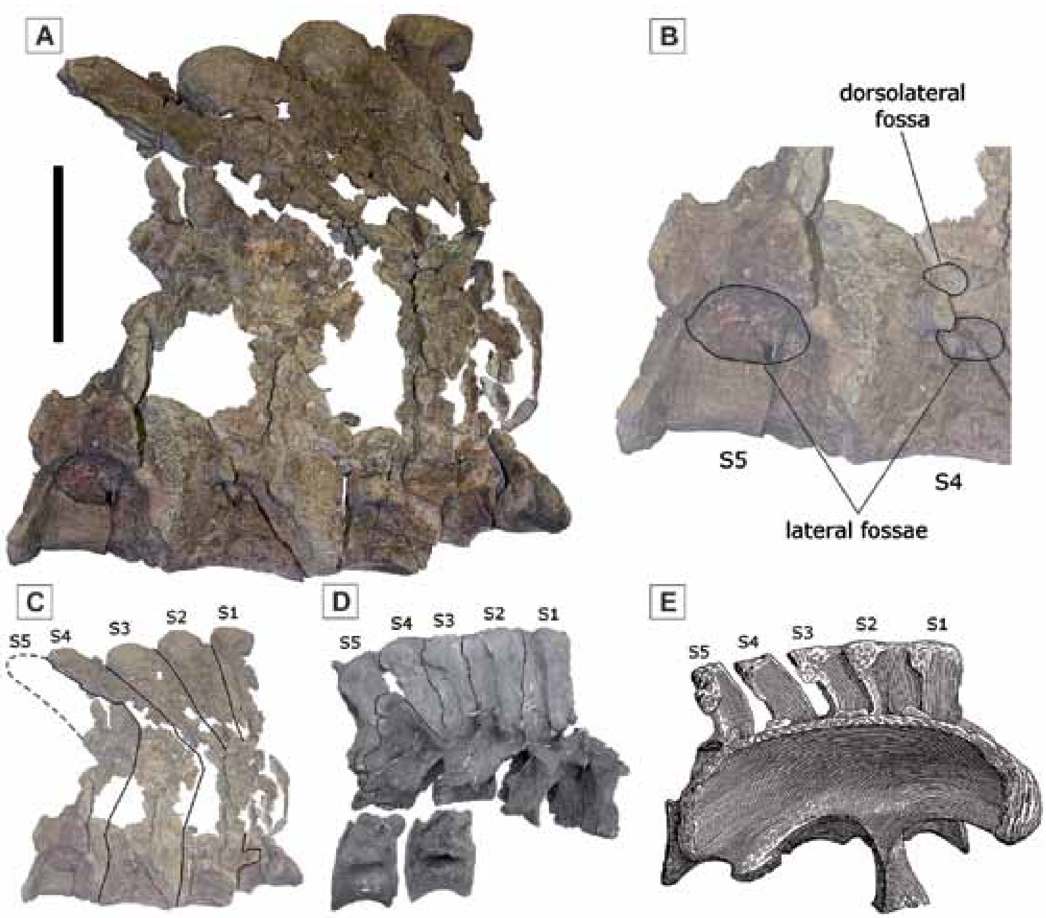

Fig. 4. Sacra of *Haplocanthosaurus*

A. MWC 8028, sacrum in right lateral view. **B.** MWC 8028, close-up of S4 and S5 centra highlighting pneumatic fossae. **C.** MWC 8028 with divisions between the vertebrae overlaid. **D.** CM 879, sacrum in right lateral view with divisions between the vertebrae overlaid. **E.** CM 572 in right lateral view, after Hatcher (1903c: plate 4). B–E are not shown at the same scale, scale bar for A = 20 cm. Note that the neural arches in CM 572 were restored during preparation, and the sacral neural spines as shown here are probably lower than they would have been in life

association with the sacrum suggests that they are posterior dorsal centra.

The dorsal neural spines (Fig. 3G) are non-bifurcate but differ from those intact on the anterior caudals in being slightly laterally expanded.

The sacrum (Fig. 4A–C) consists of at least five fused vertebrae with centrum diameters of approximately 16 cm. The sacral neural spines are graded from a nearly vertical orientation in S1 to strongly posteriorly inclined in S4; the spine of S5 was not preserved. The sacral neural arches are relatively tall, but this may be in part due to lateral compression. Additionally, the height to centrum diameter ratio of MWC 8028 is comparable to CM 879 (Fig. 4C, D) but higher than it appears to be in CM 572 (Fig. 4E; but the latter is reconstructed between the spines and centra, so the true arch height is difficult to assess in that specimen). The spine to centrum diameter ratio is lower than that seen in *Diplodocus.* Pneumatic fossae are present in the last two sacral centra, which we take to be S4 and S5. S4 has a small lateral fossa below the attachment of the sacral rib (which is broken away), and a nearly circular dorsolateral fossa above the sacral rib attachment. S5 bears only a single, large lateral fossa.

The anterior caudal vertebrae (Fig. 5A–K) are small with closed neurocentral sutures and no lateral pneumatic fossae. The centra are only ~15–20 cm in diameter and moderately amphicoelous to slightly procoelous (the differences between vertebrae likely preservational). They are antero-posteriorly short for their diameters, and have rectangular cross-sections with relatively flat ventral surfaces and straight

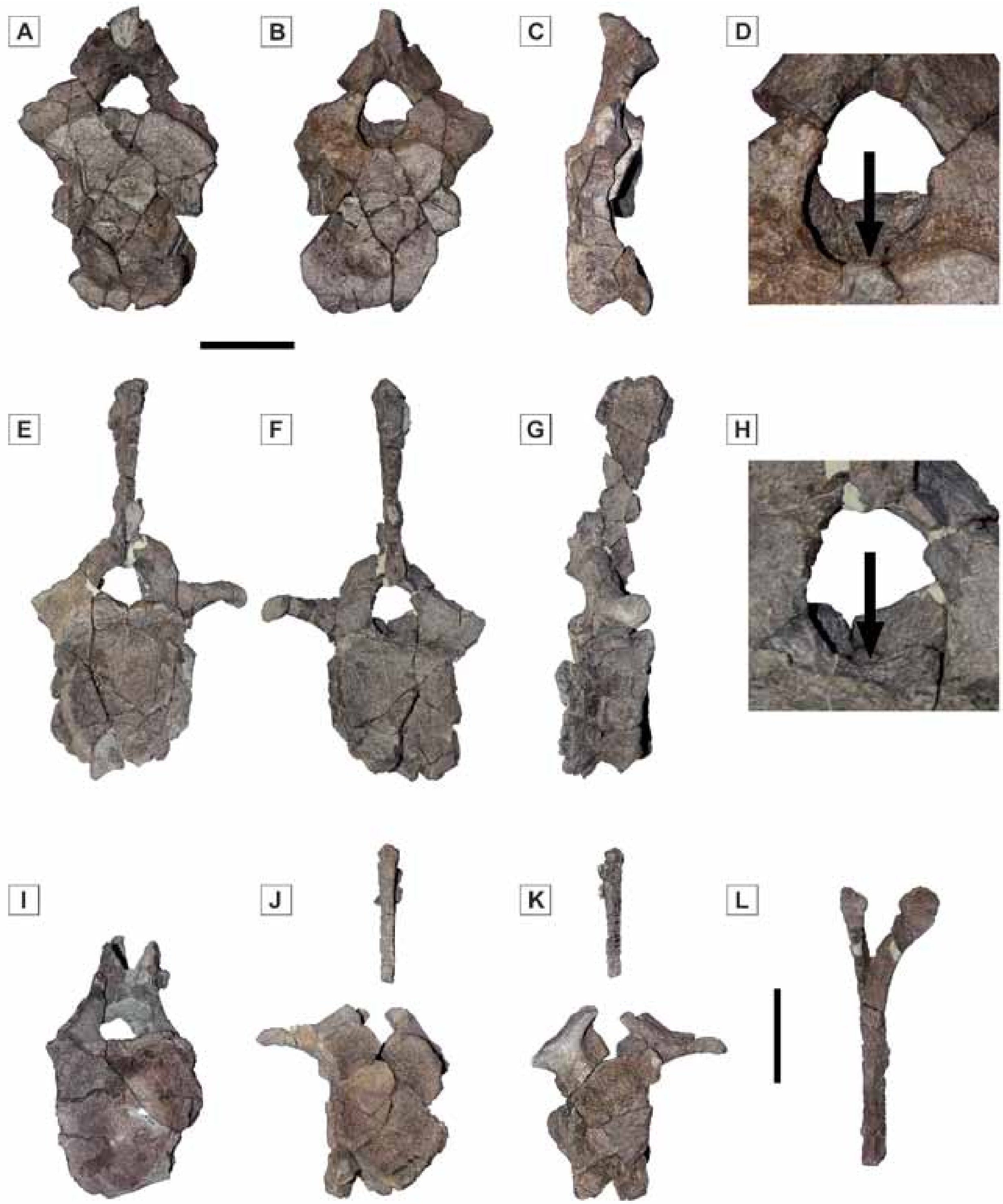

Fig. 5. MWC 8028, *Haplocanthosaurus*, caudal elements

A. Caudal 1(?) in anterior view. **B.** Caudal 1(?) in posterior view. **C.** Caudal 1(?) in right lateral view. **D.** Caudal 1(?), close-up of neural canal in posterior view with the ventral excavation highlighted by the arrow. **E.** Caudal 2(?) in anterior view. **F.** Caudal 2(?) in posterior view. **G.** Caudal 2(?) in left lateral view. **H.** Caudal 2(?), close-up of neural canal in posterior view with the ventral excavation highlighted by the arrow. **I.** Caudal 3 or 4 in anterior view. **J.** Caudal 4 or 5 in anterior view. **K.** Caudal 4 or 5 in posterior view. **L.** Chevron in posterodorsal view. Scale bars = 10 cm

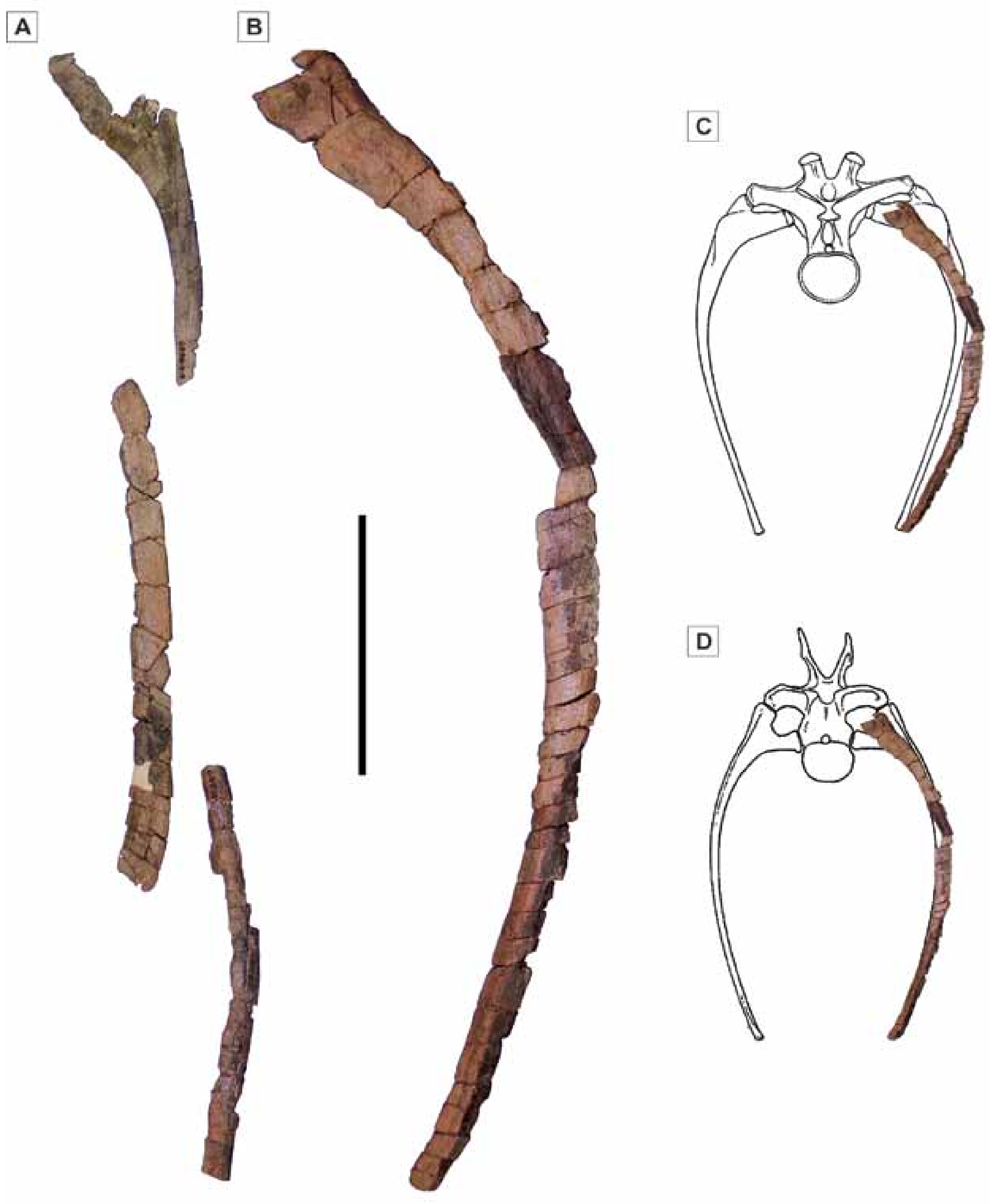

Fig. 6. MWC 8028, *Haplocanthosaurus*, ribs

A. Fragments of posterior ribs; the three pieces shown here do not belong to the same rib. **B.** The most complete posterior rib. **C.** Cross-section of *Camarasaurus* torso at the fourth dorsal vertebra (after Osborn, Mook, 1921: fig. 72), with the rib from B overlaid. **D.** Cross-section of *Diplodocus* torso at the seventh dorsal vertebra (after Holland, 1910: fig. 17), with the rib from B overlaid. Scale bar = 20 cm lateral sides. The neural canals are unusual: the anterior opening of each canal is smaller and set higher (more dorsally) than the posterior opening, and the floor of the neural canal is depressed a few millimeters into the dorsal surface of the centrum (Fig. 5D, H). The neural spines are simple, lack laminae, and are unexpanded dorsally. The caudal ribs are simple and fused to the centra. The chevron facets are large, and there are indications of anterior facets as well.

The ribs are very incomplete (Fig. 6A, B) with the most complete being a short posterior rib that is approximately 1 m in length along its lateral edge. The ribs are all apneumatic but otherwise mostly uninformative, although they do show that the animal had a deep, narrow torso like most other non-titanosaurian sauropods (Fig. 6C, D). Preserved chevrons (Fig. 5L) are simple, not fused proximally and unexpanded distally.

IDENTIFICATION

In identifying MWC 8028 we asked two questions: first, does the specimen bear any unique characters that might establish it as a new taxon, and second, if the specimen does not represent a new taxon, can it be referred to any of the known Morrison Formation sauropods? The only characters in MWC 8028 that stand out as possibly being unique are the extremely reclined spines of the posterior sacral vertebrae, and the unusual excavations in the neural canals of the caudal vertebrae.

The only other Morrison Formation sauropods with posterior sacral neural spines that are reclined to a similar degree as MWC 8028 are *Brachiosaurus altithorax* (see Riggs, 1904: plate 73) and *Haplocanthosaurus priscus* (Fig. 4D, E). This character seems to be subject to individual variation – the posterior sacral neural spines in CM 572 are more reclined than in CM 879, and the spines of MWC 8028 are a bit more reclined still, so that the three specimens form a sort of grade or cline. Ontogenetic patterns of ossification in the sacral vertebrae of Morrison Fm. sauropods are highly variable (Riggs, 1903; Wedel, Taylor, 2013: table 1), and to the extent that “fanning” of the sacral neural spines is related to fusion of the sacral neural arches and spines, it is reasonable to expect that it will also be variable. We note that CM 879 is least skeletally mature of the three specimens discussed here, and shows the least change in angle of the sacral neural spines along the series. For these reasons, it seems unwise to attach any taxonomic weight to this character.

The excavations in the neural canals of the caudal vertebrae of MWC 8028 are absent in CM 572 and FHPR 1106, and in all other Morrison Formation sauropods that we have examined. However, similar excavations have been noted in other, relatively less derived sauropods such as *Barapasaurus* (Jain *et al*., 1979). Schwarz *et al*. (2007) presented evidence for supramedullary pneumatic diverticula inside the neural canals of sauropods, similar to those found in extant birds. It is possible that the excavations are pneumatic in origin – fossae on the sacral vertebrae of MWC 8028 show that pneumatic diverticula extended at least that far caudally, and caudal pneumaticity is present in CM 879. Postcranial pneumatic features are notoriously variable (Wedel, 2005). Whether the excavations in the neural canals of the caudal vertebrae in MWC 8028 are pneumatic or not, their presence is likely due to individual variation.

Given that MWC 8028 lacks robust autapomorphies, the question arises of whether it is referable to a known taxon. Various morphological aspects prevent definitive identification of the material as any of the common diplodocid sauropods of the Morrison Formation (*Diplodocus*, *Apatosaurus*, *Barosaurus*). MWC 8028 lacks the wing-like caudal ribs, elongate neural spines with multiple laminae, and fully camerate or polycamerate centra seen in Morrison Fm. diplodocids. *Camarasaurus* possesses laterally expanded, fan-like dorsal neural spines, even in juvenile specimens (pers. obs.), and even the anterior caudal neural spines are somewhat laterally expanded. The dorsal neural spines of MWC 8028 are expanded only slightly and nowhere near their development in *Camarasaurus*; and the sacral and anterior caudal neural spines are not expanded at all, unlike *Camarasaurus*. Well-defined pneumatic fossae on the centra of the sacral vertebrae are absent in *Camarasaurus* (Wedel, 2009), but present in MWC 8028 (Fig. 4B). *Brachiosaurus* possesses much shorter sacral neural spines than MWC 8028 and has significantly more anteroposteriorly elongate dorsal centra (relative to their diameters). Even very young juvenile brachiosaurids appear to have had these relatively elongate dorsal centra (Carballido *et al*., 2012).

MWC 8028 is most similar in size and vertebral morphology to *Haplocanthosaurus priscus* (CM 572), and the stratigraphic level of its occurrence is consistent with the likelihood that the material belongs to this species. MWC 8028 is procamerate, like *H. priscus*, and, in cross-sectional CT views of the dorsal centra, has a low degree of pneumaticity, with nearly all of the lower half of the centrum consisting of solid bone (Fig. 7A–B), unlike even juvenile macronarians and diplodocids in the Morrison Formation, which are generally camerate to polycamerate (Wedel, 2003). CT scans of two posterior dorsal centra of a juvenile *Camarasaurus grandis* (MWC 2538) from the Morrison Formation at the Kings View Quarry near Fruita, Colorado, show that even in young individuals of these sauropods the dorsal centra are strongly pneumatic and camerate (Fig. 7C, D). MWC 2538 preserves in the dorsal vertebrae transversely expanded rugose neural spines, unfused neurocentral sutures, and the centra are approximately 14.6 cm in diameter.

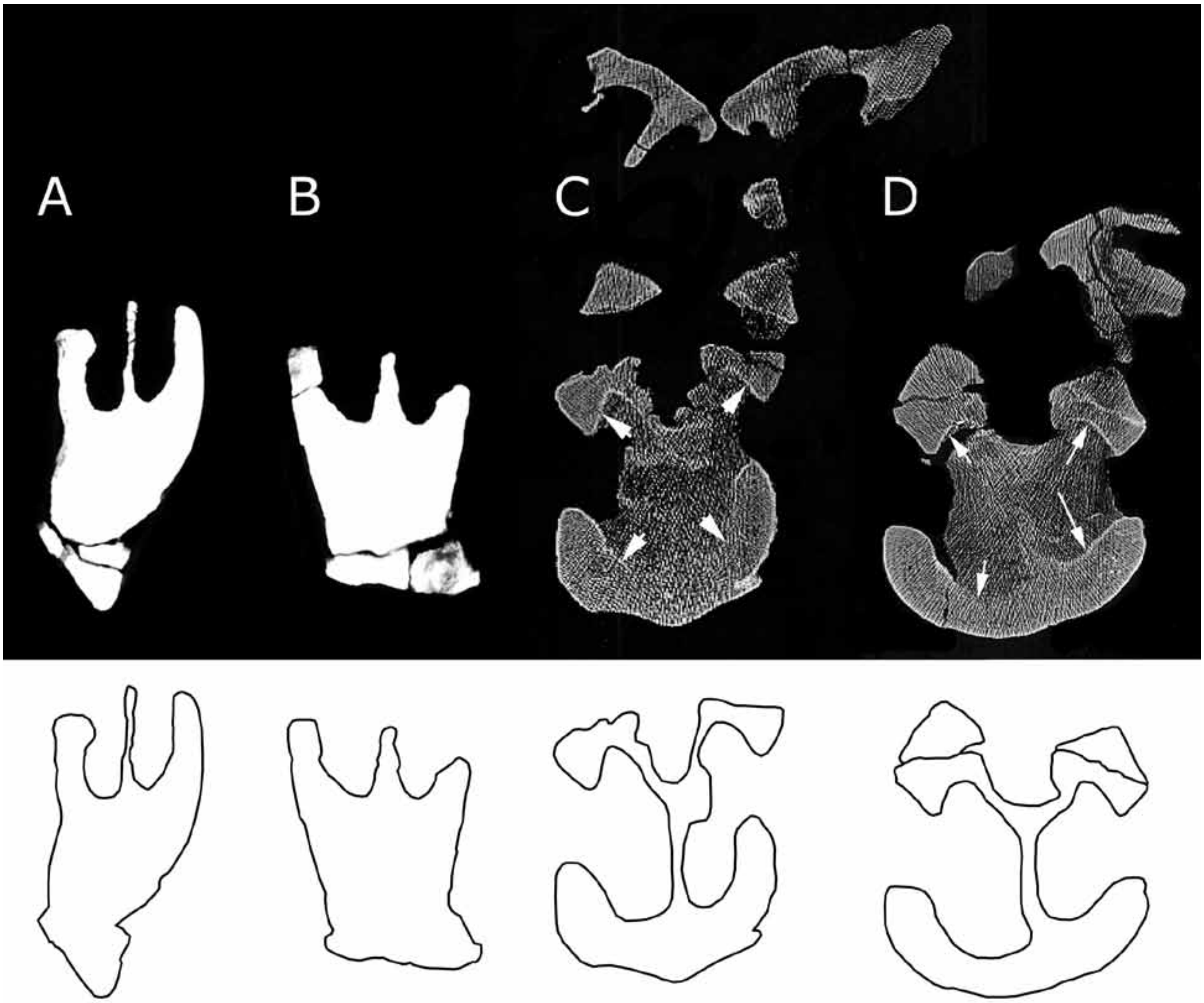

Fig. 7. CT scan image cross-sections of dorsal vertebral centra in MWC 8028 (referred to *Haplocanthosaurus*; A and B) and in a juvenile *Camarasaurus grandis* (MWC 2538; C and D)

Interpretive outlines of bone in each centrum below the CT scans. Dorsal centum diameters in all four vertebrae are approximately 15–16 cm. Note procamerate condition of centra in A and B; lower halves of the centra are solid and fossae are shallow. In C and D, the centra are camerate and the arrows point to the contact between the lower and upper edges of the camerae and the infilling matrix. These images contrast the much more pneumatic condition of the dorsal centra of even a juvenile *Camarasaurus* (C and D) with the more solid construction of the centra of MWC 8028. In CM 572 (*H. priscus*), the ventral half of each dorsal centrum is solid, as in MWC 8028 (Wedel, 2003, fig. 8; Wedel, 2009, fig. 6)

That dorsal centra of positively identifiable juvenile *Camarasaurus*, of a size comparable to those of MWC 8028, already demonstrate dramatically more pneumaticity indicates that MWC 8028 is unlikely to be simply a young individual of a more camerate sauropod species. The simple fossae of MWC 8028 are not a result of young age, and in fact nothing in the skeleton suggests a young individual; rather, the procamerate dorsal centra are of taxonomic significance and strongly suggest that the material belongs to *Haplocanthosaurus*, the only procamerate sauropod in the Morrison Formation (Wedel, 2003).

The sacral pneumatization in MWC 8028 is very similar to that present in the CM 879 specimen of *Haplocanthosaurus priscus*. In both specimens, the fourth sacral vertebra has a circular dorsolateral fossa just above the attachment of the sacral rib. Lateral fossae are more variable. In CM 879 a lateral fossa is present on the right side of S4 but absent on the left side of S4 and also absent on both sides of S5. In MWC

8028, lateral fossae are present on the right side of the centrum in both S4 and S5.

MWC 8028 is similar in morphology, but only slightly smaller than, FHPR 1106 (haplocanthosaurid), and the sacral and caudal vertebrae are ~50% smaller than CMNH 10380 (*H. delfsi*; McIntosh, Williams, 1988). The nearly rectangular cross-section of the anterior caudal vertebrae in MWC 8028 (relatively straight sides and ventral surface) is similar to what is seen in CM 572 and FHPR 1106. Perhaps the most interesting part of the skeleton preserved is the sacrum, which demonstrates relatively higher spined and slightly more posteriorly inclined sacral neural spines than previous specimens such as CM 572 and FHPR 1106. The full height of sacral 5 in CM 572 is approximately 2.44 times the height of its centrum; the same ratio in FHPR 1106 is 2.80; in *Diplodocus* (CM 94), for comparison, the full height is 3.13 times the centrum height. MWC 8028 has a full sacral height to centrum height ratio of 2.95. The height of the sacral neural spines in CM 572 may be an underestimation, however, because the bases of the spines, particularly S4, appear to be heavily reconstructed. That MWC 8028 has a higher ratio than FHPR 1106 may in part be due to lateral crushing of the former specimen. But, the posterior sweep of the sacral neural spines in MWC 8028 is not entirely unexpected, as FHPR 1106 demonstrates this characteristic to a somewhat lesser degree also.

In summary, MWC 8028 share several characters with *Haplocanthosaurus*, but does not closely resemble any other known Morrison Fm. sauropod. Nor does it appear to be a new taxon. Therefore we refer MWC 8028 to *Haplocanthosaurus* sp.

DISTRIBUTION

Haplocanthosaurus is rare in the Morrison Formation, and the Gordon-Bramson-Brothers Quarry is just the fourth locality to produce more than isolated elements attributed to this sauropod. The previous sites include: the Cleveland Museum Delfs Quarry (McIntosh, Williams, 1988) and Marsh-Felch Quarry (Hatcher, 1903c; Evanoff, Carpenter, 1998; both Garden Park, Colorado); and the Poison Creek Quarry (Erickson, 2014) in Wyoming. The Williams Slow Eagle Quarry in Utah produced the most complete and well-preserved specimen of a haplocanthosaurid, but the specimen is still under study and the generic identification has not been released (Bilbey *et al*., 2000). Other sites with unconfirmed, isolated bones that may belong to *Haplocanthosaurus* include the Red Fork of the Powder River Quarry B in Wyoming (McIntosh, 1981); and the Carnegie Quarry (Dinosaur National Monument catalog; Foster, 2003; D. Chure, pers. comm., 2014). See Table 2 for a summary of specimens. The specimen from Freezeout Hills Quarry N (listed by Foster, 2003 based on a single caudal from the FMNH) is one we cannot relocate or confirm; we suspect this is a misidentification. The Garden Park Sauropod Quarry specimen reported in Carpenter (1998) and Foster (2003) proved, on removal of more material, to be a diplodocid (K. Carpenter, pers. comm., 2014).

We note that the most diagnostic elements of *Haplocanthosaurus* are the dorsal vertebrae, and because the specimens previously identified as belonging, or possibly belonging, to this genus from the Red Fork of the Powder River B, Poison Creek, and Carnegie Quarry are based on either caudals or girdle and/or limb material, we consider these identifications tenuous. For example, the scapula from the Carnegie Quarry (DINO 4771; Table 2) lacks the dorsally and ventrally expanded distal shaft listed as an autapomorphy of *Haplocanthosaurus* by Wilson (2002) and may instead belong to *Camarasaurus*. Regarding the SMM specimen from Poison Creek, the enlarged chevron facets of *Haplocanthosaurus* can be distinctive in concert with other characters but are a somewhat variable, and thus subjective, characteristic on which to identify material; characters of the limb elements are not among the autapomorphies listed for *Haplocanthosaurus* by Wilson (2002) or Whitlock (2011). It is therefore possible that confirmed *Haplocanthosaurus* specimens are known only from the Marsh-Felch, Cleveland Delfs, and Gordon-Bramson-Brothers quarries and include just four individuals.

CLASSIFICATION

Haplocanthosaurus has had a bit of an unstable systematic history, often residing near the Macronaria-Diplodocoidea split (Taylor, Naish, 2005). It has been classified as a macronarian close to *Camarasaurus* and *Brachiosaurus* (Upchurch, 1995; Wilson, Sereno, 1998; Pisani *et al*., 2002; Upchurch *et al*., 2004), although others have had it either in the Cetiosauridae (McIntosh, 1990a, b) or, most often, allied with the Diplodocoidea as a basal taxon (Bonaparte, 1986b; Wilson, 2002; Whitlock, 2011; Mannion *et al*., 2012). In some cases it has been hypothesized as a basal neosauropod outside both Diplodocoidea and Macronaria (Harris, 2006; and compiled in Sander *et al*., 2011, fig. 4). Bones from the Gordon-Bramson-Brothers Quarry add little to the character list for *Haplocanthosaurus*, but sacra of this and other specimens suggest that the sacral neural spines are not as low as previously thought.

Table 2

Sauropod specimens from the Morrison Formation attributed to *Haplocanthosaurus*

Identification	Specimen Number	Quarry	State	Elements	Reference
H. priscus	CM 572	Marsh-Felch	Colorado	Two cervical, ten dorsals, sacrum, 19 caudals, ribs, two chevrons, ilia, pubes, ischia, femur; probably also includes CM 33995 (scap-coracoid), CM 2043 (right tibia, fibula, astragalus), and CM 2046 (left tibia and fibula)	Hatcher, 1903c
H. utterbacki (= *H. priscus*)	CM 879	Marsh-Felch	Colorado	Ten cervicals, 13 dorsals, sacrum, seven caudals, ribs, scapular, and coracoid	Hatcher, 1903c
H. delfsi	CMNH 10380	Cleveland Delfs	Colorado	Four cervicals, nine dorsals, ribs, sacrum, 14 caudals, chevrons, partial scapula, fragmentary coracoids, sternal plate, partial radius and ulna, ilia, pubis, ischium, femur	McIntosh and Williams, 1988
Haplocanthosaurus sp.	MWC 8028	Gordon-Bramson-Brothers	Colorado	Four dorsal centra, two ribs, sacrum, five caudals, three chevrons	This paper
Haplocanthosaurus?	CM 36034	Red Fork Powder River Quarry B	Wyoming	Mid caudal	McIntosh, 1981
Haplocanthosaurus?	SMM P90.37.10	Poison Creek	Wyoming	Left tibia, fibula, astragalus, calcaneum, left metatarsals I-V, three phalanges, two unguals	Erickson, 2014
Haplocanthosaurus?	SMM P84.15.4	Poison Creek	Wyoming	25+ caudals	Erickson, 2014; Foster, pers. obs., 1997
Haplocanthosaurus?	DINO 3017	Carnegie Quarry, DNM	Utah	Caudal centrum	DNM catalog; Foster, 2003
Haplocanthosaurus?	DINO 4771	Carnegie Quarry, DNM	Utah	Left scapula; juvenile	DNM catalog; Foster, 2003
Haplocanthosaurus?	DINO 13742	Carnegie Quarry, DNM	Utah	Femur	DNM catalog; Foster, 2003
Haplocantho-saurid indet.	FHPR 1106	Williams Slow Eagle	Utah	Five cervicals, seven dorsals, seven ribs, sacrum, 37 caudals, 19 chevrons, right scapula, left scap-coracoid, right coracoid, sternal plate, humeri, radii, left ulna, 10 metacarpals, phalanges, three unguals, ischia, left ilium, pubes, femora, fibulae, left tibia, astragali, calcanea, 10 metatarsals, 11 phalanges, six unguals	Bilbey *et al.*, 2000

See text for additional details regarding some identifications

SUMMARY

A very incomplete partial skeleton of a small but apparently adult sauropod from the lower one-third of the Morrison Formation near Snowmass, Colorado, is identified as *Haplocanthosaurus* based on tall neural arch peduncles, strongly reclined neural spines on the sacrum and procamerate posterior dorsal vertebrae. The occurrence of this taxon is noteworthy because it is one of the rarest of the Morrison Formation sauropods.

Acknowledgements. Thanks to Jessica and Bennett Bramson for alerting the scientific community to the find, for hosting our crews at the site, and for arranging the donation of the specimen to the MWC. Thanks to Mike Gordon for discovering the specimen and for help during the early days of the excavation. The Brothers families generously donated the specimen from their property, and Anthony Maltese and Mike Triebold shared data and materials from Triebold Paleontology's initial excavation of the site. Access to *Haplocanthosaurus* specimens CM 572 and CM 879 was courtesy of Matt Lamanna and Dan Pickering of the Carnegie Museum of Natural History; FHPR 1106 access thanks to Steve Sroka of the Utah Field House. Reviews by Brooks Britt, Spencer Lucas, and Adrian Hunt improved the manuscript and are gratefully acknowledged. Thanks to Community Hospital of Grand Junction and Moab Regional Hospital for CT imaging. Big thanks to the many MWC volunteers and staff who helped out with the excavations. Kay Fredette, Nancy Colaizzi, and several other MWC lab volunteers prepared the specimen, which became an increasingly trying task as the surrounding matrix became more indurated. Finally, data and discussions shared by Dan Chure, Cary Woodruff, Sue Ann Bilbey, and Evan Hall are greatly appreciated.

REFERENCES

BARTLESON B.L., JENSEN J.A., 1988 — The oldest (?) Morrison Formation dinosaur, Gunnison, Colorado. *The Mountain Geologist*, **25**: 129–139.

BILBEY S.A., HALL J.E., HALL D.A., 2000 — Preliminary results on a new haplocanthosaurid sauropod dinosaur from the lower Morrison Formation of northeastern Utah. *Journal of Vertebrate Paleontology*, **20** (supp. to no. 3): 30A.

BONAPARTE J.F., 1986a — Les dinosaurs (Carnosaures, Allosauridés, Sauropodes, Cétiosauridés) du Jurassique moyen de Cerro Cóndor (Chubut, Argentina). *Annales de Paléontologie*, **72**: 325–386.

BONAPARTE J.F., 1986b — The early radiation and phylogenetic relationships of the Jurassic sauropod dinosaurs, based on vertebral anatomy. *In*: The beginning of the age of dinosaurs (Ed. K. Padian): 247–258. Cambridge University Press.

CARBALLIDO J.L., MARPMANN J.S., SCHWARZ-WINGS D., PABST B., 2012 — New information on a juvenile sauropod specimen from the Morrison Formation and the reassessment of its systematic position. *Palaeontology*, **55**: 567–582.

CARPENTER K., 1998 — Vertebrate biostratigraphy of the Morrison Formation near Cañon City, Colorado. *Modern Geology*, **23**: 407–426.

DODSON P., BEHRENSMEYER A.K., BAKKER R.T., McINTOSH J.S., 1980 — Taphonomy and paleoecology of the dinosaur beds of the Jurassic Morrison Formation. *Paleobiology*, **6**: 208–232.

ERICKSON B.R., 2014 — History of the Poison Creek Expeditions 1976–1990, with description of *Haplocanthosaurus* post cranials and a subadult diplodocid skull. *Science Museum of Minnesota Monograph*, **8**: 1–34.

EVANOFF E., CARPENTER K., 1998 — History, sedimentology, and taphonomy of Felch Quarry 1 and associated sandbodies, Morrison Formation, Garden Park, Colorado. *Modern Geology*, **22**: 145–169.

FOSTER J.R., 2001 — Relative abundances of the Sauropoda (Dinosauria, Saurischia) of the Morrison Formation and implications for Late Jurassic paleoecology of North America. *Mesa Southwest Museum Bulletin*, **8**: 47–60.

FOSTER J.R., 2003 — Paleoecological analysis of the vertebrate fauna of the Morrison Formation (Upper Jurassic), Rocky Mountain region, U.S.A. *New Mexico Museum of Natural History and Science Bulletin*, **23**: 1–95.

FREEMAN V.L., 1972 — Geologic map of the Woody Creek quadrangle, Pitkin and Eagle counties, Colorado. *USGS Geologic Quadrangle Map* GQ–967, 1:24,000.

HARRIS J.D., 2006 — The significance of *Suuwassea emilieae* (Dinosauria: Sauropoda) for flagellicaudatan interrelationships and evolution. *Journal of Systematic Palaeontology*, **4**: 185–198.

HATCHER J.B., 1903a — A new sauropod dinosaur from the Jurassic of Colorado. *Proceedings of the Biological Society of Washington*, **16**: 1–2.

HATCHER J.B., 1903b — A new name for the dinosaur *Haplocanthus* Hatcher. *Proceedings of the Biological Society of Washington*, **16**: 100.

HATCHER J.B., 1903c — 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**: 1–72.

HOLLAND W.J., 1910 — A review of some recent criticisms of the restorations of sauropod dinosaurs existing in the museums of the United States, with special reference to that of *Diplodocus carnegiei* [sic] in the Carnegie Museum. *American Naturalist*, **44**: 259–283.

HUENE F. von, 1932 — Die fossile Reptil-Ordnung Saurischia, ihre Entwicklung und Geschichte. *Monographien zur Geologie und Paläontologie*, **4**: 1–361.

ICZN, 1991 — *Haplocanthosaurus* Hatcher, 1903 (Reptilia, Saurischia): conserved. *Bulletin of Zoological Nomenclature*, **48**: 83.

JAIN S.L., KUTTY T.S., ROY-CHOWDHURY T.K., CHATTERJEE S., 1979 — Some characteristics of *Barapasaurus tagorei*, a sauropod dinosaur from the Lower Jurassic of Deccan, India. Proceedings of the IV International Gondwana Symposium, Calcutta, 1: 204–216.

LUCAS S.G., HUNT A.P., 1989 — *Haplocanthosaurus* Hatcher, 1903 (Reptilia, Saurischia): proposed conservation. *Bulletin of Zoological Nomenclature*, **46**: 262–263.

MANNION P.D., UPCHURCH P., MATEUS O., BARNES R.N., JONES M.E.H., 2012 — New information on the anatomy and systematic position of *Dinheirosaurus lourinhanensis* (Sauropoda: Diplodocoidea) from the Late Jurassic of Portugal, with a review of European diplodocoids. *Journal of Systematic Palaeontology*, **10**: 521–551.

MARSH O.C., 1878 — Principal characters of American Jurassic dinosaurs. Part I. *American Journal of Science*, Series 3, **16**: 411–416.

McINTOSH J.S., 1981 — Annotated catalogue of the dinosaurs (Reptilia, Archosauria) in the collections of Carnegie Museum of Natural History. *Bulletin of Carnegie Museum of Natural History*, **18**: 1–67.

McINTOSH J.S., 1990a — Sauropoda. *In*: The dinosauria (eds D.B. Weishampel *et al*.): 345–401. University of California Press.

McINTOSH J.S., 1990b — Species determination in sauropod dinosaurs with tentative suggestions for their classification. *In*: Dinosaur systematics: Perspectives and approaches (eds K. Carpenter, P.J. Currie): 53–69. Cambridge University Press.

McINTOSH J.S., WILLIAMS M.E., 1988 — A new species of sauropod dinosaur, *Haplocanthosaurus delfsi* sp. nov., from the Upper Jurassic Morrison Fm. of Colorado. *Kirtlandia*, **43**: 3–26.

MUTSCHLER F.E., 1970 — Geologic map of the Snowmass Mountain quadrangle, Pitkin and Gunnison counties, Colorado. *USGS Geologic Quadrangle Map* GQ–853, 1:24,000.

OSBORN H.F., MOOK C.C., 1921 — *Camarasaurus*, *Amphicoelias*, and other sauropods of Cope. *Memoirs of the American Museum of Natural History, new series*, **3**: 247–387.

OWEN R., 1842 — Report on British fossil reptiles, Part II. *Reports of the British Association for the Advancement of Science*, **11**: 60–204.

PISANI D., YATES A.M., LANGER M.C., BENTON M.J., 2002 — A genus-level supertree of the Dinosauria. *Proceedings of the Royal Society of London B*, **269**: 915–921.

RIGGS E.S., 1903 — Structure and relationships of the opisthocoelian dinosaurs, part I: *Apatosaurus* Marsh. *Field Columbian Museum Publications in Geology*, **2**: 165–196.

RIGGS E.S., 1904 — Structure and relationships of the opisthocoelian dinosaurs, part II: the Brachiosauridae. *Field Columbian Museum Publications in Geology*, **2**: 229–247.

SANDER P.M., CHRISTIAN A., CLAUSS M., FECHNER R., GEE C.T., GRIEBELER E.-M., GUNGA H.-C., HUMMEL J., MALLISON H., PERRY S.F., PREUSCHOFT H., RAUHUT O.W.M., REMES K., TÜTKEN T., WINGS O., WITZEL U., 2011 — Biology of the sauropod dinosaurs: the evolution of gigantism. *Biological Reviews*, **86**: 117–155.

SCHWARZ D., FREY E., MEYER C.A., 2007 — Pneumaticity and soft-tissue reconstructions in the neck of diplodocid and dicraeosaurid sauropods. *Acta Palaeontologica Polonica*, **52**, 1: 167–188.

SEELEY H.G., 1888 — On the classification of the fossil animals commonly named Dinosauria. *Proceedings of the Royal Society of London*, **43**: 165–171.

TAYLOR M.P., NAISH D., 2005 — The phylogenetic taxonomy of Diplodocoidea (Dinosauria: Sauropoda). *PaleoBios*, **25**: 1–7.

TURNER C.E., PETERSON F., 1999 — Biostratigraphy of dinosaurs in the Upper Jurassic Morrison Formation of the Western Interior, U.S.A. *Utah Geological Survey Miscellaneous Publication*, **99-1**: 77–114.

UPCHURCH P., 1995 — The evolutionary history of sauropod dinosaurs. *Philosophical Transactions of the Royal Society of London B*, **349**: 365–390.

UPCHURCH P., BARRETT P.M., DODSON P., 2004 — Sauropoda. *In*: The Dinosauria (eds D. B. Weishampel *et al*.): 259–322. 2nd edition. University of California Press.

WEDEL M.J., 2003 — The evolution of vertebral pneumaticity in sauropod dinosaurs. *Journal of Vertebrate Paleontology*, **23**: 344–357.

WEDEL M.J., 2005 — Postcranial skeletal pneumaticity in sauropods and its implications for mass estimates. *In*: The sauropods: Evolution and paleobiology (eds J.A. Wilson, K. Curry-Rogers): 201–228. University of California Press, Berkeley.

WEDEL M.J., 2009 — Evidence for bird-like air sacs in saurischian dinosaurs. *Journal of Experimental Zoology*, **311A** (8): 611–628.

WEDEL M.J., TAYLOR M.P., 2013 — Caudal pneumaticity and pneumatic hiatuses in the sauropod dinosaurs *Giraffatitan* and *Apatosaurus*. *PLoS ONE*, **8** (10): e78213. doi: 10.1371/journal.pone.0078213

WHITLOCK J.A., 2011 — A phylogenetic analysis of Diplodocoidea (Saurischia: Sauropoda). *Zoological Journal of the Linnean Society*, **161**: 872–915.

WILSON J.A., 2002 — Sauropod dinosaur phylogeny: critique and cladistic analysis. *Zoological Journal of the Linnean Society*, **136**: 217–276.

WILSON J.A., SERENO P.C., 1998 — Early evolution and higher-level phylogeny of sauropod dinosaurs. *Society of Vertebrate Paleontology Memoir 5, Journal of Vertebrate Paleontology*, **18** (supplement to n. 2): 1–68.