Proceedings of the 9th Conference on Fossil Resources
Kemmerer, WY, April 2011

Brigham Young University Geology Studies
Volume 49(A):75–82, 2011

ARTICLE

ANCHISAURUS FROM SPRINGFIELD ARMORY

JUSTIN S. TWEET[1] and VINCENT L. SANTUCCI[2]
[1]Tweet Paleo-Consulting, 9149 79th St. S., Cottage Grove, Minnesota 55016, jtweet.nps.paleo@gmail.com
[2]National Park Service, Geologic Resources Division, 1201 Eye Street, NW, Washington, D.C. 20005, vincent_santucci@nps.gov

ABSTRACT—The term "dinosaur" was only 13 years old in 1855 when blasting operations at the Water Shops of Springfield Armory in Massachusetts uncovered the partial fossil skeleton of an extinct reptile. Paleontological discoveries were not new to the area; the Connecticut River Valley, which includes the Armory, was an early hotbed of vertebrate paleontology thanks to the combination of Late Triassic–Early Jurassic-age footprints and interested naturalists. The Armory specimen, now the holotype of *Anchisaurus polyzelus*, has passed through several generic names and been classified with theropods, prosauropods, and sauropods. Views on its paleobiology have changed from an active carnivore, to an herbivore, to an omnivore. Along the way, it has been discussed in print by numerous well-known figures in paleontology.

The holotype of *A. polyzelus* is one of a handful of tetrapod body fossils from the Hartford Basin. As part of the history of Springfield Armory National Historic Site, it is also one of many historically and scientifically significant fossil specimens associated with National Park System areas.

KEYWORDS—*Anchisaurus*, Springfield Armory National Historic Site, Portland Formation, Hartford Basin, History of Paleontology

INTRODUCTION

Although today Western states are better known for having fossils, the history of American paleontology started in the Northeast. In the United States, the first fossils now ascribed to dinosaurs were found in New England's Deerfield and Hartford basins. The uppermost Mesozoic rock unit in the Hartford Basin—the Early Jurassic-age Portland Formation—boasts North America's earliest-reported dinosaur tracks (1802) (Olsen et al. 1992) and the first dinosaur bones collected (1818) and published (1820) (Santucci 1998). Among other historic finds from the Portland Formation is a partial skeleton of a basal sauropodomorph (prosauropod in traditional usage) discovered at Springfield Armory in 1855. This specimen later became the holotype of *Anchisaurus polyzelus*.

Springfield Armory, a manufacturing site for U.S. military small arms from 1794–1968, located in Springfield, Massachusetts (Point1 in Fig. 1), was the nation's first federal armory. It included two main sites: the Hill Shops (or Hillshops), which were used as a storage depot during the American Revolutionary War era and have been partly protected as Springfield Armory National Historic Site since1974; and the Water Shops (or Watershops)—three locations on the Mill River approximately 1.6 km (1 mile) south of the Hill Shops, constructed as heavy manufacturing sites around the turn of the 19th century and presently under private ownership. Although the Water Shops are not formally administered or managed by the National Park Service as part of the National Historic Site, the national historic site maintains a relationship with the owners and interprets the Water Shops (A. MacKenzie, pers. comm., March 2010). The *Anchisaurus* skeleton was discovered when the three Water Shops were consolidated in 1855 .

The Springfield Armory complex is located in the Connecticut River Valley just east of the Connecticut River in the Hartford Basin, an early Mesozoic-age structural feature (Fig. 1). The underlying geology consists of red sandstone and siltstone bedrock (the Portland Formation) (Zen et al. 1983) overlain by much younger surficial deposits of Quaternary till and glacial lake delta outwash (Hartshorn and Koteff 1967).

GEOLOGICAL CONTEXT: THE HARTFORD BASIN

The Hartford Basin formed with the breakup of the supercontinent Pangaea during the Late Triassic. The Deerfield Basin to the north was probably continuous with it (P. Olsen, pers. comm., November 2010). The two basins belong to a series of rift basins paralleling the Appalachian Mountains from northern South Carolina to Nova Scotia. Sediments deposited in the rift basins are together known as the Newark Supergroup and record 35 million years of continental rifting (Olsen 1980a). The supergroup's formations are divided into three groups, in ascending order: the Chatham Group, Meriden Group, and Agawam Group (including the Portland Formation) (Weems and Olsen 1997). Structurally, the Hartford Basin is a half-graben that is tilted to the east and bounded on one side by a major fault (Hubert et al. 1978). Because the fault is on the east side of the basin, the formations within thicken to the east, and the younger formations, including the Portland Formation, are found in the eastern portion of the basin (Horne et al. 1993).

Flood basalts, faulting, and folding accompanied the rifting (Olsen 1980b). The eruption of the Newark Supergroup's flood basalts probably occurred over fewer than 600,000 years at about 201 Ma (Olsen et al. 1996, 2003b), straddling the Tri-

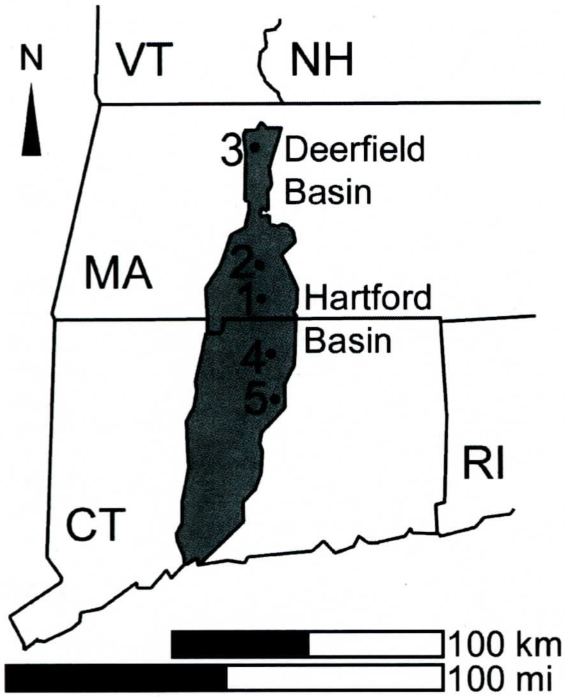

FIGURE 1. A schematic diagram of the Hartford Basin and smaller Deerfield Basin to the north, with significant locations discussed in the text denoted by points as follows: 1 represents Springfield, 2 represents South Hadley, 3 represents Greenfield, 4 represents East Windsor, and 5 represents Manchester. After Robinson and Kapo (2003), Fig. 1, courtesy of the U.S. Geological Survey.

assic–Jurassic boundary (Kozur and Weems 2010). Current research indicates an age of approximately 201.4 Ma for the oldest basalts of the Supergroup and approximately 201.3 Ma for the Triassic–Jurassic boundary (Schoene et al. 2010). The volcanic rocks are part of the Central Atlantic Magmatic Province (CAMP), one of the largest known volcanic provinces on Earth, found in outcrops from Europe and West Africa to central Brazil and eastern North America (Marzoli et al. 1999).

The Newark Supergroup is known for its cyclic depositional patterns, shifting between mud flat, shallow lake, and fluvial deposition (Olsen 1980c). Such cycles are evidence of ancient Milankovitch cycles (Olsen 1997), which are keyed to various characteristics of Earth's movement in space (Olsen and Whiteside 2008). Their modern durations can be used to establish chronologies in the rocks. The foundational cycle is the Van Houten cycle of lake transgression and regression, interpreted as representing the approximately 20,000-year cycle of the precession of the equinoxes (Olsen 1986; Olsen and Kent 1996). Several other cycles are also evident in the Hartford Basin rocks, including cycles with durations of approximately 100,000 years, 405,000 years, and 1.75 million years (Olsen 1997; Olsen and Kent 1999; Olsen et al. 2002).

THE PORTLAND FORMATION

The Portland Formation is composed of arkosic and non-arkosic sandstone, siltstone, conglomerate, and shale (Krynine 1950), deposited on top of the uppermost volcanic units of the basin, the Hampden Basalt (Hubert et al. 1978) and Granby Tuff (Olsen 1997), and dated to the first half of the Early Jurassic (Weems and Olsen 1997; Olsen et al. 2002; Kent and Olsen 2008; Kozur and Weems 2010). It varies substantially in composition vertically and horizontally (LeTourneau and McDonald 1985), and has distinct lower and upper portions: the lower half is mostly composed of fine- to medium-grained red arkose and siltstone, with some dark shale, while the upper is mostly medium- to coarse-grained red arkose with conglomerate (Krynine 1950). Cyclical rocks including lacustrine deposition are found in the lower half, while the upper half lacks cyclical rocks and is composed of fluvial rocks (Olsen et al. 2003a). Conglomerates generally represent alluvial fans, sandstones braided river systems or distal alluvial fans, siltstones floodplains, gray sandstones and siltstones lake margins, and dark siltstones and shales rift lake deposits (LeTourneau 1985). The lower Portland Formation can be interpreted as a closed basin where subsidence exceeded deposition, allowing for the formation of large lakes. The opposite was true of the upper part (Olsen 1997)—as subsidence decreased, fluvial processes came to dominate (Hubert et al. 1992). Springfield Armory's bedrock is sandstone-dominated (LeTourneau and McDonald 1985) and is from the upper, entirely fluvial part of the formation (P. Olsen, pers. comm., February 2010).

The paleogeography of the Portland Formation has been described in some detail (see for example LeTourneau and McDonald 1985). Large alluvial fans accumulated along the eastern margin of the depositional basin, near the border fault. Most of the sediment came from a narrow band of rocks to the east, immediately adjacent to the fault (Krynine 1950). During wet periods, lakes and rivers were common, whereas alluvial fans and ephemeral streams were the major depositional environments during dry periods (Horne et al. 1993). Lakes were deepest and longest-lived in the deeper eastern part of the basin, while much of the western and central basin was occupied by broad, low-gradient plains with shallow alkaline lakes (McDonald and LeTourneau 1988).

Paleoclimatological interpretations of the formation emphasize seasonality and semi-aridity (Lull 1912; LeTourneau and McDonald 1985). Deposition occurred at tropical paleolatitudes of approximately 21° to 23° N (Kent and Tauxe 2005) and the climate oscillated between humid and semi-arid over long periods (McDonald and LeTourneau 1988). Relatively arid conditions prevailed for the lower Portland Formation, but the upper part of the formation was deposited under a more humid and possibly cooler climate, perhaps due to regional uplift (Cornet 1989).

The Portland Formation boasts a diverse fossil assemblage. Microbial and plant fossils include oncolites and stromatolites (McDonald and LeTourneau 1988; McDonald 1992), palynomorphs (including fern spores and cycad pollen; Cornet and

Traverse 1975), the horsetail *Equisetites* (LeTourneau and McDonald 1985), bennettitales (McMenamin and Ulm 2004), and conifers (Cornet 1989), particularly *Brachyphyllum, Hirmeriella,* and *Pagiophyllum* (Huber et al. 2003). Significant turnover in the floral assemblage occurred midway through deposition, when plants from the Deerfield Basin spread south (Cornet 1989). Invertebrates are represented by bivalves, conchostracans, ostracodes, beetles, cockroaches, possible orthopterans, insect fragments and larvae (Huber et al. 2003), and arthropod burrows and trails, including possible crayfish and insect traces (Olsen 1980d, 1988).

Vertebrates known from body fossils include the semionotid fish "*Acentrophorus*" and *Semionotus*, the redfieldiid fish *Redfieldius*, the coelacanth *Diplurus*, the crocodylomorph *Stegomosuchus*, the coelophysoid theropod *Podokesaurus*, and *Anchisaurus* (here including *Ammosaurus*) (Olsen 1980d, 1988; LeTourneau and McDonald 1985; McDonald 1992). Tetrapod body fossils are rare in the formation, limited to eight published specimens of more than one bone and a few isolated bones (Galton 1976). They are mostly known from the formation's coarse red beds, which formed in floodplain or alluvial fan settings (McDonald 1992) in the upper fluvial part of the formation (Olsen et al. 2003a). Vertebrate trace fossils include the ichnogenera *Batrachopus* (from crocodylomorphs), *Anchisauripus*, *Eubrontes*, *Grallator* (from theropods, although a theropod maker for *Eubrontes* is not universally accepted; see Weems 2003 and 2006), *Otozoum* (from sauropodomorphs), and *Anomoepus* (from ornithischians), as well as coprolites (Olsen 1988; LeTourneau and McDonald 1985). The taxonomy of the Portland Formation tracks is convoluted (Olsen et al. 1998; Olsen and Rainforth 2003): at one point there were 98 ichnospecies in 43 ichnogenera (Lull 1912) for what are now recognized as a half-dozen common ichnogenera. Restudy has greatly simplified the taxonomy (Weems 1992; Olsen and Rainforth 2003; Rainforth 2005). Most footprints are found in shoreline or mudflat rocks immediately above or below lake sequences (Olsen and Rainforth 2003).

EARLY PALEONTOLOGY

The history of fossil discovery in the Portland Formation dates to 1802, when Pliny Moody found tracks at his family's farm in South Hadley, Massachusetts (Point 2 in Fig. 1), about 16 km (10 miles) north of Springfield. At the time, the tracks were identified with "Noah's Raven" of Biblical fame; they are now known today as examples of the ichnogenus *Anomoepus* (Olsen et al. 1992). These tracks represent the earliest report of dinosaur tracks in North America (Olsen et al. 1992).

Scientific study of fossil footprints in the Connecticut River Valley began during the 1830s. In 1835, tracks were reported at Greenfield, Massachusetts (Point 3 in Fig. 1), 53 km (33 miles) north of Springfield in what is now known as the Turners Falls Formation. The finds attracted the attention of Edward B. Hitchcock of Amherst College, who made the study of the valley's tracks his life's work (Weishampel and Young 1996). Most of Hitchcock's work was done in the Turners Falls Formation (Olsen et al. 1992), a unit older than the Portland Formation in the Deerfield Basin to the north (Weems and Olsen 1997). As the title of one of his early works made clear (Hitchcock 1836), Hitchcock first conceived of the trackmakers as birds. In hindsight, this is understandable—he was dealing with tracks of bipedal bird-like tridactyl dinosaurs. By the end of his life, Hitchcock had described enough tracks and traces to envision a diverse bestiary of invertebrates and bipedal and quadrupedal vertebrates (Hitchcock 1858, 1865).

In 1818, workmen blasting a well through Portland Formation rocks at Ketch's Mills, East Windsor, Connecticut (Point 4 in Fig. 1), 24 km (15 miles) south of Springfield, discovered what would become the first collection of dinosaur bones found in North America (Santucci 1998). Because the value of the fossils was not immediately recognized, some were accidentally partially destroyed before recovery while others were taken by workmen. Solomon Ellsworth retained most of what was left and brought the bones to the attention of Nathan Smith, who made the first published description (Smith 1820). His identification of the material as possibly human was rejected by Jeffries Wyman (1855), who described the bones as reptilian and crocodile-like but hollow. Othniel Charles Marsh later identified them as dinosaurian (Marsh 1896). The specimen, now YPM 2125 (Peabody Museum of Natural History, Yale University, New Haven, Connecticut), consists of at least three partial caudal vertebrae, part of the left femur, traces of the lower leg bones, and an articulated partial arm (Galton 1976). While at one time assigned to *Anchisaurus colurus* (Lull 1912; see below), it is now regarded as an indeterminate sauropodomorph (Galton 1976; Yates 2010). Several details of the arm and hand suggest that it is distinct from the other Portland Formation sauropodomorphs (Yates 2004, 2010).

ANCHISAURUS FROM SPRINGFIELD ARMORY

The second dinosaur body fossil from the Portland Formation is the Springfield Armory specimen of *Anchisaurus*, now reposited at Amherst College's Pratt Museum of Natural History as ACM 41109 (Fig. 2) (K. Wellspring, Pratt Museum of Natural History collections manager, pers. comm., December 2009; AM 41/109 in some sources). The specimen consists of eleven dorsal and caudal vertebrae, a partial scapula, an almost complete right manus, portions of the right forearm, a partial left hindlimb (femur, partial tibia, fibula, and pes), and two partial Ischia, some partially damaged. Its publication history spans more than 150 years (Hitchcock 1855, 1858, 1865; Cope 1870; Huene 1906; Ostrom 1971; Galton 1976; Galton and Cluver 1976; Santucci 1998; Yates 2004, 2010; Fedak and Galton 2007; Sereno 2007): ACM 41109 was found during blasting operations for improvements to the Water Shops at Mill Pond (Santucci 1998) in 1855 (A. MacKenzie, pers. comm., March 2010) in a rock unit earlier referred to as the Longmeadow Sandstone (Galton 1976). Most of the remains were discarded (Hitchcock 1855) or taken by workmen before the intervention of an excavation superin-

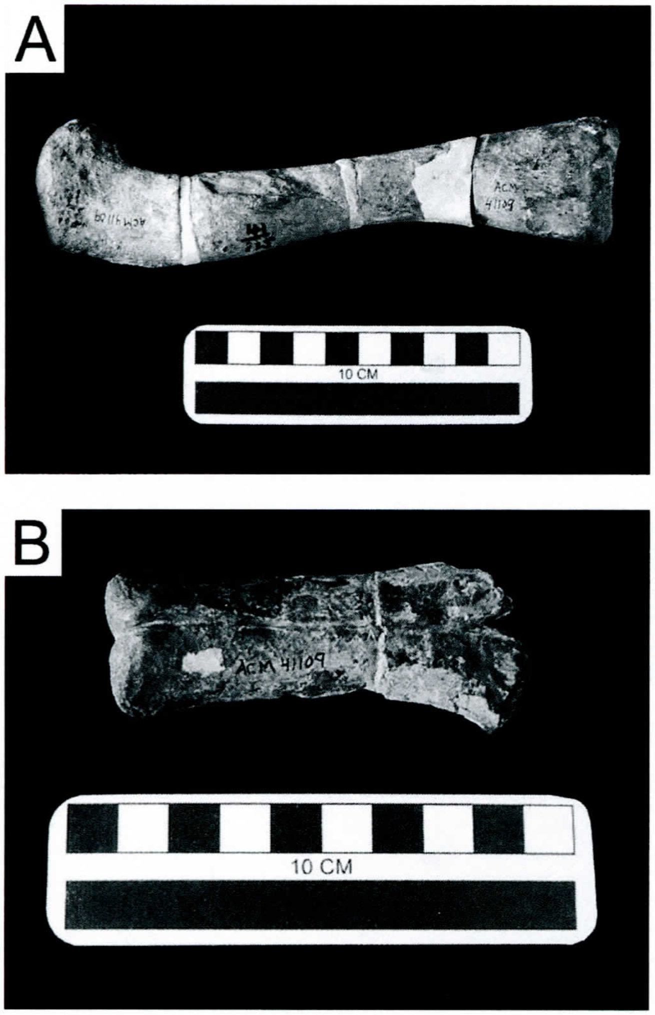

FIGURE 2. Among the bones recovered from Springfield Armory are a femur (**A**) and fused ischia (**B**). Photos by Kate Wellspring, courtesy of Amherst College Museum of Natural History, The Trustees of Amherst College.

tendent, William Smith. General James S. Whitney, the superintendent of the Armory, ordered further investigation, so Smith gathered as much as he could and sent the remains to Hitchcock (Hitchcock 1858). The press at the time took little notice of the find: dinosaurs had yet to enter the American consciousness (Santucci 1998) (the term itself had just been coined in 1842); moreover, the specimen was not identified as dinosaurian until fifteen years later (Cope 1870).

Hitchcock was the first to publish notice of the fossils (1855), then Wyman described them for Hitchcock's seminal 1858 work. As with the Ketch's Mills specimen, he recognized them as reptilian and drew attention to the hollowness of the bones, which he considered very bird-like. After consulting Sir Richard Owen, Hitchcock's son, Edward Jr., named the bones *Megadactylus polyzelus* in an appendix to the supplement to Hitchcock's 1858 work (Hitchcock 1865). Later, the skeleton was briefly described by Edward Drinker Cope (Cope 1870), but his rival Marsh, who described similar skeletons from Connecticut, was responsible for its current name. When *Megadactylus* proved to have already been used for another animal, Marsh renamed the genus *Amphisaurus* and created the family Amphisauridae (Marsh 1882). *Amphisaurus* was also already in use, so he substituted Anchisaurus and Anchisauridae (Marsh 1885). ACM 41109 is the specimen upon which *Anchisaurus polyzelus* was founded, making it the holotype for the genus and species.

THE BUCKLAND QUARRY SAUROPODOMORPHS, PORTLAND FORMATION

During the 1880s, three sauropodomorph skeletons were found at the Buckland Quarry (or Wolcott Quarry) in Manchester, Connecticut (Point 5 in Fig. 3), 35 km (22 miles) south of Springfield (Hubert et al. 1982) in a locality interpreted as a setting of ephemeral braided streams with occasional high-energy shallow floods, just west of the large alluvial fans that formed on the eastern border of the Hartford Basin. The climate at the site was seasonal and semi-arid, and streams flowed from south to north (Hubert et al. 1982). Although the Buckland Quarry is the most productive locality for dinosaur skeletons on the East Coast to date (Weishampel and Young 1996), today the quarry is overgrown and abandoned (P. Olsen, pers. comm., November 2010) and the area has been developed for a shopping mall.

All three specimens are individuals of the same taxon, probably *Anchisaurus*, and each was first described as its own species by Marsh. When quarriers discovered the first skeleton in October 1884, Charles Wolcott, the quarry owner, set it aside for Marsh. Unfortunately, the block thought to contain the anterior half and skull was incorporated into an abutment for the Hop Brook bridge in south Manchester before Marsh could take possession. When the bridge was demolished in the summer of 1969, a diligent search by a crew working for John Ostrom of Yale University recovered the missing half of the right femur and some miscellaneous dinosaur bones, but the rest of the bones reputed to have been present remain missing (Hubert et al. 1982). Marsh initially named the specimen *Anchisaurus major* in 1889 and gave it its own genus, *Ammosaurus*, two years later (Marsh 1891). Today, the specimen, YPM 208, consists of six dorsal vertebrae, the sacrum, ribs, most of the right scapula, most of the pelvis, the left leg, right femur, and right pes (Galton 1976).

In the same paper in which he named *Ammosaurus*, Marsh named another specimen from the quarry *Anchisaurus colurus* (Marsh 1891). Believing *Anchisaurus polyzelus* to be a species of the European genus *Thecodontosaurus* (Huene 1932), Friedrich von Huene coined the genus *Yaleosaurus* in 1932. The name *Yaleosaurus* was accepted by Lull (1953) and was commonly seen in dinosaur books from the middle of the 20th century, but was synonymized with *Anchisaurus* (and *A. colurus* with *A. polyzelus*) by Galton (1971, 1976). Although YPM 1883, the partial skeleton on which *A. colurus* was based, is missing much of the neck, the tail, and much of the left side (Galton 1976), the specimen is more complete than ACM 41109 and is often referenced for depictions of *Anchisaurus* and used in phylogenetic analyses.

Marsh named the third skeleton from the quarry *Anchisaurus solus* in 1892. This specimen, YPM 209, consists of a nearly complete but poorly preserved skeleton of a young individual, with only the end of the tail and part of the right arm missing (Galton 1976; Fedak and Galton 2007). Galton synonymized *Anchisaurus solus* with *Ammosaurus major*, regarding *A. solus* as a juvenile of that species (Galton 1971, 1976; Galton and Cluver 1976).

TAXONOMY AND SYSTEMATICS OF ANCHISAURUS AND AMMOSAURUS

The separation of *Anchisaurus* and *Ammosaurus*, as proposed by Marsh and later detailed by Galton (Galton 1971, 1976; Galton and Cluver 1976), was generally accepted until the late 1990s. Of recent studies to consider the matter, one favors retaining separate genera (Galton and Upchurch 2004) while five find the foot and pelvic details cited by Galton's earlier works to be inadequate and conclude that only one genus and species is represented (Sereno 1999, 2007; Yates 2004, 2010; Fedak and Galton 2007). These five publications agree that the three Buckland Quarry specimens represent one taxon; assessments of ACM 41109, however, vary. Yates (2004, 2010) and Fedak and Galton (2007) unite ACM 41109 and the Buckland Quarry specimens under *Anchisaurus polyzelus*, but Sereno (2007) considers ACM 41109 to be undiagnostic and recommends classifying the Buckland Quarry specimens as *Ammosaurus major*. Yates (2010) disagrees, finding the form of the ischia and first sacral rib in ACM 41109 to be diagnostic.

Anchisaurus is currently regarded as a basal sauropodomorph (Yates 2010), though its classification has changed as researchers piece together the evolution of dinosaurs. Marsh thought that both *Anchisaurus* and *Ammosaurus* were theropods (Marsh 1896) while Huene assigned *Ammosaurus* to Ornithischia (1906), then back to Theropoda in Ammosauridae (1914). Further complicating matters, he later assigned *Anchisaurus* and *Yaleosaurus* to Prosauropoda and transferred *Ammosaurus* to the theropod group Coelurosauria (1932), where it remained for decades (Galton 1971). The name of the ichnogenus *Anchisauripus*, which is now seen as tracks left by theropod dinosaurs (Galton 1971), reflects this confusion

Anchisaurus recently attracted attention as potentially the most primitive and smallest sauropod (Yates 2004), though Yates revised this assessment as part of ongoing research on basal sauropodomorph relationships (2010). *Anchisaurus* "became" a sauropod when the definition of Sauropoda (all sauropodomorphs more closely related to the sauropod *Saltasaurus* than to the prosauropod *Plateosaurus*) did not take into account the possibility that the traditional prosauropods did not form a group. Thus, when Yates (2004) found Anchisaurus to be closer to sauropods than to *Plateosaurus*, it became a sauropod by definition. Similar work has resulted in other prosauropods becoming sauropods, so Yates (2010) favored a modification of the definition of Sauropoda to better conform to the traditional content of the group. This would leave Anchisaurus out of Sauropoda. Complicating matters is the possibility that all known specimens of *Anchisaurus* and *Ammosaurus* represent immature individuals (Fedak and Galton 2007 [but see Yates 2004]).

PALEOBIOLOGY OF ANCHISAURUS

Views on the paleobiology of *Anchisaurus* have changed substantially since Cope described "*Megadactylus polyzelus*" in the 1870s as a leaping carnivore that dispatched prey with its claws (Cope 1870). *Anchisaurus* and *Ammosaurus* were interpreted as carnivores well into the 20th century (Lull 1912, 1953; Krynine 1950), though anchisaurs, like other basal sauropodomorphs, had iguana-like teeth and probably were mostly herbivorous, supplementing their diet with carrion and small prey (Barrett 2000). Known specimens of *Anchisaurus* were of modest size for dinosaurs. The femurs of ACM 41109, YPM 1883, and YPM 208 are 18.0 cm (7.1 in) (estimated), 21.1 cm (8.3 in), and 22.1 cm (8.7 in) long, respectively (Carrano 2006; Fedak and Galton 2007), with the length of the largest specimen (YPM 208) estimated at 3 m (10 ft) (Galton 1976). If indeed all known specimens are immature, the adult size is not yet known. Although commonly interpreted as quadrupeds, basal sauropodomorphs like *Anchisaurus* were probably unable to walk on all

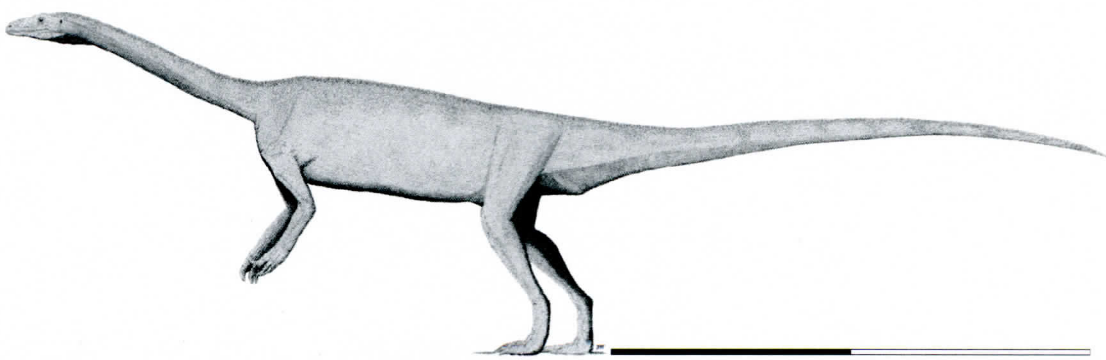

FIGURE 3. A modern restoration of Anchisaurus polyzelus as a biped, primarily after Yates (2010), with reference to Marsh (1893), Galton (1976), Carpenter (reproduced in Glut [1997]), and Paul (2010). Scale bar represents 1 m.

fours, based on their arm anatomy (Fig. 3) (Bonnan and Senter 2007). Anchisaurs may have been members of a rarely preserved upland fauna (Galton and Cluver 1976). They are known from the upper, fluvial part of the Portland Formation, along with the crocodylomorph *Stegomosuchus* (Olsen et al. 2003a).

ANCHISAURUS AMONG NATIONAL PARK SERVICE FOSSIL RESOURCES

ACM 41109 is unusual in several ways among fossil resources associated with National Park Service areas, especially in comparison to other National Park System units in the East. As a Mesozoic dinosaurian fossil, it is virtually unique among units east of 100° W longitude. Furthermore, it is the holotype specimen of a well-known genus and species. As a Portland Formation specimen, it dates from a time when tetrapods were undergoing diversification after an extinction event, representing a region with few contemporary tetrapod body fossils. Historically, ACM 41109 is among the fossils discovered and described during the formative years of American vertebrate paleontology, and is one of the first partial dinosaur skeletons found in the nation. It has been described and discussed by noted paleontologists from Hitchcock through to Cope and Marsh, von Huene, Lull, and Ostrom, as well as an assortment of contemporary workers.

At the same time, ACM 41109 is among a wealth of fossil resources associated with National Park System lands, including many other historically significant finds such as Hiram Prout's "*Palaeotherium*" in Badlands National Park (Prout 1846) and dozens of mammals described by Joseph Leidy from an area now including Niobrara National Scenic River (Leidy 1858). If recent finds are any indication (Chure et al. 2010), important fossils will be discovered in National Park System areas for as long as the National Park Service exists.

ACKNOWLEDGMENTS

This article is adapted in part from Tweet et al. (2010). We would like to thank Paul E. Olsen of Columbia University's Lamont–Doherty Earth Observatory and Robert E. Weems of the U.S. Geological Survey for their reviews and Jason Kenworthy, Alexander MacKenzie, and James C. Woods of the National Park Service for providing their assistance and additional information. Kate Wellspring of Amherst College's Pratt Museum of Natural History provided the photographs for Fig. 2.

LITERATURE CITED

Barrett, P.M. 2000. Prosauropod dinosaurs and iguanas: Speculations on the diets of extinct reptiles; p. 42–78 *in* H.-D. Sues, editor. Evolution of herbivory in terrestrial vertebrates. Cambridge University Press, Cambridge, United Kingdom.

Bonnan, M.F., and P. Senter. 2007. Were the basal sauropodomorph dinosaurs *Plateosaurus* and *Massospondylus* habitual quadrupeds? p. 139–155 *in* P.M. Barrett and D.J. Batten. Evolution and palaeobiology of early sauropodomorph dinosaurs. The Palaeontological Association, London, United Kingdom. Special Papers in Palaeontology 77.

Carrano, M.T. 2006. Body-size evolution in the Dinosauria; p. 225–268 *in* M.T. Carrano, R.W. Blob, T.J. Gaudin, and J.R. Wible, (eds.) Amniote paleobiology: perspectives on the evolution of mammals, birds, and reptiles. University of Chicago Press, Chicago, Illinois, USA.

Chure, D., B. Britt, J.A. Whitlock, and J.A. Wilson. 2010. First complete sauropod dinosaur skull from the Cretaceous of the Americas and the evolution of sauropod dentition. Naturwissenschaften 97(4):379–391.

Cope, E.D. 1870. On the *Megadactylus polyzelus* of Hitchcock. American Journal of Science 49:390–392.

Cornet, B. 1989. Hartford Basin, Connecticut and Massachusetts: Jurassic conifer assemblages and their paleoclimatic implications; p. 117–118 *in* P.E. Olsen, R.W. Schlische, and P.J.W. Gore, (eds.) Sedimentation and basin analysis in siliciclastic rock sequences: vol. 2. Tectonic, depositional, and paleoecological history of early Mesozoic rift basins, eastern North America. P.M. Hanshaw, (ed.) Field trips for the 28th international geological congress. American Geophysical Union, Washington, D.C., USA.

Cornet, B., and A. Traverse. 1975. Palynological contributions to the chronology and stratigraphy of the Hartford Basin in Connecticut and Massachusetts. Geoscience and Man 11:1–33.

Fedak, T.J., and P.M. Galton. 2007. New information on the braincase and skull of Anchisaurus polyzelus (Lower Jurassic, Connecticut, USA: Saurischia, Sauropodomorpha): Implications for sauropodomorph systematics; p. 245–260 *in* P.M. Barrett and D.J. Batten, (eds.) Evolution and palaeobiology of early sauropodomorph dinosaurs. The Palaeontological Association, London, United Kingdom. Special Papers in Palaeontology 77.

Galton, P.M. 1971. The prosauropod dinosaur *Ammosaurus*, the crocodile *Protosuchus*, and their bearing on the age of the Navajo Sandstone of northeastern Arizona. Journal of Paleontology 45(5):781–795.

Galton, P.M. 1976. Prosauropod dinosaurs (Reptilia: Saurischia) of North America. Postilla 169.

Galton, P.M., and M.A. Cluver. 1976. *Anchisaurus capensis* (Broom) and a revision of the Anchisauridae: Reptilia, Saurischia. Annals of the South African Museum 69(6):121–159.

Galton, P.M., and P. Upchurch. 2004. Prosauropoda; p. 232–258 *in* D. W. Weishampel, P. Dodson, P. and H. Osmólska, (eds.) The Dinosauria, 2nd edition. University of California Press, Berkeley, California, USA.

Glut, D.F. 1997. Dinosaurs: The encyclopedia. McFarland & Company, Inc., Jefferson, North Carolina.

Hartshorn, J.H., and C. Koteff. 1967. Geologic map of the Springfield South quadrangle, Hampden County, Massachusetts and Hartford and Tolland counties, Connecticut. U.S. Geological Survey, Reston, Virginia, USA. Scale 1:24,000.

Hitchcock, E.B. 1836. Description of the footmarks of birds (Ornithichnites) on new red sandstone in Massachusetts. American Journal of Science 29(2):307–340.

Hitchcock, E. 1855. Shark remains from the Coal Formation of Illinois, and bones and tracks from the Connecticut River Sandstone. American Journal of Science and Arts 20(60):416–417.

Hitchcock, E. 1858. Ichnology of New England. White, Boston, Massachusetts, USA.

Hitchcock, E. 1865. Supplement to the ichnology of New England. Wright and Potter, Boston, Massachusetts, USA.

Horne, G.S., N.G. McDonald, P.M. LeTourneau, and J.Z. de Boer. 1993. Paleoenvironmental traverse across the early Mesozoic Hartford rift basin, Connecticut; p. P.1–P.26 *in* J.T. Cheney and J.C. Hepburn, (eds.), Field trip guidebook for the northeastern United States: 1993 Boston GSA Conference. University of Massachusetts, Amherst, Massachusetts, USA. Contribution – Geology Department, University of Massachusetts 67(2).

Huber, P., N.G. McDonald, and P.E. Olsen. 2003. Early Jurassic insects from the Newark Supergroup, northeastern United States; p. 206–233 *in* P.M. LeTourneau and P.E. Olsen, (eds.), The great rift valleys of Pangea in eastern North America. Volume 2: Sedimentology, stratigraphy, and paleontology. Columbia University Press, New York, New York, USA.

Hubert, J.F., A.A. Reed, W.L. Dowdall, and J.M. Gilchrist. 1978. Guide to the redbeds of central Connecticut: 1978 field trip, Eastern Section of SEPM. University of Massachusetts, Amherst, Massachusetts, USA. Contribution–Geology Department, University of Massachusetts 32.

Hubert, J.F., J.M. Gilchrist, and A.A. Reed. 1982. Jurassic redbeds of the Connecticut Valley: 1, Brownstones of the Portland Formation; 2, Playa-playa lake-oligomictic lake model for parts of the East Berlin, Shuttle Meadow and Portland formations; p. 103–141 *in* R. Joesten and S.S. Quarrier, (eds.), Guidebook for field trips in Connecticut and south-central Massachusetts. New England Intercollegiate Geologic Conference, Amherst, Massachusetts, USA. Annual Meeting–New England Intercollegiate Geological Conference 74.

Hubert, J.F., P.E. Feshbach-Meriney, and M.A. Smith. 1992. The Triassic–Jurassic Hartford rift basin, Connecticut and Massachusetts: Evolution, sandstone diagenesis, and hydrocarbon history. AAPG Bulletin 76(11):1710–1734.

Huene, F.v. 1906. Über die Dinosaurier der Aussereuropaïschen Trias [in German]. Geologie und Paläontologie Abhandlungen 8:97–156.

Huene, F.v. 1914. Saurischia et Ornithischia Triadica ("Dinosauria" Triadica) [in German]; p. 1–21 *in* F. Frech, (ed). Fossilium Catalogus 1. W. Junk, Berlin, Germany. Animalia 4.

Huene, F.v. 1932. Die fossile Reptil-Ordnung Saurischia, ihre Entwicklung und Geschichte [in German]. Monographien zur Geologie und Palaeontologie, serie 1, 4(1–2):1–361.

Kent, D.V., and P.E. Olsen. 2008. Early Jurassic magnetostratigraphy and paleolatitudes from the Hartford continental rift basin (eastern North America): Testing for polarity bias and abrupt polar wander in association with the central Atlantic magmatic province. Journal of Geophysical Research 113:B06105.

Kent, D.V., and L. Tauxe. 2005. Corrected Late Triassic latitudes for continents adjacent to the North Atlantic. Science 307(5707):240–244.

Kozur, H.W., and R.E. Weems. 2010. The biostratigraphic importance of conchostracans in the continental Triassic of the northern hemisphere; p. 315–417 *in* S.G. Lucas, (ed.) The Triassic timescale. Geological Society of London, London, United Kingdom. Special Publication 334.

Krynine, P.D. 1950. Petrology, stratigraphy, and origin of the Triassic sedimentary rocks of Connecticut. State Geological and Natural History Survey of Connecticut, Hartford, Connecticut, USA. Bulletin 73.

Leidy, J. 1858. Notice of remains of extinct Vertebrata, from the valley of the Niobrara River, collected during the exploring expedition of 1857, in Nebraska. Proceedings of the Academy of Natural Sciences of Philadelphia 10:20–29.

LeTourneau, P.M. 1985. Alluvial fan development in the Lower Jurassic Portland Formation, central Connecticut: Implications for tectonics and climate. p/ 17–26 *in* G.R. Robinson Jr. and A.J. Froelich, (eds.), Proceedings of the second U.S. Geological Survey workshop on the early Mesozoic basins of the Eastern United States. U.S. Geological Survey, Reston, Virginia, USA. Circular 946.

LeTourneau, P.M., and N.G. McDonald. 1985. The sedimentology, stratigraphy and paleontology of the Lower Jurassic Portland Formation, Hartford Basin, central Connecticut; p. 353–391 *in* R.J. Tracy, ed. Guidebook for field trips in Connecticut and adjacent areas of New York and Rhode Island. State Geological and Natural History Survey of Connecticut, Hartford, Connecticut, USA. Guidebook 6.

Lull, R.S. 1912. The life of the Connecticut Trias. American Journal of Science 33(197):397–422.

Lull, R.S. 1953. Triassic life of the Connecticut Valley. Revised. Connecticut Geological and Natural History Survey, Hartford, Connecticut, USA. Bulletin 81.

Marsh, O.C. 1882. Classification of the Dinosauria. American Journal of Science 23(133):81–86.

Marsh, O.C. 1885. Names of extinct reptiles. American Journal of Science 29:169.

Marsh, O.C. 1889. Notice of new American Dinosauria. American Journal of Science 37(220):331–336.

Marsh, O.C. 1891. Notice of new vertebrate fossils. American Journal of Science 42(249):265–269.

Marsh, O.C. 1892. Notes on Triassic Dinosauria. American Journal of Science 43(258):543–546.

Marsh, O.C. 1893. Restoration of *Anchisaurus*. American Journal of Science 45(266):169–170.

Marsh, O.C. 1896. The dinosaurs of North America; p. 133–414 *in* Sixteenth Annual Report of the United States Geological Survey to the Secretary of the Interior, 1894–1895: Part 1. U.S. Geological Survey, Reston, Virginia, USA.

Marzoli, A., P.R. Renne, E.M. Piccirillo, M. Ernesto, G. Bellieni, and A. De Min. 1999. Extensive 200-million-year-old continental flood basalts of the Central Atlantic magmatic province. Science 284(5414):616–618.

McDonald, N.G. 1992. Paleontology of the early Mesozoic (Newark Supergroup) rocks of the Connecticut Valley. Northeastern Geology 14:185–200.

McDonald, N.G., and P.M. LeTourneau. 1988. Paleoenvironmental reconstruction of a fluvial-deltaic-lacustrine sequence, Lower Jurassic Portland Formation, Suffield, Connecticut; p. 24–30 *in* A.J. Froelich and G.R. Robinson Jr., (eds.), Studies of the early Mesozoic basins of the Eastern United States. U.S. Geological Survey, Reston, Virginia, USA. Bulletin 1776.

McMenamin, M.A.S., and L.B. Ulm. 2004. First report of the Mesozoic cycadeoid Ptilophyllum from Massachusetts. Northeastern Geology and Environmental Sciences 26(4):279–284.

Olsen, P.E. 1980a. Triassic and Jurassic formations of the Newark Basin; p. 2–39 *in* W. Manspeizer, (ed.) Field studies of New Jersey geology and guide to field trips: 52nd annual meeting of the New York State Geological Association. New York State Geological Association, Staten Island, New York, USA.

Olsen, P.E. 1980b. The latest Triassic and Early Jurassic formations of the Newark Basin (eastern North America, Newark Supergroup): Stratigraphy, structure and correlation. New Jersey Academy of Science Bulletin 25(2):25–51.

Olsen, P.E. 1980c. Fossil great lakes of the Newark Supergroup in New Jersey; p. 352–398 *in* W. Manspeizer, (ed.), Field studies of New Jersey geology and guide to field trips: 52nd annual meeting of the New York State Geological Association. New York State Geological Association, Staten Island, New York, USA.

Olsen, P.E. 1980d. Comparison of the vertebrate assemblages from the Newark and Hartford basins (Early Mesozoic, Newark Supergroup) of eastern North America; p. 35–53 *in* L.L. Jacobs, (ed.), Aspects of vertebrate history. Museum of Northern Arizona Press, Flagstaff, Arizona, USA.

Olsen, P.E. 1986. A 40-million-year lake record of early Mesozoic orbital climatic forcing. Science 234(4778):842–848.

Olsen, P.E. 1988. Paleontology and paleoecology of the Newark Supergroup (early Mesozoic, eastern North America); p. 185–230 *in* W. Manspeizer, (ed.), Triassic–Jurassic rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Developments in Geotectonics 22 (Part A). Elsevier, Amsterdam, The Netherlands.

Olsen, P.E., and D.V. Kent. 1996. Milankovitch climate forcing in the tropics of Pangaea during the Late Triassic. Palaeogeography, Palaeoclimatology, and Palaeoecology 122(1–4):1–26.

Olsen, P.E., and D.V. Kent. 1999. Long-period Milankovitch cycles from the Late Triassic and Early Jurassic of eastern North America and their implications for the calibration of the early Mesozoic time scale and the long-term behavior of the planets. Philosophical Transactions of the Royal Society of London (series A) 357:1761–1787.

Olsen, P.E., and E.C. Rainforth. 2003. The Early Jurassic ornithischian dinosaurian ichnogenus *Anomoepus*; p. 314–368 *in* P.M. LeTourneau and P.E. Olsen, (eds.), The great rift valleys of Pangea in eastern North America. Vol 2: Sedimentology, stratigraphy, and paleontology. Columbia University Press, New York, New York.

Olsen, P.E., and J.H. Whiteside. 2008. Pre-Quaternary Milankovitch cycles and climate variability; p. 826–835 *in* V. Gornitz, (ed.), Encyclopedia of paleoclimatology and ancient environments. Encyclopedia of earth science. Kluwer Academic Publishers, Dordretch, the Netherlands.

Olsen, P.E., B. Cornet, N.G. McDonald, and P. Huber. 1992. Stratigraphy and paleoecology of the Deerfield rift basin (Triassic–Jurassic, Newark Supergroup), Massachusetts; p. 488–535 *in* P. Robinson and J. B. Brady, (ed.), Guidebook for field trips in the Connecticut Valley region of Massachusetts and adjacent states. University of Massachusetts, Amherst, Massachusetts, USA. Contribution – Geology Department, University of Massachusetts 66(2).

Olsen, P.E., R.W. Schlische, and M.S. Fedosh. 1996. 580 ky duration of the Early Jurassic flood basalt event in eastern North America estimated using Milankovitch cyclostratigraphy; p. 11–22 *in* M. Morales, (ed.), The continental Jurassic. Museum of Northern Arizona, Flagstaff, Arizona, USA. Bulletin 60.

Olsen, P.E., J.B. Smith, and N.G. McDonald. 1998. Type material of the type species of the classic theropod footprint genera *Eubrontes*, *Anchisauripus*, and *Grallator* (Early Jurassic, Hartford and Deerfield basins, Connecticut and Massachusetts, U.S.A.). Journal of Vertebrate Paleontology 18(3):586–601.

Olsen, P.E., D.V. Kent, and P.M. LeTourneau. 2002. Stratigraphy and age of the Early Jurassic Portland Formation of Connecticut and Massachusetts: A contribution to the time scale of the Early Jurassic. Abstracts with Programs – Geological Society of America 34(1):61

Olsen, P.E., J.H. Whiteside, and P. Huber. 2003a. Causes and consequences of the Triassic–Jurassic mass extinction as seen from the Hartford basin; p. B5-1–B5-41 *in* J.B. Brady and J.T. Cheney, (eds.), Guidebook for field trips in the Five College region, 95th New England Intercollegiate Geological Conference. Department of Geology, Smith College, Northampton, Massachusetts, USA.

Olsen, P.E., D.V. Kent, M. Et-Touhami, and J.H. Puffer. 2003b. Cyclo-, magneto-, and bio-stratigraphic constraints on the duration of the CAMP event and its relationship to the Triassic–Jurassic boundary; p. 7–32 *in* W.E. Hames, J.G. McHone, P.R. Renne, and C. Ruppel, (eds.), The Central Atlantic Magmatic Province: Insights from fragments of Pangea. American Geophysical Union, Washington, D.C., USA. Geophysical Monograph Series 136.

Ostrom, J.H. 1971. Report to the National Park Service on Mesozoic vertebrate paleontological sites for possible inclusion in the Registry of Natural Landmarks. Peabody Museum of Natural History, Yale University, New Haven, Connecticut, USA.

Paul, G.S. 2010. The Princeton field guide to dinosaurs. Princeton University Press, Princeton, New Jersey.

Prout, H.A. 1846. Gigantic *Palaeotherium*. American Journal of Science 2:288–289.

Rainforth, E.R. 2005. Ichnotaxonomy of the fossil footprints of the Connecticut Valley (Early Jurassic, Newark Supergroup, Connecticut and Massachusetts). Dissertation. Columbia University, New York, New York, USA.

Robinson, G.R. Jr., and K.E. Kapo. 2003. Generalized lithology and lithogeochemical character of near-surface bedrock in the New England region. U.S. Geological Survey, Reston, Virginia, USA. Open-File Report 03–225.

Santucci, V.L. 1998. Early discoveries of dinosaurs from North America and the significance of the Springfield Armory dinosaur site. Pages 152–154 in V. L. Santucci and L. McClelland, editors. National Park Service Paleontological Research 3. NPS Technical Report NPS/NRGRD/GRDTR-98/01.

Schoene, B., J. Guex, A. Bartolini, U. Schaltegger, and T.J. Blackburn. 2010. Correlating the end-Triassic mass extinction and flood basalt volcanism at the 100 ka level. Geology 38(5):387–390.

Sereno, P.C. 1999. The evolution of dinosaurs. Science 284(5423):2137–2147.

Sereno, P.C. 2007. Basal Sauropodomorpha: Historical and recent phylogenetic hypotheses, with comments on *Ammosaurus major* (Marsh, 1889); p. 261–289 *in* P.M. Barrett and D.J. Batten, (eds.), Evolution and palaeobiology of early sauropodomorph dinosaurs. The Palaeontological Association, London, United Kingdom. Special Papers in Palaeontology 77.

Smith, N. 1820. Fossil bones found in red sandstone. American Journal of Science and Arts 2(1):146–147.

Tweet, J.S., V.L. Santucci, and J.P. Kenworthy. 2010. Paleontological resource inventory and monitoring—Northeast Temperate Network. Natural Resource Technical Report NPS/NRPC/NRTR—2010/326. National Park Service, Fort Collins, Colorado, USA.

Weems, R.E. 1992. A re-evaluation of the taxonomy of Newark Supergroup saurischian dinosaur tracks, using extensive statistical data from a recently exposed tracksite near Culpeper, Virginia; p. 113–127 *in* P.C. Sweet, (ed.), Proceeding of the 26th forum on the geology of industrial minerals. Virginia Division of Mineral Resources, Charlottesville, Virginia, USA. Publication 119.

Weems, R.E. 2003. *Plateosaurus* foot structure suggests a single trackmaker for *Eubrontes* and *Gigandipus* footprints; p. 293–313 *in* P.M. LeTourneau and P.E. Olsen, (eds.), The great rift valleys of Pangea in eastern North America. Volume 2: Sedimentology, stratigraphy, and paleontology. Columbia University Press, New York, New York, USA.

Weems, R.E. 2006. The manus print of *Kayentapus minor*: Its bearing on the biomechanics and ichnotaxonomy of early Mesozoic saurischian dinosaurs; p. 369–378 *in* J.D. Harris, S.G. Lucas, J. Spielmann, M.G. Lockley, A.R.C. Milner, and J.L. Kirkland, (eds.), The Triassic–Jurassic terrestrial transition. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 37.

Weems, R.E., and P.E. Olsen. 1997. Synthesis and revision of groups within the Newark Supergroup, eastern North America. Geological Society of America Bulletin 109(2):195–209.

Weishampel, D.B., and L. Young. 1996. Dinosaurs of the East Coast. Johns Hopkins University Press, Baltimore, Massachusetts, USA.

Wyman, J. 1855. Notice of fossil bones from the Red Sandstone of the Connecticut River Valley. American Journal of Science and Arts 20(60):394–397.

Yates, A.M. 2004. *Anchisaurus polyzelus* (Hitchcock): The smallest known sauropod dinosaur and the evolution of gigantism among sauropodomorph dinosaurs. Postilla 230.

Yates, A.M. 2010. A revision of the problematic sauropodomorph dinosaurs from Manchester, Connecticut and the status of *Anchisaurus* Marsh. Palaeontology 23(4):739–752.

Zen, E-an, R. Goldsmith, N.M. Ratcliffe, P. Robinson, R.S. Stanley, N.L. Hatch, A.F. Shride, E.G.A. Weed, and D.R. Wones. 1983. Bedrock geologic map of Massachusetts. U.S. Geological Survey, Reston, Virginia, USA. Scale 1:250,000.