The "Overlooked Marvelous Reptile"

Clint A. Boyd

The late 1800's was the time of the great "Bone Wars" in North America, when fossils in general and dinosaurs in particular were thrust into the forefront of the public's consciousness. Discoveries shipped back from the newly explored American West were thrilling the public and drawing great crowds to natural history museums across the eastern United States. Realizing the financial prize that awaited museums that unveiled the biggest and best new discoveries, American museums and universities began to send out field crews to track down new fossil localities and recover the bones of previously unknown species before others could beat them to the next big find. Two men played the central role of adversaries during this period of great scientific discovery and competition: Edward Drinker Cope and Othniel Charles Marsh. Of the two, Marsh had more funding at his disposal, being a professor at Yale University starting in 1879 and being appointed the Vertebrate Paleontologist of the United States Geological Survey beginning in 1882. As a part of the latter position, Marsh employed thirty-five fossil collectors on the federal payroll solely to find and ship back fossils of all kinds from the American West, resulting in around 3,000 shipments of fossils (Schuchert, 1939), some of which remain unopened to this day.

Chief among those "bone-diggers" hired by O. C. Marsh was an Illinoisian named John Bell Hatcher. Hatcher's interest in fossils was ignited while working as a coal miner to earn money for college. During that work he collected fossils that he found in the mine and surrounding area that dated back to the Carboniferous Period (359-299 million years ago). Hatcher attended Yale University in the early 1880s, and showed his fossil collection to several people at the university, who introduced him to O. C. Marsh. Marsh eventually hired Hatcher as an assistant and fossil collector, and sent him to scour the American West for fossils to sate Marsh's scientific appetite.

It was in that position in 1891 that Hatcher and his assistant W. H. Utterback were prospecting outcrops of the Lance Formation along Doegie Creek in modern-day Niobrara County, Wyoming. The Lance Formation of Wyoming is equivalent to the Hell Creek Formation of North Dakota, South Dakota, and Montana, dating back to the latest Cretaceous Period, the last years of the reign of the dinosaurs. Here they found a well-preserved skeleton of a small-bodied dinosaur (~13 feet long, which is small for a dinosaur!). They carefully dug out the skeleton, wrapped it up, and shipped it back to the east coast. Because they were working for the United States Geological Survey, many of the specimens they collected ended up at the United States National Museum (USNM: part of the Smithsonian Institute and now called the National Museum of Natural History) in Washington, D.C. rather than Yale University, where many of Marsh's fossils were kept.

Upon its arrival in Washington D. C., this field crate was unloaded and placed into storage, and there it patiently waited, accumulating dust in a darkened corner, for its turn in the spotlight. By the end of the 1890s, both O. C. Marsh and E. D. Cope had passed away, ending the first round of the American "Bone Wars." J. B. Hatcher was hired as the curator of paleontology and osteology at the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania and forgot about the lonely jacket from Wyoming. A new generation of vertebrate paleontologists rose to prominence in the field, and in addition to making their own discoveries, were tasked with working through the massive backlog of fossils collected during the "Bone Wars." At the USNM, a rising star named Charles Whitney Gilmore was hired in 1903 to begin working through the vast collection assembled under the instruction of O. C. Marsh. Gilmore charged in, focusing in part on specimens collected from the Lance and Hell Creek Formations of North America. As a part of that work he assembled and mounted the first skeleton of the horned dinosaur *Triceratops* ever exhibited, as well as a skeleton of the duck-billed dinosaur *Edmontosaurus*. In the early 1910s, he cracked open a largely unmarked shipping crate from Wyoming, and "it was in the nature of a surprise upon first examination to discover that it represented an undescribed form" (Gilmore, 1913, p. 1). In 1913, Gilmore briefly described this new species, which he quite appropriately named *Thescelosaurus neglectus*, "the overlooked marvelous reptile" in Latin.

Getting Ahead of the Problem

In 1915, Gilmore followed up his brief 1913 paper with a more complete description of *Thescelosaurus neglectus* based on the original two specimens (called the holotype and the paratype) and several other referred specimens. Between all those specimens, he was able to describe almost the entire animal with one notable exception: the skull. The best preserved specimen known at that time, the holotype, did not include the skull (fig. 1) and no material from the skull was preserved with any of the referred specimens. So Gilmore based his reconstruction of the skull on the most closely related species with a well-preserved skull at that time, the European *Hypsilophodon foxii* (fig. 2a). Over the years more fragmentary material was referred to *T. neglectus* from across the northwestern portion of North America: South Dakota, North Dakota, Wyoming, Montana, Saskatchewan, British Columbia, and Alaska. A partial lower jaw here, part of a braincase there, and slowly the picture began to resolve itself. It soon became clear that *Thescelosaurus neglectus* had a longer and narrower skull than *Hypsilophodon foxii* or any other closely related species, but exactly how different remained unclear (fig. 2c).

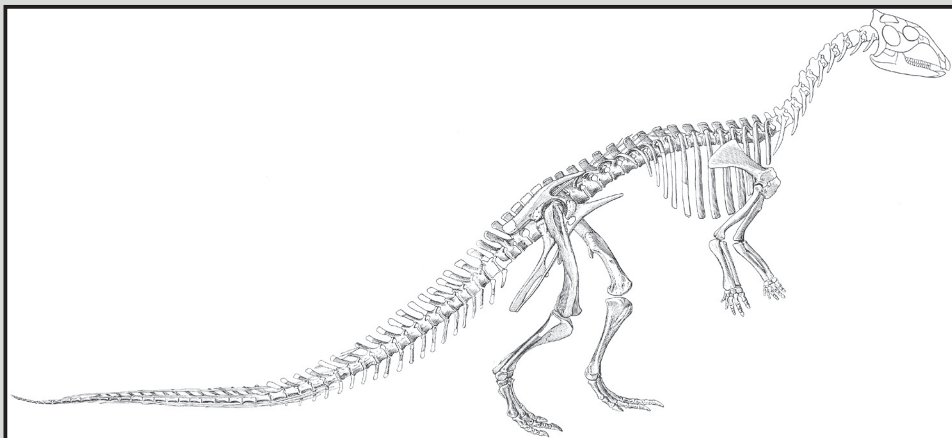

Figure 1. Line drawing of the skeleton of *Thescelosaurus neglectus* based on the holotype. Shaded bones were preserved, while outlined bones filled in with white are reconstructed. Modified from Gilmore (1915: plate 80).

In 1972, Kenneth H. Oson and Arland Jacobson discovered a partial skull (fig. 2b), along with a vertebra and two bones from the hand, in outcrops of the Hell Creek Formation in South Dakota. That specimen ended up at the South Dakota School of Mines and Technology (SDSM) in Rapid City, South Dakota, and was numbered SDSM 7210. The skull clearly belonged to the same group of animals as *Thescelosaurus neglectus*, and it was the most complete skull yet recovered from the Hell Creek Formation for that group of dinosaurs. The question was, did this skull belong to *Thescelosaurus neglectus*, or to perhaps a new, closely related species? Given that the original specimen of *Thescelosaurus neglectus* had no skull, and the new specimen included pretty much only the skull, it was difficult to determine if they were from the same species. For years the specimen was referred to ?*Thescelosaurus* sp. (indicating a tentative referral to that genus), until 1995 when Peter Galton at the University of Bridgeport decided it represented a new species that he named *Bugenasaura infernalis*, which in Latin means "the large, feminine cheeked lizard belonging to the lower regions" (in reference to the large ridge on the upper jaw bone and the fact that it came from the Hell Creek Formation) (Galton, 1995). That resolved the issue for the moment, and paleontologists awaited more complete specimens that would allow them to directly compare the known material for *Thescelosaurus neglectus* and *Bugenasaura infernalis*.

The wait for better specimens was much shorter this time. In fact, the key specimen had already been found in South Dakota in 1993 before *B. infernalis* was named, but it would

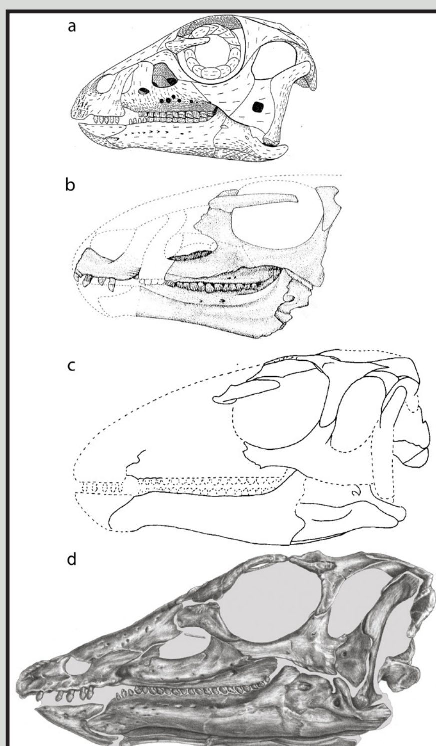

Figure 2. Skull reconstructions for *Thescelosaurus neglectus* over time. *Hypsilophodon foxii* (a) was originally used to model the skull of *Thescelosaurus neglectus* (modified from Galton, 1974: fig. 3). Later, a fragmentary skull (b) was described as the new species *Bugenasaura infernalis* (modified from Galton, 1999: fig. 1A) based on comparisons to a reconstruction of the skull of *Thescelosaurus neglectus* (b) that used information gathered from several fragmentary specimens (Modified from Galton, 1997: fig. 3H). Discovery of the "Willo" specimen (d) revealed the full anatomy of the skull of *Thescelosaurus neglectus*, and showed that *Thescelosaurus neglectus* and *Bugenasaura infernalis* were the same species (modified from Boyd, 2014: fig. 1B).

not make its way into a museum for study until near the end of the millennium. That specimen was found by Michael Hammer and was eventually purchased by the North Carolina Museum of Natural Sciences (NCSM). Known as NCSM 15728, or by its nickname "Willo," this was the first specimen to preserve a nearly complete skull along with much of the right side of the skeleton (fig. 2d). With "Willo" as a point of reference, a lot of the underlying questions about *Thescelosaurus* were clarified. It was clear now that *Thescelosaurus neglectus* and *Bugenasaura infernalis* were the same species, and since *Thescelosaurus neglectus* was named first, the name *Bugenasaura infernalis* was discarded (Boyd and others, 2009). Additionally, the "Willo" specimen showed that all of the *Thescelosaurus* material collected from the Frenchman Formation of Saskatchewan was actually from a different species, which was named *Thescelosaurus assiniboiensis* after the indigenous Assiniboine people of southern Saskatchewan (Brown and others, 2011). Thus, "Willo" provided insight into not just the anatomy of *Thescelosaurus*, but also into the diversity of these animals.

The Dinosaur with a Heart of Stone

In addition to its wonderfully preserved skull, "Willo" presented another interesting feature. Just inside the rib cage was a large iron concretion (fig. 3). CT scans of the specimen showed pockets of low density within this concretion (figs. 4a and b). When researchers saw those images one thought jumped to the front of their minds: it is a heart! Concretions are known to form around decaying organic tissue as microbes release high concentrations of ions into the surrounding sediment as byproducts of breaking down and consuming the organic matter. In this manner a variety of soft-bodied fossils are preserved in the rock record that would otherwise never be preserved since they lack hard tissues like bone or shells. The researchers studying "Willo" hypothesized that as the heart was decaying, one of these iron concretions formed around it, and that the shape of the concretion would mimic that of the original heart. They suggested that two of the lower density areas were the left and right ventricles of the heart, and that a third, elongate low-density area was the aorta extending away from the heart (fig. 4b). Moreover, the identification of a single aorta extending away from the heart would imply that this dinosaur had a four-chambered heart similar to that seen in modern birds (as opposed to the three-chambered heart of crocodilians, which have two aortae), which would suggest that this dinosaur was an endotherm (warm-blooded), just like living birds (Fisher and others, 2000). Upon announcement of this discovery "Willo" was hailed as the "Dinosaur with a heart of stone!"

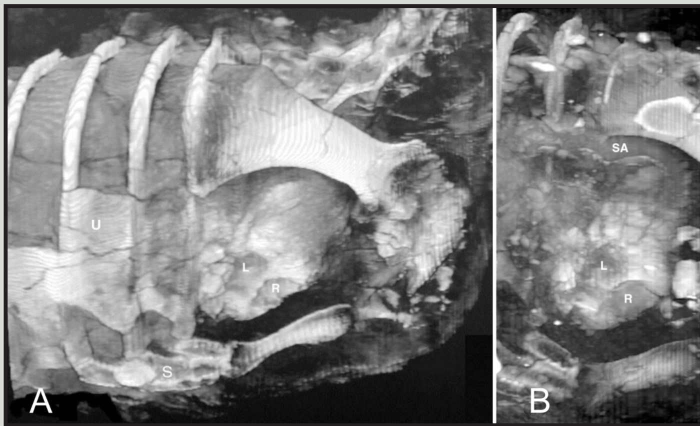

Figure 4. Images from CT scans of the chest concretion preserved in "Willo" (modified from Fisher and others, 2000: figs. 1 and 2).

Other researchers soon became critical of the identification of the iron concretion as a fossilized heart. In particular, a research group led by Timothy Rowe at The University of Texas at Austin published a response to the original paper arguing that not enough lines of evidence were presented to confirm the identification (Rowe and others, 2001). Years later, a new research team at North Carolina State University overseen by Mary Schweitzer took up the challenge of re-examining the possible heart using a wide range of analytical techniques, including higher resolution CT scans, X-ray diffraction analysis, and scanning electron microscopy. Those investigations were conducted by then graduate student Timothy Cleland as a part of his doctoral dissertation. To start with, they constructed three-

Figure 3. Photograph of the chest region of the "Willo" specimen showing the large iron concretion (NCSM 15728).

dimensional models of the low-density areas within the concretion and then compared them to models made from ostrich hearts. The result was that the low density areas did not resemble the internal structure of a heart at all (figs. 5a -5d). Next, they made thin sections of a portion of the concretion. If the concretion was formed around a heart, the concretion should be a relatively solid mass of iron-rich minerals with no sand grains mixed in. Instead, they found that the concretion was full of sand grains, and that the concretion was formed by iron-rich minerals filling in the open space between those sand grains (fig. 6a). They also found pieces of plants preserved within the concretion (fig. 6b), something that would not be expected if the structure had formed inside the chest-cavity of this animal around the heart. Finally, the chemical signature of the concretion was not what would be expected if it was formed from minerals released during the decay of organic material.

The end result was that the idea of the "heart of stone" was rejected (Cleland and others, 2011). The positioning of the concretion within the chest cavity of "Willo" was just a coincidence. While this finding was a letdown for some, it does not take away from the fact that "Willo" is an exceptionally well-preserved fossil that is providing important information about *Thescelosaurus*. However, this story does provide a good cautionary tale for paleontologists: extraordinary claims about the fossil record require extraordinary evidence.

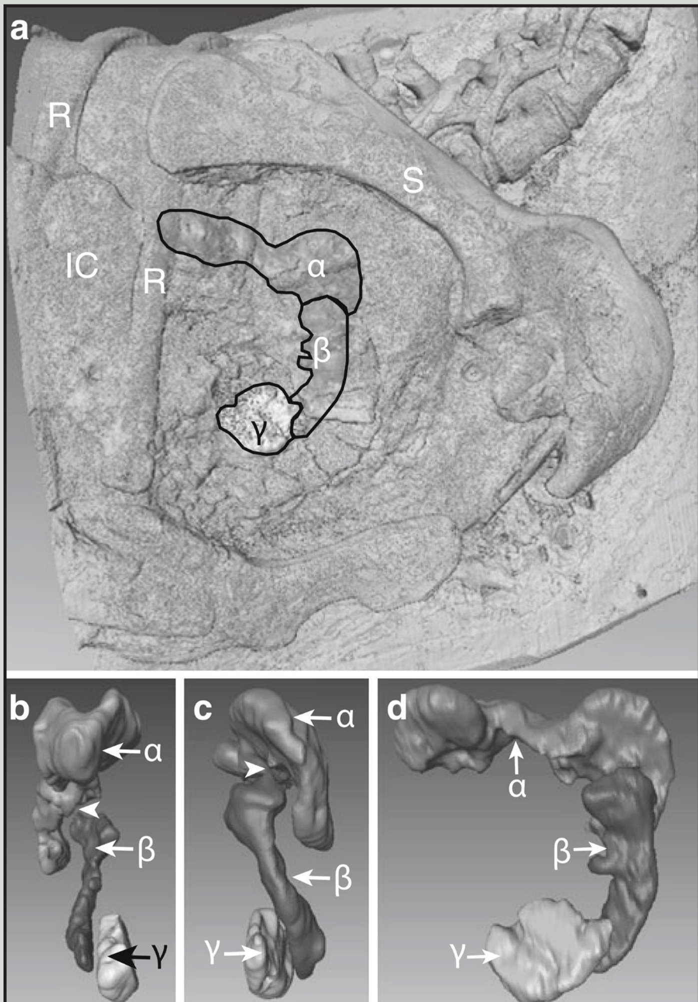

Figure 5. Images from newer CT scans of the chest concretion preserved in "Willo" with the low-density areas three-dimensionally reconstructed. In (a), the outer surface of the specimen is modeled with the outlines of the three low-density areas (α, β, γ) overlaid. The three-dimensional models are shown separately in posterior (b), anterior (c), and side (d) views. All images modified from Cleland and others (2011, figs. 2a-d). Abbreviations: IC, intercostal plate; R, rib; S, scapula.

Thescelosaurus in North Dakota

Thescelosaurus neglectus is an important part of the fauna of the Late Cretaceous Hell Creek Formation here in North Dakota. Though many think of this animal as rare and seldom encountered, the truth is many bones from this animal are collected every year by institutions working in rocks of the Hell Creek Formation, but they are often either misidentified as other animals, collected but never studied, or simply not picked up because the field crew is looking for fossils from the "more exciting" species present in the Hell Creek Formation: the large carnivore *Tyrannosaurus rex*, the horned dinosaur *Triceratops*, or the duck-billed dinosaur *Edmontosaurus*. In this way, *Thescelosaurus neglectus* remains an "overlooked, marvelous reptile" more than 100 years after it was first described. Such

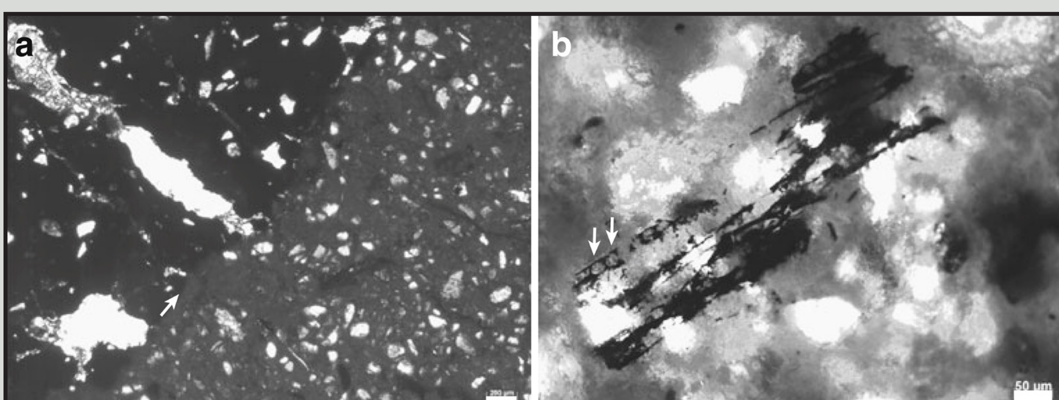

Figure 6. Thin section images taken from the chest concretion preserved in "Willo." In (a), the wall of the concretion is shown to be composed of sand grains (light colored spots) cemented together by iron-rich minerals (darker material). In (b), a small piece of plant fossil from the wall of concretion is shown surrounded by sand grains. Images modified from Cleland and others (2011: figs. 3a and b).

paleontological trophy hunting negatively impacts the field of paleontology by skewing our interpretation of the relative abundance of these species in the Hell Creek fauna and providing fewer specimens for studying the less common animals present in the Hell Creek Formation. Studies based on unbiased collecting in the Hell Creek Formation estimate that *Thescelosaurus* forms around eight percent of the fauna (Horner and others, 2011), making it an important player in the latest Cretaceous ecosystem and a critical species to learn more about.

The North Dakota State Fossil Collection contains a few *Thescelosaurus* fossils, though most consist of a single, isolated bone (fig. 7). While paleontologists working for the North Dakota Geological Survey are still searching for a well-preserved skeleton of this species to add the collection, several nice specimens were collected in the area near Marmarth, ND by the Marmarth Research Foundation under the direction of Tyler Lyson, who also works for the Denver Museum of Natural History. Those discoveries prove that good specimens of *Thescelosaurus neglectus* are out there, we just have to keep searching until we come across an overlooked specimen.

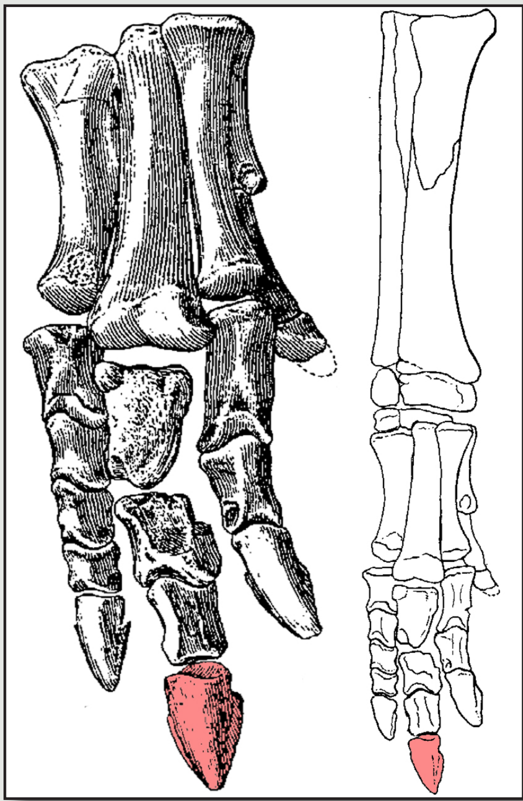

Figure 7. An ungual (claw) from the foot of *Thescelosaurus* held in the North Dakota State Fossil Collection. The dashed lines show where bone is missing along one side. This claw is from the middle toe of the foot, as highlighted in the illustrations of the foot and full hind limb of *Thescelosaurus* shown on the right (images not to scale). Illustrations modified from Gilmore (1913: figs. 4 and 5). Scale bar = 5 cm.

References

Boyd, C.A., 2014, The cranial anatomy of the neornithischian dinosaur *Thescelosaurus neglectus*: PeerJ, v. 2, no. e669, p. 1-75.

Boyd, C.A., Brown, C.M., Scheetz, R.D., and Clarke, J.A., 2009, Taxonomic revision of the basal neornithischian taxa *Thescelosaurus* and *Bugenasaura*: Journal of Vertebrate Paleontology, v. 29, no. 3, p. 758-770.

Brown, C.M., Boyd, C.A., and Russell, A., 2011, A new basal ornithopod dinosaur (Frenchman Formation, Saskatchewan, Canada), and implications for late Maastrichtian ornithischian diversity in North America: Zoological Journal of the Linnean Society, v. 163, no. 4, p. 1157-1198.

Cleland, T.P., Stoskopf, M.K., and Schweitzer, M.H., 2011, Histological, chemical, and morphological reexamination of the “heart” of a small Late Cretaceous *Thescelosaurus*: Naturwissenschaften, v. 98, no. 3, p. 203-211.

Fisher, P.E., Russell, D.A., Stoskopf, M.K., Barrick, R.E., Hammer, M., and Kuzmitz, A.A., 2000, Cardiovascular evidence for an intermediate or higher metabolic rate in an ornithischian dinosaur: Science, v. 288, p. 503-505.

Galton, P.M., 1974, The ornithischian dinosaur *Hypsilophodon* from the Wealden of the Isle of Wight: Bulletin of the British Museum (Natural History) Geology, v. 25, no. 1, p. 1-152.

Galton, P.M., 1995, The species of the basal hypsilophodontid dinosaur *Thescelosaurus* Gilmore (Ornithischia: Ornithopoda) from the Late Cretaceous of North America: Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, v. 198, no. 3, p. 291-311.

Galton, P.M., 1997, Cranial anatomy of the basal hypsilophodontid dinosaur *Thescelosaurus neglectus* Gilmore (Ornithischia: Ornithopoda) from the Upper Cretaceous of North America: Revue de Paleobiologie, v. 16, no. 1997, p. 231-258.

Galton, P.M., 1999, Cranial anatomy of the hypsilophodontid dinosaur *Bugenasaura infernalis* (Ornithischia: Ornithopoda) from the Upper Cretaceous of North America: Ruevue de Paleobiologie, v. 18, no. 1999, p. 517-534.

Gilmore, C.W., 1913, A new dinosaur from the Lance Formation of Wyoming: Smithsonian Miscellaneous Collections, v. 61, p. 1-5.

Gilmore, C.W., 1915, Osteology of *Thescelosaurus*, an orthopodous dinosaur from the Lance Formation of Wyoming: Proceedings of the United States National Museum, v. 49, no. 2127, p. 591-616.

Horner, J.R., Goodwin, M.G., and Myhrvold, N., 2011, Dinosaur census reveals abundant *Tyrannosaurus* and rare ontogenetic stages in the Upper Cretaceous Hell Creek Formation (Maastrichtian), Montana, USA: PLoS ONE, v. 6, no. 2, p. e16574.

Rowe, T., McBride, E.F., and Sereno, P.C., 2001, Dinosaur with a heart of stone: Science, v. 291, p. 783a.

Schuchert, C., 1939, Biographical memoir of Othniel Charles Marsh, 1831-1899: National Academy of Sciences, p . 1-78.