



# GEOLOGY OF THE INTERMOUNTAIN WEST

*an open-access journal of the Utah Geological Association*

ISSN 2380-7601

Volume 6

2019

## HISTORY AND GEOLOGY OF THE COPE'S NIPPLE QUARRIES IN GARDEN PARK, COLORADO—TYPE LOCALITY OF GIANT SAUROPODS IN THE UPPER JURASSIC MORRISON FORMATION

Kenneth Carpenter



Theme Issue

An Ecosystem We Thought We Knew—  
The Emerging Complexities of the Morrison Formation  
SOCIETY OF VERTEBRATE PALEONTOLOGY

*Annual Meeting, October 26 – 29, 2016*

*Grand America Hotel  
Salt Lake City, Utah, USA*



© 2019 Utah Geological Association. All rights reserved.

For permission to copy and distribute, see the following page or visit the UGA website at [www.utahgeology.org](http://www.utahgeology.org) for information.

Email inquiries to [GIW@utahgeology.org](mailto:GIW@utahgeology.org).



# GEOLOGY OF THE INTERMOUNTAIN WEST

*an open-access journal of the Utah Geological Association*

ISSN 2380-7601

Volume 6

2019

## Editors

Douglas A. Sprinkel Utah Geological Survey 801.391.1977 GIW@utahgeology.org	Thomas C. Chidsey, Jr. Utah Geological Survey 801.537.3364 tomchidsey@utah.gov
--	---

Bart J. Kowallis Brigham Young University 801.422.2467 bkowallis@gmail.com	Steven Schamel GeoX Consulting, Inc. 801.583-1146 geox-slc@comcast.net
---	---



## Society of Vertebrate Paleontology

### Editors

Kelli C. Trujillo — University of Wyoming  
John Foster — Utah Field House of Natural History  
State Park Museum  
Cary Woodruff — University of Toronto  
Octavio Mateus — Universidade Nova de Lisboa

## Production

Cover Design and Desktop Publishing  
Douglas A. Sprinkel

Cover

*Bones of **Camarasaurus supremus** as found and excavated by Oramel Lucas in 1877. Photograph was taken by C.W. Talbot (Cañon City, Colorado). See figure 4 caption for more details.*



*This is an open-access article in which the Utah Geological Association permits unrestricted use, distribution, and reproduction of text and figures that are not noted as copyrighted, provided the original author and source are credited.*

## UGA Board

### October 2018 – September 2019

President	Peter Nielsen	peternielsen@utah.gov	801.537.3359
President-Elect	Leslie Heppler	lheppler@utah.gov	801.538.5257
Program Chair	Gregory Schlenker	gcsgeoscience@gmail.com	801.745.0262
Treasurer	Dave Garbrecht	garbrechtd@yahoo.com	801.916.1911
Secretary	George Condrat	gcondrat@loughlinwater.com	435.649.4005
Past President	Paul Inkenbrandt	paulinkenbrandt@utah.gov	801.537.3361

## UGA Committees

Environmental Affairs	Craig Eaton	eaton@ihi-env.com	801.633.9396
Geologic Road Sign	Terry Massoth	twmassoth@hotmail.com	801.541.6258
Historian	Paul Anderson	paul@pbageo.com	801.364.6613
Outreach	Greg Nielson	gnielson@weber.edu	801.626.6394
Membership	Rick Ford	rford@weber.edu	801.626.6942
Public Education	Paul Jewell	pwjewell@mines.utah.edu	801.581.6636
	Matt Affolter	gfl247@yahoo.com	
Publications	Paul Inkenbrandt	paulinkenbrandt@utah.gov	801.537.3361
Publicity	Paul Inkenbrandt	paulinkenbrandt@utah.gov	801.537.3361
Social/Recreation	Roger Bon	rogerbon@xmission.com	801.942.0533

## AAPG House of Delegates

2017–2020 Term	Tom Chidsey	tomchidsey@utah.gov	801.537.3364
----------------	-------------	---------------------	--------------

## State Mapping Advisory Committee

UGA Representative	Jason Blake	blake-j@comcast.net	435.658.3423
--------------------	-------------	---------------------	--------------

## Earthquake Safety Committee

Chair	Grant Willis	gwillis@utah.gov	801.537.3355
-------	--------------	------------------	--------------

## UGA Website

**www.utahgeology.org**

Webmasters	Paul Inkenbrandt	paulinkenbrandt@utah.gov	801.537.3361
------------	------------------	--------------------------	--------------

## UGA Newsletter

Newsletter Editor	Bill Lund	uga.newsletter@gmail.com	435.590.1338
-------------------	-----------	--------------------------	--------------

*Become a member of the UGA to help support the work of the Association and receive notices for monthly meetings, annual field conferences, and new publications. Annual membership is \$20 and annual student membership is only \$5. Visit the UGA website at [www.utahgeology.org](http://www.utahgeology.org) for information and membership application.*

*The UGA board is elected annually by a voting process through UGA members. However, the UGA is a volunteer-driven organization, and we welcome your voluntary service. If you would like to participate please contact the current president or committee member corresponding with the area in which you would like to volunteer.*



## History and Geology of the Cope's Nipple Quarries in Garden Park, Colorado—Type Locality of Giant Sauropods in the Upper Jurassic Morrison Formation

**Ken Carpenter**

*Prehistoric Museum, Utah State University Eastern, Price, UT 84501; Ken.Carpenter@usu.edu; Museum of Natural History, University of Colorado, Boulder, CO 80309*

### ABSTRACT

The discovery in 1877 of what proved to be an extensive multi-taxa bonebed from the Upper Jurassic Morrison Formation helped kick-start the first Jurassic “Dinosaur Rush.” Located north of Cañon City, Colorado, the site, known today as Cope’s Nipple within the Garden Park National Natural Landmark, was worked by Oramel and Ira Lucas from 1877 to 1884, again by the Carnegie Museum in 1901, and sporadically by the Denver Museum of Natural History from 1991 to 1996. The history of this work is presented in depth for the first time using extensive archival records. The quarries occur in a single horizon around the base of Cope’s Nipple and represents a widespread bonebed in distal overbank silty mudstone that was subsequently modified by pedogenesis. Limited taphonomic data indicate the bonebed was a mix of allochthonous and autochthonous bone.

### INTRODUCTION

The first Jurassic “Dinosaur Rush” began with the near simultaneous discovery of dinosaur bones close to the towns of Morrison and Cañon City, Colorado, in 1877 (figure 1). The discoveries and their role in the “bone wars” between prominent U.S. paleontologists Othniel C. Marsh and Edward D. Cope has been told numerous times by a variety of authors, most recently by Jaffe (2000) and Thompson (2008), among others. More detailed accounts of the discoveries near Morrison by Arthur Lakes, who taught geology courses at Jarvis Hall, Colorado Territory’s first college, and his friend Henry Beckwith is told in Lakes’ journals (Kohl and McIntosh, 1997) and by Honda and Simmons (2009). Farther south, two prominent sites were found north of Cañon City in the area known as Garden Park.

The account of homesteader Marshal Felch’s discovery was told in detail by Evanoff and Carpenter (1998). The other discovery, by school teacher Oramel Lucas has been briefly discussed by Osborn (1931), Monaco (1998), and McIntosh (1998). Of these, the contribution by McIntosh was the most important because he sought to apportion the E.D. Cope dinosaur collection, which had been briefly described in a series of articles (Cope 1877a–d; 1878a–g) and later described in greater detail by Osborn and Mook (1921), to various quarries. The detailed history of the main Lucas quarries at the base of a distinctive, conical hill locally known today as Cope’s Nipple (a.k.a. “the Hill,” “Saurian Hill,” “the Nipple,” “Talbot’s Hill;” figure 1A) from where most of the Cope specimens came (figure 1B), is recounted below, along with a discussion of the sedimentology and taphonomy. Both the Felch and Lucas quarries lie within

*Citation for this article.*

*Carpenter, K., 2019, History and geology of the Cope’s Nipple Quarries in Garden Park, Colorado—type locality of giant sauropods in the Upper Jurassic Morrison Formation: Geology of the Intermountain West, v. 6, p. 31–53.*

© 2019 Utah Geological Association. All rights reserved.

For permission to use, copy, or distribute see the preceding page or the UGA website, [www.utahgeology.org](http://www.utahgeology.org), for information. Email inquiries to [GIW@utahgeology.org](mailto:GIW@utahgeology.org).

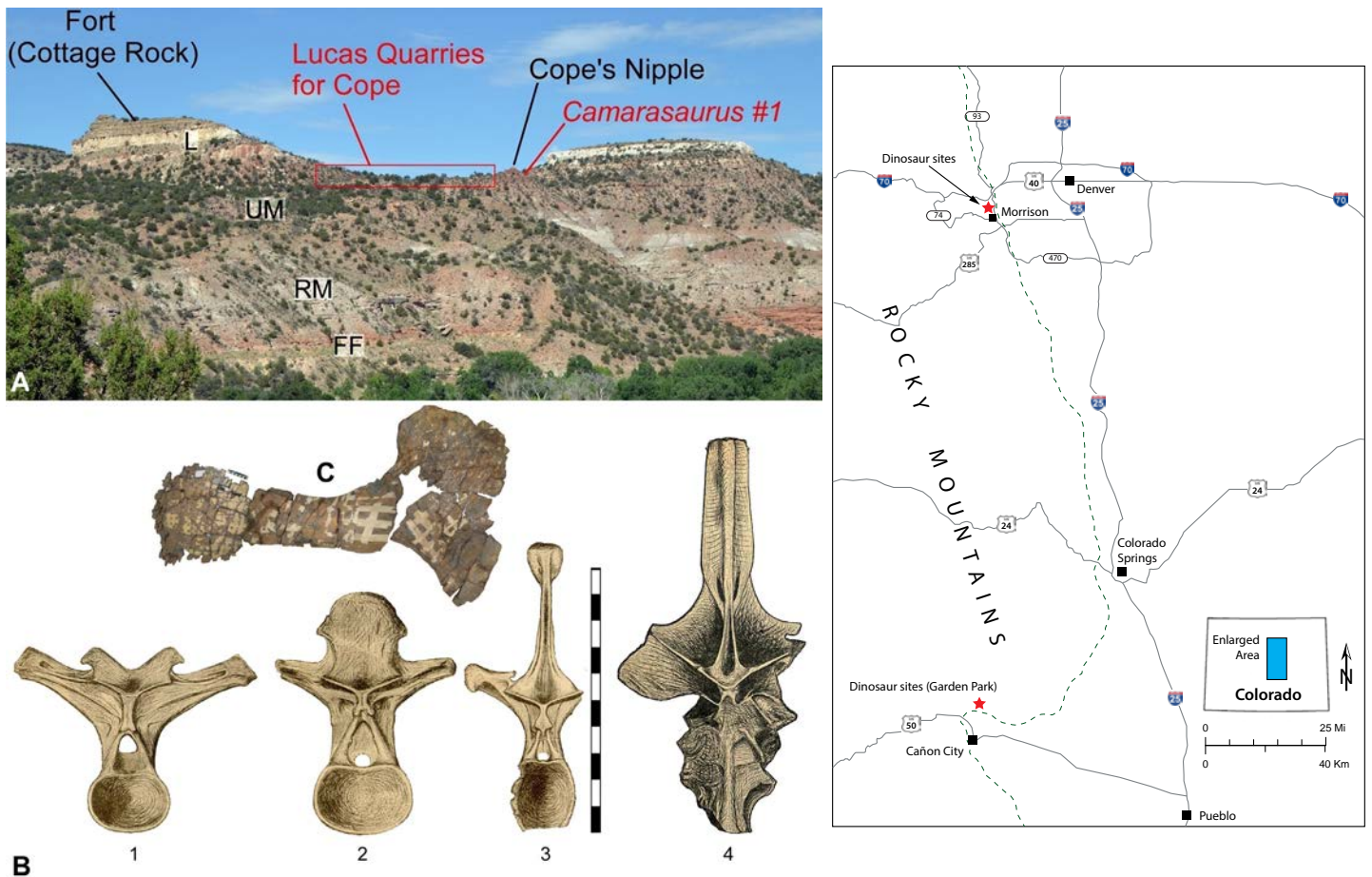


Figure 1. (A) Distant view of Cope's Nipple (aka, "The Hill," "Saurian Hill," "The Nipple") viewed west showing the location of the Lucas quarries. Fourmile Creek (Oil Creek) marked by the trees at the base of photograph (image courtesy of Vicki Garrisi, True West Properties). Abbreviations: FF – Fountain Formation (Pennsylvanian); RM – Ralston Creek Member of the Morrison Formation (see Carpenter and Lindsey, 2019); UM – unnamed member of the Morrison Formation (see Carpenter and Lindsey, 2019); L – Lytle Sandstone (Cretaceous), (B) Illustrations of sauropod dorsals made by Cope: *Camarasaurus supremus* (1) mid-dorsal (D-5), (2) a more posterior mid-dorsal (D-8), and *Amphicoelias altus* (3) probably D-10. (4) The neural arch of *Amphicoelias fragillimus* (now *Maarapunisaurus fragillimus*, Carpenter, 2018a). (C) Example of the use of paper strips glued to the surface to hold fragments together. *Haplocanthosaurus* scapula (YPM 4688) collected by Mudge, Felch, and Williston, November, 1877, from Felch Quarry. Scale in (B) = 1 m; scale in (C) = 10 cm. 1 to 3 from Cope 1878b; 4 from Cope 1878f. The green dashed line on the index map is the approximate location of the mountain front. Index map by Doug Sprinkel (Utah Geological Survey).

the Bureau of Land Management's Garden Park National Natural Landmark—formerly known as the Garden Park Paleontological Resource Area.

## MATERIALS AND METHODS

Beginning in the early 1990s, Pat Monaco and Donna Engard of Wetmore, Colorado, amassed a huge amount of E.D. Cope and O.C. Marsh archival documents for the Garden Park Paleontological Society

in Cañon City, Colorado, referred to below as "GPPS docs." These documents are now housed at the Royal Gorge Regional Museum and History Center, Cañon City, Colorado. Copies of these documents have been made available to me and I draw upon them to recount the history of the excavations around Cope's Nipple. Other correspondence by Oramel Lucas to individuals at his alma mater Oberlin College reside in the Oberlin College Archives. Among these is a letter addressed to

“Will,” presumably one of four classmates named “William” (Anonymous, 1876, p. 10–11). Copies of these correspondence were made available to me by Dan Grenard, formerly of the Bureau of Land Management, Cañon City, Colorado, and are referred to as “Oberlin Archives.” Much of the unpublished information sheds light on the collecting by Oramel William Lucas (1849–1935) and to a lesser extent by his brother Ira Hiram Lucas (1838–1920). Among the documents is a transcription of an oral account, “Discovering Dinosaurs Bones in Colorado,” made by Oramel Lucas to his daughter Ethel Lucas prior to 1935; this is referred to as “Lucas Discovery GGPS docs.” Other GPPS documents include an open letter from Lucas to the Class of 1880 on their 50<sup>th</sup> reunion (cited below as “Lucas 50<sup>th</sup>, GPPS docs”), letters from E.D. Cope, as well as copies of drawings of bones made by Oramel. Published accounts appeared in the local press and in popular books written at the time of discovery. Much of Joseph Pangborn’s (1878) eyewitness account of the Lucas excavation was repeated verbatim by Binckley and Hartwell (1879) and Rockafellow (1881). Correspondence of Oramel Lucas, David Baldwin, and Benjamin Mudge to O.C. Marsh of the Yale Peabody Museum are available at <https://peabody.yale.edu/collections/vertebrate-paleontology/correspondence-o-c-marsh>. The Carnegie Museum of Natural History reopened some of the Lucas Quarries in August through September 1901. Correspondence quoted from this time between John Hatcher, William Utterback, George Axtell, and William Holland is preserved at the Carnegie Museum of Natural History (Pittsburgh, Pennsylvania) and is referred to as “CM archives.” Minor typographic errors in quotes from all of these correspondences have been corrected except where noted by “[sic].” All of this archival information is pulled together below for the first detailed history of the excavations at Cope’s Nipple. Sedimentological and taphonomic data is gleaned in part from various documents and from the Denver Museum of Natural History excavations. Dollar conversions to 2018 values are based on [www.in2013dollars.com](http://www.in2013dollars.com).

## INSTITUTIONAL ABBREVIATIONS

AMNH—American Museum of Natural History,

New York, New York; CMNH—Carnegie Museum of Natural History, Pittsburgh, Pennsylvania; DMNH—Denver Museum of Natural History, Denver, Colorado; YPM—Yale Peabody Museum of Natural History, New Haven, Connecticut.

## LUCAS BROTHERS DIG DINOSAURS (1877–1884)

Oramel William Lucas, the discoverer of many of the Jurassic dinosaur specimens described by Edward Cope in 1877 and 1878, moved to Garden Park north of Cañon City, Colorado, in June 1876. He relocated there from Ohio where he had been a junior at Oberlin College (Anonymous, 1876, p. 10). He left college because he could not afford the costs (~\$48/quarter, Anonymous, 1876, p. 59; \$1,131 in 2018) and took a teaching position in the Garden Park one-room school arranged by his sister, Lucy Ripley, who had settled in Garden Park with her husband (Lucas Discovery GGPS docs). Lucas is also sometimes referred to as the Superintendent of Schools for Fremont County (e.g., Cope, 1877b), a position he briefly held from April to October, 1877 (Binckley and Hartwell, 1879). When he left Oberlin, he was advised by Albert Wright, professor of geology and natural history, to study geology out west. He later wrote to Wright that he would occasionally wander the hills and mountains looking for geological specimens or deer (Lucas to Wright, April 6, 1877, Oberlin Archives; Lucas was not an amateur botanist looking for plants as claimed by Jaffe, 2000). On one of these jaunts in late March 1877, he made his discovery (the month is given as April by Pangborn, 1878). As Lucas tells the story,

“I wended my way back over the ridge to my sister’s where I spent my holidays. Passing over the ridge of hills homeward I picked up a piece of rock, about three inches long and as wide as my hand, the shape of a cross section of a fish. Upon examining it closely I found there were fine white streaks running lengthwise. I at once decided that it must be petrified bone instead of a fish [probably a sauropod rib fragment].

Looking around in the vicinity I noticed a little hump of dirt, 3 or 4 inches above the level of

the ground. Taking a stick, I poked the dirt away and found a petrified bone 5 or 6 inches in diameter at the smallest place and 3 feet long. Greatly surprised, as I had never seen a petrified bone, I covered it up very carefully waiting an opportunity to take it out.

My first opportunity, I dug it out and carried it down to my boarding place. I had to make two trips as it was more than I could carry in one load.

The next Saturday I investigated the neighborhood, looking around in the vicinity, and came upon a bed of petrified bones with numerous pieces scattered around.

From this bed I eventually took out a femur bone 6 feet long and about 10 inches in diameter in the smallest place and a shoulder blade 5 1/2 feet long and 3 feet wide at the widest place and quite a number of vertebrae, joints of the back and the tail and pieces of ribs." Quote from Lucas Discovery GGPS docs.

Lucas collected more specimens and hauled them into Cañon City where they attracted local attention (Anonymous, Cañon City Avalanche newspaper, June 14, 1877, GPPS docs):

"Mr. O. W. Lucas, superintendent of the county schools, recently discovered about nine miles north of Cañon City, the fossil remains of a carnivorous and herbivorous giant which he thinks is that of the Iguanodon, a reptile of the Cretaceous period, that had somewhat the habits of the Hippopotamus. In shape, the Iguanodon, resembles a Kangaroo in the body, having a serpent-like head with flat serrated teeth, the tail being very long. It is estimated that this fossil is that of an animal at least sixty feet in length, and eighteen feet high. The short leg bone, now in possession of Mr. Lucas, is six feet in length; the hip bone is three feet three inches long, two feet wide, and twenty-one inches in diameter at the joint: the shoulder-blade is five feet six inches in length, and the vertebrae at the back and tail of corresponding size. The remains now gathered

make five wagon loads. Next week we will devote more space to this mammoth fossil, and try and describe it more fully, in the meantime it will be on exhibition at the museum of Mr. Eugene Weston, on Main Street."

Weston was a bit of a con-man, who featured himself as an auctioneer, as a middleman for the sale of mines, lands, stock, etc., outfitter for prospectors and tourists, and had a small museum that displayed and sold curiosities (advertisement in the Cañon City Times, April 19, 1877). Lucas would come to regret his involvement with Weston as is discussed below.

The following week, Lucas wrote a letter to the editor in response to the article that announced his discovery. He listed some of the characters of the dinosaurs given in one of his college textbooks, Dana's *Manual of Geology*, and noted that:

"Several of these conditions are found in the bones already taken out, sufficiently so to prove that they belong to that species of the Dinosaurs called the 'Iguanodon' as stated last week – the long bones being hollow, the pelvic arch resembling that in birds, and the sacrum consisting of four vertebrae united in one." He notes that *Iguanodon* "was estimated to have been twenty-eight to thirty feet long. Comparing the dimensions of those bones with what I have would make the latter animal from sixty-three to sixty-five feet long upon the supposition that it is an Iguanodon. That my surmise is possibly correct, I would state that a dissection of an ordinary swift, or lizard five inches in length shows many features in common with the fossil."

He goes on to note:

"I am still prosecuting the work and think that with proper care and perseverance I shall be able to secure the larger portion, if not nearly the whole skeleton. Some of the bones, especially the thin ones, are badly broken and hence require much time and patient labor to properly arrange. Another difficulty in the way of successfully prosecuting the work is that many of the bones are removed a hundred yards or more

distant, evidently soon after the animal died, it was preyed upon by some huge carnivorous animal. I have already obtained the following bones, viz: tibia, three feet one inch long; femur, six feet; hip bone, three feet three inches; sacrum, three feet one inch; shoulder blade, five feet five inches; thirteen caudal vertebrae, several dorsal vertebrae, and several ribs; a small part of the jaw bone containing six teeth, and other bones which I am at present unable to identify. I propose soon to send portions east to someone thoroughly versed in paleontologic science, that if possible, positive knowledge of species and name may be had.” Quote from Lucas, Cañon City Avalanche newspaper, June 21, 1877, GPPS docs.

All of this attention led to a stream of visitors (figure 2) as he wrote:

“A great many have been up from town nine miles to see the fossils.” Quote from Lucas to “Will,” November 22, 1878, Oberlin Archives.

This interest by the public to see dinosaur bones in the ground would be repeated years later in Utah when Earl Douglass, CMNH, announced the discovery of a dinosaur skeleton at a site that would eventually become Dinosaur National Monument (Carpenter, 2018b).

Knowing the scientific importance of the material he was finding, Lucas wrote to Wright at Oberlin College:

“I have thought that it would be not only a valuable best as interesting specimen to have in the cabinet at Oberlin, but the college is poor and so am I and I cannot afford to take it out, glue it together and transport it to Oberlin for nothing.

Do you care to have this specimen in your cabinet if so what allowance could you guarantee to me for getting it out? If you can, will you give me the name of the geological professors of some of the eastern colleges, also the proprietors of the largest museums in the country? Perhaps some of them would like it and allow me something for it.” Quote from Lucas to Wright, April 6, 1877, Oberlin Archives.

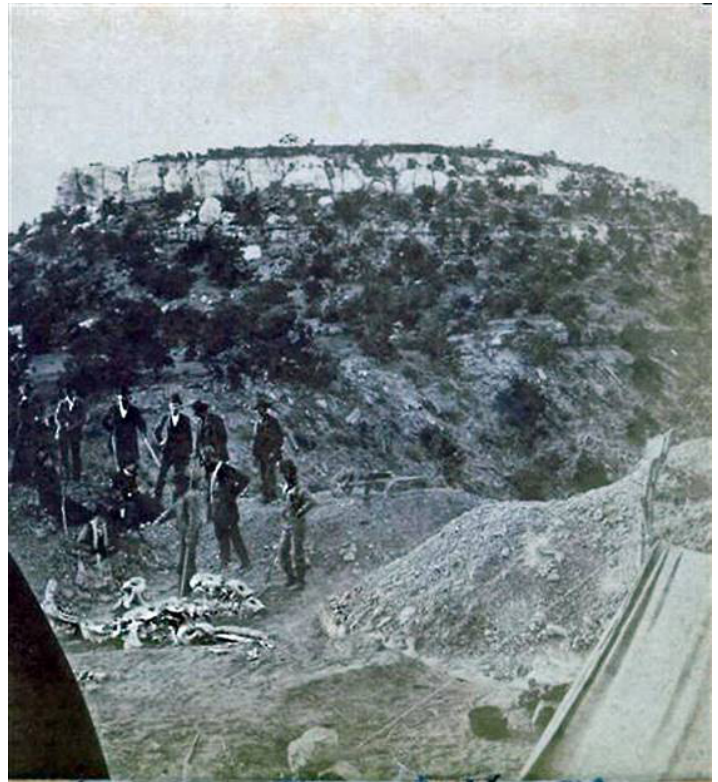


Figure 2. The earliest known photograph of visitors to a dinosaur excavation. Oramel Lucas (center, foreground) and visitors sometime during late summer 1877. These bones are also seen in figure 5B. The photograph is believed to have been taken by C.W. Talbot (image courtesy of Dan Grenard, retired, Bureau of Land Mangement, Cañon City, Colorado).

Wright confirmed that the college lacked funds to buy the specimens and referred him to O.C. Marsh at Yale University and E.D. Cope of Philadelphia (Lucas Discovery GGPS docs). Alerted by the discovery, Marsh ordered one of his collectors who was excavating at Morrison, Colorado, to investigate. The collector, Benjamin Mudge, arrived in Cañon City at sunset and quickly made his way to Weston’s shop to examine the fossils. The next day he sent Marsh his hurried observations:

“They are not Titanosaurus [a sauropod named by Marsh for bones sent to him by Arthur Lakes from Morrison, Colorado], but the most anomalous in structure of anything I ever saw.

Very few of the bones have any familiar shape or resemblance though a few of the vertebra re-

semble the Dinosaurs – others are deeply biconcave and some concave–convex. Others' are extremely unique, in having a partial frame of the centrum, with most extra-ordinary spinous processes in complex structure, ending in a kind of rounded knob, as if supporting an exoskeleton. No heavy scales or plates have been found. This knob is seen even in the chevron bone (the only one found) of the caudal vertebra. This chevron, in other respects much resembled the one I sent you in the last shipment from Morrison only, one fourth larger. The caudal vertebrae and of the cervicals(?) had a strong resemblance to Titanosaurus, and it is possible that these bones are from two animals of different genera. Only a small portion of the head, a portion of a jaw with four teeth was found, and from the count (sent to Cope, & so I did not see it), I think it belonged to a smaller animal than the larger bones. Some other portions were sent to Cope, and others are now packed and being packed, for sending. Excepting the head, the skeleton as well represented by bones of all parts, legs, pelvis, shoulder, & etc. All are on a larger scale than T[itanosaurus] m[ontanus], from 10 to 30 percent. I have the promise of the measurements. I only saw the bones by lamplight – poor at that...

[note in margin] "Lumber [sic] – possibly dorsal. The sacrum has five vertebrae furnished with spinous process with knob!!!" Quote from Mudge letter to Marsh, August 12, 1877.

A few days later Mudge wrote:

"In looking over Mr. Lucas's bones by daylight I find the sacrum is composed of four vert. – not five. It is three feet 1½ inches long one 10/12 feet high(!). The femur six feet long, largest vertebra (centrum) fourteen inches in diameter. Length of the scapula five 5/12 feet – width three 2/12. The spinous processes appear to be hollow." Quote from Mudge to Marsh, August 15, 1877.

Upon receiving the letter, Marsh fired off a telegram to Mudge on August 18 to purchase the specimen, and reiterated this in a second telegram, "Purchase specimens

if possible. Jones has violated all agreements." (Marsh to Mudge, August 21, 1877). The reference to "Jones" is supposed to be a code word for Cope (Schuchert and LeVene, 1940). The reference to an agreement with Cope is mystery because no evidence for such an agreement is known and may have only resided in Marsh's mind. The two were already deeply involved in their feud by this time and neither had any scruples about "invading" one another's collecting grounds (Osborn, 1931; Schuchert and LeVene, 1940; Jaffe, 2000; Thompson 2008).

Unfortunately, by the time Marsh telegraphed Mudge, it was too late. Unlike the cautious and surreptitious approach of Marsh, Cope had quickly responded to Lucas having learned his lesson from his slow response to Arthur Lake and having lost out on the discoveries near Morrison (Kohl and McIntosh, 1997; Jaffe 2000). Cope wrote that he wanted the specimens and would pay Lucas to excavate for him.

Marsh had actually been alerted to large bones in the Cañon City area months earlier by one of his collectors, David Baldwin, who lived there, "There are bones of large animals in the Jura near here" (Baldwin to Marsh, February 10, 1877). He later wrote Marsh about the very same bones that Lucas was excavating when Baldwin visited the site of an alleged bird fossil (the specimen became the holotype of *Hallopus victor*, Ague and others, 1995):

"I explored the place fairly [sic] thoroughly but found nothing but some very large bones all reptilian I guess. In all the vertebrae that I saw the centrum was biconcave. There are the bones of one tremendous big animal laying on a flat about 15 feet higher than the strata where this [*Hallopus* specimen] was found. One that I saw is imbedded in the red clay or in shale surrounding it measured 20 inches in across and broken off two feet long. Some parties here are digging it up and sending it to Colorado Springs to the Curiosity Shop over there where it will be sold at so much a chunk to visitors." Quote from Baldwin to Marsh, April 30, 1877.

After learning he lost out to Cope, Marsh castigated Baldwin in a letter sent August 2, 1877, for not securing the fossils. Baldwin did not get the letter until the



following month and wrote back in his defense:

“As for those largest bones at Cañon 1<sup>st</sup> another had presented[?] and had commenced digging on them before I saw them and another thing I did not suppose that you cared anything about them as I had written to you along in the winter telling you that there were large bones in the Jura near Cañon and received no notice whatever from you. I spent two or three weeks in looking around spotting localities hoping that you would write and let me know that you wanted some from there but hearing nothing from you I quit and went to prospecting.” Quote from Baldwin to Marsh, September 4, 1877.

Unknowingly, Mudge rubbed salt in Marsh's wound by reiterating the lost opportunity of securing the fossils before Cope, “I exceedingly regret that Baldwin did not secure them for you, as he might when they were first discovered.” Quote from Mudge to Marsh, August 12, 1877.

The full magnitude of what Marsh lost out on became very clear by the series of publications on the specimens by Cope (1877a–d; 1878a–g). A year later, Marsh still faulted Baldwin, who wrote in his defense again:

“I infer from what Lt. Carpenter [who had recommended Baldwin to Marsh as a collector] writes me that you suppose that I found the large bones that Lucas is digging for Cope before he (Lucas) did. Such is not the case. I never saw those bones until after Lucas had commenced digging on them. I had found bones in the Jurassic in several places two or three months before Lucas found those but I did not dig on them on account of not hearing from you that you wanted them. No one except myself has ever dug on any of them. I have shown several places to Mr. Beckwith [another collector of Marsh's] but he says that you do not want more large bones unless they should be new and what would be new I have no means of finding as mail communications with you are very uncertain.” Quote from Baldwin to Marsh, June 29, 1878.

Marsh was notorious for not communicating well with his collectors, a common complaint in the various correspondence.

The first specimen Lucas shipped to Cope was not the first fossil he found. Instead, he sent a lower jaw that Cope (1877a; see also Chure, 2001) described in August as the theropod *Laelaps trihedrodon* [= *Allosaurus* sp.] (Lucas letter to Wright, October 1, 1877). Other shipments to Cope would eventually follow (summarized by McIntosh, 1998). Shipping large, fragile fossils was not easy at this time because the use of burlap and plaster of Paris to encase the fossils had not yet been developed. Instead, hay was used to pack the fossils in crates as Cope wrote regarding the shipping of *Elasmosaurus* bones:

“It is very desirable that the specimens should be packed in such a way as to avoid friction or breakage in case of sudden jars. To accomplish this each single piece or mass, should be so surrounded in the hay or other packing as to allow of some elasticity of contact with the next. It is also important that any box should not be too large to bear the rough handling of so much weight: otherwise it may be broken. even much lost.” Quote from Cope to Theophilus Turner, February 13, 1868, in Almy (1987, p. 188).

That the use of hay to pack fossils was widespread at this time is seen by the instructions Marsh gave his collectors:

“Pack fossils in boxes of moderate size, and made of inch boards. Plenty of hay or straw should be put on the bottom, and closely around sacks of fossils, so that they cannot move when the box is turned over.” Quote from Schuchert and LeVene (1940, p. 173); see also Davidson and Everhart (2017).

The compaction of hay during transport was a serious problem as Cope noted in a letter:

“Each mass should have had a thicker wrapping of hay (still more when paper is used) & the box should be so packed as to prevent the rubbing and moving of the pieces. The largest box had

1/3 to 1/4 vacant space when it arrived & it as well as others, suffered some injury on that account.” Quote from Cope to Turner, February 13, 1868, given in Almy, 1987, p. 189.

The large, heavy, and fragile bones Lucas excavated would have been difficult to crate and ship safely from Cope's Nipple. The crates would have been hauled down an impromptu horse and wagon trail to the main unimproved dirt road along Fourmile Creek (a.k.a. Oil Creek) to the railroad station in Cañon City. From there the travel was smoother by railroad to Philadelphia, where the crates were offloaded and hauled to Cope's house. Given that chemical preservatives were not yet in use, it is amazing that the specimens arrived in Philadelphia relatively intact. Lucas did write about the difficulties he faced with the bones:

“These fossils are broken into pieces, but the pieces are in their proper places and as I take them out I glue them together but it is a great deal of work.” Quote from Lucas to Wright, April 6, 1877, Oberlin Archives.

This method was time consuming and he notes in a letter that it took seven days to extract a single cervical vertebra (Lucas to “Will,” November 22, 1877, Oberlin Archives). Another technique described:

“There are numerous thin bones bracing the diapophyses, zigapophyses [=zygapophyses] and other processes, some as thin as 1/8 of an inch, and all broken into very small pieces. I can save them only by pasting very strong paper on all the surfaces as soon as he rock is removed.” Quote from Lucas letter to “Will,” November 22, 1877, Oberlin Archives.

He reiterated this technique in a letter to O.C. Marsh when he sought to sell the specimens to him, rather than to Cope (Lucas to Marsh, March 11, 1879; Lucas had come to feel that he sold his bones to Cope too cheaply as Mudge wrote to Marsh, August 15, 1877). This precursor to the use of plaster of Paris jackets to hold fractured bone in place was independently arrived at by different people (figure 1C; see Schuchert and LeVene, 1940).

Eugene Weston, who was displaying the fossil bones found by Lucas, saw a money-making opportunity when there seemed to be great interest in the fossil bones Lucas was excavating. Mudge wrote that:

“Mr. Weston...is well acquainted with this region...he is in search of vertebrates, and has promised me the refusal of all he may find. If he strikes a good spot I shall buy him out...” Quote from Mudge to Marsh, August 26, 1877.

Searching for fossils was probably more work than Weston had anticipated, so he filed a mining claim with the Fremont County clerk for the land Lucas was excavating (Lucas Discovery GGPS docs). He then offered to sell the claim to Lucas, essentially to force Lucas to buy his own fossils. Lucas consulted a lawyer, who pointed out that by failing to first develop his claim before trying to sell it, Weston had forfeited ownership (Lucas Discovery GGPS docs). Weston conceded because he had no desire to expend the required labor. Lucas immediately filed his own claim for 20 acres (figure 3) under the General Mining Act of 1872 (30 U.S. Code section 35), which stated:

“Claims usually called ‘placers,’ including all forms of deposit, excepting veins of quartz, or other rock in place...”

At first, Lucas lived at the site in a tent (figures 2 and 4A, right side) with his brother Clarence (Lucas to “Will,” November 22, 1877, Oberlin Archives), then later built a small cabin near where the bones were located (Lucas Discovery GGPS docs). The charred foundation for that building still exists (figure 4B), with many burnt fragments of dinosaur bones laying around. These may have been bone fragments left in the cabin when it later burned. Lucas had Clarence and their father help with the excavation (figure 4A background), and he shipped the specimens to Cope in Philadelphia (Lucas to “Will,” November 22, 1877, Oberlin Archives). The newspaper articles and bones on display drew the attention of C.W. Talbor, a photographer in Cañon City as Lucas wrote:

“My diggings and a number of these large vertebrae with other bones were photographed a few days ago.” Quote from Lucas

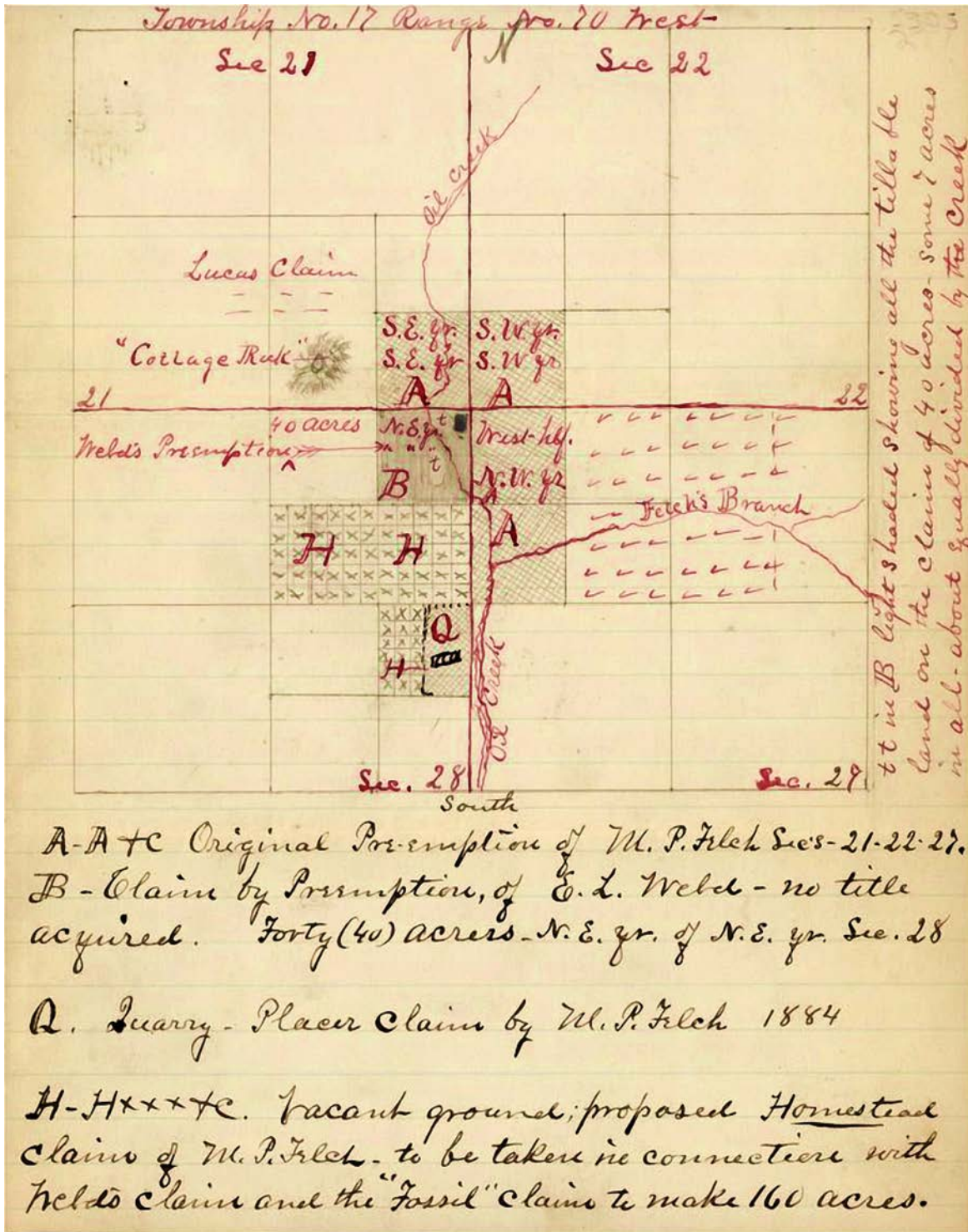


Figure 3. Map showing the location of the Oramel Lucas 1877 mining claim near Cottage Rock, as well as the Marshall Felch 1885 mining claim (Q). Text on top margin: "Township No. 17 Range No. 70 West." Text right margin: "tt in B light shaded showing all the tillable land on the claim of 40 acres - some 7 acres in all - about equally divided by the creek." Bottom text: "A-A&c Original Pre-emption of M. P. Felch Sec's - 21-22-27. B - Claim by Preemption, of E. L. Weld - no title acquired. Forty (40) acers [sic] - N.E. qt. of N.E. qt. Sec. 28. Q. Quarry - Placer Claim by M. P. Felch 1884. H-Hxxx&c. Vacant ground; proposed Homestead Claim of M. P. Felch - to be taken in connection with Weld's claim and the "Fossil" claim to make 160 acres." Map is from a letter that was sent from Felch to Marsh, March 16, 1885.

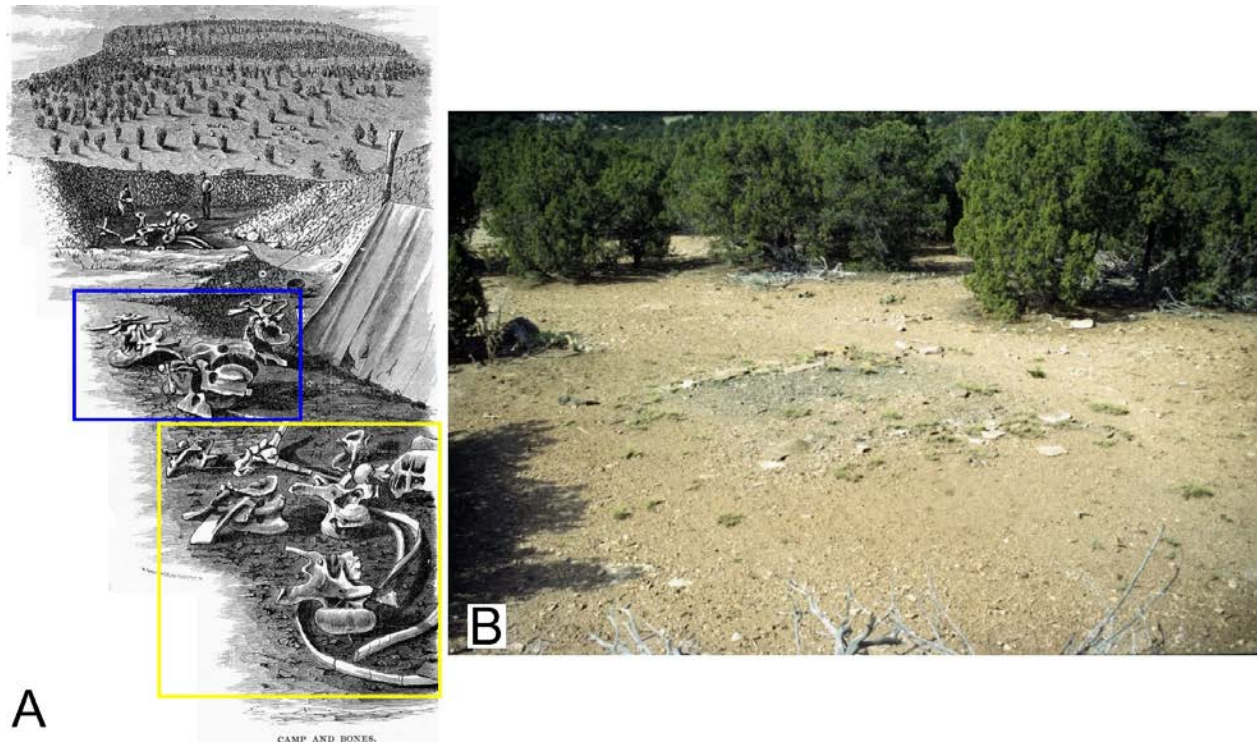


Figure 4. (A) Drawing by Y.A. Snyder (from Pangborn, 1878) of the first *Camarasaurus supremus* quarry, with the wagon-cover tent (right) that Oramel Lucas lived in to guard the site before building a cabin. Persons in the background may represent men hired to help Lucas excavate or Lucas and one of his men. The hill in the background is unnamed and appears in Cope's notebook as the "Ridge" (see figure 6A). Bones in blue box are those in figure 5A and those in yellow box are those in figure 5C. These two clusters show artistic license in and were probably drawn from photographs. (B) Foundation of the small cabin Lucas built in 1877 to protect his interests in the nearby dinosaur sites. The dark stain is charred remains of the structure and includes burnt dinosaur bone fragments.

to "Will," November 22, 1877, Oberlin Archives.

Talbot later sold stereograph cards of the bones as they lay in the ground (figure 5A and 5C, compare with 5B), and writer Joseph Pangborn presented an illustration of the entire excavation (figure 4A).

Lucas met Cope in late July 1879, when Cope made a collecting trip to Colorado and Wyoming that year (Osborn, 1931). Lucas took Cope to the various fossil sites on July 26, which Cope dutifully recorded in a small pocket notebook now preserved at the American Museum of Natural History (McIntosh 1998; Monaco 1998; GPPS docs). Cope wrote to his wife,

"Seventh day [i.e., Saturday] I made a complete survey of the Saurian beds and excavations which commenced 7 miles from town, north, and extended 7 miles further. There are signs

of many others [i.e., dinosaurs] in the rocks."  
Quote from Cope letter, July 28, 1879, in Osborn (1931, p. 259).

Fortunately for us, Cope made a crude, systematic sketch of the quarry locations in his notebook (figure 6A), which has been instrumental in relocating the main quarries in the vicinity of Cope's Nipple (figures 5B and 5C). Oramel eventually turned operations over to his older brother, Ira, later that summer. He used the money he had been paid by Cope to complete his education at Oberlin, graduating with the class of 1880 (Lucas 50th, GPPS docs.). Ira, meanwhile, continued to ship specimens to Cope through 1884 (Ira Lucas to Cope, January 17, 1884, GPPS docs), at which point all work for Cope ceased because no other sites in Garden Park were found as was later recounted:

"Have met the two men [Lucas brothers] that first



Figure 5. (A) One of the earliest photographs of a dinosaur quarry, it shows the first *Camarasaurus supremus* specimen discovered by Lucas. The photograph was taken in mid-November, 1877 (Lucas to “Will,” November 22, 1877, Oberlin Archives). (B) The hill in the background (Cottage Rock) can be matched with that in the background of (A). (C) Another view of the quarry. Tree in background can be match with tree in (B), but note the tree is now leaning. Bone in red box is in unstable position. The historical photographs are each half of two different stereopticon photographs taken and sold by C.W. Talbot (1878) of Cañon City. Caption on the back of the photographs includes: “The measurements were as follows: Thigh bones, upward, 6 feet long, 16 inches in diameter; leg bones, 5 feet long, measuring 22 inches across the toes; vertebrae, 18 inches across, with spinous process 40 inches long; ribs from 6 to 15 feet long, and 23 inches wide at intersection. All other bones in proportion.” Photo in B by Andrew Smith (Bureau of Land Management, Cañon City, Colorado).

discovered bones in that locality and worked the quarry for Cope for a number of years... They tell me that they worked the ground so long as there was any indications of bones.” Quote from Utterback to Hatcher, October 31, 1901, CM archives.

### FURTHER EXCAVATIONS—THE CARNEGIE MUSEUM OF NATURAL HISTORY (1901)

In 1898, the CMNH undertook a quest to locate a large dinosaur skeleton for display as recounted in detail by Brinkman (2010). A major quarry was opened the following year at Sheep Creek, Albany County, Wyoming, and worked for two years. The quarry produced the holotype and paratype of *Diplodocus carnegii* (see Brezinski and Kollar, 2008, for discussion of the geology). Other, smaller quarries were also excavated nearby. Well before work was completed at Sheep Creek, John Hatcher of the CMNH began considering other sites. Unlike Andrew Carnegie who only wanted a big dinosaur skeleton for his museum, Hatcher was thinking in terms of research as he noted in a letter to Holland:

“...I feel sure we have here [Garden Park] the

key to the development of the Sauropoda & I propose to corral everything in sight... There are represented here fully 500 ft. of freshwater Jura & Dinosaur remains we have found here at many horizons. Now I want to pound away here for several years & secure good series from every horizon possible, determining accurately the relative positions of the various horizons, which can be done with ease, & then work out the phylogeny of the different genera of Dinosaurs just as I have done the species of Titanotheres. It is a great undertaking but we are in a position to do it & must not let the opportunity escape us.” Quote from Hatcher to Holland, August 12, 1901, CM archives.

The reference to phylogeny of titanotheres was the article written in 1893, in which Hatcher noted stratigraphic, hence chronological, changes in titanotheres of the “Titanotheres Beds” (a.k.a. Chadron Formation) of Wyoming and South Dakota (Hatcher, 1893).

In early May 1900, months before completion of the work at Sheep Creek, Hatcher visited Marshall Felch in Garden Park to find out if anything remained at the quarry Felch worked for Marsh. An agreement for

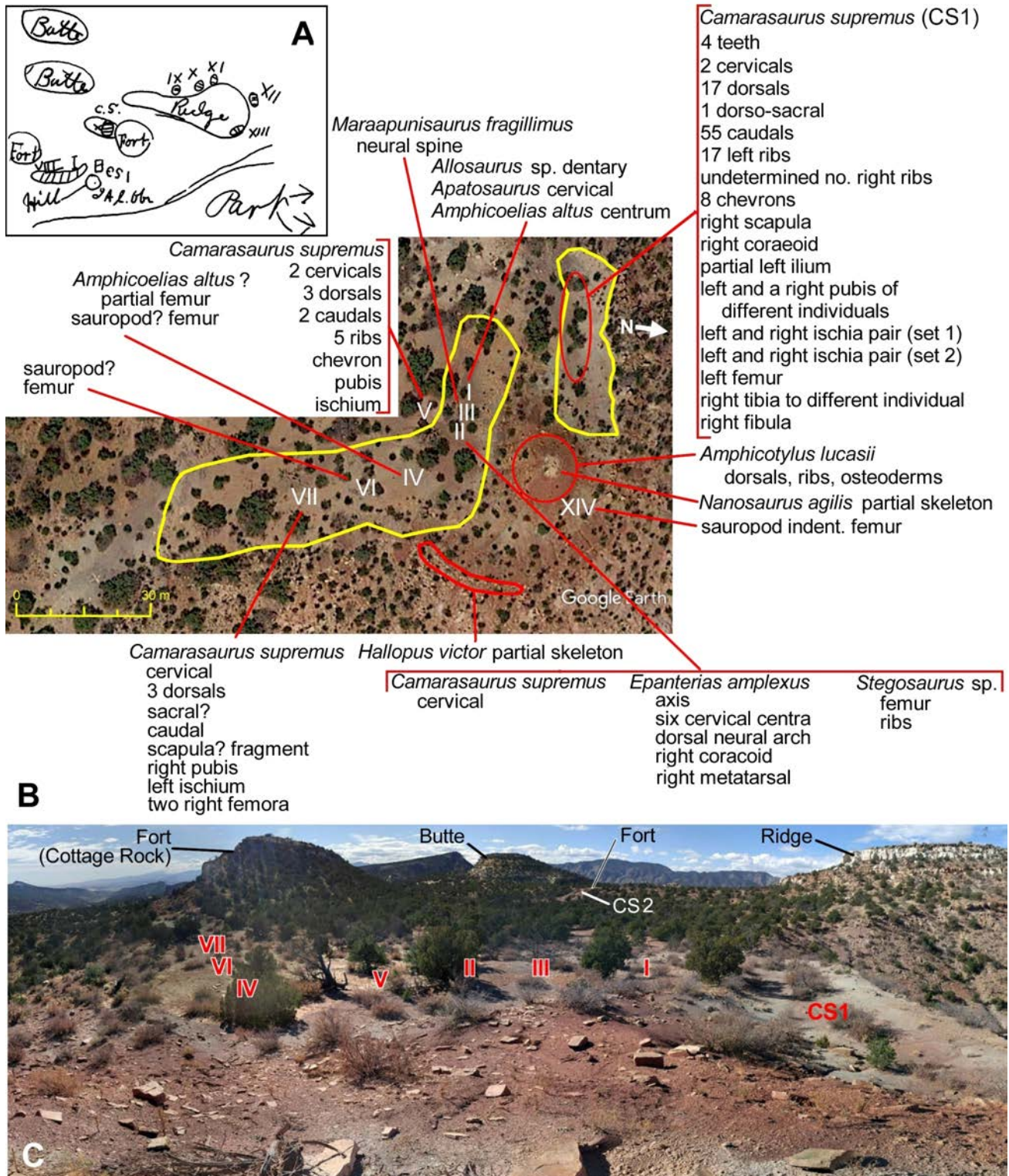


Figure 6. (A) Map of sites from E.D. Cope's notebook of 1879. (B) Overhead view (Google Earth) of the Lucas quarries (I-VII, XIV) in the vicinity of Cope's Nipple as determined from Cope's map and the areal extent of the CMNH excavations outlined in yellow. (C) Panorama (90°) from Cope's Nipple viewed south to west showing the location of the Lucas quarries (I-VII). Abbreviations: CS1 and CS2 – *Camarasaurus supremus* partial skeletons; I-VII and XIV various quarries worked by the Lucas brothers for Cope. Photo in C by Andrew Smith (Bureau of Land Management, Cañon City, Colorado).

three years was signed between Felch and the CMNH by which Felch would be paid \$25 (\$750 in 2018) per month for the rights to excavate, with payment only if specimens were found (Hatcher letters to Holland, May 9, 1900, May 31, 1900).

In November, Hatcher sent William Utterback, who he hired to help with the excavations in the Miocene of western Nebraska to Cañon City to reopen the old Felch quarry. Utterback started work there on November 3, 1900 (Hatcher to Holland, November 30, 1900, CM archives), and by April 1901, Hatcher thought about expanding work to the Lucas quarries at the Nipple on the off-chance there were still specimens left (Hatcher to Utterback, April 15, 1901, CM archives). Hatcher filed a placer mining claim (No. 59076) under his name and museum director, Holland, with the Fremont County Clerk for 40 acres around the Lucas quarries on August 10, 1901 (Hatcher to Holland, August 12, 1901, CM archives). The 1872 Mining Act allowed a maximum of 20 acres per person per claim, hence the use of both names on the claim. The claim was to prevent anyone from filing their own claim and forcing the CMNH off the land (he also filed for the Felch Quarry, placer claim No. 59075, after discovering that Felch did not own the land despite convincing Hatcher to sign a lease for the right to excavate. (Hatcher letters to Holland, May 9, 1900; May 31, 1900, CM archives). Previously, both Lucas (1877) and Felch (1884) had filed placer mining claims with the county clerk for their respective quarries (figure 3). However, neither filed the mandatory annual affidavits with the county clerk attesting that they did at least \$100 worth of work in order to maintain the claims after the last bones were excavated. Nor did either apply for a patent, which would have given them legal ownership of their claims. Thus, by the time the CMNH arrived, the claims were considered abandoned. Hatcher was furious with Felch for misleading him about ownership of the quarry, accusing him of trying to play the CMNH false (Hatcher to Holland, August 12, 1901, CM archives).

Hatcher transferred George Axtell, who was with Charles Gilmore, also from the CMNH, excavating in the Freezeout Hills, Wyoming, to Cañon City to help Utterback (Hatcher to Holland, August 12, 1901, CM archives). Axtell arrived on August 21 and initially helped

Utterback with the Felch quarry (Axtell to Hatcher, August 24, 1901, CM archives). Two weeks later, Utterback sent him to work the Lucas quarries at the Nipple (Axtell to Hatcher, September 3, 1901, CM archives; figure 7A). Axtell used a horse and plow to break up the mudstone overburden and a horse drawn drag scraper (a.k.a. 'horse and scraper') to haul away the broken-up mudstone (Axtell to Hatcher, September 20, 1901, CM archives). The scraper was a metal scoop pulled by horses to move earth (figure 8). Axtell reported to Hatcher that:

"The work in Cope quarries has so far been more of a prospecting nature. The locality where I first started in, yielded nothing more than what you saw viz the vertebra. Undoubtedly the most promising place is around and under the 'nipple' as it is locally called. I have opened another place just south of the vertebra or as I have dubbed that place 'Cope A' and think I will find some good things there. Have a large rib running into the bank now. A little plow and scrapper work will accomplish wonder, I think." Quote from Axtell to Hatcher September 3, 1901, CM archives.

Despite this optimistic start, Axtell became increasingly disappointed as time went on:

"The Cope quarries are not yielding the bone that I had hoped for. So far what bone I have found has been very fragmentary -- not worth taking up in my judgement. You will perhaps remember that when I last wrote I mentioned having found some ribs running into the bank. When uncovered I found that the proximal ends were missing. Since then I have found numerous other fragmentary ribs, pieces of process from vertebrae, the shaft of a radius (both ends gone) and a part of a large Bront[osaurus] scapula -- about two feet of the proximal end with all the thin and delicate parts gone. That's all I have to show for two weeks work...I have opened five prospects, three of them being simply excavations of the old Cope working, the other two being on opposite sides of the 'ant-hill' [i.e.,

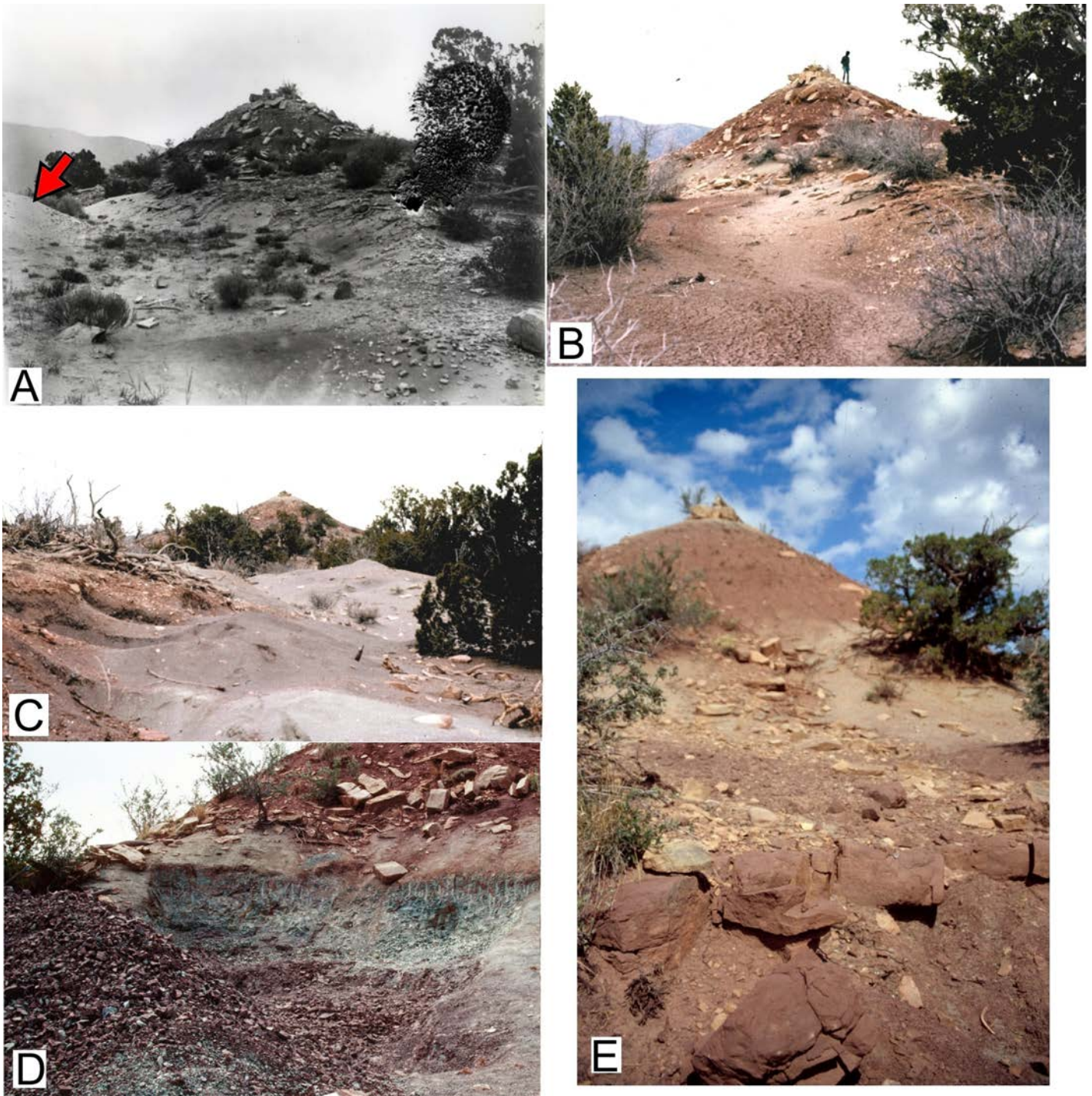


Figure 7. (A) View west towards Cope's Nipple before the CMNH excavation in 1900 (courtesy of A. Henrici, CMNH). The excavation in the center foreground is *Camarasaurus supremus* # 1 quarry 23 years after the photographs in figure 5A and 5C. Arrow shows the tailing pile seen at the far right in figure 5C. (B) View along the CMNH excavation as it is today. The excavation extended to the base of Cope's Nipple and to the edge of the buff to the left (out of view). (C) View west along a trench for quarries I–III. Several small test excavation were dug in 1991. (D) 1991 test excavation at the base of Cope's Nipple, west end of the Carnegie trench looking east. The main bone-bearing strata of Lucas is the greenish mudstone. (E) Southeast side of Cope's Nipple showing *Hallopus*-bearing sandstone in foreground and the *Nanosaurus agilis* flagstones littering the surface of the slope. The bone-bearing layer of Lucas is the light band.





Figure 8. CMNH crew using a horse and scraper to remove overburden. Agate Springs Fossil Quarry, Nebraska. From Peterson (1906).

Cope's Nipple].” Quote from Axtell to Hatcher, September 13, 1901, CM archives.

A week later this was followed by another letter in which Axtell again sounds more optimistic,

“Since I last wrote I have made something of a ‘strike’ – at least I feel a bit encouraged and hope I may be opening up what will eventually prove to be a fair quarry. I am now working out a fine cervical vertebra and also a rib. I hope these may lead to something better but of course there is a possibility that they will not. As soon as they are up and out of the way I shall begin to strip with plow and scrapper.” Quote from Axtell to Hatcher, September 20, 1901, CM archives.

The whereabouts of these bones, especially the cervical vertebra mentioned by Axtell, are unknown. There is an *Apatosaurus* dorsal (CM 2044) in the CMNH collections, but none of the other bones (A. Henrici, collections manager, CMNH, personal communication, January 18, 2018).

To get a better understanding about the Lucas excavations at the Nipple, Utterback met with the two Lucas brothers as he reported to Hatcher:

“Have met the two men that first discovered bones in that locality and worked the quarry for Cope for a number of years. They gave me considerable information regarding their find

around the Nipple...They tell me that they worked the ground so long as there was any indications of bones... These men, the Lucas Bros, tell me all of those fragments were on the surface when they worked the place.” Quote from Utterback to Hatcher, October 31, 1901, CM archives.

Despite the optimism previously expressed by Axtell, Utterback own assessment was bleak as he later reported to Hatcher:

“Mr. Hatcher I regret very much to have to report to you that our work upon the Cope quarries have resulted in a dismal failure.

It has not been for the want of hard work or energy on our part, but simply because the bones are not there. I made a stripping of 20 x 100 ft on the south side of the Nipple one of about the same dimension on the north side and failed to get even a fragment [which is at odds with Axtell's and my own experiences, see below]. At the old workings near Cottage rock we made a cut of 200 feet in length and from 10 to 20 feet in width to bed rock and found nothing but water worn fragments. I think that were you here in person and see the amount of work done and no returns you would think it a waste of time and money to continue it. In all have uncovered over 5000 square feet of surface with no returns.” Quote from Utterback to Hatcher, November 25, 1901, CM archives.

Utterback stopped work at the Nipple soon after but remained in the area a few more weeks prospecting. He found nothing substantial of the sauropods that Hatcher wanted and departed for the CMNH that December.

## ONE MORE TIME—THE DENVER MUSEUM OF NATURAL HISTORY (1991-1996)

The Nipple quarries had sat idle for ninety years when I started the Garden Park Morrison Project (see Carpenter and Lindsey, 2019, for list of published results). The goal was to locate new sites in a systematic manner by prospecting with a team of volunteers

one section of Public Land Survey at a time. A test pit was excavated at the base of the Nipple on the north side (figure 7D). Fragments of bone were encountered, which were surprisingly heavily abraded and match Utterback's "water worn fragments" (see further below). The test pit proved to be crucial to understanding the geology of the original bone-bearing horizon bed (see next section).

Additional material of *Camarasaurus supremus* was excavated in late June 1994, south of Cope's Nipple (figure 9A). The material was found in May by students from the University of Kansas who thought they were excavating on private property. The Bureau of Land Management requested that the DMNH take over and recover the specimens. During the excavation, I noticed that slabs of local yellow sandstone, 15 to 20 cm thick, had been laid over many of the bones (figure 9B). In addition, infilled trenches of reddish dirt surrounded many of the bones showing that they had been partially excavated previously (figures 8C and 8D). The location of the site and specimen best matched Cope's "Lot V" in his field notes. It is surprising that the Carnegie crew did not find the bones, nor that the Lucas brothers told Utterback of their existence. The material excavated included dorsal vertebrae, caudal vertebrae, a pubis, an ischium, and rib fragments (figure 9E).

Ground-penetrating radar was used in the hunt for any material that might remain in the area of the Nipple (figure 9F). The technology uses high frequency electromagnetic energy (radio waves in the microwave spectrum) rather than acoustic energy. The radio waves are reflected from boundaries between materials having different permittivities, i.e., where the electrical properties change. Unfortunately, the results were negative, partially because the permittivity of permineralized bone was similar to that of the encasing rock, and partly due to the stripping of so much rock by the CMNH.

## SEDIMENTOLOGY AND TAPHONOMY OF COPE'S NIPPLE

Cope's Nipple is a prominent erosional remnant that overlooks Garden Park on the west side of Fourmile Creek (figure 1A), also known as Oil Creek because of an oil well drilled in 1863 near the mouth of Fourmile

Canyon. The bone-bearing horizon from which Lucas collected most of his specimens was first reported by Cope (1877a) as being Dakota Formation, but he did not give his reasons until later (Cope, 1878a, p. 234) when he revealed that "Dr. [Ferdinand] Hayden visited the locality of Mr. Lucas' excavations, and informs me that the formation from which the *Camarasaurus* was obtained, is the Dakota." No reason was given why Hayden, of the United States Geological and Geographical Survey, referred to the red mudstones as "Dakota." Typically, Hayden referred strata to the Dakota, which he also called "#1 Cretaceous," as the hogback and ridge-forming sandstones below the "#2 Cretaceous" (i.e., Benton Shales) (e.g., Hayden, 1869). Strata immediately below, he referred to as Jurassic. These dinosaur-bearing strata in the Garden Park area were first identified as Morrison Formation by Whitman Cross (1898) and were described in greater detail by Hatcher (1901) and Mook (1916, largely repeated in Osborn and Mook, 1921). More recently, the stratigraphy and petrology of the Morrison Formation in Garden Park has been described by Hassinger (1959), Brady (1967, 1969), Enciso (1981), Sweet (1984), and Carpenter and Lindsey (2019). A stratigraphic section is presented in figure 10 (see Carpenter and Lindsey, 2019, for discussion of the Morrison members in the Garden Park area). The Lucas quarries occur very high in the Morrison Formation. Unfortunately, no radiometric date is available to ascertain whether the quarry is late Kimmeridgian or early Tithonian. The uniqueness of the fauna suggests early Tithonian based on a Kimmeridgian date obtained at a lower level in Garden Park (Trujillo and Kowallis, 2015).

The bone-bearing strata were described by Lucas (Cañon City Avalanche newspaper, June 21, 1877, GPPS docs) as "a thin stratum of fragile shale of bluish color" (see figure 7D). In my analysis, when freshly exposed, the matrix is a blocky, dusky yellow-green (Munsell Color 5Y5/2), slightly calcareous, sandy, illitic mudstone, with mottles of dusky yellow (5Y6/4) and dark yellowish-orange (10YR6/6); root casts and limonitic nodules 2 to 3 mm in diameter occur. This light, bone-bearing mudstone overlies a blocky to angular breaking, very dusky red (10R2/2), slightly calcareous claystone with grayish-green non-calcareous



Figure 9. (A) Distant view from south side of site V excavation. Cope's Nipple in the background. Some stone slabs removed from covering bones are seen in the foreground. (B) View from south side of excavation; arrows point to sandstone slabs still overlaying bone. (C) Close-up of excavation. White arrow shows undisturbed gray mudstone and red arrow shows brown infilled trench. Rib to left of white arrow is oblique to strata. (D) Overview of excavation viewed from north side. Arrow points to infilled trench between bones. (E) Schematic quarry map showing ribs (r), vertebrae centra (c), pubis (p; midline length 107 cm), and ischium (i; midline length 116 cm). All of the bones were concentrated in a small area less than 3 m across. Note that the bones are randomly oriented, although smaller bones are in the fluvial flow shadow of the larger bones. (F) Ground-penetrating radar being used in the hunt for other bone in the vicinity of site V.

mottles (10G4/2); small, 2 to 3 mm limonitic nodules occur throughout. The light, bone-bearing mudstone is overlain by a pale-red (5R6/2) weathering calcareous claystone—mottled dusky green (5GY5/2) and dusky brown (5YR2/2) when fresh—with thin pale-ol-

ive (10Y6/2) sandstone lenses and with grayish-purple (5GY6/1) nodules (see Carpenter and Lindsey, 2019, for discussion of clay minerals).

Pangborn (1878) noted, “The fossils are found in rock long upheaved, its character now a sort of shale or

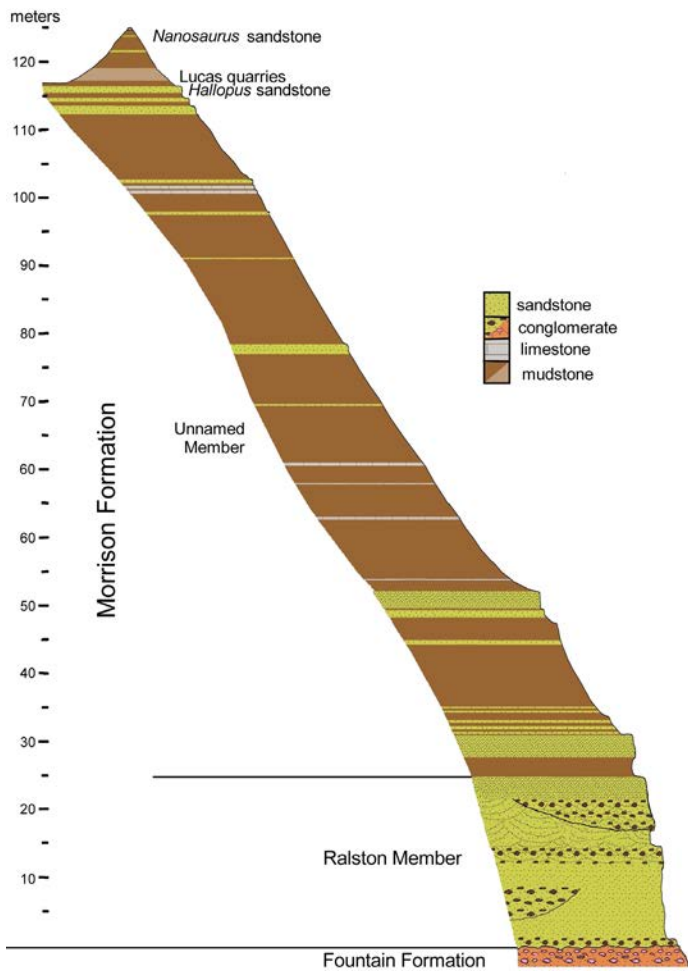


Figure 10. Stratigraphic section from the summit of Cope's Nipple to the base of the "Valley of Death" located on the north side of Cope's Nipple (see also Carpenter and Lindsey, 2019).

marlite [= marlstone] which upon being dug out and exposed to the air crumbles to pieces. In most instances, it is free from bone decay [i.e., the bones are not weathered and crumbly], the parts of animals taken out being remarkable for their clean and perfect solidity." The mudstone does indeed crumble to pieces and does easily separate from the bones, leaving them remarkably clean (figures 5A and 5C), but unfortunately also reducing the protection the matrix provided the fragile bones. In marked contrast with bones excavated for O.C. Marsh at the nearby Felch Quarry, the bones there occurred in a hard channel sandstone (Evanoff and Carpenter, 1998). In that excavation, Felch removed bone by following along joints, resulting in a considerable amount

of extraneous rock that added to the shipping costs and which had to be removed in Marsh's lab.

The bone-bearing mudstone of the Lucas sites is a paleosol that is widespread around the base of Cope's Nipple and southwards towards Cottage Rock (figures 6C and 7B to 7D). It is bracketed between two maroon mudstones, one of which is underlain by the fine-grained, tabular, maroon, *Hallopus*-sandstone (figures 7E and 10; Ague and others, 1995; Carpenter and Lindsey, 2019), and the other, higher, is a fine- to medium-grained sandstone, which produced the holotype of the ornithischian dinosaur *Nanosaurus agilis* (Carpenter and Galton, 2018). Thus, all of the specimens collected by Lucas in the vicinity of Cope's Nipple came from a single depositional unit about 1.5 m thick. Considering the limited area these bones were collected (figure 6B), they constitute a bonebed. Regrettably, Cope never required Lucas to make quarry maps, unlike the directive that Marsh gave his collectors (Evanoff and Carpenter, 1998). All we have are two photographs and a drawing (figures 4A, 5A, and 5C). These, in conjunction with Cope's notes, data in Osborn and Mook (1921) and McIntosh (1998), and the 1994 DMNH excavation, indicate scattered bone and clusters of disarticulated partial skeletons (figure 6B) covering an area of around 175 m<sup>2</sup> (expanded to around 310 m<sup>2</sup> by the CMNH). At least two strings of articulated vertebrae were discovered (figure 4A) and these appear to be roughly at right angles to each other and several meters away. These two clusters are cataloged as AMNH 5760, which McIntosh (1998) had noted consists of two individuals based on six extra dorsals, at least five extra left ribs, mismatched pubes, two extra ischia, and mismatched femur and tibia. McIntosh (1998) also noted that some of the ribs were articulated with their respective dorsal vertebrae. The occurrence of taxa represented by single bones, as well as partial skeletons, indicate an allochthonous and autochthonous origin for the bonebed.

In addition, these sections of vertebrae are ventral side up. Most of the large dorsal vertebrae, which are wider than anteroposteriorly long, lay on their articular faces, although some lie oblique to the horizontal (figure 5C, foreground). Several rib fragments were also found to lie oblique during the DMNH excavation. One smaller vertebra, possibly a cervical, also stands verti-

cally on its posterior face (figures 4A and 5C, red box), but because it is elongate it is in a fluvially unstable position than the larger vertebrae.

Bone shapes from Osborn and Mook (1921, referred to as O&M) range from cylindrical teeth with roots (O&M, plates 60 and 61), cylindrical centra (O&M, figure 22), and cylindrical metacarpals (O&M, figure 85); subspherical vertebral centra (O&M, figure 24); concave, disc-shaped coracoids (O&M, figures 27 and 82); and elongate, flat (low profile) ribs (O&M, plate 79). Thus, there is a mixture of fluvially easily transportable shapes (cylindrical and subspherical) and fluvially stable shapes (ribs, coracoid). Bone size ranges from easily transportable 1-cm-long centrum of *Tichosteus aquifacies* (= genus and species indeterminate; O&M, figure 16), to the huge, difficult to transport 1.8 m femur of *Camarasaurus supremus* (O&M, figure 107; AMNH 5760, not 5761 per McIntosh, 1998). Finally, bone preservation includes both slightly distorted vertebrae (O&M, plate 70, figure 4), as well as extremely distorted vertebrae (figure 10; O&M, figure 89; plate 74).

A 24 m<sup>3</sup> test excavation at base of Cope's Nipple (figure 7D) in 1991 revealed an abraded *Allosaurus* tooth fragment, an abraded sauropod(?) rib fragment, and a few small (few cm in diameter), rounded bone fragments dispersed in both the red and lower maroon mudstones. This excavation is immediately adjacent to the CMNH excavation and the fragments are similar to those mentioned by Axtell and Utterback in their letters to Hatcher. These abraded bones in such fine-grained sediments suggests that they were entrained into the overbank flow during flooding of a nearby river. The abraded rib was found standing vertically, possibly due to trampling when the mud was still soft. Pangborn (1878) also reported evidence of scavenging as evidenced by the co-mingling of theropod teeth (as "*Laelaps trihedron*") and *Camarasaurus* bones.

Despite the gray-green sediment color, bones excavated this unit are of the "Red Series" of Osborn and Mook (1921, p. 256). This is in contradiction to their suggestion that the grayish matrix probably produced the "Yellow Series." My conclusion is based on the statement by Lucas (Lucas, Cañon City Avalanche newspaper, June 21, 1877, GPPS docs) of the sediment color at his first *Camarasaurus* site, the color of the bones as noted by Os-

born and Mook (1921), and the specimen excavated by the DMNH, which were similar to the Red Series.

## DISCUSSION AND CONCLUSION

It has been over 140 years since a school teacher discovered a vast treasure trove of dinosaur bones in central Colorado. These and other discoveries seized the public's fascination because of their huge size as reported by Holder (1880) (figure 11A). E.D. Cope named no fewer than 14 dinosaur species (and two non-dinosaurian reptiles) over a span of two years from the specimens collected by the Lucas brothers at the Nipple and other quarries in Garden Park (Osborn and Mook, 1921). As result of this, and similar naming of taxa by O.C. Marsh, there has been what I feel to be unfair criticism of Marsh and Cope's naming practices. It is too easy to apply today's standards in vertebrate paleontology to the fledgling field of the 1800s. Given the dearth of specimens at the time, when confronted with morphological differences it made sense to assign a "handle" by which the specimen would be known. Only as more specimens were collected was it possible to demonstrate that the variation could be explained for a variety of reasons, including different stages of ontogeny, gender, and individual (Carpenter and Currie, 1990). The result was a reduction of the Cope's Nipple species to four or five taxa in more recent years. It must be remembered that biological entities are not stamped out mechanically and differences are expected among specimens. Unfortunately, there has been a return to the mechanistic over-splitting previously done by Marsh and Cope in recent years, but for different reasons through the use of large data sets for specimens to tackle biological questions (e.g., Tschopp and others, 2015). Given the short duration of the Morrison Formation (~5 m.y., Trujillo and Kowallis, 2015) and one-to-two million years for the Brushy Basin Member from which many sauropod specimens have been collected (Trujillo and Kowallis, 2015; Galli and others, 2018), the great amount of sauropod (diplodocoid) evolution implied by Tschopp and others (2015), is highly improbable for such a short time. Such large specimen-level data set analyses have their place, but the results should not be assumed to reflect biological entities. As biologist Soltis noted, "Things can

be statistically possible without being biologically possible.” (Quoted in Leford, 2018, p. 153).

The *Camarasaurus supremus* material collected by Lucas from the Cope Nipple and surrounding quarries do appear to represent the last appearance datum for the genus and for the species (table 1; figure 11). Two other staggered, partially overlapping range zones of *C. lentus* and *C. grandis* occur stratigraphically lower (Ikejiri, 2005), and these specimens demonstrate variation as expected of biological entities (Ikejiri 2004, 2008; Ikejiri and others, 2005).

The discovery of several clusters of dinosaur bones in the vicinity of Cope's Nipple at the south end of Garden Park was monumental in the history of dinosaur paleontology. Among the specimens were several partial skeletons of *Camarasaurus supremus* and these allowed for the first restoration of a sauropod dinosaur skeleton. It is unfortunate that the documents associated with the collecting of the specimens are spotty. Nevertheless, what remains indicates that the quarries are part of a large bonebed in which bones occurred

Table 1. Taxa from the Nipple quarries. Not all of Cope's holotypes (h-holotype) are from these quarries. Other taxa described by Cope (e.g., *Symphrophus musculosus*) may be from one of the Nipple quarries, but is not demonstratable. This table should be view with figure 6.

Taxa	Reference (date of publication)	Current status
<i>Amphicoelias altus</i>	Cope, 1878 field notes	sauropod
<i>Amphicoelias fragillimus</i> (h)	Cope, 1878f	<i>Maraapunisaurus fragillimus</i>
<i>Amphicoelias latus</i>	Cope, 1878f	<i>Camarasaurus supremus</i> (subadult)
<i>Amphicotylus lucasii</i> (h)	Cope, 1878d (see also Cope, 1888)	<i>Amphicotylus lucasii</i>
<i>Camarasaurus leptodirus</i>	Cope, 1878 field notes	<i>Camarasaurus supremus</i>
<i>Camarasaurus supremus</i>	Cope, 1877b	<i>Camarasaurus supremus</i> & <i>Apatosaurus</i> sp.
<i>Epanterias amplexus</i>	Cope, 1878d	<i>Epanterias amplexus</i>
<i>Hypsirhophus trihedron</i>	Cope, 1878 field notes	<i>Allosaurus</i> sp. ( <i>Epanterias</i> ?)
<i>Laelaps trihedron</i>	Cope, 1877a	<i>Allosaurus</i> sp. ( <i>Epanterias</i> ?)
<i>Morosaurus laticollis</i>	Cope, 1878 field notes	<i>Apatosaurus</i> sp.

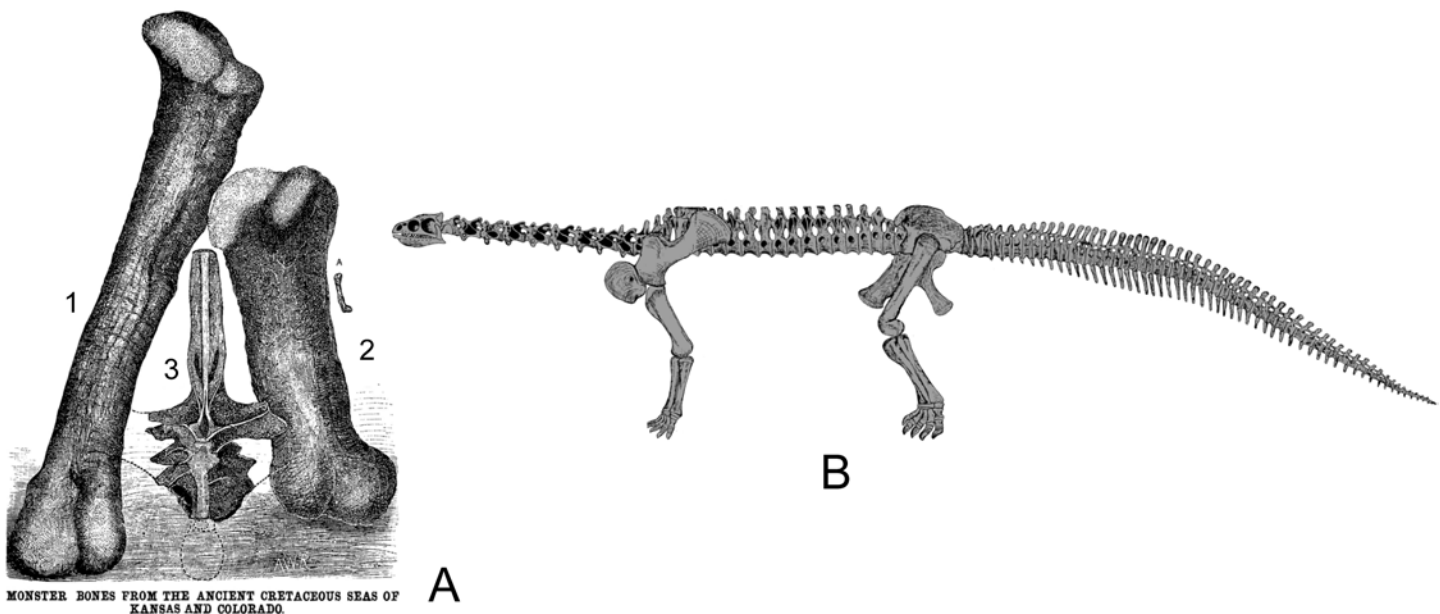


Figure 11. (A) Sketch that appeared in the semi-popular Scientific American supplement (Holder, 1880) based on illustrations by Cope. These are not to scale and were simply illustrative of the bone shapes: 1 – femur of *Amphicoelias altus* from Cope 1878c, 2 – femur of “*Amphicoelias*” *latus* (actually *Camarasaurus*) from Cope (1878c), inverted, missing portion restored. 3 – “*Amphicoelias*” *fragillimus* from Cope (1878f) reversed left to right; small bone marked “A” is a crocodilian femur. (B) First skeletal reconstruction of a sauropod made by John Ryder under the direction of E.D. Cope. The original drawing was life size and was displayed by Cope at the December 21, 1877, meeting of the American Philosophical Society in Philadelphia, Pennsylvania (modified from Osborn and Mook, 1921, plate 82).

as clusters. The occurrence of single bones and partial skeletons suggest an allochthonous and autochthonous origin for the bonebed.

## ACKNOWLEDGMENTS

A large volume of archival material pertaining to the history of the excavations around Cope's Nipple was gathered by Pat Monaco and the late Donna Engard. This material is now at the Royal Gorge Regional Museum and History Center, Cañon City, Colorado. Andrew Smith and Melissa Smeins (Bureau of Land Management, Royal Gorge Field Office, Cañon City, Colorado), Dan Grenard (retired, Bureaus of Land Management, Cañon City, Colorado) and Dan Brinkman (Yale Peabody Museum, Yale University, New Haven, Connecticut) made additional documents available. Andrew Smith tracked down copies of the Carnegie Museum of Natural History Placer Claims. I was aided at excavating at Cope's Nipple and of the abandoned *Camasaurus* specimen (#5) by Paula Canner, Kiyo Carpenter, Lora Freudberg, Patricia and Bill George, Mel Grantham, Suzanne Meyer, Robert McCarroll, Rocco Romero, David Saitta, John Shinton, Bryan Small, Jeff Stephenson, Virginia Tidwell, Mike Williams, and Bruce Young. Field work was conducted under Bureau of Land Management permit C-49819(c).

Photographs were generously provided by Vicki Garrisi (True West Properties, Woodland Park, Colorado), Andrew Smith (Bureau of Land Management, Cañon City, Colorado), and Amy Henrici (Carnegie Museum of Natural History, Pittsburgh, Pennsylvania). Amy Henrici also made available the correspondence of the vertebrate paleontology department of the Carnegie Museum of Natural History. Letters of Oramel Lucas to O.C. Marsh are in the Yale Peabody Museum of Natural History archives: <http://peabody.yale.edu/collections/vertebrate-paleontology/correspondence-o-c-marsh>. Finally, review comments by Greg Paul (independent dinosaur artist), John Whitlock (Mount Aloysius College, Cresson, Pennsylvania), Mike Taylor (University of Bristol), and John Foster (Utah Field House of Natural History State Park Museum, Vernal, Utah) are gratefully acknowledged.

## REFERENCES

*Author note: E.D. Cope published variants of the same article repeatedly. To set the record of their order straight, publication dates are given in parenthesis.*

- Ague, J., Carpenter, K., and Ostrom, J., 1995, Solution to the *Halilolopus* enigma: *American Journal of Science*, v. 295, p. 1–17.
- Almy, K.J., 1987, Thof's dragon and the letters of Capt. Theophilus Turner, M.D., U.S. Army: *Kansas History*, v. 10, no. 3, p. 170–200, [https://www.kshs.org/publicat/history/1987autumn\\_almy.pdf](https://www.kshs.org/publicat/history/1987autumn_almy.pdf), accessed April 23, 2018.
- Anonymous, 1876, Catalogue of the officers and students of Oberlin College for the college year 1876–77: Toledo, Ohio, Blade Printing & Paper Company, 61 p.
- Binckley, G.M., and Hartwell, F., 1879, Southern Colorado, historical and descriptive of Fremont and Custer Counties with their principal towns: Cañon City, Colorado, Binckley and Hartwell Publishers, 136 p.
- Brady, L.L., 1967, Stratigraphy and petrology of the Morrison Formation (Jurassic) in the vicinity of Cañon City, Colorado area: Lawrence, University of Kansas, M.S. thesis, 111 p.
- Brady, L.L., 1969, Stratigraphy and petrology of the Morrison Formation (Jurassic) of the Cañon City, Colorado area: *Journal of Sedimentary Petrology*, v. 39, p. 632–648.
- Brinkman, P.D., 2010, The second Jurassic dinosaur rush—museums and paleontology in America at the turn of the twentieth century: Chicago, Illinois, University of Chicago Press, 312 p.
- Brezinski, D.K., and Kollar, A.D., 2008, Geology of the Carnegie Museum dinosaur quarry site of *Diplodocus carnegii*, Sheep Creek, Wyoming: *Annals of Carnegie Museum*, v. 77, no. 2, p. 243–252.
- Carpenter, K., 1998, Vertebrate biostratigraphy of the Morrison Formation near Cañon City, Colorado, in Carpenter, K., Chure, D., and Kirkland, J.I., editors, *The Morrison Formation—an interdisciplinary study: Modern Geology*, v. 23, p. 407–426.
- Carpenter, K., 2018a, *Maraapunisaurus fragillimus*, n.g. (formerly *Amphicoelias fragillimus*), a basal rebbachisaurid from the Morrison Formation (Upper Jurassic) of Colorado: *Geology of the Intermountain West*, v. 5, p. 227–244.
- Carpenter, K., 2018b, Rocky start of Dinosaur National Monument (USA), the World's first dinosaur geoconservation site: *Geoconservation Research*, v. 1, no. 1, p. 1–20, E-journal: [http://gcr.khuisf.ac.ir/issue\\_115419\\_115722\\_Volume+1%2C+Issue+1%2C+Winter++and+Spring+2018%2C+Page+1-52.html](http://gcr.khuisf.ac.ir/issue_115419_115722_Volume+1%2C+Issue+1%2C+Winter++and+Spring+2018%2C+Page+1-52.html).

- Carpenter, K., and Currie, P., 1990, Introduction—on systematics and morphological variation, in Carpenter, K., and Currie, P., editors, *Dinosaur systematics—perspectives and approaches*: New York, Cambridge University Press, p. 1–8.
- Carpenter, K., and Galton, P.M., 2018, A photo documentation of bipedal ornithischian dinosaurs from the Upper Jurassic Morrison Formation, USA: *Geology of the Intermountain West*, v. 5, p. 167–207.
- Carpenter, K., and Lindsey, E., 2019, Redefining the Upper Jurassic Morrison Formation in the Garden Park Paleontological Resource Area and vicinity, eastern Colorado: *Geology of the Intermountain West*, v. 6, p. 1–30.
- Chure, D.J., 2001, On the type and referred material of *Laelaps trihedrodon* Cope 1877 (Dinosauria: Theropoda), in Tanke, H., and Carpenter, K., editors, *Mesozoic vertebrate life*: Bloomington, Indiana University Press, p. 10–18.
- Cope, E.D., 1877a, On a carnivorous dinosaur from Dakota Beds of Colorado: *Bulletin of the United States Geological and Geographical Survey*, v. 3, no. 4, p. 805–806 (Published August 15, 1877).
- Cope, E.D., 1877b, On a gigantic saurian from the Dakota epoch of Colorado: *Paleontological Bulletin*, v. 25, p. 5–10 (Published August 23, 1877).
- Cope, E.D., 1877c, On reptilian remains from Dakota beds of Colorado: *Paleontological Bulletin*, v. 26, p. 193–496 (Published November 21, 1877).
- Cope, E.D., 1877d, On *Amphicoelias*, a genus of saurians from the Dakota Epoch of Colorado: *Paleontological Bulletin*, v. 27, p. 2–5 (Published December 10, 1877).
- Cope, E.D., 1878a, On reptilian remains from the Dakota beds of Colorado: *Proceedings of the American Philosophical Society*, v. 17, p. 193–196 (Published January 9, 1878).
- Cope, E.D., 1878b, On the Vertebrata of the Dakota Epoch of Colorado: *Proceedings of the American Philosophical Society*, v. 17, p. 233–247 and 279 (Published January 12, 1878).
- Cope, E.D., 1878c, On the saurian recently discovered in the Dakota beds of Colorado: *American Naturalist*, v. 12, no. 2, p. 71–85 (Published February 1878).
- Cope, E.D., 1878d, Description of new extinct vertebrates from the Upper Tertiary and Dakota Formations: *Bulletin of the United States Geological and Geographical Survey*, v. 4, p. 379–396 (Published May 1878).
- Cope, E.D., 1878e, A new opisthocoelian dinosaur: *American Naturalist*, v. 12, p. 406 (Published June, 1878).
- Cope, E.D., 1878f, A new species of *Amphicoelias*: *American Naturalist*, v. 12, p. 563–565 (Published August 1878).
- Cope, E.D., 1878g, On a new Opisthocoelous dinosaur: *The Annals and Magazine of Natural History*, v. 2 (series 5), p. 194 (Published August 1878).
- Cope, E.D., 1888, *Goniopholis* in the Jurassic of Colorado: *American Naturalist*, v. 22, p. 1106–1107. (Published December 1888).
- Cross, W., 1898, Pikes Peak folio, Colorado: U.S. Geological Survey Folio 7, 14 p.
- Davidson, J.P., and Everhart, M.J., 2017, Scattered and shattered—a brief history of the early methods of digging, preserving and transporting Kansas fossils: *Transactions of the Kansas Academy of Science*, v. 120, no. 3–4, p. 247–258.
- Enciso, G., 1981, Paleoenvironmental analysis of the Morrison Formation in the Cañon City, Colorado, area: Lawrence, University of Kansas, M.S. thesis, 89 p.
- Evanoff, E., and Carpenter, K., 1998, History, sedimentology, and taphonomy of Felch Quarry 1 and associated sandbodies, Morrison Formation, Garden Park, Colorado, in Carpenter, K., Chure, D., and Kirkland, J.I., editors, *The Morrison Formation—an interdisciplinary study*: *Modern Geology*, v. 23, p. 145–169.
- Galli, K.G., Buchwaldt, R., Lucas, S.G., and Tanner, L., 2018, New chemical abrasion thermal ionization mass spectrometry dates from the Brushy Basin Member, Morrison Formation, western Colorado—implications for dinosaur evolution: *The Journal of Geology*, v. 126, no. 5, p. 473–486.
- Hassinger, R., 1959, Stratigraphy of the Morrison Formation of the Cañon City embayment, Colorado: Norman, University of Oklahoma, M.S. thesis, 116 p.
- Hatcher, J.B., 1893, The Titanotherium beds: *American Naturalist*, v. 27, p. 204–221.
- Hatcher, J.B., 1901, The Jurassic dinosaur deposits near Canyon City, Colorado: *Annals of the Carnegie Museum*, v. 1, p. 327–341.
- Hayden, F.V., 1869, Third annual report: United States Geological and Geographical Survey of the Territories, embracing Colorado and New Mexico, 155 p.
- Holder, C.F., 1880, Monster bones (fossils) from the ancient Cretaceous seas of Kansas and Colorado: *Scientific American Supplement*, July 31, 1880, p. 71–72.
- Honda, K.K., and Simmons, B., 2009, The legacy of Arthur Lakes: Morrison, Colorado, *Friends of Dinosaur Ridge*, 194 p.
- Ikejiri, T.A., 2004, Anatomy of *Camarasaurus lentus* (Dinosauria: Sauropoda) from the Morrison Formation (Late Jurassic), Thermopolis, central Wyoming, with determination and interpretation of ontogenetic, sexual dimorphic, and individual variation in the genus: Hays, Kansas, Fort Hays State University, M.S. thesis, 311 p.
- Ikejiri, T.A., 2005, Distribution and biochronology of *Camara-*



- saurus* (Dinosauria, Sauropoda) from the Jurassic Morrison Formation of the Rocky Mountain region, in Lucas, S.G., Zeigler, K.E., Lueth, V.W., and Owen, D.E., editors, *Geology of the Chama Basin: New Mexico Geological Society Field Conference Guidebook 56*, p. 367–379.
- Ikejiri, T.A., 2008, Slender and robust skeletal morphotypes of *Camarasaurus* (Dinosauria, Sauropoda) from the Morrison Formation (Upper Jurassic) of the Rocky Mountain region and their implications for sexual dimorphism, in Farley, G.H., and Choate, J.R., editors, *Unlocking the unknown—papers honoring Dr. Richard J. Zakrzewski: Fort Hays Studies Special Issue*, no. 2, p. 31–44.
- Ikejiri, T., Tidwell, V., and Trexler, D.L., 2005, New adult specimens of *Camarasaurus lentus* highlight ontogenetic variation within the species, in Tidwell, V., and Carpenter, K., editors, *Thunder-lizards—the sauropodomorph dinosaurs: Bloomington, Indiana University Press*, p. 154–179.
- Jaffe, M., 2000, *The gilded dinosaur—the fossil war between E.D. Cope and O.C. Marsh and the rise of American science: New York, Crown Publishers*, 432 p.
- Kohl, M.F., and McIntosh, J.S., 1997, *Discovering dinosaurs in the old west—the field journals of Arthur Lakes: Washington DC, Smithsonian Institution Press*, 198 p.
- Ledford, H., 2018, Debate blooms over Earth's first flower: *Nature*, v. 554, p. 153–154.
- McIntosh, J.S., 1998, New information about the Cope collection of sauropods from Garden Park, Colorado, in Carpenter, K., Chure, D., and Kirkland, J.I., editors, *The Morrison Formation—an interdisciplinary study: Modern Geology*, v. 23, p. 481–506.
- Mook, C.C., 1916, A study of the Morrison Formation: *Annals of the New York Academy of Sciences*, v. 27, p. 39–191.
- Monaco, P.E., 1998, A short history of dinosaur collecting in the Garden Park Fossil Area, Cañon City, Colorado, in Carpenter, K., Chure, D., and Kirkland, J.I., editors, *The Morrison Formation—an interdisciplinary study: Modern Geology*, v. 23, p. 465–480.
- Osborn, H.F., 1931, *Cope—master naturalist: Princeton, New Jersey, Princeton University Press*, 740 p.
- Osborn, H.F., and Mook, C.C., 1921, *Camarasaurus, Amphicoelias, and other sauropods of Cope: Memoirs of the American Museum of Natural History, New Series*, v. 3, no. 3, p. 248–387.
- Pangborn, J.G., 1878, *The new Rocky Mountain tourist—Arkansas Valley and San Juan guide—the tour: Chicago, Illinois, Knight and Leonard*, 64 p.
- Peterson, O.A., 1906, The Agate Spring fossil quarry: *Annals of the Carnegie Museum*, v. 3, p. 487–494.
- Rockafellow, B.F., 1881, *History of Fremont County—history of the Arkansas Valley, Colorado: Chicago, Illinois, O.L. Baskin & Co.*, p. 543–687.
- Schuchert, C., and LeVene, C.M., 1940, *O.C. Marsh, pioneer in paleontology: New Haven, Connecticut, Yale University Press*, 541 p.
- Sweet, R., 1984, *A sedimentary analysis of the Upper Jurassic Morrison Formation as it is exposed in the vicinity of Cañon City, Colorado: Stillwater, Oklahoma State University, M.S. thesis*, 210 p.
- Talbot, C.W., 1878, *Bones of the saurian, or the old graveyard—Talbot's mountain views, Oil Creek Park series: Topeka, Kansas Publishing House*, 1 p.
- Thompson, K.S., 2008, *The legacy of the mastodon—the golden age of fossils in America: New Haven, Connecticut, Yale University Press*, 424 p.
- Trujillo, K.C., and Kowallis, B.J., 2015, Recalibrated legacy  $^{40}\text{Ar}/^{39}\text{Ar}$  ages for the Upper Jurassic Morrison Formation, Western Interior, U.S.A.: *Geology of the Intermountain West*, v. 2, p. 1–8.
- Tschopp, E., Mateus, O., and Benson, R.B., 2015, A specimen-level phylogenetic analysis and taxonomic revision of Diplodocidae (Dinosauria, Sauropoda): *PeerJ*, v. 3, p. e857, <https://peerj.com/articles/857/>.

