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Field Guide to Big Bone Lick, Kentucky: Birthplace of American Vertebrate Paleontology

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Field Guide to Big Bone Lick, Kentucky: Birthplace of American Vertebrate Paleontology

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Pleistocene geology, paleontology, and the history of science at Big Bone Lick, Kentucky

Glenn W. Storrs, Cameron E. Schwalbach

Abstract

Big Bone Lick is the birthplace of vertebrate paleontology in the Western Hemisphere and has a long and celebrated history in the exploration of the American colonial frontier and of the early United States. Notable European scientists of the 18th century such as Buffon, Cuvier, and Hunter discussed the fossils found there. Prominent Americans of the time, such as Boone, Washington, Franklin, and Jefferson are also part of the site's history. It is the type locality for several extinct late Pleistocene megafaunal mammals, most notably the iconic American Mastodon, who were attracted to the area by salt licks dictated by the local geology. The valley of Big Bone Creek was unglaciated during the Wisconsinan advance and numerous saline springs well up through fractured bedrock of the Cincinnati Arch, providing essential minerals for the physiology of mammalian herbivores. The fossil remains at Big Bone Lick are an attritional assemblage, apparently including those that are the result of Native American predation. Archaeological remains from all local Native American cultural periods have also been found at the lick. The site is perhaps most notable in the history of science for its role in the development of comparative morphology and the establishment of the concept of extinction.

Historical Introduction

Big Bone Lick State Historic Site in Boone County, Kentucky is a small, but historically important state park in the glaciated Outer Bluegrass region, approximately 30 km southwest of Cincinnati, Ohio. Famous for over 200 years because of its historic and scientific significance, it was first explored by Europeans in 1739. At that time, a French military expedition was sent south from Montreal by the Quebec government of New France as that colonial territory extended from the mouth of the Mississippi River into Canada, and west of the 13 British colonies of the American continent. Its intention was to support an assault on the Chickasaw Nation, allied with the British, in the area of present-day Tennessee where hostilities between French colonists from Louisiana and Native Americans had broken out. A colonial detachment of 442 men (123 French soldiers and Canadian militiamen, plus 319 allied Native Americans) traveled down the Ohio River commanded by Charles le Moyne, the second Baron de Longueuil. Upon reaching the mouth of Big Bone Creek, the group were guided by Shawnee tribesmen approximately 5 km upstream to an area of boggy ground and saline springs (Daubenton, 1764; Stevens & Kent, 1941; Simpson, 1942, 1943; Hedeen, 2008).

Although the likely reason for their visit may have been to hunt the game that would have been plentiful near the lick, they saw that the ground was littered with large bones and teeth, now known to have accumulated over centuries. Some of these were gathered up and ultimately carried to Paris by Longueuil from New Orleans, where they were deposited in the Cabinet du Roi of Louis XV. They later became the first vertebrate fossils from the New World to be scientifically examined in Europe (Guettard, 1756; Buffon, 1761; Daubenton, 1764; Cuvier, 1806b; Jillson, 1936; Simpson, 1942, 1943; Tassy, 2002; Hedeen, 2008). These included three teeth, a left femur, and a tusk, of which the latter is now considered lost. The teeth and femur may be seen today in the collection of the Muséum national d'Histoire naturelle, Paris. One of the teeth has been designated as the lectotype for the American mastodon, *Mammut americanum* (Tassy, 2002). Daubenton (1764) established a foundational principle of vertebrate paleontology, that of comparative morphology, by comparing the femur (also from a mastodon) to those of a Siberian woolly mammoth (*Mammuthus primigenius*) and a modern elephant (Simpson, 1942). Now known as Big Bone Lick, in reference to both the large fossils found there and the salty mud from which local herbivores obtain critical minerals needed for their physiological functions, the site has for subsequent centuries been well known and avidly collected. Early trappers and traders, frontiersmen, soldiers, and future presidents collected bones and teeth here. Famously, they included William Henry Harrison, Meriwether Lewis, and William Clark, the latter two directed to collect by Thomas Jefferson (Jillson, 1936; Hedeen, 2008). A mastodon tooth said to have been found on the Ohio and presented to George Washington by John Connolly, a western Pennsylvania trader, originated from Big Bone Lick (Connolly, 1772 – published in Abbot and Twohig, 1994). Benjamin Franklin was sent specimens from the lick while he was a colonial representative in London and made one of the earliest references to changing climates. He considered that while "elephant" remains could be found at Big Bone, those animals no longer live in Kentucky, suggesting a different environmental regime in the past, writing:

> It is remarkable, that elephants now inhabit naturally only hot countries where there is no winter, and yet these remains are found in a winter country; and it is no uncommon thing to find elephants' tusks in Siberia, in great quantities, when their rivers overflow, and wash away the earth, though Siberia is still more a wintry country than that on the Ohio; which looks as if the earth had anciently been in another position, and the climates differently placed from what they are at present (Franklin, 1767 – published in Bigelow, 1904).

Daniel Boone visited the lick and examined the fossils there in 1770 (Hedeen, 2008). The renowned 18th century French naturalists Georges Cuvier and Georges-Louis Leclerc de Buffon studied material from the site, coming to conclusions of historic significance (Storrs, 2019). The father of modern geology, Charles Lyell, visited the lick in 1842 to see the famous locality for himself (Lyell, 1844; Hedeen, 2008). Even so, Native Americans had long known of this place, which for centuries and perhaps millennia, was used as an important source of both salt and game. Its fossils formed part of their mythology, and proboscidean tusks, unknown to native people other than as fossils, seem to have played a role in their stories of what were known as big buffalo (Jillson, 1936; Hedeen, 2008).

Geological Context

Big Bone Lick occupies the present valley of Big Bone Creek and its Gum Branch tributary, themselves lying within Old Eagle Creek, a part of the ancient drainage system of the Old Kentucky River, the largest tributary of the preglacial Teays River (Teller, 1973; Ray, 1974). The valley is incised into rocks of the Cincinnatian series of Upper Ordovician limestones and shales. Late Quaternary deposits now line the valley as three sets of terraces, dated respectively at approximately 25,000–19,000, 14,000–12,000, and 5,000 years bp to the present. Each surface eroded into and is lying disconformably atop the sediments of the former (Tankersley and others, 2009, 2015). The oldest deposits are dominantly blue-gray lacustrine clays, and the younger ones yellow to brown alluvial clays and silts. The tops of the valley walls represent the undissected preglacial land surface of the Lexington peneplain and are capped by alluvial sand and cobbles from the pre-Pleistocene Teays system.

Saline springs in the valley floor appear to originate under hydrostatic pressure from connate water in permeable sandstones of Cambrian to Silurian age in the Illinois Basin, based upon Na:Cl and Na:Br ratios (McCartney and others, 2005). The Middle Cambrian Simon Formation or the Middle Ordovician St. Peter Formation or their equivalents may be possible candidates, although the actual source remains uncertain. Water is forced to the surface through bedrock (Kope Formation) fractures resulting from uplift of the Cincinnati Arch (Stout and others, 1932) and ultimately rises through the overlying unconsolidated sediments. The water is rich in sodium chloride and sulfates. A Big Bone brine sampled in 2016 registered a brackish water reading of 7,240 ppm total dissolved solids (Purtill, 2017). Local bacterial reduction of sulfates results in a sulfurous odor (H_2S) (McCartney and others, 2005).

Human exploitation of the springs dates back at least centuries, as Native Americans and then frontier settlers harvested the salt by evaporation of large amounts of the brackish water. The mineral is a dietary necessity, but also was needed for the preservation of meats prior to the use of refrigeration, among other uses. Modern recreations indicate that boiling between 500 and 1,000 gallons of the lick's brine will result in a bushel of salt. Fragments of shallow, ceramic pans made for this purpose by native people have been recovered from Big Bone Lick, several of which are in the collections of Cincinnati Museum Center. The first recorded occurrence of salt-making at the lick dates from the autumn of 1755 when Mary Draper Ingles, a Virginian captured the previous summer by a Shawnee raiding party, was brought there for that purpose (Jillson, 1936; Ingles, 1969; Hedeen, 2008). Mary escaped her captors at Big Bone and her journey was famously dramatized in the historical novel *Follow the River* (Thom, 1981). Landowners and lessees operated commercial salt-making ventures, using iron kettles at Big Bone Lick from the 1780's until 1812, at which time the large amount of fuel required made the process economically unviable (Jakle, 1969; Hedeen, 2008). Remains of some of these salt works have been found buried under several feet of alluvium (Schultz, 1967), the result of seasonal backwater flooding from the Ohio River.

Historic use of the saline springs at Big Bone Lick also included medicinal baths and consumption of the mineral-rich water as a preventative and/or curative elixir. Visitors made use of them for the alleged benefit to their health from the late eighteenth century into the first decade of the twentieth century (Filson, 1784; Drake, 1828; Hedeen, 2008). Two separate incarnations of the Clay House (named for Henry Clay, the prominent Kentucky statesman), were built and operated at the lick beginning in the early nineteenth century. This resort hotel accommodated guests seeking the waters and was complete with accompanying bathhouses (Hedeen, 2008). No visible evidence of these structures remains, and indeed, of the small unincorporated town of Big Bone, only the former Methodist church and a single house adjacent to the park still exist.

Early explorers noted that ungulates traveled to salt springs to "lick the earth on account of the saline particles with which it is impregnated" (Imlay, 1792). Benjamin Franklin noted this proclivity with regard to "the Buffaloes & Deer" at Big Bone Lick (Franklin, 1768 – published in Bigelow, 1904; Simpson, 1942). The diets of herbivores in eastern North America are typically low in sodium, yet this element is essential for the proper physiological functioning of the body, including a variety of operations such as nerve conductivity and bodily fluid osmotic balance (Dethier, 1977; Hellgren and Pitts, 1997). As a result, they often consume salt-rich soil or brine through seasonal migrations to salt licks (Fraser and Reardon, 1980; Kreulen, 1985; Kraus and Schmidt, 1998). A well-established buffalo trace indicates that seasonal migrations of the American bison, *Bison bison*, made their way to Big Bone during the late Holocene, as they did to other regional saline springs, (Filson, 1784; Jakle, 1969; Hedeen, 2008). A portion of this trace, also used by Native Americans and later by travelers from Cincinnati, including Lewis and Lyell, may still be seen behind the Dinsmore Homestead historic house museum in Burlington, Kentucky. Other traces have evolved over time to trails and then roads. At the time of Longueuil's visit to Big Bone, the activity of bison had resulted in a generally unforested valley dotted by salt springs, and one or more muddy depressions equating to licks and/or wallows.

Paleontological History and Significance

Trails to the lick undoubtedly also existed for herbivore migration during the late Pleistocene when the active saline springs attracted regional populations of extinct megafauna. As noted above, Big Bone Lick is the type locality for the American mastodon, *Mammut americanum*, perhaps the most iconic representative of North American Pleistocene (commonly known as Ice Age) mammals. It was originally described based upon fossils sent by Longueuil and others to Paris and elsewhere in Europe (Guettard, 1756; Kerr, 1792; Blumenbach, 1799; Tassy, 2002). The mastodon is also by far the most common element of the Pleistocene fauna found at Big Bone.

Other holotypes originating from Big Bone Lick include those of *Bison antiquus*, the ancient bison (Leidy, 1852), *Bootherium bombifrons*, the woodland muskox (Wistar, 1818; Leidy, 1853), *Paramylodon harlani*, Harlan's ground sloth (Cooper, 1831; Cooper and others, 1831; Harlan, 1831; Owen 1840), and *Cervalces scotti*, the elk-moose (Wistar, 1818; Harlan, 1825; Scott, 1885; Lyddeker, 1898). Additionally, *Megalonyx jeffersoni*, Jefferson's ground sloth (Cooper, 1831; Hay 1923), *Mammuthus columbi*, the Columbian mammoth (Hay, 1923; Lister and Bahn, 1994), and *Equus complicatus*, the complex-toothed horse (Hay, 1923; Howe, 1982) are other extinct taxa known from the lick. The modern caribou, *Rangifer tarandus*, is a now extralimital species that has been found in the Pleistocene of Big Bone Lick (Shaler, 1871). McDonald and Scott (this volume) discuss the details and history of the Big Bone Lick fossil fauna.

The age of this fauna is latest Pleistocene, or Rancholabrean, with fossils likely no older than 25,000 years bp, nor younger than 12,000. This largely coincides with the maximum southern advance of the Wisconsinan glacier in the region, when the Hartwell Moraine was deposited in the northernmost neighborhood of present-day Cincinnati, approximately 19,000–19,500 years ago. Thus, the animals and environment of the time would have been impacted by the relative proximity of the massive continental ice sheet, about 50 km to the north, even as it continued to retreat (melt) north from 19,000 years ago onward. By 15,500 years bp, the ice sheet had retreated into Ontario and its local environmental impact was much lessened. Meltwater from the Wisconsinan glacier carried significant amounts of outwash debris of sand and gravel south into the Cincinnati area and the Ohio River, sometimes damming the mouths of valleys such as that of Big Bone Creek and resulting in the impoundment of water. Watershed erosional sediments directed into the Big Bone glacial lake settled to the valley floor, creating the oldest sediments and terrace remnants at the lick (Durrell, 1961; Ray, 1974; Durrell, 1977).

Subsequent to the presence of ponded water in the valley, Big Bone Creek resumed its normal flow, cutting down into the lacustrine sediments and depositing floodplain alluvium (Hedeen, 2008). Fossils that had accumulated in the lake sediments were periodically eroded and redeposited. Similarly, bones accumulating on the floodplain or in the creek were subject to frequent transport, intermittent deposition, and reworking as the creek meandered in the valley over time, creating new cutbanks and point bars. This is a process that is ongoing—an early map of Big Bone Lick (Cooper, 1831) shows the location of a new cut at Gum Branch spring creating an island comprising the valley's high ground (where most temporary encampments likely were made) (Fig. 1). The old channel is today essentially infilled and usually dry.

As a result of the dynamic nature of the creek, the depositional history of Big Bone sediments and fossils is a complicated one, and the fossils are normally isolated and disassociated. Fossil fragments are common and may be abraded from transport. Indeed, even style and color of preservation in both bones and teeth is variable between and within sedimentary units, with some elements dense, dark in color, and heavily permineralized, while others are light-hued, relatively lightweight, and sometimes leached of minerals. Although Big Bone Creek still occasionally tops its banks during intervals of heavy rainfall, the routine

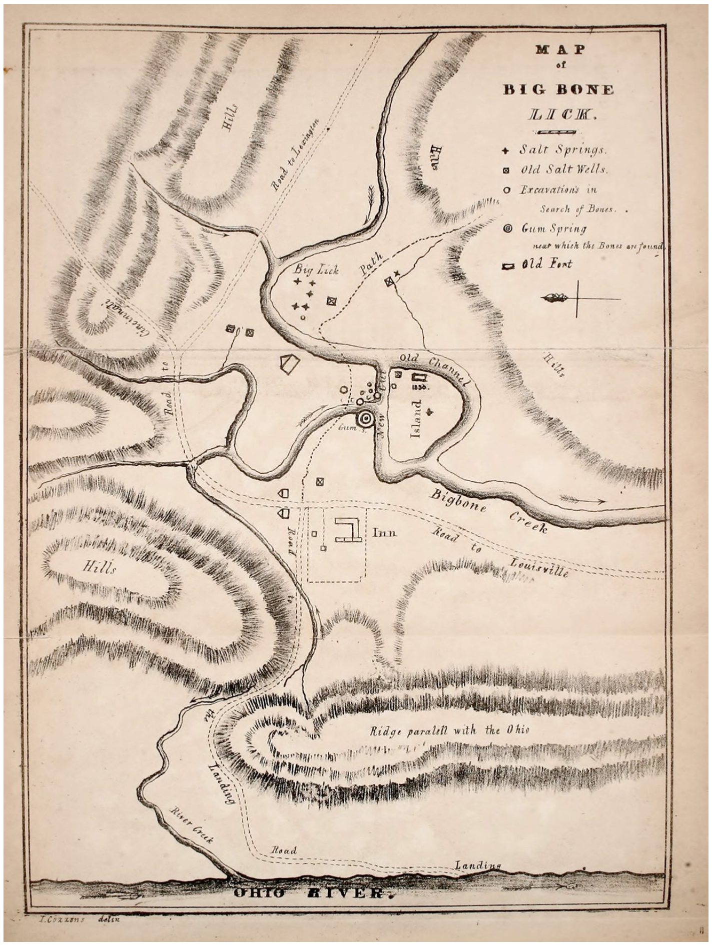


Fig 1. Big Bone Lick in 1830 as represented by William Cooper (1831). The Old Channel has since been abandoned and Big Bone Creek now flows only to the north of the Island. The Inn, Old Fort, and other structures indicated are also now long gone.

backwater flooding of the Ohio, with its appreciable deposition of silt and mud, has ceased after the twentieth century construction of a system of locks and dams which created stable navigation pools on the river.

Early reports of fossils at Big Bone Lick suggested that they could be found loose on the ground, shallowly buried, or exposed in the creek bank, in great abundance (Jillson, 1936; Bell, 1949). Anecdotally, it has long been suggested that the accumulation of bones is the result of animals having been mired in the boggy ground around the springs that was more evident at the lick in earlier times (Jillson 1936; Hedeen, 2008). Lyell (1844) claimed that this was the case, and that modern livestock were known to be trapped in this manner. Hydrological changes in the region have resulted in the existence of far fewer actively flowing springs in the valley today than are known to have been present in the past, although at least one new spring, or perhaps an old one that was reactivated, made an appearance 25 years ago and is still flowing today. The random collection of fossils by visitors, some of whom removed many, led to the need for dedicated excavation to collect specimens by the beginning of the nineteenth century.

Following the collection of fossils from the site by Longueuil in 1739 colonial explorers and traders continued to visit Big Bone Lick and pick up and carry away fossils. While some erroneous literature references to 1729 have resulted from a transcription error on Jacques Bellin's 1744 map of eastern North America which states "Endroit où on atrouvé des os d'Elephans en 1729," the original 1740 manuscript map from the expedition, after which Bellin's map was drawn, clearly states that Longueuil's Canadian army found them in 1739 (Simpson, 1942, 1943; Hedeen, 2008). While the first collection went to Paris, after 1758 many of these made their way to London, following the British occupation of Fort Duquesne (now Pittsburgh) and their control of the Ohio River Valley in the French and Indian War. New France, exclusive of Louisiana, was ceded to Great Britain at the war's conclusion in 1763, and the Kentucky territory became part of the colony of Virginia. George Croghan, a British agent for Indian Affairs in Pennsylvania, was responsible for collecting historically important mastodon specimens in 1766 that are, in part, now in the Natural History Museum, London (Kindle, 1931; Simpson, 1942). These were examined and discussed before the Royal Society (Collinson, 1768a, 1768b; Hunter 1769). The specimens sent to Benjamin Franklin also came from Croghan. Not long thereafter, the American War of Independence (1775-1783), again changed the *status quo* and Big Bone Lick fossils remained largely in the new United States. For instance, future U.S. president William Henry Harrison collected a large volume of bones from the lick in 1795, although these were accidentally lost in the Ohio River.

The identity of the mastodon was much debated in the late eighteenth century following the delivery of its fossils from Big Bone Lick to Europe. Collected tusks obviously belonged to elephants (*Mammut americanum* is not a true elephant, but rather part of a distantly related lineage within Proboscidea), but the teeth, often called grinders, were very unlike those of elephants (Fig 2). At various times, the teeth were thought to belong to a hippopotamus, an unknown elephant, or an entirely unknown animal, perhaps a carnivore or browser, called the "American *incognitum*" (Daubenton, 1764; Collinson, 1768a, 1768b; Hunter 1769). Collinson (1768b) believed that the tusks and teeth belonged to

Fig 2. Mastodon, *Mammut americanum*, tooth from Gum Branch, Big Bone Lick, Boone County, Kentucky. Presumed to have been a browsing animal, the tooth's conical cusps give the mastodon (breast tooth) its name. Cincinnati Museum Center Vertebrate Paleontology Collection, CMC VP11732.

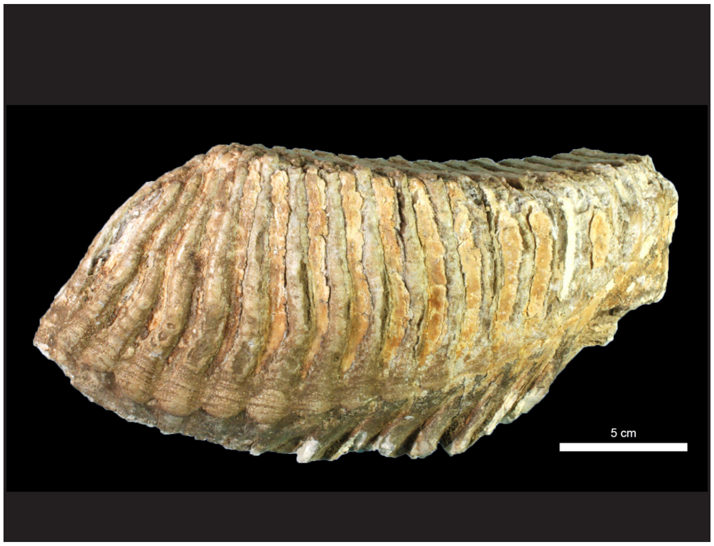


Fig 3. Right lower tooth of a mammoth, *Mammuthus columbi*, from near Hebron, Boone County, Kentucky. The tooth is constructed of numerous vertical plates of dentin and enamel, held together by cementum, as in living elephants. The flat grinding surface is indicative of a grazing habit. Cincinnati Museum Center Vertebrate Paleontology Collection, CMC VP7513.

one animal, and Hunter (1769) introduced the, at the time shocking, idea that the animal was probably extinct. Ultimately, these conclusions were accepted, and Cuvier (1799), after examining living and fossil elephant remains, concluded that not all organisms that had existed in the past remained extant. His study of the mastodon (Cuvier, 1806b), based on Big Bone Lick fossils, reinforced the concept of extinction, a major conceptual breakthrough at a time when most learned men accepted the world and its inhabitants as young and largely static. He, along with Daubenton (1764) and Hunter (1769), pioneered the use of comparative morphology in the study of fossils. Cuvier (1799, 1806a, b, c) put all the pieces of the mystery together—the *incognitum* fossils belonged to a single, extinct species, similar to but distinct from elephants, the mastodon was different from the also extinct Siberian elephant (now called the mammoth), and a true extinct elephant (actually two or more species of mammoth) was also known from North America (Fig. 3). None of these was identical to the living Asian or African elephant, although all were herbivorous, and they were adapted to colder climates than the modern forms (Simpson, 1942). Cuvier assigned the new name mastodon (French *mastodonte*) to the *incognitum*, meaning "breast-tooth" (from Greek) in reference to the conical cusps of its occlusal surface (1806b). Mammoth was restricted to the extinct elephants.

Thomas Jefferson and Big Bone Lick

One prominent American who, by 1784, had also arrived at the conclusion that the mastodon was distinct from any living elephant, was none other than Thomas Jefferson (Hedeen; 2008; Storrs, 2019). He came late to the acceptance of extinction, however, and wrote with regards to the mastodon:

> Such is the economy of nature, that no instance can be produced of her having permitted any one race of her animals to become extinct; of her having formed any link in her great work so weak as to be broken. To add to this, the traditional testimony of the Indians [is] that this animal still exists in the northern and western parts of America. ...Those parts still remain in their aboriginal state, unexplored and undisturbed by us, or by others for us. He may well exist there now, as he did formerly where we find his bones (Jefferson, 1787).

Furthermore, Jefferson hoped that Lewis and Clark would discover living mastodons during their Corps of Discovery exploration of the Louisiana Purchase (1803–1806) (Jefferson, 1803–published in Jackson, 1962). However, after the expedition's return with no sign of a mastodon, he ultimately if not immediately, had to accept that extinction had come to them.

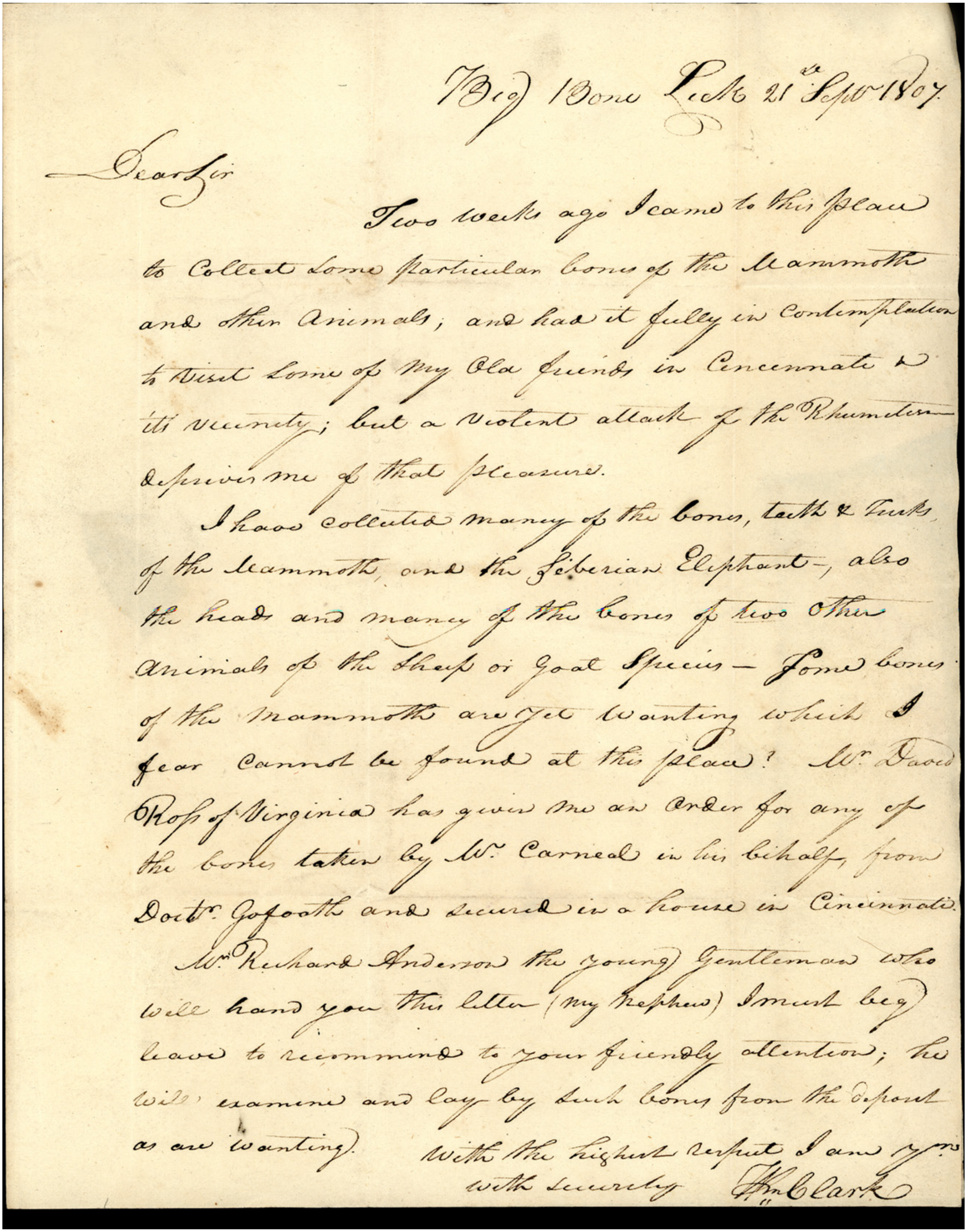
Jefferson's interest in Big Bone Lick was piqued by a 1780 request from France for information on the states that it was assisting during the colonial revolt. As Jefferson had recently been governor of Virginia, and was soon to become minister to France, the request resulted in his influential book, *Notes on the State of Virginia*. Notwithstanding, he further defended the new country against the French idea that the New World's climate and environs were inferior to the Old (Jefferson, 1787). This theory of "American degeneracy" (Buffon, 1749–1789) suggested that American animals were on average fewer in type, smaller, weaker, and less virile than those of the Old World because of their respective environments. The result was allegedly a depauperate American continent and civilization with no significant history. Naturally, this attitude was anathema to Jefferson and other Americans, thus the discovery of the mastodon was proof to them that the idea of degeneracy was surely incorrect. Therefore, the mastodon developed into an early symbol of American identity, patriotism, and pride (Semonin, 2000).

Jefferson harbored an intense interest in the mastodon and sought to acquire mastodon remains from Big Bone beginning in 1781, although he initially met with little success. By 1803, when Lewis was traveling west to Louisville to meet Clark for the start of their expedition, now President Jefferson sent him first to Cincinnati physician William Goforth in order to examine his collection. Lewis visited with Goforth, visited the lick, and was given some of Goforth's specimens, but these were lost on the Mississippi while in transit to Jefferson. After years of effort, Jefferson only succeeded when Clark, along with his brother General George Rogers Clark with a crew of 10 laborers from Cincinnati, made a large collection of mastodon and other fossils for him by digging in the vicinity of Gum Branch (where most of the productive excavations have taken place over the years) in September, 1807, after the expedition's return. Jefferson personally financed this, the country's first organized excavation for fossil remains, symbolically marking Big Bone Lick as the "birthplace of American vertebrate paleontology" (Jillson, 1936; Simpson, 1942; Schultz and others,1967; Hedeen, 2008; Storrs, 2019). As a result of the efforts of Lewis in 1803 and Clark in 1807, one might also say that, at least in a figurative sense, their famous expedition west began and ended at Big Bone Lick.

While at Big Bone, Clark wrote to James Findlay, merchant, soldier, and recent mayor of Cincinnati, with an explanation of his activities. The letter (Fig. 4) is a shorter version of his first communication from the lick, sent on the previous day, to Jefferson himself:

> General Findley [sic]
> Cincinnati
> Big Bone Lick 21st Sept
> 1807 Dear Sir
>
> Two weeks ago I came to this place to collect some particular bones of the Mammoth and other animals; and had it fully in contemplation to visit some of my old friends in Cincinnati & it's [sic] vicinity; but a violent attack of the Rhumatism [sic] deprives me of that pleasure.
>
> I have collected many of the bones, teeth & tusks of the Mammoth, and the Siberian Elephant -, also the heads and many of the bones of two other animals of the sheep or goat species – Some bones of the mammoth are yet wanting which I fear cannot be found at this place? Mr. David Ross of Virginia has given me an order for any of the bones taken by Mr. Carneal in his behalf, from Doctr. Goforth and secured in a house in Cincinnati.
>
> Mr. Richard Anderson the young Gentleman who will hand you this letter (my nephew) I must beg leave to recommend to your friendly attention; he will examine and lay by such bones from the deposit as are wanting.
>
> With the highest respect I am yours
> with security Wm Clark

The bones Clark refers to are those of the mastodon (confusingly calling them Mammoth) and the true mammoth (Siberian Elephant). (Mammoth comes from the Siberian word *mamant*, meaning earth-dweller, in reference to its remains having been found in the earth, or permafrost. The Russian word for mammoth is *mamont*. The name mammoth was previously adopted for Big Bone Lick fossils, until the mastodon was shown to be distinct (Cuvier 1806b). As a result, the generic name *Mammuthus* applies to the mammoth and *Mammut* applies to the mastodon as a compromise solution to the early confusion.) Clark's "sheep or goat species" refers to *Bootherium* and *Cervalces*, the partial



Big Bone Lick 21st Sepr 1807.

Dear Sir

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I have collected many of the bones, teeth & Tusks, of the Mammoth, and the Siberian Elephant, also the heads and many of the bones of two Other animals of the Sheep or Goat Species — Some bones of the mammoth are yet wanting which I fear Cannot be found at this place? Mr. David Ross of Virginia has given me an Order for any of the bones taken by Mr. Carneal in his behalf, from Doctr. Goforth and secured in a house in Cincinnati.

Mr. Richard Anderson the young Gentleman who will hand you this letter (my Nephew) I must beg leave to recommend to your friendly attention; he will examine and lay by such bones from the deposit as are wanting.

With the highest respect I am yrs
with sincerity Wm Clark

Fig. 4. Letter from William Clark to Cincinnatian James Findlay, sent from Big Bone Lick on the 21st of September, 1807. Cincinnati Museum Center Manuscripts Collection, Torrence Papers Mss qT691f.

skulls of which became the holotype specimens for these snew animals, as did the first partial cranium of *Bison antiquus*, also collected by Clark at this time (Wistar, 1818; Harlan, 1825; Leidy, 1852, 1853). All three of these latter specimens are preserved in the Academy of Natural Sciences in Philadelphia (Spamer and others, 1995). Clark's intention to complete a skeleton of the mastodon with those bones "as are wanting" did not materialize. Despite the assistance of David Ross, then owner of the Big Bone Lick land and a friend of Jefferson, the bones in Cincinnati were not forthcoming.

Approximately 300 bones collected by Clark eventually reached Jefferson at the White House and were arranged on the floor of the East Room in 1808, with a portion destined to go to the American Philosophical Society in Philadelphia (ultimately to the Academy of Natural Sciences), and others to the National Institute of France (and thence to the Paris Museum, home to the original 1739 collection), to which Jefferson had been elected a foreign associate in 1801 (Jillson, 1936; Rice, 1951; Hedeen, 2008; Thomson, 2008). Caspar Wistar, vice president of the American Philosophical Society (of which Jefferson was president) examined these and selected those destined for Philadelphia, later providing the initial descriptions of *Bootherium* and *Cervalces* (1818). While most of those retained by Jefferson were ultimately lost, a partial upper jaw is on view at Monticello, his Virginia home (on loan from the University of Virginia, where Jefferson's remaining specimens were transferred following his death). The organized nature of this entire undertaking, coordinated and financed by the President of the United States, as well as the scientific use to which many of the specimens were put is generally considered the formal start to the science of vertebrate paleontology in America (Storrs, 2019).

Later History

Large collections were subsequently made in 1819 for Cincinnati's Western Museum, a forerunner of Cincinnati Museum Center where Big Bone Lick fossils are now exhibited, and by William Cooper for New York's Lyceum of Natural History in 1828 (Cooper, 1831; Jillson, 1936; Simpson, 1942; Hedeen, 2008). Specimens collected in 1830 by the then owner of the lick and its health resort, Benjamin Finnell, also ended up at the Lyceum, including the partial lower jaw that became the holotype of *Paramylodon harlani* (Cooper, 1831; Cooper and others, 1831; Harlan, 1831; Owen 1840). This specimen was later destroyed by fire (McDonald and Scott, this volume), although casts survive, including one at Cincinnati Museum Center and another at Big Bone Lick State Historic Site. Nathaniel Shaler, a northern Kentucky native, and a Harvard geologist and paleontologist, made the next significant collection with scientific research in mind in 1868. He was an early American proponent of organic evolution and also served as the director of the Kentucky Geological Survey from 1862 to 1879. Shaler recognized the ephemeral, shifting nature of Big Bone springs and his excavations demonstrated again, as had Cooper's and Finnell's (Cooper, 1831), the faunal succession related to stratigraphy, with numerous bison bones much nearer the surface, and entombed in a different sediment, than the Pleistocene megafaunal remains (Shaler, 1876, 1877).

Little organized exploration of the lick took place in the twentieth century until the early 1960s when the University of Nebraska undertook new excavations (Schultz and others, 1963, 1966, 1967). They documented three faunal zones at separate excavation sites. The upper zone contained bison and deer bones, and those of domesticated animals, as well as some reworked Pleistocene specimens. This layer also produced bricks, crockery, building stones, and other historic period artifacts. A second, lower zone, contained numerous bison bones, plus those of deer and elk, and formed the bulk of the material collected. The lowest zone comprised of blue-gray silt and of variable thickness contained Pleistocene megafaunal remains, including mastodon, ground sloth, muskox, ancient bison, elk-moose, caribou, and horse, the fossils of the latter taxon including a partial cranium (pers. obs.). Unfortunately, only preliminary studies were ever published from this work.

As has been noted above, in addition to Pleistocene megafaunal remains, late Holocene bones and teeth are also common at Big Bone Lick. The vast majority of these are of the modern *Bison bison*, and enormous numbers of their bones have long been reported to occur at a shallower depth than the Pleistocene fossils (Cooper, 1831; Lyell, 1845; Shaler, 1876; Hedeen, 2008). University of Cincinnati students under the direction of Kenneth Caster recovered hundreds of such bones, now preserved at Cincinnati Museum Center, from Big Bone Creek following flooding in the 1940s. Modern bison expanded into the eastern portion of the country in the late Holocene (Rostlund, 1960), but had disappeared from the Ohio Valley around 1800 (Butler, 1885). *Odocoileus virginianus*, the white-tailed deer, *Ursus americanus*, the black bear, and apparently also *Cervus canadensis*, the wapiti or elk, are also known from Big Bone Holocene sediments (Hedeen, 2008). In 2023 a tooth of *Canis lupus*, the grey wolf, was found at the park for the first time.

Archaeological Significance

In 2007, a chance discovery by a visitor to the park led to the excavation of five associated *Bison bison* partial individuals (Storrs and others, 2009, and this volume) from a loosely lithified conglomerate layer in the bed of Big Bone Creek. Dated to an interval spanning the fifteenth to mid-seventeenth century, and with associated lithic tools, this was surely a kill and butchering site that can be attributed to the Fort Ancient Culture of Native Americans. The dates are in alignment with those estimated for the presence of modern bison in the area (Tankersley, 1986). The lithics, primarily cutting tools, were of expedient manufacture, made on-site from cherts and quartzites derived from Teays-age alluvial cobbles atop, and washing down from, the valley walls. Quickly and roughly made, these tools were just as quickly abandoned after use. Horizontal striae on some of the bones, particularly the neural spines of thoracic vertebrae, may represent cut marks. The taphonomic disposition of the skeletons also suggests predation by native hunters. The skulls were each broken open, leaving only the skull roofs and horn cores intact, and were found atop or beside flat Ordovician limestone slabs, apparently used as anvil stones, with small fragments of the skulls and teeth scattered about them. Postcranial bones were disarticulated yet concentrated in a relatively small area without signs of transport. An analysis of the larger skeletal elements present versus those missing suggests that the most desirable parts of the carcasses were transported off-site for consumption (Storrs and others, 2009, and this volume). Bison bones are known from the contemporaneous Madisonville village site in Mariemont, Ohio, less that 45 km away (Drooker, 2009).

The accumulation of fossils at Big Bone Lick is clearly an attritional assemblage, but the recognition of human predation as a source of late Holocene bison bones indicates that this same mechanism may have played an important role in the accumulation of many of the Pleistocene fossils as well. This is at odds with the oft repeated, but anecdotal and untested, miring scenario of the early explorers. While some miring and other natural deaths may have occurred, the presence of large herbivores at the site with no carnivores preserved may indicate that something else was at work. Carnivores (e.g., the saber-toothed cat, *Smilodon fatalis*, the dire wolf, *Aenocyon dirus*, and the short-faced bear, *Arctodus simus*, all known from the Midwest, if not yet Kentucky) would surely have been present, following prey species to the lick much as lions today are attracted to African watering holes. Their activities likely led in part to attrition of the megafauna and the accumulation of their remains. However, Paleoindians are now known to have been present in much of North America at least 14,500 years ago (Waters and Stafford, 2007; Waters, 2019; Becerra-Valdivia and Higham, 2020). Big Bone Lick fossils originating from the lacustrine clays predate this time period, but those from the terrace deposits of 14,000–12,000 bp, when the valley floor salt springs would have been exposed, do not. It is not unreasonable to assume that pre-agricultural human hunters were also active predators of at least part of the megafauna.

Notably, in addition to Pleistocene age animal bones, Big Bone Lick has produced Paleoindian spear points of late Pleistocene age (Tankersley and others, 2009). Their presence has not received much attention over the years, as they are less common than the fossil bones and the quest for the latter has dominated explorations there. However, William Goforth, the Cincinnati physician who actively collected Big Bone fossils and assisted both Lewis and Clark at the lick, held a collection of Big Bone artifacts, including some that were apparently found during the Clark excavation. These latter included what now are believed to be the first Paleoindian spear points ever discovered in the Americas (Tankersley, 2002). Now called Clovis points after the discovery of similar artifacts in association with extinct fauna in New Mexico in the 1920s and 1930s, they remained privately owned and/or their significance unrecognized for many years, only coming to the attention of the academic community in the 1980s. These historic artifacts have over the years passed through the hands of Clark, Goforth, his student and pioneering Cincinnati physician Daniel Drake, the defunct Western Museum of Cincinnati, Cincinnati attorney and collector Thomas Cleneay, the Cincinnati Art Museum, and ultimately into the collections of Cincinnati Museum Center (Fig. 5).

Fig. 5. Fluted Paleoindian (Clovis Point) spearheads from the William Goforth collection, Big Bone Lick, Boone County, Kentucky. These points are believed to have been collected by William Clark in 1807, possibly in association with extinct animal bones. Cincinnati Museum Center Archaeology, Thomas Cleneay Collection, 1887.5174, 1887.5790, and 1887.5436, left to right respectively.

It appears that the hunt for the mastodon and its contemporaries has not been confined to their fossil remains, but may have included their predation by Native Americans over 10,000 years ago when Pleistocene megafauna and Clovis people overlapped in time. The Clark/Goforth artifacts are not known to have been found in direct association with megafaunal remains, but more recently discovered examples from Big Bone Lick have been, although perhaps in a secondary context (Tankersley and others, 2009). Nevertheless, their discovery, and the documentation of the perhaps analogous bison kill and butchering site of 2007 are suggestive. Kimmswick, Missouri has produced a seemingly definitive mastodon kill site (Graham and others, 1981) and mastodon remains with indications of seasonal butchering that provide at least circumstantial evidence for human hunting are known elsewhere in the Midwest (Fisher, 1984, Shipman and others, 1984; Fisher, 1988). Mastodon remains, fluted biface points, tools made from mastodon and caribou bones, and a probable cut mark on a possible mastodon bone fragment have been found at western New York's Hiscock site, although scavenging rather than hunting has been suggested here (Ellis and others, 2003; Laub and Spiess, 2003; Tomenchuk, 2003). Two Big Bone Lick proboscidean bones in the collection of Cincinnati Museum Center, a phalanx (CMC VP14754) and a partial tibia (CMC VP11751), exhibit potential cut marks, suggesting butchering if not also hunting. Thus, while the evidence is not definitive, the presence of human activity at Big Bone Lick in the late Pleistocene is unequivocal, and human predation as a source of at least some of the fossil remains is likely.

Conclusion

After over 200 years of activity at Big Bone Lick, there remains much yet to be learned about this classic fossil locality. Indeed, collecting and research activity, is still taking place here. In 2017, an isolated tibia of *Paramylodon harlani* (now exhibited at the park visitor center) was found loose in the creek bed, indicating that material is still to be found at the site. Most recently, in 2020, a partial, *in situ* proboscidean tusk (CMC VP19824) was discovered by park personnel and collected by Cincinnati Museum Center from the bank of Big Bone Creek. Whereas most fossils have been collected here haphazardly, as fully eroded specimens, and without context, *in situ* bones can provide much needed data about the disposition of fossils at the lick. A video of that excavation may be seen at:

https://www.facebook.com/cincymuseum/videos/cmc-unearths-mastodon-tusk-at-big-bone-lick/712549636322567/

Big Bone Lick is unique among American paleontological sites for its prominence in both the exploration of North America and in the development of scientific and cultural thought during the formative years of our country. Fossils from the site can be found in museum and university collections around the country and around the world. Following advocacy efforts by local citizens, in 1960 the land surrounding the salt springs became part of the Commonwealth of Kentucky park system. It was listed on the National Register of Historic Places in 1972 and designated as an official stop on the Lewis and Clark Heritage Trail by the U.S. National Park Service in 2002. In 2009, the site became a National Natural Landmark and it is under consideration as a National Historic Landmark. Big Bone Lick's claim as the birthplace of American vertebrate paleontology is undoubtedly well justified.

Acknowledgments

This introduction to Big Bone Lick State Historic Site is intended to accompany field trips to the park, in particular tours of the Discovery Trail, an approximately half-mile paved loop with interpretive signage in the valley of Big Bone Creek. The trail may be accessed behind the park's visitor center, 3380 Beaver Road, Union KY 41091.

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Figure 2: Excavation map showing disposition of collected skeletal elements, Big Bone Creek, 2008.

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A new precontact *Bison bison* butchering site at Big Bone Lick, Kentucky

Glenn W. Storrs, Robert A. Genheimer, and Stanley E. Hedeen

Abstract

The 2008 discovery and excavation of minimally five sub-adult individuals of *Bison bison* at Big Bone Lick, Kentucky is interpreted as a Native American, Fort Ancient culture kill and butchering site, an exceedingly rare occurrence in the Ohio Valley. Sedimentological and taphonomic evidence indicates no significant fluvial transport of the preserved elements, as all parts of the skeleton are represented. Sixteen lithic artifacts, most identified as of expedient manufacture, were collected in close association with the *Bison* remains. Tallies of preserved skeletal elements suggest the removal and processing of select cuts from the carcasses by Native American hunters. The recognition of human predation as a source of Holocene zoological remains at Big Bone Lick suggests that this mechanism may also have played an important role in the accumulation of Pleistocene (Rancholabrean) paleontological specimens at the lick, a conclusion also suggested by earlier discoveries of Paleoindian (Clovis) projectile points there.

Introduction

The remains of large Pleistocene land mammals ("megafauna") at Big Bone Lick, Kentucky, a site approximately 40km southwest of Cincinnati, Ohio, have been known to explorers and scientists for over 280 years following their discovery in 1739 by a French military expedition under the command of Charles le Moyne, second Baron de Longueuil (1687-1755) (Hedeen, 2008; Storrs, 2019; Storrs and Schwalbach, this volume). The holotypes of *Bison antiquus*, *Cervalces scotti*, *Paramylodon harlani*, and *Bootherium bombifrons* are all from the lick (McDonald and Scott, this volume). Moreover, the original description of the American mastodon, *Mammut americanum*, was based upon specimens collected there (Tassy, 2002). In addition to the numerous late Pleistocene (Rancholabrean, Wisconsinan) fossils found at the site over the years, many Holocene skeletal remains are present at Big Bone, most notably thousands of bones of *Bison bison*. The discovery and 2008 excavation by Cincinnati Museum Center staff of a bison kill and butchering site in Big Bone Creek, an exceedingly rare occurrence in the Ohio Valley, provides insight into a possible mechanism of bone accumulation at this important paleontological and archaeological locality.

Undoubtedly, large land mammals have been attracted to Big Bone Lick for millennia by the salt springs flowing there, as saline springs provide minerals essential to the physiology of mammalian herbivores (Kreulen, 1985). Although the maximum extent of the Wisconsinan glacier in the Ohio region, some 19,000 to 19,500 years ago, did not reach as far as the Ohio River, the Big Bone Valley was heavily impacted by its presence (Durrell, 1961; Hedeen 2006). Wisconsinan clays buried in the valley floor attest to periods of ponded water created by dams of glacial outwash. It remains unclear precisely when during this period saline waters, originating through fractures in the Ordovician bedrock, began to form springs in the valley floor, but fractures in the structural Cincinnati Arch are ancient and widespread (Stout and others, 1932). The stories of early European and colonial explorers noted the boggy, "jelly ground" nature of the Big Bone Valley during the 18th and early 19th centuries, leading to the supposition that animals had become trapped in and near the springs on multiple occasions (Jillson, 1936). We hypothesize that a more likely origin for the majority of the remains entombed on the site is natural attrition, dominated by predation by large carnivores and Native Americans. Subsequent thick sedimentation due to periodic backwater flooding of the Ohio River coupled with lateral accretion packages of post-Pleistocene Big Bone Creek contributed to the entombment.

Sedimentologic and taphonomic setting

In the spring of 2007, a casual visitor to Big Bone Lick State Historic Site discovered a series of disarticulated bones of *Bison bison* exposed in the bed of Big Bone Creek (Fig. 1). Following consultation with the Kentucky Office of State Archaeology, the Kentucky Heritage Council, and park officials, the Cincinnati Museum Center was invited to excavate the new discovery (Storrs and others, 2009). Construction of

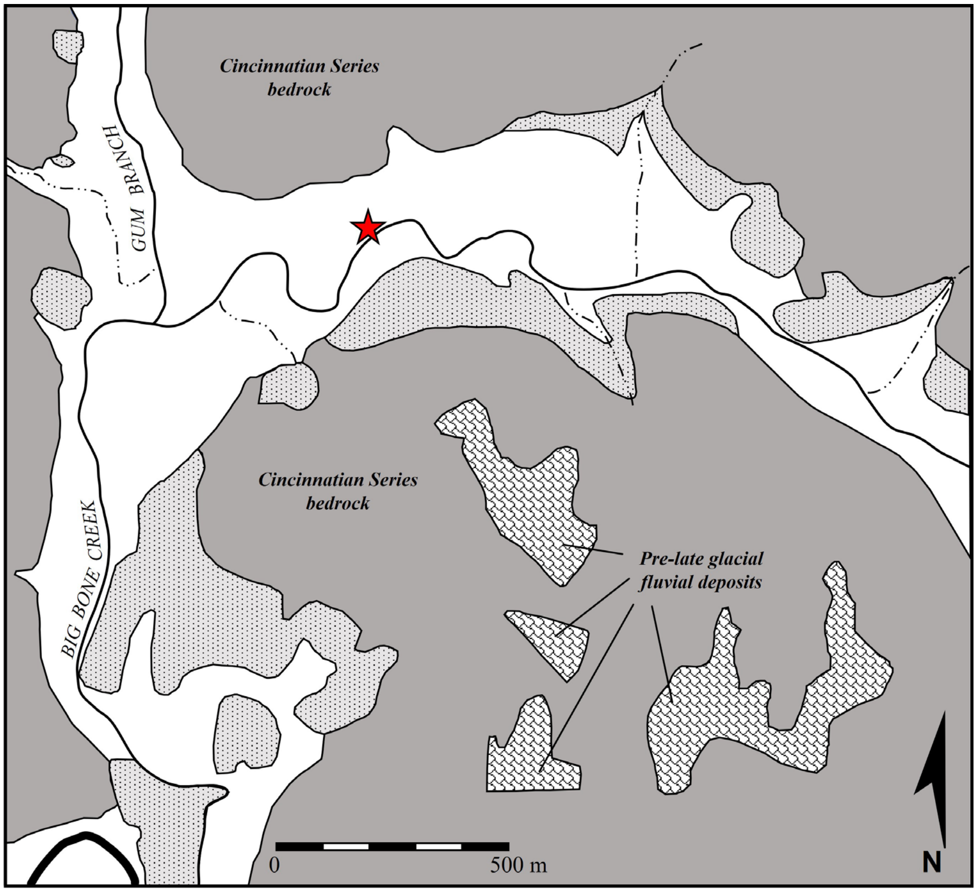

Fig. 1. Approximate location of 2008 Bison bison excavation site in Big Bone Creek, Big Bone Lick State Historic Site, Boone County, Kentucky. Stippled areas represent late Pleistocene terrace deposits (modified from Tankersley and others, 2009).

Fig. 2. Excavation map showing disposition of collected skeletal elements, Big Bone Creek, 2008. Dashed line indicates erosion-defined limit of excavation. Solid line indicates creek cutbank. Lithic tools recovered *in situ* are portrayed in solid black.

a temporary sandbag dam and pumped removal of standing water allowed division of the site into a 12 m^2 grid and subsequent specimen documentation and removal. Excavation rapidly revealed that many more bones were present than had been suggested by the original find. Ultimately, nearly 600 bones and bone fragments were collected, along with 16 definitive lithic tools (Fig. 2). A large amount of preserved wood was also present, as were nuts of the hickory tree, *Carya sp.*

All of the material was preserved within a bench of friable, organic-rich conglomerate. The unit is weakly lithified by calcareous and ferruginous cements. Clasts consist of sand and pebble-sized erratics derived from glacial outwash that partially caps the hills surrounding the valley, including chert and igneous rocks, and cobbles derived from local carbonate bedrock (Cincinnatian Series, Late Ordovician in age). Bones were dark brown to black in color when initially exposed, indicating a high degree of organic preservation; they exhibit sharp edges where broken and display little to no evidence of fluvial transport. The gravel bench is interpreted as representing a prehistoric point bar sequence from a phase of stream migration that predates the current position of the local meander. This bench is believed to be equivalent to Zone B of Schultz and others (1963, 1967). Immediately above the bone-bearing unit there are approximately 7 m of silts and clays to the north and 3-4 m to the south; these are deposits from multiple episodes of backwater flooding of the Ohio River, overbank deposition of Big Bone Creek, and reworking by lateral stream migration. The terraces formed by the two banks in this location are of different ages and represent distinct phases in the evolution of Big Bone Creek.

Faunal remains

Bison bison individuals were present in the Ohio Valley at the time of initial contact of Europeans with Native Americans, approximately 300 years ago, and were being utilized by the indigenous Fort Ancient people of the Madisonville Phase (Tankersley, 1986). The late precontact (protohistoric) Fort Ancient Culture coincides with the maximum distribution of *Bison bison* in North America (McDonald, 1981). Numerous references to precontact *Bison* remains at Big Bone Lick have been made since 1807 as, for example, reported by Jillson (1936). Subsequent excavations have produced additional *Bison bison* remains and prehistoric artifacts (Schultz and others, 1967; Tankersley, 1986; Wigda, 2006).

Bones recovered in the excavation by Cincinnati Museum Center in 2008 are all from relatively small individuals (Fig. 3). Indeed, open epiphyseal plates indicate that the preserved animals were skeletally immature. All specimens are reposited at Cincinnati Museum Center on behalf of the Commonwealth of Kentucky. The minimum number of individuals represented at the new Big Bone Lick site is five, based upon the presence of five examples each of left metatarsals, astragali, and calcanei. Table 1 displays the observed vs. expected frequencies of the skeletal elements represented by whole and fractured bones. Carpals, sternebrae, caudal vertebrae, hyoids, lateral malleoli, cuneiform tarsals, and sesamoids have preserved proportional frequencies below 30%.

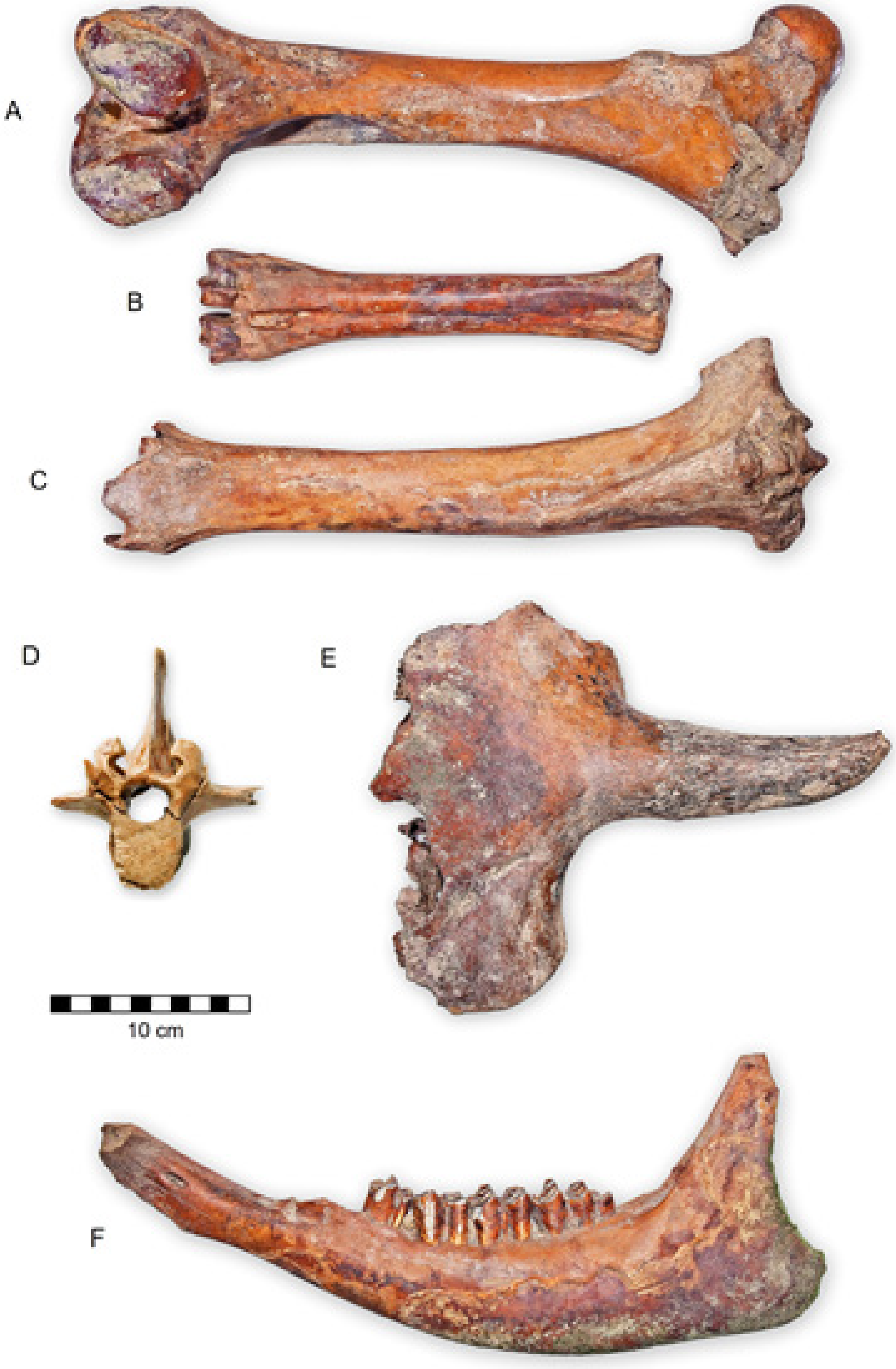

Fig. 3. Representative skeletal elements of *Bison bison* recovered from Big Bone Creek excavation, 2008. A – right femur, CMC VP10868; B – left metatarsal, CMC VP10841; C – right tibia, CMC VP10841; D – lumbar vertebra, anterior aspect, CMC VP11011; E – partial skull roof and horn core, CMC VP10915; F – left dentary, CMC VP10916.

Most of these smaller, lighter bones likely were lost through scavenging and/or fluvial winnowing prior to site burial by waterborne sediments.

Proportional frequencies of larger, heavier bones range from 30% to 80% and appear related to their specific resource value. Emerson (1993) calculated Food Utility Index (FUI) values for a variety of bones in individuals of *Bison bison*, based upon the amount of meat, marrow, and bone grease associated with each (Table 2). FUI values of bones in the axial skeleton, forelimbs, and hindlimbs were plotted against their proportional frequencies at the new Big Bone Lick site (Fig. 4). In general, bones of relatively low food utility occur at greater frequencies than do those with high values. These latter are hypothesized to have been transported offsite for consumption, presumably by Native American hunters.

Skeletal Element	Observed	Expected	Percent
Metatarsal	8	10	80%
Non-Cuneiform Tarsals	24	30	80%
Patella	8	10	80%
Metacarpal	7	10	70%
Radius-Ulna	7	10	70%
Lumbar Vertebrae	17	25	68%
Cervical Vertebrae 1-2	6	10	60%
Cranium	3	5	60%
Mandible	6	10	60%
Sacrum-Pelvis	3	5	60%
Phalanges	69	120	58%
Cervical Vertebrae 3-7	13	25	52%
Scapula	5	10	50%
Tibia	5	10	50%
Thoracic Vertebrae	30	70	43%
Femur	4	10	40%
Ribs	47	140	34%
Humerus	3	10	30%
Carpals	17	60	28%
Sternebrae	5	35	14%
Caudal Vertebrae	6	50	12%
Hyoid	1	10	10%
Lateral Malleolus	1	10	10%
Cuneiform Tarsals	1	20	5%
Sesamoids	1	120	1%

Table 1. Observed (recovered) versus expected number of skeletal elements for 5 individuals of *Bison bison,* Big Bone Creek excavation, 2008.

A disproportionate absence of high food utility bones has also been found at *Bison* mortality sites in Alberta (Landals, 1990), Montana (Kehoe, 1967), Wyoming, (Frison, 1970), and New Mexico (Speth, 1983).

Of particular interest is the fragmentary nature of the three preserved skulls recovered from the new Big Bone Lick site. Each has most of its component parts present and in close proximity to the cranium, yet they have been subjected to significant mechanical breakage resulting in the association of numerous small skull fragments and isolated teeth with each cranium. They furthermore were found lying atop or near to slabs of Ordovician limestone that potentially acted as "anvil stones." We suggest that on-site processing of these skulls by Native Americans for desirable organs, such as the brain and tongue, is responsible for their state of preservation. A number of the postcranial elements, such as the neural spines of thoracic vertebrae, exhibit striae that apparently represent cut marks.

Associated artifacts

During the 2008 excavation at Big Bone Lick, 16 Native American lithic artifacts were recovered from the conglomeratic matrix containing the bones of *Bison bison*. Thirteen are made of chert, one quartzite, one an undetermined igneous rock, and one is indeterminate. The lithics comprise five crude bifaces, three utilized flakes, two cores or core fragments, a retouched flake, two non-utilized flakes, a possible scraper, an adze, and a large hammer/chopper. The artifacts are characteristic of many regional precontact sites and thus are not temporally nor culturally diagnostic (Fig. 5).

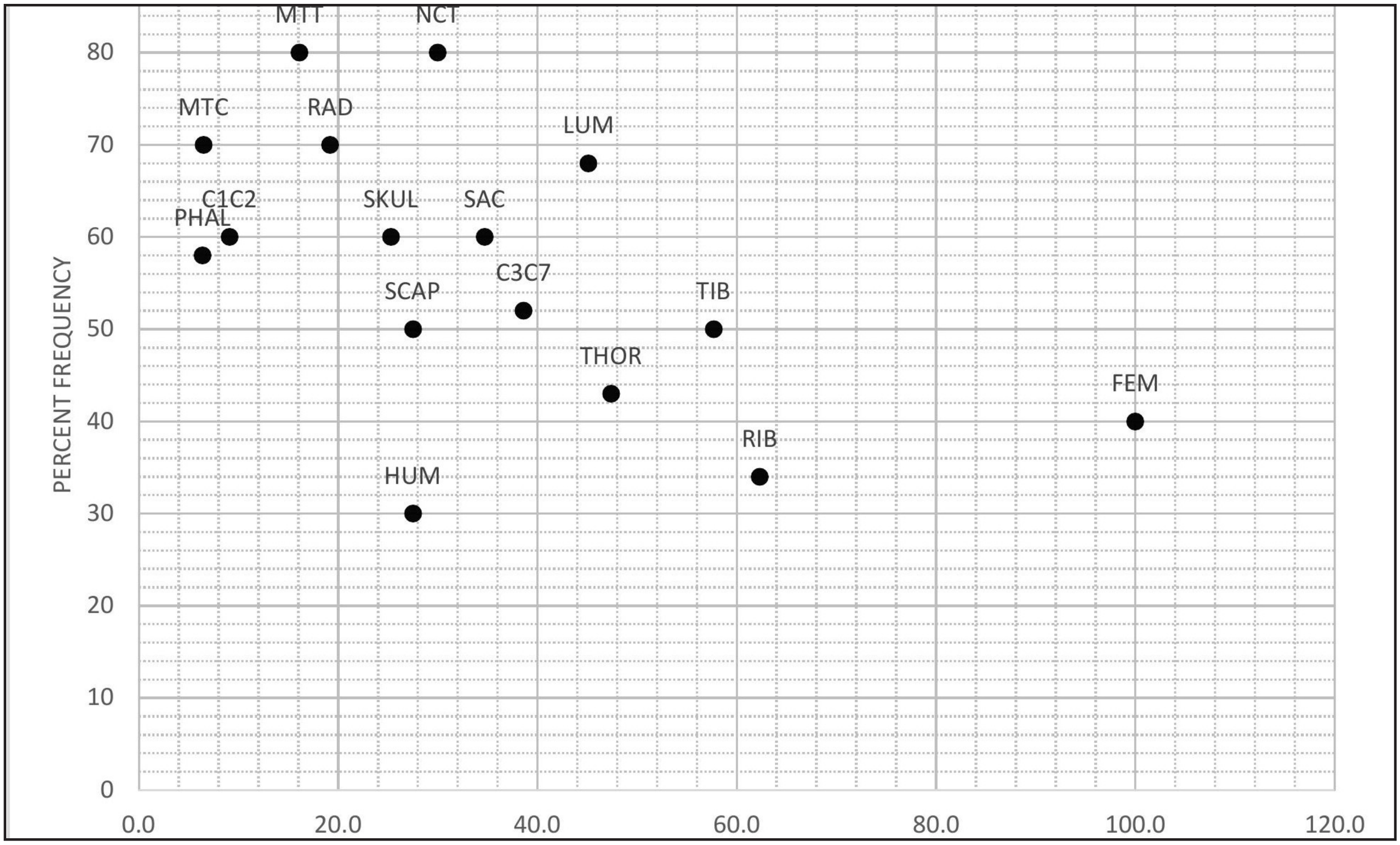

Fig. 4. Relation between proportional frequencies of skeletal elements and Food Utility Index (FUI) values of *Bison bison* for Big Bone Creek excavation, 2008. Refer to Table 2 for list of abbreviations.

At least four of the bifaces appear to be expedient tools, manufactured on-site for temporary use, with only minor primary flaking and sharpening. Three exhibit significant unknapped areas along a bifacial edge; these perhaps served as blunt areas that protected the user's hand during scraping or cutting. One artifact, a broken chert biface (CMC A70219) exhibits considerable wear and polish along flake scar edges. Whether or not hafted, these tools were undoubtedly used to cut and/or scrape. The several utilized or retouched (i.e.,

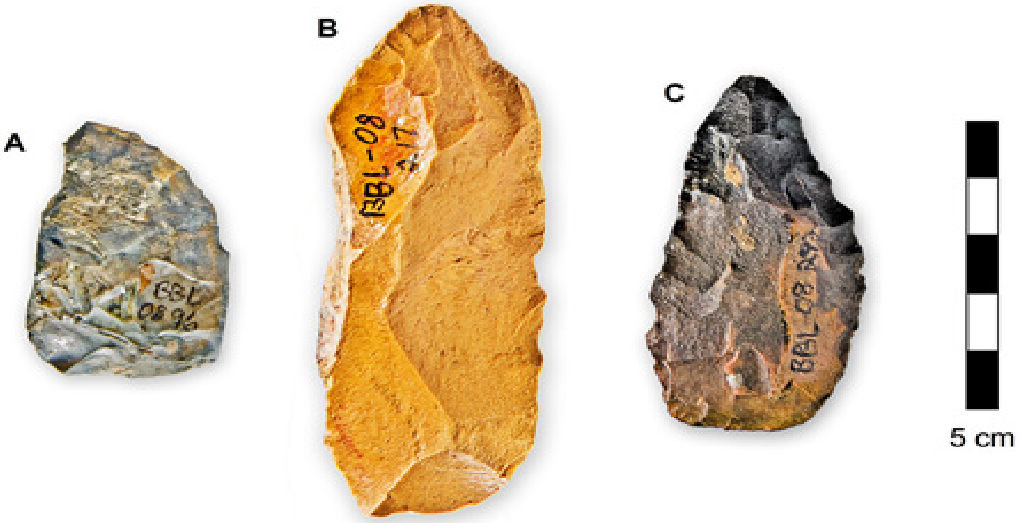

Fig. 5. Representative expedient butchering tools recovered during *Bison bison* excavation, Big Bone Creek, 2008. A – lithic biface, CMC A70218; B – lithic biface, CMC A70216; C – right tibia, CMC VP10856.

AXIAL SKELETON	
Skull (SKUL)	25.3
Cervical Vertebrae 1-2 (C1C2)	9.1
Cervical Vertebrae 3- 7 (C3C7)	38.6
Thoracic Vertebrae (THOR)	47.4
Ribs (RIB)	62.3
Lumbar Verebrae (LUM)	45.1
Sacrum-Pelvis (SAC)	34.7
FORELIMB	
Scapula (SCAP)	27.5
Humerus (HUM)	27.5
Radius-Ulna (RAD)	19.2
Metacarpal (MTC)	6.5
HINDLIMB	
Femur (FEM)	100.0
Tibia (TIB)	57.7
Non-Cuneiform Tarsals (NCT)	30.0
Metatarsal (MTT)	16.1
FOOT	
Phalanges (PHAL)	6.4

Table 2. Food Utility Index (FUI) values for bones of *Bison bison* from Emerson (1993). Higher values represent increased desirability of elements as a dietary resource.

new flake scars forming a steeper edge than previously present) flakes were also scraping tools. The large, quartzite hammer/chopper (CMC A70214) may have been used to break or smash bones, or perhaps shatter the skulls noted above. The ground bit of a stone adze (CMC A70221) shows extensive wear perpendicular to the bit, indicating that it was used for chopping. A probable hard-impact fracture removed a large segment of one face and probably broke this hafted tool just below the upper third of the bit.

At least three of the artifacts are made of Breathitt Chert, a Middle Pennsylvanian rock exposed in southeastern Kentucky, some 210 km from Big Bone Lick. One flake is Mississippian (Lower Carboniferous) Newman Chert, originating in east-central Kentucky more than 85 km from Big Bone Lick. However, all 13 chert artifacts exhibit either a water-worn or pebble cortex, indicating that their raw material was collected from secondary gravel deposits. The ancient Teays system and most of its major tributaries provide ample supplies of chert-bearing gravels, as does the Ohio River. The tops of the Big Bone Valley walls, the undissected preglacial land surface of the Lexington peneplain, are capped by alluvial sand and cobbles from the pre-Pleistocene Teays system. Many such clasts have made their way into Big Bone Creek, itself lying within Old Eagle Creek, a part of the drainage system of the Old Kentucky River, the largest tributary of the preglacial Teays River (Teller, 1973; Ray, 1974). The likely acquisition of raw material from local sources, and the crude nature of the tools suggest that butchering of *Bison* individuals here was a task that could be accomplished with a minimum of formal tools. None of the bifaces was destined for further reduction and they were, in essence, "finished" products to be discarded after use. Only the broken stone adze, albeit a tool most probably intended originally for woodworking, constitutes a late-stage finished artifact.

Radiocarbon determinations

Three radiocarbon dates have been generated from materials associated with the 2008 excavation of *Bison bison* at Big Bone Lick. The first (Beta Analytics lab no. Beta-257505) was derived from collagen extracted from a portion of *Bison* rib. Although sufficient collagen was extracted, a more negative $^{13}C/^{12}C$ ratio than would normally be expected suggests that the collagen may be somewhat depleted in carbon. Such negative ratios may indicate the presence of exogenous carbon compounds that can bias the age estimate towards a younger date. Their presence may be the result of centuries of contact with wet matrix or standing water, conditions now certainly prevailing at the site. At a 2-sigma calibration, the collagen dates to Cal CE 1660 to 1960 (Cal BP 280 to 0). Five intercepts with the calibration curve (the earliest at Cal CE 1690 [Cal BP 260]), spanning nearly three centuries, attest to the ambiguous nature of this radiocarbon estimate. It is likely that depleted carbon, possibly exogenous carbon, and documented fluctuations in modern carbon have contributed to the broad date range.

A second date (Beta-257506) was derived from non-carbonized wood recovered from the bone- and artifact-bearing conglomerate. Branch segments and leaves also were commonly recovered during the excavation, along with some nuts. At a 2-sigma calibration, the wood dates to Cal CE 1300 to 1440 (Cal BP 650-510). Unlike the collagen date, the wood date has a single intercept of radiocarbon age with the calibration curve of Cal CE 1410 (Cal BP 540). This approximates the dates for *Bison* bone occurrence reported by Tankersley (1986). A third date (Beta-259933) was derived from a single, non-carbonized hickory nut (*Carya* sp.). At a 2-sigma calibration, the nut fragment dates to Cal CE 1670 to 1780(Cal BP 280 to 160) and Cal CE 1790 to 1960 (Cal BP 160 to 0). The disparity of dates from the plants may be indicative of separate deposition of the botanical remains.

Negative archaeological evidence (i.e., the absence of confirmed *Bison* bones in faunal assemblages at most early (CE 1000-1200) and middle (CE 1200-1400/1450) regional Fort Ancient sites suggest that *Bison* were not present in this area prior to the onset of the Madisonville Phase (ca. CE 1400/1450-1650). Tankersley (1986) has previously identified a *Bison* kill with associated Fort Ancient artifacts in an embankment of Big Bone Lick Creek. A radiocarbon age determination of CE 1420 +/- 105 (UGa 4291) in calendar years was obtained. Although not significantly represented in archaeological faunal assemblages, *Bison* bones have been identified at two important Madisonville Phase sites, the Hahn Site, and the Madisonville Site itself. Two *Bison* bones, a thoracic vertebra and a calcaneum have been positively identified at the Hahn Site (43 km NE of Big Bone Lick in Newtown, Hamilton County, Ohio), both within trash-filled storage pits. The vertebra (CMC A60785) was radiocarbon dated to Cal CE 1283-1402 (Cal BP 667-548) (Robert Cook, personal communication). At the Madisonville Site (45 km NE of Big Bone Lick in Mariemont, Hamilton County, Ohio), a surprisingly large number of *Bison* artifacts, mostly beamers made from the neural spines of thoracic vertebrae, have been identified (Drooker, 1997, 2009), but none have been radiocarbon dated. Approximately 60-70 *Bison* bone beamers were recorded at the site, but only a small number of additional *Bison* artifacts or faunal elements were identified during the late 19th through early 20th century investigations conducted by Harvard University (Hooton and Willoughby, 1920). It should be noted that the Madisonville Site contains significant amounts of middle Fort Ancient material in addition to the Madisonville Phase debris making precise age determinations of *Bison* remains at the site problematic in the absence of absolute dates.

The radiocarbon dates clearly indicate that the *Bison* remains and artifacts recovered from the 2008 excavation are late precontact, protohistoric, or even early historic in a local cultural/temporal chronology, but they fail to overlap at two standard deviations, and only the wood date falls within the expected interval for interaction between modern bison and Native Americans. Both the wood date from the 2008 excavations and the Hahn date indicate that *Bison* were initially present in the greater Cincinnati area as early as the late 13th to the early 15th century, however the absence of *Bison* remains from typical local middle Fort Ancient sites suggests that the arrival of *Bison* may have been nearer the more recent end of the range. In any event, the *Bison* bonebed and associated artifacts from the 2008 excavation are attributable to the Fort Ancient Culture.

Conclusions

The 2008 Cincinnati Museum Center excavation of *Bison bison* remains and Native American artifacts at Big Bone Lick represents the first significant collection of new materials at the site in over two decades. The resulting analysis indicates the presence of a minimum of five *Bison* individuals in the excavated area. The recovered materials suggest an *in situ* kill and butchering site that may represent a model by which long-term accumulation of faunal remains at Big Bone Lick took place. Anecdotally, Pleistocene and other remains at the lick have been presumed to have accumulated as a result of individual animals having become mired in a salt spring or bog (Jillson, 1936; Hedeen, 2008). This is an untested hypothesis and is contraindicated by the general absence of carnivores in the preserved fauna. Carnivores were undoubtedly present and presumably would have been trapped too if miring was an active threat. We suggest that a more probable mechanism is that of Native American predation, although large carnivore predation and natural attrition may also have played a role. Many Big Bone Lick fossils originate from terrace deposits of 14,000 – 12,000 bp, when the valley floor salt springs would have been exposed. Paleoindians are now known to have been present in much of North America at least 14,500 years ago (Waters and Stafford, 2007; Waters, 2019; Becerra-Valdivia and Higham, 2020) and Big Bone Lick has produced Paleoindian spear points of late Pleistocene age (Tankersley and others, 2009). Possible cut marks have also been noted on mastodon bones found at the lick (Krasinski, 2010). In the case of Holocene *Bison bison* remains, the 2008 excavation, combined with the thousands of loose bones collected at the site in previous years, suggests coordinated hunts and mass kills. Although archaeological evidence of Native American visitation to the lick is available for all local cultures (Tankersley, 1985), the valley of Big Bone Creek is dominated by Paleoindian (Clovis) and Fort Ancient cultural artifacts (Tankersley, 1986, 1992), precisely coinciding with the two major episodes of megafaunal immigration – the Wisconsinan and the Ohio Valley protohistoric – and the largest accumulations of faunal remains at Big Bone Lick.

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The Pleistocene Fauna of Big Bone Lick, Boone County, Kentucky: A Rich History and Unanswered Questions

H. Gregory McDonald and Eric Scott

Abstract

Since the initial discovery of mastodons and other extinct animal remains at Big Bone Lick, Boone County, Kentucky, the site has figured prominently in our understanding of the Pleistocene fauna of North America. Ongoing research using new technology has refined our understanding of the fauna based on not only historically important specimens, many of which are holotypes, but the geological context from which they were recovered. This review not only provides an overview of the historical context for the discovery of the mammalian taxa but also places them within the context of current knowledge of their taxonomy, systematic relationships, and paleoecology.

Introduction

Despite the historical significance of the Pleistocene fauna from Big Bone Lick (Hedeen, 2008), there is unfortunately no single definitive study of the fauna or monographs on the individual taxa in the fauna such as has been published on the better-known contemporaneous Rancho La Brea fauna in California (Harris and Jefferson, 1985). For whatever reason, this lack of in-depth studies of the Big Bone fauna, probably contributed to the latest Pleistocene North American Land Mammal Age being termed the Rancholabrean, rather than the Bigbonelickian. The Rancholabrean is currently defined as starting with the first appearance of the genus *Bison* in North America south of 55° north latitude and ends with the extinction of the megafaunal species of the same region, ca. 150,000 to 10,000 years B.P. (Bell and others, 2004).

While specimens from Big Bone Lick have been included in numerous studies of different Pleistocene taxa over the years (Leidy, 1852a; 1855), the studies in themselves did not focus specifically on the fauna from Big Bone, so specimens from Big Bone often played only a supporting role rather than serving as the central focus. Whether it reflects the challenge of studying all available specimens from Big Bone Lick that over the years have been transferred to multiple widely dispersed institutions or because Big Bone Lick was so well known from a historical perspective that "everything was already known, so no new discoveries would be made" is difficult to determine. In any case, the definitive overview of the Pleistocene fauna at Big Bone Lick based on a comprehensive examination of all collections, the stratigraphic occurrence of the different taxa, and a complete chronology including more direct radiocarbon dates for many of the taxa and paleoecology of the site still waits to be done. Recent AMS radiocarbon dating has extended the age range of the bone-bearing deposits of Big Bone Lick based on the identification of three distinctive geomorphic surfaces and three stratigraphic units. The age of fauna from Big Bone Lick now extends back to the Last Glacial Maximum and date from 19,000–25,000 cal yr BP (T2, Unit 2), 12,000–14,000 cal yr BP (T3, Unit 3), and into the present to 5000 cal yr BP (T4, Unit 4) (Tankersley and others, 2015). This refined chronology will provide a firmer framework in which to better understand how the various taxa at Big Bone Lick responded to climatic and environmental change during the late Pleistocene and will help provide a better understanding of the historical collections as well as better context for future finds. It is hoped that the brief overview of the fauna provided here will stimulate additional research on this historically important but often neglected and understudied Pleistocene fauna.

Fauna

Megalonyx jeffersonii Harlan 1825 "Jefferson's Ground Sloth"

Jefferson's ground sloth was the first ground sloth found in North America and the second fossil sloth to be named. The type specimen of *Megalonyx jeffersonii* was found during saltpeter mining in a cave in West Virginia. The type specimen ANSP 12508 consists of the associated left ulna, radius, and portions of the manus including metacarpals two, three and five, the medial phalanx of the second digit, proximal and ungual of the third digit, medial and ungual phalanx of the fourth digit and the ungual of the first digit. The genus, *Megalonyx* or great claw was coined by

Fig.1. *Megalonyx jeffersonii*, right humerus (ANSP 12486)

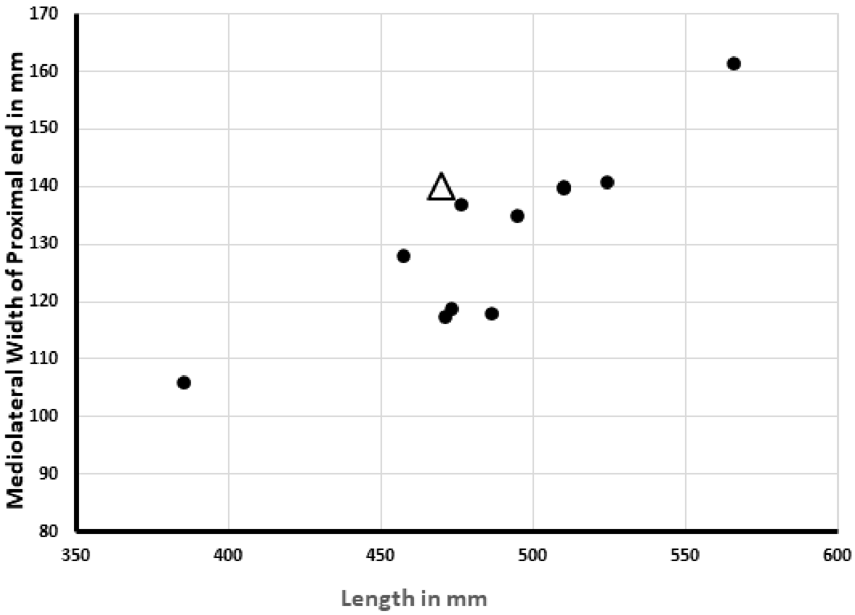

Fig.2. Scatter diagram of humerus of *Megalonyx jeffersonii* from Big Bone Lick (triangle) compared to other late Pleistocene individuals of the species.

Thomas Jefferson (1799) based on the large claws.

The specific name *jeffersonii* was proposed by Desmarest (1822) who considered it another species of *Megatherium*. Harlan (1825) was the first to use the binomen, *Megalonyx jeffersonii*. It was not known from Big Bone Lick until 1831 when a humerus (Fig. 1) was reported by Cooper (1831).

While ground sloths are a distinctive part of the North American fauna from the late Miocene until the end of the Pleistocene, the group originated in South America. Their presence in North America was the result of multiple dispersals by members of different lineages northward both before and after the formation of the Panamanian Isthmus joining North and South America (McDonald, 2005). *Megalonyx* is a member of the first lineage to disperse into North America. Following its establishment as part of the North American fauna it became widely distributed and by the Pleistocene was found as far north as the Yukon, south into Mexico and coast to coast (McDonald and others, 2000; Hoganson and McDonald, 2007).

Megalonyx provided the basis for the family Megalonychidae, a diverse group of sloths which also includes a variety of genera found only in the Caribbean. The family is characterized by the enlargement of the anteriormost tooth in both the skull and mandible into a caniniform separated from the cheek teeth (molariforms) by a prominent diastema. The form of the caniniform in megalonychids varies but in *Megalonyx* it is a prominent tusk-like structure in which the occlusal surface is at a right angle to the axis of the tooth allowing it to be used both to grasp and crush vegetation. The molariforms are generally triangular in cross-section with lophs on the mesial and distal edges of the upper and lower tooth that occluded to slice vegetation. The forelimbs were long and gracile. Members of the Megalonychidae including *Megalonyx* are distinguished from other sloths by the mediolateral expansion of the tuber calcis of the calcaneum and that the astragalus is unmodified and lacks the enlargement of the medial trochlea into an odontoid process seen in other sloths. It is inferred that that the hind foot was not rotated laterally as in other sloths. When compared with other Rancholabrean species of *Megalonyx* the single humerus (ANSP 12486) from Big Bone Lick falls into the middle of the size range of the species (Table 1, Fig. 2).

Megalonyx had the widest distribution of any of the North American sloths and has been inferred to have been primarily a forest-dweller. In those rare instances where it is found near open country it was probably associated with gallery forests along rivers. By inference it is thought to have been primarily a browser. Stable isotope data for sloths is limited but Kohn and others (2005) included *Megalonyx* in their analysis of the middle Irvingtonian Camelot fauna in South Carolina. The stable isotope analysis of the orthodentine of the sloth tooth gave a range of $\delta^{13}C$ of –13.13 to –13.30 with a mean of –13.22 + 0.07 and a range of $\delta^{18}O$ of 27.19 to 27.59 with a mean of 27.4 + 0.18 based on 7 samples. The samples were taken along the length of the tooth and the variation in values was attributed to seasonality. The low values for both carbon and oxygen in *Megalonyx* from the Camelot Site are consistent with its interpretations as a forest dweller and a browser. A single specimen (femur) of *M. jeffersonii* from the late Pleistocene (Rancholabrean) Saltville, Virginia, fauna had a $\delta^{13}C$ of −20.66, $\delta^{15}N$

of 4.65 and a C:N ratio of 3.08. These values placed *Megalonyx* in the same carbon and nitrogen isotope range as the other non-ruminants, in the fauna, *Equus*, *Mammut*, and *Mammuthus* (France and others, 2007).

There are no radiocarbon dates for the *Megalonyx* from Big Bone Lick. The youngest dates for the species include 11,235±40 rcy (UCIAMS-116401) (= 13,139 ± 91 cal yr) for the specimen from Millersburg, Ohio (McDonald and others, 2015); 11,450 ± 55rcy (=13,367 ± 125 cal yr) for a specimen from Newburgh, Orange County, New York (McDonald and others, 2019); 11,430 + 60 rcy (= 13,339 ± 133 cal yr) for the Lang Farm, Illinois specimen (Schubert and others, 2004) and 11,915 + 40 RCY for the Haven Site, North Dakota (Hoganson and McDonald, 2006). One specimen of *M. jeffersonii* from North Fairfield, Ohio dated at 11,740 + 35 rcy (= 13,623 ± 124 ca yr) has what are interpreted as cut marks on the anterior surface of a femur and is the only direct evidence of possible interaction between *Megaloynx* and humans (Redmond and others, 2012).

***Paramylodon harlani* (Owen 1840) “Harlan's Ground Sloth”**

Richard Harlan (1831) described a lower jaw from Big Bone which he referred to *Megalonyx laqueatus*, a species he had previously described from Big Bone Cave, Tennessee. The British paleontologist, Richard Owen, noted the resemblance of the dentition to *Mylodon darwini*, which he had described, based on a specimen collected by Charles Darwin in Argentina, and proposed the name, *Mylodon harlani*. Later Brown (1903) described *Paramylodon nebrascensis*, now considered a junior synonym of *harlani*, so the appropriate name for the late Pleistocene North American mylodont sloth is *Paramylodon harlani*. The North American species has been referred to the genus *Glossotherium*, but while the two genera are closely related, they are sufficiently distinct morphologically to be placed in different genera, reflecting their different evolutionary histories on separate continents (McAfee, 2009). The type specimen of *Paramylodon harlani*, a partial lower jaw, was deposited in the collections of the New York Lyceum of Natural History (the predecessor to the New York Academy of Sciences) but was lost when the collections were destroyed by a fire on May 21, 1866 (Fairchild, 1887). The type is illustrated in Leidy (1855) (Fig. 3a) and there are a few surviving plaster casts made from the type specimen in museums including the Academy of Natural Sciences of Drexel University in Philadelphia (ANSP 12538), National Museum of Natural History in Washington D.C., Cincinnati Museum Center (VP7495) in Ohio, and the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

The primary collection of *Paramylodon harlani* from Big Bone Lick was made during the excavations by the Nebraska State Museum in the 1960's and is housed there. This includes maxilla (UNSM 4385-63), braincase (UNSM 4386-63), left radius (UNSM 4262-64); right tibia (UNSM 4377-63), and right astragalus (UNSM 4404-63). A second tibia was later found at the park and is on exhibit there (KPS BBL 2017.10, Fig. 3b)

Paramylodon belongs to a group of sloths that dispersed into North America following the formation of the Isthmus of Panama. They are a member of the family Mylodontidae which is characterized by having lobate molariform teeth, although this may be reduced or lost in the anterior molariforms in advanced forms. Both the last upper and lower molariforms are bilobate and always present in all forms. The first upper tooth is often modified into a caniniform, and while it is

Fig.3. *Paramylodon harlani*, A. portion of right mandible, holotype, from Leidy, 1855. B. right tibia KPS BBL 2017.1.

present in Irvingtonian individuals of *Paramylodon*, by the Rancholabrean many individuals lack the upper caniniform, but the pattern of loss is variable and may include both or one on either side (Stock, 1925). The two families, Scelidotheriinae (restricted to South American) and Mylodontinae (represented by *Paramylodon* in North America) are distinguished by many characters such as parallel tooth rows in the former but anteriorly diverging tooth rows in the latter. The mandibular symphysis forms a well-developed spout that tends to be broad in comparison to other sloth families. While early mylodonts have an elevated mandibular condyle in later forms such as *Paramylodon* it is lower and at the level of the tooth row. While the scelidotheres retain an entepicondylar foramen on the humerus it is lost in the mylodontines. The skeleton is more robust than in other sloths with relatively shorter and stouter forearms. In the mylodontines the olecranon process of the ulna is more pronounced than in other sloths. All mylodonts have unguals that are semicircular in cross section. Both scelidotheres and mylodontines have a rotated hind foot so that the body weight is carried primarily by the fifth metatarsal and the calcaneum, but the overall morphology between the two families is distinctly different (McDonald, 2007).

The earliest records of the *Paramylodon* lineage in North America are from the early Blancan of Mexico and they reached the United States by the late Blancan ca. 2.5 Ma. Their distribution in North America is second only to that of *Megalonyx*, extending from south of the Canadian border into southern Mexico and coast to coast. They became extinct at the end of the Pleistocene but there are few published radiocarbon dates for the species.

The dentition of *Paramylodon* usually consists of five upper and four lower teeth with the posterior teeth lobate. The first upper tooth, when present, is modified into a caniniform but in late Pleistocene forms this tooth may be lost on either or both sides of the skull. This is one of the characters that distinguish *Paramylodon* from *Glossotherium* in which the upper caniniform is never lost. The occlusal surface of the molariforms is flat and the teeth lack the transverse lophs for slicing vegetation present in *Megalonyx*. The front limbs are shorter and stouter than in *Megalonyx* and the humerus lacks an entepicondylar foramen. The claws are semicircular in cross section. One distinctive character of *Paramylodon*, also found in related genera, is the presence of dermal ossicles in the skin. These have been recovered at many other sites but have not yet been reported from Big Bone, possibly reflecting the focus on the recovery of larger bones and general lack of screen washing during previous excavations.

Paramylodon is the more common of the two sloths found at Big Bone Lick. Comparison of the size of the post-cranial skeleton of individuals from Big Bone Lick

MEASUREMENT	**UNSM 4262-64 Big Bone Lick, Boone Co. KY**	**IMNH 32535 American Falls Reservoir, Power Co. ID**	**MNA V 1374 Springerville, Apache Co. AZ**	**LACM HC 1713.R.7 Rancho La Brea, Los Angeles, CA**
Length between articular surfaces	256.1	226.8	230.6	237.9
Length from proximal end to tip styloid process	317	281.4	282.2	289
Anteroposterior width of distal end	123	111.6	118.3	108.5
Mediolateral width of distal end	-	86.8	86.3	82.3
Anteroposterior length of proximal end	83.2	73.3	78.8	73.9
Mediolateral width of proximal end	61.5	58.2	61.3	57.6

Table 2. Measurements in mm of the radius of *Paramylodon harlani*. UNSM – Nebraska State Museum, Lincoln; IMNH - Idaho Museum of Natural History, Pocatello; Museum of Northern Arizona, Flagstaff; LACM HC – La Brea Tar Pits and Museum, Los Angeles

MEASUREMENT	**UNSM 4262-64 Big Bone Lick, Boone Co. KY**	**KSP BBL 2007.1 Big Bone Lick, Boone Co. KY**	**IMNH 32535 American Falls Reservoir, Power Co. ID**	**MNA V 1374 Springerville, Apache Co. AZ**	**LACM HC 1713.R.7 Rancho La Brea, Los Angeles, CA**	**TMM 30967-264 Ingleside, San Patricio Co. TX**
Length	276.7	247.5	247.7	219.4	231.8	217.7
Mediolateral width proximal end	200.8	190.5	195.2	179.1	179.9	177.5
Anteroposterior length proximal end	124.2	120	129.6	107.8	116.1	109.8
Mediolateral width of distal end	152.2	139.4	150.2	140.2	137.6	131.9
Anteroposterior length distal end	85.5	113.4	108.2	101.5	112.7	98.9

Table 3. Measurements (mm) of tibia of *Paramylodon harlani*. UNSM – Nebraska State Museum, Lincoln; IMNH - Idaho Museum of Natural History, Pocatello; KSP – Kentucky State Parks; Museum of Northern Arizona, Flagstaff; LACM HC – La Brea Tar Pits and Museum, Los Angeles; TMM – Texas Vertebrate Paleontology Collection, Jackson School Museum of Earth History, Austin

to other members of the species indicates they are at the large end of the species size range (Table 2, 3, Fig. 4). Interpreted as either a grazer or at least a mixed feeder (Naples, 1989) its presence along with bison, horse and mammoth suggests open grassland habitat. Analysis of stable isotopes of *Paramylodon* from Rancho La Brea by Coltrain and others (2004) indicates that the time-averaged $\delta^{15}N$ values are more positive than the equids or "true" nonruminants, but it did not sort with the ruminants, suggesting that *Paramylodon* was not as well suited as ruminants to high cellulose diets. Like the living sloths it may have compensated for this deficiency by retaining ingesta within its gut for as long as a week, defecating weekly rather than daily or several times a day as is common to other herbivores. The slow movement of ingesta through the digestive tract in modern sloths reflects their extremely low rates of basal metabolism. The stomachs of living sloths are also very large, and may remain full or near full, even after fasting several days. Cork (1994) considered modern sloths "foregut fermenting nonruminant mammals", and this description is probably also appropriately applied to their extinct relatives as well.

Tankersley and others (2015) reported *Megalonyx jeffersonii* from Unit 3 which is dated at 14,230 to 11,630 cal yr BP. They cite Levin and others (1965) on samples of wood collected by the Nebraska State Museum in 1963 and submitted by F. C. Whitmore.

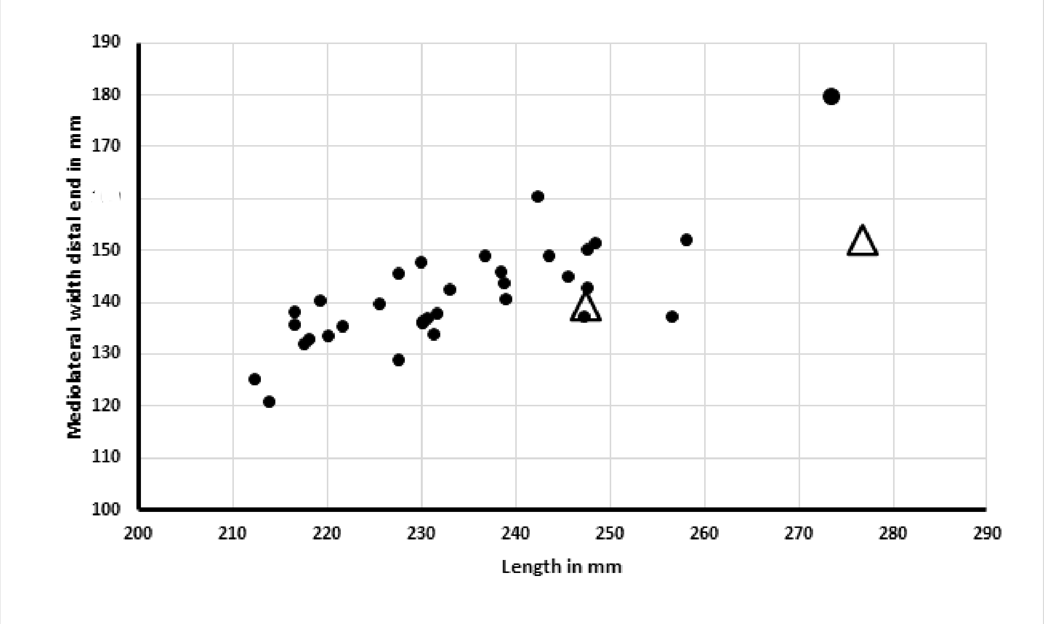

Fig. 4. Scatter diagram of tibia of *Paramylodon harlani* from Big Bone Lick (triangle) compared to other late Pleistocene individuals of the species.

The following extinct taxa were reported by Levin and others (1965) from the same level as the wood, *Equus* cf. *E. complicatus*, *Mammut americanus*, and *Mammuthus sp.* along with the sloth, *Mylodon* sp. *Mylodon* is the same taxon as what is now called *Paramylodon*. While the University of Nebraska excavations recovered multiple specimens of *Paramylodon*, no specimens of *Megalonyx* were recovered so this record is erroneous and the sloth from Unit 3 is *Paramylodon harlani*. There are only a few radiocarbon dates for *Paramylodon*. The youngest is 12,315 ± 35 rcy (= 14458 ± 330 cal yr) for a specimen from Hillsboro, Washington County, Oregon (Gilmour and others, 2015). Tankersley and others (2015) do not include *Paramylodon* in Table 4 of their paper but in addition to being present in Unit 3 *Paramylodon* could potentially be in the older units 2 and 1 at Big Bone Lick as well.

Mammut americanum Kerr 1792 "American Mastodon"

The better-known popular name for this animal, mastodon was coined by the French comparative anatomist and paleontologist, Georges Cuvier, and means breast-tooth in reference to the distinctive sets of paired cusps on the occlusal surface. Teeth and tusks of mastodons found at Big Bone Lick have the distinction of being among the first fossil vertebrate remains collected in the New World and sent back to European scholars for study. Charles Le Moyne, Second Baron de Longueuil, (1687 - 1755) collected the "grinders", to use a term popular at the time, and bones of mastodon from Big Bone Lick during his trip of 1739 down the Ohio River from Montreal to New Orleans. Sailing from New Orleans to Paris he deposited a femur, tusk and three molar teeth in the Cabinet du Roi, located in the king's botanical garden, the Jardin du Roi (now Jardin des Plantes) and the predecessor to the Museum national d'Histoire naturelle (MNHN). The teeth, a femur and tusk were described in detail by Daubenton (1764a,b,c) as belonging to an elephant. These specimens were later studied by Cuvier and all except for the tusk are still preserved in the Museum national d'Histoire naturelle, Paris (Tassey, 2002).

Osborn (1936) in Volume 1 of his monograph on the Proboscidea, in the chapter on a Historical Review of the Discovery of the Genus Mastodon (1705-1935) and of the Species *Mastodon americanus* (1792-1869) states that succeeding Buffon's description (1778) of the American Mastodon but anticipating Cuvier's description of Le Grand Mastodonte, 1806, the Scottish naturalist Robert Kerr proposed the scientific name *Elephas americanus* for tusks and grinders found in the 'Big-bone-swamp' on the banks of the Ohio. This contribution appears in a translation of portions of a recent edition of the "Systema Naturae" of Linnaeus, with improvements by Professor Gmelin, entitled, "The Animal Kingdom or Zoological System, of the Celebrated Sir Charles Linnaeus," published in 1792. His description is as follows:

> "2. American Elephant.—*Elephas americanus*. In America, on the banks of the Ohio, are found, several feet below the surface, in a marshy place called Big-bone-swamp, great numbers of tusks and grinders, supposed by many to belong to the Elephant: But the grinders are totally different, being covered uniformly with enamel, and furnished with a double row of high conic processes, like those of carnivorous animals; whereas those of the Elephant are composed of alternate perpendicular layers of bone and enamel, and are ribbed transversely on their upper surfaces, like those of graminivorous quadrupeds: Hence the species must be entirely different; and Mr. Pennant has chosen to suppose that they have belonged to an unknown species of this genus, which he names the American Elephant" (Kerr, 1792:116).

Kerr did not designate a type specimen at the time the name was proposed. The identification of a type specimen (lectotype) seems to reside with choices made by Buffon (1778) who figured a molar from Big Bone Lick, Kentucky, near the Ohio River, sent to him by P. Collinson. The tooth is a third upper molar of what appears to be the left side, is still preserved in the Muséum national d'Histoire naturelle and was included in the paper by Tassy (2002).

The earliest figure of a mastodon tooth, a lower third molar (MNHN 1643) figured and described by Guettard in 1756 was selected as the lectotype of *Mammut americanum* by Tassy (2002). The m3 is nearly certainly from Big Bone Lick, as Guettard, who described the specimen, wrote in his 1756 paper that the tooth came from the place marked on the map. The map he is speaking about is the first map of Louisiana made by Jacques-Nicolas Bellin (published in 1744). On this map Bellin reported the locality as: "endroit ou on a trouve des os d'elephant" based on Chaussegros de Lery's map of Longueuil's expedition, this locale is Big Bone Lick (Tassy pers. comm. 2009). The preservation of the specimen illustrated by Guettard is identical to that of the other specimens found by Longueuil. The question seems not to be from what locality did it originate, but whether the tooth does belong to Longueuil's collection, or not? Guettard did not state explicitly that the tooth was part of Longueuil's collection. The question is why? This question is being addressed in P. Tassy's forthcoming book "L'invention du mastodonte". His idea is that since the official collection belonged to the Cabinet du Roi, which was under Buffon and Daubenton's supervision, while Guettard was in charge of the Cabinet du Duc d'Orléans, the intense rivalry that existed between the King and his cousin may have prevented access by Guettard to the royal collection. Perhaps Guettard examined the tooth without either Buffon or Daubenton's approval. Why Guettard was parsimonious with any explanation as to the origin of this tooth and why Buffon and Daubenton never said a word on it remains a mystery. (Tassy, pers. comm. 2009).

While there is some speculation that this specimen may be part of the Longueuil collection, in all likelihood the type (or lectotype) of the American Mastodon, *Mammut americanum*, did come from Big Bone Lick. Subsequently, all additional specimens of mastodon from Big Bone collected by various expeditions over the years, including the Clark expedition sponsored by Thomas Jefferson, sent to other museums may be considered topotypic material.

Hays (1834) described *Tetracaulodon collinsii* based on a right mandibular ramus with one molar (ANSP 13101) from Big Bone Lick. While the history of the specimen is spotty, it appears that the specimen may have been part of the Jefferson collection (Spamer and others, 1995). While the animal closely resembled *Mammut americanum* in most of its characters, it was distinguished by possessing tusks in the lower jaw. This difference was originally documented by Godman (1830) who thought the presence of the lower tusks was of sufficient importance to constitute a new genus, *Tetracaulodon mastodontoideum*. Multiple subsequent discoveries have shown that lower tusks are common in *Mammut americanum* and it has been inferred that they are present only in males (Barbour, 1931).

Unlike mammoths, mastodons have no close living relatives. The teeth of the mastodon can be readily distinguished from mammoths by the low crown with the prominent paired cusps, and well developed roots (Fig. 5a,b). King and Saunders (1984) noted two morphologies in the teeth of the American mastodon. One is a smooth morphology distinguished

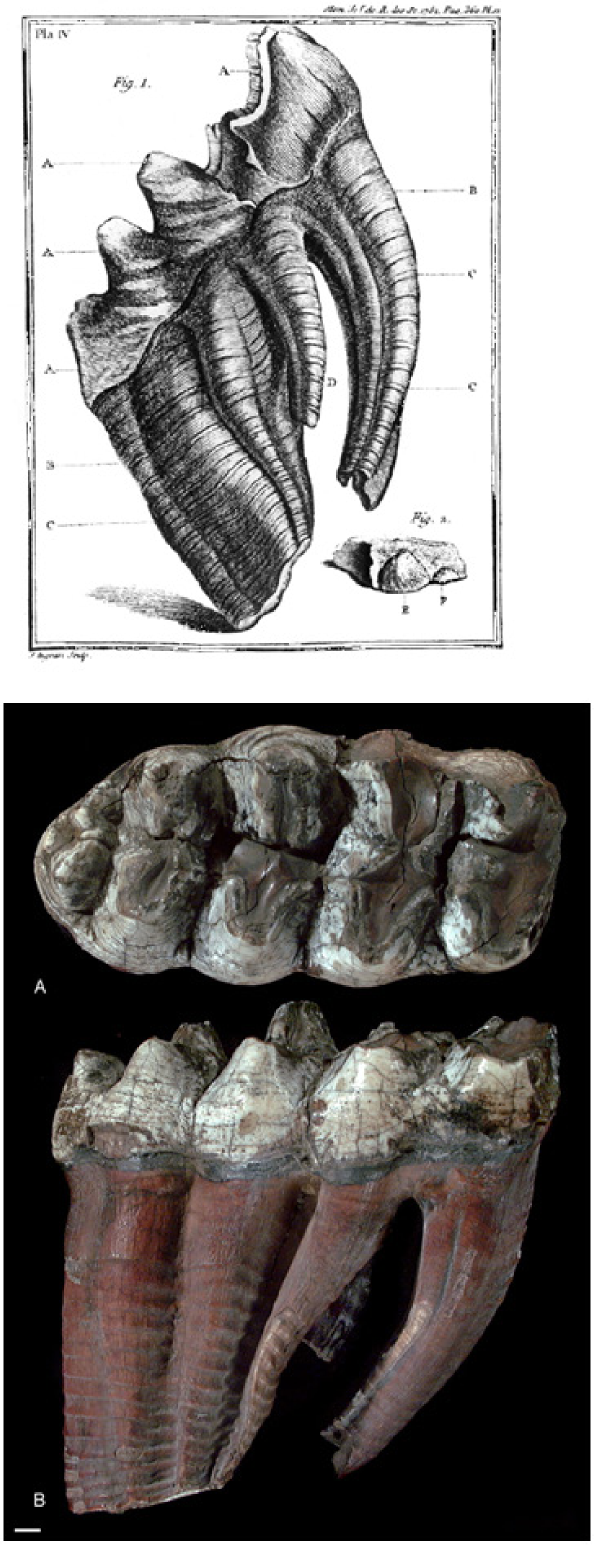

Fig. 5. *Mammut americanum*, right lower third molar, Lectotype (MNHN 1643), A. drawing of specimen from Guettard (1756), B. photograph of specimen in lateral view. After Tassy, 2002.

by transverse valleys uninterrupted except by weak or moderate cristae descending from the faces of the primary cusps, with smooth enamel and weakly developed cingula and a "rugged" morphology in which the transverse valleys are interrupted by the juncture of moderately to strongly developed cristae and the walls of the valleys along with the labial and lingual surfaces of the crown bear strong placations so the surface has numerous vertical corrugations of the enamel. The "smooth" morph is indicative of mastodons associated with a spruce dominated environment and the "rugged" morph of individuals living in open pine-parkland. In some individuals there may be a pair of vestigial mandibular tusks.

Like mammoths and living elephants, a mastodon's tooth series consisted of six teeth in each quadrant of the jaw, which erupted in sequential order. The first three teeth were relatively small and lost early while the last three teeth were considerably larger and were retained for a longer interval of time before being shed. Differences in the morphology of the first three "deciduous" teeth and the later "permanent" teeth resulted in an incorrect identification and the suggestion that tapirs were present in the fauna from Big Bone Lick. Harlan (1825) described *Tapirus mastodontoides* (ANSP 13261) based on an isolated tooth from Big Bone Lick (Fig. 6a,b). Subsequent examination of the specimen by Cooper (1831) and Hays (1834) identified the tooth as the first milk molar of a mastodon (the deciduous second premolar in modern terminology). Unfortunately, although corrected early, this error in identification has often been repeated in subsequent literature and includes tapir in the Big Bone fauna. This error was corrected again recently by Ray and Sanders (1984).

Mastodons were more heavily built than mammoths, and their limb bones are noticeably shorter and thicker (Fig. 7). In comparison to the living Asiatic elephant, mastodons had a deeper chest, broader pelvis, shorter legs, and a longer back. Height at the shoulder was between 2.7 and 3.0 m, and the total length of the body was about 4.5 m; females are noticeably smaller than males.

Fig. 6. *Mammut americanum*, deciduous second premolar, holotype of *Tapirus mastodontoides* (ANSP 13261) A. occlusal view, B. lateral view.

Despite the large amount of mastodon skeletal remains recovered from Big Bone, there is no record that any complete skeleton of a single individual was ever recovered. That only single isolated bones and tusks have been collected may simply reflect the lack of any systematic excavations by early workers or simply the taphonomy of the site in which skeletons became disarticulated. While there are numerous mounted skeletons of mastodons in museums in the United States, none are based on material from Big Bone.Mastodon from Big Bone Lick has not yet been examined to see if aDNA is present in the specimens. A study of mastodon genetics by Karpinski and others (2020) identified five well supported major clades based on mitogenomic phylogeny. The five clades are identifed by the approximate geographic provenance of their constituent specimens (i.e., A Alaska, Y Yukon, G Great Lakes, M Mexico, L Alberta/ Missouri). Based on geography it is most likely the mastodon from Big Bone Lick falls within the Great Lakes clade (Clade G) as it is between two specimens from Virginia and those from Ohio and Illinois.

Fig. 7. Femur of *Mammut americanum* from Big Bone Lick on display at the Museum national d' Histoire naturelle, Paris.

True mastodons, as distinguished from gomphotheres, entered North America from Eurasia in the Blancan and survived until the end of the Rancholabrean. Mastodon is one of the few taxa from Big Bone that have been directly dated. Accelerator Mass Spectrometry (AMS) dates based on collagen from mastodon bone of 12,210 ± 35 RCY and 11,700 ± 35 have been described by Tankersley and others (2009). While the radiocarbon evidence indicates that mastodons and Clovis people overlapped in time and Clovis points have been found at Big Bone that are physically associated with, but dispersed within the bone- bearing deposits, other than two fossils with possible cut marks there is no incontrovertible evidence that humans hunted *Mammut americanum* at the site. Carbon isotope values of proboscidean bone collagen and *Mammut americanum* enamel from Unit 2 of Tankersley and others (2015) are indicative of a C3-dominated diet, possibly consisting of coniferous twigs and herbaceous vegetation. Radiocarbon ages obtained from Unit 2 range from 19,380 to 25,520 cal yr BP so fall with the Last Glacial Maximum. During this time, the greatest volume of meltwater and outwash from the Laurentide ice sheet was channeled into the Ohio River. Mastodon remains have also been recovered from Unit 3 which represents vertical and lateral accretion of alluvial sediments. The mastodon in Unit 3 consists of disarticulated yet complete bones which are found along with heavily mineralized broken and abraded large mammal bones (Tankersley, 2009; Tankersley and others, 2009). Radiocarbon ages for Unit 3 range from 14,230 to 11,630 cal yr BP. Like the proboscideans from Unit 2, $\delta^{13}C$ and $\delta^{15}N$ values obtained from *Mammut americanum* bone collagen from Unit 3 are consistent with mastodons browsing on a wide range of resources in a mosaic environment dominated by C3 vegetation.

Mammuthus columbi (Falconer, 1857) "Columbian Mammoth"

Mammuthus columbi was proposed by Falconer (1857) based on a fragmentary tooth (upper third molar) found in the Brunswick Canal, near Darien, Georgia. A year later, Leidy described a fragmentary, poorly preserved upper third molar from the Loup Fork, Niobrara River, Nebraska, as *Elephas imperator*. Unfortunately, the holotypes of both species are inadequate for specific diagnosis and several authors including Falconer (1863), Osborn (1922) and Maglio (1973) have considered the holotypes of *Mammuthus columbi* and *Mammuthus imperator* to be indistinguishable. Both names have been used interchangeably in the literature for both the earlier intermediate mammoth (*Mammuthus imperator*) and the more progressive late Rancholabrean form (*Mammuthus columbi*). Osborn (1922) suggested calling the more advanced species *Mammuthus jeffersonii* and restricting *Mammuthus columbi* to the late middle Pleistocene mammoth. Currently both *M. jeffersonii* and *M. columbi* along with *M. primigenius* are recognized as late Pleistocene forms present in North America, with *M. jeffersonii* used for forms found near the upper Great Lakes. The two species are distinguished by the number and thickness of enamel plates. *M. jeffersonii* has more and thinner plates that resemble *M. primigenius* while in *M. columbi* there are fewer plates, and the enamel is thicker. The name *M. columbi* has usually been applied to most of the mammoths found outside of the Great Lakes region in the western United States and the southeast. While there are reports of the woolly mammoth being present at Big Bone, this is unlikely, and all mammoth remains so far recovered seem to be attributable to the Columbian mammoth.

Mammoth teeth are easily distinguished from mastodon teeth. They consist of a series of vertically-oriented flattened plates of enamel with surrounding layers of dentine (Fig. 8a,b). As the enamel is more resistant to wear during mastication than the dentine or cementum, it forms a raised surface which aids in breaking down grasses and other vegetation during chewing. Each quadrant of the jaw has six teeth, which erupt in sequential order during the life of the animal, with each successive tooth containing a greater number of plates resulting in an overall larger tooth. One of the evolutionary trends in mammoths is to increase the number of plates in each tooth with earlier species having fewer plates but with thicker enamel and later forms having more plates but with thinner enamel. Based on the tooth morphology mammoths have been considered grazers and stable isotope studies of mammoth tooth enamel of *M. columbi* in Florida (Koch and others, 1998) indicates they consumed primarily C4 grasses.

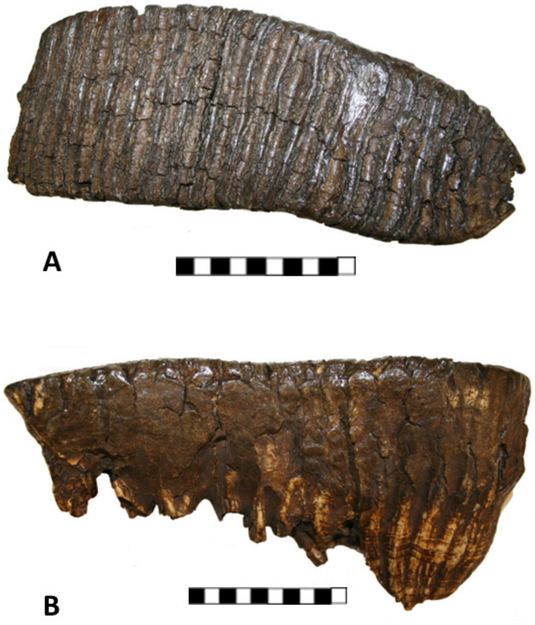

Fig. 8. *Mammuthus columbi*, molar in A. occlusal view B. lateral view.

The Columbian mammoth stood between 3.6 and 4.0 m at the shoulder and is the largest species of American mammoths. The largest individual is a specimen found in Lincoln County, Nebraska with an estimated shoulder height of 3.97 m. The cranium is distinguished from the mastodon by its high and broad profile with a deep, short rostrum. The massive mandible has a rounded symphysis, and the upper border of the coronoid process extends above the grinding surface of the molars.The first appearance of mammoths in North America was used to define the beginning of the Irvingtonian North American Land Mammal Age as conceived by Savage (1951) and terminated with the appearance of *Bison*.

Bootherium bombifrons **(Harlan, 1825) "Woodland Muskox or Helmet-headed Muskox"**

The type specimen (ANSP 12994) (Fig. 9) consists of the posterior part of a skull with both horn cores. It was collected by William and George Rogers Clark in 1807 on an expedition to Big Bone Lick financed by Thomas Jefferson to make a collection for the American Philosophical Society. General Clark employed 10 laborers for several weeks at Big Bone Lick and shipped the specimens back to Washington in three large boxes via New Orleans. This specimen was among the many fossils studied by Caspar Wistar with Jefferson when the specimens were housed in the East Room of the White House during Jefferson's presidency. The original collection was later subdivided into three smaller collections by Jefferson who presented them to the Academy of Natural Science, Philadelphia (ANSP) and the Museum national d'Histoire naturelle (MNHN) in Paris and retained some specimens for himself. The first two parts of the collection still survive in their respective institutions, but unfortunately most of the Jefferson portion was lost after his death although a mandible of a mastodon and a mammoth on loan from the University of Virginia are on loan for display in the foyer of Monticello.

While the species was originally assigned to *Bos* by Wistar the species name was proposed by Harlan (1825) also as *Bos bombifrons*. Subsequently Leidy (1852b) erected the genus *Bootherium* and included two species, *B. bombifrons* and *B. cavifrons*, with the specimen from Big Bone used as the type for *B. bombifrons*. For many years the two species were placed in separate genera, *Bootherium bombifrons* and *Symbos cavifrons*. Recent studies of the North American fossil muskox have indicated that *Bootherium bombifrons* and *Symbos*

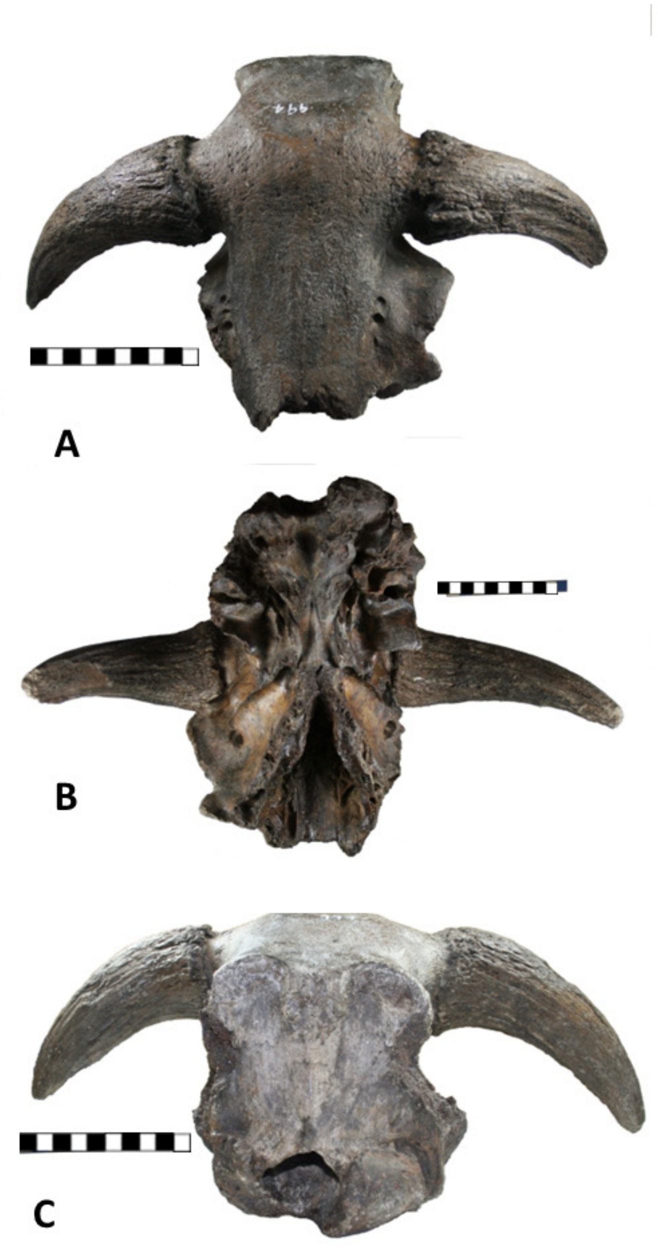

Fig. 9. *Bootherium bombifrons*, holotype, braincase (ANSP 12994) in A. dorsal view, B. ventral view, C. posterior view.

cavifrons are respectively the female and male of the same species, with *Bootherium bombifrons* being the senior name (J. McDonald and Ray, 1989). Both skull morphs have been found at Big Bone Lick and it is one of the few localities in which the two have been found together. The extraction of mitrochondrial DNA from both skull morphs by Bover and others (2018) provided independent confirmation that the two morphs represented males and females of the same species.

Bootherium was taller, more long-legged and of a slenderer build then the living muskox, *Ovibos*. Diagnostic of the horn cores of the male of *Bootherium* is the rugose and pitted surface (exostosis) between the horn cores which in the males of *Bootherium* have grown together to form a solid structure, hence one of the common names, Helmet-headed muskox. In *Ovibos* there is a distinct groove that separates the two horn cores. In the females of *Bootherium* the bases of the horn cores are widely separated and do not form the solid exostosis (Fig. 9a,b,c). The orbits of *Bootherium* do not protrude as far from the skull as in *Ovibos* suggesting a less dense covering of hair.

Bootherium bombifrons probably inhabited both plains and woodland habitat and was adapted to warmer conditions than *Ovibos moschatus*, the extant muskox. Epidermal analysis from plants extracted from the infundibula of the teeth of the Helmet-headed Muskox from Alaska included woody plant bark, *Vaccinium*, *Salix* and *Agropyron*-like, *Bromus*-like and *Poa*-like grasses (Guthrie, 1991).

The monotypic genus *Bootherium* ranges stratigraphically from the Late Irvingtonian to the end of the Wisconsinan and geographically from Alaska south to Mississippi and from the Pacific to the Atlantic coasts. Late radiocarbon dates for *Bootherium* include 10,980 + 90 for St. Mary's Reservoir, Alberta (Hills and others, 1999), 11,100 + 400 rcy for Scotts, Michigan (Semken and others, 1964), and 11,770 + 190 rcy for Monroc Kearns Gravel Pit, Utah (Nelson and Madsen, 1980).

Bison antiquus Leidy, 1852 "Ancient Bison"

The holotype of *Bison antiquus* (ANSP 12990) consists of a fragment of the posterior part of the skull with the left horn core minus its tip attached (Fig. 10a,b). This specimen, along with that of *Bootherium*, was recovered by the Clark expedition to Big Bone and first described by Wistar (1818). The species name *antiquus* was subsequently proposed by Leidy (1852).

Both this extinct species of bison and the modern species, *Bison bison*, are found at Big Bone. Remains attributable to the living species are much more common and few if any additional specimens of *B. antiquus* have been recovered or described from the site besides the holotype.

Bison antiquus is the direct ancestor to the living *Bison bison* and the evolutionary transition from one to the other is well documented with numerous samples containing intermediate forms (J. McDonald, 1981). Some researchers (Wilson, 1969) have proposed that a more appropriate taxonomy would be to include it as a subspecies of the living bison as *Bison bison antiquus*. Remains of *Bison antiquus* have been recovered from

Fig. 10. *Bison antiquus*, holotype, (ANSP 12990) braincase with left horn core in A. posterior view, B. dorsal view.

sites across North America. This has included numerous archeological sites associated with the Folsom culture of Paleoindians which actively hunted this species. A recent excavation of butchered bison at Big Bone Lick by Cincinnati Museum Center (see Storrs and others this volume) indicates that these were specimens of the morphologically modern species and not *B. antiquus*.

Bison originated in Eurasia and dispersed into North America from Asia via the Bering Land Bridge. Its first appearance in North America is used to define the Rancholabrean North American Land Mammal Age. As noted by Bell and others (2004) most attempts to establish a reliable date for the arrival of the genus *Bison* in North America have met with limited success, relying on circular reasoning and have suffered from fragmentary material resulting in dubious identifications, unclear stratigraphic position of the specimen or unsatisfactory chronologic control. Based on genomic data Froese and others (2017) identified two waves of *Bison* dispersal into North America. The first occurred between 195–135 thousand years ago and the second during the late Pleistocene, ~45–21 thousand years ago. After the first dispersal event bison quickly colonized much of North America and rapidly diversified phenotypically, including the giant long-horned morphotype *Bison latifrons* which is best known from faunas of the last interglacial, the Sangamonian.

Bison bison (Linnaeus, 1758) "Living North American Bison"

While the historical records indicate that mastodon was the most commonly found species at Big Bone Lick in the past, that is no longer the case and undoubtedly the most commonly encountered remains found at Big Bone today are of modern bison. Use of the salt licks by eastern populations of bison is well documented and undoubtedly strongly influenced Lyell's (1845) interpretations of the mode of entrapment and preservation for the Pleistocene fauna. Many early maps of the area show bison trails or "traces" converging at Big Bone Lick (Jakle, 1968). Despite the large sample available at multiple museums there has been no detailed study of the modern bison from the site. The decrease in body size of bison from about 11,000 to 5,000-4,000 B.P has been documented (J. McDonald, 1981). While the living *Bison bison* is the smallest of all North American bison, it has been observed that both the male and female *Bison bison* found at Big Bone are slightly smaller than their Great Plains counterparts based on comparative measurements of the metacarpals and crania (Widga, 2006). J. McDonald (1981:99) included five individuals (3 males, 2 females) of *Bison* from Big Bone Lick in his list of specimens referred to *Bison bison bison* and concluded that the Holocene bison found at Big Bone Lick were an eastern extension of the Plains Bison population and not a member of the Wood Bison population. A morphometric study comparing the bison from Big Bone Lick with individuals from the Great Plains suggests that the eastern *B. bison* sample at Big Bone Lick differed from Great Plains populations primarily in developmental timing and diet.

Bison bison is restricted to Holocene deposits. The oldest sediments from late Holocene Unit 4 were dated utilizing multiple approaches. These include a conventional β-decay radiocarbon age of 4820– 4440 cal yr BP, an AMS radiocarbon age of 4830–4580 cal yr BP, and two OSL ages of 5.2 ± 0.1 ka and 5.1 ± 0.1 ka. The dates for the most recent sediments from Unit 4 were dated with an AMS and yielded a radiocarbon age of 480– 300 cal yr BP and an OSL age of 0.4 ± 0.01 ka. (Tankersley and others 2015)

Cervalces scotti Lydekker, 1898 "Elk-moose"

The elk-moose, *Cervalces scotti*, was another specimen collected during the Clark expedition to Big Bone and originally described by Wistar although he did not propose a formal binomial. There is a convoluted history to the names applied to the Big Bone Lick specimen. Harlan (1825) called it *Cervus americanus*, a preoccupied name used by Erxleben in 1777 for the North American wapiti, also known as *Cervus canadensis* and sometimes synonymized with *Cervus elaphus*. Harlan's description includes not only the skull described by Wistar but also fragments of jaws and isolated molars collected from Big Bone Lick by Major S.H. Long in 1824. The skull (ANSP 11572) (Fig. 11a,b,c) described by Wistar was selected as the lectotype of *Cervalces scotti* from this syntypic series (Spamer and others, 1995). The currently accepted name, *Cervalces scotti*, was proposed by Lydekker (1898) to replace *Cervalces americanus* used by Scott (1885). A related species, *Cervalces latifrons*, which is best known from early middle Pleistocene sites in central Europe, has also been described from Alaska. Azzaroli (1981) noted the similar skull morphology of the ancestral *Alces gallicus* of Europe with that of *A. latifrons* and *A. scotti* and placed them all in *Cervalces*. Lister (1993) in contrast included all of these species in *Alces*, based on the presence of palmate antlers and other criteria. He considered *Cervalces scotti*, his *Alces scotti*, to be an endemic offshoot of *Alces latifrons*.

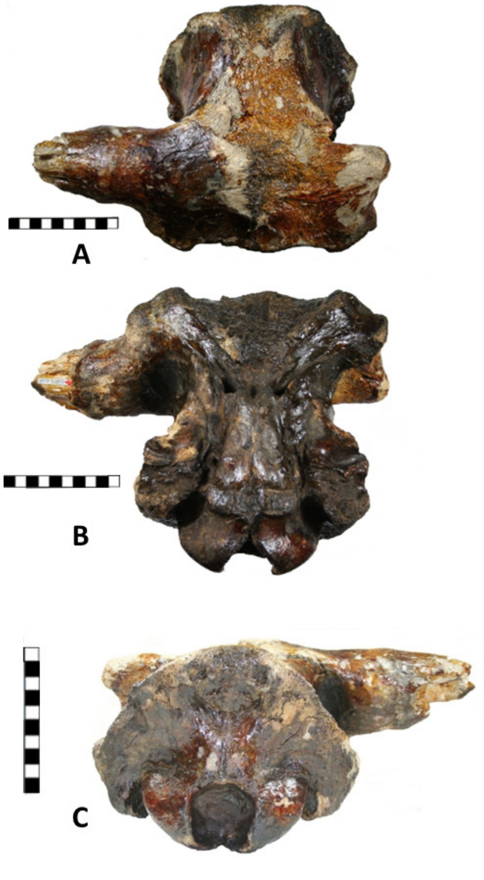

Fig.11. *Cervalces scotti,* holotype, braincase (ANSP 11572) in A. dorsal view, B. ventral view, C. posterior view.

The antlers of *Cervalces* are distinctive and more complex than any living North American cervid, and while palmated have a morphology quite distinct from both the extant *Alces alces* as well as *Alces/Cervalces latifrons*. There are three primary branches, one in each plane, each complexly palmated with numerous tines. The skull lacks the elongated premaxillae and shortened nasals seen in *Alces* and the anterior part of the skull more closely resembles *Cervus* in this regard, thus sharing with *Alces gallicus* and *Alces latifrons* the more primitive cervid skull morphology.

With a body mass of 632 kg calculated by Smith and others (2018) *Cervalces scotti* is larger than extant *Alces*. The heaviest recorded live weights of *Alces alces gigas*, the largest subspecies in Alaska, were 490 kg for an adult female and 595.5 kg for an adult male (Franzmann, 1978).

Cervalces scotti is found predominately from the eastern edge of the Great Plains eastward in the United States and is associated with the eastern deciduous forests as far south as Arkansas (Churcher and Pinsof, 1987). The highest concentration of records is in the Midwest south of the Great Lakes. Many records of *Cervalces* are based on shed antlers, but a few associated skeletons have been recovered (eg. Scott, 1885).

There is a single radiocarbon date of 13,475 ± 45 rcy BP (16237 ± 82 cal years) for *Cervalces* from Big Bone Lick, based on a metapodial (UNSM-12515) (SR-6478 (Thomas Stafford, pers.com. 2022)). Younger records for *Cervalces* indicate it survived until the latest Pleistocene elsewhere including Kluck Farm (Bevent), Marathon County, Wisconsin, 10,850 ± 60 rcy (= 12,825 ± 86 cal yr) (Aalund, 2008; Long and Yahnke, 2011)); Lang Farm, Illinois, 11,430 ± 60 rcy (Schubert and others, 2004); Kendalville, Indiana, 11,420 ± 70 rcy (Farlow and McClain, 1996); Columbia, New Jersey, 11,230± 160 rcy (Harington, 1984); Chippewa Lake, Medina County, Ohio 11,695 ± 35 rcy (= 13,582 ± 132 cal yr) (Glotzhober and McDonald 2015).

Rangifer tarandus **(Linnaeus, 1758) "Caribou"**

Among the extant species reported from Big Bone Lick but currently extirpated from the region is caribou, *Rangifer tarandus*. Today caribou have a primarily circumpolar distribution and in North America are restricted to north of the United States-Canadian border except for a small remnant population in the northern panhandle of Idaho. During the Pleistocene they were more widely distributed, especially in the eastern United States, including a record from nearby Blue Lick Springs, Nicholas County, Kentucky (J. McDonald *et. al.*, 1996). There are three records from West Virginia, New Trout Cave dated at 28,250 ± 250 rcy, and Wormhole and Organ Caves (no dates) and Saltville, Virginia (McDonald and others, 1996). *Rangifer* is known from four localities in Ohio; Castalia Marsh, Erie County; Mansfield, Richland County, Sheriden Cave, Wyandot County and Ripley Township, Huron County. It is also known from three sites in Sullivan County in southeastern Tennessee, Guy Wilson, Baker Bluff and Beartown Caves. The southernmost records include Bell Cave, Colbert County, Alabama (Churcher and others, 1989), Catalpa Creek, Clay County, Mississippi (McDonald and others, 1996) and Yarbrough Cave, Bartow County, Georgia (Martin and Sneed, 1989). As the species is adapted to colder environments, their presence farther south suggests colder conditions at lower latitudes during the Pleistocene. The extirpation of caribou from lower latitudes related to warming after the Pleistocene was noted by Shaler (1869) and has recently been addressed by Grayson and Delpech (2004). The diet of caribou includes grasses, sedges, mushrooms, and low shrubs. In winter, the lichen, *Gladonia* is a staple food. However, modern caribou show a latitudinal shift corresponding to a vegetational gradient from the taiga to the tundra with a decrease in lichen consumption from the high to low latitudes (Rivals and Semprebon, 2017). This change in diet with latitude should be reflected in carbon and nitrogen stable isotope ratios in caribou from different latitudes with values of *Rangifer* from Big Bone Lick intermediate between individuals from farther to the north or south.

Shaler (1869) did not specifically cite the skeletal elements on which he based his report of caribou at Big Bone Lick. There are 14 cataloged specimens identified as *Rangifer* from Big Bone Lick in the Museum of Comparative Zoology collections: VPM-3526 (metatarsal), VPM-3527 (shed antler), VPM-3528 (shed antler), VPM-3529 (shed antler), VPM-3530 (antler fragment), VPM-3531(shed antler), VPM-3532 (fragment of antler), VPM-3533 (antler fragment), VPM-3534 (antler fragment), VPM-3535 (antler fragment), VPM-3536 (antler fragment), VPM-3537 (antler fragment), VPM-3538 (fragments of shed antler), and VPM-3539 (antler fragment). The excavations by the Nebraska State Museum recovered additional remains of *Rangifer* including shed antlers of both adult (UNSM 49482) and juvenile (UNSM 128311) individuals (Fig. 12a,b). While many Pleistocene records of *Rangifer* are based on antlers, they are usually isolated finds and multiple finds from a single Pleistocene locality, like that documented by Miller and others (2013) for modern caribou, has only been recorded at Big Bone Lick. Lacking stratigraphic context, it is not known if they represent a single event, or a time averaged accumulation. Multiple radiometric dates or possibly Rare Earth Elements analysis would be required to resolve this issue.

The presence of shed antlers and determination of the sex can be used to indicate the season when caribou were at Big Bone Lick. Adult male caribou shed their antlers after the rut in late fall, but females retain their antlers all winter and only shed them around the time of giving birth in the spring (Gagnon and Barrette, 1992). The size of the adult antler indicates it is probably from a male. Schwartz-Narbonne (2021) documented that stable isotopes of carbon and nitrogen measured directly from antlers have the potential to provide seasonal dietary data for individuals as the stable carbon and nitrogen isotope compositions of collagen (δ^{13}CColl and δ^{15}NColl) from incrementally grown antler tissue

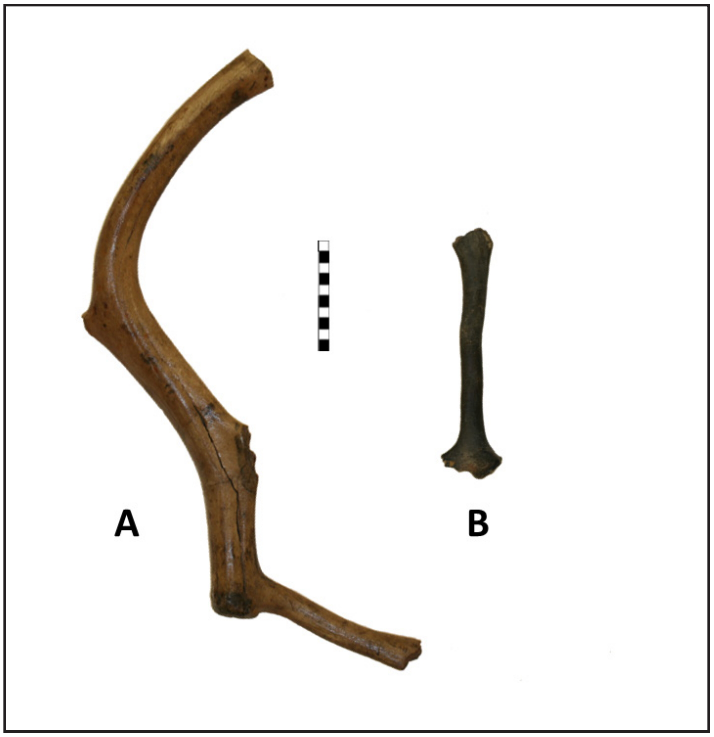

Fig. 12. *Rangifer tarandus*, shed antler of adult A. (USNM 49482) and B. juvenile (USNM 128311).

can provide time constrained dietary signals from the spring and summer growth season. The analysis of shed caribou antlers at Big Bone Lick has the potential to document seasonal use of the site by caribou. In a situation analogous to Big Bone Lick Calef and Lortie (1975) documented the use of a mineral lick on the Arctic coastal plain in the Yukon utilized by caribou. The lick was heavily utilized by females and yearlings during calving season, and they noted 60 shed antlers scattered on the lick and buried in the soil. Adult female and male caribou antlers can be differentiated and if Big Bone Lick functioned as caribou calving grounds the site should preserve measurable accumulations of shed female antlers and bones of neonatal fatalities, and these landscape bone accumulations can provide unique data on fine-scale habitat use at Big Bone Lick during the calving interval like the specimens documented in the Arctic (Miller and others, 2013).

As Shaler (1869) noted in his paper, “the position in which these remains [sic caribou] were found leaves the precise relationship in time of this species to the mammoths and mastodons a little questionable.” *Rangifer* was recovered from Unit 2 (Tankersley and others, 2015) along with *Bison bison antiquus*, *Bootherium bombifrons*, *Cervalces scotti*, *Equus complicatus*, *Mammut americanum*, and *Mammuthus* sp. This unit is a late Pleistocene lacustrine valley fill with radiocarbon dates from 19,380 to 25,520 cal yr BP (Tankersley and others, 2015). This is roughly contemporaneous with a shed antler tentatively referred to *Rangifer* from Myrtle Beach, South Carolina (USNM 467795) dated at 27,900 ± 775 rcy and indicates that the southern margin of the range of caribou was much farther south during the Last Glacial Maximum (McDonald and others, 1996). The southernmost record of *Rangifer* is Bell Cave, Colbert County, Alabama which is dated at 11,820 +480/-500 years BP (Churcher and others, 1989) indicating the northern shift in its range did not occur until the latest Pleistocene or earliest Holocene. Tankersley and others (2009) reported disarticulated remains of *Rangifer tarandus* from within the basal gravels of Unit 3, a weathered yellowish gray to yellowish brown clayey gravel, silty gravel, and silty clay deposited by alluvial processes. Radiocarbon dates obtained from both wood and bone from the base of Unit 3 range from 10,600 ± 250 RC yr B.P. (W-1358) to 12,210 ± 35 RC yr B.P. (UCIAMS-3559) so are only slightly older than the Alabama record. Feranec and Kozlowski (2016) proposed that following deglaciation caribou were the first megafaunal colonizers in New York followed by mammoth and then mastodon and the timing of caribou colonization implies that ecosystems were developed in the state prior to 16,000 cal yr BP. Big Bone Lick is 32 km south of the terminal moraine marking the southernmost margin of the Miami sublobe of the Laurentide Ice Sheet in the Mill Creek Valley. Radiocarbon dates from a cluster of tree stumps buried by glacial sediments constrain the timing of a glacier advance of the Laurentide ice sheet to its southern limit in the Cincinnati area at 19,670 ± 68 yr B.P. (Lowell and others, 1990). Initial deglaciation and retreat of the ice sheet, and ensuing environmental changes in the region, were episodic and rapid and predate the onset of the Bølling–Allerød postglacial warming (14.8 ka) as recorded by the Greenland ice cores indicating that deglaciation and landscape change along this part of the southern margin of the Laurentide Ice Sheet happened ~7 ka before the postglacial changes documented in central Greenland (Glover and others, 2011). If there was a permanent population of *Rangifer* in northern Kentucky, besides the ice sheet an additional potential limitation for northern dispersal is crossing the Ohio River. The deposition of Unit 2 at Big Bone Lick which is radiocarbon dated from 19,380 to 25,520 cal yr BP coincides with the greatest volume of meltwater and outwash from the Laurentide ice sheet being channeled into the Ohio River (Ray, 1974) and is the only unit from which *Rangifer* is recorded (Tankersley and others, 2015). The sediments of Unit 3 indicate continued vertical and lateral accretion of alluvial sediments in the valley of Big Bone Lick Creek which were deposited from 14,230 to 11,630 cal yr BP. indicating the continued presence of high water in the Big Bone Lick Creek valley (Tankersley 2009; Tankersley and others, 2009, 2015). Consequently, continued high water levels of the Ohio River may have served as a significant barrier for northern dispersal of caribou and possibly other taxa.

Direct radiocarbon dating of *Rangifer* at Big Bone Lick has not yet been done but such dates could aid in documenting how long the species remained in the area and when its range started shifting north in response to warming at the Pleistocene-Holocene transition and how quickly it moved northward with the retreat of the Laurentide Ice Sheet.

Equus complicatus Leidy 1848 "Complicated tooth Horse"

The controversy on horse nomenclature that exists elsewhere in North America also applies to the *Equus* found at Big Bone Lick. While horse material from Big Bone Lick has been referred to *Equus complicatus* over many years (e.g., Hay, 1916; Howe, 1982), there is not yet a single definitive study of the available specimens that confirms that the species from Big Bone Lick is that species. Nor has the validity of the species name *E. complicatus* itself been satisfactorily resolved.

While several dozen species of *Equus* have been described from the Pleistocene of North America, the majority are not considered valid and are interpreted to be *nomina dubia*. Consequently, despite the abundant remains of *Equus* in the North American Pleistocene available for study, considerable disagreement still exists over the number of species of *Equus* that inhabited the different regions of the continent in the late Pleistocene or even if there are regional differences in the North American Pleistocene horse fauna and what is the appropriate taxonomic nomenclature that can be applied to those taxa which seem to have distinctive morphological characters.

Part of the reason for this confusion is the conservative dental and skeletal morphology of *Equus*, which has prevented the determination of consistent distinctive morphological characters needed for species recognition. Additionally, many craniodental characters may vary dramatically with ontogeny within any given species. The apparent limits for a morphological resolution of this issue have recently been augmented by the recovery of ancient DNA from some fossil horses and linked to morphology (Barrón-Ortiz and others, 2017; Heintzman and others, 2017). Unfortunately, these studies focused on equid remains from the western United States and did not include specimens from Big Bone Lick. Based upon morphological and molecular data, western North American Pleistocene equids can be separated into a caballine and a non-caballine form at multiple different localities across most of the Western Interior; the non-caballine morph falls within the New World stilt-legged clade. Barrón-Ortiz and others (2017) also identified the existence of a second non-caballine species, referred to as *E. cedralensis*, from more southern localities that could be distinguished exclusively on the morphological analyses of the cheek teeth. While these studies provide a basis for better understanding the potential taxonomic diversity of horses in the western United States, they do not help address that question in the eastern United States – and specifically the identity of horse fossils from Big Bone Lick.

*Equus complicatu*s has the distinction of being the first species of North American Pleistocene horse to be described, thus giving it priority over other species. Thus, its seniority potentially makes it one of the

Catalog Number	*Bone*	*Length*	*AP prox*	*ML prox*	*ML distal epicondyle*	*AP keel*	*AP side of keel*
4213-65	MC3	252.5	37.8	53.4	49.2	36.7	30.1
4285-65	MC3	254	37.5	56.1	54.3	36.3	28.7
569-62	MC3	252.5	39.9	59.1	54.8	43.5	36.1
4260-65	MC3	--	38.3	57.6	--	--	--
4390-63	MC3	--	40	58.6	--	--	--
1901-62	MT3	290.7	57.6	56	56.1	45.3	33
4317-63	MT3	294.9	54.6	57.1	57.7	39.2	31.5
4106-63	MT3	280.5	57.8	60.2	58.4	45.4	34
4696-65	MT3	285.3	58	57.6	56.4	45.5	33.3
4196-63	MT3	290.2	55.3	64.3	56.3	46.4	34.9
1985-62	MT3	295.5	52.3	59.7	54.7	42.9	34.4

Table 4. Measurements of metacarpal and metatarsal of *Equus* cf. *E. complicatus* from Big Bone Lick in the Nebraska State Museum.

few names that can and should be applied to at least some of the North American specimens of *Equus*, assuming the species is valid. Leidy (1848) described 12 specimens of upper and lower horse cheek teeth found near Natchez, Adams County, Mississippi and donated to the Academy of Natural Sciences by M.W. Dickeson as *Equus americanus*. However, the name was preoccupied, so he later proposed the name *Equus complicatus* (Leidy, 1858) as a replacement. As was not uncommon for that time, no holotype specimen was designated; a left upper third molar, ANSP 11442, was later selected as the lectotype by Gidley (1901). The remaining specimens are considered paralectotypes; 11429, 11430, 11431, 11432, 11433, 11434, 11435, 11436, 11437,11438, 11439, 11440, 11441 and are housed in the Academy of Natural Sciences of Drexel University. The chief diagnostic feature of the fossils was reported to be the large size of the teeth and the complexity of the enamel pattern of the upper cheek teeth (Leidy 1848). However, these characters can vary with ontogeny, and molar teeth of young equids can be large and have strongly complex enamel patterns (Winans 1985), which brings the validity of the species into question. Winans (1985) considered the species a *nomen dubium*; a recent review of Plio-Pleistocene equids globally (Cirilli and others, 2022) did not include *E. complicatus* among its discussion of valid North American species. Nevertheless, the fossil horses from Big Bone Lick have not been reliably referred to any other valid species, and so herein we will continue to use the species *E. complicatus* to refer to horses from the site.

However, there is no reason to make the *a priori* assumption that only a single species of equid is present at Big Bone Lick. While the extant species of equids are mostly allopatric, the North American fossil record of the Equidae suggests that two or more species co-existing was the norm rather than the exception. This pattern seems to be present in the North American Pleistocene as indicated by the co-occurrence of both caballine and non-caballine species in multiple faunas throughout the western United States. This repeated co-occurrence suggests that these two groups had sufficiently different ecologies that they were not in competition with each other. Currently all records of *E. complicatus* listed in the Neotoma Database are from the southeastern United States, except for an outlier in Alberta, so referral of the horse from Big Bone Lick to this species is at least consistent in terms of geography. The horse present at Big Bone Lick is a large form, larger than the domestic horse, *Equus caballus*, although the metacarpals have similar proportions to the living species (Table 4, Fig. 14) indicating it was neither stilt- nor stout-legged as in some other North American species of *Equus*. It was approximately the size of another Pleistocene species, *Equus scotti*, but differs from the latter in the more complex enamel pattern of its dentition, especially on the upper teeth (Fig. 13a,b). Based upon the size of the metacarpal *Equus* from Big Bone Lick is among the larger species of North American late Pleistocene *Equus* (Fig. 14). *Equus* from numerous localities extending from the Gulf Coast of Texas to Florida, South Carolina, Kentucky, and Missouri have been referred to this species and it seems to have been the common large horse of the eastern United States during the later Pleistocene. Its time range is Irvingtonian to the late Rancholabrean (late Wisconsinan).

Figure 13. *Equus complicatus*, A. upper dentition, lateral view B. upper molar in occlusal view (ANSP 11496) C. left metatarsal in anterior view (UNSM 128312).

GENERAL PALEOECOLOGY

Recent AMS radiocarbon dating has extended the

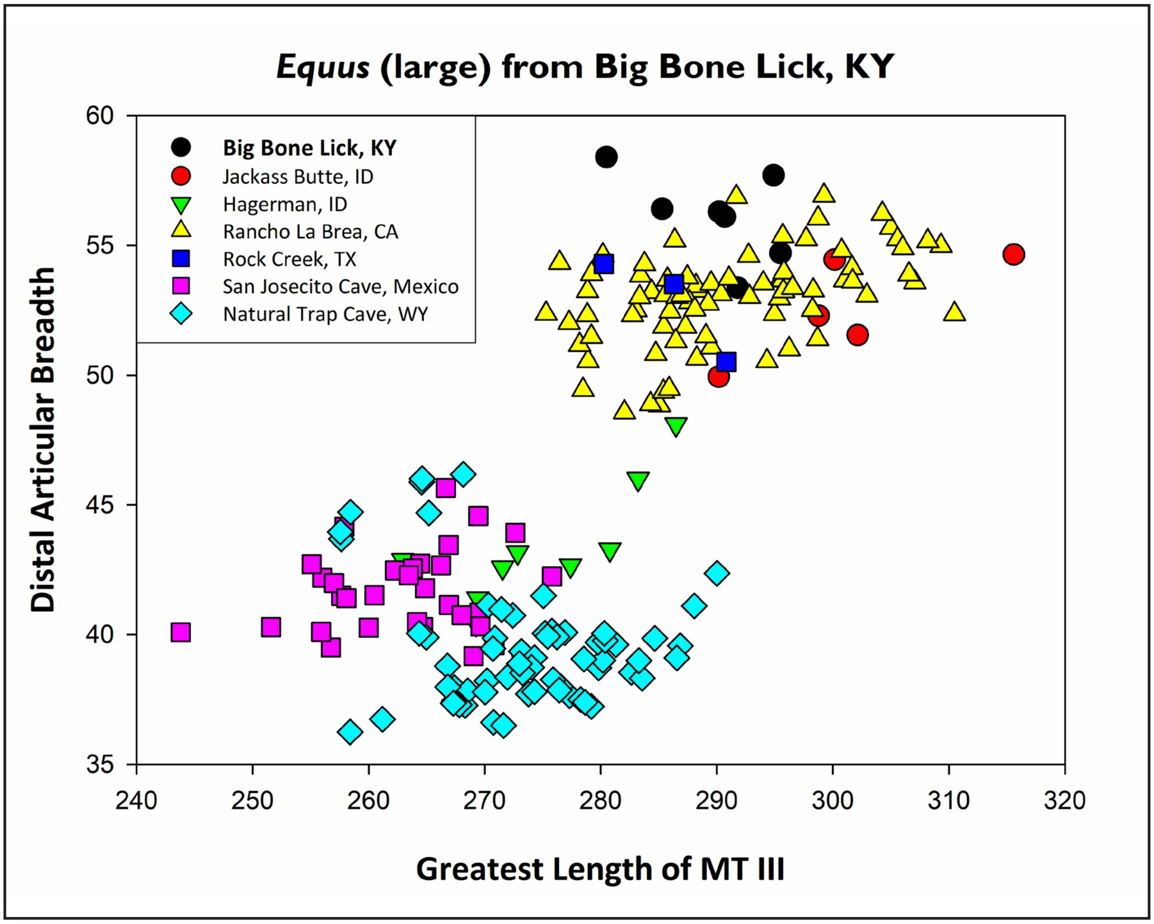

Figure 14. Bimodal plot comparing the metatarsals of *Equus* from Big Bone Lick to other late Pleistocene localities.

age of the bone-bearing deposits of Big Bone Lick back to the Last Glacial Maximum (Tankersely and others, 2015). This is based on the presence of three distinctive geomorphic surfaces and three stratigraphic units that have been dated to 19,000–25,000 calyr BP (T2, Unit 2), 12,000–14,000 cal yr BP (T3, Unit 3), and present to 5000 cal yr BP (T4, Unit 4). Table 5.

The Pleistocene fauna from Big Bone Lick includes a mix of taxa considered to be grazers such as mammoth, bison, horse, and Harlan's ground sloth and browsers including mastodon, elk-moose, and Jefferson's ground sloth. The muskox, *Bootherium*, appears to have been a woodland form and may have been more of a mixed feeder, based on epidermal analysis of plants extracted from the infundibula of the teeth of the specimens from Alaska that included both woody plant bark, *Vaccinum, Salix* and grasses including *Agropyron*-like, *Bromus*-like and *Poa*-like forms (Guthrie, 1991).

The mix of both browsers and grazers at Big Bone suggests a heterogeneous environment that included both open and forest habitat. Unfortunately, at the present paleoenvironmental reconstructions for the region based on well-dated pollen profiles are sparse and coarse-grained compared to fine-grained pollen data for regions north and south of the central Ohio River. No such data are available for the area around Big Bone Lick (Tankersley and others, 2015). However, well-dated botanical remains have been recovered from archeological sites in the region that span the late Pleistocene and Holocene (Dalbey, 1992; Drooker, 1997). These data show that C3 plants dominated with the minor exception of a few C4 plants such as Nimblewill (*Muhlenbergia schreberi*), certain grasses (Poaceae family) although *Panicum* includes species that are C3, C4, and intermediate representatives, and some species of pigweed (*Amaranthus* sp.). Additionally, Indian Chickweed (*Mollugo* sp.) is a C3-C4 intermediate, and purslane (*Portulaca* sp.) can shift from a C4 to a CAM photosynthetic pathway. If we assume that each plant taxon had an individualistic response to climatic change, then there would have been an ever-changing complex mosaic of vegetation patches at Big Bone Lick and the region in the late Pleistocene and Holocene (Tankersley and others, 2015). The macrobotanical record is also complemented by stable isotope data obtained from bulk organic matter. The stable isotope data indicates that both late Pleistocene (spruce dominated vegetation) and late Holocene habitats (temperate hardwoods) were dominated by C3 vegetation. Stable isotope data obtained from bone collagen and enamel also indicates that the landscape was dominated by C3 vegetation from the last glacial maximum to the present with more open mosaics or drier conditions possibly occurring during the late Pleistocene.

Stable isotope studies of taxa from Big Bone Lick are limited in scope. Stable carbon isotope values were obtained for enamel carbonate from two deciduous late Pleistocene mastodon molars and $\delta^{13}C$ values and $\delta^{15}N$ ratios were obtained for bone collagen from one late Pleistocene proboscidean rib, as well as a rib and scapula from two late Holocene bison. The $\delta^{13}C$ values obtained from 31 bulk organic matter samples from alluvial and lacustrine strata range in age from the last glacial maximum to modern. All faunal remains and sediments were collected from radiocarbon- and OSL-dated sediments exposed in the 2 m-wide stream profile excavations. Combining these new data with previously published data, we find relatively consistent $\delta^{13}C$ and $\delta^{15}N$ values among vertebrate taxa excavated from the site. Carbon isotope values obtained from bone collagen from late Pleistocene proboscideans range from -20.8‰ to -21.9‰ and $\delta^{15}N$ values range from 7.5‰ to 6.3‰ (Tankersley and others, 2015).

The isotopic ($\delta^{13}C$, $\delta^{18}O$) analyses of hydroxyapatite in the Holocene bison tooth enamel along with the unique progression of tooth wear in older age groups was interpreted by Widga (2006) that the bison at Big Bone Lick in the Holocene were obligate browsers with a diet higher in C3 plants than their Great Plains counterparts. Longitudinal sampling of two lower third molars gave ranges of $\delta^{13}C$ of - 12.58 to -16.00 and $\delta^{18}O$ of - 8.25 to -5.26. In contrast, the carbon isotope values derived from the bone collagen of the late Holocene *Bison bison* at Big Bone Lick by Tankersley and others (2015) were higher with a range from -23.8‰ to -24.1‰ and the $\delta^{15}N$ isotope ratios ranged from 5.7‰ to 4.4‰.

The fauna from Big Bone lacks many other herbivores well documented from elsewhere in Kentucky and the surrounding regions including both extinct peccaries, *Platygonus compressus* and *Mylohyus nasutus*; and the giant beaver, *Castoroides ohioensis*, although the white-tailed deer, *Odocoileus virginianus*, has been recovered. It is also important to note that while the type specimen of *Bison latifrons*, (ANSP 12993), the posterior portion of a skull with the basal portion of the left horn core, was found on a tributary of the Ohio River about 12 to 14 miles north of Big Bone, this species of bison has never been documented as part of the fauna of Big Bone Lick, despite reports of its presence in the older literature. Smaller taxa such as lagomorphs, shews and moles as well as small carnivores are also currently not documented as part of the Pleistocene fauna despite attempts to recover small vertebrates made by the Nebraska State Museum in the 1960's but without success. A few undescribed rodent teeth and fish and amphibian bones are in the collection of Cincinnati Museum Center. To date, the fauna lacks any reptiles.

Notably missing so far from the fauna recovered from Big Bone are large carnivores. None of the large predators, including the sabertooth, *Smilodon fatalis*, dire wolf, *Aenocyon dirus* or short-faced bear, *Arctodus simus*, which are known from the surrounding areas have yet to be recovered. Given the traditional scenario of the salt bogs at Big Bone Lick serving as areas of entrapment for the herbivores it is surprising that there is not more evidence of at least carnivore scavenging on the carcasses or even some entrapment of the carnivores themselves similar to that described for Rancho La Brea (Harris and Jefferson, 1985). To date the only large carnivores reported from Big Bone are the black bear, *Ursus americanus*, and the grey wolf, *Canis lupus*.

The first published radiocarbon dates for Big Bone Lick were based on solid carbon, so are not considered as reliable as the dates using AMS. These older dates are included in Table 6 along with more recent radiocarbon dates.

Despite its preeminent role in the history of vertebrate paleontology in the United States, there is still much to be learned about the paleontology and geology of Big Bone Lick. Recent work by Von Mann (2005) provides a good example of new technology and studies that can be applied to the site. Some of these have already been applied to taxa from the site, but only in a limited way, to a small number of taxa. A combination of the reexamination of historical collections combined with new excavations and material collected with tighter stratigraphic control will provide more contexts for the fauna and obtaining more AMS radiocarbon dates and stable isotope analysis, will certainly improve our understanding of the site and its geology and paleontology. Currently the only extinct taxon that has been dated is the mastodon, and similar high-quality dates are needed for other taxa, in order to help place them within a tighter chronology and permit a determination as to how the different taxa were responding to climatic and environmental change from the Last Glacial Maximum to the Holocene. Perhaps even the application of Rare Earth Analysis (REE) to some of the historical and modern collections will help provide another link between Big Bone Lick's past and future.

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