THE STERNBERG ELEPHANT QUARRY NEAR PENDENNIS, LANE COUNTY, KANSAS: THE FORGOTTEN MAMMOTH SITE

STERNBERG MUSEUM / MUSEUM OF THE HIGH PLAINS

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ABSTRACT

In 1894, Charles H. Sternberg excavated a site in northeastern Lane County, Kansas, where he reportedly collected as many as 200 elephant teeth, suggesting a minimum number of 50 individuals from the site. The site was described as a small, circular basin in the Niobrara Chalk, below fossiliferous exposures of 'Loup Fork,' likely Ogallala rocks. The fossils were encased in a hard, light grey matrix likened to the 'mortar beds' and this sediment and additional mineral coatings can be seen on many of the specimens today. The exact location of the site, however, has not been established. A review of all the fossils from the site resulted in the location of 60 specimens that currently are curated in three museum collections (American Museum of Natural History, University of Kansas Museum of Natural History, and the San Diego Museum of Natural History). Assignment of the available material to ontogenetic age shows that 86% of the individuals were 29 years or younger, suggesting that a taphonomic filter operated at the site to collect mostly young individuals, perhaps a natural trap. The specimens are conservatively identified as belonging to the Elephantinae because of a lack of diagnostic cranial material.

INTRODUCTION

Fossil elephants and their relatives have held mankind's attention since the earliest days of their discovery. The history of paleontology in North America is closely connected to the collection of proboscideans in that the first documented fossils ever collected on this continent were elephants shipped to France in 1740 (Simpson, 1942). Proboscidean fossils were the subject of much interest by early Americans, including the likes of Benjamin Franklin and Thomas Jefferson (Simpson, 1942). One colorful account was given of the life history of the mastodon (*Mammut americanum*) by George Turner, who attributed to the animal "the ferocity of the tiger" and a carnivorous diet (Turner, 1799:518). Because of their size and hardiness of their bones and teeth, elephant remains seem to be ubiquitous, readily being preserved in a wide range of sedimentary systems.

Several single-site accumulations of multiple individual mammoths are known in North America. The Hot Springs Mammoth Site in South Dakota preserves the most individuals in situ and is the best known and most intensively studied. As of July 2006, the site had 55 documented individuals based upon tusk count and, considering the extent of the deposit based on drill hole evidence, many more are likely to be found there (Agenbroad, pers. comm., February, 2007). The Hot

TABLE 1. Single site accumulations of multiple *Mammuthus* individuals in North America.

Site Name	MNI	References	Comments
Hot Spring, South Dakota	55+	Agenbroad, pers. comm.	
Pendennis, Kansas	50+	Sternberg, 1898	Estimated MNI from number of teeth collected
Lamb Springs, Colorado	30+	Stanford et al., 1981; Rancier et al., 1982; Haynes, 1985	Possible archeological association, but not clear (Haynes, 1985)
Charleston, South Carolina	20	Agenbroad, 1984	Listed as phosphate beds. More than one locality?
Waco, Texas	15	Fox et al., 1992; Haynes, 1992	Archeological association
Lehner Ranch, Arizona	13	Haury et al., 1959; Saunders, 1977, 1980	Archeological association
Dent, Colorado	13	Figgins, 1933	Archeological association
Colby, Wyoming	7	Frison, 1976, 1978, 1986	Archeological association
Frankstown, Pennsylvania	7	Agenbroad, 1984	Listed as a cave fill deposit
Bradenton, Florida	7	Agenbroad, 1984	Listed as river sands, all one locality?
Blackwater Draw, New Mexico	6	Saunders, 1992	Archeological association
Dutton, Colorado	5+	Agenbroad, 1984	Listed as a pond
Selby, Colorado	5+	Agenbroad, 1984	Listed as a pond
Miami, Texas	5	Agenbroad, 1984	Archeological association
Murray Springs, Arizona	4	Saunders, 1992	Archeological association
Slanton, Texas	4	Agenbroad, 1984	Listed as lake beds
Silverspring, Florida	3	Agenbroad, 1984	Listed as spring/pond deposit
Lubbock Lake, Texas	3	Johnson, 1987	Archeological association
Lange/Ferguson, South Dakota	2	Martin, 1987; Hannus, 1990	Archeological association
Leikem, Arizona	2	Saunders, 1992	Archeological association

Springs Site acted as a natural trap for mammoths around a spring and has no known archeological associations.

Some sites with multiple individual mammoths, such as Lamb Springs, Colorado, do have archeological evidence which suggests that those sites were used as kill or butchering sites. Table 1 presents a list of sites in North America that have preserved multiple individual mammoths.

The Sternberg Elephant Quarry excavated near Pendennis, in Lane County, Kansas, might have rivaled the Hot Springs Site in number of individual mammoths preserved, based on the number of teeth supposedly collected, and yet is almost forgotten. The lack of attention paid to the site is due to its overall lack of documentation and subsequent loss of most of the material. Regrettably, the overall story of the Sternberg Elephant Quarry is one of lost opportunities for science.

This paper is a compilation of the site's history. The known fossils from the site are itemized and information about the specimens and the mammoth population from the site are presented for the first time.

Institutional Abbreviations — **AMNH**, American Museum of Natural History, New York City; **KUVP**, University of Kansas Natural History Museum Division of Vertebrate Paleontology, Lawrence, Kansas; **KSU**, Kansas State University, Manhattan, Kansas, **SDNMH**, San Diego Natural History Museum, San Diego, California; **Ward's**, Ward's Natural History Establishment, Rochester, New York, not a modern-day repository.

HISTORY OF THE SITE

As will be established, inconsistencies and uncertainties seem to abound with regard to the Sternberg Elephant Quarry. It is unclear exactly by whom and when the site was first discovered. Isolated teeth at the American Museum of Natural History (AMNH 8069) are listed as being purchased from H. T. Martin in 1893. Williston reported to the Kansas Academy of Sciences in December 1896 (later published, Williston, 1898:91) that "Three years ago an extraordinary deposit was discovered in Lane county [sic], in the valley of the Smoky Hill, by Mr. Chas. Sternberg…" suggesting a date of discovery in 1893. Sternberg wrote that he discovered the site in 1894 (Sternberg, 1898).

Intrigue is added to the situation with some archival material. In handwritten notes that appear to be a draft of Sternberg's 1898 paper (Canadian Museum of Nature Archives), Sternberg wrote that he was alerted to the site by a settler in Lane County, and he gained "possession" of the site to commence digging. Additionally, in correspondence between Henry Ward and Sternberg (12 February 1895), Ward wrote, "I presume that the mammoth teeth are the same ones that were offered me last year by Mr. Martin?" So it is not entirely clear what role H. T. Martin played in the early history of the site, but Sternberg has been credited with the site's discovery and excavation.

There was apparently a lot of fossil collecting activity in the region in 1894. The Scott City Republican reported that H. T. Martin was shipping fossils from Scott City in May (Scott City Republican, 17 May 1894), that Sternberg was collecting on the mammoth site by July (Scott City Republican, 5 July 1894), and that Samuel Williston was in the area in August (Scott City Republican, 2 August 1894).

PHYSICAL CHARACTER OF THE SITE

Some clues are available as to the physical character of the locality. Williston (1898:91) wrote that the mammoth material came from "a small area, not more than two or three rods in diameter...The deposit was in a basin in a small ravine that had been hollowed out of the Niobrara chalk, and considerably below the Loup Fork beds, which here yielded teeth of *Protohippus placidus*. In the vicinity, and from a higher horizon, were obtained teeth of *Protohippus lenticularis*, a typical Goodnight bed species. There can be no question of the local character of the *Elephas* deposit. Everything indicates that the spot was the site of some old spring to which the different animals had come and died."

Sternberg wrote that the deposit was "in this small basin, about 20 feet in diameter and 5 feet deep in the center" (Sternberg, 1898:169). This is in contrast to Williston's statement about the diameter of the site being 2 or 3 rods, a rod being unit of measure used in the past and equaling 5.03 meters (16.5 feet). So, according to Williston's estimate, the diameter of the site is 10 to 15 meters, whereas Sternberg estimated it as only about 6 meters.

Further clues about the nature of the site are provided by Sternberg. Sternberg (1898:169) wrote "As the deposit was 100 feet below the Loup Fork beds, that showed their heavy escarpments at the head of the ravine, south." He also noted that the matrix around the bones was very concrete-like, and he thought it was reworked 'mortar bed' material (Ogallala Group today). A very hard, light grey mineral cement, and occasionally a globular mineral coating, can be seen on many of the teeth preserved from the site.

LOCATION OF THE SITE

Museum records and publications do not provide precise statements about the location of the site. The first published reference to the site was Williston (1898), but he just noted the site was in Lane County, Kansas. Sternberg's own account (1898:169) stated that the site "was in the southeastern corner of Lane County," however the directional reference is undoubtedly a mistake. All other references to the site indicate that it is near the Smoky Hill River, northeast of Pendennis, although even the distance from Pendennis is variously given. Hay (1924:71) wrote "In a letter to the writer, April 1911, he [Sternberg] gave the locality as 7 miles northeast of Pendennis, in the northeastern corner of Lane County, this was probably an estimate of distance along winding roads." Hay's doubts about the distance likely stems from the fact that 7 miles northeastward from Pendennis places one outside Lane County, in either Gove or Ness counties depending upon the exact azimuth traveled. Records at the AMNH say the locality is 6 miles northeast of Pendennis, and some specimen labels at KU suggest that the locality is 5 miles northeast on the Lane-Ness county line.

With the clues about the physical character of the site and the hints of its location, a field search was conducted to see if the site could be relocated. If the site could be confidently relocated, the geology of the area might provide valuable insight into the taphonomic processes that concentrated a large number of individual mammoths at the spot. An effort was also made to scour archival sources for additional clues, including a search of newspaper accounts, letters, and other documents. As can be seen, much of the evidence about the site is incomplete at best and contradictory at worst. The potential search area, being generally northeast of Pendennis, and within 5 to 7 miles, is fairly vast. It is especially difficult to locate a small basin, 6 to 15 meters in diameter, which may or may not still be there. The basin could have been subsequently filled either by a land owner or by natural processes such as being infilled by sediment storms of the Dust Bowl. Even with references provided to the possible topography of the site, such as being eroded into the Niobrara Formation with "Loup Fork" beds being above the site, no modern day location can be pointed to with any confidence as being the Sternberg Elephant Quarry.

MATERIAL

The fossil material from the Sternberg Elephant Quarry is poorly documented. Williston (1898:91) wrote that "portions of a score or more" of mammoths were represented at the site, indicating that "[s]ome seventy or more of the teeth" were in the KU collection. Sternberg seemed to bristle a bit about Wil-

TABLE 2. List of all specimens from the Sternberg Elephant Quarry in Lane County, Kansas, that can be accounted for either in the literature or in museum collections. Abbreviations: Collection, museum or collection name; Number, curation number; AEY, African elephant years; Pl pres, number of plates preserved on the tooth; Pl abrad, number of plates abraded by wear; We, width of the widest enamel loop on the tooth; Wc, width of the tooth, including cement, LF, lamellar frequency, or number of tooth plates in a 10 cm section of tooth; En thick, average enamel thickness; Description, additional information. Measurements are in cm.

Collection	Number	AEY	Pl pres	Pl abrad	We	Wc	LF	En thick	Description
Lower Teeth									
KUVP	5530	4	5	5	51.7	54.2	8.0	1.43	left m3
KUVP	5530	4	4		38.3	48.4	14.0	1.47	left m3
KUVP	7640	14	6	6	62.2	70.2	7.2	2.50	left m4
KUVP	87829	18	8	8	64	76	7.6	2.33	left m4
KUVP	87847	19	4	4	57.9	73	8.0	2.47	left m4
KUVP	87815	7	4	0		64	8.1		left m3
KUVP	87830	16	9	9	68.3	72.7	9.0	1.63	right m4
SDNMH	14092	8							m4
SDNMH	14093	13							m4
SDNMH	14098	7							m4
KUVP	87826	26	6	6	72.1	81.4	5.4	1.90	left m5
KUVP	87813	32	9	9	90.6	96	5.4	1.93	left m5
KUVP	87812	27	5	5	75.2	93	5.5	2.37	right m5
KUVP	87805	21	8	5	61.3	69.5	6.5	1.70	left m5
KUVP	87844	27	6		73.4	84	6.7	1.79	right m5
KUVP	87822	24	8	7	74.6	77.4	6.8	2.15	left m5
KUVP	87824	26	8	6	65.7	79	7.1	2.17	left m5
KUVP	87825	26	5	5	66.1	81	7.1	1.90	right m5
KUVP	87827	29	5	6	72.2	78.8	7.2	2.40	right m5
KUVP	87816	21	5	0		73	7.2		left m5
KUVP	87819	27	3	3	57.3	81	7.4	1.95	left m5
KUVP	87820	27	6	4	60.7	77.2	8.1	2.00	left m5
KUVP	87838	30	9	9	82.9	88.4	8.5		right m5
KUVP	87811	23	6	5	69.9	86	8.7	2.13	right m5
KUVP	87823	26	9	8	64.4	78.3	8.8	1.67	left m5
KUVP	87818	21	6	0		67	10.2		left m5
KUVP	87809	40	14	8	70.2	79.3	7.8	2.35	right m6
AMNH	8069		13	0			8		right m5, with 13 plates, likely 16 originally, referred to in Hay, 1924:72
KUVP	87845		6			79	8.7		right molar
Ward's							10		m5 referred to by Hay,1924:48, current location unknown
AMNH	21892	39							lower jaw
AMNH	8069	?	11		45				One of the "milk-teeth" mentioned in Hay 1924:48
AMNH	8069	?	11		45				One of the "milk-teeth" mentioned in Hay 1924:48
AMNH	8069	?	11			45			One of the "milk-teeth" mentioned in Hay 1924:48
KUVP	87810		6						right molar
KUVP	87814		11	7					right molar

TABLE 2, cont.

Collection	Number	AEY	Pl pres	Pl abrad	We	Wc	LF	En thick	Description
Upper Teeth									
KUVP	87801		7	3	37.3	56.6	7.6	1.50	left M3
KUVP	87840		6	5	47	63	8.0	1.90	right M3
KUVP	87832		7	7	78	82.6	6.6	2.40	left M4
KUVP	87817		6	3	47.25	68	6.9	1.70	right M4
KUVP	87808		9	7	69.7	78.1	7.4	1.33	right M4
KUVP	87828		8	8	69.9	78.3	8.3	1.70	left M4
KUVP	87802		11	5	53.6	80	8.7	1.65	left M4
KUVP	87846		6	6	64	73	8.9	1.75	right M4
KUVP	87837		8	0		63	9.0		right M4
KUVP	87807		14	11	65.5	72.5	9.3	1.77	right M4
KUVP	87831		8	8	64.6	75.1	9.8	1.67	left M4
KUVP	87843		11	11	70.5	74	10.0	1.56	left M4
KUVP	87842		6			96	3.7	2.62	left M5
KUVP	87806		17	9	70.1	76.9	7.6	2.17	right M5
KUVP	87839		8	8	88.4	98	7.9	1.80	right M5
KUVP	87834		19	11	80.5	85.7	8.1	1.90	left M5
KUVP	87803		8	7	53.9	63.7	8.3	1.63	left M5
KUVP	87841		8	8	84.5	91	8.3	1.60	right M5
KUVP	87833		6	6	62.4	68.1	9.7	1.75	left M5
SDNMH	80681								M5
KUVP	5530		20	9	68	79	8.2	1.74	left M6
KUVP	87833		19	6	91.9	80	8.5	1.80	left M6
AMNH	8609		18			85	8		right molar
AMNH	8609		18			85	8		left molar
Ward's							10		M6 referred to by Hay,1924:48, current location unknown
Indet. Teeth or Skeletal Frags									
KSU									large tooth referred to by Sternberg, 1898, current location unknown
SDNMH	14094								tooth fragment
SDNMH	14109								skull fragment
SDNMH	14110								partial tooth
SDNMH	14111								right metacarpal III
SDNMH	14112								calcaneus
SDNMH	80728								vertebral centrum

liston's estimated number of individuals, writing, "The professor is conservative in his estimate of the number of animals found by myself in this small basin…I left at least a car-load of 20,000 pounds of the broken up bones, too friable to save" (Sternberg, 1898:169). He added, "Perfect bones and complete skeletons could not be procured. I got out about 200 fine teeth" (Sternberg, 1898:169). Apparently, tusks were also found, as Sternberg noted that they "were broken into pieces from one to four feet in length. I uncovered one however, that was 14 feet long, recurved, 8 inches in diameter at the base, but too friable to save" (Sternberg, 1898:169). Sternberg also referred to the site in at least two places in his first autobiography (Sternberg, 1909:134; 159-160).

If Sternberg is accurate in his statement of the number of teeth recovered, the minimum number of individuals preserved at the site is remarkable. Elephants are almost unique among mammals in the progression of their teeth through their mouths throughout their life times. Basically, elephant teeth do not appear at one time during life, but emerge and are worn away in a horizontal progression of six cheek teeth in each mouth quadrant throughout life. The teeth are large, and few teeth can be accommodated in the mouth at one time, so at any point in an animal's life only a limited number of teeth are exposed and in use. Only one or two teeth are in wear within a mouth quadrant as a rule (upper left and right, and lower left and right). The implication for the Sternberg Elephant Quarry is that if 200 teeth were collected, and if Sternberg recovered every tooth from each individual, one could estimate the minimum number of individuals (MNI) as approximately 50, or 200 teeth divided by four teeth in wear at one time. This estimate could be high, as more than one tooth could be in wear at one time in a mouth quadrant; but since it is unlikely that every tooth from all individuals were truly recovered, it provides some sense of the number of individual mammoths preserved at the site.

It should also be noted that, given the unusual progression of teeth in elephants, the teeth often are referred to as molars one through six; molars one through three in this terminology corresponding to deciduous premolars two, three, and four in other mammals, and molars four through six corresponding to the true molars one through three. Details of elephant dentition and discussions of tooth progression and formation can be found in Roth (1989).

Unfortunately, most of the material collected from the Sternberg Elephant Quarry does not seem to have been curated into museum collections, so most of the specimens cannot be examined and the number of specimens collected cannot be confirmed. Effort was made to locate or account for as many specimens as possible. A summary of the material is presented below, and all of the specimens identified from the site and their present status are provided in Table 2.

Hay provided the first partial itemization of the teeth from the site. He noted (Hay, 1924:48) several teeth in the collection of the AMNH, including two upper molars he supposed to be from the same individual, and three lower deciduous molars, and (Hay, 1924:71) a lower right molar in the collection, thus he called out a total of six isolated teeth curated in the AMNH (these teeth all are all curated as AMNH 8069).

Hay also noted that at that time Ward's Natural History Establishment at Rochester, New York had two teeth, "last upper molar, and a lower penultimate, which are labeled as coming from Lane County. They may have been a part of Sternberg's collection" (Hay, 1924:48).

Sternberg provided some additional specimen accounts. He noted, "A number of nearly perfect sets of lower jaws were found. The large bones were usually broken to pieces, and no two bones were found together. Remains in great abundance were found of all ages, from the young elephant to the full-grown bull. The largest molar I procured measured in length a grinding surface of 17 inches. This, I believe, is the largest elephant tooth in existence. It is now in the Kansas State Agricultural College [KSU]" (Sternberg, 1898:169). Sternberg also gave a tantalizing hint of specimens that displayed pathologies. "I found a couple of remarkable examples of morbid anatomy in two large molars. They were in the shape of horse-shoe, the distal ends turned and pressed closely against the proximal ends in the jaws of fully matured animals" (Sternberg, 1898:169). Only one jaw is presently known from the site (AMNH 21892), and the location of the Kansas State material and the pathologic specimen is unknown.

The largest single collection from the site was the teeth shipped to the University of Kansas. Williston (1898:91) stated that "seventy or more" of the teeth went there, but today only 48 teeth are curated as being from the site. There are additional specimens, including some postcranial material, in the KUVP collection labeled as coming from Lane County. The preservation of some of the material, but not all, looked similar to the Sternberg Elephant Quarry. Because it is not clear they are from the site, they are conservatively excluded here.

During the course of this investigation some additional specimens were identified as possibly coming from the Sternberg Elephant Quarry, but the evidence is not conclusive. A relevant undated newspaper clipping was discovered, perhaps from a San Diego, California newspaper from around 1921. At that time, Charles H. Sternberg had relocated to San Diego (Rogers, 1991), and there he was reunited with an old friend, William Bourne from Scott City, Kansas. Bourne had been the editor of the Scott City Republican and had actually visited the Sternberg Elephant Quarry while Sternberg was excavating it (Scott City Republican, 20 September 1894). Bourne helped arrange for the San Diego Museum of Natural History to purchase specimens from Sternberg (Riser, 1995), prompting Sternberg's note for the newspaper.

In the undated newspaper text (Glenbow Museum Archives, Calgary, Alberta, Canada), Sternberg wrote "I have just put on exhibition at the Natural History Museum at Balboa park [sic] a case containing the teeth of this elephant (meaning a "Colombian" elephant) as well as of the mammoth. Those of the Colombian elephant came from a specimen I discovered 27 years ago in Lane County, Kas...I might say, in passing, the present specimens were collected and presented by W. O. Bourne of this city."

The material today at the SDNHM attributed to W. O. Bourne and listed from Lane County, Kansas, includes some teeth as well as other bones and fragments. Many of the specimens show light grey "mortar" cement adhering to the surface, similar to sediment observed on KU material from the site. Bourne was there with Sternberg, he could have easily taken these specimens with Sternberg's blessing as souvenirs, then many years later given them to the SDNHM, and Sternberg's newspaper text indicates that the specimens came from the mammoth quarry site. The circumstantial evidence is strong enough for the specimens to be included here as from the site.

As an aside, if the bones preserved in the SDNHM are from the site and are representative of the state of preservation of the bone at the site, then it is disappointing that Sternberg did not try and save the bones. The bones have held up well despite not being heavily permineralized. Sternberg wrote in several places about the poor state of preservation of the bones and tusks from the site. In his 1898 account, as already mentioned, he said the tusks were mostly broken up into sections, and the 9,000+ kilograms (20,000 pounds) of bone found at the site were too friable to save. He further stated, "I thought at first the deposit was unlimited, and that the broken bones could be used as fertilizers. Prof. Bailey, Chemist of the State University, kindly gave me an analysis, which showed but 10 per cent. less phosphate of lime than Armour's ground fresh bone meal" (Sternberg, 1898:169). What he does not say here, but is implied and confirmed in an undated newspaper clipping (Glenbow Museum Archives, Calgary, Alberta, Canada), is that he hoped to sell the bones by the train-car load as fertilizer. So, of the 200 presumed teeth originally collected we can account for 68 specimens, including the material from SDNHM and the lost specimens from Ward's and KSU collections, 60 of which are curated in modern repositories.

TOOTH POSITION ASSIGNMENT

Because of the unique nature of how elephant teeth progress through the mouth during their lifetimes, it can be difficult to assign individual teeth to a position in the jaw (i.e., molar 1-6). Some morphologic characters distinguish the teeth in the progression. The early teeth (molars 1-3) are usually relatively easy to recognize based on overall size and shape. And the last molars, if complete on the posterior side, can be recognized by the tapering off of the plates since they were not constrained during their development by a tooth behind them. The middle teeth (molars 4 and 5) can be problematic for teeth assignment. Broken teeth can further complicate the situation.

If the teeth are whole, or nearly so, they generally can be separated by overall size—the later teeth in the series being larger; however, the later teeth of smaller individuals could be misidentified as earlier teeth in the series of larger individuals. Agenbroad (1994) compared data from Roth and Shoshani (1988) on the Asian elephant (*Elephas maximus*), Laws' (1966) data from the African elephant (*Loxodonta africana*), and *Mammuthus* specimens from various sites, including Hot Springs. There is considerable spread and overlap in the data, as well as differences in the average slopes in the lines of best fit for each taxon. Haynes (1991, tables A5A and A5B) provides tables compiling total plate counts for both *Mammuthus columbi* and *Mammuthus primigenius*.

Making tooth assignments for the specimens from the Sternberg Elephant Quarry was at times problematic because the teeth were mostly incomplete. It was at times even difficult to differentiate upper teeth from lower teeth, this distinction usually being made by overall tooth shape and the angle at which the plates intersect the occlusial plane. All available evidence was used, such as plate orientation with regard to occlusial plane, overall tooth width (overall tooth length was only available in a few cases and so total plate count was also lacking), shape of the posterior and anterior ends of the tooth, and general shape of the occlusial surface to suggest a tooth position. Tooth determination was admittedly subjective at times, but each tooth was examined individually and a best determination settled upon (Table 2).

TAXONOMY

The first major comprehensive work on the taxonomy of the Proboscidea was by Osborn (1936 and 1942). Osborn severely oversplit the group, but his work was comprehensive of the material that was available at the time and so remains a valuable reference. The next major revision to include the Elephantinae (*Stegodibelodon* (*Primelephas* (*Loxodonta* (*Elephas*, *Mammuthus*)))) was provided by Maglio (1973). This work set the standard for the study of fossil elephants in several significant ways. He developed a standardized methodology for the measurement of elephant teeth, and although the majority of Maglio's research efforts focused on African and Eurasian taxa, he did introduce a simplified taxonomic scheme for the North American taxa that has been widely adopted ever since. More recent taxonomic research has focused on higher level relationships within Proboscidea (e.g., Tassy, 1988, 1996; Kalb et al., 1996; Lambert and Shoshani, 1998; and Todd and Roth, 1996). A comprehensive review of North America elephant taxa has not been published since Osborn, although there have been a few summary reviews (Kurtén and Anderson, 1980; Graham, 1986; and Agenbroad, 1984 and 1994), an unpublished dissertation (Madden, 1981), and a thesis covering mammoths from Arizona (Saunders, 1970).

The current hypotheses hold *Mammuthus meridionalis* to be the first elephantid species to arrive in North America from Asia, sometime before 1.5 million years ago (Maglio, 1973). A North American lineage then evolved, producing several autochthonous and progressive species, *Mammuthus imperator* and *Mammuthus columbi* respectively. The morphological progression of these species is marked by an increase in

TABLE 3. Average lamellar frequency (LF) and average enamel thickness (En) for all teeth identified from the Sternberg Elephant Quarry, separated by tooth position.

Tooth	Average LF	Average En thick
m1		
m2		
m3	11.0	1.4
m4	8.0	2.0
m5	7.3	2.5
m6	7.8	2.4
M1		
M2		
M3	7.8	1.7
M4	8.5	1.7
M5	7.6	1.9
M6	8.4	1.8

the absolute number of tooth plates and a general thinning of the enamel bands–basically a linear progression toward more densely spaced tooth plates. Late in the Pleistocene, another wave of elephantid immigration into North America was marked by the arrival of *Mammuthus primigenius*, again from Asia. The late Pleistocene autochthonous North American species *Mammuthus columbi* and the immigrant *Mammuthus primigenius* are considered convergent in their dental characters of increased plate number and reduced enamel thickness. Graham (1986) points to this hypothesis in explaining why the arctic-adapted *Mammuthus primigenius* was identified in archaeological sites as far south as Mexico. Another late Pleistocene taxon recognized from North America is *Mammuthus exilis*, the dwarf species from Santa Rosa Island, one of the Channel Islands (Stock and Furlong, 1928; Roth, 1993). The monophyly of *Mammuthus* and the relationships of all included species has yet to be explicitly tested using modern cladistic approaches. The completion of such an analysis is important for assessing the current ideas regarding the evolutionary history of *Mammuthus*.

Hay (1924) was the first to discuss the mammoths from the Sternberg Elephant Quarry in any detail. He thought that the variation in morphology among the specimens indicated that two species were present at the site, "*Elephas columbi*" and "*Elephas boreus*." Osborn Fig.d the lower jaw from the site (AMNH 21892) and named it as a paratype of his "*Elephas jeffersonii*," and he rejected the name "*E. boreus*" on the grounds that it was the same as "*Parelephas jeffersonii*" (Osborn, 1942: Fig. 960 A).

Few of the teeth preserved from the Sternberg Elephant Quarry are complete. Thus, total plate count is impossible to obtain in most cases. Lamellar frequency and enamel thicknesses were obtained. The measurements were taken generally following Maglio (1973), counting the number of plates in a 10-cm section of tooth on both the lingual and labial sides of the tooth, and at several levels of the tooth's height if possible. Values were then averaged. Plates were measured as beginning at the anterior enamel edge, and include the enamel loop and cement posterior to the anterior enamel limb of the next plate. In many cases, the overall size of the tooth did not allow a full 10-cm section to be examined, and in those cases, a section of whole plates was counted and their distance along the tooth was recorded, and the value was standardized mathematically for a 10-cm section (number of plates counted * 100/measurement for the plates counted).

The lamellar frequencies obtained on the specimens show a great degree of variation. The lamellar frequency of 27 lower teeth ranged from 5.4 to 14.0. Twenty four upper teeth exhibited lamellar frequencies of 3.7 to 10.0. These results are summarized in Table 3. The low end of the results are within the range reported for *Mammuthus meridionalis* (3.5 to 7.7 in Maglio, 1973), whereas the high end of the range are within and above the range reported for *Mammuthus primigenius* (7 to 12 in Maglio, 1973).

Enamel thickness also was obtained by measuring up to three places on the anterior edge of the plate, taking care to measure perpendicularly to the plane of the enamel, but this was often difficult given the angle at which the plates join the occlusial surface. Those results are less variable than lamellar frequencies, ranging from 1.4 to 2.5 mm. The results for both lamellar frequencies and enamel thickness are summarized by tooth in Table 3.

Modern phylogenetic hypotheses of Elephantinae relationships suggest that *Elephas* and *Mammuthus* form a clade (Tassy, 1996; Kalb et al., 1996). Maglio (1973) identified several morphological differences, both cranial and dental, intended to facilitate distinguishing *Elephas* and *Mammuthus*. However, most of the dental characters show significant overlap (e.g., M3 having 10 to 27 plates in *Elephas*, and 8 to 27 in *Mammuthus*; lamellar frequency on M3 from 3.5 to 9.0 in *Elephas*, and 3.0 to 11. 0 in *Mammuthus*; and enamel thickness on M3 of 4.0 to 2.0 mm in *Elephas*, and 5.5 to 1.0 in *Mammuthus*). Cranial material is lacking from the Sternberg Elephant Quarry, therefore it is not possible on morphologic grounds alone to assign the material from the Sternberg Elephant Quarry to a more precise taxon than the Elephantinae, or perhaps the unnamed clade containing both *Elephas* and *Mammuthus*. Since Maglio (1973), most works have just adopted *Mammuthus* as the North American elephantid taxon. However,

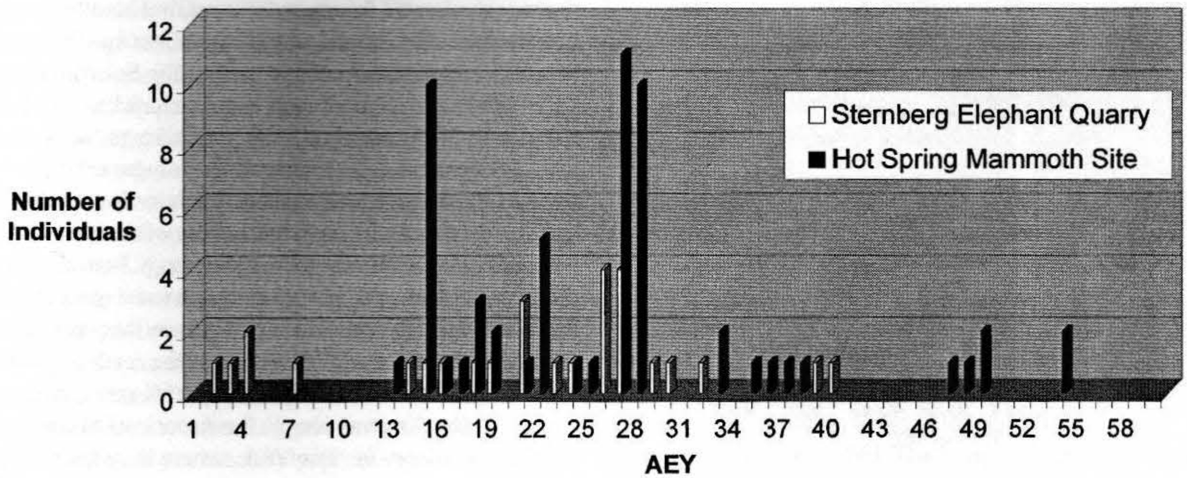

FIGURE 1. Age distribution of the individual mammoths at the Sternberg Elephant Quarry, Kansas and the Hot Springs Mammoth Site, South Dakota. Numbers of individuals are shown with their assigned African elephant year (AEY) ontogenetic age determination. Data on Hot Springs from Agenbroad, 1994.

lacking a comprehensive phylogenetic analysis of North American Elephantinae at a refined taxonomic level, identifying material more precisely than morphology allows only the 'illusion of accuracy,' and may in fact be hindering the advancement of knowledge about elephantid relationships and paleobiogeography in North America.

POPULATION STRUCTURE

Having multiple individual elephants preserved in a single locality provides the opportunity to study their demographics. Elephant teeth progress through the mouth of the individual throughout its lifetime, and by determining a tooth's position and its relative state of wear it is possible to make some assertion about the ontogenic age of the individual at the time of death. This has been codified for *Loxodonta africana* lower teeth by Laws (1966; see also Fatti et. al., 1980; and Jachmann, 1988), and applied to mammoths (Saunders, 1977; Haynes, 1985 and 1991:Appendix; and Agenbroad, 1994). The teeth are assigned to a wear class based upon eruption stage and degree of wear, and the classes have been correlated to a standard number of African elephant years (AEY). There are methodological differences between different authors, and using different aging criteria (e.g., between Laws, 1966 and methods used by Haynes, 1991) could lead to slightly different results. Haynes (1985) noted that using a modified set of criteria, he would age an individual at 12 years, whereas the individual would be scored as 15 or 16 years using the Laws criteria. Agenbroad and Mead (1987) used both methods on the Hot Springs population and found modest differences. Variation of a few years will not greatly affect the results presented here, but the error inherent in the practice needs to be acknowledged.

There are several assumptions that must be made when considering the Sternberg Elephant Quarry population. We only have a fraction of the entire sample reportedly collected from the site, and the sample may or may not be representative. From the sample that we do have, we can only assign AEY ages to the lower teeth as those are the teeth used in the models (Laws, 1966). Also, we are almost completely ignorant of the depositional setting and any taphonomic processes that might have occurred at the site. We do not know over what time span the site was actively accumulating its fauna. But, assuming that the specimens we can assign an age to are representative of all the fossils, we can make some statement about the preferential preservation of some age classes. Also, it should be noted that assigning an age estimate to a particular tooth is highly dependent on proper tooth position determination, and any error in that determination will have profound impact on an age assignment.

Table 2 shows the AEY assignments applied to the lower molars from the site. The age assignments range from 4 to 40 years old, with an average of 21.5. By comparison, the range of individual ages at the Hot Springs Mammoth Site is slightly older, ranging from 13 to 54 years, with an average age of 26.4 years. The individuals from both sites are plotted by age in Fig. 1, and the sites are compared by percentage in 10 year age classes in Fig. 2.

The overall pattern of the two sites is very similar. Both sites are biased overall toward younger individuals, and Agenbroad and Mead (1994) argued that this pattern shows a selective death assemblage,

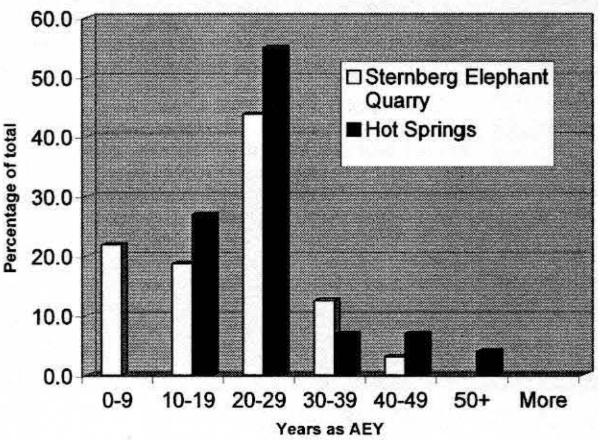

FIGURE 2. Comparison of the age distributions of individual mammoths from the Sternberg Mammoth Site, Kansas, and the Hot Springs Mammoth Site, South Dakota. Individuals are grouped by 10-year age class and shown as a percentage of the total number of aged specimens. Data on Hot Springs from Agenbroad, 1994.

as opposed to catastrophic or attritional patterns. The Hot Springs Site is dominated by animals in the 10-19 and 20-29 age groups, with individuals tailing out into the higher age classes. The Sternberg Elephant Quarry also is dominated by animals in the 20-29 class, but is slightly more skewed toward the younger classes. Eighty-six percent of the individuals are in the 20-29 class or younger.

Hot Springs acted as a natural trap. The geology of the site indicates that a spring developed in a sink hole, with steep walls formed by the relatively slick Spearfish Formation bedrock (Laury, 1994). All the animals examined from the site have been sexed as male. The site seems to have been selective for the behavior of young male mammoths, with mostly young individuals, and a few older ones, becoming trapped (Agenbroad, pers. comm., April, 2007).

Certainly, the individuals preserved at the Sternberg Elephant Quarry that can be assigned an ontogenic age are juvenile or young adult. Unfortunately, we lack specific information about the depositional setting. Although Williston's (1898) assertion that the site was a spring is suggestive, it might be taking the available evidence on the Sternberg Elephant Quarry too far to suggest that the site was a natural trap in a similar fashion as the Hot Springs Mammoth Site, but another explanation for the observed population structure is hard to imagine.

CONCLUSIONS

The Sternberg Elephant Quarry has an interesting history. The site was excavated by Charles H. Sternberg, a fossil collector of great note who contributed a lifetime of work collecting for museums around the world. He was driven by science, but also by the economic reality that he needed to collect specimens to sell to support himself and his family. Somehow, he gained the rights to collect in northeastern Lane County, Kansas, in the summer of 1894 and there he 'mined' the locality for elephant teeth. Evidently he felt that the non-dental material was not worth saving, perhaps not marketable to the museum buyers of the time, and therefore not worth the effort to preserve. Instead, being resourceful, he hoped to sell the bone to be ground for fertilizer, but it is not clear if this was in fact transacted. We know that a sizable collection of the teeth from the site was preserved at the University of Kansas, and a smaller collection was sent to the American Museum of Natural History in New York, where they reside today. Some specimens seem to have made their way to SDNHM through Sternberg's association with W. O. Bourne. At least some specimens were sent to Henry Ward, who developed the scientific supply company specializing (then as now) in sending materials to schools and museums. Hay (1924) mentions specimens at Ward's, and there is preserved correspondence between Sternberg and Ward about the sale of mammoth teeth. Although a 'smoking gun' document showing a bill of sale for numerous teeth was not found in the course of this study, the sale of the teeth to Ward and his subsequent distribution of the material piecemeal to far-flung buyers is the most likely explanation for the fate of the unaccounted-for teeth.

We have some information about the nature and location of the site, but it too remains lost. There are likely no more mammoths to be found at the site, as Sternberg indicated that he recovered them all. But perhaps the site can yet be located, and it might be possible to add to our understanding about its physical character and perhaps the mechanism that accumulate the fauna at this site. The evidence indicates that the mammoths preserved there were primarily young individuals, perhaps victims of a trap. In any case, the Sternberg Elephant Quarry was one of only a handful of sites known to have preserved many individual mammoths within North America.

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