Evidence for a human occupation of the North American Great Plains during the Last Glacial Maximum

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Ten mammoth bone sites older than 11,700 rcybp in the central Great Plains of North America (figure 1) provide evidence of a human occupation during the Last Glacial Maximum and before the beginning of the Clovis techo-complex at *ca.* 11 500 rcypb. The senior author has worked on seven of these sites in the last 20 years. The other three sites were investigated by Dennis Stanford of the Smithsonian Institution from the mid 1970's through the early 1980's. The evidence for a human technology, the geological context and the age of each site will be discussed. Experimental breakage and flaking of elephant limb bone provides support for the hypothesis that only humans wielding hammer stones can produce the type of impact points with negative bulbs of percussion and bone flakes found at these sites, and that indeed the late Pleistocene sites discussed are archaeological in origin. In conclusion, a model of human arrival in the central Great Plains of North America will be presented.

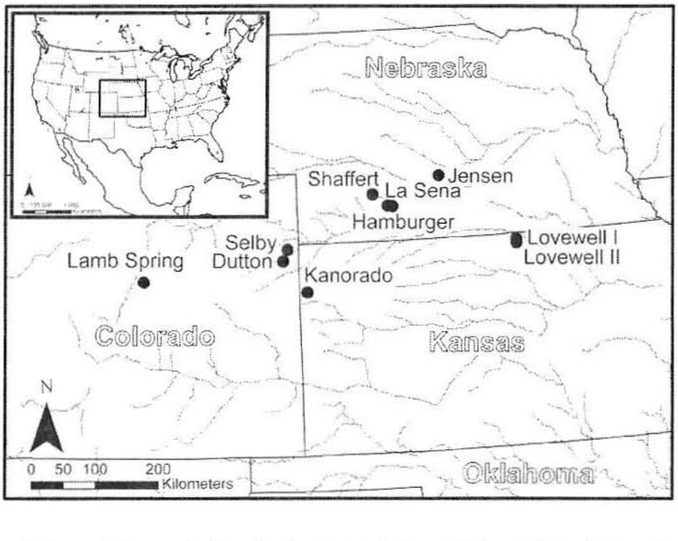

Figure 1. Map of the 10 Mammoth Sites in the Central Great Plains of North America.

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Smithsonian Investigations, 1975-1981

Dutton and Selby

Two sites, Dutton and Selby, in the plains of eastern Colorado, USA, were excavated by Dennis Stanford of the Smithsonian Institution in the mid to late 1970's (Stanford, 1979; Stanford and Graham, 1985). The two sites are situated in upland playas in a late Wisconsin loess landscape. Evidence for a pre-Clovis occupation at the Dutton and Selby sites is derived from impacted and flaked mammoth and large ungulate bone in the Peorian loess, lacustrine levels and an overlying buried soil at both sites. Mammoth bone from the Dutton Site was radiocarbon dated to 11,710 $\pm$ 150 (SI-2877) and this is considered a minimum age. Impact points on mammoth and large ungulate limb bones show how the bones were broken for marrow extraction and the production of bone tools and choppers. These tools are reported from levels dating back as far at 16,330 $\pm$ 320 (SI-5185) in Peorian loess. Several lithic flakes were found in the screen washing from the pre-Clovis level, however none were found in place. Stanford (1999) urges caution in the interpretation of the mammoth bone modification as evidence of human actions after earlier interpreting the bone breakage as human in origin. Work by the author on additional sites in the central Great Plains and experimental breakage of elephant limb bone discussed below suggest that Stanford's earlier interpretation was correct (Stanford, 1979; Stanford *et al.*, 1981; Stanford and Graham, 1985).

The Lamb Spring Site

The Lamb Spring Site south of Denver, Colorado, consists of numerous mammoth skeletons found around several spring seeps (Rancier *et al.*, 1982; Fisher, 1992; Mandryk, 1998; Stanford *et al.*, 1981). Evidence for human modification of mammoth bone consists of the presence of impacted and flaked limb bones, while lighter bones like ribs and scapulae are intact. The presence of two stone artifacts, a 16.3 kg boulder with battering on the pointed end and a flaked quartzite bifacial wedge support the hypothesis that humans were responsible for the bone breakage according to the site excavator (Stanford, 1999). However, Fisher (1992) interprets this data as inconclusive. Three radiocarbon ages are reported for the site, with two bone dates of 11,735 $\pm$ 95 (SI-4850) and 13,140 $\pm$ 1000 (M-1464), and one on organics of 12,750 $\pm$ 150 (SI-6487). The geological situation is complex as multiple spring channels contain mammoth bone. Dixon *et al.* (1997) suggest the main concentration of mammoth bone is in the range of 13,000-14,000 rcybp; however, some radiocarbon ages from the deposit are as early as 17,850 $\pm$ 550 (Elias and Nelson, 1989) and some bone is from deposits dating 25,000-26,000 rcybp (Mandryk, 1998). All the radiocarbon ages from Pleistocene deposits are older than Clovis. However, direct dating of the impacted and flaked limb bone would help resolve the age of the proposed human involvement with the site.

Table 1. Mammoth sites in the Central Great Plains with geological deposits and ages

Sites	Geology	C-14 age	Evidence of Human Technology
1. Dutton	Lacustrine silt/clay and loess	11,710±150 – 16,330±320	impact points, bone flaking
2. Selby	Lacustrine silts/clay and loess	(same stratigraphy and age as Dutton)	impact points, bone flaking
3. Lamb Springs	alluvial spring deposits	11,735±95 – 26,000	Impact points, bone flaking, hammer stone, lithic wedge, differential breakage of limb bone
4. La Sena	Peorian loess	18,440±145	impact points, cone flake, bone flaking, anvil and spatial patterning of debit age around anvil, differential breakage of limb bone
5. Shaffert	Peorian loess	15,600±300	impact points, bone flaking
6. Hamburger	Peorian loess	16,480±60	impact points, differential breakage of limb bone
7. Jensen	Peorian loess	14,830±230	impact point, bone flaking, differential breakage of limb bone
8. Lovewell I	Fine-grain alluvium	20,430±300	bone stacking, spiral fractures, skull position
9. Lovewell II	Fine-grain alluvium	19,530±80	impact points, cone flakes, bone flaking, bifacially flaked bone tool, polished bone tool
10. Kanorado	Fine-grain alluvium	12,375±35 & 12,670±60	impact point, bone flake scar, differential breakage of limb bone

Recent Investigations, 1989-2008

Seven sites containing human-modified mammoth bone have been investigated by the senior author in the last 20 years. These include La Sena, Hamburger, Jensen, Shaffert, Lovewell I & II and Kanorado. These sites range in age from *ca.* 12,000-20,000 rcybp and all were excavated in very fine-grained loess or alluvium (table 1). These geological deposits are very low energy depositional situations ideal for studying taphonomy of mammoth bone because geological forces were not a factor in the bone breakage.

Medicine Creek Valley Sites, Southwest Nebraska

La Sena Mammoth

Investigated from 1989-1998, the La Sena Mammoth Site consists of a single adult male mammoth situated 3.5 m deep in late Wisconsin Peorian loess at Medicine Creek Reservoir in southwest Nebraska (Holen, 2006; Holen and May, 2002; May and Holen, 1993). Evidence of human modification of the mammoth bone is in the form of differential breakage patterns on limb bone versus lighter bones like ribs and vertebrae. The only complete elements on the site are ribs and vertebrae, while the limb bones were heavily broken while still fresh by blows from an object that is 5 cm in diameter at the point of impact. Impact points occur on both femora and on opposite sides of the bone. Bone flakes are also present (figure 2) in addition to one cone flake. There are no chipped stone tools associated with the mammoth

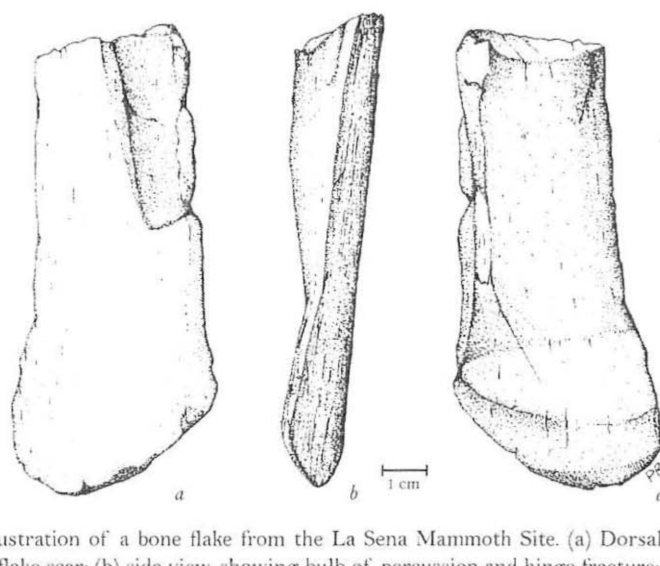


Figure 2. Illustration of a bone flake from the La Sena Mammoth Site. (a) Dorsal (Cortical) face exhibiting a flake scar; (b) side view, showing bulb of percussion and hinge fracture; (c) ventral face showing bulb of percussion and platform.

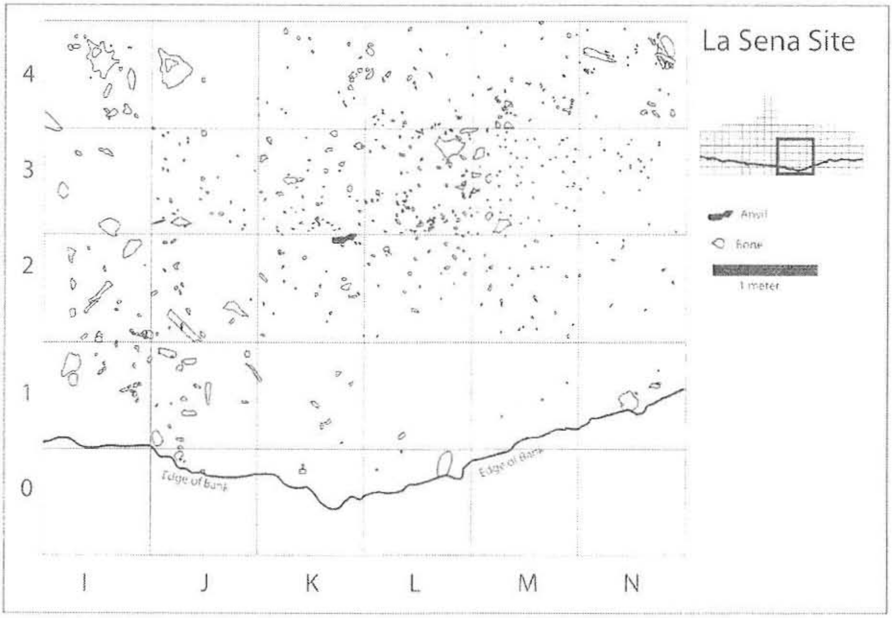


Figure 3. La Sena Mammoth Site, the anvil and distribution of bone debitage surrounding the anvil.

indicating that it was probably not killed and butchered by humans. It appears that the bone was quarried for use in making bone tools, although marrow extraction cannot be ruled out. A heavy concentration of small spirally fractured pieces of limb bone around a broken vertebra standing vertically with wear patterns on the upper surface indicate that this bone was used as the anvil on which to break the limb bones (figure 3).

The La Sena Mammoth Site is well-dated at 18,440 ± 145 (AA-6972) with stratigraphically sequent dates both above and below the mammoth (Holen, 2006; Holen and May, 2002; May and Holen, 1993). These ages agree with the well-dated regional sequence for Peorian loess.

The Hamburger Mammoth

The Hamburger Mammoth Site is situated at Medicine Creek Reservoir about 2 km distant from the La Sena Mammoth, about 4 m deep in late Wisconsin Peorian loess (Holen and May, 2009). The mammoth was excavated from 2000-2002 and consists of the partial remains of a single adult mammoth about 34-36 years old. The mammoth consists of highly fragmented post-cranial elements, skull fragments and molars. Only seven complete elements were found, one tibia, five ribs and one foot bone (figure 4). Many limb elements

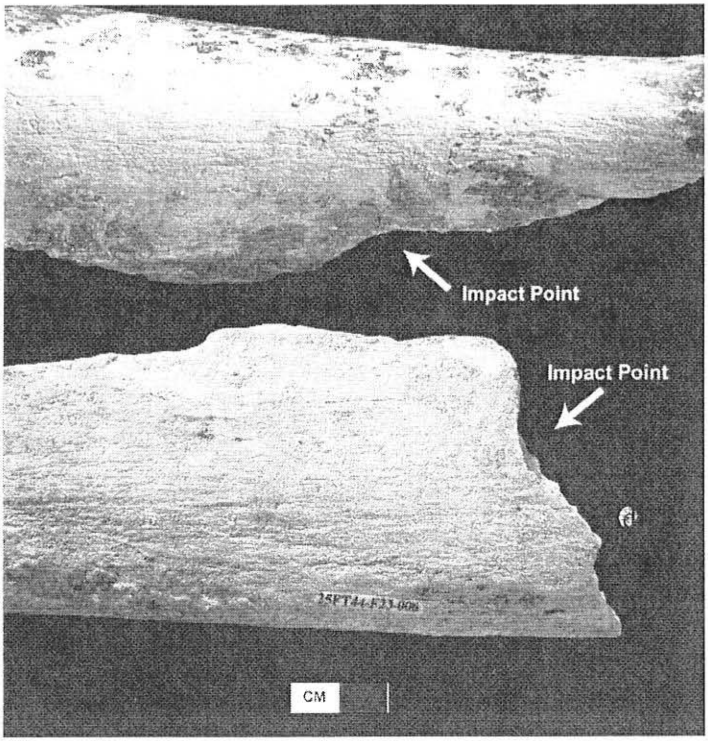


Figure 4. Impact points on mammoth limb bone from the Hamburger Mammoth site.

are spirally fractured and three segments exhibit impact points (figure 4). The lack of stone tools and chop/cut marks on the bone indicates that humans did not butcher the mammoth. Instead, like the La Sena Mammoth, bone quarrying is indicated. A single radiocarbon age was obtained on cortical limb bone, this age is 16,480 $\pm$ 60 rcybp (CAMS-94859).

The Shaffert Mammoth

The Shaffert Mammoth Site is situated in the Peorian Loess uplands of a tributary of Medicine Creek (Holen and May, 2002) about 21 km northwest and upstream from the La Sena Site. Unfortunately, much of the site eroded away before our investigations in 1995-1997. The site consists of the partial skeleton of an adult mammoth that exhibits numerous spiral fractures on limb bones. One limb bone exhibits an impact point and one flake scar indicating that humans broke the bone. One radiocarbon age of 15,600 $\pm$ 60 (CAMS-38688) was obtained from bone collagen. This age agrees well with the stratigraphic position of the mammoth in Peorian loess.

Mammoths at Lovewell Reservoir, North-Central Kansas

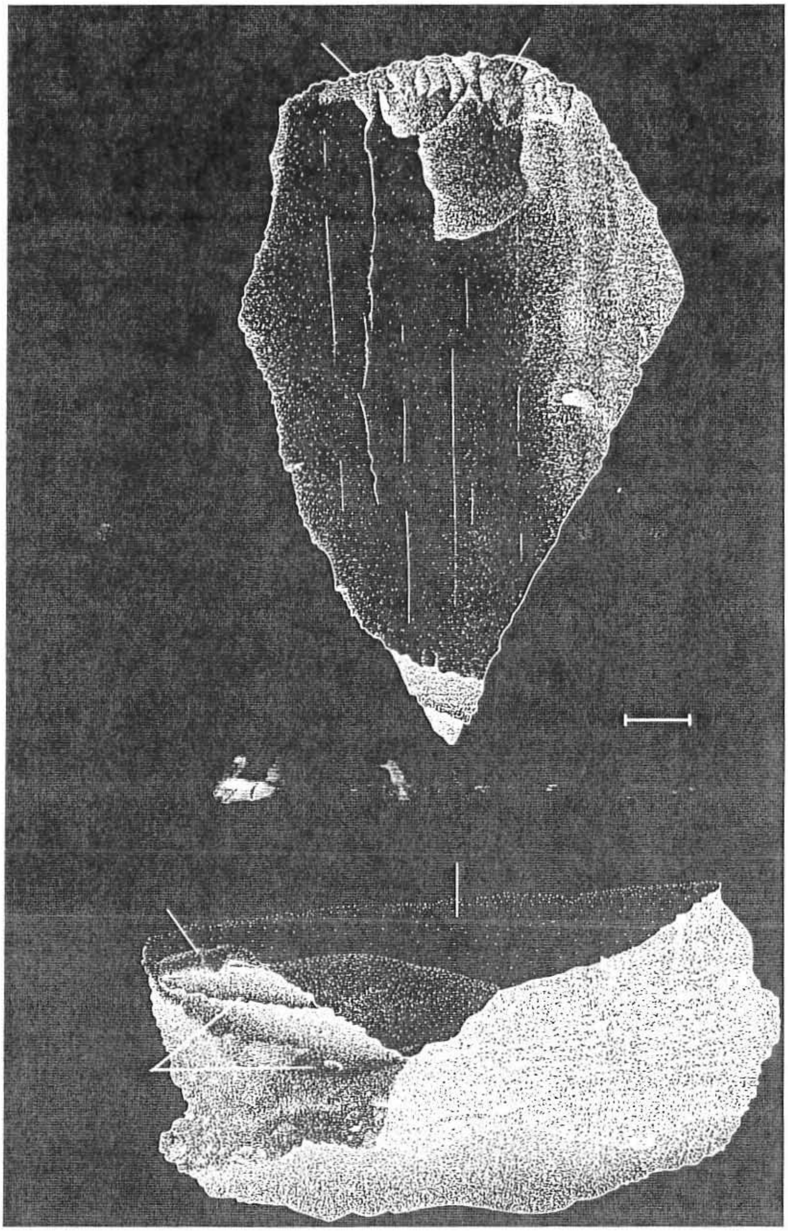
The Lovewell Mammoth Site is located at Lovewell Reservoir in north central Kansas and consists of two separate concentrations of mammoth bone that were modified by humans (Holen, 2006, 2007). Excavations were conducted in 1969, 1991, 2002, and 2004.

Lovewell Mammoth I

Lovewell Mammoth I was excavated in 1969 by archaeologists from the Kansas State Historical Society (Holen, 2006, 2007). They noted numerous spiral fractures on the limb bone, bone stacking, and the reversed position of the skull with the tusks pointing back toward the post-cranial skeleton. Unfortunately, the excavation was not completed because a geologist told the excavators that the mammoth was in a geological deposit that was over 100,000 years old. The archaeologists left the excavation and the reservoir covered the mammoth. The site was almost completely destroyed by 1991 when the reservoir was low enough to expose the mammoth again. Discovery of an *in situ* rib in 2002 allowed one radiocarbon age of 20,430 ± 300 (CAMS-1127[illegible]). The mammoth is now known to be situated in alluvial silt that is part of the late Gilman Canyon Formation and not in pre-Sangamon Loveland Loess as previously reported in 1969.

Lovewell Mammoth II

The Lovewell Mammoth II was discovered in 1991 when the reservoir was at very low level (Holen, 1996, 2006). It was presumed at the time that the mammoth described above had been re-discovered, but additional excavation in 2002 produced evidence of two mammoths separated by about 80 m and in different alluvial fills. Excavation in 1991, 2002, and 2004 revealed a partial single mammoth situated in alluvium in a shallow swale. The mammoth exhibits highly fragmented spirally fractured limb bone (Holen, 2006, 2007). The limb bone exhibits impact points, cone flakes and numerous bone flakes and flake scars are present (figure 5). One bifacially flaked piece of cortical limb bone appears to be a small chopping tool. The tip of a highly polished bone tool (Holen, 1996) appears to be the broken tip of a bone rod, similar to those found in Clovis and upper Paleolithic sites. Two radiocarbon ages indicate the site dates to the Last Glacial Maximum, with the first age (Holen, 1996) on bone of 18,250 ± 90 (CAMS-15636). A more recent bone collagen radiocarbon sample taken from the bifacially flaked bone tool provides the best age for the site of 19,530 ± 80rcybp (UCIAMS-11211) (Holen, 2006, 2007) because it was acquired from more highly-purified bone collagen.



Step

Figure 5. Thick cortical limb bone segment from the Lovewell II Mammoth Site exhibiting intersecting radial fractures and a negative flake scar (upper) and an impact point (lower).

The Jensen Mammoth

The Jensen Mammoth, in the Platte River Valley in south-central Nebraska was first excavated by paleontologists from the University of Nebraska State Museum in 1993 and by archaeologists from the same institution in 1993-1996 (Holen, 1995; May and Holen, 2005). The site contains much of the skeleton of a single old adult male mammoth situated in Peorian loess. The mammoth exhibits differential breakage of some limb bones, while the ribs, vertebrae and other lighter elements are generally complete. The limb bone exhibits impact points and a bone flake is present (figure 6). The lack of stone tools and the fact that this old mammoth probably died naturally indicates that the only action taken by humans was the breakage of selected limb bones, probably to quarry bone segments for the manufacture of bone tools. Two radiocarbon ages, one on bulk soil humates and one on bone collagen, are available. The sediment date is 14,830 ± 220 rcybp (Tx-8135) and the bone date is 13,880 ± 90 rcybp (Beta-68859). In this case, the sediment age is considered the more accurate of the two based on the stratigraphic position of the mammoth 3.5 m deep in Peorian loess.

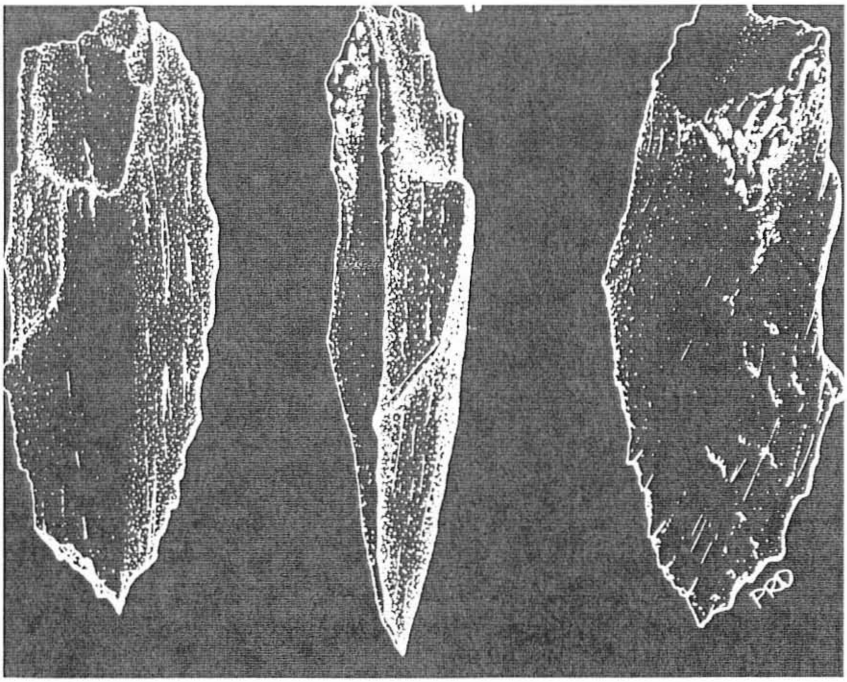


Figure 6. Illustration of a bone flake from the Jensen Mammoth Site. (a) Dorsal (Cortical) face exhibiting two flake scars; (b) side view, showing bulb of percussion and feathered termination; (c) ventral face showing bulb of percussion and platform.

The Kanorado Locality

The Kanorado Locality was first excavated by paleontologists from the Denver Museum of Natural History (now Nature & Science) in 1976 after a mammoth molar was found in a construction cut by the landowner. The locality is located in a late Pleistocene/early Holocene alluvial fill along Middle Beaver Creek in very western Kansas. The paleontologist at the time recognized differential breakage of limb bones that did not appear to be natural. An attempt to get archaeologists interested in excavating the site failed. The locality was later tested by archaeologists from the same institution in 1981, but no definitive archaeological component was identified.

The locality has been reinvestigated by archaeologists and geoarchaeologists from the Denver Museum and the University of Kansas from 2002-2008. At least three late Pleistocene and three early Holocene archaeological components have been identified at three archaeological sites within the locality with the oldest components being *ca.* 11,000 to 13,000 rcybp (Mandel *et al.*, 2004), including one Clovis age lithic component. The oldest component at site 14SN105 consists of mammoth limb bone that exhibits an impact point and a negative flake scar (figure 7). These elements are derived from a component dated to 12,375 $\pm$ 35 rcybp (UCIAMS-11214) on bone collagen. At site 14SN101 a piece of spirally fractured mammoth limb bone is dated to 12,670 $\pm$ 60 rcybp (NZA-28699). While no stone tools have been found in these components, the fracture patterns on mammoth limb bone indicate human technology is present.

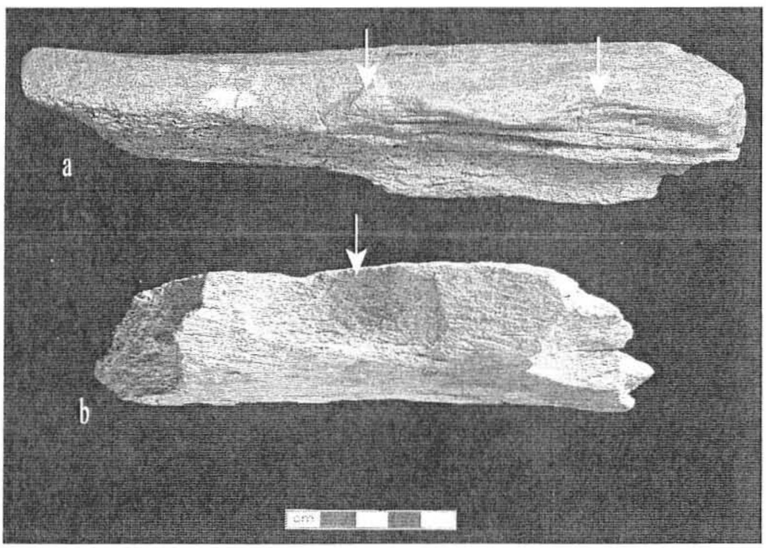


Figure 7. Mammoth cortical limb bone segments from the Kanorado locality, site 14SN105. (a). Two impact scars shown by arrows; (b) flake scar shown by arrow.

Discussion

Evidence from the 10 mammoth sites presented above indicates three things in common; their geological context in fine-grained eolian or alluvial sediments, radiocarbon or stratigraphic ages that are older than the Clovis techno-complex and the mammoth limb bone was heavily broken while the bone was still fresh by high-velocity impacts (table 1). One site, Lamb Springs, contains a large boulder with battering on one end that was probably the hammer used to break the mammoth limb bone. The fine-grained low energy geological context of each site eliminates the possibility that geological processes were responsible for the breakage of the limb bone. Previously, other hypotheses offered to explain this mammoth limb bone breakage by carnivore gnawing and mammoth trampling and have been rejected (Holen, 2006). The two sites with the best evidence for human modification of mammoth limb bone are La Sena and Lovewell II. Lamb Springs with the associated hammer stone and chipped stone wedge also offers good evidence of human technology, but the actual modified mammoth bone needs to be dated as the site may be multi-component.

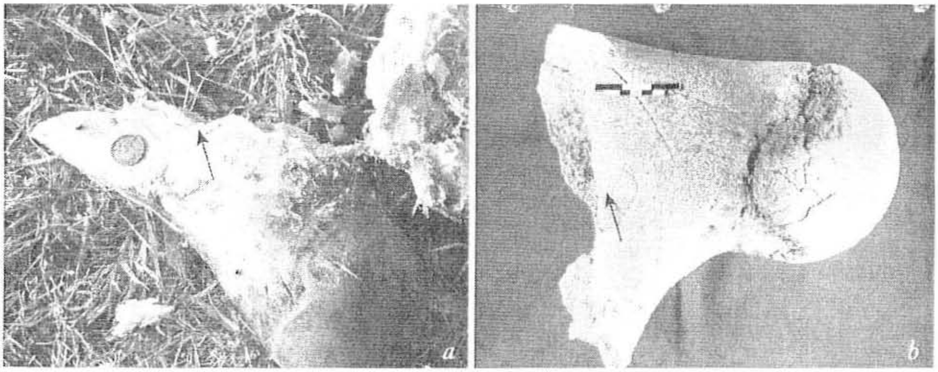


Figure 8. Experimentally-produced impact point. (a) On proximal elephant femur and impact point; (b) on La Sena proximal elephant femur (circular depression has not detached).

Evidence of the same type of mammoth bone breakage, including impact points, cone flakes and bone flaking, from Clovis-age sites in America support the hypothesis that humans commonly broke mammoth limb bone in order to make expedient and highly patterned bone tools (Arroyo-Cabrales *et al.*, 2001; Hannus, 1989,1990; Johnson, 1985; Miller, 1989; Steele and Carlson, 1989). Morlan had concluded that: "Actualistic and experimental studies have failed thus far to identify any agency other than hammer stone use by people that can induce fractures by point loading on fresh proboscidean bone" (Morlan, 1984). This interpretation is supported by evidence from the sites reported above and by later researchers (Arroyo-Cabrales *et al.*, 2001; Hannus, 1989, 1990; Holen, 2006, 2007; Johnson, 1985; Miller, 1989; Steele and Carlson, 1989) and Morlan's conclusion has not been refuted. The sites discussed above that exhibit impact points and bone flaking date between 11,700 and 20,500 rcybp, indicating a human presence on the central Great Plains of North America during and just after the Last Glacial Maximum (LGM) and before the Clovis techno-complex.

Experimental Elephant Limb Bone Fracturing

An elephant limb bone breakage experiment was conducted by the authors in Tanzania, Africa, in 2006, in order to better understand the mechanics of impacting and flaking thick cortical proboscidean limb bone and to reproduce the impact points and bone flaking present on the mammoth limb bone at several sites noted above (Holen and Holen, 2006). The ultimate goal was to further test the hypothesis that humans wielding hammer stones could produce the types of impact points, cone flakes, spiral fractures and bone flaking found at the mammoth sites. This type of experiment with breaking elephant limb bone has been conducted before in the Ginsberg Experiment (Stanford *et al.*, 1981) and the Denver Elephant Project (Hershey, 1979); however, the complete results of this research have never been published.

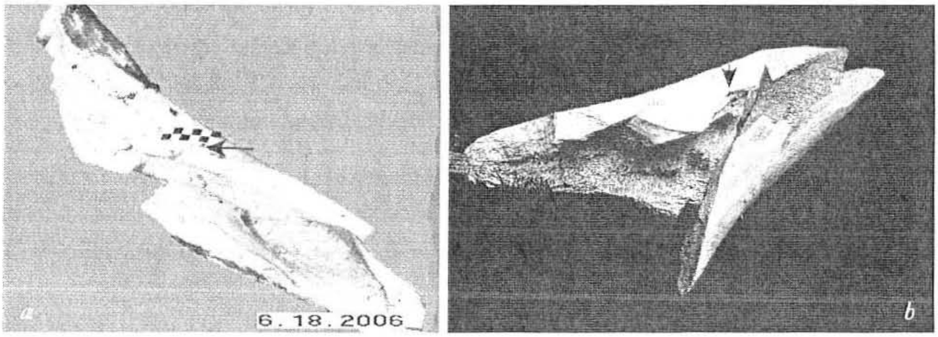


Figure 9. Experimentally-produced impact point and long intersecting spiral fractures on elephant femur mid-shaft (a, refit of two segments), and impact point and long intersecting spiral fractures on La Sena mammoth femur mid-shaft (b, refit of four segments).

A 28-30 year old male elephant died along a road in Ngorogoro Crater National Park. The authors were allowed to remove one femur from the elephant for the experiment, but were not allowed to remove any of the elephant bone from the country. The experiment involved the production of impact points and bone flaking like that present on limb bone from the La Sena Site, Lovewell Mammoth and several other sites discussed above. In order to break the femur, a 4.5 kg cobble was hafted onto a 1.2 m-long wooden handle with cow rawhide (figure 8). The cobble tapered to a 5 cm diameter point and provided a large mass to small point ratio in order to produce the same size of impact points found on the La Sena mammoth femora. An anvil was constructed from dimension lumber with the narrow 5 cm wide edge of the 5 by 10 cm board as the anvil surface. This was done to replicate the approximate width of the vertebrae anvil found at the La Sena Site (Holen, 2006; figure 2 above).

Figure 10. Steven Holen breaking elephant femur on an anvil using a 4.5 kg hammer stone hafted on a long handle.

The elephant femur proved to be amazingly durable and it took 10 blows to break the femur near the proximal end and produce an impact notch (figure 9a). Subsequent blows to the mid-shaft produced negative bulbs of percussion and long spiral fractures (figure 10a). Bone flaking was accomplished with a 0.5 kg hand-held hammerstone. Both longitudinal and transverse flakes were produced. A longitudinal flake 13.9 cm long exhibited a prominent bulb of percussion (figure 11a) and a transverse flake 14.2 cm wide exhibited a diffuse bulb of percussion (figure 12a). The impact notches, long spiral fractures, intersecting radial fractures and bone flakes are morphologically identical to those from the La Sena and Lovewell sites (figures 10b, 11b, 12b). The distribution of small pieces of bone debitage around the anvil (figure 13) replicates the distribution pattern around the bone anvil at the La Sena Mammoth Site (figure 2; Holen and Holen, 2006).

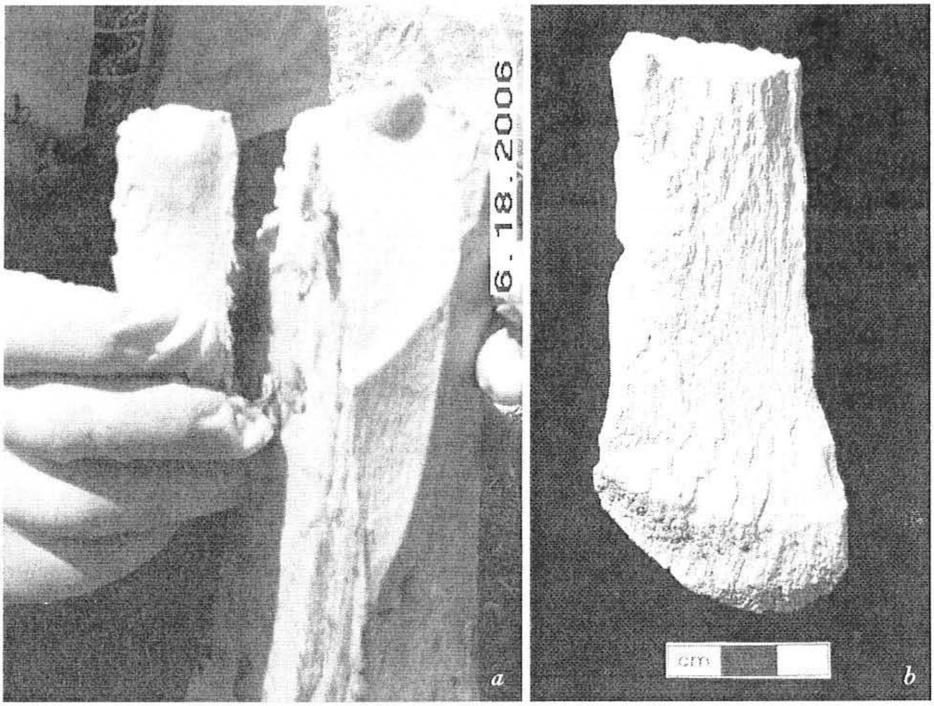


Figure 11. Longitudinal flake (13.9 cm long) experimentally produced on elephant femur (a), and longitudinal flake (10.3 cm long) on La Sena mammoth limb bone (b).

The results of this experiment indicate that humans wielding hafted hammer stones cause the same types of impact points and cone flakes on elephant limb bones as those found on mammoth limb bones in Clovis and pre-Clovis age sites. Bone flaking with a hand-held hammer stone produced both longitudinal and transverse flakes like those excavated at several of the sites discussed above. This experiment, along with the earlier elephant bone breakage experiments, strengthens the argument that only humans wielding hammer stones can produce this type of breakage on thick cortical mammoth limb bone.

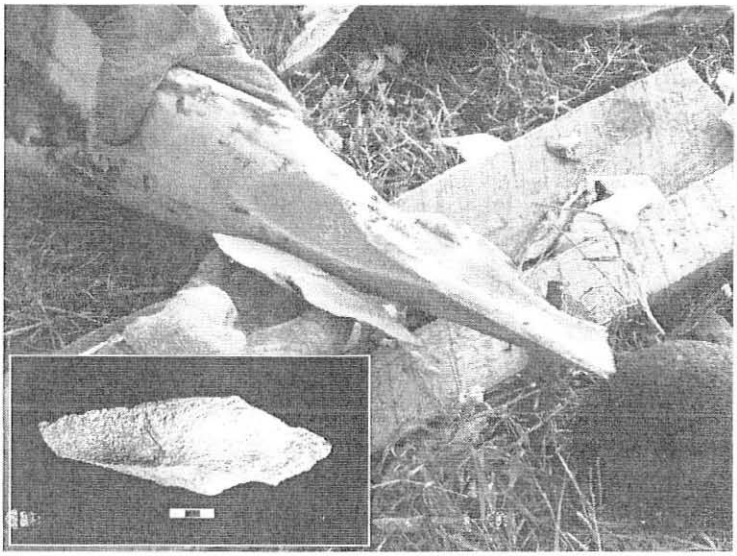


Figure 12. Transverse flake (14.2 cm wide) experimentally produced on elephant femur (upper) and transverse flake (20.3 cm wide) on Lovewell Mammoth II limb bone (insert).

Figure 13. Distribution of bone debitage surrounding the anvil in the elephant bone breakage experiment.

Conclusion

Glacial ice covered Canada during the Last Glacial Maximum (LGM) (figure 14) from about 22,000 rcybp and after the LGM until *ca.* 11,500 rcybp. This fact indicates that humans must have arrived on the Great Plains before the ice blocked the interior North American route *ca.* 22,000 rcybp.

Late Pleistocene Upper Paleolithic populations became adapted to the treeless steppe biome in Eastern Europe and southern Siberia *ca.* 35,000-40,000 years ago (Hoffecker and Elias, 2007). This generally treeless biome extended across Siberia into Alaska and graded into the Great Plains steppe biome in the interior of North America. Once humans adapted to the Mammoth Steppe biome they could move relatively rapidly across Siberia into Alaska and south into the Great Plains of North America and further south into Mexico.

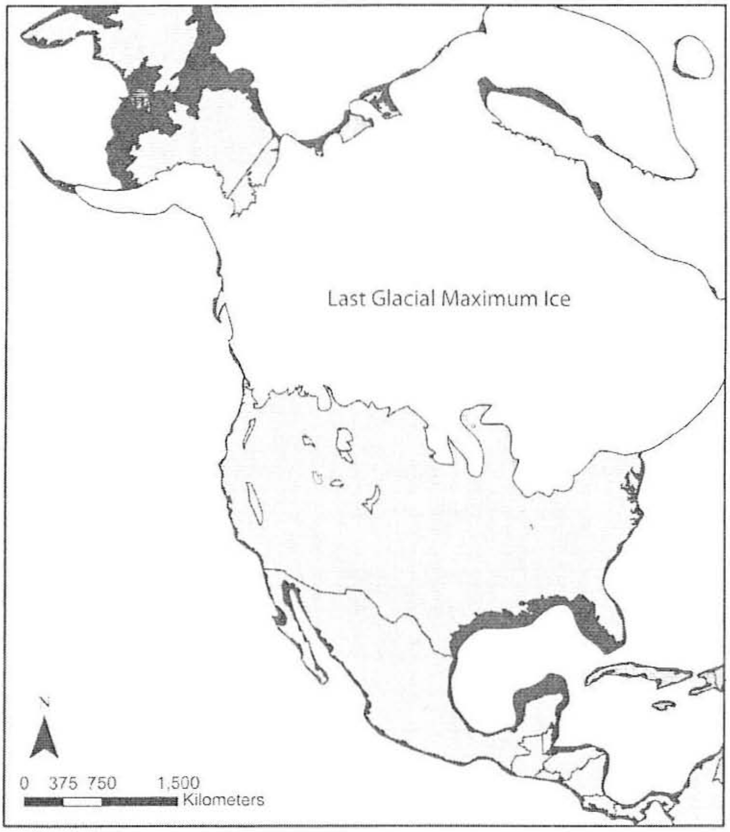


Figure 14. Last Glacial Maximum ice covers Canada from ca. 22,000 to 11,500 rcybp.

Human adaptation that led to the movement into this treeless Mammoth Steppe included a sophisticated bone and ivory technology including eyed needles that allowed humans to manufacture sewn clothing necessary to live in far northern climates. They also invented the use of bone as fuel, a necessary adaptation to a treeless environment. The invention of mammoth bone structures that did not require extensive use of wood also allowed people to live on the treeless steppe. A sophisticated lithic technology based on bifacial and blade tools allowed the production of the bone and ivory technology as well as high-quality lithic hunting and butchering tools.

Evidence of this far northern human adaptation to Arctic environments comes from both eastern and western Siberia (Pavlov and Indrelid, 2000; Pitulko *et al.*, 2004). Sites at 65° or farther north in northeastern Europe in Siberia and dating more than 25,000 rcybp include Bryzovaya, at 25,000-33,000 rcybp, and Mamontovaya Kurya, at 34,000-37,000 rcybp (Pavlov and Indrelid, 2000). Pitulko *et al.* (2004) describe the Yana Rhino Horn Site on the Yana River in the Beringian portion of Siberia at 72° north. The site consists of a rhinoceros horn beveled rod, two beveled bone rods, numerous stone tools, charred bone and numerous faunal remains eroding from a permafrost terrace fill. The site is well-dated to 27,000-28,000 rcybp, indicating humans were well-adapted to Arctic conditions in Beringia during the mid-Wisconsin. Because the ice sheet completely covered Canada about 22,000 rcybp and closed the land route into the central North American continent, humans therefore would have had 5,000-6,000 years to enter the Great Plains of North America from Siberia before the corridor closed. The distance from the Yana Rhino Horn Site to the U.S.-Canadian border is *ca.* 5,265 km via the Bering Land Bridge and southward east of the Rocky Mountain. This distance indicates that human groups would have had to expand at the rate of one km a year from the Yana River Site to an area not covered by LGM ice to have populated the Great Plains of North America before the ice blocked the corridor (figure 15). The human groups were already adapted to Arctic conditions so this expansion rate does not seem insurmountable once the adaptation is in place.

Evidence from the Old Crow Locality and Bluefish Caves in the Yukon provide further evidence that this adaptation reached North America at an early date. Impacted and flaked mammoth limb bone found at the Old Crow Locality and Bluefish Cave in the Yukon date back to 40,000 rcybp (Cinq-Mars, 1990; Morlan, 1984, 1986, 2003). Cut marks on bison bone from Old Crow date as early as 42,000 rcybp (Morlan, 2003) suggesting the human Arctic adaptation may have been even earlier that recorded at the Yana Rhino Horn Site. This evidence has generally been ignored by the archaeological community, but it has not been refuted. The impacted and flaked mammoth bone evidence for human occupation of the Yukon represents the same type of impact points and bone flaking found at the La Sena and other LGM mammoth sites and Clovis-age mammoth sites in the Great Plains (Holen, 2006). It would appear, based on this evidence, that humans bearing an Upper Paleolithic culture reached the Great Plains south of Canada sometime between 22,000 and 40,000

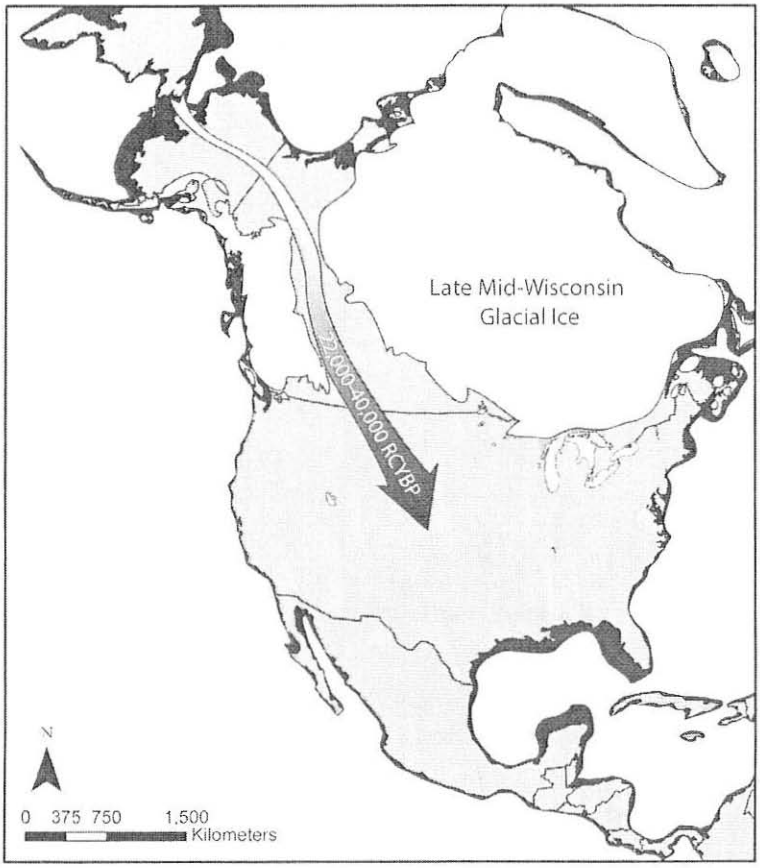


Figure 15. Hypothesized Mid-Wisconsin expansion of upper Paleolithic peoples from Beringia south to the Great Plains of North America.

rcybp (Holen, 2006) and that this hypothesis cannot be refuted with evidence presently available. Mandryk *et al.* (2001) suggest that the northern part of this "ice-free corridor" could have been blocked by glacial ice by 27,000 rcybp, indicating that the age range for this early human migration would have been before this date. An early coastal migration down the west coast of North America appears to have also occurred based on evidence from South America. This is not to suggest that these were the only or the earliest entries of humans into North America. Humans may have entered North America by both coastal and interior routes at several different periods.

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