Mammoth Graveyard

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Overview

When members of a construction crew bulldozed over a swath of land in Hot Springs, South Dakota one day in 1974, they were stunned to find a mass gravesite for Columbian mammoths.

The Columbian mammoth (*Mammuthus columbi*), a species of elephant, lived in North America during the late Pleistocene epoch. Scientists believe it went extinct about 11,000 years ago.

The crew postponed any further development near the site, and in stepped geologist Dr. Larry Agenbroad, who was then teaching at Chadron State College in Nebraska. In August 1975, Agenbroad and his team found a complete skull of a mammoth, with tusks. Providentially, the skull had been preserved before the bones could become displaced. The discovery justified a more substantive and continuous excavation, and in 1976, Agenbroad teamed up with Earthwatch to launch what is now the longest-running Earthwatch project on the portfolio.

In 1979, the team found its first "articulated" mammoth skeleton—meaning they were able to mount a nearly full mammoth body—plus additional skulls, tusks and bones. Soon after, Agenbroad worked with the local community to form a non-profit organization known as The Mammoth Site of Hot Springs, SD, Inc. They built a special facility around the site to enable public tours of the ongoing research excavation. The building was completed in 1986, and opened its doors to visitors - whose numbers soon exceeded 100,000 per year—as well as to volunteers enthusiastic to contribute to the excavation. The facility continues to benefit the local economy and offers a unique educational experience for students.

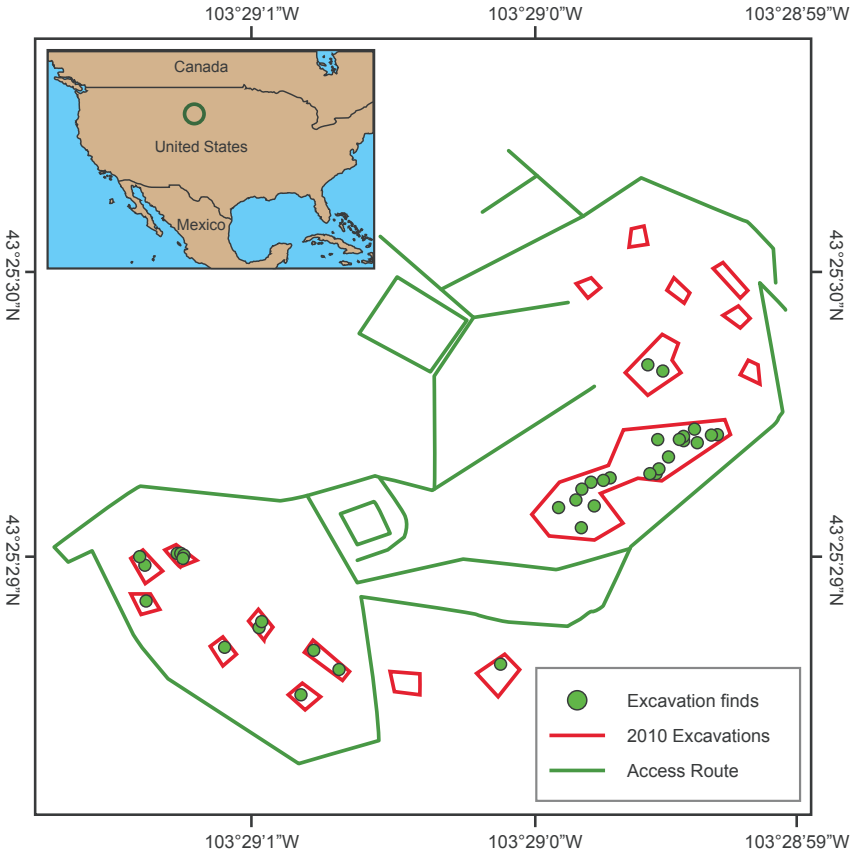

Figure 1: Map of the site showing areas under active excavation by team members in 2010.

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Geologic and hydrologic research revealed how the gravesite came into being. A sinkhole formed 26,000 years ago, after the roof of a cave collapsed. A pond formed when warm water from underground rose to the surface. Over time, this watering hole—which attracted the mammoths—filled with layers of silt and sediments that trapped the mammoths that ventured into it. Eventually, the watering hole became a mud hole, preserving the mammoth remains.

Researchers believe that the herbivorous mammoths were enticed by the warm water and green pond vegetation, entered the pond to eat, drink or bathe—and could not escape. Unable to scale the steep shale banks, the mammoths were trapped in the pit, eventually starving, drowning, or dying from sheer exhaustion.

The site is now the largest repository of Columbian mammoths in North America, and 60 complete mammoth skeletons —including three woolly mammoths (*Mammuthus primigenius*) have been unearthed to date.

Although it's not known exactly how deep the site is, drilling as far down as 67 feet has still brought up bones and ivory. At this time, approximately 50% of this depth has been investigated. What makes the site even more unusual is that

Figure 2: The *in situ* preservation and display of the fossil material at the Hot Springs mammoth site has served as a model for other paleontological and archaeological localities such as Ashfall Fossil Bed, Nebraska, and Waco, Texas.

the animals found here are in the exact same place they were when they died. In many other paleontological sites, around a sand bar or a riverbed, the remains of the animals move over time.

There are three goals of this Earthwatch project: to analyze the fossil community and environment within the sinkhole sediments; to provide a reconstructed "glimpse" into the composition, age, behavior, and way in which the Columbian mammoth population became fossilized (taphonomy); and to educate the wider community by providing an on-going, *in situ*, exhibit of the mammoths.

The research objectives are:

- To excavate, preserve and exhibit areas of the site, in both lateral and vertical dimensions
- To carry out taxonomic analyses of the yearly bone bed maps and selected skeletal elements via a computer mapping program
- To continue mapping all bones encountered on-site
- To continue numbering all *in situ* bones and those in storage

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Outcomes

Since 1976, more than 700 Earthwatch volunteers have helped Dr. Agenbroad and the research team to build a picture of South Dakota's Black Hills mountain environment at the peak of the last glaciation. They excavate the bone bed using trowels and other hand tools, they then wash, cast, and preserve their finds. They also use the animal's teeth to determine its age, and analyze specimens to figure out when each individual mammoth died.

Over the project's lifetime, several important facts regarding the mammoths and their environment have been established. First, all of the mammoths found to date were male, based on pelvis measurements derived from specimens found in frozen conditions. Dental data have also indicated that about 87% were 12-29 years old when they died. A mammoth's lifespan was between 60 to 80 years, so it seems the younger males were more likely to become entrapped in the hole, perhaps due to behavior specific to this age and sex.

To determine the time of year that the males tended to fall victim to the sinkhole, the team performed an oxygen isotope study on 15 tusks. The first laboratory results confirmed that the males died in early winter, while the second indicated that others died during the spring thaw. They believe that these two seasonal intervals account for most of the entrapments over a period of 300 to 750 years.

Scientists and volunteers have unearthed a variety of other animals in this area as well, including camel, llama, antelope, wolf, coyote, plus a whole host of invertebrates—helping scientists to develop and refine their model of how the local environment "worked" at the time (who was there, who ate who, etc).

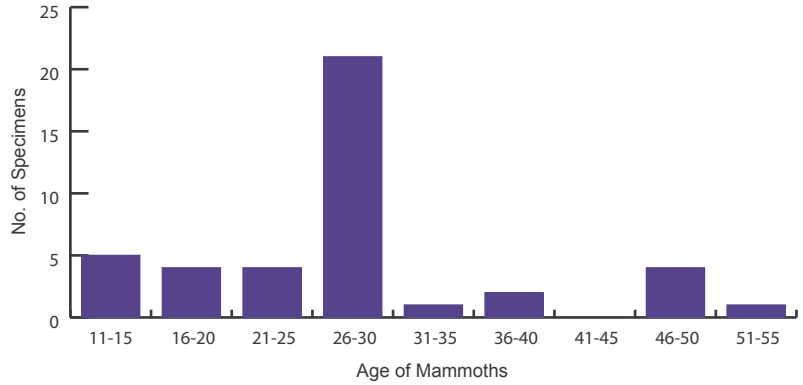

Figure 3: Graph showing how many mammoth specimens of each age range have been found at the Hot Springs site. Results indicate there is a high proportion of young (26-30 year old) mammoths.

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The researchers believe animals such as bison and horses were spared entrapment because their behaviors did not draw them to the sinkhole, perhaps because they are true grazers and the vegetation at the edge of a thermal pond was not enough to lure them into a dangerous place.

In 2010, the teams focused their efforts on the south-central area of the site, and the western portion of the bone bed. Dr. Agenbroad estimates that approximately five metric tons of back dirt was screen-washed, dried, placed in labeled bags and transferred to the laboratory for analyses during the one-month Earthwatch season. In total the teams found 64 mammoth bones, 541 fragments of mammoth bones, coprolites (fossilized animal dung), the tooth of a giant short-faced bear (*Arctodos simus*), an antelope, and several prairie dog (*Cynomys spp.*) remains. CAT scans of the short-faced bear and antelope remains will be done in 2011, revealing the internal bone structure without destroying the samples.

Over the course of the project, the methods used to map the bones have improved tremendously. Initially, in 1975, the teams laid out a square-meter grid using string, and drew a map on graph paper that correlated with the grid on the ground. These field maps were put together to provide a bone map for each season, and ultimately, the entire exposed bone bed. The teams progressed to using an "EDM transit" (Electronic Distance Measurement Transit) and computer mapping software, and then the EDM was replaced with a more high-tech, robotic transit and software. After 2001, the process of mapping was further enhanced by the installation of an overhead crane, which could lift heavy casts from the bone bed. A camera mounted on the crane allows the team to take photos of each bone added to the map. These photos were then converted to a computer image and bone coordinates established resulting in a map with greater than 3 millimeter accuracy.

An advantage of completing a bone bed map *in situ* is that if at some point in the future scientists develop a new analytical method, then the map will yield new insights into the factors affecting how the bones were deposited at the site.

The team is in the final stages of preparing an Osteological Atlas (a collection of illustrations of bones) for the Columbian mammoth. Once completed, it will be available for any scientist to carry out research on any specimen of the Order *Proboscidea* (elephants and their extinct relatives).

Figure 4: Earthwatch volunteers excavate the bone bed using trowels and other hand tools, then help preserve finds.

Recent Publications

Agenbroad, L., Esker, D. and Wilkins, J. (2010) The Mammoth Site of Hot Springs, SD: field trip and road log from Rapid City to the Mammoth Site. In; Terry, M., Duke, E. and Tickle, J. (Eds.) *South Dakota School of Mines and Technology Bulletin* **21:**178-186

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Falkingham, P., Agenbroad, L., Thompson, K. and Maning, P. (2010) Bird tracks at the Hot Springs Mammoth Site, South Dakota, USA. *Ichnos*, **17:**34-39