MAMMOTH TRUMPET

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Center for the Study of the First Americans
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A Fiery End to Clovis?

This photo was taken by Soviet geologist Kulik 21 years after a comet exploded in the upper atmosphere over Siberia in 1908. Trees, 80 million of them within a radius of 16 miles, were flattened and flash-burned when a chunk of ice and dust half the size of a football field slammed into Earth at 70,000 miles an hour. Geophysicist Allen West and his research team say this was a mere whisper, however, compared with the roar 12,900 years ago when a comet spanning *kilometers* shook North America. Intense heat formed a shroud of soot, creating a "nuclear winter" that ushered in the Younger Dryas cold snap. North American megafauna were doomed, and Clovis people's numbers were so decimated that the culture fell into swift decline, never to recover. To support this bold theory, Dr. West points to more than a dozen lines of evidence collected at Clovis-age sites across North America and as far away as Belgium. Installment 1 of our multi-part series exploring this Earth-shaking event starts on page 1.

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THE CLOVIS COMET

Part I: Evidence for a Cosmic Collision 12,900 Years Ago

FOR REASONS still not entirely understood, most of the large animals in the New World became extinct at the end of the Pleistocene epoch. For decades, their passing has been a source of wonder and contention among the researchers who study them. Natural vegetation shifts, climate changes, over-hunting by humans, plagues, and various combinations thereof have been put forward as proximate causes of the extinctions, though no definitive consensus has been reached.

As it turns out, all those theories might be further off the mark than previously realized. If the authors of a study published in the 7 October 2007 issue of the *Proceedings of the National Academy of Science* (*PNAS*) are correct—and over a dozen converging lines of evidence argue that they are—then a comet hit North America 12,900 years ago, dooming the Pleistocene megafauna and decimating the local human population.

BILL COVINGTON

Allen West sampling a backhoe trench profile at the Big Pine Tree site for Clovis-age sediments.

Allen West, whose research was the impetus for the *PNAS* study, realizes that some observers won't like the theory. But he's convinced it's the explanation that best fits the facts. The signs are well documented and copious; when taken together, they form a composite "smoking gun" that strongly suggests that something came out of the stars and hit us at the beginning of the Holocene. Following standard scientific protocol, West and his research team have entertained many other theories in search of a viable alternative. But in the end, he says, "We sure can't think of one."

Back to the deep freeze

Just as things were warming up after the long Pleistocene Ice Age, an abrupt temperature reversal plunged the Northern Hemisphere into a thousand-year cold spell known as the Younger Dryas (YD) interval. The beginning of the YD in North America, Greenland, and Western Europe is well established at 12,900 CALYBP. At about the same time, the last of the Pleistocene megafauna were disappearing in North America and the Clovis culture was breathing its last.

A recent reexamination of the Clovis time range by geochronologist Tom Stafford and geoarchaeologist Mike Waters (**MT 22-3, -4,** "Clovis Dethroned: A New Perspective on the First Americans") makes it clear that, among other things, Clovis came to an end in the extraordinarily brief period 12,800–12,925 CALYBP. Their conclusion is consistent with data compiled by C. Vance Haynes, who has demonstrated the presence of dark organic deposits, known to scientists as "black mats," that mark the end of the Clovis era at more than 50 different archaeological sites across North America. They form a boundary that's easily identified in about one-third of the known Clovis sites, and the best explanation for them is that they represent significant organic enrichment of the local sediments via algal blooms or a sudden infusion of charcoal or soot. The formation of black mats dates conclusively to the beginning of the YD interval.

The sudden onset of the Younger Dryas is implicated, therefore, in the decline of Clovis. But what triggered the YD in the first place? Traditional explanations center on a sudden influx of glacial meltwater into the North Atlantic, which would have disrupted the saline density and interfered with established patterns of ocean circulation that contributed to the warming of the Northern Hemisphere. This explanation seems reasonable, since it's well known that modern England, for example, would be significantly colder without the Gulf Stream. But oddly enough, it didn't happen during any previous interglacial, so some random event must have triggered the abrupt climate change.

That random event might have been the impact of a relatively small highly fragmented comet or asteroid, particularly one that exploded in the upper atmosphere, igniting fires over a large area. Such an event would fill the atmosphere with soot and dust that would block out significant amounts of solar radiation for weeks or months, resulting in a "nuclear winter" effect. Even after the skies cleared, feedback mechanisms involving reflected solar radiation from newly formed snow and glaciers would maintain frigid temperatures for centuries.

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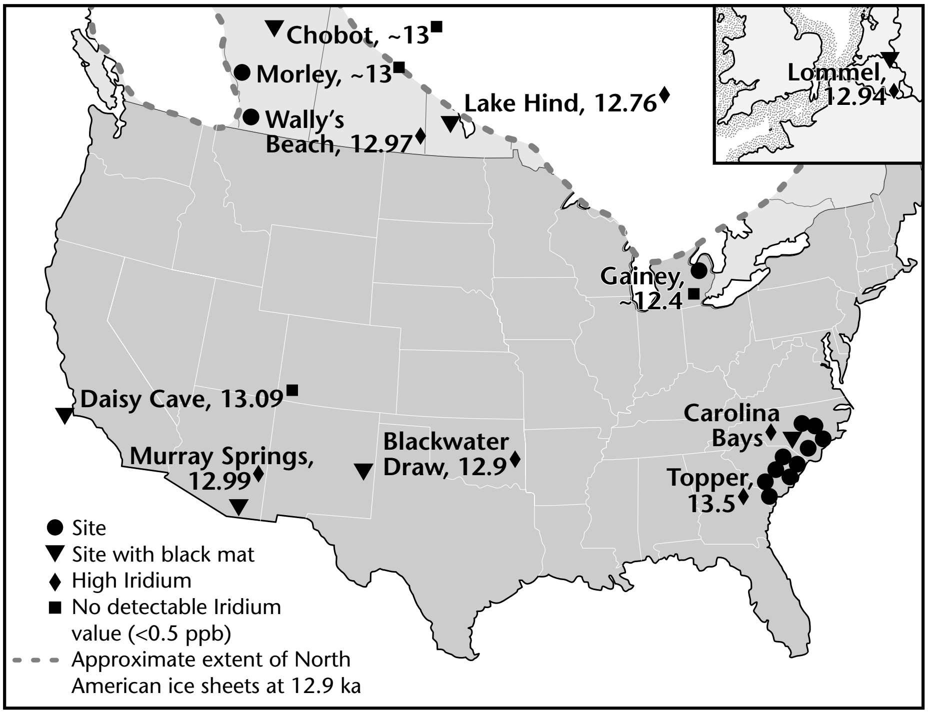
Many years may pass between the time an important discovery is made and the acceptance of research results by the scientific community. To facilitate communication among all parties interested in staying abreast of breaking news in First Americans studies, the **Mammoth Trumpet**, a science news magazine, provides a forum for reporting and discussing new and potentially controversial information important to understanding the peopling of the Americas. We encourage submission of articles to the Managing Editor and letters to the Editor. Views published in the **Mammoth Trumpet** are the views of contributors, and do not reflect the views of the editor or **Center** personnel.

–Michael R. Waters, Director

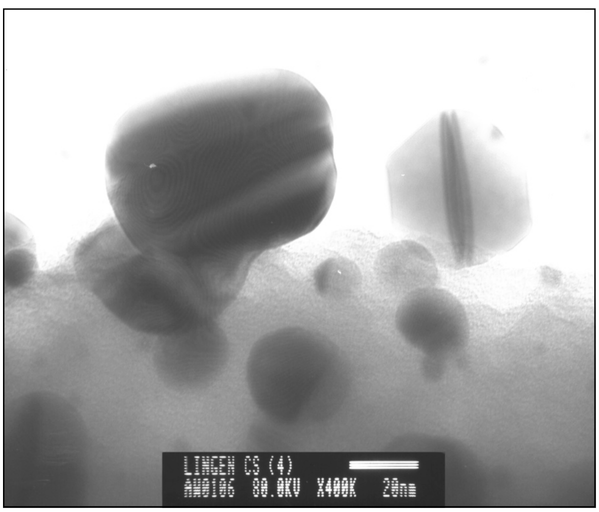


AFTER FIRESTONE ET AL.

Sites investigated in the study including Lommel, Belgium, with their calibrated Younger Dryas boundary (YDB) dates. For the Carolina Bays, 3 of 5 sediment analyses revealed detectable Ir values, though ages of the Bays determined by optically stimulated luminescence (OSL) are inconsistent. The approximate extent of the North American ice sheets at 12.9 ka is consistent with the research team's observations that all sites were ice-free at the time of the YD event.

Hit me with your best shot

You might think the idea of a giant space object hitting the Earth is outlandish, but it's not as if it hasn't happened before. In fact, mounting evidence suggests that it's happened hundreds of times in the geological past. The best-known example is the Cretaceous-Tertiary (KT) event, which killed off the non-avian dinosaurs and paved the way for a mammalian florescence that continues to this day. The general scientific consensus is that the KT event occurred when a celestial body 10 km (6 mi) across smashed into Mexico's Yucatán peninsula 65 MYA, putting an end to the Cretaceous period with thunderous finality. Evidence also points to a similar but much larger impact 251 MYA, at the end of the Permian. Both events occurred abruptly, both are marked in the geologic record by enrichment of certain elements and the formation of items typically associated with extraterrestrial (ET) impactors, and both caused mass extinctions that killed off a sizable percentage of life on Earth.



ALLEN WEST

Typical nanodiamonds. Scale is in nanometers (a millionth of a millimeter).

ET impactors come in two basic flavors, asteroids and comets. Both the Cretaceous and Permian objects are believed to have been asteroids, giant space rocks that are stony or metallic in composition. Comets, on the other hand, are more like vast dirty snowballs, loosely compacted masses of ice and dust that originate in the outer reaches of the solar system. Although they sound less dangerous than asteroids, comets can be bad news, too. In 1908, for example, something exploded 8 km over Tunguska, Siberia, blowing down and flash-burning 2,150 km^2 (830 mi^2) worth of timber without leaving an obvious crater— exactly what would be expected of a cometary impact. As far as we can tell, the Tunguska event was caused by a comet fragment less than 50 m across. The object responsible for the YD and Dr. Haynes's black mats is believed to have been something similar, but much larger: a full-fledged comet that makes the Tunguska impactor look tiny by comparison. No crater has ever been linked to the event; nor, given the nature of the beast, is one ever expected to be.

Building the case for the Clovis event

Dr. West is a geophysicist who spent most of his career consulting for petroleum exploration and mining companies on three continents, so he's well versed in the Earth's history. After retiring several years ago, he landed a deal to write a book about a subject of great interest to him: the possibility of ET impacts in the recent geologic past. He was familiar with a theory proposed by Drs. Richard Firestone and William Topping in these very pages (**MT 16-2,** "Terrestrial Evidence of a Nuclear Catastrophe in Paleoindian Times"), which argued that a nearby supernova event had enriched Clovis-age sediments with radiocarbon, skewing Paleo dates by about 20,000 years. While the Firestone/Topping theory is now considered unlikely, it was based in part upon Topping's recovery of tiny magnetic microspherules in immediate post-Clovis sediments at the Gainey, Michigan, Paleoamerican site. These microspherules are part of the normal cosmic rain, but at Gainey they are present at abnormally high levels. West wondered if he had find the same result at other Clovis sites.

"As it turns out, there were a lot of the early sites in my

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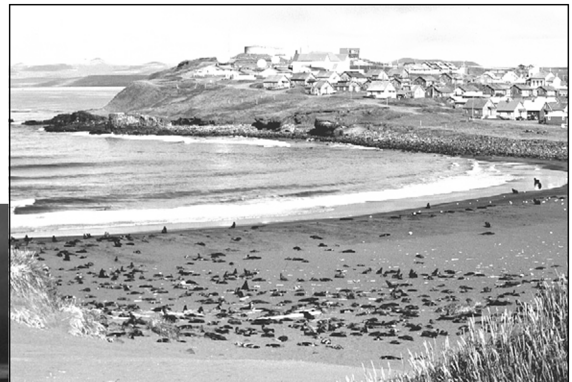
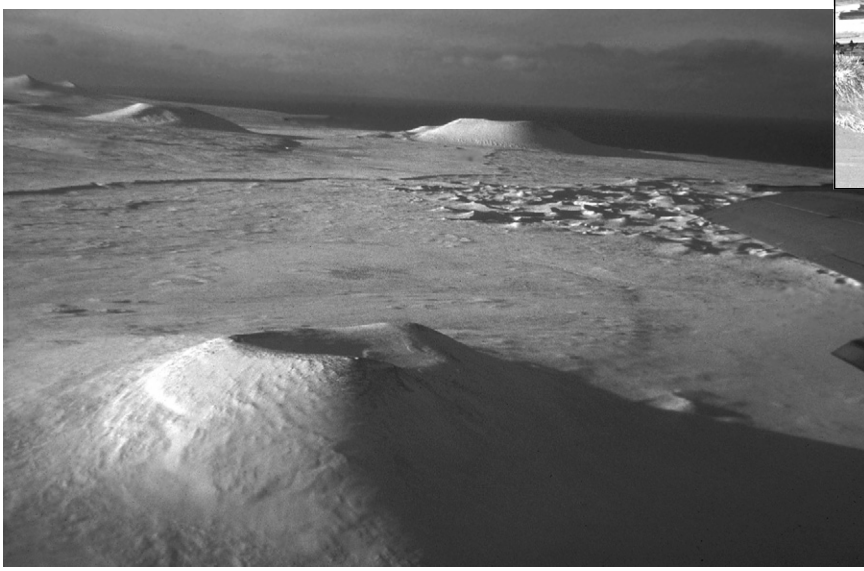
Pribilof Islands Mammoths

The Last to Fall



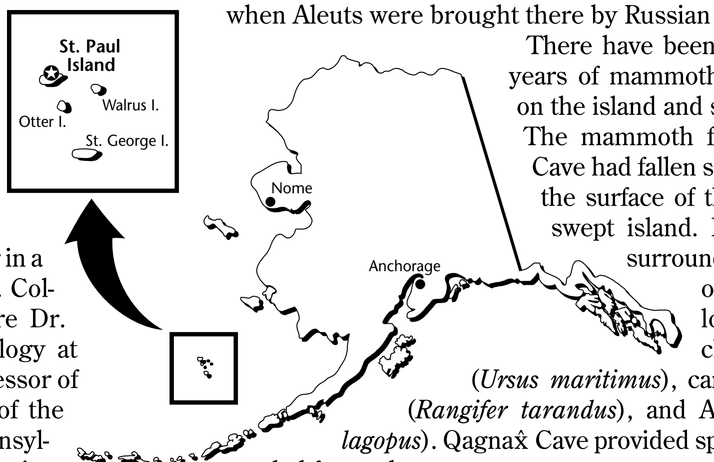


ALL PHOTOS: DOUGLAS W. VELTRE

Two views of St. Paul Island. *Above,* St. Paul village, with northern fur seals on the beach. *Left,* volcanic cinder cones dominate the central portion of St. Paul Island, as seen in this winter aerial photo.

FROM THE BOTTOM of a subterranean ice box on a small island in the Bering Sea, researchers have recovered the remains of a woolly mammoth considered to be the youngest example of Quaternary megafauna yet found in North America.

The mammoth (*Mammuthus primigenius*) was discovered in Qagnax̂ Cave (aptly named for the Aleut word for bone) on St. Paul Island in the Pribilof Island chain of eastern Beringia, according to David Yesner. Dr. Yesner, professor of Anthropology at the University of Alaska Anchorage, and primary spokesman for the ongoing research project, says that radiocarbon analysis shows the mammoth died about 5700 RCYBP (approximately 6,500 calibrated calendar years ago)—long after the species is commonly thought to have become extinct on the continent about 13,000 years ago.



Extensive details of the project will appear in a future issue of *Quaternary Research* journal. Collaborating with Yesner on the project were Dr. Douglas W. Veltre, professor of Anthropology at UAA; Dr. Kristine J. Crossen, associate professor of Geology at UAA; Dr. Russell W. Graham of the Earth and Mineral Sciences Museum at Pennsylvania State University; and Dr. Joan W. Coltrain, professor of Anthropology at the University of Utah.

A remote time capsule

The Pribilof Islands, volcanic in origin, are among the most isolated in North America. They lie about 500 km southwest of the Alaskan mainland and about 400 km northwest of the Aleutian Islands. The islands today are covered with thin grasses and alder shrubs. Since the islands were connected to the mainland until about 13,000 years ago, Yesner notes that mammoths had ample time to get there. Mammoth and polar bear remains have been noted on the Pribilof Islands over the past 175 years.

No prehistoric archaeological sites have been found on St. Paul Island; Aleut oral tradition suggests the island was known to exist, but it remained uninhabited until the late 18th century, when Aleuts were brought there by Russian fur hunters.

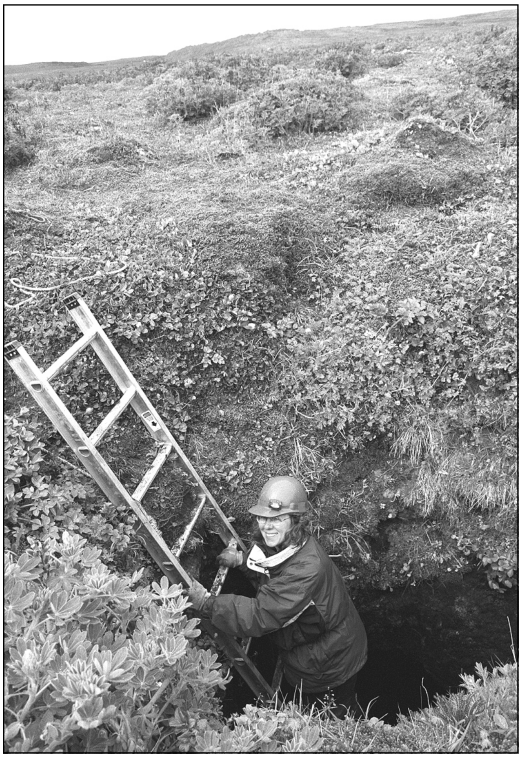
There have been reports over the years of mammoth teeth recovered on the island and subsequently lost. The mammoth found in Qagnax̂ Cave had fallen some 30 ft beneath the surface of this remote, windswept island. Its remains were surrounded by the bones of other mid-Holocene fauna including polar bear (*Ursus maritimus*), caribou or reindeer (*Rangifer tarandus*), and Arctic fox (*Alopex lagopus*). Qagnax̂ Cave provided specimens urgently needed for study.

Qagnax̂ Cave discovered and scrutinized

The cave and its contents came to light in the winter of 1999–2000, when two reindeer hunters riding an all-terrain vehicle through grass on the island's central highlands nearly fell into a large hole that disappeared underground. After news of the discovery reached the nearby town of about 500 people, visitors explored the cave and collected curios including mammoth and polar bear teeth.

In early 2000, some of those items were sent to Veltre at UAA for identification. The next summer local folks guided Veltre, together with a colleague from Arkansas and a group of students, on an inspection tour of the cave.

What they discovered was a vertical shaft, about 2 m wide at its narrowest, that drops 4 m from the surface to the roof of the cave. Using head lamps for light, the crew descended a long ladder into the cave, which is about 10 m high and 15 m in diameter. Crossen describes it as a typical lava tube cave, whose overhead entrance was created when the ceiling collapsed after the lava flowed out of the cave. Despite the darkness, dampness, and chill, Veltre says he was dazzled by what he saw there.



Kristine Crossen emerges from Qagnax̂ Cave during the week-long investigation in 2003.

"I was amazed to see bones lying all over the cave floor," he recalls. "During about an hour in the cave, we made a small collection of items, and I knew right away from the mammoth, polar bear, and caribou bones that this was worth coming back to take a look at. We returned [to the university] with samples of mammoth tooth fragments, polar bear teeth, and some photos. We really didn't want to disturb the cave very much."

It was clear to Veltre that they had stumbled onto a "natural trap" for animals. Back in his office, he left a mammoth molar sitting on his desk in plain sight, where it attracted Yesner's eye whenever he walked past. If he intended it as bait, it worked. As Yesner says, "I started suggesting to him that we really ought to put together some kind of project and go back to the cave." Because it was probably one of the most isolated places in North America, Yesner reasoned it would be the ideal setting to study issues related to mammoth extinction. "We just privately said to each other that it would really be neat if this turned out to be some kind of long-surviving Holocene mammoth site," Yesner adds.

Team members excavate a mammoth molar from beneath large blocks of roof fall.

From this "hunch" emerged a detailed research project. Funded with money from the University of Alaska Anchorage, and a variety of private sources—and outfitted, thanks to logistical support (including lodging and laboratory facilities) from the Aleut TDX tribal corporation of St. Paul—a team of specialists returned to the cave in 2003.

A dark, chilling experience

An equipment problem immediately added excitement to their project. "We intended to bring along a 40-foot-long ladder to make it easier to get into the 30-foot-deep cave," Yesner says, the extra ladder length intended to provide generous gripping surface for safety while preparing to descend and climb off the ladder. "Unfortunately," he relates, "it turned out that at the last minute somebody had bought the 40-foot ladder and so we bought a 36-foot one, which barely cleared the lip of the cave shaft and "made getting into and out of the cave a bit adventuresome, a bit hairy."

Once again, this time equipped with head-lamps and hand-held Coleman lanterns, they entered the cave for a week of intense work. Besides providing light, the lanterns radiated welcome heat. The temperature in the soggy cave hovered around 35 degrees F, considerably cooler than the outside temperature that, in the 40s, seemed balmy. "It just wasn't that much above freezing down there," Yesner says.

They set out to reconstruct the geologic context of the cave, map the cave and its artifacts, and collect specimens for analysis. In addition to precisely dating cave remains, researchers hoped to determine how and when mammoths and polar bears got to the island, how they got into the cave, and what might have happened to them after that.

But first they had to overcome the problem of moving around bones scattered like pick-up-sticks across the cave floor. Crossen remembers that it was difficult to walk, since the cave floor "was covered with a thin moist and gooey dust."

It was also littered with boulders and rockfall that often hid interesting things such as prime bone or tooth specimens. The floor, she says, was so covered in debris that "it was almost impossible to walk around without stepping on bones."

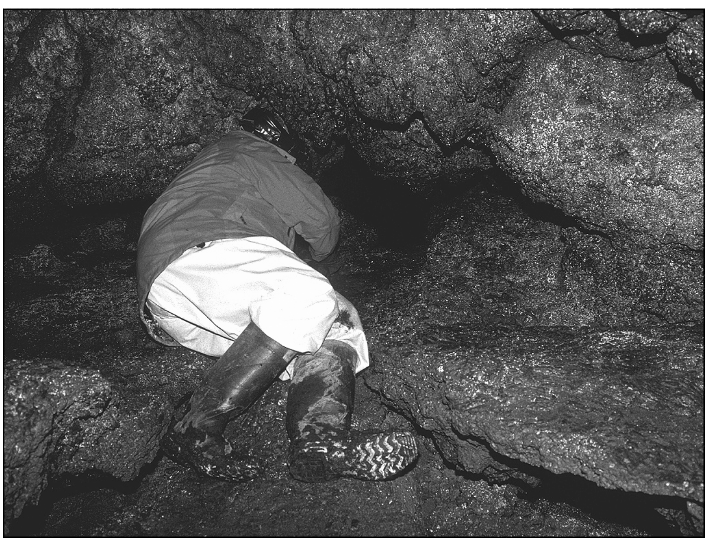
The cave also contained side passages too constricted by rockfall debris to allow researchers to enter. Researchers inspected the recesses by lamp light, saw little of interest, and decided not to investigate at that time.

A large debris cone built up beneath the roof opening needed careful excavation. Crossen describes the material as fine sand and silt, likely windblown into the cave and deposited so that at its trailing edge it feathered into the cave floor. Later grain-size analysis of the sediments provided some surprises. Odd-sized particles in the sediments viewed under a scanning electron microscope turned out to be diatoms. "So it seems there is a shaft of sunlight that comes down to the floor of the cave," Crossen explains, "and there are some photosynthetic organisms living in the bottom of the cave as well."

A ladder descends from the cave mouth to the debris cone on the floor.

Bones are the prize

There was no shortage of bones to inspect. According to Yesner, "we mapped in 100 different units, or clusters, of bones. It took us five days to map and collect all the material." Excavating a test in the debris cone, however, revealed "next to nothing" in the way of bones. Researchers didn't find significant cultural material in the cave, only fragments of old cut dimension-type lumber, indicating someone may have entered the cave during the World War II era. There is no way of knowing, of course, what might have been taken from the cave at that time.



A member of the 2003 research team investigates one of the side chambers of Qagnax̂ Cave.

The team paper reports that researchers recovered 1,750 bones from the cave; 70 percent are from at least 25 Arctic foxes. The collection also includes 250 bones from as many as seven different polar bears, 275 bones from at least four caribou, and a dozen or so bird bones.

Seven mammoth bones recovered from the cave—four molar teeth and bone fragments that include a scapula—are all believed to have come from one animal at the smaller end of the standard size range for the Beringian woolly mammoth. Yesner notes that 24 collection units contain hundreds of additional mammoth molar plate fragments, or tooth flakes. No mammoth tusks were found, prompting researchers to speculate that they may have been removed at an earlier date.

Many of the polar bear and caribou bones showed signs of having been chewed by carnivores. The mammoth bones were gnawed to the "point of unrecognizability," researchers note. Fox bones, by contrast, showed very little taphonomic alteration. Researchers concluded from this evidence that "trapped, but still living, foxes" were probably the primary scavengers. But polar bears might have participated when earlier animals were trapped in the cave, probably having accidentally tumbled down the grass-hidden shaft.

Dates from the polar bear bones (ranging from 4000 to 4600 RCYBP) suggest to Yesner that the bears probably crossed to the island on pack ice during a spike in the Neoglacial period—approximately 4,000 to 4,600 years ago.

As for mammoths, researchers suggest in their joint paper they likely came to the island when sea level was at its lowest during the Last Glacial Maximum, about 18,000 years ago—when the Pribilof Islands were a high range of hills near the edge of the Beringian plain. The islands were separated from the mainland around 13,000 years ago. Dating of the Qagnax̂ Cave mammoth bones and teeth leaves little doubt, says Yesner, that "Wrangel Island in the Russian Arctic is not the only isolated place where Beringian mammoths survived into the mid-Holocene." And the suite of dates from Qagnax̂ Cave also firmly establish that "these are the youngest dates ever for mammoths, or other Pleistocene megafauna, in North America."

Mammoths in literature

Research elsewhere shows that Beringian woolly mammoths survived on Wrangel Island until at least 3,700 years ago (**MT 14-1**, "Mammoths' Last Stand"). Because the specimens were quite small—but are now widely accepted as falling within the standard size range for Beringian woolly mammoths—misleading publicity dubbed them a "dwarfed" version of the woolly mammoth. Consequently they were being linked to remains of a very small Columbian mammoth (*Mammuthus columbi*), whose complete skeleton was found on southern California's Channel Islands in 1994 and determined to be a dwarf subspecies (pygmy mammoth, or *Mammuthus exilis*)—which coexisted with early Americans (**MT 21-4,** "First Lady of the New World: Arlington Springs Woman"). A recent paper by researchers from Northern Arizona University notes that the remains of small mammoths were found on the Channel Islands from the time of the Coast and Geodetic survey there in 1856, and that these animals first appeared in scientific literature in 1876. In light of recent studies of the woolly mammoths of Wrangel Island and Qagnax̂ Cave, Yesner says it now appears that Columbian mammoths might have had the only true dwarf subspecies, believed to have become smaller through selective evolution triggered by such increasing environmental stresses as a shrinking land mass and population overcrowding.

How did these mammoths avoid extinction?

Although Yesner and the other researchers still don't know for certain how the mammoths survived on St. Paul Island well into the Holocene, they speculate that the species may have benefited from the extreme isolation of the Pribilofs and consequent freedom from human predation. We must bear in mind that new research has refuted the "blitzkrieg" theory, which casts man, the predator, in the role of the principal agent of megafaunal extinction; instead, scientists now have evidence that ecological changes triggered a double pulse of extinctions and that human hunters were at most a marginal factor (**MT 22-1,** "The Timing of Megafaunal Extinctions in North America: Earlier Than You Think"). It could be argued, of course, that St. Paul Island represents a special case, for if even a small band of efficient hunters armed with Clovis-tipped spears had gained access to this insular sanctuary, they quite likely could have killed off the entire mammoth population. Nevertheless, the island remained free of human predators and also escaped the ecological calamity at the Pleistocene/Holocene transition that doomed mammoths everywhere else in North America.

Yesner feels that a part of the answer to the prolonged existence of mammoths on St. Paul Island may be found in their diet. Carbon and nitrogen isotope analysis of the Qagnax̂ specimens suggests that they enjoyed unusually nutritious forage—lush grasses enriched by mid-Holocene tephras that were partially formed by extensive volcanic activity, the same volcanic activity that formed the cave. "There is no question that the maritime grasslands provided a rich environ-

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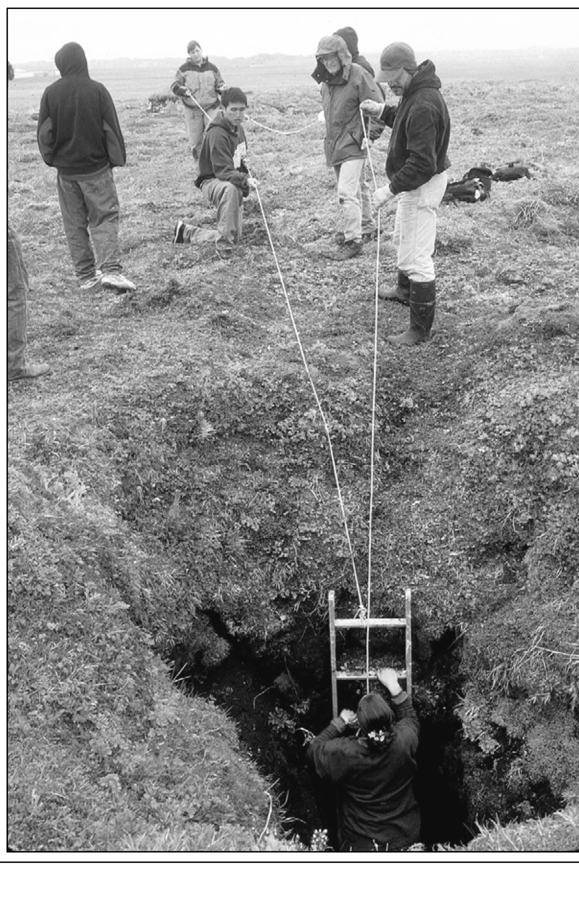

Entering Qagnax̂ Cave, summer 2000, as part of the first examination of the cave.

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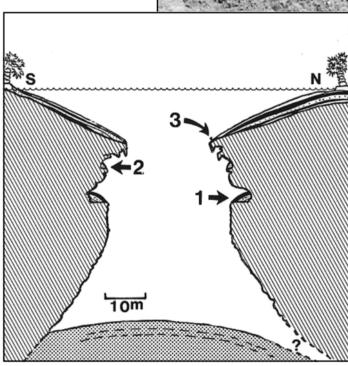
DIVING into Paleo Florida

BEFORE THE NORTHERN GLACIERS MELTED, sea levels rose, and water became more plentiful, long before there was an Everglades and Lake Okeechobee, Florida's lower peninsula was a cool, dry savanna-like landscape about twice as broad as it is today. Freshwater was scarce. Near the center of this prehistoric landscape, a site in southwest Florida today less than 10 miles inland from the Gulf of Mexico, sparkled a particularly attractive watering hole that drew hunters and prey.

Near the twilight of the last Ice Age, a hungry prehistoric hunter watched a giant land tortoise crawl along the edge of this oasis. For the hunter, this ancient evening turned out well. He impaled the tortoise on a sharp stick and cooked it on site for a hearty meal. That's the picture described by underwater archaeologists who more than 12,000 years later found the shell of the now extinct tortoise species pierced by a stake on what is known as the "27-meter ledge," a shelf 90 ft below the present surface of Little Salt Spring. The tortoise, we have to remember, was killed on dry land that existed before the site was later inundated and incorporated into the depths of the widening spring.

In John A. Gifford's view, Little Salt Spring (8SO18) near North Port in Sarasota County, Florida, is one of the most significant archaeological sites in North America. Dr. Gifford, professor of marine affairs and policy at the University of Miami's Rosenstiel School of Marine & Atmospheric Science, is also principal investigator of the Little Salt Spring Underwater Archaeology Project. For more than a quarter century, the spring has given archaeologists tantalizing glimpses into the world of Paleoindian hunters and gatherers.


PETER MASA



C. J. CLAUSEN ET AL.

Above, **low-altitude oblique aerial view of Little Salt Spring from the south (January 2006).** ***Inset,*** **Clausen's 1979 drawing of a cross section of the spring: 1, the 27-meter ledge on which the tortoise and stake were excavated; 2, the 16-meter ledge; 3, the drop-off at 12–13 m, where most of the wooden stakes have been excavated.**

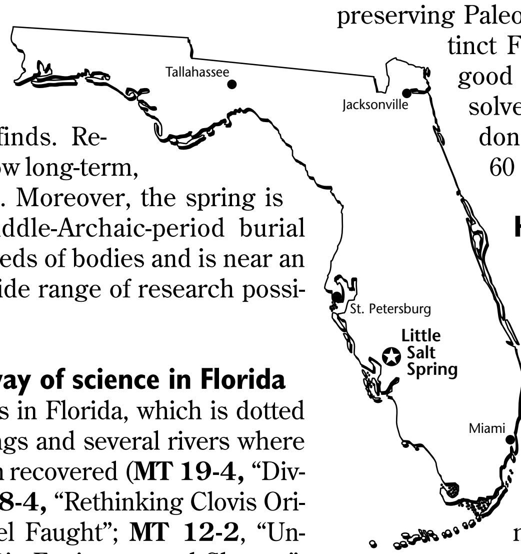
It's an invariable law: Discoveries draw critics

The impaled tortoise shell, one of the most important finds at the spring, dates to 12,000 RCYBP (about 14,000 CALYBP). This remarkable artifact has also been highly contentious. Some researchers doubt that the stake was actually used to kill the tortoise; the dating of the stake, they argue, is at odds with calcium carbonate dates from the tortoise shell. Gifford, using collagen dating on the shell (a technique not available to researchers in the 1970s when it was found), has determined that its age is commensurate with that earlier published for the stake in the 1979 edition of *Science* by underwater archaeologist Carl C. J. Clausen.

Some critics also claim there was insufficient "direct contextual association" between the stake and the fate of the tortoise. Clausen maintains that the stake's point of entry into the tortoise shell—along with carbonized long bones and fire-hardened clay found around the tortoise remains—strongly supports his hunter-and-prey hypothesis. Ambiguous, say the critics, who want more evidence. Although Gifford concedes that Clausen's report lacks clarity on the issue, he has evidence to calm the debate. "I found a 16mm color film shot when the tortoise was excavated," Gifford explains, "that shows the direct contextual association of the stake with the tortoise shell." Convinced it was a real association, Gifford robustly defends Clausen's published account. He plans to discuss the issue at the March 2008 SAA meetings and will likely show the film too.

Artifacts pulled from the spring over the years include a 7,000-year-old greenstone pendant, and a carved atlatl handle (spear thrower) believed to be from the Early Archaic (8,000 to 9,000 years old). The spring also yielded four non-returning boomerangs that Gifford says are so rare they may be "the only four in the world." He frankly admits that researchers don't know what to make of them; lacking comparative artifacts, they can't identify with certainty the function of the curved throwing sticks.

Sharpened wooden stakes, wooden digging sticks, human bones, bones from such prehistoric megafauna as the giant ground sloth, and a curiously sparse collection of arrowheads and non-diagnostic lithics cram laboratory storage bins. "Mind-boggling," Gifford says of the finds. Recorded dates from the artifacts show long-term, continuous occupation of the site. Moreover, the spring is associated with an early- to middle-Archaic-period burial ground containing possibly hundreds of bodies and is near an Archaic village site—opening a wide range of research possibilities.



Submarine archaeology, the way of science in Florida

Underwater archaeology flourishes in Florida, which is dotted by more than 600 freshwater springs and several rivers where Paleoindian artifacts also have been recovered (**MT 19-4,** "Diving into Florida Prehistory"; **MT 18-4,** "Rethinking Clovis Origins: A Conversation with Michael Faught"; **MT 12-2**, "Underwater Site Opens Window on Big Environmental Change"; **MT 10-1**, "Underwater Site Details Mastodons' Life History"; **MT 3-2**, "Florida Archaeologists Plunge Into the Past").

Little Salt Spring was originally believed to be a shallow-water pond. In 1959 William Royal, a retired Air Force officer, began scuba diving there and discovered it to be an hourglass-shaped sinkhole nearly 80 m deep, typical of Florida's karst topography. Early researchers describe its surface as approximately 78 m in diameter and about 5 m above sea level. A sinkhole is similar in many respects to the *cenote* found in the Yucatán—a relatively shallow water-filled basin above a vertical underwater cavern (**MT 20-3,** "Early Humans South of the Border: New Finds from the Yucatán Peninsula"). In a sinkhole, deep vents at the cavern bottom feed oxygen-depleted ground water, producing an anoxic environment below a depth of about 3 m. Bacteria necessary for decomposition are prevented from forming, thus creating an ideal environment for preserving Paleoindian artifacts as well as fossil bones of extinct Florida megafauna. "We have extraordinarily good preservation because there is almost no dissolved oxygen in the water," Gifford says. "We don't have 100 percent preservation, but we have 60 to 70 percent preservation, and that's great."

Hard-won fame for a challenging site

As a graduate student in the 1970s, Gifford heard of archaeological discoveries being made at the spring. It was about the time when the property owners, the General Development Foundation, hired Clausen, then the Florida State Archaeologist, to direct the Little Salt Spring Research Facility. Thus began an intensive era of company-financed academic research there. Clausen made many of the earliest finds at the spring and set the stage for Gifford's later study.

Clausen's years of research at the spring convinced him of the overall importance of the site to understanding Paleoindian life. "Unique cultural evidence," he writes, "especially artifacts of wood, bone and shell, which seldom survive in the Southeast, has been preserved in what can be described as a natural time capsule at Little Salt Spring." The site has yielded evidence among the earliest of human activity in Florida, their association with an extinct vertebrate in the Southeast, and evidence that they preyed on an extinct species of giant tortoise. (The evidence of early human presence at Little Salt Spring is supported by the discovery below the Aucilla River surface of an American mastodon tusk bearing cutmarks. The tusk has been dated to 12,425 ± 35 RCYBP.) Clausen determined that humans occupied the site between 12,000 and 9,000 years ago, and again between 6,800 and 5,200 years ago. Gifford emphasizes that his research confirms Clausen's conclusions concerning the site's occupational dates and archaeological significance.

J. GIFFORD

Digital photomosaic, made from five 35mm color slides taken underwater in December 1975, shows the stake in direct association with the tortoise (the plates are the shattered plastron) in the excavation trench on the 27-meter ledge.

State and federal officials in 1979 placed Little Salt Spring on the National Register of Historic Places, thereby confirming the site's research potential. In 1982, the General Development Foundation donated the site to Miami University. The university in 1983 hired Gifford to direct the present Little Salt Spring Project. Unfortunately they didn't hand him a pot of money, the

THOMAS STREET

Gifford (*right*) describes late-Paleoindian wooden artifacts recovered from Little Salt Spring basin excavations to a local newspaper reporter.

mother's milk of archaeology. He admits that finding money to continue research has been difficult. Conducting underwater archaeology is expensive—about 10 times more costly than terrestrial archaeology. A lack of funds curtailed research at the site between 1982 and 1992, but money has gradually surfaced. The University of Miami and other donors fund activities, including underwater archaeological field schools up to three weeks in duration that Gifford has conducted since 1993.

The hard way to do business

Gifford's underwater work is time-consuming and equipment-intensive. Working conditions in the field are quite different from those faced by terrestrial archaeologists. A 2007 feature story in the *Tampa Tribune* recounts a typical underwater session: After wriggling into scuba gear and tanks, research divers cross a pontoon bridge onto a floating platform at the spring. From there, they plunge through upper level aquarium-like swarms of small fish and turtles to deeper excavation sites. Using an underwater vacuum powered by a pool pump, divers clear specific areas, working from a suspended trampoline secured by plastic pipe to hold equipment and collected artifacts. Excavation moves with tortoise-like slowness, with divers frequently measuring minute progress in weeks. Gradually, though, the spring yields a few more of its secrets.

BOTH: J. GIFFORD

Late-Paleoindian (ca. 9250 RCYBP) deer ▲ antler artifact of unknown function recovered from Little Salt Spring.

Middle-Archaic greenstone pendant from ▶ the east slope of the Little Salt Spring basin, ca. 6000–7000 RCYBP.

"Much of the work we have done has complemented Clausen's work," Gifford says. After more than a decade, Gifford's research has yielded more wooden tools and a pendant of non-native greenstone that possibly came as a trade item from the Appalachian region, the suspected source of the greenstone. His team has also found a second greenstone pendant, which has yet to be identified and sourced, and a series of pointed wooden stakes excavated from about 35 ft below the water, one of which has been dated at 9350 ± 90 RCYBP (Beta-216035), about 10,500 CALYBP. Gifford is confident the stakes were driven into sediments at the drop-off above the water's surface during the late paleo period. He suspects that the stakes served as anchor points for lowering objects, perhaps people, over the edge and down into the throat of the spring to the water's surface, which at that time may have been 20 ft below the level of the stakes, or about 55 ft below the present surface of the spring.

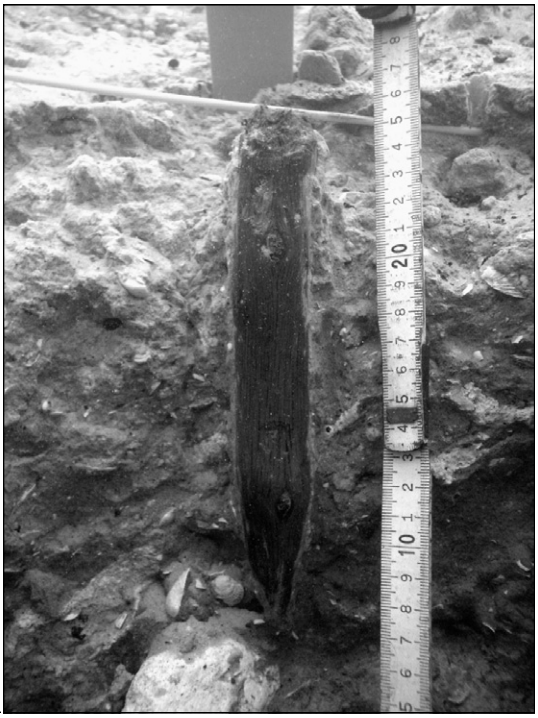
Not only have money problems eased since Gifford took over research at Little Salt Spring, help of a non-financial nature appeared in the person of 26 divers with the Florida Aquarium, boasting more than 1,000 hours' combined diving experience, who have participated for the past three years. The Aquarium also plans to exhibit some of the artifacts recovered by Gifford's team. The restored tortoise shell and stake have been on public display at the Museum of Florida History in Tallahassee.

Meanwhile, Gifford's field school students have opened three 2-by-2-m underwater test excavations. "Actually," he explains, "we are still working on one of them because we have not yet hit bedrock." The process gobbles time, and sometimes divers surface empty-handed. Progress can be maddeningly slow: In a 2-week field season in 2007, it took one week just to excavate a 10-cm-deep level. However, with the excavation now coming onto new sediments, the potential is promising. Divers haven't yet hit bedrock, further buoying Gifford's hopes for new finds.

Gearing up for the job

Other benefits, too, accrue from work at the site. Researchers are perfecting new techniques for recording excavations. To take the place of still photography and sketching artistry used by their terrestrial counterparts, Gifford and his fellow researchers create digital video mosaics of the excavation. The process saves time in their underwater time-pressured environment and produces more detailed results than traditional methods. Gifford has amassed a large database of digitized records that can be quickly and easily expanded, used, and shared with other researchers.

Excited about finds at the site to date, Gifford is eager to take the next major step. His sights are set on the 27-meter ledge. Only 5 percent of this natural re-entrant has been explored, and Gifford believes it has the greatest potential for extremely old finds. Exploring it, however, will be a particularly expensive venture, requiring specialized equipment and an exotic mixture of breathing gases for divers that includes helium, nitrogen, and oxygen. The optimum breathing mixture allows divers to stay at the 90-ft depth for 50 to 60 minutes in the morning and the afternoon, a marked increase over 20 minutes of bottom time limited by the standard compressed-air breathing mixture—which also requires a lengthy decompression time and involves added health risks. More bottom time means more opportunity to make discoveries.



J. GIFFORD

Underwater photo, taken in March 2006, of a partially excavated oak stake in situ at a depth of about 12 m. Since the upper portion of this stake, like all the others, is missing, its original length is unknown. This stake has been dated to 9350 ± 90 RCYBP, or 10750–10260 CALYBP (2-sigma). Gifford admits that "we still don't know why these stakes were being driven into the soft sediment just above the drop-off." Clausen's theory is that they were "belaying pins" to secure ropes used to lower something to the water's surface, which 10,000 years ago would have been a few meters below the drop-off.

Data with an unsettling edge

Little Salt Spring has opened a window on Paleoindian life. The site also has given researchers a yardstick for measuring climate change, and the data reveal a fact that may bode a bleak future for human habitation of south Florida.

At the nub is how to explain the fact that no cultural remains younger than 5,500 years have been found in the sinkhole. This issue has puzzled researchers for years because it suggests human occupants suddenly abandoned the site. The prevailing wisdom, whose adherents included Clausen, theorizes that the exodus was the result of climate change, perhaps because the area around the spring became more arid and therefore less habitable, or perhaps because burgeoning water supplies elsewhere, caused by climate warming and glacier melt, lured people away from Little Salt Spring.

Gifford's team, however, offers an alternate hypothesis that suggests the site bears witness to an ancient event hostile to humans. In a study presented in the 2005 edition of the journal *Palaeogeography, Palaeoclimatology, Palaeoecology,* Carlos A. Alvarez Zarikian (a graduate student of Gifford's), Gifford, and others examine fossilized organisms known as ostrocods found in Little Salt Spring. They conclude that increases in saltwater, as glaciers melted and sea levels rose, may have degraded the water quality at the spring and forced humans to seek habitation elsewhere. Their study is a cautionary tale of what may lie in store for Florida if global warming causes a rise in sea level as predicted. "I have seen a number of predictions," Gifford remarks, "and it doesn't look good for south Florida." His primary concern, however, is uncovering the lives of past occupants around the spring.

Although Gifford concedes that we may never know for certain what caused people to vacate the spring, he is confident that continuing paleoenvironmental research will more clearly define the chain of events taking place at what had once been, without question, a scarce oasis and valued hunting ground for a very long time. It most certainly should produce more artifacts to examine.

"I think we have the potential for finding very old, and very well preserved, material," Gifford says. "We certainly have an untapped reservoir of material to explore here."

–George Wisner

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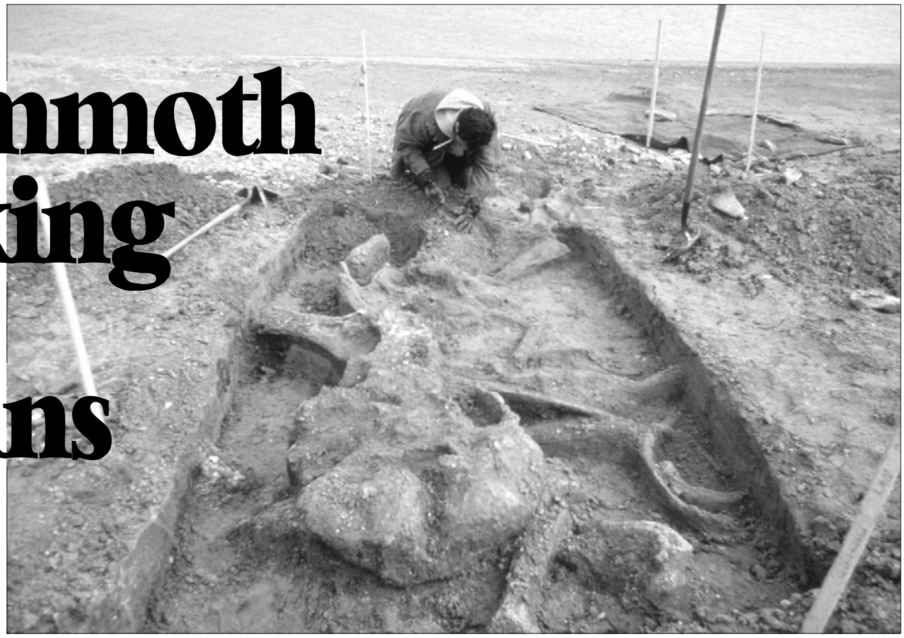
Suggested Readings

Clausen, C. J., A. D. Cohen, C. Emiliani, J. A. Holman, and J. J. Stipp 1979 "Little Salt Spring, Florida: A Unique Underwater Site." In *Science*, 203:609–14.

Kornake, S. 2007 "Deep in Florida's Past: The Artifacts in Little Salt Spring Could Help Rewrite History." *Tampa Tribune*, Metro Section, Monday, July 2.

Zarikian, C. A. A., P. K. Swart, J. A. Gifford, and P. L. Blackwelder 2005 "Holocene Paleohydrology of Little Salt Spring, Florida, Based on Ostracod Assemblages and Stable Isotopes." In *Palaeogeography, Palaeoclimatology, Palaeoecology*, 225:134–156.

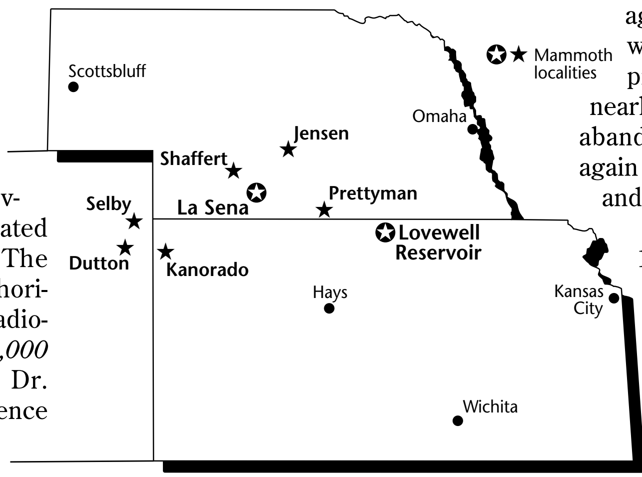
Early Mammoth Bone Flaking *on the* Great Plains



KANSAS STATE HISTORICAL SOCIETY

Excavating the Lovewell mammoth I in 1969. Note the nearly complete skull, large limb, and ribs.

UNEARTHING A BROKEN mammoth leg bone is sure to make an archaeologist's eyes light up, especially if the bone shows evidence of spiral fracturing. There just aren't many natural agents that can break an adult mammoth femur or tibia, and a spiral fracture is proof the bone was broken when green, most likely by humans pillaging a fresh carcass for nutritious marrow or quarrying the skeleton for toolstock. For Steve Holen, Curator of Archaeology of the Denver Museum of Nature & Science, spirally fractured mammoth limb bones and worked flakes of bone found at the Lovewell Reservoir site in Kansas and the La Sena site in Nebraska are unmistakable evidence of human scavengers, who may also have been mammoth hunters.



The significance of these discoveries, impressive enough if they dated to Clovis times, is explosive: The bones and their associated soil horizons date to earlier than 18,000 radiocarbon years before present, *7,000 radiocarbon years before Clovis*. Dr. Holen believes he has found evidence of human activity in the central Great Plains during the Last Glacial Maximum (LGM)—and he may have added a big gun to the armory of pre-Clovis research.

New finds on the prolific high prairie

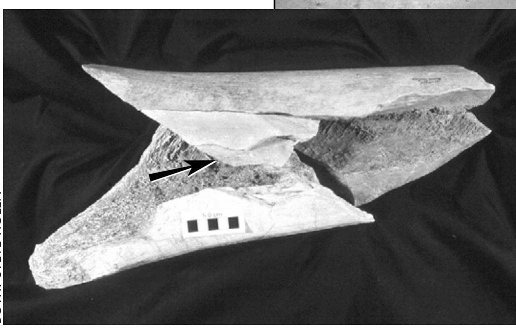
The area where Nebraska, Colorado, and Kansas meet has yielded a wealth of mammoth remains over the years, some of them bearing evidence of Clovis butchering and bone quarrying. In fact, human handiwork detected on mammoth remains found at the Lovewell Reservoir site in northern Kansas was identified for a time as Clovis in origin. But that was just one detour in the tortuous journey from discovery to recognition that dragged on for more than 20 years.

The skeleton of a mammoth, eroding out of the bank of the reservoir, was noticed by a local resident in 1969 when the water level had fallen. Excitement was intense at finding a nearly complete skull and skeleton because the skull was lying upside down and many bones appeared to have been stacked as though by orderly workers. Enthusiasm turned to disappointment, however, when a consulting geologist identified the red fill surrounding the skeleton as Loveland loess of Illinoian age. Since the mammoth at death would therefore predate human presence in North America by nearly 90,000 years, the skeleton was abandoned by archaeologists. It was again covered by rising reservoir water and lay submerged for 22 years.

Interest was sparked anew in 1989, when excavations at the Eckles Clovis site 800 m from the mammoth revealed that much of the terrace fill along the shore—and possibly including the fill surrounding the mammoth—was much younger than Illinoian material. A drought in 1991 again lowered the water level and gave investigators another chance to examine the mammoth. Excavations that year yielded many pieces of spirally fractured and flaked adult mammoth limb bone in in situ beach silt. Not only had the bone been fragmented when green, one bone artifact bore polish from use wear. Considering the presence of the nearby Eckles site, the investigators at first assumed the skeleton dated to Clovis times, about 11,000 RCYBP. That was before a fragment of limb bone notched by impact returned a radiocarbon date of 18,250 ± 90 RCYBP!

Recurring droughts in 2002 and 2004 lowered the water level and made it possible to retrieve more broken and flaked bone. Investigators were finally able to make sense of the geology when they recovered a rib fragment from red silts 80 m from the 1991 and 2002 excavations, which dated to 20,430 ± 300 RCYBP. They realized this was the same silt (from younger Gilman Canyon Formation deposits) that had been mistakenly identified because of its color as Loveland loess in 1969. Finally, in 2005 they determined that *two* mammoth skeletons had been discovered at Lovewell Reservoir, the one uncovered in 1969 and subsequently referred to as mammoth I (which yielded the date of 20,430 ± 300 RCYBP), and the one from which bones and artifacts were recovered in the 1991–2004 excavations, subsequently referred to as mammoth II (which dated to 18,250 ± 90 RCYBP, as mentioned above).

▲Spirally fractured limb bone of the La Sena mammoth, the largest piece recovered.



BOTH: STEVE HOLEN

◀Refitted pieces of fractured femur of the La Sena mammoth. Spiral fractures radiate from the dynamic loading point. The arrow points to a cone flake.

Almost 700 pieces of bone have been recovered from mammoth II. A piece of cortical bone recovered in 2002 was dated by Stafford Laboratory in Boulder, Colorado, at 19,350 ± 80 RCYBP; Holen considers this more reliable than the earlier date of 18,250 ± 90 RCYBP because this date was run nearly 10 years after the first one and Dr. Tom Stafford's methods in collagen purification had progressed significantly during this period.

Broken by humans or natural causes?

Holen, anticipating protests from fellow scientists that the bones had been broken by natural forces and not by human action, especially since no stone tools were found with the mammoth remains, plays devil's advocate to his own case. Rebutting the argument that the limb bones may have been broken by the weight of overlying sediments, he points out root etching on the bones that confirms their shallow burial. (In the case of the La Sena remains discussed below, even though they were once buried under 10 m of loess only two mammoth bones—both ribs—were broken by sediment loading.)

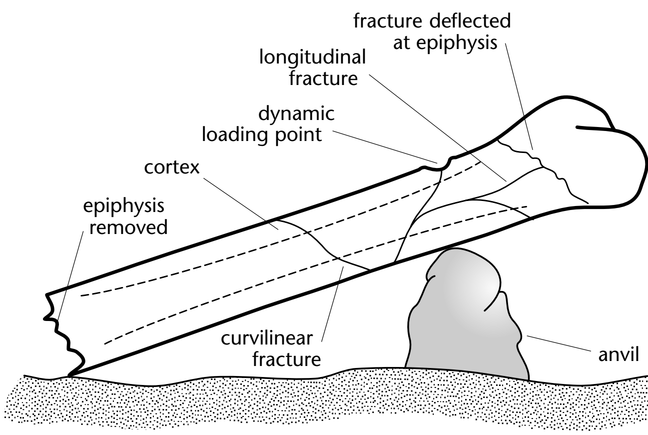
Could the breakage be attributed to animal trampling or gnawing? Not according to renowned European archaeologist and taphonomist Dr. Paola Villa, who examined the bones in 2005 and found them all "very robust, not brittle and resistant to breakage," and in a good state of preservation. "I have seen no cutmarks," she writes, "and no gnaw marks (i.e., no ragged edges, no grooves, no scooping of cancellous bone, no tooth punctures or tooth pits)."

All the evidence weighs in on Holen's side of the argument: These bones were broken by people who walked the Plains with mammoths 8,000 years before Clovis.

Support from the La Sena site

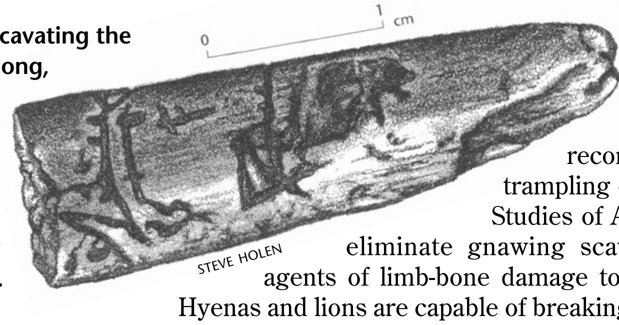
The evidence from the single mammoth found in southern Nebraska is just as intriguing as that from the Lovewell mammoths. At the La Sena site the completely disarticulated skeletal remains of an adult male mammoth, scattered over an area of more than 200 m^2, were excavated from a depth of 3½ m. (Of nearly 10 m of late-Wisconsin loess that had once covered the skeleton, about 6 m was removed by Holocene erosion.) Bone from the skeleton was radiocarbon-dated at 18,440 ± 145 RCYBP. The skeletal elements are only slightly weathered, meaning they had been rapidly buried by the windblown loess.

Although investigators couldn't find evidence of butchering or stone tools associated with the remains, it was the wide-



A limb bone consists of the shank (diaphysis) and a knobby projection on each end (epiphysis). These components, unjoined in a young animal, become fused (ankylosed) as the animal matures. The tough shell (cortex) of the diaphysis encloses the marrow within the medullar cavity; the epiphyses, even in a mature animal, have a spongy (cancellous) consistency. Because of its high moisture content, the cortex of green bone is somewhat plastic (*ductile* is the term taphonomists prefer). When the diaphysis is struck a sufficiently violent blow, an impact crater is formed at the dynamic loading point, sometimes spattering small conical flakes; tension and shear forces in the semi-rigid green cortex interact to produce characteristic curvilinear (spiral) fractures. Dry bone, on the other hand, is brittle and shatters into pieces of irregular size and shape, like glass or pottery.

spread damage to the bones themselves that caught their attention. Both femurs had been heavily broken, shedding *spirally fractured* fragments. Dynamic loading points (areas of localized damage caused by violent blows by a stone or similar massive object) were found on both femurs. The much lighter fibula had been broken in two, and fractured fragments of limb bone were found intermixed with both intact and less heavily damaged vertebrae and ribs.



This bone artifact was found when excavating the Lovewell mammoth II in 1991. Now 3½ cm long, its tip had been broken and the fractured end rounded with use. The root etching is consistent with marks on other bone fragments of the skeleton; one was radio-carbon-dated at 19,530 ± 80 RCYBP. Holen describes this artifact in an article in *Current Research in the Pleistocene,* vol. 13.

Perhaps the most tantalizing specimen found at La Sena is a broken vertebra. Unlike the other vertebrae that were found lying horizontally on the old soil surface, this element was standing upright, its lower surface buried 6 cm below the old soil surface. The upper surface had been broken, then worn smooth, and alongside the vertebra investigators found a cluster of spirally fractured fragments of limb bone. The evidence suggests it served as an anvil for shattering leg bones.

The issues of trampling and carnivore gnawing

A wealth of research supports Holen's contention that the damage to the mammoth skeletons at the Lovewell Reservoir and La Sena sites is indeed man-made and not the result of natural forces.

The transverse process of this broken vertebra of the La Sena mammoth lies 6 cm below the original ground surface (dotted line). It appears to have served as an anvil for breaking leg bones.

Field studies by University of Nevada, Reno archaeologist Gary Haynes at death sites of the mammoth's closest living relative, the African elephant, verify that trampling of remains by living elephants occurs infrequently and usually only if an animal dies at a water hole. "Kicking and trampling are hit or miss processes," Dr. Haynes writes, "unless elephants return in large numbers to the site seasonally, in which case bones may be widely scattered and broken." Moreover, Haynes notes that skeletons most liable to damage are those of younger animals whose epiphyses haven't yet fused and whose bones are therefore more susceptible to breaking. In the instance of a typical isolated single-animal death, like that of the mammoths Holen is studying, Haynes confirms that trampling and kicking "rarely affect bones as severely as around water sources." His findings are confirmed by Dr. Diana Crader, whose studies of seven deaths of single adult elephants, even some that occurred close to streams, didn't record a single instance of trampling damage.

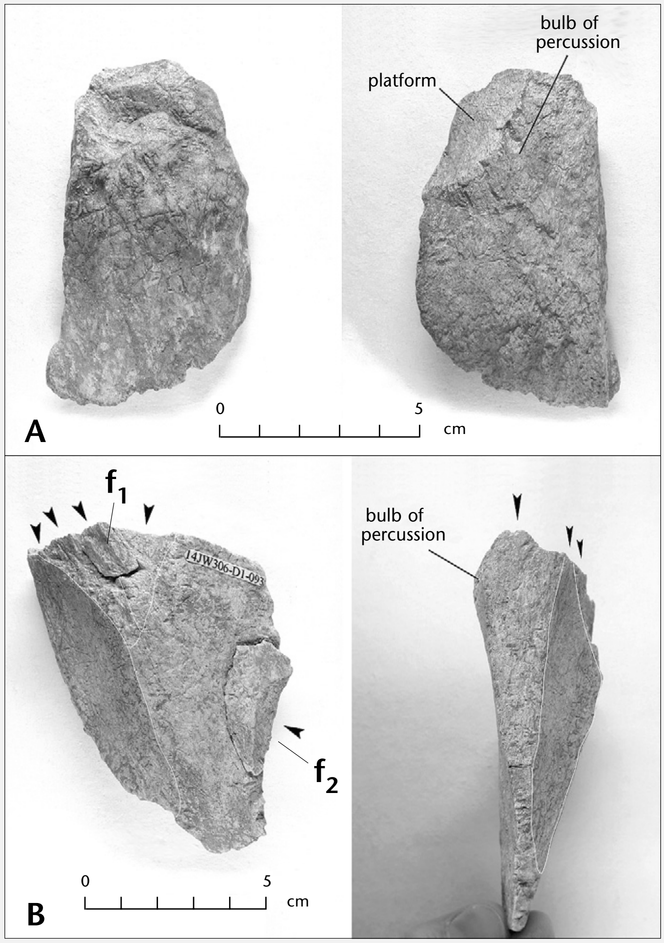
Studies of African elephants also eliminate gnawing scavengers as possible agents of limb-bone damage to Holen's mammoths. Hyenas and lions are capable of breaking the bones of prey as large as 1,000 kg (wildebeest, zebra, and buffalo, for example). When feeding on elephants, though, hyenas can only fracture their limb bones, Haynes points out, "after first eating epiphyses, then grasping the remaining shaft with jaws and levering off large pieces of compact bones." Moreover, he notes that "long bone elements that do suffer breakage during carnivore feeding are usually derived from still growing individuals," in other words, from immature individuals whose epiphyses haven't yet fused. Holen argues that the epiphyses of the femora of the La Sena mammoth (a fully mature animal, not a youngster) are intact and that the fracture planes originate at midshaft, the toughest part of the leg bone.

Were there gnawing carnivores in Pleistocene North America capable of fracturing mammoth limb bones? The most robust specimens roaming the land were the American lion and dire wolf. Haynes concedes that the sheer size of mammoth limb bones "probably presented even the largest and hungriest Pleistocene scavengers with gnawing problems too formidable to allow fragmentation." Authorities agree that even the giant short-faced bear, *Arctodus simus,* should be dismissed as a candidate capable of breaking a mammoth leg bone. It was a fearsome beast, even larger than today's grizzly, and demonstrated its proficiency at cracking the bones of large ungulates. Nevertheless, archaeologist Dr. Eileen Johnson of Lubbock Lake Landmark argues that *A. simus* lacked the masticatory apparatus needed to break a mammoth leg bone at midshaft, and Haynes considers hypothetical gnawing by bears "a far-fetched explanation for the existence of fragmented mammoth bones in any assemblage."

Elephants are handy to have around

The last mammoths, a dwarf species, died 4,000 years ago on Wrangel Island, off Siberia. If a scientist wants to collect em-

Shaping Bone Just Like Stone



FLAKED BONES from the 2002 excavation of Lovewell mammoth II bear features remarkably similar to knapped-chert artifacts: a striking platform, bulb of percussion, ripple marks, curved ventral surface, and hinge or feather termination. Although taphonomy authority Paola Villa cannot state with certainty that the flaked-bone specimens were used as tools, she confirms that the scars on the worked flakes were "apparently due to percussion flaking of their fractured edges, following the primary fracture."

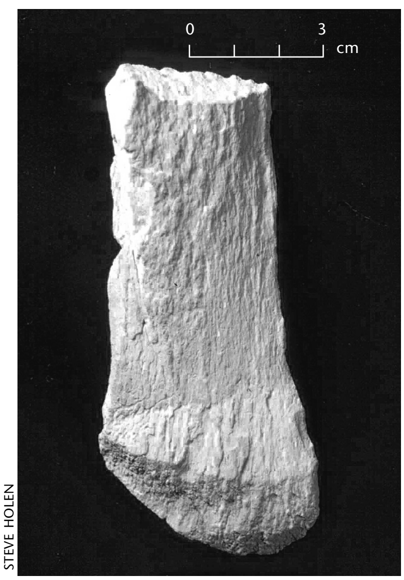
These two bone flakes from Lovewell mammoth II have been culturally modified using techniques quite similar to those used to create lithic tools. The flake in **A** has a platform, bulb of percussion, and feather termination. Oriented as shown in the face on the left, the distal end and right lateral margin have low-angled edges; the left lateral margin is blunt, with a 90-degree edge. "If this piece were a stone artifact," says Holen, "it could be classified as a naturally backed flake."

The flake in **B** (dorsal face on the left, profile on the right) has a bulb of percussion, lines of force, and a feather termination. Two small flakes (**f_1** and **f_2**) were found still adhering to the surface of the parent flake. The feather termination was subsequently flaked from two directions, seen from scars on the dorsal surface: **f_1** and three arrows, aligned longitudinally; and the single flake scar (**f_2**) aligned laterally on the right margin. Holen remarks that "if these three objects were stone, they could be classified as a core with two refitted flakes that failed to initially detach during reduction." Working with bone requires remarkably little modification of techniques used to knap stone.

pirical data about mammoths, the next best subject to a live mammoth is a live African elephant. By observing today's elephants, farsighted scientists like Gary Haynes can glimpse valuable clues about yesterday's proboscideans.

The classic example of an elephant serving as a proxy for a mammoth is the Ginsberg experiment, conducted in the winter of 1977–78 by Smithsonian archaeologist Dennis Stanford and interested scholars, including Dr. Richard Morlan, archaeologist with the Canadian Museum of Civilization, and Dr. Rob Bonnichsen, founder and director of CSFA until his death in 2004. Ginsberg was a 23-year-old female African elephant that died in the Franklin Park Zoo in Boston. At Dr. Stanford's request, zoo curators agreed to transport the corpse to the research station of the National Zoological Park in Front Royal, Virginia. The aim of Stanford and colleagues was to test whether a Clovis point could penetrate the thick hide of the elephant (and, by extension, of a mammoth). It was also their chance to attempt to butcher a mammoth-size corpse using Clovis tools. They were exhilarated, too, by the opportunity to test theories of pre-Clovis hunters, whose existence was unproven at the time. Can a spear tipped with stone or bone bring down a mammoth? Using only stone tools, is it possible to break the limb bone of a mammoth? Can sharpened bone flakes function as butchering knives?

Using replicas of Clovis points and biface tools, Stanford and his team were able to penetrate the hide and dismember bones. After they had exposed a leg bone, still attached to the carcass, it was time for the moment everyone had been waiting for. "As we watched with anticipation," Stanford recalls, "Robson Bonnichsen lifted a twenty-one-pound



A bone flake from the La Sena mammoth, ca. 18,440 RCYBP.

stone high overhead and threw it down onto the leg." If you knew Rob, you remember him as 6 feet tall plus a little, and much stronger than his spare frame would have you believe. "The tough bone did not break," Stanford reports. "Bonnichsen tried again and again, and at last, on the fifth blow, the bone broke into three pieces."

This is eloquent testimony to the ruggedness and resistance to damage of a mammoth leg bone. It's also vindication for archaeologists who interpret spirally fractured mammoth leg bones as irrefutable proof of human presence. "We quickly examined the spiral fractures and the impact impression," says Stanford. "They were identical to those present on the Dutton and Selby specimens" (mammoth remains then under investigation at sites in eastern Colorado).

Using elephant bone as toolstock, the scientists also demonstrated that a bone flake can be modified without a great deal of effort into an effective knife, first by creating a flat striking platform, then striking the platform with a soft hammer (they used a baton made of elk antler) to remove long thin flakes from the core. "The bone flakes were extremely sharp," Stanford writes, "and with some effort functioned very well as cutting tools." They found that a bone tool doesn't hold an edge as well as a stone one; since a bone tool could only be resharpened by grinding, a laborious process, it was easier just to discard a dull tool and make a new one.

For five days the scientists labored outdoors. "A light snow dusted the elephant carcass," Stanford remembers, "helping us imagine we were Ice Age hunters." The Ginsberg experiment was a bone-chilling, gory exercise, made worthwhile because it proved in Stanford's view that "humans could have killed and butchered a mammoth largely without the aid of stone tools, and that they could have controlled the flaking of mammoth bone as a raw material."

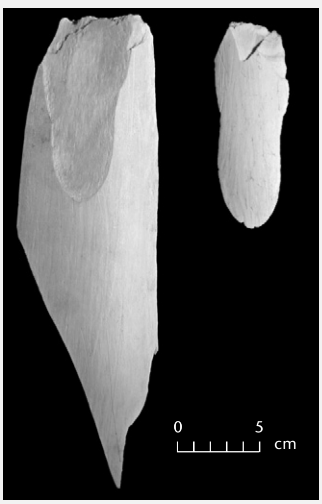
Project Ginsberg

CHIP CLARK

◀ Bloody fingers hold material struck from Ginsberg's femur by a hammerstone to create a platform for removing flakes, which were then made into butchering tools.

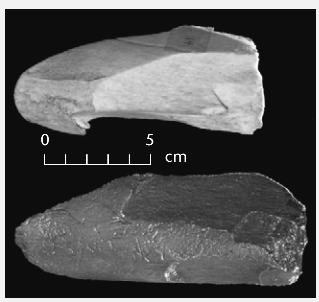
VICTOR KRANTZ

A flake struck from a core made ▶ from Ginsberg's limb bone.



VICTOR KRANTZ

◀ The same flake (*right*) and the core it was struck from, after being cleaned in the Smithsonian lab. The flake was a very effective butchering tool. Bone knives actually sliced slightly frozen meat more easily than thawed. Says Stanford, "We were impressed that the flaking quality of the fresh elephant bone was similar to stone, although it took more force to break." He notes that bone, being less brittle than stone, has the additional advantage of not breaking when subjected to lateral stress: You can pry with a bone tool, but not with one of stone.



VICTOR KRANTZ

These two bone flakes might ▶ appear to have been made by the same toolmaker. The upper one was made from Ginsberg's leg bone. The lower one is a specimen of worked mammoth bone from the Old Crow Basin in Yukon, ca. 29,000 RCYBP.

Ginsberg revisited

Holen found the opportunity to practice firsthand Ice Age techniques for quarrying bone of elephant qua mammoth in summer 2006. While he and his wife, Kathleen, were participating in a research project and field school in Tanzania (not far from the Laetoli site, famous for the oldest known hominid footprints more than 3½ million years old), they discovered the corpse of a male elephant about 30 years old. Although conservation-conscious Tanzanian authorities will not permit elephant skeletal parts to leave the country, they granted Holen permission to detach a femur for on-site experiments.

To break the bone, Holen used a hafted 4.3-kg stone hammer. Just as Bonnichsen had discovered 30 years earlier, not every blow resulted in a break. He reports that effective blows created "impact points with negative cones of percussion, cone flakes and radiating spiral fractures of the type present on both femora excavated at the La Sena Mammoth Site." Using ½-kg stone cobbles as hard hammers, Holen detached flakes from spirally fractured fragments that "exhibited prominent bulbs of percussion and had either hinged or feathered terminations," characteristics that "replicated those found in both the La Sena and the Lovewell mammoth bone assemblages."

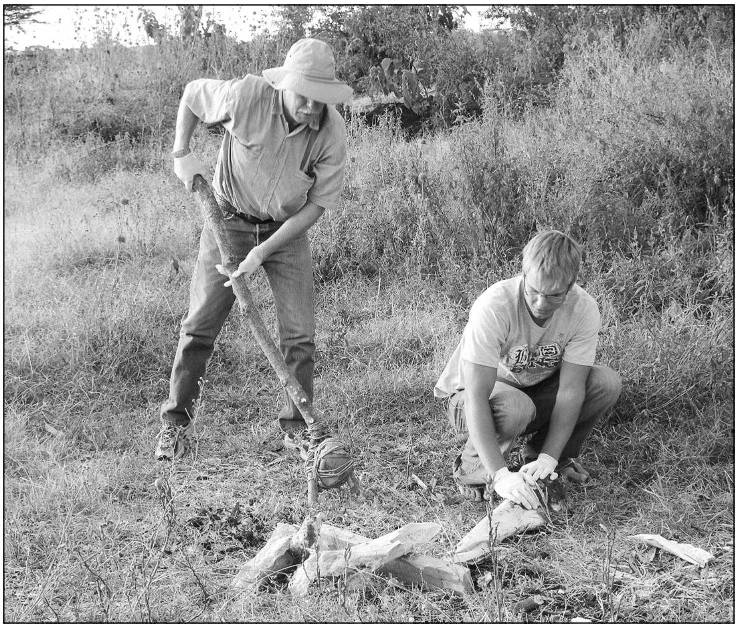
Q.E.D.

The impact on First American studies

Holen is fully aware of the profound consequences of his contention that humans occupied the Great Plains at the time of the Last Glacial Maximum. To accept his proposal that mammoths and humans coexisted in North America fully 7,000 years before Clovis requires a massive shift in the center of gravity of Peopling of the Americas theories.

Until nearly the end of the last century scientists believed that an Ice-Free Corridor enabled the passage of Clovis-age migrants from Beringia to North America, thence as far south as Tierra del Fuego. Their time-honored paradigm was tattered not only by discovery of the Monte Verde site in Chile and evidence of other human occupations in the Americas that predate Clovis, but also by new discoveries that throw a shadow on the corridor. Dr. James Burns infers from radiocarbon dating of Pleistocene fauna in central Alberta that an ice sheet blocked human passage into lower North America from about 21,000 to 11,600 RCYBP. Corroborating evidence that glacial ice blocked the passage during the late Wisconsin comes from studies by Dr. Lionel Jackson, Jr. and colleagues of cosmogenic chlorine dates on glacial erratics.

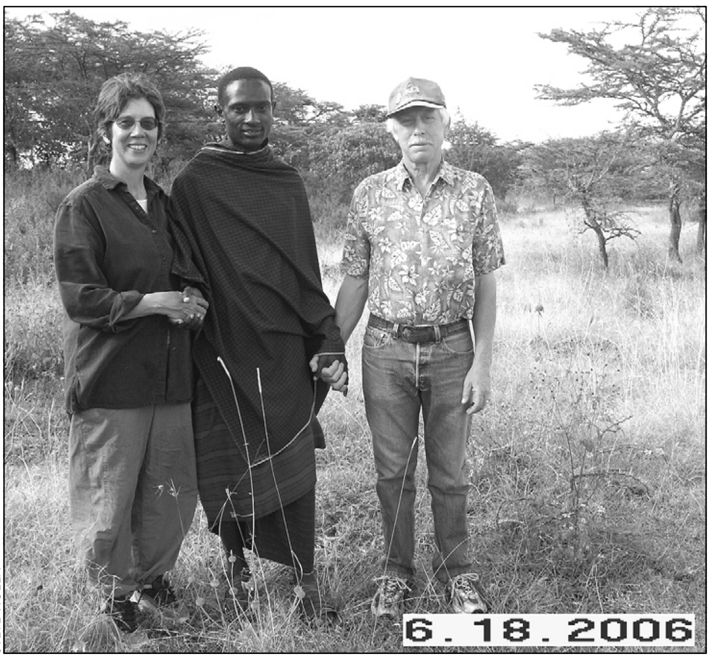
With the existence of a traversable Ice-Free Corridor reduced to an untenably narrow window of time, scientists are exploring alternative routes to the Western Hemisphere by Asian emigrants. Proponents of the coastal-entry theory are searching for evidence that boat people settled the Pacific Coast; among them are Daryl Fedje, who is dredging submarine sites along the Queen Charlotte Islands of Canada; E. James Dixon in On Your Knees Cave, Prince of Wales Island in Alaska (**MT 20-4,** "E. James Dixon and the Peopling of the New World"); Roberta Hall and Loren Davis along the Oregon coast (**MT 22-1,** "Late-Pleistocene Occupations on the Oregon Coast"), and Alan Bryan and Ruth Gruhn in Baja California (**MT 17-2,** "The Baja Connection").



KATHLEEN HOLEN

Holen (*left*) and Adam Thomas fracture the femur of the Tanzanian elephant using a hafted stone hammer.

Some scientists propose theories of migration that don't depend on travel by foot or boat from Asia. Stanford and colleague Bruce Bradley adhere to their Solutrean migration theory, which envisions European boat travelers crossing the Atlantic Ocean (**MT 17-1,** "Immigrants from the *Other* Side?"). Argentinian scholar Augusto Cardich,



STEVE HOLEN

Kathleen and Steve Holen in Tanzania with Parkepu, a young Maasai, who was just heading off to college to earn a degree so that he would be better able to help his people. Kathe, a Nurse Practitioner, is an avocational archaeologist. In October she presented her first professional archaeological conference paper on a beveled bone rod from the Lindenmeier site in Colorado.

Suggested Readings

Holen, S. R. 1996 The Lovewell Mammoth: A Late Wisconsin Site in North-Central Kansas. *Current Research in the Pleistocene,* 13:69–70.

——— 2006 Taphonomy of Two Last Glacial Maximum Mammoth Sites in the Central Great Plains of North America: A Preliminary Report on La Sena and Lovewell. *Quaternary International,* 142–143:30–43.

——— 2007 The Age and Taphonomy of Mammoths at Lovewell Reservoir, Jewell County, Kansas, USA. *Quaternary International,* 169–170:51–63.

Stanford, D., R. Bonnichsen, and R. E. Morlan 1981 The Ginsberg Experiment: Modern and Prehistoric Evidence of a Bone-Flaking Technology. *Science,* 212:438–40.

Stanford, D. 1987 The Ginsberg Experiment. *Natural History,* 9:10–14.

drawing on similarities in primitive rock art found in Australia and Patagonia, makes a cognitive leap and proposes that boat people skirted the Southern ice shelf and crossed the South Atlantic (**MT 16-2,** "The First Americans: Were They Australians?").

Holen doesn't advocate abandoning the classic theory that Asians crossed the Bering Ice Bridge on foot and populated North America as far south as Mexico. Instead, the presence of humans on the Great Plains at the time of the LGM suggests to him that their forebears crossed from Asia *before* the Ice-Free Corridor was closed. The evidence, he says, "suggests that a steppe-adapted Upper Paleolithic population migrated overland from Siberia to Beringia and then southward into the Great Plains sometime between 21,000 and 40,000 RCYBP, before glaciation in Canada closed the migration route."

Support for this theory, he is quick to point out, isn't limited just to the evidence of pre-Clovis man-made bone breaks at the Lovewell Reservoir and La Sena sites. He cites discoveries in the Yukon: similar mammoth-bone flaking found at the Old Crow Basin in northern Yukon dating to 25,000–40,000 RCYBP; and cutmarks from stone tools found on bison bones dating to 36,500 and 42,000 RCYBP. Holen reminds us that his fellow scientist Richard Morlan, who died last January (**MT 22-2,** "In Memoriam: Richard E. Morlan"), remarked that evidence from the Yukon has never been adequately refuted. "The hypothesis that humans were in eastern Beringia by 40,000 RCYBP has not been falsified," says Holen, paraphrasing Morlan. "Instead it is generally ignored in the literature."

Steve Holen is raising our level of awareness.

–JMC

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Pribilof Islands Mammoths

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ment for sustaining these mammoths," he says. "But the increased volcanism also may have contributed to their survival. We just don't know."

Although scientists haven't determined exactly when mammoths on the Pribilofs became extinct, Yesner speculates it might have occurred around the time when polar bears arrived.

Collected bone specimens have given researchers material for ancient-DNA analysis, which may answer questions related to mammoth and polar bear evolution. Yesner is confident the studies, soon to be underway, will paint a more complete picture of the animals at Qagnax̂ Cave and their environment.

–George Wisner

Suggested Readings

Agenbroad, L. D., and D. P. Morris 1998 "Giant Island/Pygmy Mammoths: The Late Pleistocene Prehistory of Channel Islands National Park." National Park Service Web site www.nature.nps.gov//geology/paleontology/pub/grd4/chis.doc

Yesner, D. R., D. W. Veltre, K. J. Crossen, and R. W. Graham 2005 "5,700-year-old Mammoth Remains from Qagnax̂ Cave, Pribilof Islands, Alaska." In *The World of Elephants,* edited by L. D. Agenbroad and R. L. Symington, pp. 200–04. Mammoth Scientific Papers No. 4, Mammoth Site of Hot Springs, S.D.

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This caribou mandible is typical of many well-preserved animal bones that lay on the cave floor.

MAMMOTH TRUMPET

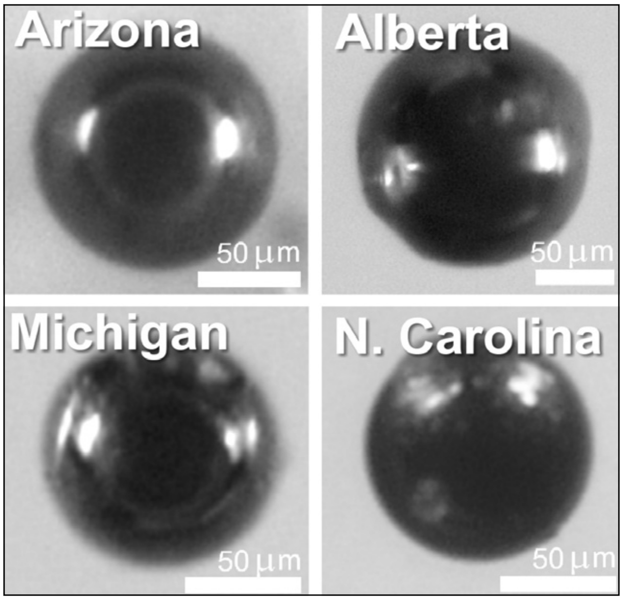
The Clovis Comet

continued from page 3

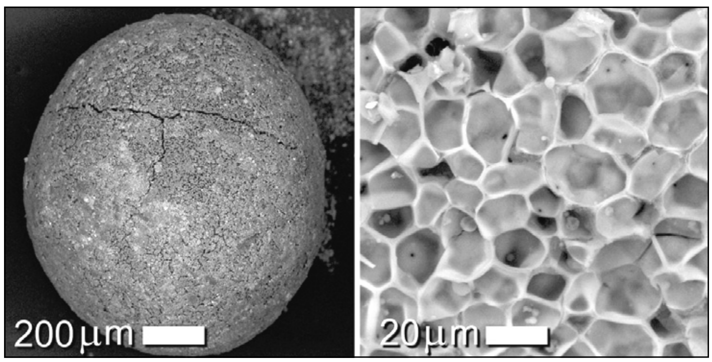
backyard," says West, who lives in Arizona. He obtained permission from Vance Haynes to collect samples of the Clovis sediments at Murray Springs, Arizona, and sure enough, they were loaded with microspherules. "That's when I got interested and really expanded the book. Rick Firestone agreed to come in as a coauthor, and I was in a position where I could fund the research." Eventually they built a team consisting of chemists, physicists, archaeologists, geologists, and various other specialists to help them evaluate the anomaly.

Research at Blackwater Draw, New Mexico (the Clovis type site), revealed that the microspherules were present in the Clovis sediments there as well. Since then, West and his team have found microspherules and a suite of other markers in the YD horizons of seven other Clovis and equivalent-age sites, including Chobot, Morley Drumlin, and Wally's Beach (all in Alberta, Canada); Topper in South Carolina; Lommel in Belgium; Daisy Cave in California; and Lake Hind in Manitoba. (West notes that he first learned of the archaeological discoveries of Anton and Maria Chobot of Buck Lake, Alberta, in **MT 16-1,** "Finding Early Peoples in Alberta.") They've also tested sediments from a number of Carolina bays, elliptical depressions long suspected to be associated with an ET impact event. Not all the impact markers have been identified at all the sites, but all sites present multiple markers at the YD boundary.

In addition to unusually high concentrations of microspherules (sometimes exceeding 2,000 times the normal background level), they've identified enriched levels of iridium and nickel at some sites—typical markers of ET impacts. Also common are spongy carbon spherules, glass-like carbon, soot, and polycyclic aromatic hydrocarbons, all evidence of high-temperature fires; Haynes's black mats; and, at four sites, carbon fullerenes containing demonstrably extraterrestrial helium. At 12 Clovis-age sites in 5 countries on 2 continents, they also found microscopic nanodiamonds,



◀ **Magnetic microspherules observed in YD sediments at Murray Springs in Arizona, Chobot in Alberta, Gainey in Michigan, and Howard Bay in North Carolina. Scale is in microns.**



▼ **Exterior (*left*) and latticework interior of a typical carbon spherule, in this case from South Carolina. Scale is in microns.**

BOTH: ALLEN WEST

WHAT'S A COMET?

Comets, meteors, asteroids, meteorites, supernovas—nonscientists among us have a hard time sorting out heavenly bodies. Astrophysicist Carl Sagan, in the companion book to his TV series *Cosmos,* tells how he once hit a communication snag when trying to explain to someone, What's a comet?

He was a graduate student in 1957, on duty one night at the Yerkes Observatory of the University of Chicago when the phone rang. When Sagan answered, the caller replied, "Lemme talk to a shtrominer."

The fellow was obviously quite soused. Sagan politely asked if he could help.

"Well," said the caller, "see, we're havin' this garden party out here in Wilmette, and there's somethin' in the sky. The funny part is, though, if you look straight at it, it goes away. But if you don't look at it, there it is."

Sagan thought it useless to try to explain that since the most sensitive part of the retina lies outside the center of your field of view, faint objects are best viewed by averting your vision slightly. He knew that a newly discovered comet called Arend-Roland was barely visible in the night sky at that time. So he told the caller he was probably looking at a comet.

After a long pause the caller asked, "Wash' a comet?"

Sagan replied, "A comet is a snowball one mile across."

After a longer pause the caller said, "Lemme talk to a *real* shtrominer."

–Ed.

which have exactly one known origin: ET impacts. That was the clincher. "At one point we looked at the possibility of major volcanism, but it just doesn't fit all the data," West says. "No volcanic eruption produces nanodiamonds." In his opinion, an extraterrestrial impact remains the best explanation for the totality of their findings.

Al Goodyear, who also contributed to the *PNAS* paper, agrees. He became involved in the project in the spring of 2005, when West contacted him about visiting Topper in order to sample the Clovis-age sediments there for ET markers. "I wasn't exactly sure what he wanted at first," Dr. Goodyear recalls, "but he explained that his team was going around America sampling sediments from Clovis sites with good context. He also explained that if their theory was right, they'd be able to tell me and other Paleoamerican researchers where the 12,900-year-old level was in a site. For sites without carbon for dating, this seemed like a good benefit."

BILL COVINGTON

Allen West (*left*) and Al Goodyear (*center*) consulting with backhoe operator John Thompson of Clariant Corporation at the Big Pine Tree site (38AL143), one mile from the Topper site in South Carolina.

Although Goodyear was a little skeptical at first, he was soon convinced. "Topper produced the iridium," he reports, "plus now they're finding trillions of nanodiamonds there." In addition, he soon came to realize that his own research indicated that something odd was happening immediately post-Clovis. In fall 2005, he reevaluated the South Carolina Paleoindian Point Database in preparation for that year's Clovis in the Southeast Conference in Columbia, South Carolina, reclassifying Redstone fluted points that had previously been identified as Clovis (*Current Research in the Pleistocene,* vol. 23, "Recognizing the Redstone Fluted Point in the South Carolina Paleoindian Point Database"). "When I finished," Goodyear explains, "I found that I had from 4 to 5 times more Clovis points than Redstones, the fluted-point type thought to come after Clovis. I examined the North Carolina and Virginia data and found essentially the same thing." Goodyear hypothesized that his results might indicate a widespread population decline, possibly as a result of the catastrophic Clovis impact postulated by Allen West's team. Currently, he and West are examining the data for evidence of similar patterns of population decline throughout the East.

D. J. KENNETT

C. Vance Haynes (*front*) and Allen West examining the black mat at the Murray Springs site in Arizona.

Reasonable doubt

Although the jury's still out on the matter, the clues unearthed by West and his team point toward a catastrophic impact at the end of the Clovis era. But what happened, exactly? The details remain sketchy, but the culprit was apparently a heavily fragmented multi-kilometer-sized icy body, similar to but much larger than the Tunguska impactor, which exploded over the continental ice sheet covering northeastern Canada. A cushion of ice 1 to 2 miles thick, after all, might explain why an impact crater associated with the event hasn't been found. While West admits that the absence of a crater blunts the theory, he argues that the other evidence more than makes up for it. "We have more than 14 lines of evidence that there was an impact," he points out. "We tell the people who don't believe this to point to a single place in the geological record where all these markers occur that *isn't* considered an impact."

We'll discuss the nature of the Clovis event in more detail in Part II of this series, "What the Data Tell Us." MT

–Floyd Largent

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