MAMMOTH TRUMPET

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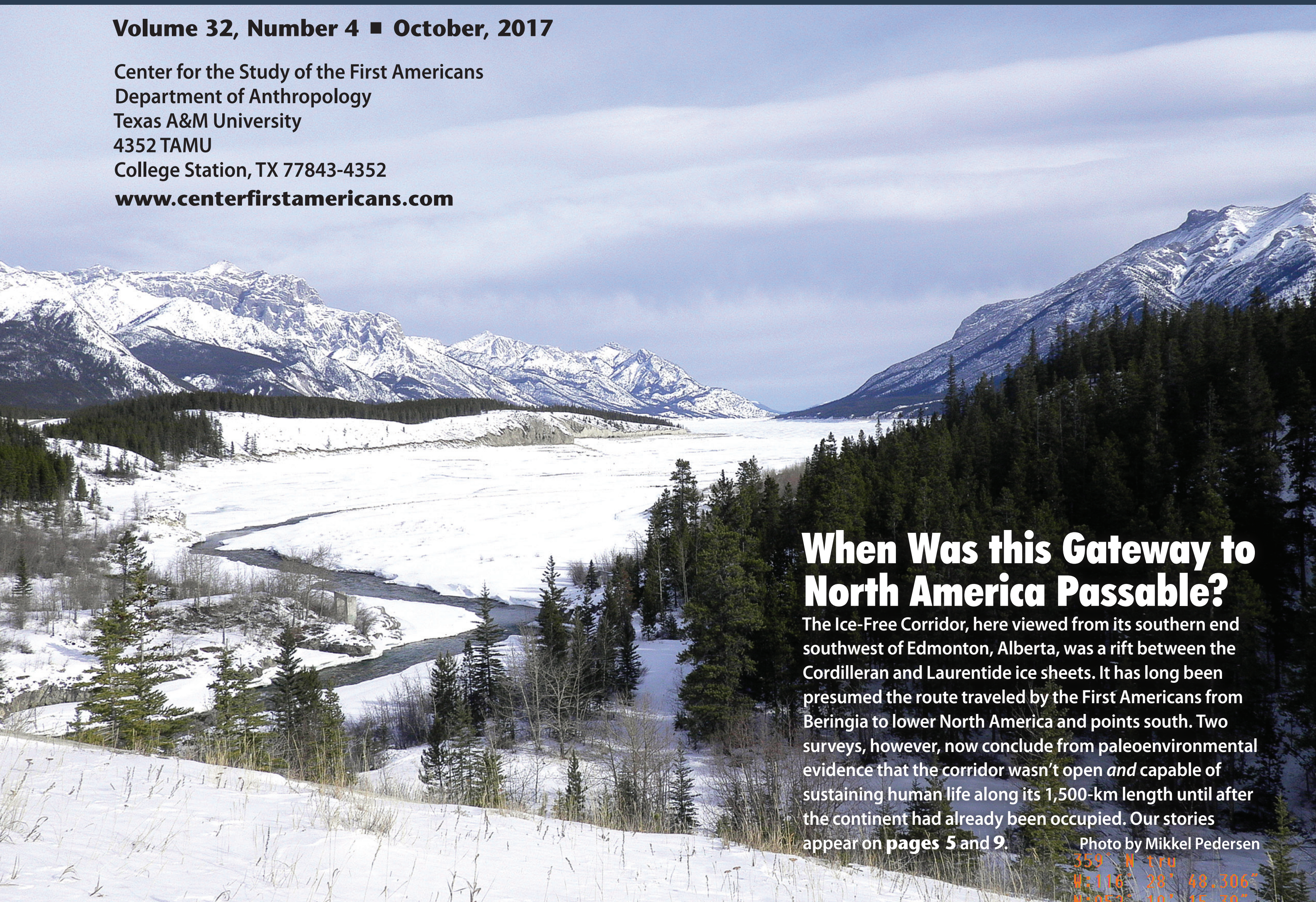

When Was this Gateway to North America Passable?

The Ice-Free Corridor, here viewed from its southern end southwest of Edmonton, Alberta, was a rift between the Cordilleran and Laurentide ice sheets. It has long been presumed the route traveled by the First Americans from Beringia to lower North America and points south. Two surveys, however, now conclude from paleoenvironmental evidence that the corridor wasn't open *and* capable of sustaining human life along its 1,500-km length until after the continent had already been occupied. Our stories appear on **pages 5** and **9**. Photo by Mikkel Pedersen

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Re-examining a classic First Americans site

Return to Old Vero

IN LATE MAY 2016, Vero Beach in Florida found itself in the national news for the first time in years. In a widely reported event, a shark attacked a woman swimming off its picturesque white sand beach in what experts termed "an exploratory bite." Fortunately, she suffered no life-threatening injuries. Before then, aside from a quiet 60-year stint as the Dodgers' spring training camp, few non-Floridians had ever heard of Vero Beach . . . except, of course, for First Americans researchers. For us, the name conjures up a classic but controversial archaeological site—one that has recently been re investigated by some of the top names in the field.

Fragment of 9,000-year-old cordage in situ, 2015 excavations.

C. ANDREW HEMMINGS

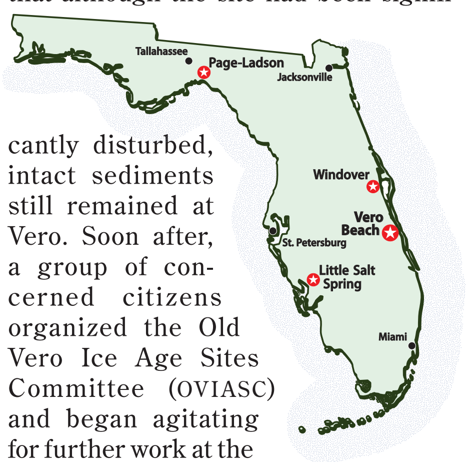
Known simply as Vero until incorporated in 1925, Vero Beach is the hometown of "Vero Man." Although we still don't know how old Vero Man is, it remains one of the oldest collections of human remains ever discovered in the New World—and among the first ever taken seriously as such. It all began in 1912, when canal excavations unearthed a trove of Ice Age animal bones. It evolved into an archaeological site in 1915, explain investigators James Adovasio and C. Andrew Hemmings, both of the Harbor Branch Oceanographic Institute (HBOI) of Florida Atlanta University (FAU), when Frank Ayers found in situ human bones eroding from the wall of the adjacent irrigation canal. Florida State geologist Elias H. Sellards promptly returned to the site and discovered additional in situ human remains. These discoveries set in motion additional field work throughout 1916, and promoted site visits by a large number of "Early Man" authorities of the time.

Vero Man challenged long-held scientific assumptions. Consequently the bones—and Sellards's assertion that their association with the remains of long-extinct animals proved their antiquity—were all but buried in the overburden of doubt heaped on them by those whose life

INSIDE

work they threatened. Physical anthropologist Aleš Hrdlička, for example, refused to believe the Vero finds were more than 4,000 years old; he insisted they had been buried in graves intruding into much older deposits. Hrdlička's reputation carried a lot of weight, and given the site's lukewarm reception from other members of the scientific community, Vero thereafter was mostly ignored. Sellards himself left for Texas in 1919. More work conducted in 1956–57 yielded more than 20,000 animal bones, but no new human remains.

Fast forward to 2008, when local officials proposed a water treatment plant whose construction might damage whatever remained of the site. A series of cores taken from 2008 to 2012 revealed that although the site had been significantly disturbed, intact sediments still remained at Vero. Soon after, a group of concerned citizens organized the Old Vero Ice Age Sites Committee (OVIASC) and began agitating for further work at the site using modern methods that might settle the matter of early human occupation once and for all. They invited Dr. Hemmings to conduct further work there and were themselves prepared to finance the research. Since 2013 Dr. Adovasio and Hemmings, both highly respected members of the First Americans research community, have conducted fieldwork and associated analyses under the auspices of the HBOI and OVIASC. A third partner, Mercyhurst Archaeological Institute of Mercyhurst University in Pennsylvania, recently withdrew after cosponsoring the 2013–15 excavations.



When the coprincipal investigators first returned to the Old Vero Site (also known as 8IR009, for the ninth site to be discovered in Indian River County, Florida), they had no trouble marrying their new investigations with Sellards's, for he had accurately recorded distances, elevations, and orientations of specimens referred to specific locations on a nearby railroad track that still exists. These datum points enabled the new Vero team to remove overburden, establish the boundaries of the early work, and begin new excavations of their own.

Putting Vero into context

It's hard to overstate the importance of the Old Vero site to First American studies. Despite the cynicism of Hrdlička and others, generations of nascent archaeologists regard it as one of the first sites to suggest that humanity's tenure in the New World exceeded a few thousand years.

As Adovasio and Hemmings explain, "The Old Vero Site was the first locality to seriously challenge the received wisdom of the early 1900s that humans and Ice Age animals were not contemporaries on the New World landscape.

MAMMOTH TRUMPET

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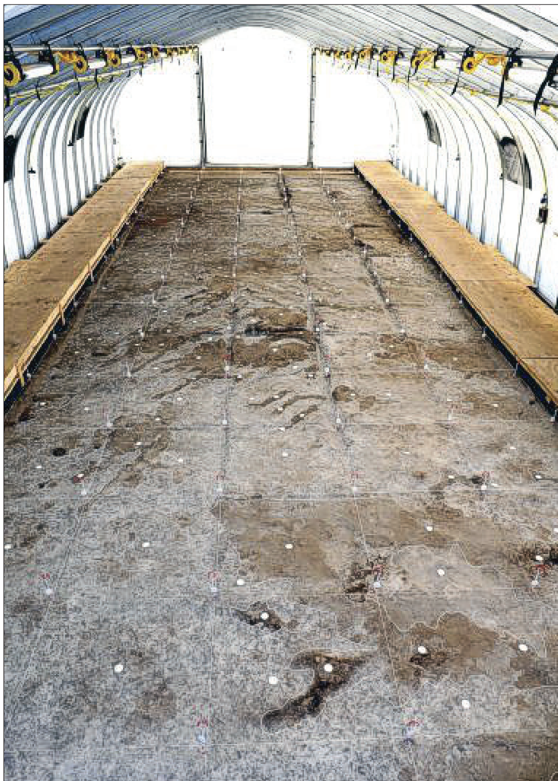
–Michael R. Waters, Director

Hrdlička, William Henry Holmes, and Thomas and Rollin Chamberlain (father-and-son geologists at the University of Chicago) all opined that humans had entered the New World only after the last Ice Age had ended and, therefore, all claims of an earlier entry were deemed specious. . . . Sellards announced the Vero Man Site to the world in the 1 July 1916 issue of *Science,* and for the next few years Vero became the epicenter of the North American archaeological world.”

But Vero fell into limbo after Hrdlička finished his systematic criticism of the fieldwork, geological reconstruction, and cultural association of the faunal materials claimed by Sellards and his allies. In his last word on anything concerning Early Man, in 1925 Holmes called Sellards's work at Vero “dangerous to the cause of science”—“Which we of course put on the back of our crew's T-shirts for the Society of American Archaeology site tour in 2016,” reports Hemmings. Because few lithic artifacts had been found at the site, Sellards couldn't point to a “smoking gun” to prove his interpretation. The initial investigations occurred well before radiocarbon dating, fossil pollen analysis, and other advanced analytical techniques had been added to the archaeological toolkit.



C. ANDREW HEMMINGS

WeatherPort interior with overburden removed, 2015.

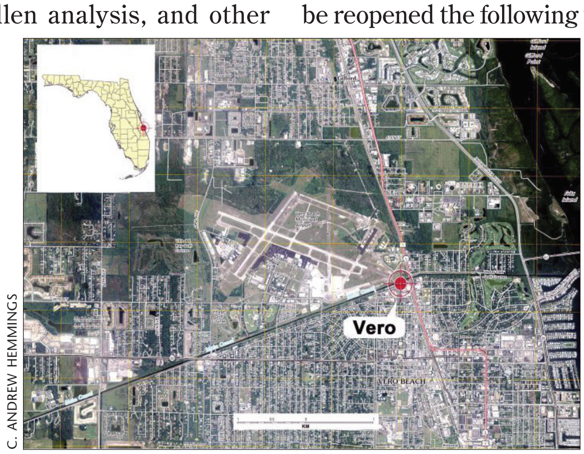
C. ANDREW HEMMINGS

Clean stratigraphic profile of the Old Vero site during the 2015 excavations.

The site was visited sporadically by researchers from 1917 on, but Sellards alone bothered to publish his research. His Vero publications, which continued until his death in 1961, were enough to keep interest alive, if barely. Vero remained on the list of questionable “Early Man” sites for decades. Unlike many of those sites, however, Vero was preserved largely intact, despite being located within the city limits. Adovasio explains that the site has been preserved “largely by the efforts of the Indian River Water Control District in the person of David Gunter, and the efforts of OVIASC, in conjunction with several prominent Florida-based archaeologists such as Barbara Purdy and Glenn Doran.”

Adovasio and Hemmings became involved when they were engaged in an underwater investigation of the continental shelf off Florida's west coast, sponsored by National Oceanic and Atmospheric Administration (**MT 26-1,** “Prehistoric Florida submerged: Finding clues on the continental shelf”). The president of the OVIASC asked Hemmings if he was interested in re-excavating Vero, and Hemmings in turn invited Adovasio to participate. Assured that intact deposits remained and that funding would be adequate to do the job right, Adovasio and Hemmings agreed to participate.

Hemmings, Adovasio, and their team have completed three seasons of rigorous fieldwork, widely perceived as state-of-the-art in approach and execution. The logistics (“extraordinarily complex,” according to Adovasio) include a utilities-equipped WeatherPort shelter erected over the excavation area, and the construction of an extensive drainage system. Unexcavated deposits are carefully backfilled at the end of each season, only to be reopened the following year.



C. ANDREW HEMMINGS

Location of the Old Vero site within Vero Beach, Florida.

Meticulous research

The techniques used at Vero were developed by Adovasio and his colleagues during their work in the 1990s at Meadowcroft Rockshelter in Pennsylvania. Announcement that the occupation at Meadowcroft predated Clovis ignited a firestorm of controversy, because at the time the Clovis-First model dominated

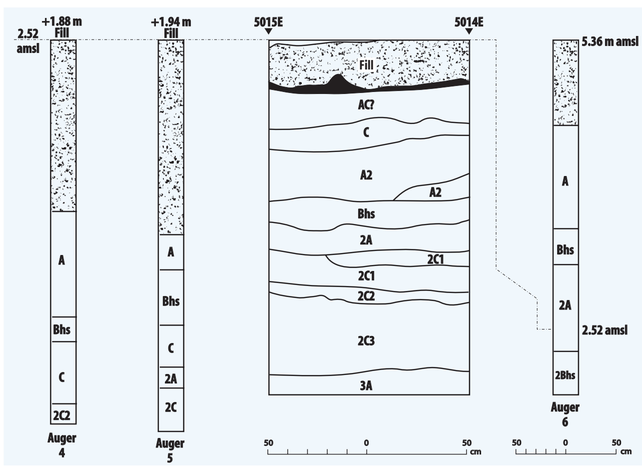
First Americans studies. They nonetheless persevered with careful scholarship and unassailable fieldwork until Clovis was ultimately proven not to be the first New World culture (**MT 22-3,** "Clovis dethroned"). Today a substantial sector of the scientific community, though by no means its entirety, accepts Meadowcroft as a pre-Clovis site.

"The current excavations at Vero are being conducted with the most rigorous protocols currently known in the field," Adovasio explains. He speaks as a realist who understands that their team's discoveries, before being accepted, must overcome intellectual inertia among fellow scientists. High-resolution protocols therefore "are absolutely critical to establishing—without possible refutation—the stratigraphy, context, and association of all recovered materials in the current excavations." He notes that the Old Vero site excavations are the most extensive of their kind currently underway in eastern North America.

Hemmings (*left*) and Adovasio off the coast of Florida, 2009.

JAMES M. ADOVASIO

One particularly exciting find from the 2015 season is a piece of preserved cordage, which dates from at least 9,000 CALYBP—a rare discovery indeed in Florida's climate, where heat and humidity normally rapidly decompose such artifacts. Made of three interwoven strands of what appear to be sabal palm fibers, this piece was recovered en bloc—that is, an entire block of the sediments around the artifact was removed, with the cordage in the center, for it was far too fragile to excavate in place.



General stratigraphy profile of the Old Vero site.

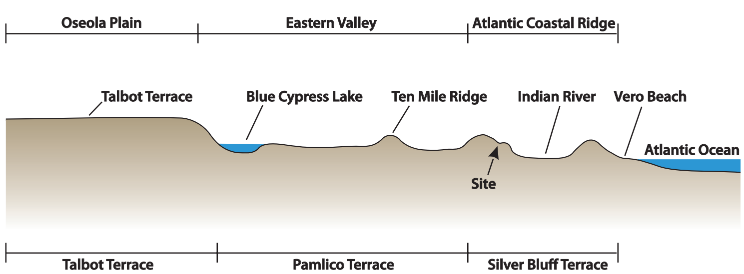
AFTER C. ANDREW HEMMINGS

Even more exciting, it turned out not to be an isolated find. "Since then, additional plant fiber-derived artifacts have been recovered and are currently under analysis," Adovasio reports. "The age and technological attributes of these materials are consistent with those recovered by Glen Doran from the Windover Bog [in nearby Brevard County]" (**MT 31-2,** "The Windover site: A Paleoamerican tableau"). Unlike those artifacts, however, the Vero cordage wasn't preserved in oxygen-free bog deposits.

Unfortunately, the human remains recovered at Vero in the early part of the 20th century have been scattered among at least 22 institutions. Some have been lost, and chemical treatment has made it impossible to radiocarbon date those that remain. Nor has the current round of excavations produced new human bone for study. It has, however, yielded evidence of multiple Prehistoric occupations, some decidedly older than the cordage. The uppermost, represented by both biological materials and stone tools, dates from the Middle Archaic era back into the Early Archaic—a period spanning about 4000–11,000 CALYBP, dating almost to the classic Paleoamerican era. The last weeks of the 2106 excavations also yielded a bone bed containing the remains of long-extinct *Bison antiquus,* as well as the bones of prey animals yet to be identified. Some of the bones seem calcined, having been exposed to intense, possibly deliberate burning. "The bone bed is intercalated with extensive amounts of ash and charcoal strongly suggestive of a human presence," according to Adovasio and Hemmings. "The minimal age of the bone bed is 13,000–14,000 CALYBP." This pushes the occupation "well into the Middle Paleoindian period, if not earlier."

The future of Old Vero's past

With its intact deposits and potential for teaching us more about humanity's history in the New World, not to mention a rich library of faunal data, the Old Vero Site may ultimately surpass its current legendary standing in the First Americans community. FAU and OVIASC continue to work there under the leadership of Adovasio and Hemmings. In addition to the bone bed and multiple examples of cordage now recovered from the Paleoamerican/Early Archaic deposits, they've identified "multiple Late Wisconsin–age and Holocene stacked paleosols, which



General geomorphology of the Old Vero site.

AFTER C. ANDREW HEMMINGS

continued on page 8

Was the Ice-Free Corridor the Route Followed by the First Americans?

Part 1: Pollen and eDNA Evidence

North America ca. 14,000 CALYBP. The newly formed Ice-Free Corridor lies between the continental ice sheets.

FROM PEDERSEN ET AL. 2016, *NATURE*

DURING THE LAST GLACIAL MAXIMUM a continuous sheet of glacial ice, 2 miles thick in places, covered all of northern North America. It formed an impassable barrier to any landbound hunter-gatherers living in Beringia and prevented them from exploring farther south. Before they could migrate into the New World along a land route, two events had to occur. First, a gap had to form between the Cordilleran Ice Sheet to the west and the much more massive Laurentide Ice Sheet to the east. Next, plants had to recolonize this cold, water-logged landscape to support herbivores and thereby provide food for human hunters on their journey. New research indicates these events didn't occur until around 12,600 CALYBP. The First Americans, who arrived more than 14,000 years ago, must therefore have found some other way to enter the continent, perhaps in boats along the Pacific Rim (**MT 24-3,** "Putting muscle into coastal-entry research").

In this 2-part series, we'll examine the evidence for when the passageway between the glaciers opened, and for when the environment along its 1,500-km length could have sustained human life. In part 1, we'll review the results of a study, published in the 1 September issue of the journal *Nature*, of ancient DNA, pollen, and plant macrofossils recovered from sediment cores extracted from lakes in Alberta and British Columbia. In the same issue of *Nature,* Suzanne McGowan, with the School of Geography at the University of Nottingham, declares that the study provides "the most complete picture yet of the timing and pattern of plant and animal development in a central 'bottleneck' region of the ice-free corridor (thought to be one of the last places in the corridor to become habitable)."

In part 2 (page 9 in this issue), we'll review two separate papers that similarly use ancient DNA, radiocarbon dating, and other methods to study ancient elk and bison to gain insights into the same two questions: When did the Ice-Free Corridor open, and when did the environment within the corridor become a suitable route of entry for humans to the New World?

UNLESS NOTED, ALL PHOTOS: MIKKEL WINTHER PEDERSEN

In the lab, Pedersen removes samples of ancient mud. To prevent contamination from modern sources he uses sterile tools and wears a mask, full body suit, and gloves.

Needed, a *habitable* avenue for humans

The timing of the opening of the Ice-Free Corridor, the gap that opened between the two great continental ice sheets, has been the focus of research for decades. The consensus of the scientific community is that it appeared sometime between 15,000 and 14,000 CALYBP, and that this gap was the gateway that finally freed Asian populations inhabiting Beringia to expand into North America and, only slightly later, South America.

But just because the corridor opened doesn't mean it was habitable. How long did it take for plants and animals, necessary to sustain human life, to return to the intensely cold and water-logged landscape? Was it years, or centuries?

Mikkel Pedersen and Eske Willerslev, with the University of Copenhagen Centre for GeoGenetics, along with 15 coauthors representing 13 additional institutions from four countries, contributed to various aspects of interdisciplinary research aimed at answering these questions.

The frozen surface of Charlie Lake, more than half a meter thick, was strong enough to support a pickup truck that the Willerslev and Pedersen team used to haul equipment and cores.

Paleoenvironmental data preserved in lake-bottom sediment

Pedersen, Willerslev, and their team collected nine sediment cores from two remaining remnants of Glacial Lake Peace, a massive lake that formed when the Laurentide Ice Sheet began to melt and retreat at around 15,000 CALYBP. They note that "this area was amongst the last segments of the corridor to open and is pivotal to understanding its history as a biogeographic passageway." The layers of sediment that accumulated in this basin contain a variety of plant and animal fossil traces that record changes in the environment from the time when the lake initially formed to when it shrank and fragmented into smaller, separate lakes.

Sediment cores up to 6 m long were extracted.

Although the microfossils that their team recovered and studied aren't as spectacular as mammoth bones, they constitute a much more representative sample of the diversity of animals that lived in the Ice-Free Corridor. Large fossil bones have been found that include mammoth, bison, horse "and probably some camel, musk ox and caribou." But none of these bones are older than about 13,000 CALYBP and therefore can only tell us the earliest date at which "the corridor became a viable passageway over its entirety," not what the corridor was like in the centuries after it first opened.

Like faunal remains, pollen data have serious limitations. Some plants don't produce pollen, particularly the kinds of pioneering plants that are of special interest in a study of the earliest phases of plant colonization in the Ice-Free Corridor. Moreover, of pollen-producing plants, some produce abundant pollen and others produce relatively little. Since many kinds of pollen can be carried by the wind over great distances, the composition of pollen varieties found in a lake basin doesn't necessarily reflect the proportions of different plant types in the local vegetation mix.

Environmental DNA, a useful gauge

Pedersen, Willerslev, and their coauthors define "environmental DNA" (eDNA) as "molecular fossils of local organisms derived from somatic tissues, urine and faeces." Decaying animal corpses as well as parts of plants that fall or are washed into a lake, or into streams feeding the lake, release fragments of DNA into the water, which then settle onto the lake bottom. Animals urinating or defecating in the watershed of the lake also introduce fragments of DNA that accumulate in the layers of sediment at the lake bottom. As layer upon layer accumulates, a record of changes in the environment at this location builds up like pages in a book.

The team used a method called "shotgun sequencing," which interprets the many small DNA fragments in the layers of Lake Peace muck as fragments of pages from the many books that represent the genomes of the plants and animals that successively occupied the vicinity. By identifying page fragments that shared portions of the same text and piecing them together, they reconstructed enough of the original books to determine which books, or species of plants and animals, were members of the library of life in each layer of lake muck.

Team member Willerslev pioneered the analytic method of environmental DNA research, which extracts DNA of mammals, birds, and plants directly from ancient sediments (**MT 27-4,** “Mass extinction of megamammals: A prehistoric who-done-it”).

Using eDNA and pollen data, Pedersen and Willerslev’s team thus reconstructed the changing environment of this region of the Ice-Free Corridor from its formation in the late Pleistocene until late in the Holocene. The bottommost, therefore the earliest, layer consists of gravel deposited by the glaciers. This is followed by multiple layers of silt with little organic matter, which reflect the evolution of the environment during the early stages of Glacial Lake Peace.

- **Before ca. 12,600 CALYBP** The region “appears to have been largely unvegetated.” Grasses and sedges became established shortly thereafter.
- **Ca. 12,600–11,600 CALYBP** The region was a steppe dominated by plants like sagebrush and buttercup, with scattered birch and willow trees. Poplar and black elderberry trees grew on higher elevations. The steppe vegetation “supported a variety of animals,” including bison, vole, and jackrabbit, which appeared by 12,400 CALYBP. Later, as poplar trees became more abundant, elk, moose, and bald eagles appeared and reached peak numbers at around 11,600 CALYBP. Pike are present by about 11,700 CALYBP; since pike are a top predator, a rich “fish community” must also have been present by this time.
- **Ca. 11,600 CALYBP** The sediment data record a dramatic change to “sandy organic rich mud,” which marks the end of the Pleistocene, the beginning of the Holocene Epoch, and the break-up of Lake Peace into smaller, discrete lakes with their particular histories. A boreal forest, dominated by spruce, pine, and birch, became established at this time.
- **Ca. 11,500 CALYBP** Pollen influx declined as green algae became more common. The team attributes these changes to “changing nutrient sources, lake chemistry, sediment input” and other factors that followed the break-up of Lake Peace into numerous smaller lake basins.
- **Ca. 11,300 CALYBP** Pollen rain increased in at least one of the smaller lakes. The team interprets the fluctuation as “responses of a highly dynamic landscape” to unstable weather patterns associated with the nearby glaciers.

Does the eDNA record provide a reliable picture of ancient environments?

At around 7000 CALYBP, the pollen and plant macrofossil data show that alder trees were growing in the vicinity, but alder eDNA does not show up in the record until around 5500 CALYBP. This discrepancy led the team to do a variety of statistical tests to determine whether the plant communities identified through eDNA corresponded to the plant communities identified in the pollen data. These tests confirmed that, despite this anomaly, there was overall consistency between the main pollen zones and the groups of species identified through their eDNA, and that eDNA can therefore accurately identify “large ecological changes found in pollen records.”

Nevertheless, other discrepancies between the pollen and eDNA profiles suggest that some plant species, owing to differences in their reproductive processes or in the taphonomic histories of sampling locations, might be under- or over-represented in pollen or eDNA. The record for poplar is the most notable discrepancy identified by the team. In one of the small lakes that were originally part of Peace Lake, the “pollen and eDNA signals are congruent” from 11,600 to about 11,200 CALYBP, but in levels older than 12,100 CALYBP the eDNA signal “is more pronounced.” In another of the smaller lakes, poplar pollen occurs only in the oldest layers, whereas poplar eDNA is abundant throughout the record. The team therefore concludes from the eDNA that “poplar was probably more abundant in the regional vegetation than has previously been shown” by pollen data. Pedersen, Willerslev, and their coauthors argue that this observation has “important implications for human occupation” because poplar would have provided food for game animals as well as “fuel, shelter, and tools” for humans.

The fieldwork, conducted in the winters of 2012 and 2013, used a lightweight percussion corer operated while standing on the frozen surface of Charlie Lake, a relict of Glacial Lake Peace.

The eDNA record also generally provides a more complete picture of the composition of animals in the environment than can be deduced from faunal remains. Large fossil bones are rarely preserved at all, and even when preserved they are rarely discovered and reported in the scientific literature. The earliest elk fossils in the area date to around 10,200 CALYBP, but the eDNA indicates elk were present as early as 11,500 CALYBP. Of course, it’s even rarer for the remains of smaller animals to be preserved and discovered.

On the other hand, the team concedes that “there are also notable absences in eDNA compared to the vertebrate record." Fossil remains from Charlie Lake Cave, which is located along one of the small lakes sampled by Pedersen and Willerslev's team, has abundant remains of "waterfowl and other birds and fish," yet these various species are absent from the eDNA record. Likewise, beaver are known to have lived in the area as early as 11,000 CALYBP, but they only show up in the eDNA record between 5400 and 3000 CALYBP. The important take-away message is that we get a more complete record of the presence of plants and animals when we combine as many lines of evidence as possible.

"A window onto ancient worlds"

Suzanne McGowan writes in her companion review of Pedersen, Willerslev, and their coauthors' paper that "the analysis of ancient DNA in the ice-free corridor has provided a window onto ancient worlds."

The Ice-Free Corridor opened in this bottleneck region between 15,000 and 14,000 CALYBP, and the melting ice sheets flooded much of the landscape beneath the cold waters of Glacial Lake Peace. By 12,600 CALYBP the ice and much of the water had receded and plants had recolonized the landscape, followed closely by large and small animals. Not until around 12,500 CALYBP was the corridor capable of sustaining hunter-gatherers for the time it would take to travel the length of the 1,500-km corridor.

We know that people were well established in North and South America more than two thousand years before the Ice-Free Corridor was open and capable of supporting human life (**MT 27-2,** "Buttermilk Creek: A pre-Clovis occupation along the margin of the Southern High Plains; **MT 32-2,** "The Page-Ladson Site: 'An Uncommon Doorway to Our Past'"). The conclusion is therefore inescapable that those people must have entered the lower regions of the Americas by some other route. Pedersen, Willerslev, and their colleagues concur that the most likely route was along the coast. They considered the proposal that a pre-Clovis population entered along the coast and later merged with a Clovis migration that followed the Ice-Free Corridor, but since the Clovis culture was present in North America by 13,500 CALYBP and the Ice-Free Corridor was unable to sustain people until 12,500 CALYBP, that idea won't hold water.

McGowan concludes her review of the paper by Pedersen, Willerslev, and their coauthors with the observation that "further investigation of the hypotheses for human migration into the Americas will require close integration of studies analyzing archaeology, genetics and ancient environments, which should, in turn, identify pathways for developing more complete interpretations of sedimentary ancient DNA." It's clear that the work of Pedersen, Willerslev and their team have laid a solid foundation for those future studies by making a convincing case for the primacy of a coastal entry route for the very first Americans. MT

–Brad Lepper

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Suggested Readings

McGowan, S. 2016 Muddy messages about American migration. Nature 537:43–44.

Pedersen, M. W., A. Ruter, C. Schweger, H. Friebe, R. A. Staff, K. K. Kjeldsen, M. L. Z. Mendoza, A. B. Beaudoin, C. Zutter, N. K. Larsen, B. A. Potter, R. Nielsen, R. A. Rainville, L. Orlando, D. J. Meltzer, K. H. Kjær, and E. Willerslev 2016 Postglacial viability and colonization in North America's ice-free corridor. *Nature* 537:45–49.

Return to Old Vero

continued from page 4

conform to paleosols previously identified on St. Catherines island in Georgia and in eastern Maryland." These buried, former surface soils represent long periods of stability and weathering, logical places to find human living floors.

The 2016 field season is over, but during the off-season there's plenty to analyze, and publications to write and submit. Even better, there's more to come. In 2017, Adovasio, Hemmings, et al. will resume excavating the bone bed found near the end of the 2016 fieldwork, and test other areas of the site for intact deposits that might reveal further secrets about some of the first people to walk the North American continent.

A hundred years ago, some experts closed the book on Vero as an early human occupation site. To our good fortune, researchers like E. H. Sellards tucked a bookmark in place, which sustained a low level of interest and kept the site visible in scientific consciousness. Re-examining Vero in the past few years, using modern scientific methods, has proven they were right to do so. Continuing research promises to teach us even more.

Who knows what our scientific descendants might discover at Vero a century from now? MT

–Floyd Largent

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To learn more about the archaeological history of the Vero Beach site and current investigations, log on to the Old Vero Ice Age Sites Committee website: **http://www.oviasc.org/**

Was the Ice-Free Corridor the Route Followed by the First Americans?

Part 2: Megafaunal Evidence

THE ICE-FREE CORRIDOR is the gap that opened in the massive continental glaciers that covered all of northern North America during the Pleistocene Epoch. With the gradual melting of the Cordilleran Ice Sheet to the west and the Laurentide Ice Sheet to the east, a 1,400-km-long rift opened in the formerly continuous mass of ice. Once recolonized by plants and animals, this corridor would have offered humans living in Beringia an avenue for walking into a new (at least to them) world. The big question is whether this is the route into that New World that the very first Americans actually followed.

In the first of this 2-part series of articles on when the Ice-Free Corridor was both open and habitable (page 5 in this issue), we focused on evidence from environmental DNA, pollen, and plant macrofossils obtained from cores extracted from layers of lake muck from a key area inside the corridor. These data give an overview of the broad spectrum of plant and animal life that inhabited the Ice-Free Corridor from the parting of the ice sheets to the onset of the more-or-less modern environment.

In part 2, we'll review the results of two studies that examine the evidence for a particular species of large mammal known to have been hunted by the First Americans. Do these data support the rich, multi-species lake-core record, or do they challenge the interpretations based on that record?

Where the buffalo roam

Peter Heintzman, with the Department of Ecology and Evolutionary Biology at the University of California, Santa Cruz, and Beth Shapiro, from the same department and with a joint appointment with the University of California Santa Cruz Genomics Institute, along with 15 coauthors, obtained new radiocarbon dates as well as ancient DNA from fossil bison recovered from the corridor region and adjacent areas in Beringia. Their purpose was to assess when the corridor opened and was hospitable for large mammals and humans.

The team chose bison as an ideal species for answering these questions because bison are one of the most abundant fossilized megamammals recovered from sites in the western interior of North America, so data were plentiful. Moreover, unlike many other large mammals, "bison survived the extinction event at the end of the Pleistocene" and bison genomes "contain the signature of a genetic bottleneck" resulting from its near extinction at that time. This means that comparing ancient and modern genomes can provide insights into "how ice age environmental changes affected their distribution and abundance." To avoid complications from the potentially confusing plethora of species of bison, the team chose to focus on only one, *Bison priscus,* the steppe bison, because it was the first to enter North America from Asia during the Pleistocene (**MT 24-4,** "Bison carcass dates the Ice-free Corridor").

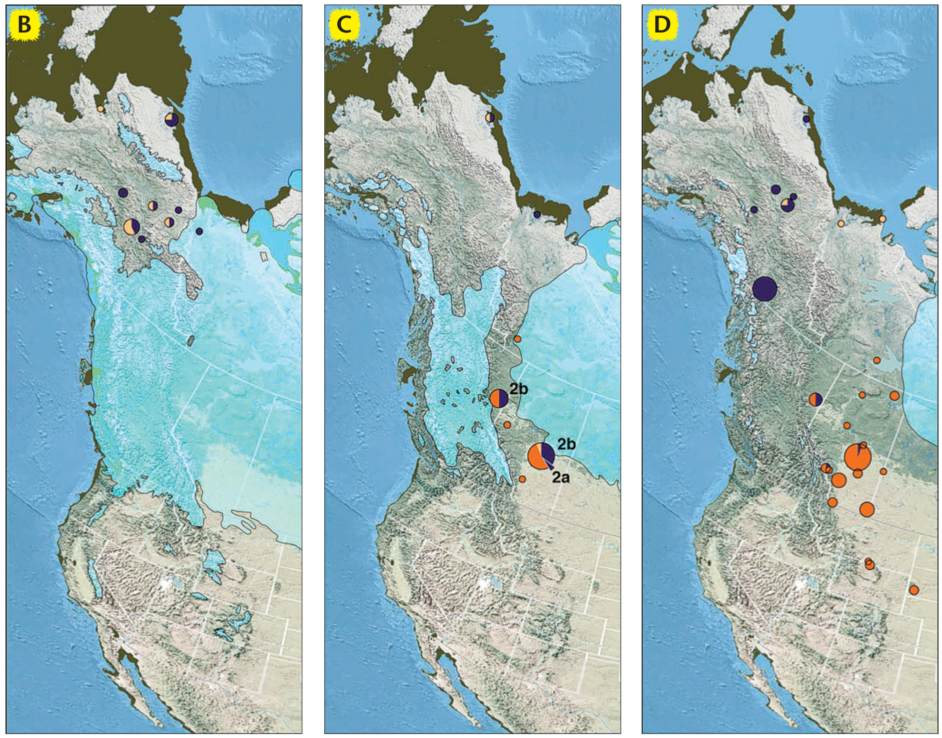
Yukon paleontologist Grant Zazula holding a steppe-bison skull from his collection at the Yukon Paleontology Museum.

YUKON GOVERNMENT

Heintzman, Shapiro, and their team first radiocarbon dated 78 North American bison fossils, of which 49 were recovered from the corridor region. Then they identified mitochondrial haplotypes for 45 of the dated fossils. Mitochondria are organelles in the cytoplasm of cells that have their own DNA. Because mitochondrial

Geographic distribution and clade assignment of 192 radiocarbon-dated or present-day North American bison. Bison mitochondrial clade 1a arises in the south during the interval depicted in B.

- **A** >23,000 CALYBP, before glacial coalescence;
- **B** 23,000–13,500 CALYBP, during glacial coalescence;
- **C** 13,500–12,000 CALYBP, as the corridor opens;
- **D** <12,000 CALYBP.



FROM WWW.PNAS.ORG/CGI/DOI/10.1073 PNAS.1601077113

DNA (mtDNA) is much more abundant in tissue samples than nuclear DNA, it's much easier to recover from ancient fossils. In addition, since mutations accumulate faster in mtDNA than in nuclear DNA, mtDNA provides a more sensitive measure of short-term changes between populations. A disadvantage of using mtDNA for such studies is that it is only passed from mothers to offspring and therefore only tracks the maternal line of inheritance.

The Heintzman–Shapiro team combined their new mtDNA data with previously published results to arrive at a "mitochondrial genealogy for a total of 192 late-Pleistocene, Holocene, and present-day North American bison, including 37 from the corridor region and within the time frame of interest." They identified two distinct "clades," or groups, that reflect an ancient division in their ancestry. All present-day bison belong to Clade 1, "with a maternal common ancestor that postdates the LGM" [Last Glacial Maximum]. Clade 2 comprises two subclades. Subclade 2a, a population of bison that current data suggest was "geographically restricted to southern Yukon and interior Alaska," survived to as recently as 325–490 CALYBP. Subclade 2b, "geographically isolated to the region of the postglacial corridor," also became extinct sometime after 400 CALYBP. The Heintzman–Shapiro team interpret these results as an indication that at the end of the Pleistocene bison populations were being broken up by expanding spruce forests into small subpopulations, increasingly isolated from one another in shrinking pockets of open habitat.

Based on the presence of bison from all three clades at the Clover Bar site near the southern end of the corridor at around 13,000 CALYBP, the Heintzman–Shapiro team conclude that the "postglacial corridor was fully open for dispersals" by this time. The Subclade 2a bison had entered the corridor at the north end, whereas the other bison as well as horses, lions, camels, and musk oxen had recolonized the corridor from the south end.

Elk and the First Americans

Meirav Meiri with the Institute of Archaeology at Tel Aviv University, Ian Barnes with the London Natural History Museum and the University of London, and 11 coauthors representing institutions in Russia, Canada, and the United States used a combination of ancient DNA and radiocarbon dating to investigate the timing of the migration of elk (wapiti) into North America as a way of determining when the environment of the Bering Land Bridge was capable of sustaining large mammals. They weren't focused on issues related to the Ice Free Corridor, but their work certainly has important implications for our understanding of this later phase of the elk migration into North America. Their results were published in 2013 in the Proceedings of the Royal Society B.

The Meiri–Barnes team found that the oldest elk fossils in Alaska were about 15,000 years old, which suggests they arrived in Beringia at about the same time as people. Based on this correspondence, the team suggest that a study of the elk migration has "the potential to illuminate the timing and mode of faunal and human expansion into the New World."

The Meiri–Barnes team obtained "a total of 113 samples from ancient antlers, teeth, and bones of Asian and North American wapiti . . . from museums across Eurasia and North America." They also collected 74 modern elk specimens from across Asia and North America. The team obtained radiocarbon dates for 32 of the 113 ancient specimens. Twenty-two of the 113 already had been dated, so the ages of a total of 54 specimens were established.

REBECCA JOHNSON, THE AUSTRALIAN MUSEUM

Barnes and Shapiro at the Plant and Animal Genomes conference in San Diego, 2017.

The team recovered mtDNA from 44 of the 113 ancient specimens and 49 of the 74 recent specimens. The DNA extractions for the ancient and modern samples were conducted at different labs to reduce the possibility of cross-contamination. The results of these analyses paint a detailed picture of the colonization of North America by elk.

The radiocarbon dates establish that elk were present in northeast Siberia from between 50,000 and 400 years ago. In contrast, elk in North America date from 15,000 to 5,000 years ago. (Elk currently living in Alaska are recent reintroductions.) These results confirm that the American elk originated in Siberia and that elk could thrive at higher, and therefore colder, latitudes than previously thought.

The mtDNA analysis identified two major groups of elk: a very diverse group of modern wapiti from central Asia and northeastern Russia, and ancient specimens from northeastern China and northeast Siberia; and a group that included modern American wapiti, central Asian individuals, and ancient samples from Beringia (both northeast Siberia and Alaska) and Alberta. The mtDNA data therefore "strongly support an expansion of a subset of the northeast Siberia population into North America via Beringia," and finally conclude that all American elk are descendants of that original colonization.

The Meiri–Barnes team conclude that the environment of central Beringia "was a barrier that prevented wapiti (and moose) from crossing to Alaska" until after 15,000 years ago. Once the Ice-Free Corridor opened and became habitable, the elk moved rapidly southward from eastern Beringia into the rest of northern North America. The Meiri–Barnes team suggest that "the subsequent expansion of both humans and wapiti through the lower 48 states also appears to have occurred as part of a common ecological event." Therefore, "the ecology of wapiti . . . includes key limiting factors that can enhance our understanding of human dispersal" not just from Asia into Beringia, but also from Beringia into and through the Ice Free Corridor.

Ice-Free Corridor—not just a glacial door opening

The 2013 study by the Meiri–Barnes team and the 2016 study by the Heintzman–Shapiro team both show how understanding the migration histories of large mammals can contribute to our understanding of the migration history of the humans who hunted them. Both studies also demonstrate the significance of museum collections for providing specimens that can reveal important insights when new analytical techniques for their study are developed.

The Heintzman–Shapiro team showed that the Ice-Free Corridor was not viable for bison until around 13,000 CALYBP and therefore assume it also was not viable for humans until then. They acknowledge that humans were present in the Americas by at least 14,000 CALYBP, so they infer that the corridor couldn't have been the route used "for the initial human dispersal into the Americas." Therefore, "the first indigenous peoples leaving Beringia probably took a coastal route or potentially moved through western North America before glacial coalescence."

The work of the Meiri–Barnes team shows that elk (and moose) were in eastern Beringia perhaps as early as 15,000 years ago. Mikkel Pedersen, Eske Willerslev, and their colleagues estimate that the Ice-Free Corridor did not become habitable for large mammals until around 12,500 CALYBP (page 5, this issue). The research of the Heintzman–Shapiro team indicates that southern bison already had begun to move into the southern end of the Ice Free Corridor by 13,400 CALYBP

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From predator to best friend

What we know about the origin of dogs

Part 2 of 2

During the Age of Exploration, our historical ancestors found humans and dogs together over most of the world, except in Polynesia and a few other isolated regions with relatively recent populations. Europe, Asia, Africa, the Americas, and even Australia had dogs. Some scientists believe humans and dogs have been together for so long that both have co-evolved, as each depended on the other for survival. Certainly humans have changed dogs drastically; whether they've changed us is less easy to prove. "The dog is considered 'man's best friend,' and if we would not have co-evolved, such

First American dogs

The first Europeans to arrive on American shores weren't surprised to find domesticated dogs living in native villages, earning their keep as pack animals and watchdogs. It drove home the notion that human/canine coexistence was a global norm, that somewhere in the distant past humans and wolves had formed an alliance that spread throughout the world.

Scientists still don't agree upon when or where that partnership was formed. Anthropologists and archaeologists assume it took place well before humans colonized the New World, which leads to the widespread assumption that dogs must have accompanied migrants from Northeast Asia on their journey east, whether by boat or across Beringia. So no one was shocked when Paleoamerican sites yielded dog remains and even deliberate burials. What introduced confusion was that none seemed older than 9500–10,000 CALYBP.

Researchers are still pushing back the date when humans first arrived. Dog remains become less common in North American sites the further back in time you go, and seem to disappear altogether by about 10,000 CALYBP. This raises the possibility that dogs came to the New World after the first humans did. There's no solid evidence of regular contact between the Old and New Worlds after the Beringian Land Bridge was inundated at the end of the Pleistocene. But as Stuart Fiedel points out, the Inuit took dogs across the Arctic, and earlier microblade users could also have crossed the Bering Strait with dogs. "The problem," he says, "is that we have no evidence of early contact between Paleoindians or Early Archaic folks and Arctic groups that would have provided a path for transfer of domestic dogs." On the other hand, there's no evidence that dogs were separately domesticated in the Americas; indeed, Fiedel insists that the genetic evidence indicates otherwise.

In 2014, a multidisciplinary team of scientists led by Kelsey Witt published a paper in the online version of *Journal of Human Evolution* in which they conclude that at the time of the earliest unequivocal dog burials, about 9,000 years ago, the American dog population was rather small, at just 1,000 females. If dogs had been companions of Paleoamericans from the very beginning, one might expect a larger population. But add to the fact that no evidence of dogs has been found in the Americas before about 10,500 CALYBP, whereas we know for a fact that humans were here thousands of years earlier. It's therefore reasonable to conclude that dogs were a later arrival. Whenever they arrived, they derived from a "small subgroup of domestic dogs—all very closely related," Witt theorizes. At some point, she and her team may be able to identify where that founder group originated, but their research hasn't reached that point yet.

An assemblage of dog remains from the Janey B. Goode site near St. Louis included dozens of dogs, so Witt and her team sampled a large number of them. "We expected that a larger dog population would have higher levels of diversity, but we actually found the opposite—the Janey B. Goode dogs had the lowest diversity of any other dog population we studied," she notes. "This suggests that perhaps deliberate breeding might have been going on in the region."

a nomenclature would lack any meaning," notes Thalmann. "There is, for instance, evidence that dogs shared the same migration routes as early humans, which I consider a clear sign of co-evolution."

The sorest bone of contention about the origin of dogs is *where* they originated. An easy solution is to admit the possibility of multiple origins, as Skoglund et al. and others propose. In this scenario, populations of wolves evolved into dogs independently in a number of locations and possibly even at different times. Although the hypothesis is out of favor nowadays, some paleontologists have proposed that isolated populations of *Homo erectus* similarly evolved independently into archaic *Homo sapiens*. So why can't *Canis lupus* have experienced a similar multiple independent evolution?


THE UNIVERSITY OF OULU, FINLAND

Thalmann with friends.

Several finds that may represent "aborted" domestication events—including a 33,000-year-old Samoyed-like canid skull discovered in Siberia by Nikolai Ovodov of the Russian Academy of Sciences in the 1970s—support this idea (**MT 28-2,** "Ancient Siberian canid skull raises questions"). It's even possible that an independent domestication event occurred in the New World; unfortunately, European dogs, which outbred native ones, have displaced native dog populations, leaving as possible candidates for New World domestication only the American Eskimo and Carolina Dog. Some of the major players in the First Dogs field (including Savolainen), however, dismiss the possibility of multiple origins. Concerning the possibility of an independent origin for native American dogs, Stuart Fiedel states that "there's no chance that dogs were domesticated independently here, because there are both modern and ancient haplotypes in the Americas that fall into ubiquitous Old World dog clades." (Interestingly, he notes, Native Americans seem to have experimented with taming or domesticating foxes.)

Most researchers perceive dog evolution as a singular event

Although Witt admits the possibility of a separate domestication event in the Americas, she's not dogmatic about it. "It's possible . . . there are some dogs with wolf mitochondrial DNA. In some cases, this DNA could have come from Eurasian or American wolves, so it's hard to say where the dogs came from." But it's interesting to note that canine remains at Dust Cave, Alabama, about a thousand miles from Illinois, date to about the same age as dogs studied at Janey B. Goode and at the Koster site, also in Illinois. This suggests either *very* rapid diffusion, or a longer tenure in North America for dogs than the Witt team's results suggest.


Fiedel (*far right*) in Costa Rica, 2010.

STUART FIEDEL

"I don't doubt that dogs could and did spread very rapidly," Dr. Fiedel states, "but I think it happened as part of the rapid Paleoindian expansion at 13,600–12,800, not at 10,000–9500 CALYBP." Furthermore, he cautions that very little is currently known about canine mutation rates. "Witt et al.'s date of ca. 9500 [CALYBP] for American dog origins is based on a mutation rate that could be erroneous," he explains, "and they themselves seem surprised by the lack of fit with the archaeological data. There was certainly introgression with local wolves in North America, probably mostly accidental—which is how black fur was introduced into wolves." (MT 24-4, "Big black wolf").

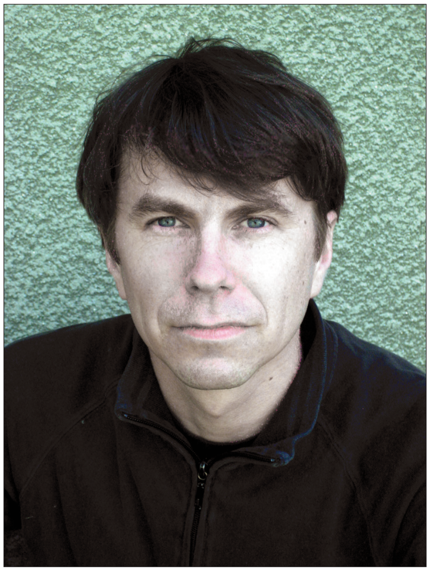
Witt doesn't disagree. "Even if the dog has DNA sequences from wolves in the Americas, we would have to look at other parts of the genome (besides the mitochondria) to determine if this is due to interbreeding with wolves or a separate domestication event." Whatever the case, her team's research indicates that dog populations throughout the Americas began to rise steadily after 9,500 years ago, before plateauing 1,200 years ago.

The scientific jury's still out on the origin of American dogs. Witt foresees the need for additional detailed research before a final verdict is handed down. "Given that we're focusing on a small region of the mitochondrial genome (300 base pairs)," she says, "our conclusion about the timing of dog arrival to the Americas should be tested further before we feel that this can be strongly supported. We're currently working on sequencing complete mitochondrial genomes (16,000 base pairs) and intend to run the same analyses to see if the timing of entry to the Americas looks the same. Previous studies have found that results from the complete mitochondrial genome differ from those from just a short segment, so we want to examine mitogenome data to see if our results are the same."

It boils down to this: Who let the dogs in, and when? Only time and further research will tell. We'll keep you posted.

–Floyd Largent

that could only have occurred once, then spread throughout the world by the same vehicle of diffusion that dispersed such technological innovations as the bow-and-arrow and ceramics. Based on his DNA research, Savolainen argues for an ASY (Asia south of the Yangtze) origin less than 16,300 years ago, possibly in association with the rise of agriculture. Thalmann and his colleagues, on the other hand, propose a European origin for dogs as early as 33,000 CALYBP, well before the adoption of agriculture. If they're correct, the first dogs may have been bred to hunt, like some breeds today. Meanwhile, another group, voiced by UCLA biologist Robert Wayne in a 2010 *Nature* article, champions a Middle Eastern origin. They also theorize a multiple-origins model in which early Middle Eastern dogs spread around the world by diffusion and back-bred with local wolf populations to produce new domesticates.



Savolainen, 2009. PETER SAVOLAINEN

Skoglund et al., reporting on the 35,000-year-old Siberian specimen known as the "Taimyr wolf" in *Current Biology,* believe that it "belonged to a population that diverged from the common ancestor of present-day wolves and dogs very close in time to the appearance of the domestic dog lineage." They pinpoint the wolf/dog split at about 37,000 years ago, slightly pre-dating Taimyr. If that's true, then Ovodov's 33,000-year-old Siberian proto-dog may not signal an aborted domestication attempt after all. Even more recently, Russian scientists have regaled us with the story of several 12,700-year-old well-preserved dog puppies found in Siberia. And then there's the DNA study led by Laura M. Shannon and Adam R. Boyko at Cornell University, which in the October 2015 issue of the *Proceedings of the National Academy of Sciences (PNAS)* identifies Central Asia as the true origin of dogs, probably in the Nepal/Mongolia region, at least 15,000 years ago.

You can see why some observers consider the origin of dogs a headache-inducing conundrum.

Multiple-origins proponents don't have any problem with separate domestication events, especially in the Old World. It would certainly simplify our picture of dog origins, but that doesn't mean it happened. Single-origin theories are just as logical, perhaps more so since there's no evidence that wolf/human coexistence inevitably leads to the evolution and domestication of dogs.

Like so many paleontological and evolutionary puzzles, at the moment we're trying to assemble a finished product despite missing pieces. That's fine, because that's the way science works; and sometimes, by studying what we already know, we can fill in a gap or two. But the definitive origin of dogs evades our grasp in spite of the last decade of significant advances and productive work by scientists of the caliber of Savolainen and Thalmann. Before we make a final determination, we'll have to dig up a few more of the puzzle pieces first. There's hope that an extensive new worldwide DNA study, led by biologist Greger Larson of the University of Oxford and supported by researchers all over the world, will provide the final clues that clarify the origins question. But until we unearth a canine Lucy or identify the dog's mitochondrial Eve, it remains a juicy mystery we can really sink our teeth into.

–Floyd Largent

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Suggested Readings

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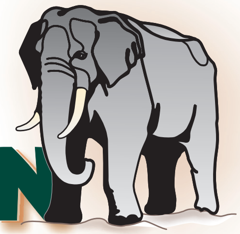
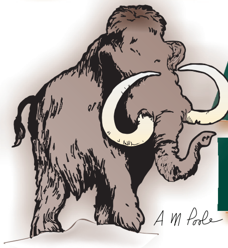
Gary Haynes



A Predilection for Proboscideans



GARY HAYNES may tell you the most important event in his life probably was in his graduate student days when he met Dennis Stanford at the Smithsonian Institution Natural History Museum in the mid 1970s. Stanford's research on early American sites with broken animal bones ignited a passion that is still with Haynes. With youth-fueled enthusiasm and a new Ph.D. in 1982, he set off for the distant shores of southern Africa to study elephants and record how bones of the world's largest terrestrial mammals become broken and marked as they enter the future fossil record.

This new direction in research came after years of archaeological work starting at the Thunderbird Paleoindian site in Virginia, with a specialty in lithics, followed by four years studying modern noncultural bone sites of animals smaller than elephants in remote parts of North America and Australia.

His 40 years of taphonomic fieldwork in countries around the world hasn't lacked drama and danger. One time, alone and unarmed in African elephant country, he was charged from behind by a big leopard which had mistaken the motor-drive sound from his camera for an animal's distress call. The leopard turned away only a couple of meters from him after Haynes threw out his arms and shouted as loud as he could. Haynes then drove two hours on a hardly visible sand track to the nearest bar. Another close call came in northern Canada, when he was also alone and unarmed, and found himself surrounded by a pack of wild wolves. The wolves appeared trotting in his direction as he was photographing a partly eaten bison carcass. The wolves stopped 10 m from him and looked at him in surprise, and Haynes remembers going through a strange series of feelings—first, embarrassment at being discovered so close, then alarm at being surrounded, and then a certainty of impending death—before all but one of the wolves rushed off in different directions. The last one stood watching as Haynes photographed him before slinking away.

J. KLIMOWICZ

First Americans and megafaunal extinctions

Haynes earned his M.A. in 1978 and Ph.D. in 1981 in Anthropology from the Catholic University of America. The dispersal of modern humans throughout so many world ecozones in such a brief time span has fascinated him for most of his life. "The hunting of so many large mammal species by dispersing modern humans," he tells us, "is an extraordinary feature of near time and begs to be better studied. It's impossible to ignore the temporal and spatial association of human range expansions with the otherwise unexplainable waves of megafaunal extinctions, especially in the Americas."

Haynes holding a carved and polished artifact of mammoth ivory called a "boomerang" from Oblazowa Cave in Poland, attributed to the Gravettian culture.

Most likely arriving 15,000–14,000 years ago in Alaska and shortly afterwards in the lower 48, Central America, Mexico, and South America, First Americans, Haynes believes, rapidly ("and I mean rapidly!") explored and dispersed throughout the New World. Everything he has learned convinces him that the ancestral populations of the First Americans were exclusively from northern Asia.

"Gary's take on the origins of the First Americans has always been high on empiricism and low on speculation," says Ted Goebel, Associate Director of CSFA. "As a result, his opinions carry a lot of weight with me. Gary's unique taphonomic perspective is incredibly important, but unfortunately many archaeologists investigating the peopling of the Americas have not paid much attention to his actualistic research with elephants in Africa.

Haynes examining an elephant-death site in Zimbabwe, 1985.

E. PAIGE

"During the last two decades at least, Gary has had a place at the big table in the major debates regarding Paleoindian origins and adaptations, not just interpreting Clovis hunting, but also the timing of the initial human migration to the Americas, the process of human dispersal, and the extinction of Pleistocene megamammals. His outstanding contribution has been matched by very few others, and none has exceeded it.

"There is so much about Gary that young scientists should emulate—for example, his day-to-day work ethic, his skepticism tempered with a strong sense of collegiality, his interdisciplinary and international frames of reference, and, most of all, his unflappable 'stay-the-course' attitude in the face of criticism and even disregard."

The catastrophic extinction of North American proboscideans

Soon after 11,000 RCYBP, mammoths and mastodonts disappeared from the North American landscape, along with 33 other genera of large mammals. This widespread extinction coincided with the arrival of Clovis fluted-point makers. With rare exceptions, these Clovis inhabitants were the first to arrive in most parts of the Americas during the Pleistocene. Haynes finds the synchronicity of their arrival and the disappearance of mammoths and mastodonts impossible to dismiss as mere coincidence.

Haynes flaking a freshly filleted elephant femur.

According to Haynes, the extinction of America's largest forms of animal life was an eco-catastrophe that developed swiftly and unexpectedly. "If the first settlers in North America targeted large mammals as preferred prey," Haynes says, "their opportunistic foraging may have eradicated mammoth and mastodont populations that had survived earlier cycles of ecological stress during numerous rapid climactic oscillations." The grazing and browsing of large herbivores has a major effect on ecosystems and is known to increase productivity in African grasslands; therefore their removal could have had the opposite effect.

Three propositions

Haynes's explanation of the process that wiped out proboscideans in North America rests on three propositions.

■ At the end of the Pleistocene, severe climate reversals were out of phase with the extinction event. The return to cold conditions of the Younger Dryas may not have had the same serious effects everywhere. Where it did occur it came after some extinctions had already happened, but it also preceded extinctions of other species, according to some research. The dated last appearances of mammoths and mastodons straddle the boundaries of the Younger Dryas.

E. PAIGE

Haynes disarticulating an elephant humerus after stripping the meat during the government-sanctioned elephant culling of the 1980s.

- Clovis fluted points were present over most of North America 11,600–10,500 RCYBP and have been found in association with megamammal skeletons in a sizable number of sites in North America. According to Haynes, "The differences among the sites suggest that human behavior created some sites and not others, but clearly support the idea that Clovis foragers killed mammoths." The killing of such large prey animals was a rational and efficient human decision, based on the relative ease of tracking them.
- Clovis foragers with an extremely low population density colonized a huge, diverse continent.

Human nutritional requirements are satisfied by various supplements to a meat-rich diet; megamammal hunters or scavengers could easily add enough fat and plant material to their diets to avoid protein poisoning or chronic disease.

Megamammals: optimal foraging at Pleistocene end

Prehistoric hunters evaluated their food returns patch by patch, with the best patches being the resource refugia where animals congregated near water and preferred forage, as climate change continued to alter North American landscapes. Mammoths and mastodonts were highly ranked food resources easily found in the refugial patches. Like modern elephants, they left obvious trails and sign. Even as their numbers declined, these slow-reproducing species were prime prey for hunters because of the rich return.

First Americans evaluated the potential return from animals they encountered and therefore ranked the largest mammals most desirable if there was a chance of procuring them. Although other animals were likely more plentiful, and mammoths and mastodonts were probably more dangerous to kill, a successful hunt that yielded many times the amount of food from other prey made the risk worthwhile.

If Clovis people preferred megamammals and continued to hunt them even as the numbers of these animals decreased, the opportunistic targeting of proboscideans, the very model of Clovis subsistence, may have led to their extinction.

A change in patch dynamics

At the end of the LGM (Last Glacial Maximum), the changing climate radically altered the geographic distribution of many animal species.

Keystone megamammals, by feeding, trampling, and wallowing, had maintained relatively high biotic diversity. By pruning woody plants, enlarging water holes and mineral licks, and suppressing fires, megamammals opened up vegetation patches. After the LGM, however, the once large areas of Pleistocene plant mosaics shrank and became increasingly separated from each other, resulting in broader zones of more uniform vegetation. Gradually the ranges of grazing and browsing animals were widely separated from each other, with the result that at the end of the Pleistocene the largest terrestrial mammals were clustered and isolated. Thus they became desirable prey for hunters.

Yet the late-Pleistocene climate change and resulting stresses can't have been responsible for all extinctions. Some animals suffered from disappearing forage; others were favored by changes in plant distribution. Tracts of woodlands in North America didn't disappear at the end of the Pleistocene, for example, but populations of browsing mastodonts and other species that depended on woodlands did. No compelling evidence exists that both mammoth and mastodont populations suffered greater stress at the end of the Pleistocene than they had experienced during almost two million years of earlier climate oscillations.

Haynes believes a combination of events drove megamammals to extinction. Climate-driven change made the animals easier to locate and kill by forcing them into refugial areas. People carrying well-prepared, sturdy tools dispersed into ranges where mammoths and mastodonts could be found. Fluted-point makers, like all foragers, were generalized gatherers and hunters, but were not averse to targeting even the very largest animals they encountered.

Comparing mammoth exploitations

In North America, wherever Clovis sites contain faunal remains, proboscidean bones are often found associated with distinctive Clovis artifacts. The archaeological record thus reflects a unique subsistence base that seems in some parts of America to center upon mammoth or mastodont. If this was indeed a preference, it may have originated in Upper Paleolithic Eurasia and eventually spread across Beringia to North America. In fact, North American assemblages earlier than Clovis also contain proboscidean remains and sometimes items such as broken bones interpreted as artifacts. Haynes finds some of these bones-only sites hard to accept as cultural—but if they are true archaeological sites, they suggest an evolving kind of foraging strategy.

Fossil evidence confirms that humans exploited mammoths in Siberia, northeast Asia, Beringia, and North America. Haynes's studies, however, suggest an important distinction: Although northeast Asian and Siberian people hunted, killed, and ate mammoths, their hunters didn't concentrate on mammoths with the intensity of North American hunters.

J. KLIMOWICZ

Haynes under a Paris street sign. "This is appropriate," he says, "because I wrote a book about the Clovis archaeological culture in North America." (The street was, in fact, named after an ancient Frankish monarch.)

Paradoxically, mammoth predation had been even more intense 30,000–20,000 RCYBP, far to the west of Siberia, in central Europe. The changes in human focus on mammoths over time and space probably has to do with climatic periods when the very largest terrestrial mammals became more vulnerable owing to greater seasonal differences in weather—such as severe storminess and extremes in moisture availability—or to sustained crowding around limited resources. One recently discovered effect of climate change toward the end of the Pleistocene was a loss of genetic diversity in mammoths and other species, resulting from the geographic separation of subpopulations into refugial patches. Overall population health must have been relatively low. The climate-caused demise of the mammoth was not inevitable—the species had survived these periods before—but a new factor entered the equation: Very large mammals like mammoths, already experiencing increased vulnerability, were possibly a catalyst for the rapid spread of skilled and efficient hunter-gatherers out of Asia into North America.

In fossil-bone collections from Asia and North America, a few taxa of mammals recurrently predominate. Small mammals like foxes and hares abound in assemblages from many parts of Eurasia. Large mammals such as horses and bison are abundant in much of Asia and Alaska. But proboscidean-dominated sites occur near the end of the Pleistocene in Siberia and northeast Asia, perhaps because late-Pleistocene cultural complexes of that part of the world became opportunistic exploiters of mammoths.

The opportunity to study mammoth proxies

By the late 1970s, it had become clear that intensive study was needed of the potential place that proboscideans (mammoths and mastodonts) may have had in global human dispersals. Haynes found his chance to study elephants first-hand in the early 1980s, when Dennis Stanford heard that Zimbabwe was planning large-scale culling operations to reduce the elephant population in Hwange National Park. At the time Stanford had a previous commitment in China, so Haynes jumped at the chance to go to Africa. Although he visited several African nations, Zimbabwe was most supportive of his proposed work. For the next three decades he carried out his studies of what can be called elephant-bone rain, taphonomic shorthand for the pre-burial and pre-fossilization input of bones to the earth's surface from cultural and non-cultural deaths.

Herds of African elephants occupying a large protected area of remote wilderness left bone scatters that sometimes differed markedly from proboscidean remains found in North America, but at other times were eerie mirror images. Wet-season predation on large mammals occurred in many upland locales; dry-season predation, on the other hand, was concentrated around water sources. In Africa aggressive competitive feeding by scavengers scattered bone widely at predator kills, a clue to what must have been the case in Pleistocene America when so many more carnivores were still alive.

In a major sustained drought in the early and mid-1980s, Haynes regularly visited the last remaining water sources to monitor animal casualties and to investigate bone scatters. He also made surface collections at predation bone sites, along streams, and at other water sources to study how the ecological implications of carcass modification by carnivores affect the composition of fossil-bone deposits. He observed how elephants die, how people butcher them in the field and carnivores scavenge them, and how the bone sites change over the years. He discovered significant patterns in elephant bone accumulations at places where many starvation die-offs had occurred over past decades, and recorded how bones are broken and marked by human and non-human actions such as trampling.

Haynes cleaning the profile of an excavation unit in an Early Stone Age (Acheulean handaxe) site in Zimbabwe, early 2000s.

Fringe effects of sustained taphonomic research

As a taphonomic researcher, Haynes has done 40 years of fieldwork on modern animal-bone sites to enhance his knowledge of fossil assemblages. His studies, not limited to proboscidean bones, involve many species in widespread locales. But ironically enough, the taphonomic fieldwork in Africa re-awakened his long-ago interest in lithics, since he kept finding abundant Stone Age archaeological sites while walking many hundreds of kilometers looking for animal bones. These archaeological sites date from almost 1 million years ago to the last few hundred years. In 2008–10, with NSF funding and able geoarchaeological assistance from Teresa Wriston, he excavated rockshelters in northwest-

Bill Barse helping Haynes pull his foot out of dense muck at the Inglewood mammoth site in Maryland, 1982.

ern Zimbabwe, uncovering clues about the lifeways of hunter-gatherers and Iron Age farming communities, and recording a rich rock-art record going back 3000 years.

"Gary has been an inspiration to me throughout our careers because of his dedication to field taphonomy," says Kay Behrensmeyer of the Smithsonian. "His careful documentation and interpretation of what happens to bones in the wild is an essential resource for taphonomists worldwide."

A lifetime of contributions to anthropology

"I first met Gary in 1994 when I was working on my Ph.D. thesis about the taphonomy of woolly mammoth remains from an archaeological site in Poland, Kraków Spadzista," says Piotr Wojtal of the Polish Academy of Sciences. "I remember that I had sent him a letter with questions about our site and its mammoth remains. I also invited him to visit our excavations at the site. I was really surprised when he accepted the invitation and came to Kraków. After that meeting, we have continued to work together many times studying the Kraków mammoth-kill site. Gary's knowledge of proboscidean taphonomy is incredible. His influence has been exceptional in helping us understand the creation of assemblages of mammoth and elephant remains throughout the world. His studies give us a unique opportunity to reconstruct the cultural and noncultural processes of many thousands of years ago. Without Gary's research, our taphonomic studies of archaeological and paleontological sites would certainly not be so well grounded and accurate."

Pages and pages of awards and grants decorate Gary Haynes's CV. He's the author of several books and an impressive list of articles dating from 1978 to present. Recently retired from teaching, he is now starting to write up some of a backlog of research results from over 40 years of taphonomic research. "My studies of the life and death of large mammals and their bone sites have been eye-openers for me," he confides to us, "showing me how little we know about the life and death of extinct big animals."

–Martha Deeringer

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Suggested Readings

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Ice-Free Corridor Route, part 2

continued from page 11

and northern bison were moving into the northern parts of the corridor by 13,100 CALYBP.

Each of the studies considered in this series of articles on the Ice-Free Corridor provides a key piece of the ecological puzzle that ultimately will help to establish the timing and route(s) followed by the first Americans in their epic journey of discovery. The work of the Meiri–Barnes team demonstrates that "faunal remains from ecologically sensitive taxa have significant potential to identify barriers and corridors to migration." The new studies by Pedersen and Willerslev and the Heintzman–Shapiro team corroborate this conclusion and offer important new evidence indicating that the Ice-Free Corridor did not need to be open for humans to successfully colonize the Americas. Either humans were already here before the Last Glacial Maximum, when the great ice sheets expanded and closed the corridor, or they bypassed the ice by following the coast in boats.

–Brad Lepper

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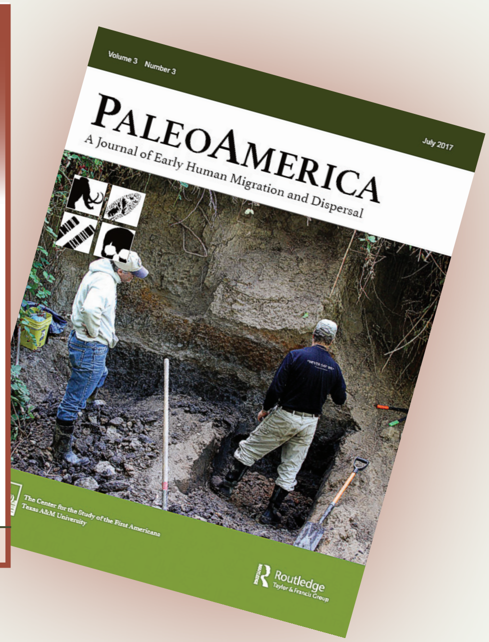

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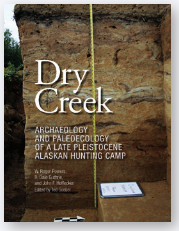

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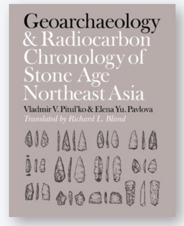

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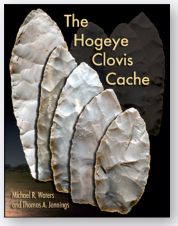

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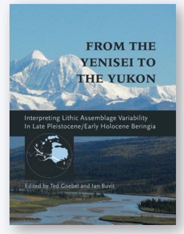

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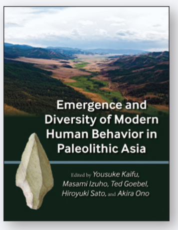

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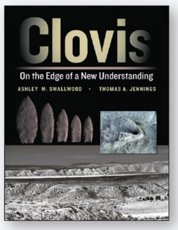

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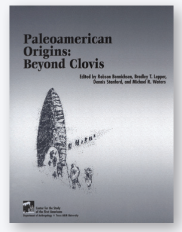

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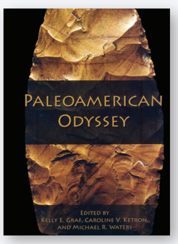

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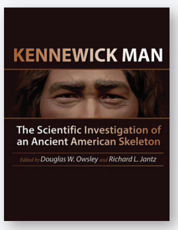

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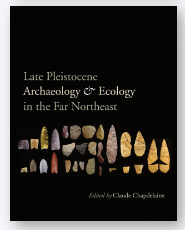

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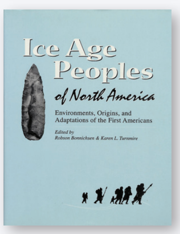

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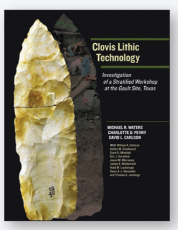

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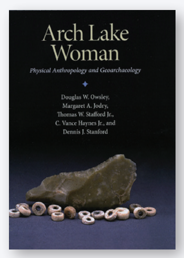

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