MAMMOTH TRUMPET

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The Essential Tool for Making Needles

SOME ARCHAEOLOGISTS believe the impact of the Younger Dryas Cold Event (YDCE) was insignificant. Alan Osborn, Assistant Professor at the University of Nebraska, Omaha, and Curator of Anthropology at the University of Nebraska State Museum in Lincoln, believes otherwise. In his article in the 2014 issue of *American Antiquity,* Dr. Osborn argues that the YDCE was a climatological and environmental 'bottleneck.' His research began with the unassuming spurred flake graver, a small expedient tool made from lithic debitage. He contends that only when this artifact is put into the context of the YDCE and linked with making bone needles, essential for stitching warm fur clothing needed to survive the unusually cold winters of that period, is its significance realized.

Osborn was working for the government monitoring a Folsom project in North Dakota in the 1990s when he realized that writing progress reports wasn't satisfying his curious nature. "I decided to identify a number of different archeological questions I wanted to study on the side," he recalls, "and as a consequence I started researching Paleoindians at the museum in Lincoln." To his glee he discovered the Anderson collection, an assemblage of artifacts gathered by a family that lived in northeast Colorado during the Dust Bowl, the ecological disaster

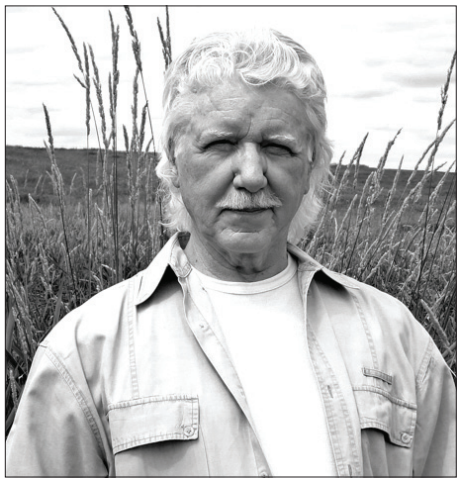
An artist's conception of Paleolithic skin garments suggested by a carved-ivory figurine found at Mal'ta, a 24,000-year-old occupation in Siberia. The technology used to stitch together hides, created by these genetic forebears of Paleoamericans, traveled with them to the New World.

Inside

of the 1930s caused by extreme drought aggravated by poor crop management and lax farming practices. Over-plowing created huge blowouts that exposed artifacts by the thousands, artifacts that otherwise would have remained deeply buried. It was the Anderson collection that introduced him to gravers, "small, somewhat nondescript tools that are basically made of leftovers from making stone tools." Their distinguishing characteristic is a tiny needlelike projection.

A spurred flake graver by any name

Osborn started searching for examples of gravers from coast to coast. Unfortunately, archaeologists have coined at least 10 different names for this one tool. A thorough research of spurred flake gravers thus also requires scrutinizing reports in search of photos and drawings of spurs, spurred perforators, denticulate gravers, compass coring coronet gravers, three-prong gravers, borers, piercers, and cutters. This hodgepodge of names means that a "graver" reported found at a particular site may turn out to be a different artifact altogether. Osborn warns that you see "different names for the same thing, and the same name for different things. You have to be careful because it can potentially be pretty important."



Osborn, 2015.

The profusion of names isn't surprising, given that the tool is nothing more than a small flat flake with a tiny tip, or spur. This spur, about the size of a grain of rice, is the distinctive feature of the artifact. Osborn prefers the term *spurred flake graver,* which describes the appearance of the artifact and how it's made and also its intended use: to grave eyes in bone, antler or ivory sewing needles.

Whose toolkit, tattoo artist's or needle maker's?

Some archaeologists suggest that gravers were used for executing designs, possibly even for tattooing by puncturing the skin with the spur and then rubbing in dyes. In the face of a number of functions proposed for the tool, Osborn asked himself, Why don't we see them for a longer period of time? His research shows that spurred flake gravers appear rather suddenly, archaeologically speaking, at about 13,000 CALYBP, then disappear by roughly 11,000 CALYBP. Their suggested use in tattooing doesn't account for the limited time span.

MAMMOTH TRUMPET

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Mammoth Trumpet
Department of Anthropology, Texas A&M University
4352 TAMU
College Station, TX 77843-4352

Michael R. Waters	Director and General Editor e-mail: mwaters@tamu.edu
Ted Goebel	Associate Director and Editor, **PaleoAmerica** e-mail: goebel@tamu.edu
James M. Chandler	Editor, **Mammoth Trumpet** e-mail: wordsmiths@touchnc.net
Christel Cooper	Office Manager e-mail: csfa@tamu.edu
C&C Wordsmiths	Layout and Design
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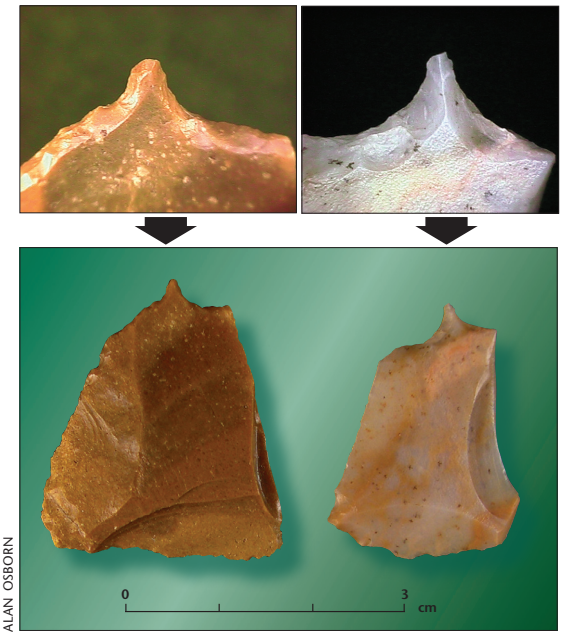
–Michael R. Waters, Director

Osborn began to compile graver information from Ontario south to the Great Lakes, west to Washington State, then east of the Rocky Mountains into the Southwest down to Texas, an area that takes in a huge portion of unglaciated North America. Few spurred flake gravers have been found in the Southeast. There are, however, paleoclimate studies that suggest the Southeast experienced atmospheric conditions during the YDCE that resulted in a warmer, wetter environment than in other parts of the country, which would moderate the need for warm clothing and the tools used to make it. Elevation also affected the impact of the Younger Dryas cold snap on different areas of North America.

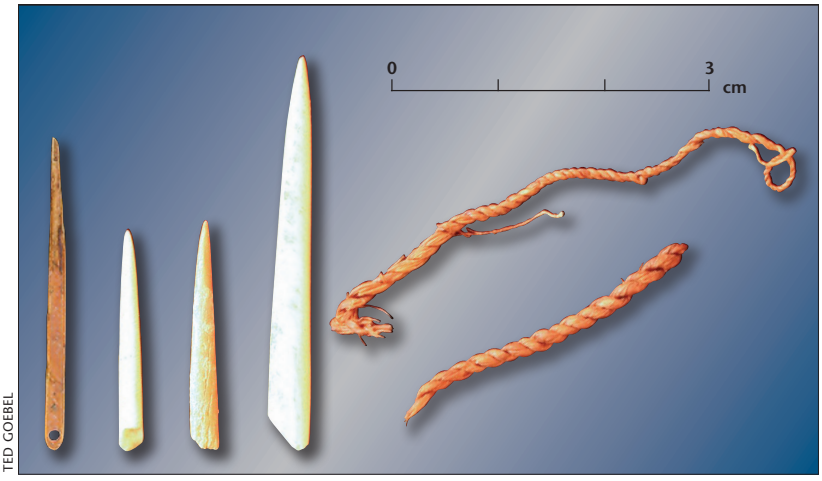


ALAN OSBORN

Spurred flake gravers from Yuma County, Colorado (microphotographs 30x).

An *aha!* moment

Archaeologist Frank Roberts, who directed the large-scale excavations at the Lindenmeier Folsom site in northeast Colorado, suggested that gravers may have been used for tattooing. On the other hand, Henry T. Irwin proposed that gravers had possibly been utilized by Paleoindians at both Lindenmeier and Lind Coulee in Washington to grave eyes in bone needles. This argument was based in part upon his own unpublished experimental research. Whereas some needles have round holes that were clearly drilled, others have a slit eye that could have been gouged by a spurred flake graver. Moreover, a nick by a graver may have been needed to center the hole made by a drill. This possible connection between needles and gravers struck a resonant chord with Osborn, who at the time was studying tailor-made fur clothing and cold adaptation.



TED GOEBEL

Complete eyed needle, broken needles, and fragments of cordage from a hearth feature dated to 10,300 RCYBP at Bonneville Estates Rockshelter in eastern Nevada.

Osborn turned his attention to studies of the YDCE, an abrupt climate shift that occurred between 12,940 and 11,640 CALYBP. These dates straddle the appearance of spurred flake gravers and eyed bone needles. In Europe, Russia, and Siberia, bone needles appear during the main ice age at 22,000 CALYBP and reappear with the YDCE, which produced a precipitous drop in temperature in as little as 10–20 years. What once appeared to be inconsequential bits of bone and stone may have been a key to human survival over a large part of the Earth's surface.

To chart changing temperatures, paleoclimatologists gathered information from glacial ice cores in Greenland, which, like the rings on a tree, record an accurate year-by-year climate history. The track of temperature variations can also be inferred from sea-floor sediment cores, radiocarbon-dated coral sequences, chemical tracers in bethic foraminifera, freshwater midges, speleothem sequences, buried ice wedges, pollen and macrofossil records, tree rings, and stable isotopes in soil and water. When it comes to interpreting the data, however, not all scientists agree on just how cold it truly got during the YDCE in North America. Osborn believes the appearance of gravers and needles in the archaeological record during this time confirms that plummeting temperatures required lifestyle changes in order to survive.

Needles in an archaeological haystack

Details about needles are sparse in the archaeological record, not because they weren't found, but because, even as recently as a decade ago, archaeology suffered from a male-centric focus on projectile points, spear points, dart points, and knives. Needles when recorded were typically vaguely described and relegated to the end of an artifact inventory. For example, most cultural anthropologists who worked with the Inuit paid little attention to bone needles. As a consequence Osborn has yet to find any record of how they were made or if any had slitted rather than drilled eyes.

There's no doubt that bone needles were valued by Paleoamerican women who used them. An exquisite example is the burial of the Buhl Woman discovered in Idaho. She was 17 to 21 years of age when she died 10,675 ± 95 CALYBP. Included in her grave goods was an eyed needle. It shows no sign of wear and therefore apparently served a ceremonial function, which suggests the value her people placed on the tool. A report in the 1998 issue of *American Antiquity* notes that although it isn't a slitted-eye needle, microscopic examination of the round eye shows that it was "carefully gouged with a hand-held per-

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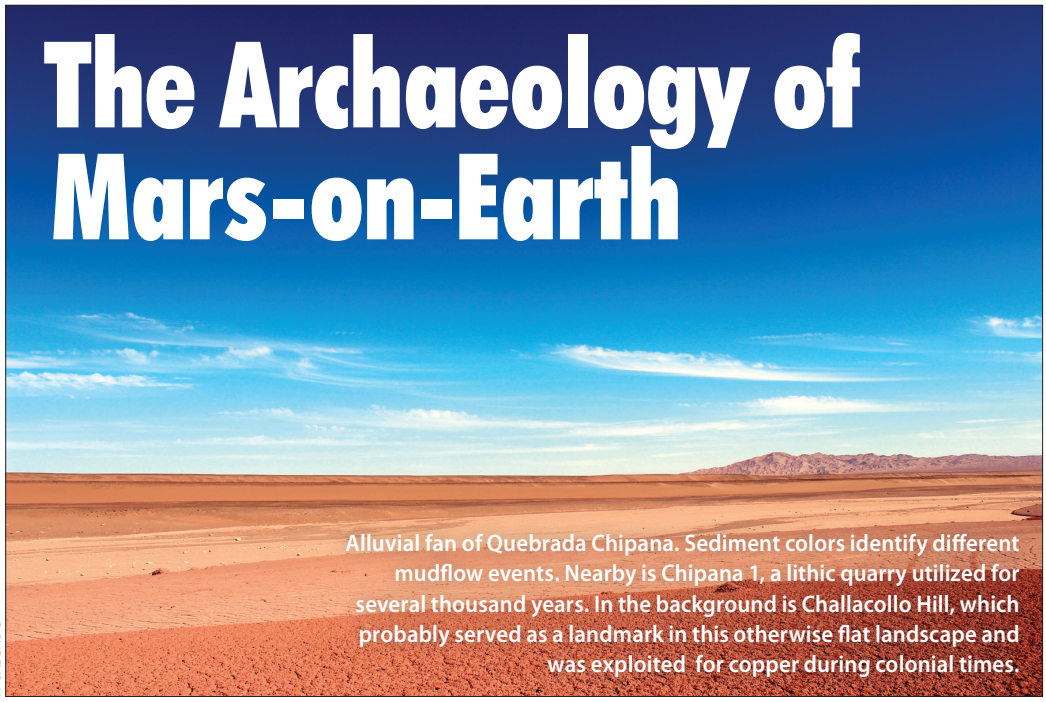
The Archaeology of Mars-on-Earth



P. SALGADO

Alluvial fan of Quebrada Chipana. Sediment colors identify different mudflow events. Nearby is Chipana 1, a lithic quarry utilized for several thousand years. In the background is Challacollo Hill, which probably served as a landmark in this otherwise flat landscape and was exploited for copper during colonial times.

WHEN TELEVISION PRODUCERS of "Space Odyssey: Voyage to the Planets" looked for locations to film Mars scenes, they turned to the Atacama Desert of northern Chile. In June 2013 NASA sent a four-wheeled rover named Zoe to the Atacama to help scientists understand how life survives in extreme environments, a study with implications for both Earth and Mars. The findings of the Zoe operation are currently aiding scientists in determining how best to equip its next Mars rover, set to launch for the Red Planet in 2020.

The Atacama, whose craggy terrain and salty soils mimic the surface of Mars, boasts the dubious distinction of being the most arid wasteland on Earth. Years can pass between one rainfall and the next. Stretching from the Pacific Ocean up to 4000 masl along the western Andean slope, the Atacama spans more than 12 degrees of latitude. Its position between two mountain chains, the Andes and the Chilean Coast Range, prevents moisture advection from both the Pacific and the Atlantic, thus creating a two-sided rain shadow. Geological research suggests that in some parts of the Desert, such as in today's Chile, hyperaridity has persisted for 10 to 15 million years—since the late Miocene—making it the oldest continuously arid region on the planet.

Middens useful in reconstructing paleoenvironments

Claudio Latorre Hidalgo, Quaternary paleoecologist at the Pontifical Catholic University of Chile, first looked to the otherwordly Atacama Desert 12 years ago when Mike Smith, a pioneering desert archaeologist and honorary senior research fellow at the National Museum of Australia, launched the Southern Desert Conference, which brings together researchers working on environmental and archaeological research in the deserts of the Southern Hemisphere. "In 2003, we had our first Southern Deserts Conference, and we recently had our fourth in Mendoza, Argentina," Latorre says. At the first conference he met archaeologist Calogero Santoro of the University of Tarapacá in Arica, Chile. The irony doesn't escape Latorre: "We're both Chileans working on similar things, but we didn't really talk until that conference in Australia."

Latorre showed his new colleague the research he was doing for his Ph.D. on developing a paleoecological record of vegetation change in the Atacama. What captured Santoro's attention was rodent middens—nests made by rock-dwelling rodents—and what they said about environmental context. The rodents build their dens of plant fragments, animal dung, and small rocks. Three factors slow the decay of midden materials: crystallized rodent urine, which binds together the aggregate; the dry climate of the desert; and protection from the elements offered by rock overhangs or caves.

Materials incorporated into a midden, some dated to 50,000 years, can be analyzed to reconstruct past environments. "These things get preserved over thousands of years, and they're used for paleoecological reconstruction in arid environments," Latorre explains, "and in South America we have chinchilla rats (loosely related to the chinchilla). We use the middens to reconstruct past vegetation on the landscape. It can be 10,000 or 20,000 years old, a snapshot of the landscape from that time."

The Atacama isn't a barrier after all

For decades, researchers assumed the Atacama stood as an obstacle to human settlement and biotic dispersal. Scientists therefore excavated sites along the Pacific coast or in upper-elevation zones in the adjacent Andes but ignored the hyperarid core. In recent years, however, new evidence has emerged that gives clues for understanding the cultural complexity and diversity of the peopling of South America during the last Ice Age. Latorre

and Santoro lead a pack of researchers on this front.

It was while investigating middens for evidence of past environments that they discovered lithic artifacts "strewn across the desert." After considering the consequences of past climate change, they concluded that the forbidding desert wasn't a barrier to human occupation after all. Latorre recalls that they set out to search for sites first in the Precordillera, a mountain range that lies between the Andes and the Intermediate Depression. Then Eugenia Gayó, a Ph.D. student of his, started developing paleoecological records from plant macrofossil beds discovered in the middle of the hyperarid core. "These were literally alluvial fans in the middle of a landscape that looks like Mars today," Latorre says, "and these fans had gallery forests and riparian vegetation growing late in the Pleistocene. Even though this was a hyperarid landscape with no rainfall, the gallery forests were there because of groundwater moving through the system, and that was driving the availability of these resource patches during the late Pleistocene." He credits its discrete local oases, or "paleowetlands," within the inland Atacama Desert with sustaining human populations during this time. What he and Santoro found is that these ecosystems were so extensive that this area of the hyperarid core contains some of the largest concentrations of late-Pleistocene sites per square km in all of South America.


J. RECH

Pleistocene wood: 18,000-year-old logs, preserved by the severely desiccating environment, protruding from a fluvial sequence.

Their team discovered the key site, Quebrada Maní 12 (QM 12), in a hyperarid drainage of the southernmost portion of the Pampa del Tamarugal, one of the largest closed inland basins in northern Chile. This 12,000- to 13,000-year-old human occupation lies 85 km from the Pacific Ocean at an elevation of 1240 m. Excavations at QM 12 reveal a diverse cultural assemblage of lithics, burnt and cut bones, marine gastropods, pigments, plant fibers, and wooden artifacts near a prepared fireplace. Although they originally thought it was just a single camp, now as they do more archaeological studies they find that people stayed there longer and performed many activities. "There are wooden and stone artifacts," Latorre notes, "shells from the coast, pigments and rocks from the highlands for making lithic tools." In fact, the lithic technology shows that QM 12 occupants were highly skilled knappers who chiefly used bifacial reduction. High-quality toolstone was brought to the site from at least one remote source.


P. UGALDE

Rech collecting geological samples from Quebrada Sipuca, located in the hyperarid core of the Atacama south of the Maní basin.

Movement over vast territory

"We have evidence that these people were moving all over the place," Latorre says. Shells from the coast and obsidian and other volcanic rocks from the Andes point to the mobility and resourcefulness of the Quebrada Maní occupants. The problem now is to sort out migration routes that linked the profusion of habitats. What, he asks, was the role of the Atacama vis-à-vis the ecosystems of the Andes and the Pacific? "This enormous diversity of habitats and settlements shows up at the same time," he tells us. He cites as examples Dan Sandweiss's work on the coast (**MT 20-4, 21-1,** "Early maritime adaptation in western South America") and work by Juan Albarracin, Jose Capriles, and Kurt Rademaker in the Andes (**MT 30-4,** this issue, "Reaching new heights in the Peruvian Andes"). "What were these migrational routes?" he wonders. "These are open questions."

Latorre and Santoro hypothesize that it wasn't scarcity of resources


C. SANTORO

Latorre photographing a seagull egg found on Pampa del Tamarugal south of the Quebrada Maní 12 basin, about 60 km from the Pacific Ocean.

that drove populations to cross large expanses of territory, but the urgent need to locate other people. Males needed to find mates, for one thing. Santoro believes that an entirely selfish motive spurred these early settlers to seek human connections and collaborate with other populations: to ensure survival. "They shared resources to share information," he explains. Information was very important because water was present in the Atacama Desert only in certain locations. Instead of fighting for it, people looked for social ways to share the scarce resource and thus survive in this extreme environment. Santoro wonders whether lithic technologies and other knowledge were also shared. If so, did there exist a network of sites?

C. SALAS

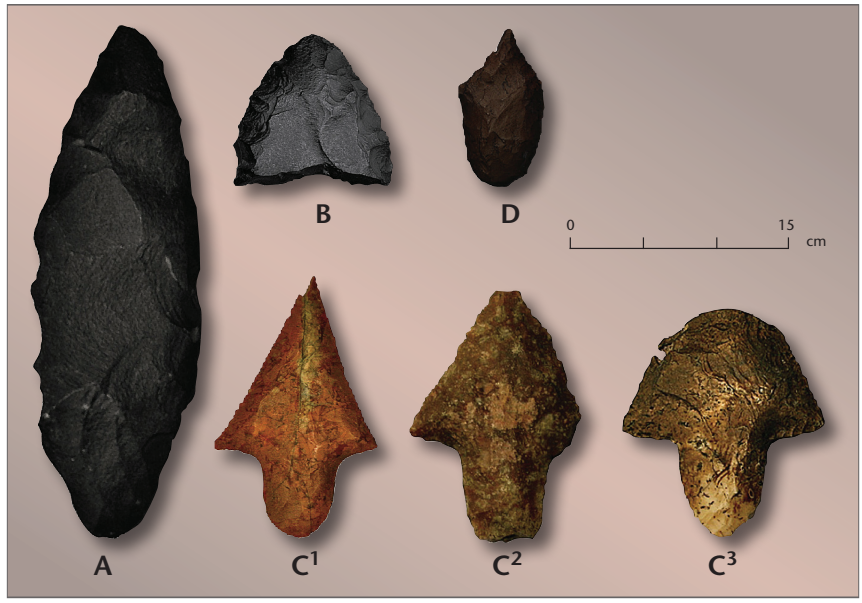
Santoro *(left)* and Rech examining specimens of *Equisetum* sp. (horsetail), *Distichlis spicata* (desert saltgrass), **and Gramineae preserved in situ on the lower terraces of Quebrada Maní 12. These plants were growing at the time of human occupation 11,400–12,000 years ago.**

And did this network promote human migration? These questions inform Latorre and Santoro's research as they move from an inductive approach to a more deductive methodology.

A way station in the desert

Human movement not only spanned long distances, it also crossed distinct epochs. Quebrada Maní, for instance, was repeatedly abandoned for thousands of years at a time, only to be resettled again. Santoro observes that "people kept going back to these inland locations over time because the desert lies between the Pacific Ocean and the high Andes, two major ecological systems for people. You had to move through the desert, which led to colonizing the Atacama more than once." Archaeological excavations and radiocarbon datings along the Quebrada Maní drainage identified at least two different periods of prehistoric human occupation: a late-Pleistocene phase, 12,800–11,700 CALYBP, discovered on the surface of a terrace labeled QM12, and a later occupation, dated from 2600 to 700 CALYBP, characterized by cultivated fields, irrigation canals, and ceramics on the lower Pleistocene terraces. These younger sites, abandoned as recently as 680 years ago, were part of an occupation coinciding with increased fluvial output in Quebrada Maní during the late Holocene.

Although these successive human occupations aren't clearly delineated, the surface of the Atacama is extremely stable. Late-Pleistocene occupations were settled on surfaces that date back to the late Miocene. Latorre challenges us to "imagine a landscape that's been fossilized for 5 million years. What you have is a surface that's exposed to the atmosphere for a period of millions of years, and that's the surface that these late-Pleistocene occupants came to settle on, to build their encampments." You can find 12,000- or 13,000-year-old dates in the first 37 cm of surface, but below that lies rock-hard gypsum salt, which forms a concrete crust; nothing can be retrieved below that. Latorre explains that patches of the first 37 cm have been disturbed over and over again, with the result that "the site stratigraphy is composed of completely reworked material. It's this thing that was used for a brief period of time and then abandoned. By brief period I mean 900 years."



FROM QUATERNARY SCIENCE REVIEWS 77 (2013) 19E30

Lithic tools found on the surface of QM12. A, thin elongated bifacial tool in advanced stage of reduction; B, naturally broken bifacial tool reworked in one margin as a burin and sidescraper; C, triangular stemmed projectile points that resemble Las Cuevas–type points; D, "Parapatane" reworked projectile point. A, B, and D are made of locally available rocks; projectile points C^1–C^3 are made of toolstone from extra-local (about 20 km distant) or unknown sources.

Points C and D, whose morphologies are normally associated with highland early-Archaic points, are the first specimens found on the lowlands of the Atacama Desert. For the authors this could mean either that "the surface of the site is compounded of a mixture of late-Pleistocene and early-Archaic materials" or that these typologies "are even more ancient than we have supposed for years and actually originated in the lowlands of the Atacama."

Environmental versus cultural motives

We know a site was occupied for, say, 900 years, but we don't know whether the occupation was interrupted by climate change or by human agency. Latorre believes that climate was responsible for patterns of movement over time. He notes that "the youngest dates we have for these sites is 11,700 ka, and the last dates we have for any paleoecological evidence, where there was water, is 11,600 ka. So literally the groundwater table collapsed because of lower infiltration and decreased recharge in the high Andes, which dried out the wetlands, forcing these guys to move somewhere else."

P. SALGADO

Santoro showing the Quebrada Maní 12 site to visitors.

Santoro argues that cultural forces can also drive human movement through time. "We think everything is related to or an effect of environmental conditions," he explains, "but there are cultural conditions. People decide to go to one place or another because of political or ideological reasons, and these may work in tandem with ecological constraints. The Pacific was an attractive environment where there was plenty of water and food, but people managed to find *quebradas* from the Andes on down."

The task of examining cultural aspects extends to the very artifacts found at Quebrada Maní. "They were very good artists skilled at making beautiful lithic tools," Santoro says, "and they were also skilled at making textiles, or processing fibers. We don't know whether there were designated people doing that, or whether everyone had those abilities. My impression is that there were special people doing these things, since they were so good at it. They concentrated on doing one specific task." If he is correct, then the first settlers of the Atacama developed professional specialization that we find in advanced societies today, where efficiency and skill are closely intertwined.

How far did Paleoamericans of Chile travel to get high-quality toolstone? To answer that, Santoro's team has been sending found obsidian to Michael Glascock at the Archaeometry Laboratory, Research Reactor Center, University of Missouri,

for analysis, and they eagerly anticipate the arrival of lithics expert Nicholas Tripsevich of the University of California, Berkeley, with a portable x-ray machine to analyze obsidian samples from different sites in northern Chile and compare their chemical signatures with samples from southern Peru and Bolivia (**MT 24-2,** "Following the obsidian trail"). These studies, says Santoro, "will help us understand the mobility of these people, to see how far they went to get their raw materials and bring them to camp." Tracking just how far these people traveled to procure toolstone of the desired quality and color is also a way of gauging their esthetic motives.

Not only were their toolmakers highly skilled, they were also imaginative. To maximize the use obtained from imported toolstone, they modified existing artifacts to create new tools. This resourceful innovation appears in Paleoamerican occupations and in later occupations as well.

Amazing preservation

Set down a stone artifact in the Atacama, or even one made of bone or wood, and it will remain there for thousands of years. Thanks to the remarkable preservation in the hyperarid desert, we can get answers to sophisticated questions about human subsistence patterns in the Atacama. Geologist Jason Rech of Miami University in Oxford, Ohio, who has been working in the Atacama since the late '90s, joined forces with Latorre and Santoro to help answer some of the geological questions on site formation and landscape evolution. The Atacama, he tells us, is unlike other deserts: "The margins of the desert have fluctuated, but its core—unlike the Mojave or other deserts that were relatively wet during the Pleistocene—has remained dry for millions of years. If you look at soils in the Atacama they're filled with sulfates, nitrates, and chloride salts, which we don't get in most deserts, and these are incredibly soluble salts that only accumulate when you have hyperaridity."

P. UGALDE

Surveying in Quebrada Sipuca *(left–right)* Universidad de Chile anthropologist Donald Jackson, Santoro, Latorre, and Rech.

The combination of salts in the soil—known locally as caliche—as well as the dry climate of the Atacama contribute to exceptional preservation and landscape stability. A majority of these salts are anhydrous; if there is any water, the material soaks it up. Thus ancient materials are essentially embalmed. At the late-Pleistocene occupation at QM12 were found dung, animal fibers, and two sticks that had been stuck into the soil and were still erect—probably used to roast meat. "You just don't get that at 12,000-year-old sites in North America," Rech emphasizes. "So often when we look at the archaeological record we find lithics and bone, but here we have a lot more cultural material that we can use to identify how people lived."

Rech describes ramifications of the remarkable capacity of the Atacama to preserve organic materials. "In most other locations you've had 10,000–15,000 years of erosion, but in the Atacama sites are only covered by 5–15 cm of sediment," he explains. "Logs 17,000 years old still lie on the landscape surface. In fact, in the Atacama in the 19th and 20th centuries people mined these Pleistocene trees to use them for charcoal in the heyday of the saltpeter industry. It's not just an isolated tree out there; you go into these alluvial fans and floodplains that drain out of the Andes to find trunks or large portions of these trees that were buried by sediment, and they're mining out these ancient trees to use as firewood today. That's the kind of preservation we're dealing with there."

For centuries international interests have tapped the rich mineral reserves of the Atacama. The desert has deposits of copper and other metals, and the world's largest natural supply of sodium nitrate, which was mined on a huge scale and carried by fleets of square-riggers around Cape Horn to ports in the eastern U.S. and Europe. In the 19th century the Atacama border dispute between Chile and Bolivia over these resources led to the War of the Pacific. It's interesting to note that in the film "The Motorcycle Diaries," it was in this area that young Che Guevara met a group of abused miners, who kindled his first political stirrings.

QM12 as a biogeographic corridor

Thanks to amazing preservation, researchers have been able to date lithic debitage, organic material, and other artifacts at Quebrada Maní while reconstructing an environmental backdrop across past climate changes. Site QM12, adjacent to Quebrada Maní, lies on an inactive alluvial fan (about 7 million years old) defined as Terrace 1. According to Rech, the site is located on an old landscape surface that sits above the modern floodplain and the late-Pleistocene floodplain.

This surface, which lacks vegetation, is covered by desert pavement and blanketed by a well-developed sulfate soil composed of anhydrite and gypsum. Although the local environment remained hyperarid in the Pleistocene, there appeared a network of freshwater oases, which served as biogeographic corridors for groups of hunter-gatherers who traversed the otherwise barren landscape. Rech is certain that Paleoamericans traveled along these biogeographical corridors, where water was plentiful. "The majority of the perennial water wetland deposits are older than the site of QM12," he says, "but it appears there was an active floodplain there, so there was prob-

ably seasonal or perennial water in the streams." Although few streams make it from the Andes to the Pacific ocean today, he's confident that water recharge in the Andes made water available during the late Pleistocene.

QM12 overlooks late-Pleistocene wetland and overbank deposits. Around 16,000–17,000 years ago it was a wetland with abundant standing or flowing water; around 12,000 years ago it was a vegetative floodplain. For Rech, this means that the water table is close to the surface here. "When people talk about earlier human arrivals we have very conducive environments for humans 15,000–17,000 years ago. If humans were there at that time, we should find the sites. We should find evidence for it." In that earlier period it would have been a pleasant place to live. QM12 overlooks the Andes and the coast, and plentiful water and shade trees made the surroundings green and fresh. Rech admits that "today it's hard to be there because it's hot and windy, but in those days it was an attractive place to stay."

C. SANTORO

Santoro's team excavating at the late-Pleistocene Quebrada Maní 32 site.

The spark of inquiry

By integrating paleoclimate and landscape evolution with archaeological survey work, researchers have documented instances of human adaptation to an extreme environment in terminal-Pleistocene South America. The hyperarid core of the Atacama is no longer seen as an obstacle to human settlement and dispersal. Instead, we now know that biogeographical corridors created a favorable environment for people at different moments in prehistory.

The Atacama, our closest analog to Mars, gives us a glimpse into the origins of human history. It's also an ideal platform for probing the deepest questions about our cosmic origins: Because of its high altitude, nearly non-existent cloud cover, and absence of pollution, the Atacama is one of the best places in the world to conduct astronomical observations. The Atacama Large Millimeter/submillimeter Array (ALMA) under construction will be the highest astronomical observatory on Earth and the largest astronomical project in existence.

But Latorre and colleagues prefer to keep their eyes on Earth, looking to the past as they move towards the future. Further research is supported by grants from CONICYT (the Chilean National Commission for Scientific and Technological Research) and their own universities. A geomorphologist recently proposed a collaborative investigation of paleoshorelines to find further evidence of earlier occupations. Their work bears on several overlapping time frames of different lengths. There's the exploratory phase, when humans first appeared in the Atacama, and the colonization phase, exemplified by the occupation of site QM12. Overlaying these efforts is their search for the answer to the questions, How old is the Atacama, and when did the landscape become hyperarid? "We are indeed looking for older sites," says Latorre, "but also tying this into the climate evolution of the Atacama using evidence from past shorelines and other relicts left behind from past climate change." He complains happily, "There's almost too much going on!"

–Katy Dycus

How to contact the principals of this article:

Claudio Latorre Hidalgo
Department of Ecology
Pontifical Catholic University of Chile
Casilla 114-D, Santiago, Chile
e-mail: clatorreh@uc.cl or clatorre@bio.puc.cl

Jason Rech
Department of Geology
Miami University
Oxford, OH 45056
e-mail: rechja@muohio.edu

Calogero M. Santoro
Instituto de Alta Investigación
Tarapacá University
Antofagasta 1520, Casilla 6-D, Arica 1000000, Chile
e-mail: calogero_santoro@yahoo.com

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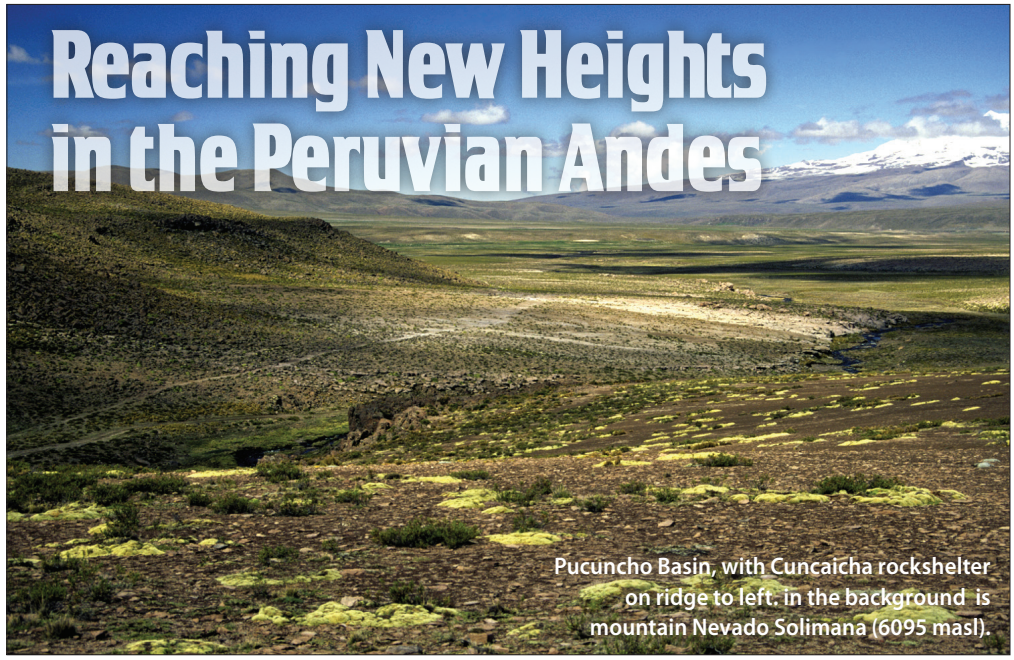
Reaching New Heights in the Peruvian Andes

Part II

WHEN ARCHAEOLOGISTS in the '90s found a handful of obsidian—volcanic glass—at Quebrada Jaguay in Peru, the oldest fishing settlement in the Americas—the seed was planted for Kurt Rademaker's research years later. Since obsidian comes from the Sierra, Rademaker, a postdoctoral researcher at Tubingen University in Germany, wondered how this fishing settlement was linked with the Andes mountains.

As Rademaker mapped the obsidian source at higher elevations in the Peruvian Andes in search of human settlements, he came upon Cuncaicha rockshelter, the Pleistocene archaeological site at the highest altitude yet discovered in the world. On identifying glacial landforms across the landscape, he sought to involve his friend, glacial geologist Gordon Bromley of the University of Maine.



Pucuncho Basin, with Cuncaicha rockshelter on ridge to left. in the background is mountain Nevado Solimana (6095 masl).

KURT RADEMAKER

A rewarding collaboration

When Rademaker and Bromley met over drinks, Rademaker asked his friend what he knew about dating surface exposures and whether he could handle high altitudes. Bromley was intrigued and agreed to join the team. During their first field season together in 2005, the physical hardship imposed by working at extreme altitudes frustrated Bromley's attempts to find cultural material in the glacial deposits of the upper elevations of the Andes. "But just beyond the glacial hills and moraines," Bromley remembers, "there were labyrinths and voids in the bedrock where you could easily hunker down and work on obsidian and be out of the wind and everything." This landscape, a glacial environment next to a nonglacial one, begged for research to discover whether humans had been present in either landscape.

Exciting sights lay ahead. Rademaker and Bromley climbed a mountain called Firura, on the north side of the Bofedal Pucuncho. The vista from the top of Firura takes in the whole Pucuncho Basin and immense Coropuna behind it, with prolific glacial deposits. Rademaker explains that "it was our basic objective from the start of our projects that we would attempt to integrate the records at a scale that would be meaningful. That isn't as easy as it sounds. Many archaeologists try to incorporate environmental information and many earth scientists try to apply what they know to archaeology, with varying degrees of success. In our case, what made this work was a concerted, long-term effort to make our records comparable." He credits their success with their training in an interdisciplinary institute at University of Maine that helps them understand how to communicate with scientists in other disciplines and define common, realistic research goals. "It's like communicating with someone who speaks a foreign language," says Rademaker, "much easier to do when both parties understand a little bit of the other person's language.

Sonia Zarrillo excavating Cuncaicha rockshelter.

KURT RADEMAKER

An oasis high in the Andes

The enormous Pucuncho Basin is surrounded by three immense promontories—Coropuna with its ice cap, and Firura and Solimana, which support small glaciers—which are themselves surrounded by many glaciated volcanic ranges. The basin is a well-watered and productive feature that stands out in marked contrast to the surrounding arid plateau. Reasoning that Paleoindians likely visited the basin on their way to quarrying Alca obsidian, Rademaker searched in and around the basin for archaeological sites. Bromley focused on climatic events in the history of the area. Logistically, it made sense to combine projects because both Bromley and

Rademaker felt certain the two records would overlap at some point. "Coupled climate-human system" describes how these projects are interwoven. "I study the climate and paleoenvironmental history of the tropics in general and Pucuncho in particular," says Bromley, "and humans are an integral part of both and so must be incorporated into that. Similarly, Kurt's investigations into human history in these southern Peruvian Andes must have a complete environmental and climatic context as its canvas; otherwise we'd never truly know what these people were up to, why they travelled to Pucuncho, why they kept leaving, and so forth. So the two are intrinsically linked, and our way of researching both simultaneously means that neither of us ever views his own work in a vacuum."

KURT RADEMAKER

WALTER BECKWITH

◀ Peter Leach with ground-penetrating radar.

▼ Leach and Sonia Zarrillo conducting ground-penetrating-radar survey in rockshelter.

Studying moraines as glacial footprints

The glacial deposits of Nevado Coropuna became the central focus of Bromley's research. The highest volcano in Peru and one of the largest in the world, it is, says Bromley, "a sprawling massive thing with one of the biggest ice caps in all of the tropics." For local inhabitants it's the principal mountain deity, *apu,* in this southern Peruvian region. Its name, in fact, means shrine on the *puna* (plateau). Bromley and Rademaker were once treated to a song about Coropuna by local schoolchildren. Bromley recalls that "an old lady we gave a lift to in 2012 waxed lyrical about there being a lake of fire at the top in which stands a golden bull—we didn't see either, but who's to say? The fact that this is a deity is very cool, but in no way was it the reason for our working there. That said, the mountain has kept providing, over and over again!"

Bromley set about mapping a high-resolution glacial chronology for this landform to provide a climatic and environmental context for Rademaker's archaeology. "We didn't know what we'd find archaeologically," Bromley says, "and it filled a vacuum of not knowing anything about tropical paleoclimates and how tropical climates behaved. We sort of killed two birds with one stone."

To date the glaciers and thereby establish an environmental timeline that could be directly correlated with the archaeological chronology, Bromley studied moraines through cosmogenic surface exposure dating. "Glaciers are filthy," he explains, "and covered in boulders, sand, and general crud. They deposit all that material around the margins of the glacier, and you end up with these great big sinuous ridges of rubble called moraines. When the ice has retreated and disappeared, there's still that ridge on the landscape showing exactly how big the ice used to be." A moraine therefore is essentially a glacial footprint.

After comparing moraines of that time period, Bromley came to the startling conclusion that ice wasn't a barrier to human travel and endeavor. It's an assertion, he realizes, that flies in the face of models of human migrations and colonizations. "It was colder, of course," he explains, "but not by very much. This is a rough estimate, but I'd say about 3 degrees Celsius colder when people arrived. It doesn't sound like a lot, but then the last Ice Age was 5 or 6 degrees colder. I think that people live in much more extreme environments than that—they live where they have to."

By mapping moraines Bromley can determine the scale of ice at different times. For him that's very important "because that's like a temperature measurement. You know what ice is like. It's very sensitive. If the climate warms up, the ice shrinks and disappears, and the reverse happens if it cools. If you look at the landscape at Coropuna, you see all these moraines going uphill, and you can see how the ice has shrunk and shrunk and shrunk. That's telling you that during that period it was getting warmer

KURT RADEMAKER

Willy Yépez Álvarez screening for artifacts at Cuncaicha rockshelter.

and warmer and warmer. We need to find out exactly when those changes happened because that tells us when the climate was colder, when it was warmer, and how fast it responded—like rates of change." And this is where helium dating, or cosmogenic surface-exposure dating, comes in.

Charting the retreat of glaciers

The earth is constantly bombarded by cosmogenic radiation from distant supernova events, "basically neutrons zipping along really fast," as Bromley describes the process, "and they're bombarding the earth and passing through you and me and everything, but when they hit a rock they penetrate the first few meters, then die down." Those particles are bombarding elements in the rock like oxygen and silicon (any element that's a constituent of a mineral) all day every day. Every substance it hits, silicon atoms, for example, it breaks apart via spallation. "So you end up with this interaction between cosmic radiation and these elements in the rocks," he says. These reactions produce rare isotopes, called cosmogenic nuclides. Silicon atoms react by producing isotopes of aluminum and neon and, most important for Bromley, helium.

KURT RADEMAKER

The team's campsite in the Pucuncho Basin. Cuncaicha rockshelter is on the hill in the background.

Inside a glacier is fresh rock that has never been exposed to the atmosphere. When rock is dumped out at the glacier margin, creating these moraines, it's exposed to the atmosphere and radiation for the first time, and these minerals at the surface start accumulating cosmogenic nuclides. "It's as if a clock starts ticking as soon as that rock falls off the ice," says Bromley. "As soon as it's exposed it starts collecting these cosmogenic nuclides. And it does that for thousands of years till I come along and take a sample. If I know the production rate of helium and can measure the concentration of helium, then I can solve for time."

KURT RADEMAKER

Christopher Miller sampling sediments in Cuncaicha rockshelter.

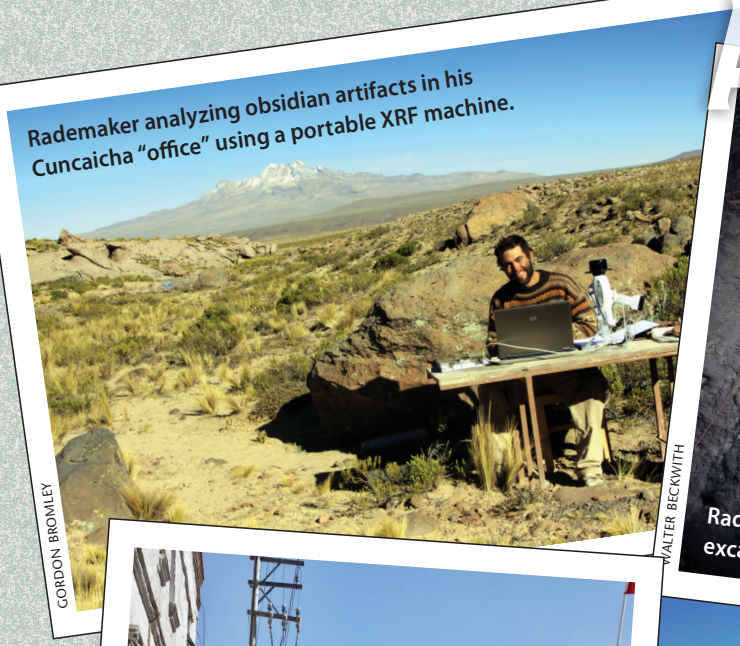
Cosmogenic surface exposure dating, this sophisticated method for determining the age of the climate events that formed moraines, involves a combination of physics, chemistry, and mathematics, and has revolutionized earth sciences in recent decades. "There are people who get fired up about developing the theory, and then those who are most excited to apply the theory. I like to use it. All I do is follow a recipe and then end up with some good numbers that make sense." Bromley the geologist acknowledges that everything begins simply—by walking around and spending a lot of time observing the landscape. "That's the kind of thing I enjoy most," he confesses, "the arts side. Making the drawings. Figuring out what the landscape looked like in the past. And that's the basis for the chemistry and mathematics and stuff. It's like a puzzle, and it's really intoxicating to be the one who gets to figure it out."

Nevado Coropuna as a paleo thermometer

As a component of the landscape that Paleoindians explored, Coropuna is important in two respects: It was a source of water, and it was also a massive active volcano. This dual role complicates the archaeological record. Bromley explains that "through a Holocene portion of Kurt's record you see no people living there—he calls them 'silences.' Why did people disappear for so long and then come back, disappear, and come back again? Environmental factors could very well be a part of that. It could be volcanism or dessication from prolonged Holocene droughts. We don't know the answer." Bromley is confident, however, that they'll find the answer, thanks to Coropuna, which he calls "the perfect paleo thermometer to look at this stuff, the perfect volcanic record. It takes care of those two things, and somewhere in the middle we can look at lake records in Pucuncho to assess what was happening to affect people's land use." By examining Pucuncho Basin, with its lakes and wetlands, massive glaciers, and volcanoes, Rademaker and Bromley hope to learn what people were capable of and why they were periodically absent.

Their curiosity is contagious. Even some of the locals are interested in learning about Coropuna. "They were interested in hearing about volcanoes from a scientific perspective and hearing about the wet season," says Bromley. "They had all experienced this directly, and they didn't kick up a fuss at all with

Archaeology à la Peru



Rademaker analyzing obsidian artifacts in his Cuncaicha "office" using a portable XRF machine.

GORDON BROMLEY

Rademaker *(left)* and Sonia Zarrillo excavating Cuncaicha rockshelter.

WALTER BECKWITH

Loading the field vehicle in Arequipa: *(left–right)* Peter Leach, Walter Beckwith, Kurt Rademaker.

SONIA ZARRILLO

View of mountain Nevado Solimana (6095 masl) from the plateau.

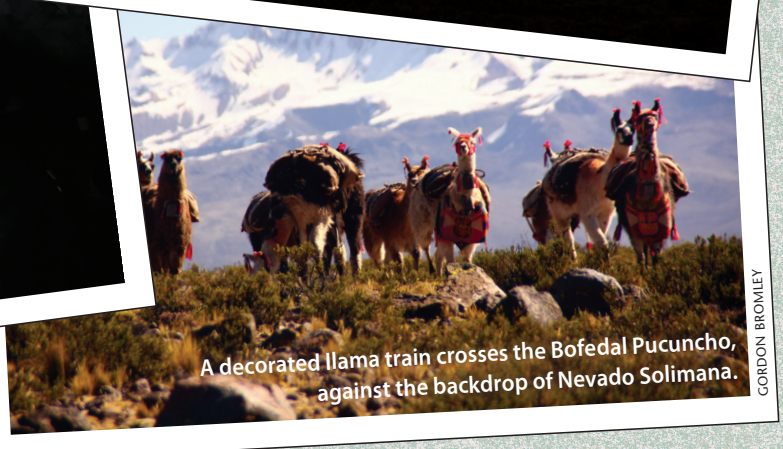
SONIA ZARRILLO

Alpenglow illuminating the western slopes of Nevado Coropuna.

GORDON BROMLEY

Field team excavating Cuncaicha, 2012: *(left–right)* David Reid, Elizabeth Olson, Christopher Miller, Willy Yépez-Álvarez, Tamara Labanowski.

KURT RADEMAKER



A decorated llama train crosses the Bofedal Pucuncho, against the backdrop of Nevado Solimana.

GORDON BROMLEY

a bunch of white people scurrying up, looking at a mountain." With the effects of global warming occurring before their eyes, they asked Bromley how long they could count on the ice cap as a water source. He says, "They're thinking, Here it is, this is happening, so what do we do to mitigate it for ourselves?"

Today the landscape is drying out and the ice cap of Coropuna is melting. Thousands of years ago, though, when early Americans arrived here en route to establishing residence at high-altitude sites, the landscape was wetter and more productive. Bromley hypothesizes that the climate was wetter because abrupt climate changes pushed tropical rain belts farther south during certain periods. Consequently Peru had a more robust wet season than now, which meant more water, more snowfall, more rain, and higher water levels. Bromley has a hunch, admittedly unscientific, that human occupation of the Peruvian Andes was simply a happy incident in history: "I just think they walked into that landscape at that time and were met with favorable conditions."

GORDON BROMLEY

Sr. Zuñiga of Pucuncho and Rademaker during the 2007 field season.

The entire picture on one canvas

Rademaker and Bromley sing the praises of interdisciplinary research. The advantage of their joint enterprise, says Rademaker, is that "we get a better understanding of the human past by investigating the evolution of landscapes—glaciers, volcanoes, lakes, bogs, plants, animals, people—everything. Together, the Coropuna moraine record and the well-dated archaeological sequence at Cuncaicha provide a high-resolution view of Andean landscape evolution and human settlement."

Could Rademaker and Bromley have conducted their projects independently? Sure, but their results would have been deprived of interdisciplinary nuances. In Bromley's view, "There's this paradigm that there was so much ice out there that people could never have gotten through so early on. This shows how it works well to work together. Besides that, it was fun! It was just a riot and still is. To climb these mountains and just explore."

When Bromley is out in the field, he registers an inner shift. "We become slightly different people," he explains. "We eat dust all the time, and it's cool because you live by the daylight and the day is about eleven hours long. And then you have these long frigid nights where everything is iced up. You learn to appreciate the moon and the phases of the moon. You learn to anticipate when it's going to be around and when you can use it, where you can forage for fuel, where you can go to get the most sunshine. It's really nice to be in tune with nature. It hurts not to be there."

Bromley sees a team of scientists working together as a troupe of musicians, each member playing an important instrument, together creating beautiful music when they play in harmony. He believes that "none of the archaeology would be as interesting without the paleoenvironmental context, and none of the environmental context would be as interesting without the human context—and part of the human context is what happens biologically. You can even get a paleoenvironmental record out of human teeth!"

Perhaps this coming together of great minds is best viewed in the warmth of a blazing campfire. Bromley reflects on the pleasure of "just sitting around a campfire. It brings everything together at the end of the day. The archaeologist comes back in, the geologist comes back in, and they say what they've been doing, what they've found or not found." It's only when you can't go back, he says, that you start to panic and realize how special it is. "I didn't go back last year and it almost broke my heart, but with luck I shall return this year."

–Katy Dycus

The Essential Tool for Making Needles

continued from page 3

forator and was not drilled with a rotating drill." Moreover, a "perforating tool" was used to form the eye, which was gouged "halfway from both sides" based on replication studies by lithics analysts Jim Wood and Gene Titmus.

Osborn is frankly amazed that needles were ever found by archaeologists. "Excavation screens are quarter-inch mesh," he reminds us. "These things are so tiny it makes you wonder, if they found them at all, that it must mean there are a lot more of them." Later use of bone needles trends to what he calls the "punch and stitch" technique used to make deerskin clothing when tailoring isn't required. He believes that needles were probably used later to make moccasins, but he finds little evidence for fine needlework after the YDCE.

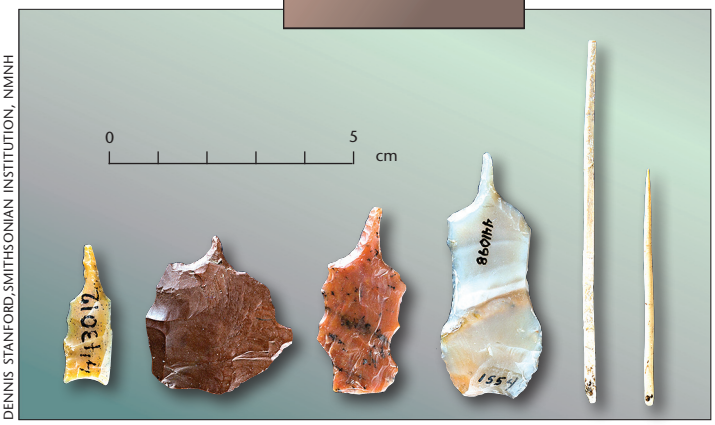
Making clothing was women's work

If winter temperatures during the YDCE were as extreme as Osborn believes, lack of proper gear could be life threatening. Women were critical in outfitting their family with winter garb. In the Arctic a woman spends about 105 hours in the fall to make just one winter outfit, and she does this for every

member of her family. Hides are taken in the fall after botflies quit boring holes in them but in plenty of time to make outfits for everyone in the family. This winter survival suit is an inner parka (with the fur to the inside), an outer parka (with the fur to the outside and a fur-trimmed hood), pants, mittens, and boots.

The window of opportunity for taking hides in early fall is brief. Because it was critical that Paleoamericans made their warm clothing before the onset of winter, it's likely they would settle into sewing camps. Ethnographic examples suggest these camps might be either near a coast or close to where hides were processed. Women may have carried a bag of gravers so they had all their bone needles and gravers handy when they began to make clothing. Osborn describes the atmosphere of sewing camps as almost ritualistic, or at least very carefully coordinated and controlled "so people didn't mess around." Sometimes they didn't even take time to cook. The Lindenmeier site in northern Colorado (**MT 27-4,** "Folsom bench mark: The Lindenmeier site") may have included one of these sewing camps, suggested by clusters of needle fragments found along with gravers. "They had to use a lot of gravers," Osborne explains, because bone needles broke often. If the remaining shank was long enough they would bore another hole in it.

TED GOEBEL



DENNIS STANFORD,SMITHSONIAN INSTITUTION, NMNH

Osborne jokes that bone needles were "make or break" items, both with regard to surviving the YDCE and because most needles found have been broken. Paleoamerican seamstresses, though, weren't careless with their bone needles. In fact, to protect them they stuck their needles into a piece of leather that was stored in a protective tube and retrieved by an attached cord. Osborn says these cases were generally ornamented and decorated, "similar to great-grandma's sewing kit. A lot of them are quite elaborate and carefully made."

As for the question of why some needle eyes are round and some are slitted, the literature doesn't offer any explanation. Osborn believes an eye made in a slitted shape makes a more streamlined needle, a superior needle for sewing boots because it makes the smallest hole and thereby minimizes leakage. He hints that he may look into the question of slitted versus round eyes in the future.

Appreciating the importance of gravers

What we find in the archaeological record assumes significance, says Osborn, once we place it in context and link it to a dynamic picture of the past. A typical spurred flake graver doesn't make a bold statement and can be easily overlooked or ignored, but it becomes valuable once put into a broader context. He remembers that during his training in New Mexico his professor, Lewis Binford, told his students that "the answers to archeological questions usually don't come from archaeology."

◀ Eyed needle found with the Buhl Woman burial in Idaho. Her skeleton was radiocarbon dated to 10,675 ± 95 RCYBP.

▼ Four of the sharpest gravers and two bone needles found at the Lindenmeier Folsom site in Colorado. The tips of these gravers appear too large to have made the extremely fine eyes of these needles, which means that Folsom toolmakers were capable of making gravers even more precise than these.

In this case gravers and needles don't really mean anything until you view them in the context of the Younger Dryas. Logic dictates that the need for custom-fitted, tailored fur clothing, demanded by the unusual cold of the YDCE, requires needles and that those needles require an eye. Not only are gravers technologically capable of making the eyes, they are found in close proximity to needles both spatially and temporally. For Osborn the hypothesis that gravers were used to make those eyes is therefore eminently reasonable. He doesn't discount the suggestion that spurred flake gravers may also have been used in tattooing, but when put in perspective "suddenly tattooing doesn't seem as important. It could mean they had a lot more important things to do than tattooing. They had to scramble and make survival suits, literally."

–Dale Graham

How to contact the principal of this article:
Alan J. Osborn
Sociology & Anthropology Department
University of Nebraska–Omaha
6001 Dodge St.
Omaha, NE 68182
e-mail: Aosborn2@unomaha.edu

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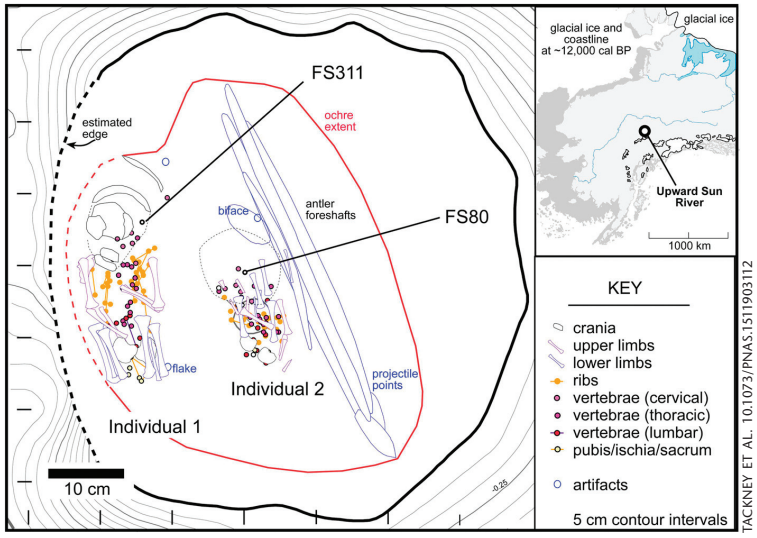
Digging Deeper into Upward Sun

Excavating the double-infant burial, 2013.

BEN A. POTTER

THE UPWARD SUN RIVER site in central Alaska was already a rarity among Paleoindian sites, boasting four components dating between 13,200 and 8000 CALYBP and a residential structure. Then in 2010 the remains of a cremated 3-year-old child were discovered inside the central pit hearth of the structure (**MT 26-4,** "Child of Beringia"). Ben Potter of the University of Alaska, Fairbanks, and his team worked cooperatively with Native leaders to unearth the child, who, after 11,500 years of waiting, became the first burial of Pleistocene age found in the North American Arctic and Subarctic.

Who would have guessed that directly below the toddler two infants had been laid to rest with great care? These infants, however, hadn't been cremated. Instead, they had been buried with grave goods directly below the hearth in a pit specifically dug for that purpose. The disparate burials could suggest two different cultures or time periods, but the age of the infants appears to coincide closely with that of the cremated 3-year-old. So closely, in fact, that the events appear to have occurred in subsequent seasons, if not the very same season. Same time. Same place. Same people.



Plan view of burial of Individuals 1 and 2; *(Inset)* location of Upward Sun River site.

TACKNEY ET AL. 10.1073/PNAS.1511903112

Eleven millennia since sunlight

Dr. Potter is no slouch when it comes to radiocarbon dating, having literally written the work organizing central Alaskan radiocarbon dates and deciphering the patterns that emerged from them. At the Upward Sun site many C-14 dates were taken from cultural features within various layers of the site. The children and the subterranean dwelling are members of the same component. Charcoal within the hearth that held the 3-year-old was dated to 11,500 CALYBP. The infants' pit, radiocarbon dated by charcoal that had adhered to an antler buried with them, dated to 11,600–11,230 CALYBP, which fits nicely within the frame of dates taken from upper and lower levels. To confirm this evidence, geoarchaeological observations and back-scatter plots confirm that the area has suffered little disturbance. The context of the human remains also shows little disturbance.

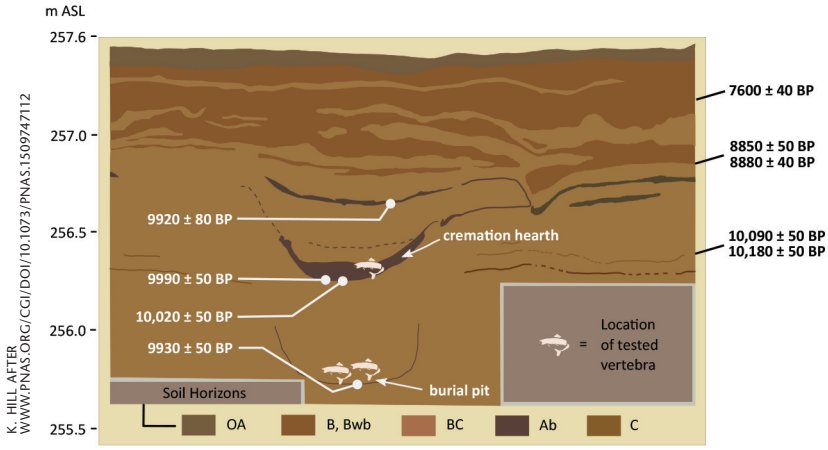
What animal bones have to say

Faunal analysis informs us about the season when the dwelling was occupied and the prey animals the occupants subsisted on. During excavation $^{1}/_{8}$-in. screens were used to ensure that, besides the remains of larger animals, smaller, more delicate and easily missed remains were also caught and included in the analysis. All the feature and control samples were collected in bulk and analyzed in Potter's lab.

Analysis of the assemblages of faunal remains revealed that the occupants of the dwelling when the infants were buried and when the 3-year-old was buried subsisted on a similar diet, which suggests the location was occupied at the same time of year for both burial events. Associated radiocarbon dates suggest that the events could have occurred on successive years, if not

during the very same year. It's therefore possible that the same inhabitants buried both the cremated child and the infants.

In both instances a number of different species were consumed. Large mammals constitute a relatively small portion of animal remains found here, and the large-mammal bones that were found were fragmented and burned and thus couldn't be identified. Although the thickness of some bones suggests that some large animals, such as bison and wapiti (elk), were eaten, salmon, ground squirrels, and birds made up the greatest part of the faunal assemblage. Salmon and ground squirrels are particularly interesting because they identify summer as the season of occupation. The ground-squirrel remains were of immature specimens. Typically born in the spring, these animals whose remains were found had attained the stage of growth normally reached by summer. As for salmon, they migrate on a predictable cycle and would have been present in summer. From the known seasonal timeline of salmon migration and ground-squirrel birth and growth, archaeologists determined the season of the burial and the cremation between mid-July and early August. Since remains of both of these animal species were found in abundance before the infants were buried and while the upper hearth was used prior to the cremation, it appears that both events took place during the same season, possibly in the same year.



K. HILL AFTER WWW.PNAS.ORG/CGI/DOI/10.1073/PNAS.1509747112

Upward Sun River stratigraphy, chronology, and aDNA and stable-isotope fishbone samples.

Faunal remains found within the hearth show it wasn't originally dug for the purpose of cremating the 3-year-old child. It was first used for cooking and burning refuse before being repurposed for the cremation. After the cremation, the pit was no longer used as a hearth. The hearth was located in the center of the dwelling. Some burnt faunal remains were found within the fill, under the hearth but above the burials, indicating that there was an earlier hearth in the same location through which the burial pit was dug, and a later use of the same hearth.

The infants, a double burial done with care

The carefully placed infants and their grave goods lay approximately 40 cm below the 3-year-old's pit. This deeper pit was dug not as a hearth, but as a grave. The infants' burial shaft is almost completely flat bottomed, steep sided, and approximately the same diameter as the cremation hearth above. The paucity of charcoal and ash indicates it was never used as a fire pit.

To give the full picture, the burial pit is 40–50 cm below the hearth, and 90 cm below the floor of the dwelling. The infants' skeletons are relatively complete and articulated, which suggests the ground wasn't disturbed. Archaeologists have determined that Individual 1 was placed near the western edge of the pit lying face up, head toward the river, knees tucked into its chest. The left arm was flexed to the chest, the hand near the chin. The right arm extended across the torso to the left. Individual 2 was situated near the center of the pit, but the position was more difficult to determine. It appears that this infant was initially buried in an upright, sitting position, knees to chest. Upon recovery, this infant's skeleton was partially disarticulated, with the torso flung forward over the legs. The left arm was extended beside the back and behind the pelvis. By carefully measuring elevations while excavating Individual 2, archaeologists determined that the skull, thoracic vertebrae, and hands were higher than the bones of the lumbar vertebrae (the lowest vertebrae), pelvis, and legs. This makes sense if the tiny child had been placed in the burial pit in a sitting position, and explains why the bones of the torso were found on top of those of the legs. The considerable weight of the soil covering the infants (over 1 m had accumulated over the millennia) likely shifted the torso forward over the legs.

Attention to ceremony

Both infants were covered with an ocher-rich residue, which may indicate they were wrapped in shrouds before burial. Red ocher also covered the associated grave goods: hafted bifaces and four decorated rods.

The rods were made of antler, likely from wapiti (elk), with bi-beveled cross section (an edge slanted on both sides) and a series of X's carved across the upper surface. Why rods are common in paleo sites in North America is currently up for debate. One popular idea is that they may have been foreshafts affixed to spears, so a hunter, instead of carrying several spears, could carry several rods with projectile points attached. The rods would have been fashioned to be easily attached to and removed from the spear, thus making the spear versatile to serve different needs. Though the rods found in the burial resemble rods typically found in paleo sites, three are considerably longer than usual and the carvings are unprecedented.

Lithic points were found lying at the ends of two of the rods as if they had been hafted to them. Any sinew or cord that may have been used to bind the points to the rods would likely have disintegrated, which leads Potter and his team to believe that the bifaces were indeed hafted to the rods at the time of burial. If so, they are the earliest known hafted bifaces found in primary (undisturbed) context in North America. The antler rods and two of the bifaces were lying roughly parallel to each other and to the infants, facing toward the Tanana River and perpendicular to the sand dune, a pronounced terrace feature

north of the river. It would seem that the burial party had these prominent landforms in mind when they laid the infants to rest.

What the infants have to tell us

They weren't old enough to talk, but the infants have a story to tell Potter's team. Based on skeletal and dental development, Individual 1 appears to have survived birth and lived for a period of from a few days to a few months. Development measurements are based on modern children's growth. Because Potter's team can't assume ancient children grew at the same rate as modern children, however, their estimated age of Individual 1 is only approximate. For Individual 2, less developed than Individual 1, all they can determine with fair certainty from its tiny skeleton is that the child was a late-term fetus. It therefore appears that one infant died before birth, and the other survived birth only a short while.

It's difficult to determine from skeletal material if a child was male or female. Features of skull and pelvic fragments suggest that both infants may have been girls. DNA analysis could confirm or refute this. The best laboratories in the world were employed to attempt to extract ancient DNA from the skeletons, and they have been successful. The DNA, however, has yet to reveal the sex of the children. DNA analysis is no quick process. Besides clarifying the infants' relationship to each other, DNA analysis could reveal their relationship to the cremated child and to both ancient and modern humans. It could also help answer many questions about health and population characteristics.

Were they twins?

Several clues cause Potter's team to suspect the infants were twins. First, they were irrefutably buried together. Possibly Individual 2 had previously been buried and was exhumed to be interred with Individual 1. Twins are, of course, at greater risk than a single birth during pregnancy and delivery (the

TODAY SALMON ARE EXPLOITED along the North Pacific Rim as a valuable foodstuff. They were no less important to prehistoric foragers from time out of mind. Exactly how long ago Early Americans began to make these Pacific invaders part of their livelihood and their culture has been anyone's guess. New information from the Upward Sun site may push the date back further than anyone expected. A team of scientists including Ben Potter, Carrin Halffman, Brian Kemp, and others have interpreted fish remains, DNA evidence, and isotopic analysis from the Upward Sun site to weave a conclusive web of evidence that Early Americans exploited salmon runs in the terminal Pleistocene, around 11,500 CALYBP.

A delicate subject

Fish bones are fragile. This means, in the first place, that they don't preserve well in the archaeological record. Although a large sturdy mammoth rib might last millennia, fish bones (tiny to the point of transparency) are quickly obliterated by time and the elements. Second of all, even when fish bones are preserved, the problem once again is size. Tiny, even minuscule fish bones are notorious for slipping through any but the finest-mesh screens. And let's face it, historically archaeologists have been a bit more mammoth happy than fish happy. Not that you can blame them, of course. There isn't an archaeologist born who would get more excited about excavating a fish than a mammoth.

So they ate fish. What's the big deal?

The Upward Sun site is nowhere near the coast. In fact, it's only about 50 km downstream of today's farthest upstream salmon spawning areas in the Tanana River. The fish remains from Upward Sun came from the central hearth feature, above the interred infants, which held the cremated three-year-old. The feature contained 308 fish specimens, most of them fragmentary and burned. The species was salmon, specifically a variety that follows a seasonal cycle of swimming upriver from the Pacific Ocean to spawn. This travel period has a short window . . . but a predictable one. This fact has piqued the attention of archaeologists. To exploit salmon runs, hunter-gatherers would need to know the migration habits of salmon and the character of the water course. The depth of knowledge of Beringians in these areas has implications toward their diet, subsistence strategies, and, if history is a guide, ties to cultural traditions.

Bone morphology + DNA + isotope analysis = conclusion

Fish vertebrae from the pit feature were first compared with those of modern fish and identified as the genus *Oncorhynchus,* which includes a number of species of Pacific salmon and trout. Certain morphological characteristics of the bones caused researchers to lean toward *Oncorhynchus keta,* or chum salmon. But faunal researchers hesitate to identify to the species level on the basis of bone morphology alone. DNA evidence, on the other hand, is a solid foundation that bears a lot of weight.

In this case the weight placed on the premise of chum salmon is considerable. A number of closely related (and morphologically similar) species don't participate in spawning runs that are so significant to archaeologists. In fact, pocket populations of most species of salmon live out their lives in freshwater and therefore never make spawning runs. The only species that hasn't displayed this conduct is (you guessed it) chum salmon.Talk about convenient.

chance of premature delivery of a deceased fetus is roughly 68 percent). What's more, the late-term death of one twin before birth can adversely affect the surviving twin by contributing to diminished growth, developmental problems, and early death.

The answers to these questions can't be found by analyzing the skeletons. DNA analysis is the key to solving the riddle. Recent work has at least partially answered this question. Mitochondrial DNA or mtDNA extracted from the infants demonstrates two different mtDNA lineages. Because mtDNA is inherited from the mother, this proves that the infants weren't twins. Whether they shared a father can't be determined. One thing is certain: Since they weren't twins, this group experienced a higher child-mortality rate then we would expect for a small band of hunter-gatherers.

Short time, many differences: Why?

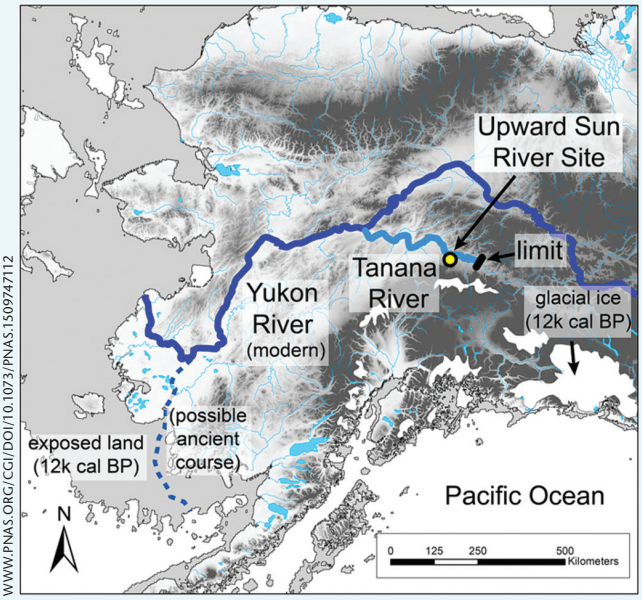
The 3-year-old child and the infants were laid to rest in a considerably different manner. The infants were buried; the 3-year-old child was cremated. The infants were oriented toward the river; the 3-year-old's cremation seems to lack orientation to the river or any distinct landform. The infants were accompanied with grave goods; the cremation was of the child only. What accounts for the different mortuary practices? It seems unlikely the group's mortuary traditions would have changed in the short time between the cremation and the burial. It's equally unlikely that the infants were buried and the 3-year-old cremated by different groups . . . who, though having different mortuary traditions, just happened to bury their children in exactly the same place.

Perhaps the group's mortuary practices varied by season. For example, those who died in winter months may have been customarily cremated in a shallow (and more easily dug) pit, and those who died in warmer weather were buried in a deeper hole. This road is a dead end, though, because

The picture gets a bit cloudy, however, because captive chum have been raised in freshwater habitats, thereby demonstrating they don't depend on a saltwater phase in their life cycle.

To prove that the fish bones found at Upward Sun were from Pacific-dwelling chum salmon that seasonally swam up the Tanana, Potter and his team had to resort to stable-isotope analysis to measure the isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), which tend to be higher in marine animals than in freshwater animals. Stable-isotope analysis of modern salmon stock verifies that the theory is sound. If salmon spent most of their lives in the Pacific before heading inland, then stable-isotope analysis should detect this.

Potter's team analyzed the DNA of two unburned vertebral specimens from Upward Sun, and performed stable-isotope analysis on a third specimen. Repeatable and independent mtDNA analysis identified the species as chum salmon, and the carbon and nitrogen isotope ratios were comparable to those of modern Pacific salmon and higher than found in modern freshwater fish. From these results the team conclude that the Upward Sun site is the earliest archaeological site in North America with evidence of Pacific salmon. This means that Beringians had knowledge of spawning patterns and designed a subsistence strategy to take advantage of this seasonal resource. Inland Beringia has often been thought of as an area of limited resources. Now salmon can be added to the growing list of resources that Beringians exploited, including other fish, mammals (large and small), and waterfowl.



Location of Upward Sun River site; course of the Tanana-Yukon River and possible course across the Bering Shelf during lower sea level; and modern chum salmon fall spawning limit along the Tanana River.

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Other fishy possibilities

Fish remains, rarely found in Paleoindian sites, were reported at the Aubrey site in Texas and the Shawnee-Minisink site in Pennsylvania. At both sites neither the species nor genera were identified. On the Channel Islands off the coast of California, Jon Erlandson reports three sites of Paleoindian age that contained multiple taxa of fish. In Kamchatka at Ushki 1, Level 6 (ca. 12,160 CALYBP) houses yielded burnt fish bones, possibly of the salmon variety.

In Beringia both the Mead Cultural Zone 3 (ca. 11,990 CALYBP) and Broken Mammoth Cultural Zone 3 (ca. 12,080 CALYBP) in Alaska have yielded evidence of fish remains. According to Potter, the Mead fish are freshwater and the Broken Mammoth specimens, although salmonids, haven't been identified to the species level.

Go fish

All this research tells us that by the terminal Pleistocene Early Americans knew how to take advantage of seasonal salmon runs in Beringia. Once thought by archaeologists an ecosystem with few resources to offer, Beringia, we're just learning, was a land where industrious people found ample resources. Of the 40 earliest sites in northwest North America (14,000–11,500 CALYBP), 36 lie within the interior. Of those, 60%, including the Upward Sun site, are found near the bottom lands of large rivers. Evidently Early Americans valued rivers and their resources. If you're looking for such sites, this might not be a bad kind of place to toss your line in the water.

–K. Hill

faunal data confirm that all three children were buried or cremated in summer. A theory that can't be confirmed or refuted is that mortuary treatment differed according to the sex of the child. The resolution to this theory will have to wait for DNA analysis.

The current information leaves open two possibilities. The first is that the infants and the 3-year-old were treated differently because of their age; that is, mortuary practices for infants may have differed from those for children old enough to walk and talk. The second is that the differences were merely the result of situational factors such as an unexpected death or the presence or absence of certain individuals within the group. That the infants shared a grave poses another interesting line of questions. Were they buried together because they were somehow related, or simply because they were infants whose deaths coincided?

Decorated antler bibeveled foreshafts and associated bifaces.

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Comparison with Anzick and Ushki

Beveled rods were also found with the Anzick child, a Clovis burial in Montana (**MT 29-2,** "Clovis child answers fundamental questions about the First Americans"). Like the Upward Sun infants, the Anzick child was buried in a pit with red ocher and grave goods, including beveled rods, projectile points, and other lithic tools. Such grave goods suggest a group that valued hunting. Unlike the Anzick child, however, the infants of Upward Sun were buried within a residential feature. This is also true of a site in western Beringia called Ushki 1. Like Upward Sun, Ushki 1 has burials within a camp feature near a braided river. Its inhabitants subsisted at least partially on fish. Upward Sun thus shares certain burial practices with both Anzick and Ushki 1. Geographically, it's located between them.

Drawing conclusions about Upward Sun

Any archaeological site is an upside-down cake. The pit hearth at Upward Sun was dug and used for cooking, refuse disposal, and warmth. Upon the death of the infants, a burial pit was excavated by making the hearth deeper, and the children were placed inside. With the infants sealed safely below, the hearth was returned to use. A short time after, possibly during the same summer or the one following, the 3-year-old was cremated within the pit hearth, the remains were covered with earth, the hearth was abandoned, and likely the structure as well.

That's the rough narrative left in the earth. But it leaves certain questions unanswered. Exactly how were they related to one another (if at all) and to other ancient and modern Native Americans? What were the diets of the mothers? Hopefully the DNA from the three children can provided enough information to tell us their relationship with each other. It can also illuminate their genetic relationship to other burials, including that of the Anzick child and those of Ushki 1, and answer a host of other questions.

But for now we must wait. The children have waited 11,500 years. I suppose we can wait a little longer.

–K. Hill

How to contact the principal of this article:
Ben A. Potter
Department Chair and Associate Professor
Department of Anthropology
University of Alaska
Fairbanks, AK 99775
e-mail: bapotter@alaska.edu

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