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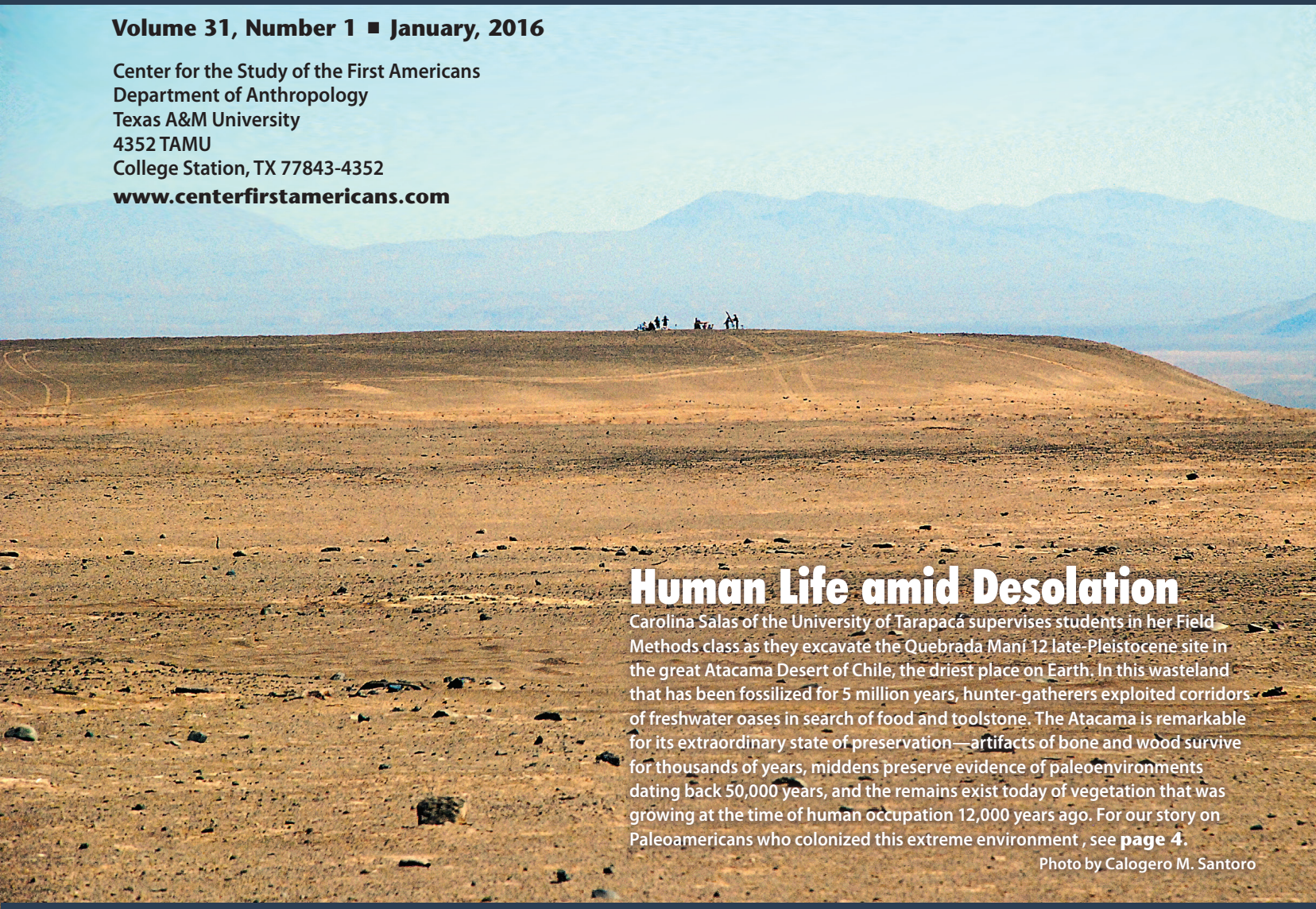
Center for the Study of the First Americans
Department of Anthropology
Texas A&M University
4352 TAMU
College Station, TX 77843-4352
www.centerfirstamericans.com



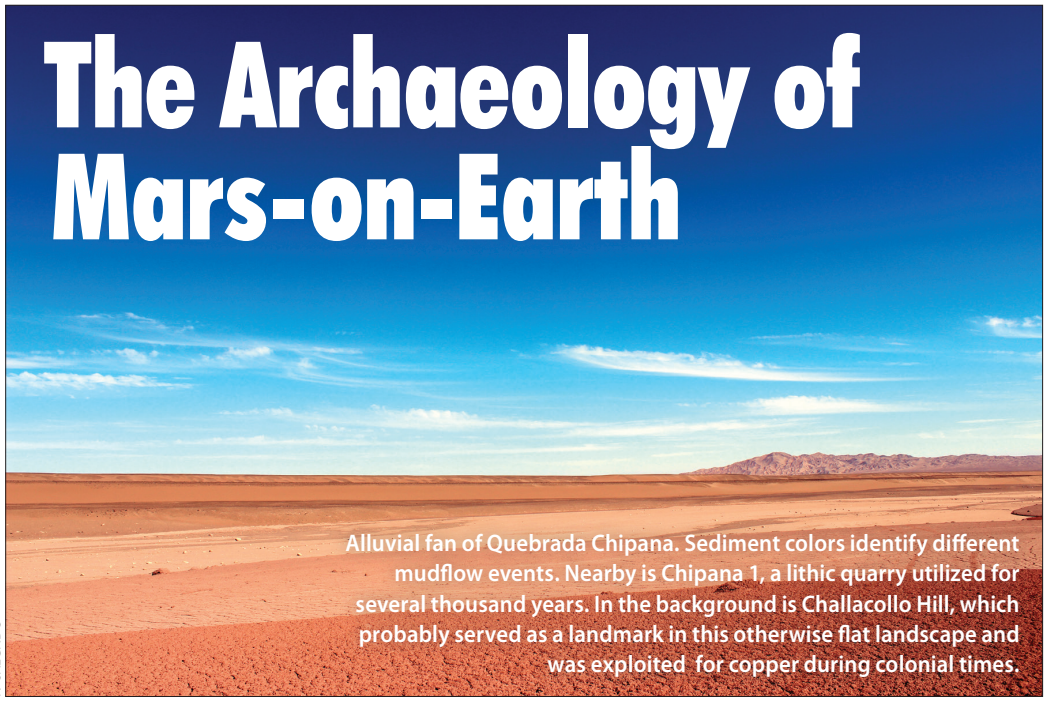
Human Life amid Desolation

Carolina Salas of the University of Tarapacá supervises students in her Field Methods class as they excavate the Quebrada Maní 12 late-Pleistocene site in the great Atacama Desert of Chile, the driest place on Earth. In this wasteland that has been fossilized for 5 million years, hunter-gatherers exploited corridors of freshwater oases in search of food and toolstone. The Atacama is remarkable for its extraordinary state of preservation—artifacts of bone and wood survive for thousands of years, middens preserve evidence of paleoenvironments dating back 50,000 years, and the remains exist today of vegetation that was growing at the time of human occupation 12,000 years ago. For our story on Paleoamericans who colonized this extreme environment , see **page 4.**

Photo by Calogero M. Santoro

The Center for the Study of the First Americans fosters research and public interest in the Peopling of the Americas. The **Center,** an integral part of the Department of Anthropology at **Texas A&M University,** promotes interdisciplinary scholarly dialogue among physical, geological, biological and social scientists. The **Mammoth Trumpet,** news magazine of the **Center,** seeks to involve you in the peopling of the Americas by reporting on developments in all pertinent areas of knowledge.

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

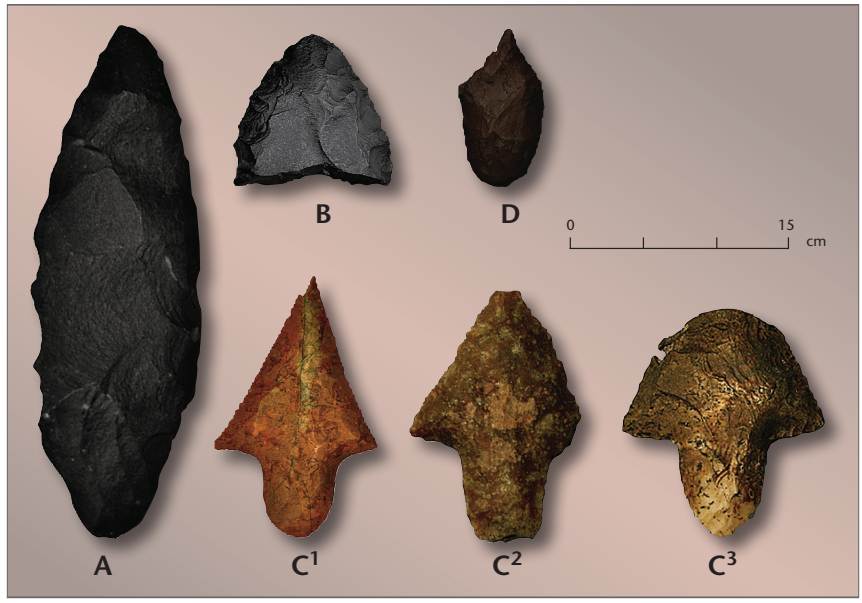
Santoro *(left)* and Rech examining specimens of *Equisetum* sp. (horsetail), *Distichlis spicata* (desert saltgrass), **and Gramineae preserved in situ on the lower terraces of Quebrada Maní 12. These plants were growing at the time of human occupation 11,400–12,000 years ago.**

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

Suggested Readings

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