EXTREME LIVING

After humans arrived in South America, they quickly spread into some of its most remote corners.

BY BARBARA FRASER

From the mouth of a cave high in the Andes, Kurt Rademaker surveys the plateau below. At an altitude of 4,500 metres, there are no trees in sight, just beige soil dotted with tufts of dry grass, green cushion plants and a few clusters of vicuñas and other camel relatives grazing near a stream.

The landscape looks bleak, but Rademaker views it through the eyes of the people who built a fire in the rock shelter, named Cuncaicha, about 12,400 years ago. These hunter-gatherers were some of the earliest known residents of South America and they chose to live at this extreme altitude — higher than any Ice Age encampment found thus far in the New World. Despite the thin air and sub-freezing night-time temperatures, this plain would have seemed a hospitable neighbourhood to those people, says Rademaker, an archaeologist at the University of Maine in Orono.

"The basin has fresh water, camelids, stone for toolmaking, combustible fuel for fires and rock shelters for living in," he says. "Basically, everything you need to live is here. This is one of the richest basins I've seen, and it probably was then, too."

Rademaker is one of a growing number of young archaeologists investigating how hunter-gatherers first colonized South America at the close of the Pleistocene epoch, when the last Ice Age was waning. Casting aside old dogmas, these researchers are finding that people arrived significantly earlier than previously believed, and adapted rapidly to environments from the arid western coastline to the Amazon jungle and the frosty heights of the Andes.

By teaming up with geologists, climate scientists and other researchers, archaeologists are gaining a clearer picture of what the ancient environments were like and how people migrated across the landscape — clues that are leading them to other ancient occupation sites.

HIDDEN ANCESTRY

"The archaeology that's being done in South America is becoming more scientific with the development of new methodologies, and there's a level of collegiality developing among younger researchers," says Rademaker. "We're all really excited about the new developments that are coming faster and faster." But researchers are racing against time as South American countries rapidly expand mining, road building and other activities that threaten to obliterate evidence from promising sites.

For decades, a fractious attitude prevailed over research on the earliest people in the Americas. One of the most acrimonious disputes concerned a site in southern Chile called Monte Verde, which Tom Dillehay, an anthropologist now at Vanderbilt University in Nashville, Tennessee, excavated in the 1970s and 1980s. He found evidence of human occupation[1] that he dated to about 14,500 years ago. Dillehay's conclusions regarding Monte Verde put him in direct conflict with the accepted wisdom among leading archaeologists that people from Siberia did not spread across North America and venture south before around 13,000 years ago. That is the age of the Clovis culture, a group of big-game hunters who used distinctive spear points that are found littered across the United States. The Clovis people were thought to be the pioneers in North America, and many archaeologists there dismissed Dillehay's claim that Monte Verde was older.

But antagonism has faded over the past six years, as convincing evidence of pre-Clovis sites has emerged in North America (see *Nature* **485,** 30–32; 2012). Meanwhile, South American archaeologists, who were never as sceptical as their northern colleagues, have

BARBARA FRASER

Above: Christopher Miller (left) and Rademaker survey sites in the Pucuncho Basin in August.
Left: Kurt Rademaker explores the Cuncaicha rock shelter in the Andes.

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found more sites dated between 14,000 and 12,000 years ago, indicating that hunter-gatherers had spread through South America before and during the rise of the Clovis culture in the north.

Now that researchers have moved beyond that debate, they are making greater headway in studying when people reached South America and what they did when they got there.

Rademaker's finds in the Andes are helping to answer those questions — and pose new ones. His journey began 150 kilometres away from the Andes cave, on Peru's arid coast at Quebrada Jaguay, where Daniel Sandweiss, an anthropologist at the University of Maine and Rademaker's graduate adviser, was excavating a site that dated to the end of the last Ice Age, between 13,000 and 11,000 years ago. Sandweiss had uncovered the remains of seafood meals, as well as flakes of obsidian produced as people chipped at the glassy mineral to make stone tools[2]. There are no obsidian deposits along that coastline, so the material must have come from formations high in the Andes.

Rademaker travelled into the mountains and found a large outcrop of the obsidian known as Alca[3] at Mount Condorsayana in 2004. Over the next three years, he studied the obsidian deposits and evidence of past glaciation in the area with geologist Gordon Bromley of the University of Maine.

Those field trips gave Rademaker his first glimpse of the Pucuncho Basin, an alpine wetland with a stream, numerous vicuñas, llamas and alpacas, and a ready supply of cushion plants, which the researchers discovered are rich in resin and can burn easily. The basin was also littered with points and shards left by early toolmakers. Hiking down the stream, he glanced up the hill to his left and saw a yawning gap — the Cuncaicha rock shelter, which he began excavating in 2007.

"This is the first time we've found a site this old in the high Andes," Rademaker says. On a day in August, he wraps a bandana over his mouth and nose and shovels dirt into buckets to fill in an excavation pit that is no longer needed. As he works, his shirt sleeve pulls up, revealing a glimpse of meticulously detailed hominin skulls tattooed up his right arm — from *Australopithecus afarensis* near his wrist to *Homo sapiens* on his shoulder. This late in the field season, his field trousers are frayed and he has had to bind his left hiking boot with several strata of duct tape.

A chilly breeze whips across the Pucuncho plateau as some of Rademaker's companions struggle with the thin air. As well as cautioning his team members to prepare for the cold, Rademaker ensures that they acclimate gradually to the lack of oxygen.

Even while battling the extremes, the team has gathered evidence contradicting the conventional wisdom that the mountains were too high, cold and inhospitable for early human habitation. Bromley's data show that at the end of the last Ice Age, glaciers were mainly confined to some alpine valleys, and Pucuncho and other areas were not glaciated. Palaeoclimate data indicate that the environment was probably wetter then, so there might have been more plants and animals available for the early residents, says Rademaker.

"These Palaeo-Indians were able to live in one of the most extreme environments on Earth, at the end of an ice age, and they seem to have done so quite successfully," he says. "This tells us that Palaeo-Indians were capable of living just about anywhere."

There are large numbers of animal bones, mainly from deer and vicuñas, in the earliest layers of sediment in the Cuncaicha rock shelter, showing that the inhabitants found abundant game on the plateau. And some of the tools were made of stone not available in the area, indicating that residents of the cave either travelled outside the region or exchanged materials with other groups that did. Some tools show traces of plant starch, which the researchers hope to analyse to work out what the cave-dwellers ate, and whether they domesticated tubers or other plants.

The researchers have also found a fragment from a human skull at the site. It has not yielded DNA and its age is uncertain, but it hints that the cave could contain early human remains, says Rademaker.

TOOL TRADE

Farther south, César Méndez has followed similar clues in his search for late-Pleistocene sites along the Chilean coast. Beginning in 2004, Méndez, an anthropologist at the University of Chile in Santiago, and his colleagues excavated an ancient encampment, which they dated to around 13,000 years ago[4].

Some of the stone tools at the site, called Quebrada Santa Julia, were made of translucent quartz that is not found in coastal deposits. Like Rademaker, Méndez mapped potential paths towards known quartz deposits inland. Sampling along those routes, his team found an outcrop of translucent quartz at a site where people had lived and quarried between 12,600 and 11,400 years ago. The similarity with Quebrada Santa Julia in terms of age and tool-making

techniques suggests that the coastal tools came from these mountain outcrops.

"What we're seeing is that 12,000 years ago or more, these groups already had networks, knew the landscape and moved between the coast and the interior," says Méndez.

Sites such as Quebrada Jaguay and Quebrada Santa Julia suggest that some early hunter-gatherers in South America might have travelled along the coast, taking advantage of the fish, shellfish, animals and plants found in wetlands and near river deltas, says Dillehay. He is finding more evidence beneath Huaca Prieta, a 32-metre-high mound on the coast of northern Peru (see 'Conquering a continent').

The mound was first excavated in the 1940s, but Dillehay dug deeper and uncovered traces of Ice Age settlements in 2010. Radiocarbon dating indicates[5] that humans had lived there as much as 14,200 years ago, when the area was surrounded by wetlands.

COASTAL DRIFT

If early people did migrate along the coast, some of the best evidence has probably been swallowed up by the ocean. At the end of the Pleistocene, melting ice sheets caused sea levels to rise by 70 metres, which would have flooded much of the former coastline. That effect would have been greatest in some regions of eastern South America, where the land is relatively flat and the ocean migrated well inland.

At the border between Uruguay and Argentina, for example, archaeologists suspect that ancient people might have hunted and camped on a broad delta that formerly existed at the mouth of the Uruguay River. But any such sites would have been drowned when the sea advanced by more than 120 kilometres, says Rafael Suárez, an archaeologist at the University of the Republic in Montevideo.

Suárez has looked for clues upriver, and has dated several residential sites to between 12,900 and 10,200 years ago. Some tools found at a site called Pay Paso are made of translucent agate, which apparently came from quarries near the border with Brazil about 150 kilometres away. And other tools from Uruguay have been found 500 kilometres to the south in Argentina's Buenos Aires province[6], says Nora Flegenheimer, an archaeologist with the National Scientific and Technical Research Council (CONICET) in Necochea, Argentina. Such finds point to widespread trade or travel routes in eastern South America.

Some archaeologists wonder whether early residents of the continent might even have crossed the Andes. Bolivian archaeologist José Capriles of the University of Tarapacá in Arica, Chile, has raised that possibility after studying 12,800-year-old artefacts at Cueva Bautista, a rock shelter 3,930 metres above sea level in southwestern Bolivia. He notes that a similarly aged site exists at the same latitude in Chile on the western slope of the Andes. Future research could explore tools found at both sites to see whether people migrated from one side to the other or established trading routes.

But some of the best evidence for Pleistocene humans in South America may disappear soon, owing to rapid expansion in industrial-scale agriculture, road building and other forms of development. Those human threats come on top of the natural ones — wind erosion and changing watercourses — that constantly alter landscapes.

Suárez and his team had to call the navy to evacuate them from a site in Uruguay last December, when floodwaters rose dangerously in the lake behind a nearby hydroelectric dam. A proposed dam could also flood sites in the Ocoña River valley in Peru, which Rademaker thinks could have been an early route from the coast to the Andes.

In the highlands, the rapid expansion of mining can be both a bane and a blessing. Archaeologists discovered Bolivia's Cueva Bautista site during a survey for a road leading to a mine. But open-pit mines threaten many other sites, says Capriles.

Archaeological surveys must be carried out before development and infrastructure projects can go ahead, but the people who perform such studies do not always recognize the subtle signs of ancient human occupation, the researchers say. And even if the surveys do turn up important archaeological evidence, developing countries are often reluctant to let the past stand in the way of the future.

"I've never seen such destruction as you get in Peru," says Dillehay. He has witnessed bulldozers ravage sites and landowners destroy evidence to avoid delaying construction work.

There are no signs yet of such activity reaching Rademaker's survey site in the high Peruvian Andes. Over the past decade, he and his colleagues have extensively explored the region on foot in an effort to determine whether the inhabitants of the Cuncaicha rock shelter traded for their exotic tools and whether they lived there year-round. The answers may lie in undiscovered occupation sites between the cave and the coast, so Rademaker is exploring likely avenues, mapping the routes that would have required the least energy expenditure while providing access to water and food.

The researchers have backpacked along dozens of streams and rivers, sometimes clambering up steep cliffs to avoid flash floods, always with an eye out for gashes in the rock face that signal a potential shelter. Early inhabitants probably would have explored the new landscape in the same way with the same targets in mind.

Rademaker surveyed four rock shelters this year but all of them were inhabited too recently — only 4,000 to 6,000 years ago. Still, he is convinced that there are more late-Pleistocene sites in the Andes. Early inhabitants must have found other places like the Pucuncho Basin and the Cuncaicha rock shelter. They might have followed rivers that flow from the highlands to the coast. Or perhaps they trailed the herds of wild guanacos that still descend along spurs of the Andes nearly to the ocean shore.

Each field season dangles more possibilities before Rademaker's team. "I went for a walk one night, found another confluence and found another cave," he says. "It's never-ending." ■

Barbara Fraser *is a writer in Lima, Peru.*

1. Dillehay, T. D. *et al. Science* **320,** 784–786 (2008).
2. Sandweiss, D. H. *et al. Science* **281,** 1830–1832 (1998).
3. Rademaker, K. *et al. Geology* **41,** 779–782 (2013).
4. Méndez, C., Jackson, D., Seguel, R. & Nuevo Delaunay, A. *Curr. Res. Pleistocene* **27,** 19–21 (2010).
5. Dillehay. T. D. *et al. Quat. Res.* **77,** 418–423 (2012).
6. Flegenheimer, N., Bayón, C., Valente, M., Baeza, J. & Femenías, J. *Quat. Int.* **109–110,** 49–64 (2003).