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Inside the Armadillo's Den, a giant palaeoburrow in southern Brazil.

# WHO CARVED SOUTH AMERICA'S MYSTERIOUS ANCIENT TUNNELS?

In Brazil and nearby nations, researchers are investigating the origins of vast burrows cut into solid sandstone. Their chief suspect – extinct ice age beasts. **By Meghie Rodrigues**

**A**t age 75, Vadevino Alano keeps up a brisk pace as he strides through the forest on the way to the Armadillo's Den – a spectacular cave in southern Brazil. When he reaches the cave's opening, Alano is dwarfed by the size of the hole, which is big enough to accommodate a van.

Alano steps into the cave and enters a different world. The air is noticeably warmer and the cavern echoes loudly as Alano, who is a local guide, discusses the cave's history with Juliano Campos, an archaeologist at the University of the Extreme South of Santa Catarina (UNESC) in Criciúma, Brazil. According to local legend,

the Armadillo's Den – known as *Toca do Tatu* in Portuguese – was a hiding place where Jesuit missionaries stored gold centuries ago. But the real treasure is more ancient and strange.

Campos points to the ceiling of the cave, which is covered with deep grooves. He and other researchers suspect that the scars were carved by giant ground sloths that roamed the region until they went extinct more than 10,000 years ago. "This is an archaeological and palaeontological marvel," says Campos.

For generations, these structures have puzzled travellers and scientists, who have debated how they formed. Explorers in the early twentieth century attributed the spaces to ancient

Indigenous groups. But research in the past decade has coalesced around the theory that the caves were carved by extinct megafauna.

Palaeontologists have been amassing evidence to tease out which creatures were responsible and how they carved such huge burrows – the biggest known caves of their type in the world – from solid rock. But many questions remain about these enigmatic formations, says Campos.

## The vast desert

Researchers call these caves giant palaeoburrows and most are concentrated in Brazil, with a few in Argentina, says Heinrich Frank,

a retired geologist formerly at the Federal University of Rio Grande do Sul in Porto Alegre, Brazil. He founded the Palaeoburrows Project research group in the early 2000s to study these structures.

According to Francisco Buchmann, a palaeo-oceanographer at São Paulo State University in São Vicente, Brazil, the majority of the caves are found in a particular layer of sandstone called the Botucatu Formation. It dates to more than 100 million years ago, a time when the region was a large desert. “The Sahara is small compared to this one,” says Buchmann, who leads the Palaeoburrows Project with Frank.

Because of how those desert sands solidified, the Botucatu sandstone is soft enough to carve but not so soft that it falls apart too easily, says Maria Carolina Villaça Gomes, a physical geographer at the State University of Rio de Janeiro in Brazil.

Inside the Armadillo’s Den, the rock is covered with modern graffiti, which researchers can spot because its edges are much crisper than those of the inscriptions made by ancient human residents. Alano points to a zig-zag carving on the wall. “This line puzzled many explorers who came here in the past,” he says. “But what it most certainly shows is an ancient map of the Rocinha River that flows nearby,” because it depicts specific bends seen in the nearby canyons. “Past Indigenous groups could have used it to orient themselves in the region,” says Alano, a descendant of one of the Indigenous groups that could have left the inscription.

Just a few metres beyond the zig-zag line, the cave presents evidence of even older residents. The large scratches on the walls and ceiling have stunned palaeontologists and other scientists from across South America.

Frank and Buchmann were part of the first group to describe the Armadillo’s Den, and suggested in 2012 that it was carved by ancient megafauna<sup>1</sup>. It is an example of what palaeontologists refer to as an ichnofossil: tracks, tunnels and other marks left by ancient organisms.

## Gone with a trace

The South American palaeoburrows might be the largest ichnofossils known so far, says Luis Buatois, an ichnologist at the University of Saskatchewan in Saskatoon, Canada.

In the field of ichnology, researchers assign genus and species names to specific ichnofossils. In a study of these caves, Buchmann, Frank and their colleagues divided the South American palaeoburrows into two types: *Megaichnus minor* and *Megaichnus major*<sup>2</sup>. The *M. minor* type includes tunnels with openings measuring 0.6–1.5 metres wide by 0.5–0.9 metres high, and a maximum length of 30 metres. The *M. major* type is massive: more than 2 m high by 4 m wide, with a length that can exceed 50 m.

The longest described so far is in Pará state in the Amazon region, with combined

internal galleries some 1,500 metres long, says Buchmann.

According to Frank, there are between 1,500 and 2,000 of these structures in South America, but none on other continents, which baffles scientists. Caves of the *M. major* type have so far been found only in Brazil. Just a few of each type of cave have been described in detail, and they are hard to find because most – about 70% of the *M. major* ones – are filled with rubble. “We often find them when a company is doing some earth-moving work for construction,” Frank says.

Knowledge of these caves goes back more than a century, and researchers have long thought the giant palaeoburrows were archaeological structures left by people. But in 2001, Sergio Vizcaíno, head of the vertebrate palaeontology department at the La Plata Museum in Argentina and his colleagues proposed that the large palaeoburrows that have claw-like markings on the walls and roof could have been excavated by ground sloths belonging to the extinct genera *Scelidotherium* and *Glossotherium*<sup>3</sup>. The scratches are a match for these animals’ claws, he and his colleagues argued.

One species, *Glossotherium robustum*, a South American sloth that lived between 4 million and 12,500 years ago, reached more than 3 metres in length and weighed up to 1,500 kilograms. A smaller species of sloth, *Scelidotherium leptcephalum*, inhabited South America between about 800,000 and 11,000 years ago. It is thought to have been about one metre long, weighing up to one tonne.

According to Richard Fariña, a palaeontologist at the University of the Republic Uruguay in Montevideo, the anatomy of these large ancient sloths suggests that they were efficient diggers.

Despite their size and strength, individual animals might not have carved each burrow, says Vizcaíno. He suggests that the caves might instead have been the work of several animals over time. “Palaeoburrows must be transgenerational, as the energy cost decreases when the work is done by many individuals,” he says.

Why these animals would dig such large, long burrows is not clear, however. Néstor Toledo, a comparative anatomist at the La Plata Museum argues that giant prehistoric armadillos might have carved the smaller burrows to hide from predators, and giant sloths “could have started digging to protect themselves from a colder and drier climate” during ice ages. Ground sloths might also have used the caves to hide offspring from predators.

But the idea that the caves served as protection from other animals does not appeal to Cástor Cartelle, a palaeontologist and curator of the archaeology collection at the PUC Minas Museum of Natural Sciences in Belo Horizonte, Brazil. To him, these animals’ offspring had nothing to fear. “Why would an animal this size need refuge?” he asks.

Instead, Cartelle says the scratches suggest

that ground sloths could have taken advantage of naturally existing caves to sharpen their claws. “The markings on the walls match the number of fingers and the anatomy of these animals – but it really makes no sense to me in saying they have carved these burrows.”

## Shortage of scientists

Researchers say it will be hard to find definitive answers. One problem is that there isn’t much available information on the structures, says Arthur Philippe Bechtel, a geographer at the Federal University of Santa Catarina in Florianópolis, Brazil. “We don’t have many measurements” of their rock types and environment, he says. There is also a lack of standardized data – on the burrows’ external appearance, conservation state and morphology, for example – which makes analysis difficult, he says.

Last year, Bechtel and Gomes co-authored a study that aimed to refine palaeoburrow classifications<sup>4</sup>. They highlighted particular elements that appear often in descriptions of the caves and proposed a checklist of items “so that we can build a more solid and standardized database for the future,” says Gomes.

One challenge that most researchers agree on is the need for wider knowledge of these structures – especially in the absence of specific legislation to protect them.

Another issue is attracting researchers to the field. “This is not an area of palaeontology that yields mind-boggling studies in the short term,” says João Henrique Ricetti, a palaeontologist at Contestado University in Mafra, Brazil, and a co-author of the study with Bechtel and Gomes.

There are also concerns over conservation of the giant palaeoburrows. The Armadillo’s Den, deemed one of the best preserved of these structures in Brazil, is filled with graffiti, including love vows, people’s names and dates, which compete for space with the ancient claw marks and Indigenous inscriptions.

Although they are little known outside South America, the palaeoburrows deserve much more attention, say the researchers who study them. “These structures are spectacular enough to gain attention from scientists in other parts of the world,” says Buatois.

Alano agrees. He has taken several researchers to the Armadillo’s Den, but most come from nearby institutions. “The more diverse people come to study the place, the more knowledge we’ll have about it,” says Alano. “Who knows what they’ll find in the future?”

**Meghie Rodrigues** is a freelance reporter in Paraná, Brazil.

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