Archaeologists found hundreds of mammoth skeletons during the 3-year construction of the new Felipe Ángeles International Airport north of Mexico City.

BONES BENEATH THE RUNWAY

How a military megaproject led to Mexico's biggest paleontological discovery—and is reshaping what we know about mammoths

RODRIGO PÉREZ ORTEGA, in Mexico City

PHOTO: RICARDO FLORES/XINHUA VIA ZUMA

The story of Mexico's biggest fossil discovery begins with politics, not science. During his campaign for the country's presidency in 2017, Andrés Manuel López Obrador pledged to scrap a half-built new airport in eastern Mexico City, citing cost overruns and corruption over the course of its construction. Once in office, he replaced it with an alternative plan: to build the Felipe Ángeles International Airport at a military base in Santa Lucía, 50 kilometers north of the capital. In October 2019, the army began to dig.

Massive bones appeared almost immediately.

The first mammoth emerged on 5 November. Then another. And another. Within weeks, the six archaeologists who had been called in had swelled to 56, supervising more than 400 construction workers. Excavators paused whenever bone fragments surfaced. To meet construction deadlines, several excavation areas were opened simultaneously across the site. "We were overwhelmed because every day we were finding them—every day, every day, every day," recalls Rubén Manzanilla López, an archaeologist with the country's National Institute of Anthropology and History (INAH) who supervised the salvage excavation, which was supported by the Mexican military.

By 2022, Manzanilla López and his team had amassed more than 50,000 Pleistocene bones from just 3700 hectares. Among them are at least 500 mammoths, 200 camels, 70 horses, 15 giant ground sloths, as well as the remains of dire wolves, saber-toothed cats, bison, armadillos, birds, freshwater snails—and one human skeleton. Nicknamed Yotzin ("unique" in Nahuatl), the man may have died during a hunt or been trampled by a mammoth. The scale of the discovery rivals—and in some ways surpasses—California's La Brea Tar Pits, the most famous ice age fossil site in North America.

It is also bringing a once-obscure population of tropical mammoths into the light. In the popular imagination, mammoths are cold-adapted furry giants plodding across the frozen tundra. And indeed, most mammoth fossils are found in high-latitude landscapes such as Siberia, Alaska, or Canada. Yet one species, the Columbian mammoth (*Mammuthus columbi*), ranged as far south as Costa Rica. Little was known about these peculiar southern populations and how they relate to their more numerous northerly relatives.

The Santa Lucía mammoths, trapped not in tar like the La Brea fauna, but in the shallows of an ancient lake, are now filling in the picture of the species. From the bones, Mexican scientists have recovered the first-ever DNA from tropical mammoths, gleaning new insights into the beasts' evolutionary history.

"If you had told me 5 years ago that I would be collecting these samples, I would have said, 'You're crazy,'" says the scientist who led the DNA analysis, Federico Sánchez Quinto, a paleogenomicist at the International Laboratory for Human Genome Research of the National Autonomous University of Mexico (UNAM).

In a paper published online in *Science* this week, Sánchez Quinto and his team depict the Santa Lucía mammoths as a previously unknown lineage that split from northern Columbian mammoths hundreds of thousands of years ago; they also shed light on how these animals fared before ultimately dying out. The findings open a new, more complex chapter in mammoths' evolutionary story, says Adrian Lister, a paleobiologist at the Natural History Museum in London who was not involved in the research. "This paper really is an exciting beginning of something."

MAMMOTHS HAVE an evolutionary history as complex as the lands they once crossed. The massive, tusked herbivores evolved from ancient African ancestors about 6 million years ago and migrated across Eurasia starting about 3 million years ago. The woolly mammoth (*M. primigenius*), adapted to cold climes, emerged in Siberia and crossed into North America. Columbian mammoths—larger and less hairy—appeared later in North America and spread south into Central America.

In 2021, Love Dalén, a paleogenomicist at the Centre for Palaeogenetics in Sweden, and his colleagues sequenced the genomes of three mammoths from Siberia and compared them with previously sequenced genomes of other mammoths. They found evidence that Columbian mammoths were hybrids. Dalén's team argued they emerged when descendants of a 1-million-year-old male steppe mammoth (*M. trogontherii*)—a Siberian species found in the Krestovka locality—mated with female woolly mammoths. This hybridization event, Dalén and his colleagues hypothesized, happened at least once in the early Middle Pleistocene, about 800,000 to 400,000 years ago. But the subsequent evolutionary history of the Columbian mammoths remained cloudy.

Like all Mexicans, Sánchez Quinto had heard the news of the mammoth trove at Santa Lucía. Trained in Europe, he had just returned to Mexico to set up a lab. His expertise was in human paleogenomics, but the chance to work on mammoths—especially on ones from such an unusual setting—was irresistible.

The noisy, dusty excavations were nothing like the hushed genetics labs Sánchez Quinto was used to. "It was an apocalyptic scene," he recalls. The combination of multiple open excavation areas, heavy machinery, and the sprawling footprint of the airport meant archaeologists were often rushing from one find to another. In many cases, mammoth skulls were quickly cataloged and stabilized with wooden structures. Tusks especially, softened by millennia of exposure to water and minerals, crumbled easily because they weren't fully fossilized.

> "Every day we were finding them—every day, every day, every day."
>
> **Rubén Manzanilla López**
> National Institute of Anthropology and History

"We tried to save as much as we could," says Joaquín Arroyo Cabrales, a paleontologist and mammoth expert with INAH who was leading a simultaneous research project at the site. At one point, bones filled a whole hangar. Researchers also took samples from soil and from fossils of small animals—axolotls, frogs, rabbits, and even flamingos—to figure out everything from the chemistry of the ancient lake to the ecosystem the mammoths were part of. So far, there are five ongoing research projects.

One is Sánchez Quinto's. With permission from Arroyo Cabrales,

he and his team set up a sterile tent in a military barracks to drill into 73 massive teeth—each the size of a shoebox—in hopes of finding ancient DNA. Although several mammoths had been found around the Basin of Mexico since the 20th century, nobody had extracted enough DNA from them in good enough condition to be analyzed.

Recovering DNA from fossils in the tropics is notoriously difficult: Heat and humidity break down the molecules far faster than in the frozen north. But the inner dentine of the molars from the Santa Lucía mammoths had preserved their genetic history. Still, Sánchez Quinto feared too little nuclear DNA had survived to be studied, and he decided to focus on mitochondrial DNA (mtDNA), inherited only from the mother. Although mtDNA carries less information than nuclear DNA, it is simpler, shorter, and far more abundant.

Sánchez Quinto remembers the moment he first saw the genetic results from the Santa Lucía molars. "My heart skipped a beat," he says. "I literally lost my breath." He and his team succeeded in sequencing 61 complete mitochondrial genomes, more than doubling the global total for Columbian mammoths.

"It's impressive from Federico's team to get mitochondrial genomes out of so many mammoths from such a low latitude and such an old age," Dalén says. "It's a tour de force."

In the new *Science* paper, Sánchez Quinto and his colleagues draw conclusions from the DNA about the evolution of both the Columbian mammoths and the population that once roamed the Basin of Mexico. They find the Mexican mammoths are genetically distant from Columbian mammoths from Canada and the United States—the tropical giants formed an entirely separate branch even further removed from woolly mammoths from North America and Eurasia.

Genetic dating suggests this lineage diverged from northern populations between 400,000 and 300,000 years ago and then persisted in isolation, becoming so distinctive that Lister asks, "Should we really be calling it a Columbian mammoth? [Or] give it a new name—a Mexican mammoth?"

Within the Mexican lineage, the researchers identified three distinct sublineages, suggesting each experienced long periods of isolation in the grassy highlands of the Basin of Mexico. Volcanic ranges may have acted as natural enclosures, sequestering these groups into genetic clusters.

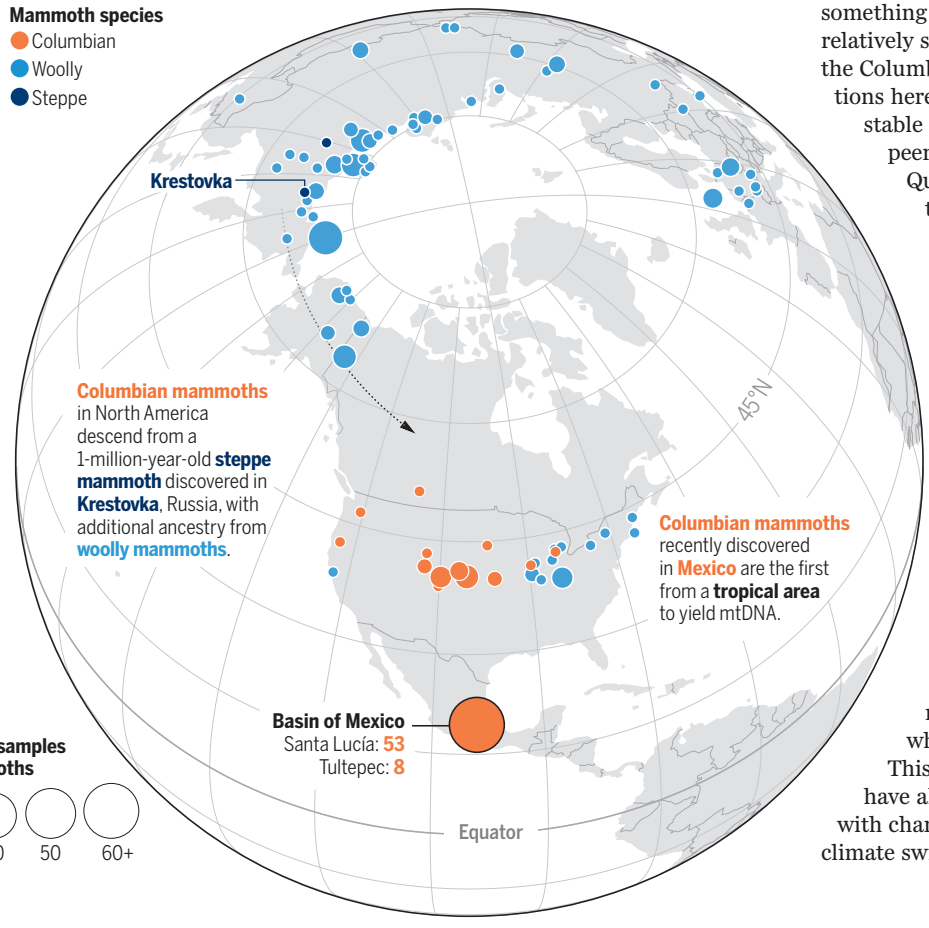
Because the Mexican lineage is substantially different from the ones in Canada and the U.S., the researchers suggest hybridization events between woolly and steppe mammoths happened more than once around the same time, producing multiple Columbian mammoth lineages that spread across the continent.

The Mexican mammoths are "not just a little offshoot" of the larger northern population, Dalén says. "Rather, [they] have hundreds of thousands of years of history in Mexico. It's a proud lineage."

RADIOCARBON DATING of five samples puts the Santa Lucía mammoths at between 16,000 and 11,000 years old. At the younger end of that range, other mammoths in North America were in serious decline because of shifting climates, human hunting pressures, or some combination thereof. Yet the genetic data from Santa Lucía suggested something unusual: Despite having relatively small population sizes, the Columbian mammoth populations here appear to have remained stable even as their northerly peers died off. Sánchez Quinto cautions, however, that this remains to be confirmed with evidence from younger samples. Environment and diet may explain that stability. In 2023, another group of Mexican researchers analyzed carbon isotopes—which contain clues to an animal's diet—in mammoth teeth from Santa Lucía. They found the mammoths ate a mix of shrubs, trees, and grasses, unlike woolly mammoths farther north, which ate mainly grasses. This dietary flexibility would have allowed them to cope with changes in vegetation amid climate swings.

Stomping grounds

Different species of mammoths lived throughout much of Eurasia and North America from 3 million to about 4000 years ago. Mammoths from cold, northern latitudes have yielded most of the genetic material analyzed so far, but Mexican researchers recovered mitochondrial DNA (mtDNA) from a mammoth population near what is now Mexico City. DNA comparisons are shedding light on mammoth family history.



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Bones found over 3 years of excavation near Mexico City overwhelmed multiple storage spaces and were eventually moved to a giant warehouse.

PHOTO: MARIA AVILA-ARCOS

Still, their low population numbers may have eventually caught up with them.

Silvia González, a geoarchaeologist at Liverpool John Moores University, had previously suspected Mexican mammoths suffered from low genetic diversity. Nearby, at a site called Tocuila, she had seen deformed molars and skeletal anomalies—signs of inbreeding. "It's clear that this is a terminal population," she says.

Ultimately, the Mexican mammoths vanished about 11,000 years ago, alongside much of North America's megafauna. Whether climate change, human hunting, or both sealed their fate remains uncertain, Sánchez Quinto says.

THE ROAR OF jet engines now fills the air where the mammoths once grazed. Political attention faded and military funding for research dried up once the airport was completed in 2022. But while the army was still flush with construction money, it built a paleontological museum at Santa Lucía, as well as a research center and a storage facility—both donated to INAH to study and store the fossils. In February 2022, the Quinametzin Museum opened, named after the Nahuatl word for "giant." In its main hall, a mounted female mammoth skeleton named Nochipa ("eternal" in Nahuatl) towers over visitors. The museum displays a fraction of the site's richness: skulls of different species, and vertebrae stacked like prehistoric beads. Interactive exhibits explain the excavation process and the late Pleistocene ecosystem of the Basin of Mexico.

Just a few meters away, INAH paleontologist Felisa Aguilar Arellano leads a small team that safekeeps a huge, climate-controlled storage facility full of fossils. Packaged bones or various sizes fill endless racks. Between them, mammoth skulls—some with their tusks still attached—are cradled in yellowish foam and wrapped in plastic. It's impossible to move through the fossil riches. Aguilar Arellano says the facility contains only 40% of the total collection. The rest is stored elsewhere on the base.

Tens of thousands of bones remain unstudied. Scientists are now seeking grants and forging collaborations, including with researchers at the La Brea Tar Pits, to date key specimens and refine extinction timelines, Aguilar Arellano says. Sánchez Quinto, for his part, says his team now aims to isolate the nuclear DNA from several mammoths, hoping to sharpen their picture of the animals' ancestry.

Aguilar Arellano hopes the collection spurs a shift in Mexico, where archaeology has long overshadowed paleontology. "I believe that the paleontological [potential] … continues to be neglected," she says. Sánchez Quinto is already witnessing such shift—his project has inspired graduate students to study mammoth genetics and Pleistocene ecosystems. "The knowledge generated here has a local impact and contributes to forming new lines of research, and training tomorrow's scientists."

María Ávila Árcos, a human population geneticist at UNAM who led the sequencing with Sánchez Quinto, takes an even broader view. "For me, the message that I'm left with is beyond just the history of mammoths. By studying these underrepresented places, it opens up your perspective a lot about the history of a species." □