Metropolitan Mammoth

One fossil's journey from riverbed to museum exhibit (view PDF)

by Nick Pyenson

One July Saturday in 2005, Roger Castillo took a walk with his dog along the flood channel of the Guadalupe River, just north of the San Jose Airport. After monitoring the river's watershed as a volunteer for the Guadalupe-Coyote Resource Conservation District for many years, Castillo, a truck mechanic, had developed the eye of a naturalist. He knew that the objects poking out of the sandy clays of the levee that day were clearly unusual. They looked mostly like the odd, cobble-sized rocks found in stream beds around the Bay Area, but their cylindrical shapes were a little peculiar. Castillo had discovered the eroding tusks and skeleton of a mammoth.

The word "mammoth" evokes iconic images of the Ice Ages. People tend to imagine an enormous elephantine animal, covered in long, shaggy orange fur, trumpeting on the steppe. Mammoths, however, were much more widespread and diverse than pop culture implies. They lived in North America, Europe, and Asia until they went extinct about 10,000 years ago, and woolly mammoths evolved in the tundra steppe ecosystem from ancestors that lived in more temperate and tropical climates. All of the mammoths in North America belonged to one genus, Mammuthus, which descended from mammoths that migrated from Africa to Asia, and then across the Bering Sea land bridge to North America. Castillo had discovered the bones of a Columbian mammoth, Mammuthus columbi, which inhabited the grasslands of what is now the western United States during the Pleistocene epoch.

Fossil discoveries aren't always as serendipitous as Castillo's. Paleontologists usually find fossils because they look in the right places, or, more precisely, at the right kinds of sedimentary rocks. Studying the geological record reveals the kind of environment the rocks represent, and therefore which layers likely hold the remains of dead organisms. Researchers also rely on previous workers' descriptions of known fossil-rich spots. Other times, paleontologists explore a place for the first time with no expectations. And often it's not paleontologists who make the discovery but members of the public. Amateur fossil finds can be made after years of diligently combing cliff faces following seasonal erosion, or they can simply be spotted by an observant hiker. Either way, amateur paleontologists play the same role that amateur astronomers do; non-professionals have just as much of a chance at making the big, textbook-changing discoveries.

Castillo knew that his find was important, and he quickly contacted the property owners, the Santa Clara Valley Water District (SCVWD), as well as paleontologists at Bay Area universities. Mark Goodwin, assistant director of the University of California Museum of Paleontology (UCMP), received Castillo's call and came to investigate the site. Goodwin identified the bones exposed on the surface, which included two tusks, a leg bone, and parts of what appeared to be the shoulder or pelvis. The tusks were broken and their cross-sections revealed concentric rings characteristic of mammalian growth patterns. Overall, the bones were in good shape and had only been recently exposed to the elements. Because of their size and structure, Goodwin knew that the bones belonged to a mammoth or a mastodon (a near relative of mammoths that lived in wooded parklands instead of grasslands), and he decided that enough remained below the surface to merit a full-scale excavation.

Digging up the past

Discovering fossils can be exciting, but paleontologists must work cautiously as they preserve any exposed specimens. Quickly moving about an area with fossils may inadvertently destroy or obscure associated remains, and thus lose valuable information. One of the biggest concerns with the San Jose mammoth was the prevention of illegal collecting, vandalism, or accidental disruption of the discovery site, so both volunteers and security guards hired by the SCVWD cordoned off the site.

Goodwin and several graduate students excavated the site over the weeks following the discovery (full disclosure: the author was a member of the excavation crew). The number of people participating in any dig depends on the location and size of the quarry as well as the number and type of fossils being recovered. For

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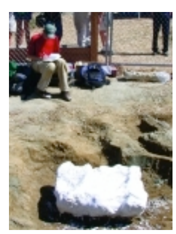
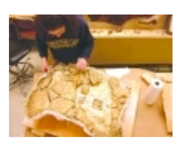
Photos by Mark Goodwin and Jane Mason

Illustration by Carl Buell





excavations that involve large animals, like dinosaurs or mammoths, field crews can number in the dozens. Given the location of some quarries—accessible sometimes only by walking trails—organizing that many people can be quite a challenge. Add the necessity of supplying crews with food, tents and equipment, and field paleontology can seem like a military campaign.

Urban paleontology, however, is a different story. "It was really great to be able to drive right up to the study site. We'd drive within 100 feet of the gated-in area and we only had to carry our materials a short way. It was much nicer than other places I'd done work in that way," says Jenny McGuire, a graduate student in the department of integrative biology (IB). She and Randall Irmis, another graduate student in IB, began the excavation by taking careful field notes and photographs. "Field notes form the basis of your knowledge for any site," says Irmis. "The main idea is that you want your field notes to be able to explain to someone who's never seen the site exactly where you were, what you saw, and what you collected. Months or even years may pass before others review what you did. And you may not have the luxury to go back to the field, especially if it's in another country."

The discovery of a mammoth just miles from the San Jose airport generated so much regional media attention that the mammoth earned the nickname "Lupe", after the Guadalupe River floodplain on which its fossils were found (although it's not clear from the available evidence if Lupe was male or female). Interestingly, Lupe wasn't the first mammoth found in the Bay Area. Since the early 20th century, paleontologists from UC Berkeley, the US Geological Survey in Menlo Park, and the California Academy of Sciences have discovered fragments of Pleistocene-era vertebrates from numerous Bay Area locations, especially on the San Francisco peninsula. Lupe is unique, however, because pieces of the skeleton were all found together, unlike previous finds that have been limited to a bit of tooth or vertebra.

Finding fossils is only half the job, and does not answer the larger questions of how the organism proceeded from its death, dismemberment, scavenging and burial, to becoming a fossil poking out of the ground. For paleontologists, understanding the whole sweep of processes that begins at death and ends at discovery of any fossil is an integral part of reconstructing its past life. In Lupe's case, this meant not only carefully excavating, but also painstakingly recording details of preservation and the precise position, orientation and condition of each bone in the excavator's field notes. Researchers also describe and record the surrounding sediments that entomb the bones—features like the color, texture, orientation, and grain size of the sediments reflect the environment in which the bones were deposited. Once under controlled laboratory conditions, detailed examination of the bones may reveal damage from trampling, exposure to the elements, or scavenging animals.

Once paleontologists assess the excavation site and thoroughly document what's exposed, the messier task of digging begins. In this aspect, paleontology in the 21st century is much like it was in the 19th century: swinging pick axes, shoveling loose rock, and lots of hammers hitting chisels. But amidst the din of tools clamoring, there can still be some order. Paleontology borrows methods from allied fields, like archaeology, including the use of grids, usually built out of yards of string held taut by poles placed at specific intervals. New bones discovered during the quarrying can be mapped and photographed with high precision; video and even GPS instruments are part of the tool kit for a modern paleontologist.

When large bones are exposed, paleontologists may decide to build a plaster field jacket around the block of bone and rock to safely transport the whole section back to the lab for more careful preparation. During the excavation of Lupe, field jackets were built for the pelvis, skull, tibia, and rib cage. Field jackets can be as small as a bowl or as large as a grand piano, depending on the fossils encapsulated. Preparing a field jacket starts with digging a trench around the bone. Eventually, the fossil is undercut to the point where it is supported by a pedestal of sediment, and then the top surface is encased in wet toilet paper followed by a layer of burlap dipped in plaster. As the plaster dries, it forms a hard jacket around the fossil. The jacket is then broken off its pedestal by a strong whack from a hammer and chisel, or, for larger jackets, pried loose by one or more crowbars. The resultant field jacket looks something like an oblong onion, with a bit of dirt peeking out the top. Details like the direction of magnetic north and which side is up are usually written in indelible marker on the jacket along with an alphanumeric code of field numbers that corresponds to a set of field notes.

For the largest plaster jackets, sometimes only construction equipment will do the trick. When readily available (and when site access allows), front-end loaders can pick up jackets too heavy to be moved by hand. In Montana, UCMP scientists have even used helicopters provided by Jack Horner and the Museum of the Rockies to return fossil samples from quarries that were otherwise inaccessible to vehicles. Sometimes paleontologists aren't nearly that lucky and have to improvise with two-by-fours and brute strength. In Lupe's case, the SCVWD provided a boom truck to hoist the plaster jackets from the site into vehicles that later transported them to the UCMP.

Removing the jacket
Once back in Berkeley, the plaster jackets of mammoth bones were unloaded at the Valley Life Sciences Building and hefted to their next destination, the UCMP fossil preparation laboratory, where fossils arriving from the field are unlocked from the surrounding rock. Preparation is equal parts science and art. For Jane Mason, UCMP senior preparator, this blend isn't such a stretch with her fine art degree. "Fossils in rock matrix are like statues locked in marble, and so you need an appreciation of anatomy and material properties to know how to bring fossils out of the matrix. It's not like scrubbing the dishes—sometimes you need to work delicately grain by grain." Mason explains how she deals with large tasks, like when field crews bring back a mammoth: "Every fossil that comes into the lab has its own unique needs and features. When I first get a field jacket, my first task is to develop a strategy based on careful observations: which side of the jacket do I open first? Is there a good side or a bad side? I study the jacket and the field notes associated with it to know exactly what I'm getting into before I start."

Beyond removing the jacket, different kinds of rock and preservation methods require different preparation strategies. "Sometimes fossils can be encased in rock that's as hard as concrete and regular mechanical preparation won't work. Then, we usually turn to solvents and acids to slowly dissolve the rock around the fossil," says Mason. Luckily, Lupe was preserved in soft, sandy clays that hadn't yet turned to rock, so Mason was able to prepare the mammoth using standard tools like dental picks, razor blades, and soft brushes.

As with many fossils, Lupe's secrets were revealed bit by bit. Currently there's no way to determine if Lupe was male or female, but it was likely an immature animal when it died because the growth plates of its long bones had not yet fully fused. Further evidence came from careful preparation of the skull, which revealed erupting molars—the telltale sign of a sub-adult. Additionally, the quarry has yielded more than a single mammoth because more than one arm bone from the same side was recovered from the site.

Finally, since mammoths are known to have gone extinct 10,000 years ago, Lupe's presence makes the age of the sediments of the Guadalupe River much older than previously thought. It will take more sophisticated methods such as stable isotope or carbon dating to determine the exact age. Much of the science is in progress—it's not unusual for comprehensive research on even a few fossil specimens to take decades until it's published.

A cabinet of one's own
When all of the preparation is done, museum specimens get unique catalog numbers inked on them and are placed in storage. Most fossils in the UCMP fit easily in small boxes that can be neatly arranged in drawers and cabinets according to geographic location and geologic time period. Microscopic foraminifera (protists) and mammal teeth can be mounted on slides or in vials so that they won't get lost in a drawer. Larger specimens, like a mammoth skull, pose a more serious problem. Pat Holroyd, UCMP museum scientist, explains, "We're always excited to receive new accessions, but space is always at a premium. Ideally, we would like to curate everything that's donated to the museum, but in practice we need to be selective about what kind of material it is, the quality of information about where it was found, and whether it needs special curation or preparation." Some of the cabinets in the UCMP's collections have been specially designed to store so-called oversize specimens—dinosaurs, whales, or mammoths—and there's additional storage space at two off-campus facilities in Berkeley. Lupe probably would have been relegated to one of these two sites if it weren't for the unique circumstances of its discovery.

Because the UCMP is an accredited federal and state repository for paleontological resources, it has the means to properly care for fossils that are found fortuitously, like Lupe. However, Lupe has generated a massive amount of public interest, especially locally in the South Bay, where it was found. As a result of this enthusiasm, the UCMP has paired its public outreach program—which has a strong presence in local, regional, and even international education—with the Children's Discovery Museum (CDM) of San Jose to create an exhibition highlighting Lupe's discovery and excavation. Instead of being stored away from public view, Lupe will be on loan to the CDM in an exhibition focusing on how paleontologists use evidence to reconstruct stories from the past. The CDM exhibit, scheduled to open in San Jose in 2009, will be aimed primarily at elementary school children. It will be the first of its kind geared specifically to that age group to feature a single specimen like Lupe, according to Marilee Jennings, Associate Director and Director of Development at CDM.

From its initial discovery by a sharp-eyed citizen to its future role in inspiring the next generation of paleontologists, Lupe's story highlights the hard work and careful forethought required to bring fossil finds to public light. Lupe, however, is just one example of all of the steps involved in paleontology. When you consider all the hours spent bringing a single bone from the field to the museum, it becomes apparent that the UCMP fossils represent thousands of hours of labor. Museums of

paleontology are veritable archives of past biodiversity, and as we begin to acknowledge the human hand in our current biodiversity crises, we can look to fossils like Lupe as a tangible reminder of the reality of extinction.
Nick Pyenson is a graduate student in integrative biology.

Want to know more? Check out:
www.ucmp.berkeley.edu/mammal/mammoth/

A brief history of mammoths
The closest living relatives of mammoths are the Asian and African elephant, but a myriad of extinct branches fall between these lineages. The oldest known mammoths lived about 3 million years ago in Africa and later migrated to Asia. North American mammoths evolved from Eurasian mammoths (Mammuthus meridionalis) that lived about 300,000 years ago, and whose descendents crossed the Bering land bridge to the Americas. By the end of the last ice age, around 11,000 years ago, mammoths had evolved into three different species of mammoths that lived on the mainland of North America: the woolly mammoth (M. primigenius), Jefferson's mammoth (M. jeffersonii), and the Columbian mammoth (M. columbi)—Lupe is a member of the latter group. Adult Columbian mammoths reached as much as 12 feet high at the shoulder and likely weighed between six to eight tons, slightly larger than the living African elephant. Columbian mammoths are well known from the western states of the US, especially from sites like the La Brea tar pits in Los Angeles.

Not all mammoths were large, however. During the Pleistocene, sea levels rose and fell many times, allowing terrestrial animals like elephants to reach formerly remote islands (although elephants are excellent swimmers and would likely have reached most islands anyway). Many different species of elephants (including those of the genus Mammuthus) evolved into dwarf forms, some no larger than a pony. The remains of these pygmy elephants have been found on islands in the Mediterranean Sea, East Asia, Wrangel Island north of Siberia, and the Channel Islands in southern California. Island dwarfing is a phenomenon that has happened repeatedly to large mammals confined to islands.

When Lupe lived, during the Pleistocene epoch, the Bay Area was a far different place (there was no San Francisco Bay), and the organisms that shared her environment were part of an ecosystem that we continue to live in, albeit without mammoths, dire wolves, giant sloths, and a host of other megafauna. Scientists continue to debate the causes and consequences of the extinction of Pleistocene megafauna. Many researchers have implicated the arrival, about 10,000 years ago, of an apex predator, Homo sapiens, in their demise. Others maintain that abrupt global climate change during glacial-interglacial cycling caused their extinction. Some paleoecologists, like UC Berkeley integrative biology professor Tony Barnosky, have proposed a one-two punch scenario, where human predation coupled with climate change proved too much for the survival of these lineages.

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