The Snowmastodon Project: Cutting-edge science on the blade of a bulldozer

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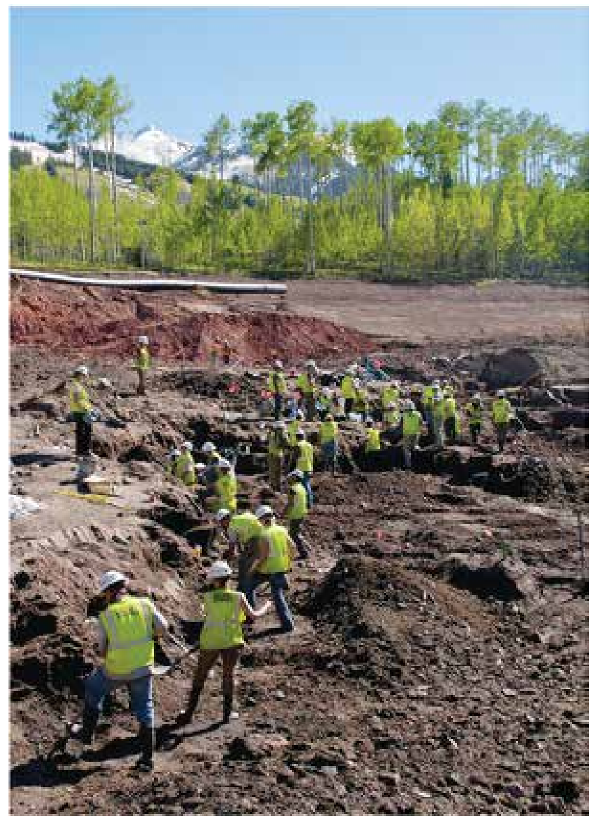

Figure 1. An army of scientists and volunteers removed ~8,000 cubic meters of sediment (all by hand!) from the Ziegler Reservoir fossil site near Snowmass Village, Colorado, USA, and recovered thousands of Pleistocene fossils.

FIRST A DISCOVERY, THEN DIGGING LIKE MAD

Scalpel. Knife. Shovel. A bulldozer's blade.

Cutting-edge science happens at a variety of scales, from the individual and intimate to the large-scale and collaborative. The publication of a special issue of *Quaternary Research* in Nov. 2014 dedicated to the scientific findings of the "Snowmastodon Project" highlights what can be done when natural history museums, governmental agencies, and academic institutions work toward a common goal.

On 14 Oct. 2010, a third-generation bulldozer driver named Jesse Steele was pushing dirt as part of a reservoir expansion project high in the Rocky Mountains at Ziegler Reservoir, just outside Snowmass Village, Colorado, USA. The reservoir was to be enlarged to meet the needs of a growing population and a local ski resort, and up until that point, the work was right on schedule. When Steele pushed up some strange bones along with the usual lake muds, however, it was apparent that everything was about to change.

The new owners of the site, the Snowmass Water and Sanitation District (SWSD) placed phone calls, first to the Colorado State Geological Survey and then to the Denver Museum of Nature & Science (DMNS). Within a day of the discovery, the DMNS had mobilized a group of scientists, including several geologists from the U.S. Geological Survey (USGS), to visit the site and determine if the find was an isolated occurrence or perhaps the beginning of something larger. As it turned out, the term "large" wasn't quite right. Huge, perhaps? Enormous? Epic? Maybe all of the above?

During a span of three weeks in the fall of 2010 and seven weeks in the spring of 2011, dozens of scientists from around the world joined more than 250 volunteers to recover a treasure-trove of late Pleistocene fossils that included American mastodon, Columbian mammoth, and other large megafauna and to study the site and its history. The excavations were conducted initially using a technique called "bladerunning," during which a scientist would walk alongside the blade of a bulldozer and ask the driver to a halt whenever evidence of a fossil popped up. When that happened, the bulldozer would move over a bit, the site would be flagged, and a team of volunteers would race over, dig like mad, and document the position and orientation of the fossil before removing it for transport offsite. The driver would then work in a different area with the bladerunner in tow until the site was cleared.

This delicate dance between construction and science proceeded amidst a climate of growing trust. On one hand, it was

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obvious to everyone that what was being uncovered at the site was truly remarkable and perhaps unprecedented. On the other hand, the construction crew had a very real deadline to meet. The question on everyone's mind was, "Can we really pull this off in time?"

After the furious schedule of the salvage operation in 2010, it was clear that site was vast and important. The bladerunning technique had to be abandoned in 2011 because there were simply too many fossils. An army of highly trained volunteers was brought in with the task of excavating dirt, rocks, and bones for eight hours a day, six days a week. The clank of metal shovels echoed through the subalpine forest day after day amidst project co-leader Kirk Johnson's imploring calls to "dig faster!" and an occasional cry of "bring me the head of Ziggy the sloth!" During the 2011 field season alone, the crew removed roughly 8,000 cubic meters of sediment, all by hand, and recovered more than 5,000 large bones and tens of thousands of smaller ones. On average, a large bone was pulled out of the ground about every five minutes for the entirety of the dig. The work was hard, no doubt, but the allure of discovery was a powerful force!

NEXT, A WOBBLE, AND THEN THE FINISH LINE

Each night, after meals prepared by yet another group of volunteers, the team would get together for a daily round of show-and-tell. It was a fun and light-hearted way to recount the day's finds, as well as to encourage and challenge each other as the days grew longer. One particular night, toward the end of the 2011 season, a visitor questioned the team about the long-term plans for the site. Until then, with so much work to be done before the impending deadline, little energy was directed at anything but moving the next pile of dirt. With the crowd perking up a bit, and the transfer of thought moving from the present to the future, he suggested that the site was of such scientific importance that the team should reconsider their agreement with SWSD and push for some sort of effort to preserve the site as an open-pit paleontological site where visitors could view the specimens laid out as they were discovered.

Intense debate, alternatives, and opinions were thrown about late into the night. The enlarged lake basin, which by then was nearly ten meters deep, was supposed to be filled with water in just a few short months. What lay before us was a pretty simple, but terrifying, conundrum: "Do we want a palace (park/museum) or a puddle (reservoir)?" Arguments went back and forth, with the idea of preserving the site gaining traction.

At that point, an observation was made. The site was incredible to be sure. And the preservation of the fossil material—including intact conifer cones and sedge leaves that remained green after nearly 100,000 years of burial, not to mention tusks that were so pristine that they reflected the image of the person holding them—were things that none of us had ever seen. But what was it about the site that allowed for such preservation over such a long period of time? Was it an open pit in the past? Obviously not—it was a lake. If we really wanted fossils that remained in the lake sediments to be preserved for future generations, what better way to do this than to return the site to its original condition? After still more debate, a final decision was made: We would return the site to its original condition and landowner intent, that is, a lake. Knowing they could make good on their promises, Kirk Johnson and project co-leader Ian Miller breathed sighs of relief and got back to work.

Remarkably, the SWSD had also been thinking about the long-term plans for the site as they neared completion of the dam. On their own initiative, the SWSD built a gravel road that extended down to the bottom of the lake basin. Their idea was that some time in the future, during summer months in years where the demand for water was low, the lake could be drained and a new round of excavations could take place. Thus, the delicate dance between science and construction had come full circle—from the uneasy wariness of the first few days after the initial discovery, to full cooperation and promises kept—and work at the site was complete.

AND FINALLY, ON TO THE FUTURE

Using a combination of dating techniques ranging from radiocarbon and cosmogenic surface-exposure dating to uranium series and optically stimulated luminescence, scientists ultimately determined that lake sediments at the site spanned 85,000 years, from ~140,000 to 55,000 years before present, including the end of Marine Oxygen Isotope Stage (MIS) 6, all of MIS 5 and MIS 4, and the earliest part of MIS 3. Importantly, the site provides the first opportunity to study ecosystem response to climate change during the Last Interglacial Period (MIS 5) at high elevation (~2705 m above sea level) in the Colorado Rockies.

Thus far, scientists have used a variety of environmental proxies, including pollen, plant macrofossils, tree rings, macro- and micro-vertebrates, and macro- and micro-invertebrates, as well as close examination of the stratigraphy, particle size distribution, and geochemistry of the lake sediments, to reconstruct changes in environmental conditions at the site over time. However, there are still tremendous opportunities for future work for those interested in studying aspects of the site that were not covered by the original studies. Vertebrate fossils are housed at the DMNS; pollen, plant macrofossils, and invertebrates (insects, chironomids, mollusks, and ostracodes) are stored at various academic institutions; and sediment cores that span the entire lake sequence are available for study through the USGS. It is our hope that the collaborative spirit of the Snowmastodon Project will inspire scientific studies for generations to come.

REFERENCE CITED

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