Palace tour. Video game technology lets researchers virtually stroll Nimrud's palace.

ARCHAEOLOGY

Virtual Archaeologists Recreate Parts of Ancient Worlds

Using techniques borrowed from the entertainment industry, more and more archaeologists are boosting their imaginations and insights with virtual worlds

Back in the late 1990s, archaeologist Sam Paley of the University at Buffalo in New York was frustrated in his study of the throne room of the 9th century B.C.E. Northwest Palace at Nimrud, the storied Assyrian capital in what is now Iraq. The room was embellished by paintings and bas reliefs aimed at impressing visitors, but the artwork and inscriptions were dispersed in bits and pieces in 60 museums around the globe, and Paley was having trouble picturing the layout. Then at a conference he heard a presentation by Donald Sanders, a leading proponent of using interactive 3D computer graphics in archaeology, and enlisted Sanders's help.

The pair spent many years getting photographs from museums and building a virtual 3D model. Finally, they were able to imagine and test detailed hypotheses about the throne room's layout. For example, had there been enough light to see the artwork in the presumed windowless room? Sanders assumed that the Assyrians used oil torches. Different oils produce light in different ranges of the spectrum, and certain types of light accentuate certain colors, so he simulated various types of oils in strategically situated torches. Sanders concluded that the torches could have been fueled by several types of fish oil and positioned to enhance the art so people could have seen it. Today, "you can walk in the palace of a virtual-reality model," says Paley. A 3D rendering of the model is now on display at the Metropolitan Museum of Art in New York City, and Sanders is at work on a reconstruction of the whole palace.

The throne room is a classic example of the growth of virtual archaeology, in which archaeologists use computers to recreate the environment and conditions of the past, including objects, buildings, and landscapes with human actors, such as ancient battles. The field is a natural evolution of archaeology in the digital age, says archaeologist Maurizio Forte of the University of California, Merced, who spent 3 years recreating the landscape of Rome in the second century C.E. And although virtual archaeology arose in the mid-1990s, it is only now going mainstream, as archaeologists realize the benefits of using computers to make the most of their necessarily incomplete data.

As costs go down, virtual archaeology "definitely is on the rise," says Sanders, with several hundred projects worldwide and plans for a new multimedia journal in the works. Sanders, who has his own company, Learning Sites Inc. in Williamstown, Massachusetts, argues that virtual worlds offer archaeologists the best way to "test complex spatial, behavioral, or temporal hypotheses."

Recreating the Four Corners

As the field continues to develop, a virtual expert "is now a standard member of the archaeological team" in many countries, says Bernard Frischer, an archaeologist and art historian at the University of Virginia, Charlottesville. Sanders says this is partly due to the decreasing cost of the tools of the virtual trade, such as laser scanners. (Sanders's projects cost anywhere from a few thousand to $100,000.) The field also gets a boost from the entertainment industry: The technology is the same as that used in video games and movie special effects, and many universities have recently added 3D modeling programs. "Once [universities] invest in the technology, they have to look for excuses to use it," says Sanders. Many recent archaeology grads are familiar with virtual techniques, although older archaeologists may not understand the technology as well, says Sanders, leading to "a digital divide."

Despite such frivolous roots, virtual experts are setting their sights on some of archaeology's thorniest scientific problems. For example, one of the enduring mysteries of American archaeology is why the Ancestral Puebloan peoples, or Anasazi, abandoned the Four Corners region of the Southwestern United States some 700 years ago, leaving striking cliff dwellings behind. Decades of study have yielded answers including conflict and climate change.

Researchers with the Village Ecodynamics Project (VEP), led by Tim Kohler of Washington State University, Pullman, and Ziad Kobti of the University of Windsor in Canada, took a different tack to solving the mystery: They virtually recreated a prehistoric world, including everything from landscape to climate to human behavior. They were intent on solving several puzzles, including a cycle of population growth and decline from 920 to 1280 C.E., by which time the Pueblo peoples had left the area. Using archaeological data for variables such as numbers of households, ethnographic data on behaviors such as food sharing, and tree ring and soil data for

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climate clues, the researchers meticulously recreated part of the Ancestral Puebloans homeland—an 1827-square-kilometer area in southwest Colorado.

Then they put 200 virtual Pueblo households on the landscape and let them respond to various real-life scenarios, choosing how much corn to grow, how many animals to kill, and so on; their work will be described in a forthcoming book from the University of California Press.

"A part of the simulation is looking at the economic structure of these societies," explains Mark Varien, a VEP archaeologist with Crow Canyon Archaeological Center in Dolores, Colorado. If a household couldn't grow enough corn to survive, the simulation shows how they might have coped, for example, by trading with another household or spending more time hunting game. The simulation is not 3D, but the team did put representations of "agents" onto a two-dimensional landscape. "Spatial relationships are really important," says Kohler, because location was key to determining how a household obtained food, water, and wood. Such simulations "let you look at the interaction between humans and their environment" in a way that traditional archaeology can't," says Varien.

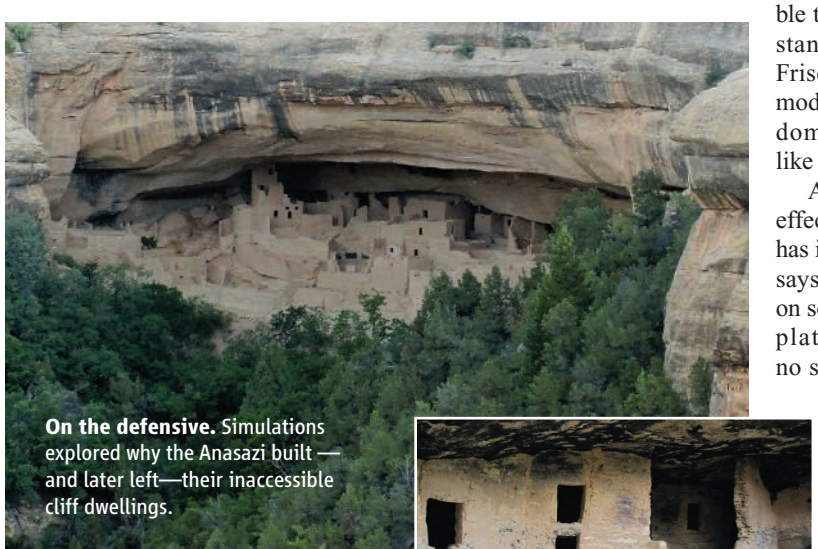
One key result: Households resorted to overhunting deer by 900 C.E. Regardless of the variables incorporated in the simulation, households begin "to seriously deplete deer populations" at that time, says Kohler.

The simulation also suggests, and archaeological evidence confirms, that turkeys were domesticated at about this time, perhaps because deer were scarce. Another notable result was extensive deforestation, which wasn't clearly seen in the archaeological record. "Without the simulation, you couldn't calculate the effect of people collecting wood every day," says Kohler.

Kohler believes that many small social units of the Ancestral Puebloans merged into a single large unit that was less-resilient. The production of maize, the primary food for both people and turkeys, declined sharply around 1270 C.E. due to changes in climate that included drought and cooler summers. This, along with conflict and environmental degradation, led to the exodus.

Around 1250 C.E., archaeological evidence suggests movement into defensible settings around springs; this is when the cliff dwellings of Mesa Verde National Park were built. The suggestion that the move "might have been due to competition or conflict is strengthened by the simulation results," says Kohler. The simulations expanded on the existing evidence, revealing details of the unfortunate tale of "lots of people, organized in a way that was highly tuned to competition, heavily dependent on just one resource, and having to cope with widespread violence," says Kohler. "Things fell apart."

The work is an innovative example of what simulations can achieve, says Thomas J. Baerwald of the National Science Foundation, who directs the program that funds VEP. By examining both human activities and the environment, the VEP team has helped reveal the relationship between them, Baerwald says.



On the defensive. Simulations explored why the Anasazi built — and later left—their inaccessible cliff dwellings.

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Traveling in time

In addition to recreating ancient buildings and cultures, virtual archaeologists can go back in time to test hypotheses. For example, many archaeologists believe that the Inka, who fashioned a vast empire during the 15th and 16th centuries in western South America, built large stone pillars to record the sun's location on the horizon during the solstices. Researchers posited that two Inka towers on the Island of the Sun in Lake Titicaca in Bolivia served as markers of the sun's position on the winter solstice at sunset (*Science*, 9 October 1998, p. 227). But other scholars speculated instead that the towers were used as tombs.

The solstice hypothesis could be empirically tested only during sunset on or near the June solstice, and the towers are only partially preserved, making verification difficult. So Frischer and colleague Chris Johanson of the University of California, Los Angeles, devised a virtual-empirical test that eliminates the constraints of time and space. They built a 3D model of the topography of the island and the sanctuary. Using astronomical data, they reconstructed the apparent course of the sun at sunset on dates surrounding the winter solstice in the year 1500 C.E. Their model confirmed the solstice hypothesis, Frischer and Johnson wrote in a book chapter last year, by showing that the "solar pillars would have been visible to the masses of devotees standing to the south," says Frischer. "Once we have the model, we can explore at random," he says. "We can be like time travelers."

Although it can be highly effective, virtual archaeology has its problems, too. Sanders says virtual models are built on so many different software platforms that "there are no standards," which makes viewing them difficult. Given how easy it is to manipulate a virtual model, there is also the matter of trusting its accuracy. He says researchers should make sure that viewers know the evidence and assumptions behind each model.

"Virtual archaeology's number-one problem is how to collect, peer-review, and publish all the 3D digital models that scientists are making in increasing numbers each year," Frischer says. "At the moment, very few of these models, which must number over 1000 by now, are available online. Most—after having been used once for a specific purpose—are sitting in storage on old CD-ROMs and hard disks."

Frischer hopes to remedy this problem next year by launching SAVE, a peer-reviewed online journal for virtual models, though he still needs more funds for the venture. He adds that it would be highly ironic if archaeologists, charged with recording and publishing on the world's cultural heritage, left no record of their own virtual work.

–MICHAEL BAWAYA

Michael Bawaya is the editor of *American Archaeology*.

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