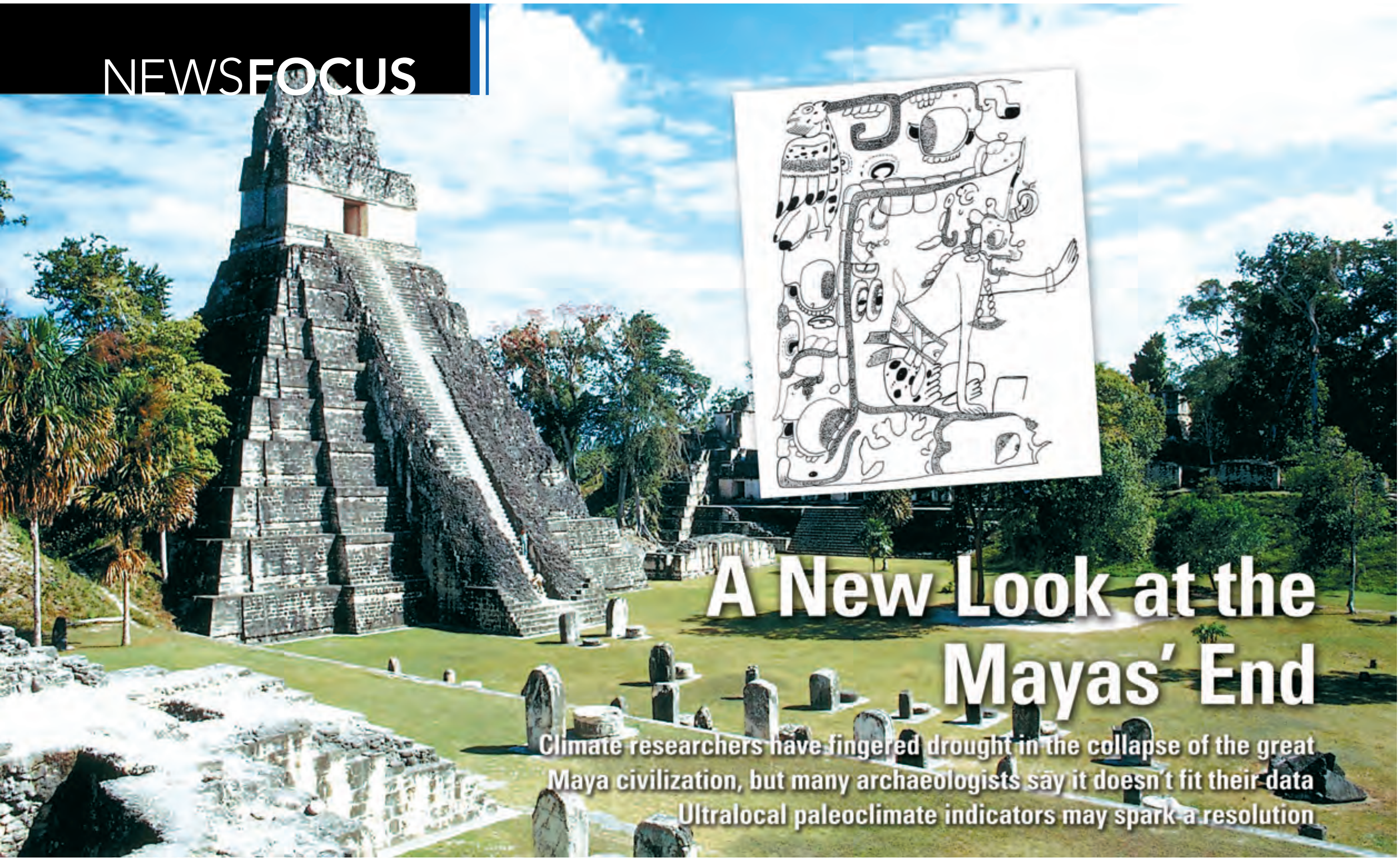


A New Look at the Mayas' End

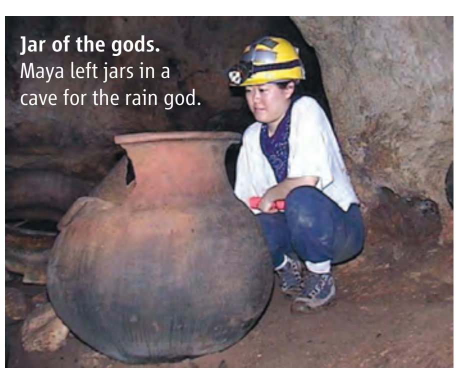
Climate researchers have fingered drought in the collapse of the great Maya civilization, but many archaeologists say it doesn't fit their data. Ultralocal paleoclimate indicators may spark a resolution

IN THE EARLY 8TH CENTURY C.E., THE MAYA city-state of Tikal eclipsed all rivals, becoming the most populous polity in the Americas. As many as 62,000 Maya nobles, artisans, and others squeezed into Tikal's crowded residential districts in what is now Guatemala; another 30,000 people, according to one estimate, toiled in verdant cornfields nearby. Tikal's divine kings ruled in splendor. They gleamed with jade jewels, commanded an army of artists and scribes, and presided over the construction of monumental causeways, temples, and pyramids.

During the century that followed, however, Tikal fell on hard times. Its building boom collapsed, its artists ceased to carve hieroglyphic inscriptions and paint murals, and its kings vanished. After 830 C.E., Tikal's population plummeted to just 15% to 20% of its peak. And Tikal was not alone. Elsewhere in the Maya world—a 324,000-square-kilometer area spanning southeastern Mexico and upper Central America (see map)—dozens of other city-states crumbled between 695 and 1050 C.E. The big question is why?

Archaeologists have proposed many theories, from peasant revolts to plagues and volcanic eruptions. But starting in the 1980s, many researchers focused on the role of climate. The idea gained traction in the 1990s, and today paleoclimatic indicators from lakes in the Yucatán Peninsula and the ocean floor off Venezuela suggest that a series of devastating droughts struck the Maya lands beginning in 760 C.E. The evidence for these climatic catastrophes "is overwhelming now," says Richardson Gill, an independent archaeologist based in San Antonio, Texas. "How could 95% of the cities in the Maya lowland, which relied on surface water reservoirs that had to be replenished annually, survive a 9-year drought?"

Many other Maya archaeologists, however, say the megadrought theory just doesn't fit their findings. Some Maya centers fell before the proposed droughts began, whereas others flourished even during the parched times. Several cities in the humid lowlands failed before those in drier regions did. The wide variation in space and time of the collapse has left many climate scientists and archaeologists at loggerheads. "The idea that people were dying in the Maya plazas from thirst is all very overblown and oversensationalized," says archaeologist David Webster of Pennsylvania State University (PSU), University Park.



Jar of the gods. Maya left jars in a cave for the rain god.

New studies, several of which are being presented at the Society for American Archaeology (SAA) meetings in Atlanta, Georgia, this week, suggest productive ways out of this impasse. Researchers are using novel paleoclimatic indicators tied closely to specific archaeological sites to see just what ancient Mayans experienced; others are modeling the climatic impact of deforestation. These efforts show a new willingness among archaeologists to work hand-in-glove with the paleoclimatologists, says archaeologist Brian Fagan, a professor emeritus at the University of California, Santa Barbara. "This is a form of multidisciplinary research that we never ever envisioned before," Fagan says. "It's very exciting."

The slow collapse

The Maya occupied one of the most environmentally varied territories in the world—a patchwork of coastal plains, scrub forest, tropical forest, and temperate highlands. Today, annual rainfall ranges from 500 millimeters in the north to 4000 mm in the central lowlands, but most rain falls from May

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The power of water. Tikal's grand monuments depended on the favor of rain god Chac (*inset*).

to December. To obtain water the rest of the year, the Maya settled along rivers and lakes and built reservoirs and canals to manage rainwater. By the Late Classic period, from 600 to 900 C.E., the Maya had founded more than 100 urban centers.

The collapse of the city-states began during about 695 C.E., in the wet Petexbatún region of southern Guatemala, and proceeded sporadically over the next 350 years. Given the protracted timetable and the clues unearthed at individual sites, many archaeologists concluded by the early 1990s that the Classic Maya civilization was felled by a toxic cocktail of social and environmental factors, including war, overpopulation, soil erosion, and restive populations tired of the demands of self-aggrandizing rulers. It's a view many archaeologists still hold. "When you have something as complex as Classic Maya society, it's going to take a complex string of events to bring that to an end," says Andrew Scherer, an archaeologist at Baylor University in Waco, Texas.

But beginning in 1995, geologist David Hodell of the University of Cambridge in the United Kingdom and his team began pointing to the role of climate change. They analyzed gypsum—which accumulates as water evaporates in dry periods—in cores from a lake in northern Yucatán and showed that the period from 750 to 850 C.E. was the driest in a 7000-year-long period (*Science*, 18 May 2001, pp. 1293 and 1367). Other indicators supported this picture. A Swiss-led team studied titanium—which declines in riverborne sediments when water erosion decreases during parched periods—in a marine core from the Cariaco Basin off Venezuela. They found an extended dry period punctuated by three severe multiyear droughts: 810, 860, and 910 C.E. (*Science*, 14 March 2003, p. 1731). Then in a 2007 paper in *Palaeogeography, Palaeoclimatology, Palaeoecology*, researchers analyzed a variety of data—oxygen isotopes for gauging rainfall, luminescence for studying the rate of water flow from a cave ceiling, and other indicators—from a stalagmite from the Macal Chasm cave in western Belize. They found four extreme dry periods centered at about 780, 910, 1074, and 1139 C.E.

Some archaeologists were convinced. But when others went looking for evidence of severe climate change at their sites, they could not find it. In the Petexbatún region, for example, a 7-year interdisciplinary project by Arthur Demarest of Vanderbilt University in Nashville, Tennessee, concluded that the inhabitants had a relatively stable diet of corn and meat throughout the collapse period. Skeletal remains displayed no increases in anemia or infectious disease, as might be expected in a starving populace. "If there's a drought, but it doesn't affect people's health, then what does it matter?" says Demarest. Instead, his team uncovered extensive evidence of a bitter, nearly century-long rivalry between the region's rulers over trade routes, which sparked intense warfare and the destruction of the site of Dos Pilas in 760 C.E.

One difficulty in correlating climatic and archaeological data at some sites is the relatively large error ranges of radiocarbon dates. Another may be regional variation:

Wet and dry. The Maya lived in a patchwork of environments, and some cities in wet areas collapsed before drier ones.

SOURCE: AFTER SHARER AND TRAXLER, 2006

"Droughts can be quite localized," notes Jason Yaeger, an archaeologist at the University of Wisconsin, Madison. "So I'm a little skeptical about taking the Venezuela record and applying it directly to the Maya lowlands without local proxy records."

One way out is to devise paleoclimatic indicators that come directly from dated archaeological sites. That's just what zooarchaeologists Kitty Emery and Erin Kennedy Thornton of the University of Florida, Gainesville, set out to do, by using the animal bones that litter Maya deposits to track the proportions of wetland fauna over time. The researchers "have hit on something really exciting here that no one else has done before for the Maya. And that is to use the habitat information of the animals hunted, exploited, and eaten by the Maya as a proxy for climate change," says archaeologist Heather McKillop of Louisiana State University in Baton Rouge.

Emery and Thornton, who presented their unpublished study this week at SAA, compiled lists of animal bones from 22 dated Maya sites and selected 15,000 identified specimens from more than 65 species, including animals such as jaguars that sometimes hunt near water and storks and musk turtles that spend much of their lives in wetlands. Then the researchers gathered published habitat data on the proportion of time each animal spent in aquatic or wetland environments and verified this with tropical forest ecologists. "We can say that a particular species will spend 20% its time in one habitat and 10% in another," says Emery.

She averaged the values of all species to get pictures of available habitat at given points in time and looked for changes in the proportion of wetland animals from 1800 B.C.E. to 1821 C.E. (Examining shifts in the proportion of wetland animals, rather than absolute numbers, should correct for varying hunting intensity and for animal responses to habitat change, she said.)

Although she cautions that larger samples are needed, the results so far fit well with the regional paleoclimate data: Swamp-loving species at 22 sites increased from 1% to 7% of specimens from 600 to 800 C.E., a period other proxies pointed to as relatively moist. But during the Maya collapse from 800 to 1000 C.E., swampland animals declined in all five watersheds from 7% to 2%, strongly suggesting that wetlands had shrunk markedly. However, when viewed from this ultralocal perspective, the dry periods look serious but not catastrophic, says Emery. Not one wetland species in the study disappeared completely between 800 and 1000 C.E. "I don't think there was anything that killed off enough fauna or enough landscape that it would have caused a collapse of human populations," she says.

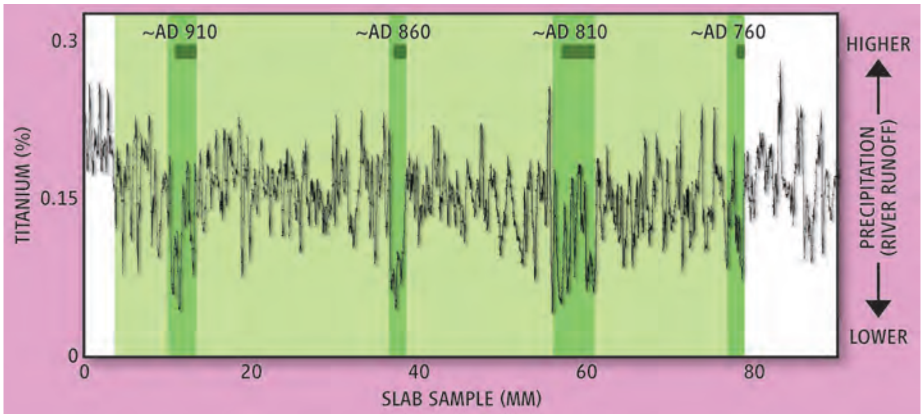
Appeasing the rain gods

In bark-paper books, Maya scribes painted pictures of a rain god they called Chac. Artworks show Chac residing in a cave and creating precipitation by pouring water from an overturned jar. Between 680 and 960 C.E., Maya in western Belize created a Chac-oriented drought cult, centered in caves, to appeal for rain, according to a study in the current issue of *Latin American Antiquity* by University of Arizona, Tucson, archaeologist Holley Moyes, Belize Institute of Archaeology president Jaime Awe, and their colleagues. At Chechem Ha Cave, the team mapped 300 meters of tunnels and excavated the central chamber. To illuminate the passages—which appear to have been used exclusively for ritual—the Maya carried wood torches that spewed charcoal, and Moyes's team plotted the specks on each excavated surface. The density pointed to the intensity of ritual use and to where ceremonies were performed. The charcoal provided 48 radiocarbon dates, showing that the Maya had visited the cave repeatedly from as early as 1300 B.C.E. to about 950 C.E. Over time, the Maya left behind 1901 ceramic shards or complete pots.

The team discerned a major shift in ritual practices. Before 680 C.E., the Maya journeyed to the cave's central chamber to perform rites around a giant stalactite and pool, sometimes leaving broken pottery and twice leaving an intact jar and whole dish. After 680 C.E., however, ritualists deposited 51 whole jars and numerous other partially intact vessels, sometimes inverted, throughout the cave, including areas previously unvisited. "They left more ceramics between 680 and 960 C.E. than all the other periods put together," says Moyes. Many of the vessels were large wide-mouthed jars likely used for water collection. "These jars are what rain deities use," says Moyes. "So this is the perfect gift for a rain deity."

The changing rituals occurred during a prolonged dry period in the region, from 700 to 1135 C.E., according to paleoclimate studies of luminescence, stable isotopes, and other data in a stalagmite from a cave only 15 kilometers away, done by geologist James Webster of the U.S. Environmental Protection Agency and colleagues. Moyes and Awe surveyed 53 caves in central and southern Belize and found a similar pattern of large, whole jars left on ledges during the proposed dry period—evidence, they suggest, of a previously unknown drought cult. "When things get really tough, I think the Maya elaborate on what they are willing to give these rain gods," Moyes says. "I think they are trying to give them nicer gifts."

Other researchers say that Moyes's work offers important insights. "This is a novel way to address the issue of drought," says Lisa Lucero, an archaeologist at the University of Illinois, Urbana-Champaign. "And the results support data from other sources, such as lake cores."



Sign of the times. The amount of titanium in sediment drops when rainfall and water erosion decline. This data from the Cariaco Basin spotlights droughts at 810, 860, and 910 C.E. that may have affected the Maya lands.

Clearing forests, drying climate

If drought helped drive the collapse of many Maya cities, the Maya themselves may be partly to blame: Their own practices, such as deforestation, may have changed climate and helped speed their downfall. That idea was popularized in environmental historian Jared Diamond's 2005 book *Collapse*.

The Maya cut trees to plant cornfields and use as fuel, both for cooking and for heating limestone to make lime for the plaster they lavished on their building projects. Evidence suggests that at least some city-states had extensively cleared forests at the time of the collapse. A 1988 pollen analysis indicated, for example, that the Maya at Copan cleared 23 square kilometers of pine forest by 800 C.E. And in a paper now in press in *Estudios de Cultura Maya*, archaeologists Isabel Villaseñor of University College London and James Aimers of the State University of New York, Geneseo, demonstrate that the Maya at Palenque and Calakmul substituted inferior clay for lime in their plasters just before the Classic collapse, suggesting most trees were gone.

At the SAA meeting, a team led by archaeologist Thomas Sever of the University of Alabama, Huntsville, reported the first results from a major computer simulation of climate and deforestation in the Maya lands. "There's always been the notional concept that deforestation leads to less rainfall," says Daniel Irwin, a research scientist at NASA in Huntsville, Alabama. "A lot of people have theorized about this impact going back in time to the Maya, but this, I believe, is the first time a research team has used climate models to demonstrate it."

Studies show that deforestation affects climate in several ways. A logged landscape absorbs more sunshine, and its new vegetation possesses shallow roots that reduce the amount of ground water returned to the atmosphere. It also offers less resistance to wind, so gusts can quickly replace humid air with dry air. To simulate deforestation, Sever and colleague Robert Oglesby, a paleoclimatologist at the University of Nebraska, Lincoln, used two climate models and ran two extreme scenarios—complete deforestation and an entirely treed landscape—to establish the boundaries of what might have happened.

Removing all trees across the Maya territory clearly changed climate for the worse. On average, says Sever, "there was a 3° to 5° increase in temperature, and this led to a 20% to 30% reduction in rainfall." Each region was hit a little differently, however. "You get a varying amount of decreases in rainfall and increases in temperature," says team member Robert Griffin, a Ph.D. student at PSU, "so this adds a spatial pattern to it." Of course, not all Maya lands were deforested, and the study's next phase will examine how farm production affected the extent of deforestation and degree of drought.

Although Maya archaeologists clearly have their work cut out for them as they gather new kinds of data, some researchers think the picture is growing clearer. "Now that the data [are] coming in, we can really take the idea of climate change seriously," says Fagan. "I don't think that anyone is saying that drought is the only cause, but it clearly is a significant factor."

–HEATHER PRINGLE

Heather Pringle is a contributing editor at Archaeology magazine.

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