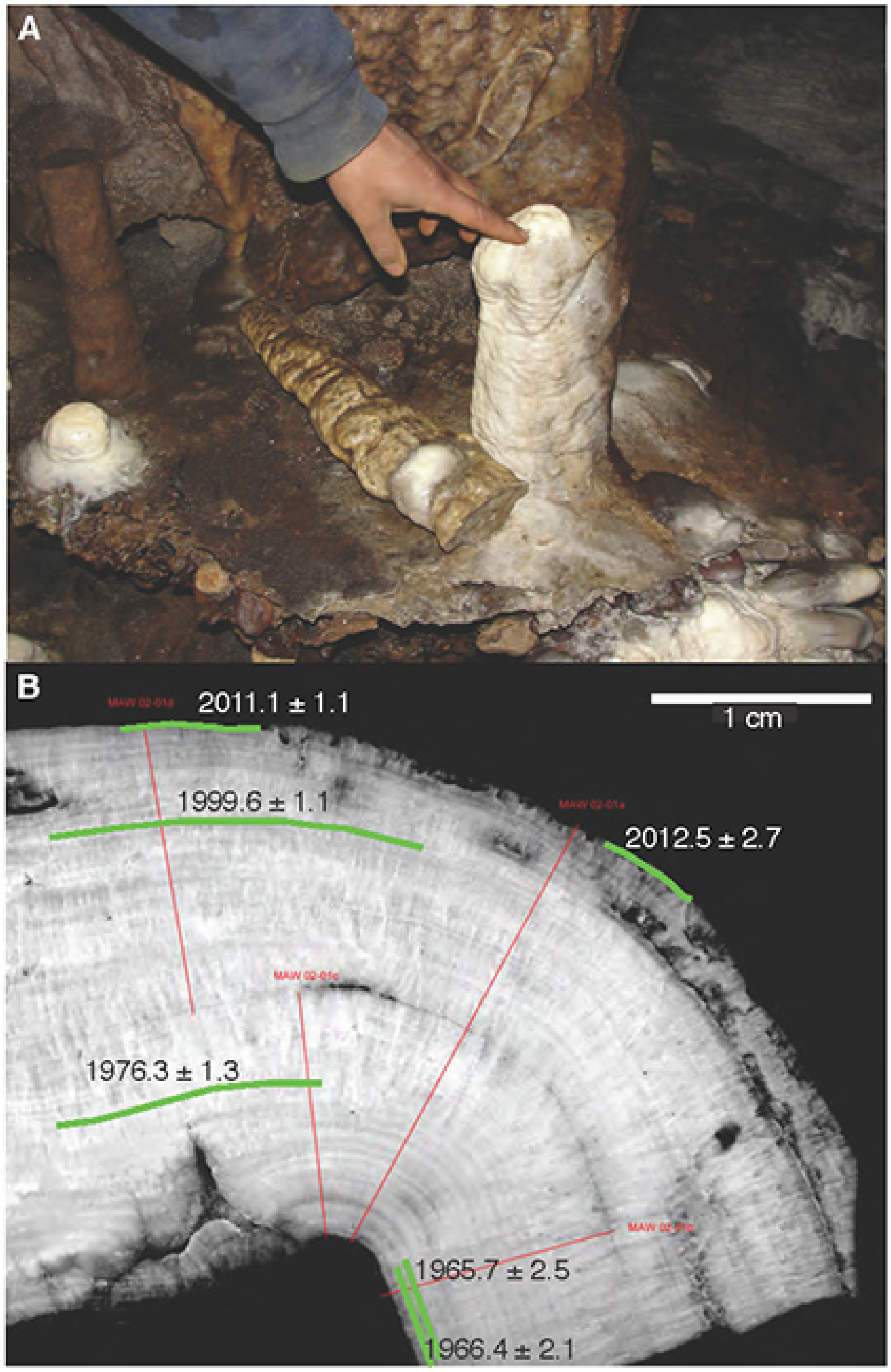
Deciphering clues to prehistoric climate changes locked in cave deposits

May 23 2015, by David Salisbury



Small stalagmite in the Mawmluh cave before it was collected. Below, a gray-scale image of a slab of the stalagmite after it was prepared for analysis. The red lines show the locations where the layers were counted and the green lines show the locations where the material was dated. The adjacent numbers are the dates with the uncertainties of the measurements. Credit: Jessica Oster.

When the conversation turns to the weather and the climate, most people's thoughts naturally drift upward toward the clouds, but Jessica Oster's sink down into the subterranean world of stalactites and stalagmites.

That is because the assistant professor of earth and environmental sciences at Vanderbilt University is a member of a small group of earth scientists who are pioneering in the use of mineral cave deposits, collectively known as speleothems, as proxies for the prehistoric climate.

It turns out that the steady dripping of water deep underground can reveal a surprising amount of information about the constantly changing cycles of heat and cold, precipitation and drought in the turbulent atmosphere above. As water seeps down through the ground it picks up minerals, most commonly calcium carbonate. When this mineral-rich water drips into caves, it leaves mineral deposits behind that form layers which grow during wet periods and form dusty skins when the water dries up.

Today, scientists can date these layers with extreme precision based on the radioactive decay of uranium into its daughter product thorium. Variations in the thickness of the layers is determined by a combination of the amount of water seeping into the cave and the concentration of carbon dioxide in the cave's atmosphere so, when conditions are right, they can provide a measure of how the amount of precipitation above the cave varies over time. By analyzing the ratios of heavy to light isotopes of oxygen present in the layers, the researchers can track changes in the temperature at which the water originally condensed into droplets in the atmosphere changes and whether the rainfall's point of origin was local or if traveled a long way before falling to the ground.

The value of this information is illustrated by the results of a study published May 19 in the journal *Geophysical Research Letters* by Oster's group, working with colleagues from the Berkeley Geochronology Center, the Smithsonian Institution National Museum of Natural History and the University of Cambridge titled "Northeast Indian stalagmite records Pacific decadal climate change: Implications for moisture transport and drought in India."

In the study, Oster and her team made a detailed record of the last 50 years of growth of a stalagmite that formed in Mawmluh Cave in the East Khasi Hills district in the northeastern Indian state of Meghalaya, an area credited as the rainiest place on Earth.

Studies of historical records in India suggest that reduced monsoon rainfall in central India has occurred when the sea surface temperatures in specific regions of the Pacific Ocean were warmer than normal. These naturally recurring sea surface temperature "anomalies" are known as the El Niño Modoki, which occurs in the central Pacific, and the Pacific Decadal Oscillation, which takes place in the northern Pacific. (By contrast, the historical record indicates that the traditional El Niño, which occurs in the eastern Pacific, has little effect on rainfall levels in the subcontinent.)

When the researchers analyzed the Mawmluh stalagmite record, the results were consistent with the historical record. Specifically, they found that during El Niño Modoki events, when drought was occurring in central India, the mineral chemistry suggested more localized storm events occurred above the cave, while during the non-El Niño periods, the water that seeped into the cave had traveled much farther before it fell, which is the typical monsoon pattern.

"Now that we have shown that the Mawmluh cave record agrees with the instrumental record for the last 50 years, we hope to use it to investigate relationships between the Indian monsoon and El Niño during prehistoric times such as the Holocene," said Oster.

Jessica Oster at the entrance of a Tennessee cave that she has begun studying. Credit: Zachary Eagles, Vanderbilt University

The Holocene Climate Optimum was a period of global climate warming that occurred between six to nine thousand years ago. At that time, the global average temperatures were somewhere between four to six degrees Celsius higher than they are today. That is the range of warming that climatologists are predicting due to the build-up of greenhouse gases in the atmosphere from human activity. So information about the behavior of the monsoon during the Holocene could provide clues to how it is likely to behave in the future. This knowledge could be very important for the 600 million people living on the Indian subcontinent who rely on the monsoon, which provides the area with 75 percent of its annual rainfall.

"The study actually grew out of an accidental discovery," said Oster. Vanderbilt graduate student Chris Myers visited the cave, which co-author Sebastian Breitenbach from Cambridge has been studying for several years, to see if it contained enough broken speleothems so they could use them to date major prehistoric earthquakes in the area.

Myers found a number of columns that appear to have broken off in the magnitude 8.6 earthquake that hit Assam, Tibet in 1950. But he also discovered a number of new stalagmites that had begun growing on the broken bases. When he examined these in detail he found that they had very thick layers and high concentrates of uranium, which made them perfect for analysis.

Because of the large amount of water running into the cave, the stalagmite they choose to analyze had grown about 2.5 centimeters in 50 years. (If that seems slow, compare it with growth rates of a few millimeters in a thousand years found in caves in arid regions like the Sierra Nevada.) As a result, the annual layers averaged about 0.4 millimeters thick - wide enough for the researchers to get seven to eight samples per layer, which is slightly better than one measurement every two months.

The amount of information about the climate that scientists can extract from the stalagmites and stalactites in a cave is amazing. But the value of this approach increases substantially as the number of caves that can act as climate proxies increases.

It is not a simple task. Because each cave is unique, the scientists have to study it for several years before they understand it well enough to use it as a proxy. For example, they must establish how long it takes water to move from the surface down to the cave, a factor that can vary from days to months.

Efforts to use the mineral deposits in caves as climate proxies began in the 1990's. Currently, there are only a few dozen scientists who are pursuing this line of research and they have analyzed the mineral deposits from 100 to 200 caves in this fashion.

Warren D. Sharp from the Berkeley Geochronology Center, Ralf Bennartz, professor of earth and environmental sciences at Vanderbilt, Neil P. Kelley from the Smithsonian National Museum of Natural History and Vanderbilt Laboratory Manager and doctoral student Aaron Covey also contributed to the study, which was supported by the Vanderbilt International Office, National Science Foundation grant OISE-0968354 and additional awards and grants from the Cave Research Foundation, the Geological Society of America and the Swiss National Science Foundation.

More information: *Geophysical Research Letters* , onlinelibrary.wiley.com/doi/10 … 02/2015GL063826/full

Provided by Vanderbilt University