Scientists investigate Grand Canyon's ancient past to predict future climate impacts

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The Grand Canyon is known as one of the Seven Natural Wonders of the World. Credit: Matthew Lachniet

The Grand Canyon's valleys and millions of years of rock layers spanning Earth's history have earned it a designation as one of the Seven Natural Wonders of the World. But, according to a new UNLV study, its marvels extend to vast cave systems that lie beneath the surface, which just might hold clues to better understand the future of climate change—by studying nature's past.

A research team—led by UNLV paleoclimatologist and professor Matthew Lachniet—pulled an ancient stalagmite from the floor of an undisturbed Grand Canyon cave. By studying the mineral deposits' geochemistry, they were able to analyze precipitation patterns during the rapidly warming period following the last Ice Age to improve understanding about the potential impact of future climate change on summer monsoon rains in the U.S. Southwest and northwestern Mexico.

Their findings, published Oct. 2 in *Nature Geoscience*, revealed that increasing levels of water seeped into the cave between 8,500 and 14,000 years ago, during a period known as the early Holocene when temperatures rose throughout the region. Using a paleoclimate model, the researchers determined that this was likely caused by intensified and expanded summer rainfall stemming from atmospheric impacts on air circulation patterns that more quickly melted the winter snowpacks and sped up the evaporation process that fuels monsoon rains.

This is significant, authors say, because most of the water currently infiltrating through the bedrock and into caves and aquifers—and contributing to groundwater recharge—comes from winter snowmelt. During the early Holocene, however, when peak temperatures were only slightly warmer than today, both summer and winter moisture contributed to groundwater recharge in the region.

The authors suggest that future warming, which could cause temperatures to rise above those of the early Holocene, may also lead to greater rates of summer rainfall on the high-elevation Colorado Plateau and an intensifying North American monsoon, the pattern of pronounced and increased thunderstorms and precipitation that typically occur between June and mid-September.

UNLV professor Matthew Lachniet holds a stalagmite retrieved from a Grand Canyon cave. Credit: Laura Sangaila

"What was surprising about our results is that during this past warm period, both the summer monsoon and infiltration into the cave increased, which suggests that summer was important for Grand Canyon groundwater recharge, even though today it is not an important season for recharge," said Lachniet, who personally retrieved the stalagmite from a cave in the Redwall Formation on the South Rim of eastern Grand Canyon in 2017. "While we still expect the region to dry in the future, more intense summer rainfall may actually infiltrate into the subsurface more than it does today."

Stalagmites are common cave formations that act as ancient rain gauges that record historic climate change. They grow as mineral-rich waters seep through the ground above and drop from the tips of stalactites on cave ceilings. Calcite minerals from tiny drops of water accumulate over thousands of years, and much like tree rings, accurately record the rainfall history of an area. Three natural forms of oxygen are found in water, and the quantity of one form decreases as rainfall increases. This information is locked into the stalagmites over time.

Because of the distinct difference in the oxygen isotope composition between summer and winter precipitation, it is possible to estimate the relative contributions from each season. Variation in uranium-234 isotope and changes in the growth thickness of stalagmite give indication of the change in the amount of precipitation.

"We were able to validate the oxygen record with the growth data, with the uranium isotope data to confirm that in fact, we see significant increases in summer moisture during this warm period, which we attribute to the monsoon," said the University of New Mexico professor Yemane Asmerom. "Unfortunately, effective moisture is the balance between precipitation and evaporation. Unlike the more temperate Grand Canyon climate, the dry southern part is likely to be drier, as a result of the increased temperatures."

The research team used stalagmite samples to reconstruct groundwater recharge rates—or, the amount of water that penetrates the aquifers—in the Grand Canyon area during the early years of the Holocene period. High groundwater recharge rates likely occurred on other high-elevation plateaus in the region, too, they said, though it's unclear how the activity applies to hotter, low-elevation deserts.

UNLV paleoclimatologist Matthew Lachniet retrieved the stalagmite from an undisturbed Grand Canyon cave in 2017. Credit: Laura Sangaila

What is clear is that ongoing human-caused climate change is leading to hotter temperatures throughout southwestern North America, including the Grand Canyon region. Alongside population growth and agricultural pressures, this warming can reduce the infiltration of surface water into groundwater aquifers. Groundwater recharge rates also depend on the frequency and intensity of summer rains associated with monsoon season.

Though summer infiltration isn't a significant contributor to groundwater recharge in the region today, these latest findings suggest that could change in the future as the climate warms and monsoonal moisture increases. What's unknown is how a projected decrease in winter precipitation and snowpack could impact overall groundwater reserves.

In addition to Lachniet and Asmerom, the following researchers collaborated on the report: Xiaojing Du and Sylvia G. Dee of Rice University; Victor Polyak of the University of New Mexico; and Benjamin W. Tobin of the University of Kentucky.

More information: Matthew S. Lachniet et al, Elevated Grand Canyon groundwater recharge during the warm Early Holocene, *Nature Geoscience* (2023). DOI: 10.1038/s41561-023-01272-6

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