

Measuring the tempo of Utah's red rock towers

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A rock tower called “The Bike Seat.” Credit: Geohazards research group

You won't see them move no matter how closely you watch.

You won't hear their vibrations, even with your ear pressed to the cool sandstone.

But new research shows that the red [rock](#) towers found in Southern Utah and throughout the Colorado Plateau are in constant motion, vibrating with their own signature rhythms as unique as their dramatic profiles against the depth of the blue desert sky.

University of Utah researchers know well how rock towers and arches shimmy, twist and sway in response to far-off earthquakes, wind and even ocean waves. Their latest research compiles a first-of-its-kind dataset to show that the dynamic properties, i.e. the frequencies at which the rocks vibrate and the ways they deform during that vibration, can be largely predicted using the same mathematics that describe how beams in built structures resonate.

Knowing these properties is crucial to understanding the seismic stability of a rock tower and its susceptibility to hazardous vibrations. But it's tough to get the needed data, partly because getting to the base of the towers often requires traveling through treacherous terrain—and then someone has to climb them to place a seismometer at the top.

With the help of experienced climbers, though, University of Utah researchers have now measured the dynamic properties of 14 rock towers and fins in Utah, creating a unique dataset with a variety of heights and tower shapes.

"This ability to make predictions about a tower's fundamental frequency using just the tower's width, height, and material properties is powerful because that means someone doesn't necessarily have to climb a 300-foot (100 m) tower with a seismometer to get this information," says lead author Riley Finnegan, a doctoral student in geophysics. "And knowing this information is important for any assessments related to the

seismic stability of a tower or potential vibration damage."

The study is published in *Seismological Research Letters* and was funded by the National Science Foundation and the University of Utah Office of Undergraduate Research.

Scaling the tops of towers

Finnegan, Jeff Moore, associate professor of geology and geophysics, and colleagues have spent years measuring and cataloging arches and other rock forms to understand how they move.

To get their seismometers to the tops of these towers, the researchers teamed up with climbing expert Kathryn Vollinger, who together with her partner ascended the towers hauling the instruments to the top. Then they waited while the instruments recorded data and carried them back down.

The researchers drew on the help of others as well. Jackson Bodtker, a recent graduate now at the University of Calgary, climbed three towers in one day. Alex Dzubay, a senior majoring in geophysics, scrambled up a thousand-foot cliff to access one tower. Moore's family even contributed, measuring dimensions of rock towers in Arizona.

"So many talented, eager, and helpful people were involved in the fieldwork," Finnegan says. "A group of us went to three of the sites after Kathryn's climbs to fly the drone to make 3D models, and I personally could barely get to the base of one of the towers, let alone start thinking about carrying our equipment to the base and then climb up with it all in tow."

Respecting the land

Some of the sites studied have special significance to local Native American tribes, including the towers in Valley of the Gods, Bears Ears, Utah. The valley, according to the Bears Ears Inter-Tribal Coalition, "...is considered sacred to the Navajo, who interpret the giant sandstone monuments as ancient Navajo warriors frozen in stone—and time."

Finnegan says the researchers met with teachers from Whitehorse High in Montezuma Creek near Valley of the Gods and that one of the students, Weston Manygoats, joined them for fieldwork. "He is extremely bright and hardworking, and we were very grateful for his assistance," Finnegan says.

The research team strove to practice respectful visitation during their fieldwork, and recommends that others visiting the Bears Ears area consult with guidelines from the Coalition and visit the Friends of Cedar Mesa Visitor Center in Bluff, UT. Visitors are asked to stay on marked trails, visit cultural sites with respect, leave any cultural objects as they are found, and avoid touching rock art.

"We hope that by recognizing these towers are constantly in motion, trembling, swaying and shuddering in response to wind and energy coursing through the Earth, visitors to these sometimes sacred landscapes will have an added layer of respect, and ultimately that our measurements will inspire a spirit of care for these amazingly unique places," Moore says.

Rocks swaying like trees

In all, this study compiled ambient vibration data for 14 rock towers and fins collected over several years. While the team had previously reported measurements from a single landform, the 120 m high Castleton Tower, the new compilation is larger and broader than any previously published dataset and spans a variety of tower heights and

geometries.

The results showed that the fundamental frequencies of the rock towers varied between ~1 Hz (one cycle per second) and 15 Hz, and that larger towers have lower fundamental frequencies. In general, the towers bend and sway like trees and tall buildings. At higher frequencies the towers twist around their central axis.

"Probably most surprising to me was how well our data agreed with theory, and how well our models supported the data," Finnegan says. That theory predicts that the fundamental frequency at which a beam vibrates is proportional to its width divided by its height squared. The rock towers largely followed that relationship.

The predicted frequencies of the rock towers' vibrations differed from the observed data by about 4%. And the predicted angle of the towers' motions deviated from the actual data by 14° on average."

"Maybe I'm overly excited and surprised about this," Finnegan says, "but I've made enough models of rock arches in some of our other work that frustratingly didn't produce strong matches to the data, so it was refreshing to me to be able to predict tower modes given the geometry."

The new measurements, together with previously published data, provide guidance on estimating the natural frequencies of other rock towers, pillars and fins, in different settings across the world, values which are needed in order to conduct seismic stability and vibration risk assessments, as well as assess the probable intensity of past shaking. Knowing how to predict rock towers' properties, Finnegan says, makes it much easier to assess the health of a tower with fewer measurements.

Some of the most rewarding times I have had in the field are times when I'm able to slow down, sit and listen and imagine these towers in

motion," Moore says. "We can't see or hear or feel their motion, but it is very real and is always (and has always been) happening. For me, this new perspective creates a renewed and intimate connection with the landscape."

More information: Riley Finnegan et al, Ambient Vibration Modal Analysis of Natural Rock Towers and Fins, *Seismological Research Letters* (2022). [DOI: 10.1785/0220210325](https://doi.org/10.1785/0220210325)

Provided by University of Utah

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