Yosemite's granite cliffs are 'breathing,' and heat can make them fall

Sean Greene, Los Angeles Times, 3-28-16

The domes and arches etched into Yosemite's famed granite cliffs may seem frozen in time, but in reality they're constantly moving.

The dramatic rock formations were formed as layers of rock peeled away from the mountainside, like an onion. The flakes remain attached at a few points but are completely hollow in the middle. If you were to pound on one with your fist, you'd hear an echo.

In Yosemite, these precarious attachments – geologists call them "exfoliations" – fall at a rate of one a week, on average. Most often, they collapse because water repeatedly freezes and thaws in the cracks, destabilizing the cliffs. Sometimes they fall apart during an earthquake.

Other times though, rockfalls happen on sunny days with no sign of rain or seismic activity. Now geologists from the U.S. Geological Survey and the National Park Service have found a potential cause for the seemingly spontaneous rockfalls: heat.

As the temperature rises from morning to afternoon, the thin outer layer of rock moves ever so slightly away from the cliff, then returns as the evening cools.

A pair of geologists collected evidence for this idea in the park's Royal Arches, a cliff overlooking Yosemite Valley not far from the Majestic Yosemite Hotel (formerly known as the Ahwahnee Hotel). For 3.5 years, Brian Collins of USGS's landslide hazards program and Greg Stock of the park service monitored a 19-meter-tall exfoliation that clings to a near-vertical cliff.

Collins and Stock climbed alongside the flaking rock and installed three "crackmeters" behind the slab to see how much it moved throughout the day. The sensors, wedged in place by scissor jacks, measured the strain on a taut wire and were able to detect movements as slight as 0.001 centimeters.

The scientists also installed a variety of temperature and other weather gauges.

Their measurements revealed that a 20-metric ton wall of granite can move about one centimeter a day.

"We look around the landscape and we see thousands and thousands of these flakes and we have to assume they're all moving," Collins said. "They're kind of breathing."

As the cliffs inhale and exhale, the tips of the cracks weaken. Over time, the cracks slowly opens wider and the stress from the heat can prompt the rock to fall.

Heat not only moves the rock, it deforms it. Using lasers, the geologists observed a phenomenon known as thermal bowing, in which the center of the slab bulges outward as the exterior heats up while the interior remains cool. As the cracks get longer, the stress on the points where the slab is still attached grows larger. This further separates the slab from the cliff.

The effect is significant enough for climbers to notice, Collins said. Climbers will scale a particular route in the morning, leaving their hardware for securing ropes embedded in the wall. When they return in the afternoon, they notice their gear has shifted in some way.

The results, published Monday in the journal Nature Geoscience, offer a potential explanation for the “spontaneous” summertime rockfalls that occur not only in Yosemite, but also in mountain ranges in Japan, France, Brazil and Switzerland, the authors wrote.

Park officials maintain a database of all rockfalls in Yosemite since 1857. Usually weather and earthquakes cause the rocks to fall, but there have also been cases when tree roots jostled the rocks loose or lightning struck the cliffs. A few years ago, the park service had to move a campground because of the risk of rockfalls.

For many of the 925 incidents, too little information was recorded at the time to determine a cause. In about 200 other cases, the rockfall was well documented but the cause remained unclear.

The geologists found that 15% of all rockfalls with no recognizable cause occurred in the hottest hours of the day, between 1 p.m. and 6 p.m., and during the hottest months, July, August and September. It may not sound like much, but if these rockfalls had occurred randomly, only 6% of them would have happened during these times.

“All of a sudden we can say, ‘Well, maybe the thermal stress factor had something to do with it,’” Collins said.

Even normal swings in temperature over the course of a day or season are enough to trigger rockfalls. That realization should inform the way officials view the risks associated with living or camping near such formations.

“Rockfalls do not always need an extreme event like an earthquake or rainstorm to occur,” wrote Valentin S. Gischig, a geologist at the Swiss Competence Center for Energy Research, in a commentary accompanying the study.

“Rockfalls induced by temperature fluctuations should be considered in rockfall hazard assessments — and not just for the famous granitic cliffs of Yosemite, but for inhabited mountain regions throughout the world," he added. ”Possibly, as the climate warms in the coming decades, thermally induced rockfalls may become even more important to hazard assessment and cliff erosion.”

Although the study authors didn't examine long-term data, Collins said it’s reasonable to expect that rising temperatures would affect Yosemite’s cliffs.

“If you continue to heat things up, these sheets could expand even further,” he said.

Mostly, Collins said the study offers a new perspective on the park’s beloved mountains.

“The sun and the temperature are enough to make the rock move up there,” he said. “It’s just kind of a neat thing that I think people don’t think about.”