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Not My Fault: Precarious rocks and quake risk

Lori Dengler/For the Times-Standard
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Large earthquakes are relatively infrequent events. A challenge in seismic hazard analysis is figuring out the strength and likelihood of future earthquakes. Hundreds or thousands of years may elapse between successive events in a particular area. Instrumental recordings are barely over a century old, not nearly long enough for hazard analysis. Newspapers, church records, diaries and other writings extend the record back further, but don't provide broad, continuous or quantitative coverage. China is the only country in the world with written records that reaching back two millenia, but even in China, not all areas were populated and some strong earthquakes didn't make it into their logs.

I was in grad school when I first heard the term paleoseismology. Kerry Sieh, while still an undergraduate, began looking in trenches for geologic evidence of earthquakes in the 1960s and 70s. He perfected the use of the backhoe as a field geology tool during his PHD studies of the San Andreas fault zone. Kerry's work took the chronology of earthquakes on the San Andreas from the earliest known event in 1857 back into the 6th century. His daughter attended HSU and for a few years we were treated to regular visits and seminars from Kerry. Trench studies became the norm of earthquake geology and my colleagues Gary Carver, Bud Burke, Mark Hemphill-Haley and legions of HSU undergraduates and graduate students have used the technique all over the world.

Backhoes are useful when a fault breaks the surface, but are of little use in ascertaining past earthquakes if faults aren't visible and you don't know where to dig. In many areas, fault traces are obscured by thick layers of sediments. Offshore faults may produce strong shaking on land but are beyond the reach of backhoes.

In 1992 I heard Jim Brune give a paper at the fall meeting of the American Geophysical Union. AGU is a huge meeting and most of the talks and posters make little lasting impression on me. But I remember Brune's talk clearly. He looked at the distribution of precariously perched rocks and boulders and compared it to earthquake probability maps. The premise was these rocks had stood precariously balanced for tens of thousands of years. If they were still standing, no strong shaking had occurred in that time span.

Brune, a seismologist at the University Nevada Reno, is a geophysicist and an expert in seismic waves. He authored one of the most widely cited papers on the nature and strength of vibrations produced by fault slip in 1970. But Jim was not one to work only on computers and in laboratories. He also spent much time in the desert examining faults in the field and doing post-earthquake reconnaissance studies.

If you have hiked in the canyon lands of Utah, Arizona, Colorado or New Mexico you have noticed great boulders perched precariously on the landscape. You may have even taken photographs of family members trying to hold the rock in place. Brune recognized that precarious balanced rocks (PBRs – it is a geologic term) were not only great photo op locations, but also indicators of past earthquakes, or rather non-earthquakes.

PBRs were not the main focus of Brune's studies at the time, but he did put several grad students to work on developing a computer program to analyze the physics behind these rocks and estimate what level of shaking it would take to displace them. With this methodology, he was able to put constraints on which areas had experienced strong shaking in the past 10,000 years, the time window often to define whether a fault is active or not.

The 1999 M7.1 Hector Mine earthquake in the Mojave Desert proved a boon to Brune's studies. He had studied the area before the earthquake and identified several rocks that stood before the quake and had toppled afterwards. By using the data from a strong motion instrument nearby, Brune was able to calibrate his models and estimate that the earthquake shaking had to exceed 20% of the gravitational acceleration to knock the rocks over. From the age of the rocks, he estimated it had been at least 10,000 years since similar shaking had occurred in the area.

Precarious rocks cropped up in the news last month when Anna Rood, a graduate student at Imperial College, London published a study of delicately balanced boulders in the journal AGU Advances. Anna works on the Central California coast in the vicinity of the PG&E Diablo Canyon nuclear power plant. Anna and the Imperial College team use cosmogenic surface exposure dating to get more precise estimate of how long a rock has stood in its place. Cosmogenic dating is a little like a very bad sunburn. It measures the changes to the rock's surface caused by cosmic rays – the longer it's been exposed, the worse the 'burn' so to speak.

There is no shortage of seismic risk studies in the vicinity of Diablo Canyon, the only operating nuclear power plant in California. Nuclear power plants and waste repositories are sites where identifying potential seismic hazard has societal health implications. What I found particularly interesting about the new study is that it contradicts the current consensus based on modeling the size and return period of earthquakes from the identified faults in the region. Rood's group finds strong shaking in the area is significantly less frequent than previously thought, reducing the maximum magnitude of earthquakes over the past 10,000 years in the region by about 27%.

Diablo Canyon was originally designed to withstand a magnitude 6.75 earthquake and was later reinforced to make it through a 7.5. PG&E plans to decommission the two reactors in 2024 and 2025.

Note: More about Anna Rood and colleagues study at https://temblor.net/earthquake-insights/ready-to-roll-rocks-improve-seismic-hazard-models-12080/

Lori Dengler is an emeritus professor of geology at Humboldt State University, an expert in tsunami and earthquake hazards. All Not My Fault columns are archived at https://www2.humboldt.edu/kamome/resources and may be reused for educational purposes. Leave a message at (707) 826-6019 or email Kamome@humboldt.edu for questions/comments about this column, or to request a free copy of the North Coast preparedness magazine "Living on Shaky Ground."

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