Precariously balanced rocks suggest San Jacinto, San Andreas may have ruptured together

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An example of precariously balanced rocks in the Grass Valley area of the San Bernardino Mountains. The boulders lie near the San Andreas Fault within one of the highest seismic-hazard areas in the United States. Credit: Lisa Grant Ludwig

Stacked in gravity-defying arrangements in the western San Bernardino Mountains, granite boulders that should have been toppled long ago by earthquakes are maintaining a stubborn if precarious balance. In puzzling out why these rocks still stand, researchers have uncovered connections between Southern California's San Jacinto and San Andreas faults that could change how the region plans for future earthquakes.

In their study published online August 5 in *Seismological Research Letters* (SRL), Lisa Grant Ludwig of University of California, Irvine and colleagues write that the precariously balanced rocks (PBRs) have survived as a result of interactions between the faults that have weakened earthquake ground shaking near the rocks.

One such interaction, the researchers say, might be a rupture that began on the San Andreas Fault but then jumped over to the San Jacinto Fault, near Cajon Pass. "These faults influence each other, and it looks like sometimes they have probably ruptured together in the past," said Grant Ludwig. "We can't say so for sure, but that's what our data point toward, and it's an important possibility that we should think about in doing our earthquake planning."

Cajon Pass is the site of "some very important, lifeline infrastructure like I-15, and we should be considering the possibility that there might be broader disruptions in that area," Grant Ludwig added.

Most of the seismic hazard maps that engineers and others use to guide the design of buildings, aqueducts and other important infrastructure often only account for the ground shaking and other impacts produced by ruptures along one fault, she noted.

"This paper suggests that we might consider the impact of a rupture that involves both the San Jacinto and San Andreas Faults, which has the potential to affect more people than just the San Andreas or just the San Jacinto," Grant Ludwig said.

The precariously balanced rocks (PBRs) analyzed in the SRL study are part of a massive PBR dataset developed by co-author James Brune and his research group at the University of Nevada, Reno. Grant Ludwig, Brune, and their colleagues examined 36 PBRs near Silverwood Lake and Grass Valley that lay only seven to 10 kilometers away from the San Andreas or San Jacinto Faults. The PBRs are at least 10,000 years old, and should have experienced ground shaking from 50 to 100 large, surface-rupturing earthquakes over that time.

Scientists measure the fragility of these rocks by studying their geometry and doing field tests like tilt analyses, where they put a pulley on a PBR and measure the force required to "tilt it to the point where if you let it go, it will fall under the influence of gravity," Grant Ludwig explained.

The researchers report this force as a measure of acceleration. Just a person in the passenger seat of a car tilts back when the driver steps on the gas pedal, the PBRs tilt in response the ground accelerating beneath them as the result of an earthquake. Ludwig also compared the phenomenon to pulling a small rug out from under a tower of Lego blocks. The higher the acceleration of the pulled rug, the more likely it is that it will topple the tower.

Ludwig and colleagues compared PBR fragilities with the expected acceleration of the ground in three earthquake scenarios created by the U.S. Geological Survey's "ShakeMap" program: a magnitude 7.8 rupture of the southern San Andreas Fault, a magnitude 7.4 San Andreas quake near San Bernardino, and the 1857 magnitude 7.9 Fort Tejon earthquake.

These earthquake scenarios, along with National Seismic Hazard Maps for the area, predicted that these 36 PBRs would have toppled a long time ago. "It was a real scientific puzzle, a real head-scratcher," said Grant Ludwig. "How can you have these rocks right next to the San Andreas Fault? It's an interesting scientific question, but it also has practical implications, because we want our seismic hazard maps to be as good as possible."

After a decade's work investigating many possible answers to the puzzle, the researchers concluded that only interactions between the San Jacinto and San Andreas Faults could have produced the kind of rupture pattern that would preserve the area's precariously balanced rocks.

Recognizing this interaction between the two major faults could change earthquake planning scenarios for the area, Ludwig concluded.

"The San Jacinto fault has been very seismically active. It has produced a lot of earthquakes during the historic period. And the Southern San Andreas fault has not, it has been pretty quiet since 1857," she said. "This brings up the question of whether we might have an earthquake on the San Jacinto that triggers one on the Southern San Andreas, or vice versa."

More information: The study, "Reconciling precariously balanced rocks (PBRs) with large earthquakes on the San Andreas fault system," will be published online August 5 and in the September/October print edition of *SRL*.

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