Spring tides trigger tremors deep on California's San Andreas fault

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Things have been pretty quiet lately along the earthquake-prone San Andreas fault, where the grinding of tectonic plates is slowly shearing part of California off of North America. But 20 to 30 kilometers down, there's a whole lot of shaking going on. Below the town of Parkfield, California, hundreds of thousands of slow microearthquakes called tremors go off routinely where Earth's brittle crust gets weaker and softer. Now, scientists have shown that these tremors are triggered by the rhythmic pulsing of the tides: not just the twice-daily tides that occur as the moon revolves around Earth, but also the twice-monthly spring tides that occur when the sun and moon align and pull strongly on the planet. The finding gives scientists a new window into a deeper part of the San Andreas fault, and new insight into how stress builds up on small patches of the fault until they snap.

"We're finding out something about the loading rate on the faults and how fast this stress is accumulating on these patches," says Nicholas van der Elst, a seismologist at the U.S. Geological Survey in Pasadena, California, and the lead author of the study.

Stress builds up along the San Andreas fault as the Pacific plate tries to slip past the North American plate at a rate of several centimeters per year. But along most of the fault, the plates get jammed up and remain stuck until they reach a snapping point or are triggered to release the accumulated strain. Scientists have long wondered whether the tides could provide the proverbial straw. The tides not only slosh the oceans back and forth, but they also induce the shell of the solid earth to flex ever so slightly—sometimes in directions that happen to be aligned with faults.

However, the tidal forces are incredibly weak in comparison with the forces that arise from the tectonic plate motions, and there are only a few confirmed examples of a connection between quakes and tides, mostly from deep faults underneath the edges of the oceans. That's because in these regions, ocean sloshing forces add to the flexing of the earth, and water can lubricate and weaken faults. In 2002, scientists showed that tides triggered tremors on underwater volcanoes. And in 2004, scientists found that tidally triggered earthquakes could occur on some faults where ocean plates dive under continental plates. But for the most part, scientists have been unable to find a strong connection between tides and quakes on faults like the San Andreas—at least big quakes in the upper crust, says Eliza Richardson, a seismologist at Pennsylvania State University, University Park, who was not involved in the study. "In general there's not a big, strong signal," she says. "It's considered elusive."

But as seismometers got more sensitive and were laid down in more places, scientists started to identify tremors in the lower crust. In these deeper regions, faults are weaker, and that means that tides can play a more important role. In 2012, scientists spotted deep tremors on the San Andreas fault below Parkfield that were tidally triggered, at the twice-a-day tidal peaks associated with the lunar day. In the new study, Van der Elst and his team found that bursts of tremors were also triggered during waxing of the twice-monthly spring tides, when the moon is aligned with the sun. Using a catalog of 4 million tremors that occurred between 2008 and 2015, they pinpointed the location and timing of the tremors in relation to the tides, they report today in the *Proceedings of the National Academy of Sciences.* Van der Elst says that the daily tidal peaks seem to trigger the littlest, deepest tremors, whereas the larger spring tide sets off larger patches of slip higher up.

Richardson says that the study team has identified a transition zone between the upper crust, where big earthquakes go off on the rare occasions when there is slip, and the deep, soft crust, where the fault grinds along more quietly, through the slippage of nearly continuous little tremors. “There’s kind of a gradation,” she says. “These guys have figured out that there’s a class of these [tremors] that are shallower, and they behave differently than the ones that are a little deeper.”

The tremors can’t predict the next “big one,” but in the long term, they could help scientists understand how big ones are set off. Some major earthquakes, such as the 2011 magnitude-9 Tohoku quake in Japan, are preceded by large “slow-slip events,” in which part of the fault moves quietly, without seismic notice, loading the fault to the point of rupture. Some scientists think that a burst of small tremors could signal a slow-slip event and imply that a big rupture is imminent. “We’re all waiting to see if the tremor pattern changes before or after a big earthquake,” Van der Elst says.