Times Standard

Not My Fault: All About Earthquake Swarms

Lori Dengler for the Times-Standard

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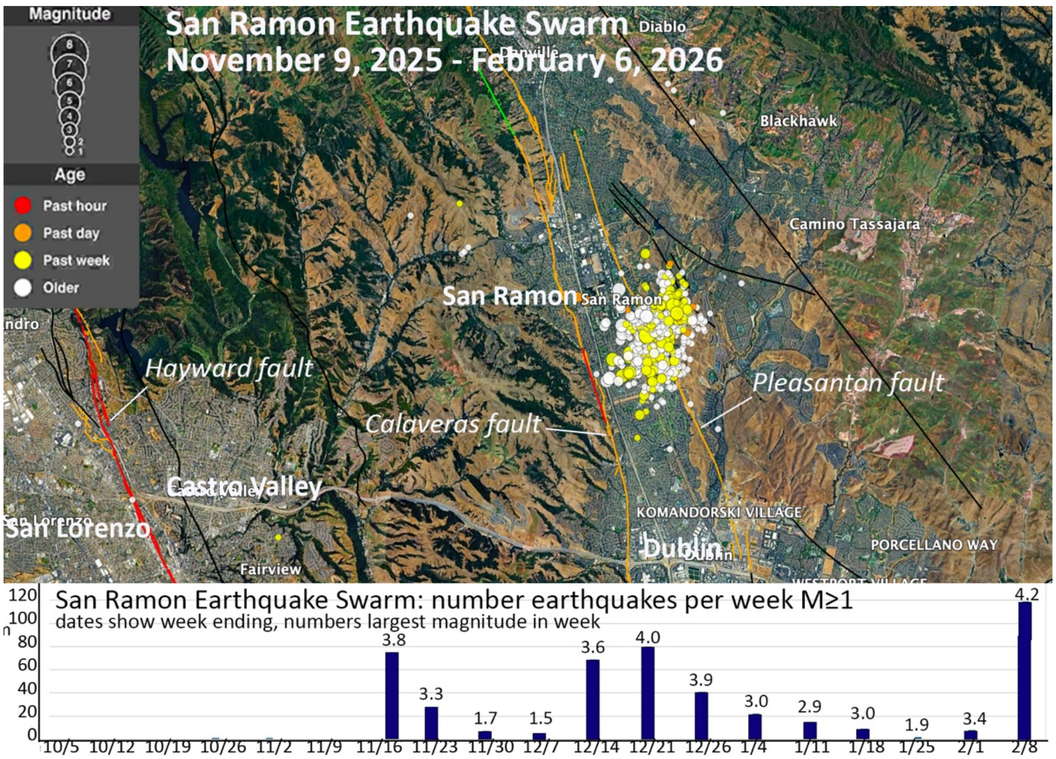

This map shows the nearly 600 earthquake epicenters recorded by the USGS between Nov. 9, 2025, and Feb. 6. Most are smaller than magnitude 2 and not reported felt, but 24 were in the M3 to M4 range and 84 reported felt by at least 10 people. Also labeled are the Hayward, Calaveras, and Pleasanton faults. The bottom graph shows weekly earthquake totals, with the week ending date given on the axis and the largest magnitude earthquake of the week.

It's been a jiggly week in the east San Francisco Bay Area. The USGS recorded 120 earthquakes centered within a few miles of the city of San Ramon. Most were too small to be felt, but six were in the M3 range and the largest, a magnitude 4.2 on Monday, triggered over 5000 "Did You Feel It?" reports to the USGS web site, some as far away as Fresno and South Lake Tahoe.

This week's seismic activity continued an earthquake swarm that began last November. On November 9, an area two to four miles from San Ramon lit up with small earthquakes. Beginning with a 3.8, 88 small earthquakes followed in the next 24 hours. None were large enough to cause any damage, but many were felt lightly in the east Bay region. The burst of activity died down over the next few days and by mid-December, appeared to be over. But on December 19, activity picked up with a 3.8 and 4.0. Activity subsided again but this week surged, providing the largest magnitude (4.2) and the most vigorous part of the swarm to date.

Earthquake swarms behave very differently than typical earthquake sequences. Most strongly felt earthquakes sequences consist of a largest earthquake (mainshock), followed by smaller earthquakes (aftershocks). Some may be preceded in the hours/days/weeks beforehand by smaller earthquakes (foreshocks) and a few may feature doubletons, two large quakes of nearly the same size close together in time and space. But the overall pattern of bigger earthquakes followed by weeks/months/years of declining earthquake activity is the norm.

The December 5, 2024, M7 Mendocino fault earthquake is a good example of a typical earthquake sequence. It was centered about 40 miles west of Cape Mendocino and was immediately followed by smaller earthquakes. Nearly 200 aftershocks were recorded in the first 24 hours. The number rapidly declined, 80 on day two and 35 on day three. The largest magnitude aftershock was M5.3, occurring nine days after the mainshock.

The aftershocks were all located in a 40-mile-long zone between the M7.0 and Cape Mendocino, clearly defining the area that ruptured in the mainshock. By December 20, the rate had declined to a few per day. The number continued to slowly ebb, registering a few per week by August. There are still occasional earthquakes in the aftershock zone, but we are pretty much back to the level of activity that characterized the area before the M7.0.

This mainshock – aftershock pattern holds for a wide range of earthquake sizes. The largest magnitude aftershock is roughly one magnitude unit small than the mainshock. The duration of an aftershock sequence depends on the magnitude of the mainshock. Extremely large earthquakes have very long aftershock windows, the 2011 M9.1 in Japan continued to produce aftershocks for nearly a decade.

Aftershocks are caused by irregularities in slip during the main earthquake. The December 2024 M7 caused the rocks to the north in the Gorda plate to move almost six feet relative to the rock in the Pacific plate to the south. This slip was by no means smooth or continuous. A tremendous amount of pressure holds the two sides of the fault together, fault zones aren't smooth, and some patches moved a bit more than others causing an uneven slip distribution and stress irregularities. Stress is concentrated near the ends of the rupture in the transition between the part of the fault that moved and the part that didn't and many of the aftershocks were in these areas. Aftershocks are nature's way of ironing out this uneven stress distribution and will continue until the region has found a new stable configuration.

Swarms behave very differently. They consist of dozens to thousands of earthquakes of similar size closely clustered in time and space with no steady magnitude decay. They may last for days, weeks, and in unusual cases, for years. They may start, pause and start again at irregular intervals. The San Ramon swarm as I write has produced 600 earthquakes including seven between magnitudes 3.8 and 4.2 with three periods of intensified activity to date. The earthquakes are closely clustered, creating a few mile diameter splotch on a map.

Swarms aren't uncommon and San Ramon isn't the only California swarm happening right now. On January 19, a M4.9 earthquake occurred in southern California's Coachella Valley near Indio. Since then, 680 earthquakes have struck a two-mile wide area centered eight miles north of the San Andreas fault, including 12 earthquakes of M3 or larger. While near the San Andreas, these are not generated by that fault. The larger earthquakes in the swarm show extensional faulting aligned nearly perpendicular to the San Andreas trend.

The most common California swarm location is in Imperial County near the Salton Sea. Every year this area experiences one or more bursts of small earthquakes, sometimes lasting only a few days and at other times persisting for several weeks. Very small earthquakes are always occurring in this transition zone between the southern end of the San Andreas transform fault and the spreading center in the Gulf of California, but much of the activity occurs in swarm bursts. In June of 2021 a particularly vigorous swarm hit the area producing 2400 earthquakes in a one-month period including a M5.3 and seven in the M4 range.

Earthquake swarms are also common in volcanic areas, sometimes heralding the arrival of an eruption and other times, the movement of magma at depth. One of the most intriguing of such swarms is near the town of Pahala on Hawaii's south coast. Over 400 earthquakes of M3 and larger and thousands of smaller ones have occurred in this area since 2015. I wrote about this swarm (5/30/2021) because of its longevity and depth. The Pahala swarm quakes are 20 to 30 miles deep and show no relationship to eruptive activity on the surface. It's still not clear what is causing these unusual earthquakes, but all of the explanations involve fluids and the movement of magma at depth.

Fluids are the key to understanding earthquake swarms. There's no magma movement to explain California swarms but there are other fluids. Earthquakes occur beneath the water table and there are multiple sources of fluids in areas where earthquake occur. Some fluids are released during compaction of deeply buried sediments and others from crystallization and metamorphism. Fluids play an important role in promoting or inhibiting earthquake activity. High pore water pressure pushes mineral grains apart, reducing friction and allowing fault movement at stresses where dry rock is firmly stuck. Continued supply of fluids will produce a steady stream of earthquakes. We see this every day at the Geysers Geothermal Area north of Santa Rosa. The injection of water into the hot rock provides a steady source of energy but also produces more small earthquakes year in and year out than any other part of the state.

California is crisscrossed by faults. Fault movement over millions of years has juxtaposed different rock types adjacent to one another, impeding or enhancing the flow of deep fluids. The location of the San Ramone swarm sandwiched between the Calaveras and Pleasanton faults is no accident. Fluids are blocked by lateral discontinuities enhancing swarm creation. San Ramon is no stranger to earthquake swarms, at least seven have been identified since 1976.

The good news about earthquake swarms is they don't appear to lead to bigger quakes. Not a single one has ever been associated with a major earthquake. They live and die with the fluid source that feeds them, and the magnitudes are not large enough to significantly alter the stress on surrounding faults. But there is always a caveat. Nature has a way of surprising us and there are plenty of other faults quake capable of producing large and damaging earthquakes at any time, regardless of whether a swarm is happening nearby.

Lori Dengler is an emeritus professor of geology at Cal Poly Humboldt, and an expert in tsunami and earthquake hazards. The opinions expressed are hers and not the Times--Standard's. All Not My Fault columns are archived online at https://kamome.humboldt.edu/taxonomy/term/5 and may be reused for educational purposes. Leave a message at (707) 826-6019 or email Kamome@humboldt.edu for questions and comments about this column or to request copies of the preparedness magazine "Living on Shaky Ground."