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Not My Fault: Recent North Coast earthquakes might be related

Lori Dengler and Bob McPherson for the Times-Standard

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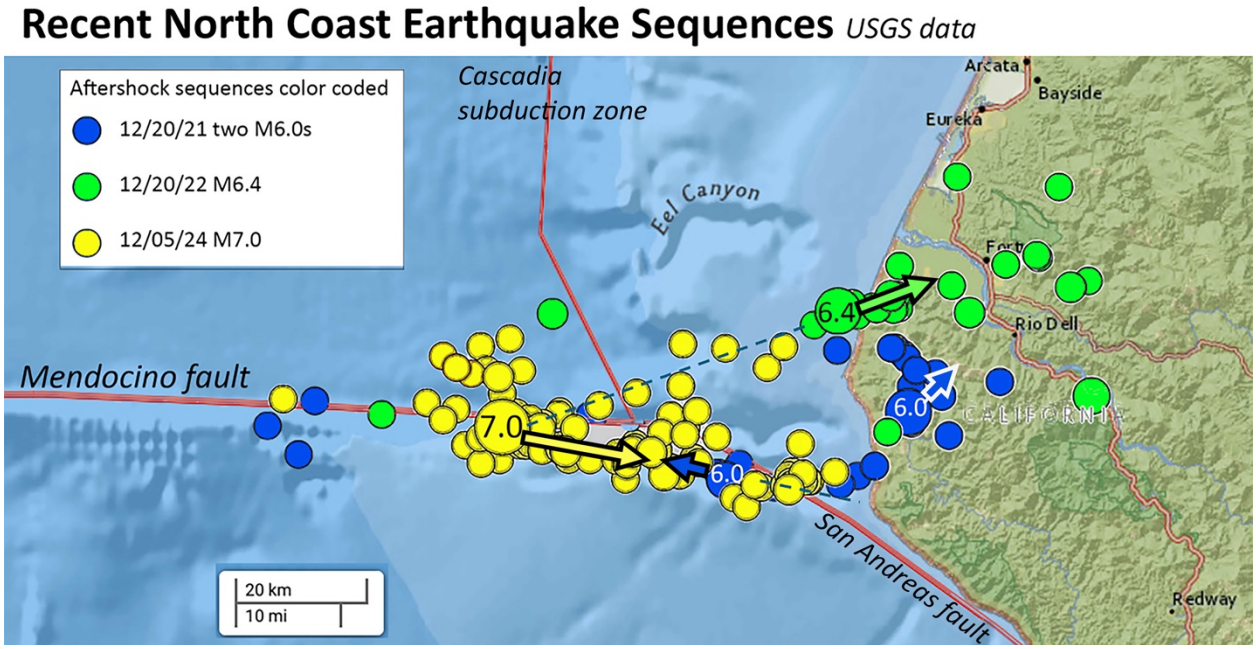

Recent earthquakes in the vicinity of the Mendocino triple junction where the Mendocino and San Andreas faults and Cascadia subduction zone interact. Blue shows epicenters of the two 2021 M6.0 earthquakes and M≥3 aftershocks recorded over the following four months; blue arrows show the direction of fault rupture. Green shows the 2022 M6.4 Ferndale earthquake and its aftershocks and the green arrow the direction of rupture. Yellow circles and arrow show the most recent sequence that began on December 5, 2024. Dotted lines outline the triangular piece of the Gorda plate that is being pushed under Humboldt County.

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It's been ten days since our magnitude 7.0 earthquake and what has been learned? A small army of scientists has been in the field looking for landslides, liquefaction, and talking to residents about what happened. USGS seismologists and local colleagues have installed over 100 seismometers and tens of strong motion detectors to better locate aftershocks, and to understand why certain communities experience amplified ground accelerations.

These are busy days for those of us who follow North Coast tectonics. Every earthquake is an opportunity to learn more about the forces driving our tectonics, how this earthquake relates to previous ones, and the likelihood of future earthquakes. For my colleagues, it's also a time to think about the bigger picture and, in some cases, clarify ideas that have been niggling at the back of the brain for years.

I've plumbed the brain of friend and colleague Bob McPherson to add to today's column. I met Bob in 1978 when I first came to Humboldt as a temporary instructor. Bob had graduated from the Geology Department four years earlier and was working as a seismologist for TERA Corporation deploying, maintaining and interpreting the data from a seismic network studying the seismic safety of the Humboldt Bay Nuclear Power Plant.

Bob knew far more about earthquakes on the North Coast than anyone else and three years later, when the Geology Department added a Master's degree program and I had become a permanent faculty member, I eagerly agreed to be his thesis advisor. His understanding of the complexity of our faults and earthquake sources was greater than mine and my main contribution to his thesis project was editing the text.

Bob and I often collaborated in post-earthquake reconnaissance. In 1992 we co-authored a paper with fellow Humboldt emeritus professor Gary Carver on our regional earthquake sources that remains the only comprehensive treatment to this day (link below). Bob was the one to point out the enigma of the 1954 M6.5 earthquake spurring a re-examination of that event, led by colleague Peggy Hellweg, and to recognize that even our deeply buried earthquake faults produce repeating earthquakes. The December 2022 M6.4 near Ferndale appears to have ruptured the same fault as a mid-5 earthquake in 1975.

There is much about the December 5 earthquake that is known. The Mendocino fault extends west about 170 miles from Cape Mendocino. It marks the plate boundary between the Gorda plate to the north and the Pacific plate to the south. It's what we call a transform plate boundary, like the San Andreas fault system, where the relative motion between the two plates is horizontal, moving like traffic on a British highway. It is a very active fault, producing more than 200 earthquakes of magnitude 4 or larger since 1990 including a M7.1 in 1994 and a 6.6 in 2016. If measured by the rate of moderate to strong earthquakes, it is the most active fault in California.

On December 5th, we know that the earthquake rupture began 39 miles west of Petrolia and proceeded towards the coast, stopping offshore of Cape Mendocino. When the fault movement stopped, the rock along the fault had slipped over six feet relative to each other. Seismologists can measure that slip by analyzing seismograms and the aftershock zone. There is considerable pressure holding the two sides of a fault together and slip is not uniform. Some areas move more than others.

Aftershocks are nature's way of evening out the irregularity of fault slip. As I write, nearly 600 small earthquakes have been recorded along and near the December 5th rupture zone. Most of these have been far too small to be felt, but 14 made it into the M4 range, large enough to be felt in the Cape Mendocino area and southern Humboldt. As each day passes, the number of aftershocks is declining, although the USGS gives a small chance that some larger aftershocks are still a possibility.

We know that the December 5th earthquake is not an aftershock of the December 2022 M6.4 earthquake just offshore of Ferndale. That earthquake produced a vigorous aftershock sequence including a 5.4 which some Rio Dell residents reported feeling more strongly than the mainshock. But by the end of 2023, seismologists agreed that the earthquake activity had returned to background levels in the area and until December 5th, seismic activity has been relatively quiet.

Every large earthquake leaves a lasting impression – not only in the minds of the people who experienced it, but also in the earth itself. The 2022 earthquake was not on the Mendocino fault but less than ten miles away. The length of its rupture wasn't as large and the slip only half as much as in this year's quake, but it still moved a lot of real estate and profoundly influenced the state of stress around the fault, including on neighboring faults such as the Mendocino fault.

Seismologists call this stress transfer. Push or pull in one area causes the stress in adjacent areas to increase or decrease. An example of stress transfer is seen on a pool table when the energy of one ball is transmitted to others. The process takes place far more slowly in the earth and it may take months, years, or decades before a different segment of the fault or an adjacent one responds.

Bob thinks the stress transfer story and the December 5th earthquake goes back at least to December 20th, 2021 when an earthquake ruptured a patch of the Mendocino fault close to the coast. Eleven seconds later a second earthquake ruptured an entirely different fault nearly 20 miles away beneath Cape Mendocino. Bob and I were part of a group that reassessed these quakes (link below), determining they were both magnitude 6 and the second quake was triggered by the seismic waves produced by the first. It was an example of stress transfer on a very short fuse for earthquakes.

The second 2021 earthquake was on a fault oriented in a NNE direction and its fault rupture gave a shove to the north. One year later, the earth responded with the 2022 Ferndale quake. That earthquake started just offshore and ruptured a 12-mile-long fault in an ENE direction heading towards Fortuna. The combination of orientation, directivity, and regional geology put Rio Dell in the bullseye, producing some of the strongest ground motions ever recorded in a California earthquake. Recent estimates of damage put the losses at close to $90 million.

The 2022 earthquake also changed the stress field in the vicinity and especially in the direction of the Mendocino fault line. Extending the 2022 rupture back to that fault puts it almost exactly where the December 5th M7.0 earthquake initiated. It's a reasonable hypothesis to imagine 2021 helped trigger the 2022 earthquake which in turn created an additional nudge to trigger 2024.

The December 5th quake did cause damage. Homes in the Mattole Valley were shaken strongly, and damage was reported in several areas of southern Humboldt. But the peak accelerations were only about as third as strong as in 2022, and even though the magnitude was larger and shaking lasted longer, it did not cause nearly as much damage.

This interrelationship of earthquakes is nothing new. The 1992 M7.2 Cape Mendocino earthquake triggered two large earthquakes offshore in the following eighteen hours and there were similar sequences in the 1980s. But the 2021, 2022, and 2024 quakes may illustrate this complex balance between the faults in the vicinity of the Mendocino triple junction more clearly than ever before.

Is this the end of the story? Definitely not. That six plus feet of slip on December 5th has also changed the stress field, loading and unloading other faults in the region. It may take weeks or years before the next large earthquake occurs, but it is definitely coming.

Note: North Coast seismicity papers: “The 2021 and 2022 North Coast California Earthquake Sequences and Fault Complexity in the Vicinity of the Mendocino Triple Junction"
https://kamome.humboldt.edu/sites/default/files/Hellweg%202024.pdf
“Sources of North Coast Seismicity”
https://kamome.humboldt.edu/sites/default/files/Sources%20of%20North%20Coast%20Seismicity.pdf

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