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Not My Fault: Digging deeper into US seismic hazards

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Last week's column generated more questions about seismic hazards. Why is the earthquake hazard lower in Oregon than in California or Washington and what's with all those Midwestern and Eastern hotspots when most of the continental US is so far from plate boundaries?

Let's look at the West Coast first. We're close to plate boundaries, the San Andreas transform in most of California and the Cascadia subduction zone in Northern California up to Southern Canada. No surprise that our earthquake hazard is higher than the rest of the US mainland. But there's a distinct difference between the worlds of the San Andreas and Cascadia, and not all parts of the Cascadia margin are uniform.

Offhand, where would you expect more earthquakes – on the San Andreas transform or associated with the Cascadia subduction zone? If you have had a geology class, you might say the subduction zone. Subduction zones are the most seismically active places on the planet accounting for roughly 70% of the earthquakes and more than 90% of the earthquake energy released.

Subduction zones vary considerably in character depending on where they are located, how fast the two sides are converging and how old the subducting crust is. Different sections along the same subduction zone may behave differently. And, like all of us, subduction zones also age and change with time. The modern day Cascadia subduction zone is only a tiny remnant of what the boundary once looked like when the Farallon plate covered most of what we now call the eastern Pacific.

Seismologists divide what remains of that subduction zone in the Pacific Northwest into three areas: the Gorda plate segment (or Gorda deformation zone) off the Northern California coast and southernmost Oregon, the Juan de Fuca from Cape Blanco to Northern State, and the Explorer segment from Vancouver Island to Queen Charlotte Sound. Anyone looking at a seismicity map (see figure) will notice these regions are behaving very differently.

Since 1980, the southern or Gorda plate region has produced over 700 earthquakes of magnitude 4 or larger, including five in the 7 range and twelve 6s. The Explorer region is also very active, tallying up nearly 800 quakes including 23 in the M6 range. The Juan de Fuca is the largest area and between the other two. It had fewer than half as many earthquakes and only one in the M6 range not counting the far offshore activity on the Blanco fault.

To confuse the story even further, none of the modern earthquake activity in the Cascadia subduction zone region is on the subduction zone interface. The last interplate earthquake was more than 300 years ago. The current activity in the Gorda and Explorer regions are because these two plates are now so small that they are breaking up. The movement of the larger plates around them has put them in a seismic vise. Many scientists argue that the Explorer region is no longer a coherent plate and likely was not part of the most recent Cascadia subduction zone earthquake in 1700. The Gorda plate is headed in the same direction and earthquakes like the 1980 M7.2 and 2010 M6.5 were the result of that break up process.

What does this current lack of seismic activity on the subduction zone proper mean? It's locked – that's seismospeak for the two sides stuck tightly together and not moving at all. This isn't just a guess. We can measure this locking by what's happening to the ground surface above the interface. As subduction pulls the plate beneath the surface, it causes the ground to bulge and move ever-so-slightly to the northeast, measurable with high precision GPS instruments. But it won't remain locked (or quiet) forever. And when it slips, the result is likely to be an earthquake in the upper 8 to 9 range.

All of this is factored into the USGS seismic hazard map – the current high level of activity in Northern California and in Washington State and British Columbia and the currently locked subduction zone. Northern California and Washington have more frequent earthquakes related to the break up of the Gorda and Explorer plates but we will all be a part of the next subduction zone quake.

As to the hotspots in SE Missouri and South Carolina, the seismic risk in these areas is real and based on historic earthquakes. Three great earthquakes occurred over a three month period in 1811 and 1812. There were no seismographs then so magnitude the magnitude estimates as high as the mid to upper 7 range is based on felt reports. This is called the New Madrid seismic zone, after the small Missouri town located near the epicenter of the largest earthquake. An earthquake believed to be

nearly as large struck near Charleston, South Carolina in August 1886.

The New Madrid and Charleston earthquakes were natural tectonic events that had nothing to do with human activity. They are a long way from modern plate boundaries and earth scientists have long debated their origins. The most plausible explanation to me goes back to plate tectonics – but not the tectonics of the modern world. Turn back the clock 300 million or so years when all the continents were connected in one giant mass called Pangaea. The supercontinent held together for over 100 million years, but eventually began a long and difficult breakup process. The African continent today gives a glimpse of what may have happened. Today's Rift Valley is the sign it is beginning to break up. There are numerous fissures in East Africa that will continue to grow over the next few tens of millions of years. Eventually one continuous fracture zone will win out forming the edges of a new mid African ocean.

What happens to the old tears that didn't become part of the new plate boundary? As the African sea gets larger and larger, they will keep drifting apart each on their new plate. But, like stretch marks, they will never vanish completely, always somewhat weaker than the surrounding rocks and places where strain accumulates. It's plausible that the fault systems in the Midwest and Eastern part of the US are similar features, the stretch marks that go back to the birth of the Atlantic Ocean and, more than 100 million years later, are still zones of occasional tectonic activity.

Note: The current USGS seismic hazard is posted at https://www.usgs.gov/media/images/2018-long-term-national-seismic-hazard-map.

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