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Not My Fault: Are there any places with no earthquakes?

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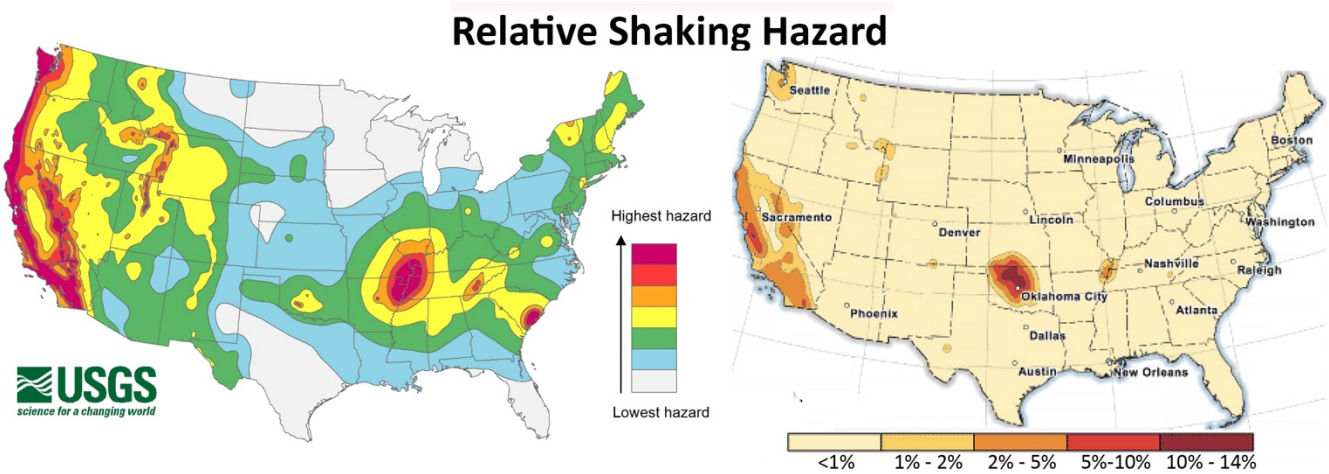

Two USGS relative shaking maps. Left: Likelihood of strong and potentially damaging earthquakes in the next fifty years. Right: One-year estimate of light to moderate shaking during the year 2018.

Not very many people like earthquakes. I have several friends who really despise them. The December 20th M6.4 Ferndale earthquake was terrifying and each smaller quake since then sticks another needle into the fear wound. That fear has become so strong that some of my friends are considering leaving the area.

Is it possible to find a place that never has earthquakes? If you look on a long enough time window the answer is no. Every part of the earth's surface has experienced shaking at some time in the past and will do so again in the future. But some places are definitely shakier than others.

Why do earthquakes occur? Most fifth graders would quickly say plate tectonics. I'm glad earth science is taught in elementary school and that plate tectonics is included but their answer is not quite right. A better answer is heat.

It's true that the majority of our planet's quakes are concentrated in relatively narrow zones. In the 1960s geoscientists used this and other data to develop plate tectonic theory. Earth's surface is organized into a number of relatively stable or "rigid" zones called plates that move relative to one another. Stress and earthquakes are concentrated in the boundary areas between the plates.

Heat and gravity drive the creation and movement of plates. The interior of the earth is hot, and heat always heads towards the cooler surface. The most efficient way to get rid of heat on a planetary scale is convection. Convection allows heat to move quickly, like a boiling pot of water. It's hard to think of

the solid earth 'boiling' but it does so, albeit very slowly, more like cool molasses with a lot of time to slowly ooze.

Plate tectonics has been operating on earth for billions of years, constantly rearranging the planet's surface. Heat causes continents to split and spread apart producing new oceans. The sea floor rocks cool, and gravity eventually pulls them down, creating new subduction zones. The process repeats over and over. Continents are too buoyant to sink but are constantly rearranged – sometimes scattered widely and at other times assembled into massive supercontinents and always developing more geologic scars in the process.

The result is quite different than the simple plate picture learned in elementary schools. Plate boundaries are not the simple lines shown in textbooks and may encompass zones hundreds or thousands of miles wide. Residual stresses from rifting and collisions in the distant geologic past still lurk in the depths and may trigger earthquakes millions of years later.

Global seismic hazard maps (https://www.gfz-potsdam.de/en/GSHAP%20-%20Global%20Seimic%20Hazard%20Map) show relative risk of strong shaking anywhere on the planet. They are based on historic earthquake patterns, active faults, and stress calculations. It's no surprise that the Pacific rim shows up as one of the highest seismic zones as it is almost entirely ringed by subduction zones. The continent with the lowest risk is Antarctica, not too surprising as it is surrounded by divergent plate boundaries that are sbout 1000 miles away from the coast. But low risk doesn't mean no risk. Four earthquakes of magnitude 7.5 and larger have occurred in the vicinity of Antarctica in the past fifty years.

Antarctica is not a viable moving option. What about the United States? The USGS is tasked with compiling earthquake hazard maps and updating them at least every five years (https://www.usgs.gov/programs/earthquake-hazards/hazards). The official maps are displayed in terms that engineers use for building design and infrastructure planning and most people are quickly lost in the technical language of peak ground velocity and probabilities.

A simplified picture of relative hazard illustrates general shaking potential. For engineering purposes, the probability of shaking strong enough to damage structures over a fifty-year time window is what is usually mapped. Fifty years is a standard lifespan for structures and is incorporated into building codes.

The most recent US fifty-year map was compiled in 2018 – a new one will be coming out later this year. Our fifth grader's plate tectonics map would show plate boundaries only along the western edge of the lower 48 states, so it is no surprise that the West Coast shows up in the brightest colors signifying high hazard. But the map is more complicated. There is a nearly equally bright zone paralleling the California – Nevada border and colors continue to the Rocky Mountains reflecting that some of the Pacific – North America plate motion is accommodated over this entire region.

More surprising are the bullseyes in the Midwest and eastern part of the country. They reflect two major earthquake sequences that occurred in the 19th century - the New Madrid quakes of 1811 and 1812 in Missouri and Arkansas and the 1886 Charleston, South Carolina earthquake. There is also a belt of earthquake activity running roughly along the Appalachians extending into Canada.

Damaging earthquakes are far rarer than felt ones. I recently stumbled onto a USGS map for 2018 that estimated chances of experiencing shaking of Intensity III or stronger (noticed by most people indoors) over the next year. There are some similarities between this map and the fifty-year strong shaking one. California still pops out as a higher-than-average place to feel a quake.

But there are surprises. The most likely place to experience modest shaking during the single year of 2018 was Oklahoma. And the map was nearly correct. Between 2014 and 2017, Oklahoma experienced more felt quakes than any other place in the continental US. The high point was 2015 when Oklahoma had five times as many magnitude 3 and larger quakes than California.

These one- year maps are strongly influenced by two factors that don't show up in the strong shaking fifty-year maps: induced seismicity and aftershock sequences. The Oklahoma bullseye is caused by injection of drilling waste fluids into deep wells. Oklahoma was the most dramatic example of the sudden increase in earthquakes beginning in 2010. Most of the quakes were small but four were in the magnitude 5 range and caused some damage. The as yet unanswered question is can injection cause major quakes.

The USGS discontinued the one-year maps after 2018. A one-year projection today would look different. Oklahoma began regulating injection in 2015 and earthquake activity has dropped from a high of over 800 magnitude 3 and larger quakes in 2015 to only 12 last year. The new injection bullseye would be in West Texas. We'd also see elevated zones where aftershocks have increased activity above background levels following larger quakes since 2018.

The take home message? There are places with less earthquake risk. North Dakota and Florida have had the fewest quakes in the past few hundred years. But there is no place in the US where earth quake shaking will never be felt. Every state has other threats too – including winter storms, wildfires, flooding, and hurricanes. There are no US states without at least one declared natural disaster in the past five years. Weighing all the risk factors, I'll continue to take my chances on the North Coast.

Lori Dengler is an emeritus professor of geology at Humboldt State University, 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. Downloadable copies of the North Coast preparedness magazine "Living on Shaky Ground" are posted at https://rctwg.humboldt.edu/prepare/shaky-ground.