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Not My Fault: When it comes to tsunamis, length of shaking, not strength, is what matters

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Feedback is always appreciated. Last week I was lucky and got a question too. The question – what shaking does length has to do with magnitude? It's a good question both scientifically and from a preparedness perspective.

Magnitude is frequently misunderstood or used incorrectly. Magnitude is a proxy for how much energy the earthquake rupture produces. In my classes, I used the light bulb analogy: magnitude, like wattage is the same, no matter how close are far you are from the source. Wattage won't tell you how well illuminated your area is – that will depend on how close you are to the bulb and other factors like fog or smoke where you happen to be. Magnitude alone won't tell you how strong the ground will shake where you are located.

There are just three factors that control magnitude – the area of the fault, the amount of slip between the two sides, and how strong the fault is. That's it – nothing about how strong the shaking is or how much damage is caused. Nothing about whether the shaking is sharp or rolling. Your experience of a particular earthquake will be very different depending on how near or far away you are, what the local geologic conditions are like and what type of building you are in. And yet the magnitude is the same number everywhere (see note).

All earthquakes involve rupture on a roughly planar surface. Slip and fault area go together. A magnitude 5 earthquake might have a rupture length on the order of a few thousand feet with a slip or offset of less than a foot. Magnitude 9 earthquakes will have dimensions of hundreds of miles and offsets of 60 feet or more.

What does this all have to do with shaking length? It takes time to rupture a fault. Unlike fault models shown in textbooks, one side of the fault doesn't move all at the same time relative to the other. An earthquake starts at a single point at some depth beneath the surface. In California, most earthquakes nucleate at depths between two and ten miles.

That initial point where the rupture starts is the hypocenter or focus. The rupture then grows, both towards to the surface and in one or two directions along the fault. In the 1906 earthquake, rupture initiated about two miles off the coast of San Francisco's Sunset District, seven miles beneath the surface. The rupture grew both to the north and south and a speed of several miles per second, reaching as far south as Santa Cruz in 18 seconds and making it to Cape Mendocino to the north in just over two minutes for a total rupture length of 275 miles.

The whole time the rupture grows, it produces seismic waves and it's these waves that you experience as the earthquake. Seismic waves travel a little faster than the rupture. San Franciscans in 1906 began feeling the shaking almost immediately because they were so close to the initial starting point. They continued to feel shaking for about a minute as the rupture propagated away from them to both the north and the south. By the time the rupture made it to Humboldt County, it was too far away from San Francisco to be felt. In Santa Cruz, it took about 15 seconds after the rupture began for people to begin feeling it, but once the seismic waves arrived, the shaking was just about as strong and lasted nearly as long as in San Francisco.

The USGS animation of the 1906 rupture (https://earthquake.usgs.gov/education/shakingsimulations/1906/) gives a feel for both the time lag and the shaking duration in different parts of the SF Bay Area. In very large earthquakes like 1906, it's not how close you are to the epicenter that is important but how near you are to the rupturing fault. The entire 250 mile-long fault rupture from Santa Cruz to Humboldt County was the source and it didn't matter whether you were in San Francisco, Santa Cruz, Santa Rosa or Shelter Cove – you were all very close to the fault and you all experienced strong shaking that lasted a long time.

Last week I recalled the 1992 Cape Mendocino earthquake. Counting the shaking duration accomplished two things. First, it gave my mind something to focus on during the shaking and helped to calm me down. It also gave me a rough idea of magnitude. Shaking that lasts only a few seconds is probably a magnitude 3 or 4. When I counted to 72 in 1992, I was pretty sure this earthquake was a in the upper 6 to mid 7 range.

Magnitude is a key to tsunami danger. Most tsunamis are caused by large magnitude earthquakes beneath the sea floor. The fault slip deforms the sea floor causing an area to drop or rise and suddenly displacing the ocean water above it. This water bulge or depression propagates outward as a tsunami. The larger magnitude, the greater the deformed area and the bigger the tsunami.

Tsunamis are tricky. Don't equate large magnitude with feeling strong shaking. Some deadly tsunamis were produced by earthquakes that didn't feel very strong. In October 2010, an earthquake occurred off the coast of Central Sumatra, Indonesia. It had a magnitude of 7.8 and survivors said it wasn't nearly as strong as other recent earthquakes they had experienced. But they did not that the weak shaking lasted a very long time. It is an example of a "tsunami earthquake," an earthquake that produces a much larger tsunami than expected from its strength. The long duration is the important clue that the rupture area was large.

Shaking that lasts a few seconds, even if the jolts are very sharp, means small magnitude and no tsunami. Shaking that lasts a very long time, even if weak, means potential big trouble and time to head to high ground if you are at the coast or in a tsunami zone. Not sure? We always say "when in doubt, drill it out," treat it as the real thing and practice your evacuation skills.

Note: While in theory magnitude is a single number, in practice there can be small variations. There are different ways of calculating magnitude and seismic groups access different groups of instruments often resulting in slightly different magnitude numbers. It is not unusual for initial magnitude estimates to change by several decimal points and further analysis is completed.

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