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Not My Fault: New tsunami threat to California?

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A paper was published this month in the Proceedings of the National Academy of Sciences. It proposed a new mechanism for generating tsunamis that has possible implications for California. The paper, "Anatomy of Strike-Slip Fault Tsunami-genesis," was led by Ares Rosakis at CalTech and included tsunami modelers and fault rupture experts.

The prevailing wisdom is that earthquakes on strike-slip faults, where the ground moves horizontally, are unlikely to produce big tsunamis. There are exceptions but we have usually attributed them to submarine landslides triggered by the shaking.

In September 2018, an earthquake on the Indonesian Island of Sulawesi brought strike-slip tsunamis to the fore (Not My Fault December 19, 2018). The M7.5 earthquake triggered both strong ground shaking and a tsunami that reached at least twenty feet high, killing more than 4300 people. Faulting was strike-slip and there was head scratching over how the tsunami was formed.

Geography clearly played a role. The earthquake rupture extended nearly 150 miles along western Sulawesi. Palu Bay is a deep 19-mile-long narrow body of water, and it was in the center of the rupture zone. The large tsunami waves were confined to the shores of the Bay, quickly becoming negligible outside of it.

The new Rosakis paper offers an explanation. Their argument starts with how faults rupture. All quakes start at a single point (the focus) and grow. I use the analogy of a rock hitting a windshield. The impact site is the focus and then the crack proceeds to grow – sometimes in one direction and sometimes in two. In earthquakes, the longer the rupture, the larger the magnitude and the bigger the felt area.

Just like windshield cracks, earthquake faults grow at different speeds. Typically, the speed of fault rupture is a little slower than seismic S-waves, the secondary or shear wave. From a human perspective, it's still very fast, propagating at a few miles per second. The 1906 rupture began just offshore of San Francisco and then sped all the way to Cape Mendocino in about 100 seconds.

A few earthquake ruptures are even faster than the shear wave velocity. Called supershear earthquakes, and just like aircraft breaking the sound barrier, they create a sort of sonic boom. No, you won't hear them, but the pressures are high enough to pulverize rock in the fault zone. This isn't just hypothesis. We can measure how fast faults rupture. At least thirteen large earthquakes since 1999 have qualified as supershear events.

Until now, supershear was more of a scientific curiosity than a potential hazard. There is no evidence that rupture speed influences shaking damage. But the Rosakis paper suggests in some circumstance, a danger lurks underwater.

A tsunami is caused by elevating (or depressing) the entire water column in a body of water. The most common cause is earthquake faulting that uplifts or drops the ocean floor. Submarine volcanic eruptions and landslides can also produce the same result. But tsunamis are also be caused by large-scale pressure variations. In recent years we have become aware of meteotsunamis caused by very large slow-moving low-pressure systems that cause a water column to rise. The pressure anomalies caused by such systems are responsible for several modest tsunamis in the past decade including six in the US since 2000.

The mechanism proposed by Rosakis team also calls for pressure as the source of water displacement. Supershear produces a high-pressure Mach cone at the rupture front. In the deep ocean, such pressure would quickly dissipate with no adverse effect. But in a deep shallow bay like Palu, "The sides of the bay focus and direct the supershear rupture's energy, much like the walls of a bathtub direct bathwater sloshed around by a child. After that initial mega-jolt sends water sloshing vertically, gravity takes over and a tsunami is created," according to the CalTech press release.

This new study won't change the hazard assessment for the North Coast. Humboldt Bay is too shallow and Crescent Bay has the wrong shape. There is one place in California that at first glance looks like Palu. Tomales Bay is long and narrow, and the San Andreas fault runs right beneath it. There are significant differences, however. Tomales is shallow. We are also pretty sure that no tsunami was produced in Tomales Bay in the 1906 earthquake, now thought by some to have been a supershear rupture, when some of the largest strike-slip displacement ever measured occurred right under the Bay.

What about other areas of the state? The California Geological Survey is the State Agency responsible for compiling State tsunami hazard maps and the second generation of state maps are almost complete (see https://www.conservation.ca.gov/cgs/tsunami/maps). They have looked at the potential of strike-slip faults to produce tsunamis but the supershear concept is new. My guess is that the Rosati paper will cause tsunami modelers to look more closely at the proposed mechanism and run independent models to see if it stands up to scrutiny.

California tsunami maps are worst-case scenarios, based on the largest credible tsunami threat to each part of the state. A tsunami caused by a ~M9 earthquake on the Cascadia subduction zone is the biggest threat to Humboldt and Del Norte Counties. In other areas the greatest threat comes from Alaska or the Aleutian Islands. The State team will certainly be looking at the new modeling closely, but unless it reveals a greater threat than the existing studies, it won't show up on new maps.

The public safety message remains unchanged. Whenever you feel an earthquake near the coast, especially if the shaking lasts a long time, assume a tsunami is coming and move to high ground. In the 2018 Sulawesi earthquake, a festival had brought many people to Palu. Many were from inland areas and might not have recognized that the shaking was their warning to get away from the coast. Evacuate first and ask questions later! If no tsunami resulted, consider it a successful drill that will help to save you next time.

Note: Read about the recent study at:
https://www.caltech.edu/about/news/contrary-to-previous-belief-strike-slip-faults-can-generate-large-tsunamis.

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