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Not My Fault: A very large aftershock reminder that the Kamchatka earthquake sequence is not over

Lori Dengler for the Times-Standard

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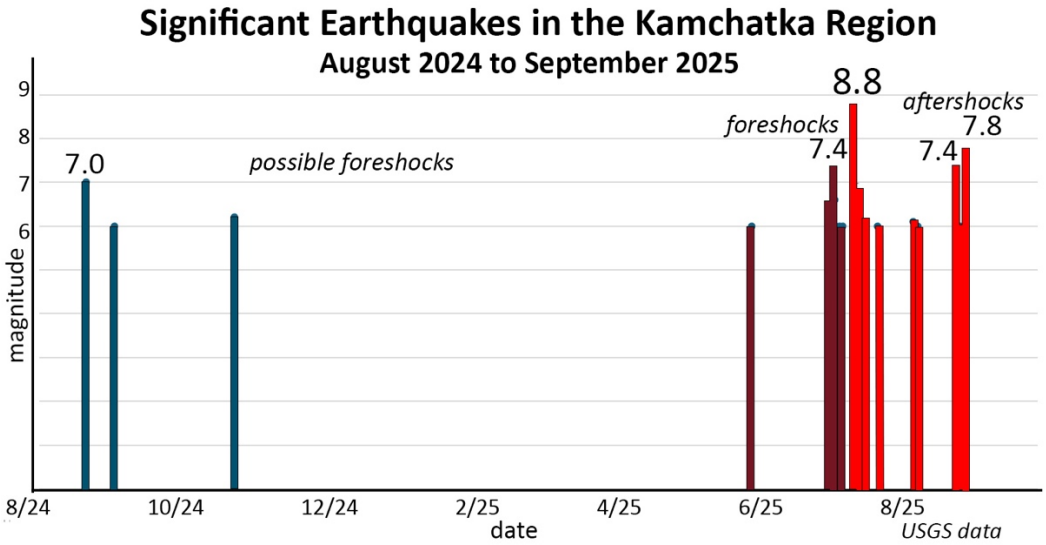

A timeline of the magnitude 6 and larger earthquakes in the Kamchatka sequence. The dark blue lines in 2024 are possible foreshocks and the purple lines in 2025 are when the rate of earthquake activity significantly increased and produced a M7.4. The M8.8 mainshock and aftershocks are shown in red, including this week's M7.4 and 7.8. There are numerous smaller earthquakes not shown on this graph (USGS data).

It's been nearly two months since the largest earthquake of the past 14 years ripped 450 miles of the Kuril Kamchatka trench in the northwestern Pacific. It caused strong shaking in Kamchatka and spawned a tsunami that was recorded in much of the Pacific. Since July 29th, there have been a steady stream of aftershocks that until this week appeared to be slowly declining. Last Saturday that trend was interrupted by a magnitude 7.4 and on Thursday, a magnitude 7.8, becoming the two largest aftershocks of the sequence to date.

The Kamchatka earthquake is important for many reasons. Earthquakes of magnitude 8.5 and larger are rare beasts on our planet and only 17 have been recorded since the era of seismographs beginning in the late 19th century. The Kamchatka mainshock is currently tied for 6th place on the list of the largest earthquakes of all times.

Since the Kamchatka mainshock, scientists from around the world have been looking more closely at the earthquake and tsunami data, using it to test models of fault rupture, ground motion, and the tsunami characteristics. More information is available on damage and

response both in the epicentral region and areas around the Pacific. I'll elaborate on several of these aspects today and in next week's column.

• The Kamchatka earthquake was preceded by a long duration and unusually vigorous foreshock sequence

July 29th wasn't the first time a very large earthquake struck the Kamchatka region. In November 1952, a M9.0 earthquake ruptured this same area of the Kamchatka Kuril trench and paleoseismic studies suggest earthquakes of this size or even larger occurred in 1737 and 1841. A recently published paper by Stein and colleagues at Temblor (see link at bottom) puts the recent Kamchatka earthquake into the framework of the earthquake cycle, where every great earthquake lays the groundwork for the next one.

Ten days before the M8.8 earthquake, a spurt of earthquakes began off the east coast of Kamchatka. It started with a 5.0 on July 20th that was followed by a 6.6 and a 7.4 later that day and numerous smaller earthquakes. Over the next nine days, 48 earthquakes between magnitude 5 to 6 and many smaller ones were recorded, a rate nearly six times higher than the mean for a M7.4 earthquake.

Earthquakes may seem a random process to us, shaking our foundations when we least expect them. But they are the result of stresses that have been operating for millennia, finally rupturing the ground when those forces exceed material strength. Earthquakes in Kamchatka, like those in the Pacific Northwest, are the result of complex plate interactions. Plate motions cause deformation and strain to accumulate. When the rock strength is exceeded, earthquake occur. Each large earthquake changes the stress pattern, the fault slip increasing stress in some areas and decreasing it in others, affecting the likelihood of ruptures on adjacent faults and fault segments.

Stein et al. take a longer perspective and argue that foreshocks actually began almost a year earlier when a M7.0 struck in August of 2024. That earthquake was located in the same area as the epicenters of the 2025 earthquakes. But the rate of smaller earthquake activity didn't accelerate until July 2025, so those earthquakes alone don't clearly presage a much larger quake to follow.

How to tell if a particular earthquake foreshadows something much larger is one of the perplexing problems of seismology. Certainly, the higher-than-average aftershock rate is a reason to raise eyebrows, and similar high rates have been seen after other large earthquakes such as the M6.2 Joshua Tree quake in 1992 which preceded the M7.3 Landers quake on the same fault system by two months. But there is a wide range of aftershock activity rates following large quakes that don't turn out to be foreshocks. The Temblor study suggests more detailed analysis of the stress changes could lead to an answer.

• Earthquake shaking caused relatively little damage to the built environment

Unlike most large earthquakes or tsunamis, there has been no flood of outside experts into Kamchatka to study the earthquake and tsunami impacts. But much can be ascertained by remote assessment and Russian scientists and engineers have communicated some findings with international colleagues. The larger earthquakes in the sequence were widely felt and the M7 and larger events caused some damage, but even the M8.8 mainshock caused only moderate damage and few injuries.

There was damage but it was almost all non-structural. Part of an airport ceiling collapsed in Petropavlovsk and more than 1,400 homes reported cracks in walls and facades. Pipelines and roads suffered cracks, telephone and utility services disrupted. In Severo-Kurilsk, the largest town in the northern Kuril Islands just south of Kamchatka nearly 90% of chimneys toppled and some damage was reported to apartment buildings and other structures.

There were no deaths and few injuries caused by shaking, and damage was far less than the catastrophic M6.0 Afghanistan earthquake on August 31 with its estimated death toll of 3000. There are several reasons, the first is location. The Kamchatka earthquake was roughly 80 miles away from populated centers, the Afghanistan quake almost beneath the third largest city in the country. Distance from the source not only reduces the shaking strength but also filters out the higher frequencies more likely to damage structures. The difference is also a testament to engineering and a built environment that much more resilient to ground shaking than Afghanistan. Most larger buildings in Kamchatka are constructed to codes not much different than those in California and smaller buildings are wood frame, far more earthquake resilient than the adobe and stone structures in Afghanistan.

• Aftershocks to date

In seismology, it's a general rule that larger the mainshock, the more robust the aftershock sequence. Robust means a larger area, more events, and larger magnitudes. By my rough tally, there have been 345 aftershocks of magnitude 5 and larger in the vicinity of the July 29th rupture zone. The rupture zone was over 450 miles in length and aftershocks are occurring through this area and at the ends. The largest aftershocks to date occurred this week – a 7.4 a week ago and a 7.8 on Thursday. It's not at all unusual for large aftershocks to happen weeks or months after the mainshock, and Kamchatka has proven that point.

Aftershocks are earthquakes in their own right, no different in their capacity to produce strong shaking, ground deformation, or produce tsunamis than any stand-alone earthquake of similar magnitude. Both of these M7s caused tsunami assessments by the U.S. tsunami warning centers and the 7.8 triggered a tsunami threat message for Russian coastlines with 600 miles of the epicenter and an Advisory for the western Aleutian Islands. Other U.S. States and territories including the West Coast were never deemed at risk. A modest tsunami was produced, estimated a 2 feet high in Kamchatka but not large enough to cause damage.

Have we seen the largest aftershocks? I can't predict the future so it's not possible to say. Another rule of thumb I was taught in grad school is that the largest aftershock is typically about one magnitude unit less than the mainshock, so there's a good chance that this week's M7.8 will fit the bill. But nature is capable of surprises so I wouldn't rule out more M7s.

Next week a closer look at the Kamchatka tsunami and why it didn't cause more damage.

For more on foreshock modeling see
https://temblor.net/earthquake-insights/huge-july-2025-kamchatka-earthquake-follows-unusually-productive-foreshock-sequence-16866/
I am giving a free webinar about the Kamchatka earthquake and tsunami next Thursday at 1 p.m. Go to https://cascadiaquakes.org/2025/09/08/clip-webinar-series-2025-26/ for information on how to sign up.

Lori Dengler is an emeritus professor of geology at Cal Poly Humboldt, and 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 or to request copies of the preparedness magazine "Living on Shaky Ground."