Paired earthquakes separated in time and space

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Earthquakes occurring at the edges of tectonic plates can trigger events at a distance and much later in time, according to a team of researchers reporting in today's issue of *Nature*. These doublet earthquakes may hold an underestimated hazard, but may also shed light on earthquake dynamics.

"The last great outer rise earthquakes that occurred were in the 1930s and 1970s," said Charles J. Ammon, associate professor of geoscience, Penn State. "We did not then have the equipment to record the details of those events." The outer rise is the region seaward of the deep-sea trench that marks the top of the plate boundary

In late 2006 and early 2007, two large earthquakes occurred near Japan separated by about 60 days. These earthquakes took place in the area of the Kuril Islands that are located from the westernmost point of the Japanese Island of Hokkaido to the southern tip of the Kamchatka Peninsula. The first event took place on Nov. 15, 2006 when the edge of the Pacific plate thrust under the arc of the Kuril Islands, initiating a magnitude 8.3 event and causing some damage in Japan and a small tsunami that caused minor damage in Crescent City, California. About 60 days later, on Jan. 13, 2007, a magnitude 8.1 earthquake occurred in "the upper portion of the Pacific plate, producing one of the largest recorded shallow extensional earthquakes."

This second earthquake was not at a plate boundary and was not directly caused by subduction -- the moving of one plate beneath the other.

Rather, it was a normal faulting event, where the Pacific plate stretched, bent and broke.

While Japan and the Kamchatka Peninsula are active earthquake areas, the region of the Kuril Islands where the large November earthquake occurred, had not had a large earthquake since 1915 and researchers are unsure of the exact nature of that event.

Working with Hiroo Kanamori, the John E. and Hazel S. Smits professor of geophysics, emeritus, California Institute of Technology, and Thorne Lay, professor of Earth & planetary sciences, University of California, Santa Cruz, the Penn State researcher looked at the sequence of seismic activity that link these two earthquakes into a doublet.

"Such large doublet earthquakes, though rare, could be an underestimated hazard," says Ammon. "We are also interested in what these events tell us about how earthquakes interact, how the stresses and interactions allow one earthquake to trigger another."

Looking at the seismic record, the researchers found a series of smaller, foreshock earthquakes beginning about 45 days before Nov. 15. On Nov. 15, there was the magnitude 8.3 earthquake on the plate boundary, the largest event of 2006.

"Within minutes of the Nov. 15 earthquake, seismic activity began on the Pacific plate in the area where the January earthquake would take place," says Ammon. "This large second earthquake generated a larger amplitude of shaking in the frequency range that affects human-made structures than the first earthquake."

Usually, aftershocks from a large earthquake are at least one order of magnitude less than the main event and taper off rapidly. In this case, the events within the Pacific plate east of the plate boundary did not taper

off, and the second event that occurred in January was about the same size as the first earthquake.

Earthquakes at plate boundaries in subduction zones occur when the plate that is going under – being subducted – gets temporarily stuck and causes compression in the plate away from the edge. Tension builds and when the plate overcomes the friction holding it, it moves downward, slipping under the top plate and causing an earthquake. According to the researchers, the second earthquake that occurred on the Pacific plate happened because of bending experienced by the pacific plate that occurs before it subducts beneath the upper plate. As the front edge of the plate slipped, the plate east of the November earthquake bent, cracked and broke in January.

Like pie crust, when the Earth's crust bends, small cracks begin to appear – these were the small shocks that began immediately after the first earthquake – but when the bending becomes severe, a larger region of the crust breaks – creating the second, very large event.

In the United States, subduction zones exist only in the Pacific Northwest, Alaska and the area around Puerto Rico. The researchers note, "Triggering of a large outer rise rupture with strong high-frequency shaking constitutes an important potential seismic hazard that needs to be considered in other regions."

Source: Penn State