Scientists underestimated potential for Tohoku quake. Now what?

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The massive Tohoku, Japan, earthquake in 2011 and Sumatra-Andaman superquake in 2004 stunned scientists because neither region was thought to be capable of producing a megathrust earthquake with a magnitude exceeding 8.4.

Now earthquake scientists are going back to the proverbial drawing board and admitting that existing predictive models looking at maximum earthquake size are no longer valid.

In a new analysis published in the journal *Seismological Research Letters*, a team of scientists led by Oregon State University's Chris Goldfinger describes how past global estimates of earthquake potential were constrained by short historical records and even shorter instrumental records. To gain a better appreciation for earthquake potential, he says, scientists need to investigate longer paleoseismic records.

"Once you start examining the paleoseismic and geodetic records, it becomes apparent that there had been the kind of long-term plate deformation required by a giant earthquake such as the one that struck Japan in 2011," Goldfinger said. "Paleoseismic work has confirmed several likely predecessors to Tohoku, at about 1,000-year intervals."

The researchers also identified long-term "supercycles" of energy within plate boundary faults, which appear to store this energy like a battery for many thousands of years before yielding a giant earthquake and releasing the pressure. At the same time, smaller earthquakes occur that do not dissipate to any great extent the energy stored within the plates.

The newly published analysis acknowledges that scientists historically may have underestimated the number of regions capable of producing major earthquakes on a scale of Tohoku.

"Since the 1970s, scientists have divided the world into plate boundaries that can generate 9.0 earthquakes versus those that cannot," said Goldfinger, a professor in OSU's College of Earth, Ocean, and Atmospheric Sciences. "Those models were already being called into question when Sumatra drove one stake through their heart, and Tohoku drove the second one.

"Now we have no models that work," he added, "and we may not have for decades. We have to assume, however, that the potential for 9.0 subduction zone earthquakes is much more widespread than originally thought."

Both Tohoku and Sumatra were written off in the textbooks as not having the potential for a major earthquake, Goldfinger pointed out.

"Their plate age was too old, and they didn't have a really large earthquake in their recent history," Goldfinger said. "In fact, if you look at a northern Japan seismic risk map from several years ago, it looks quite benign – but this was an artifact of recent statistics."

Paleoseismic evidence of subduction zone earthquakes is not yet plentiful in most cases, so little is known about the long-term earthquake potential of most major faults. Scientists can determine whether a fault has ruptured in the past – when and to what extent – but they cannot easily estimate how big a specific earthquake might have been. Most, Goldfinger says, fall into ranges – say, 8.4 to 8.7.

Nevertheless, that type of evidence can be more telling than historical records because it may take many thousands of years to capture the full range of earthquake behavior.

In their analysis, the researchers point to several subduction zone areas that previously had been discounted as potential 9.0 earthquake producers – but may be due for reconsideration. These include central Chile, Peru, New Zealand, the Kuriles fault between Japan and Russia, the western Aleutian Islands, the Philippines, Java, the Antilles Islands and Makran, Pakistan/Iran.

Onshore faults such as the Himalayan Front may also be hiding outsized earthquakes, the researchers add. Their work was supported by the National Science Foundation.

Goldfinger, who directs the Active Tectonics and Seafloor Mapping Laboratory at Oregon State, is a leading expert on the Cascadia Subduction Zone off the Pacific Northwest coast of North America. His comparative studies have taken him to the Indian Ocean, Japan and Chile, and in 2007, he led the first American research ship into Sumatra waters in nearly 30 years to study similarities between the Indian Ocean subduction zone and Cascadia.

Paleoseismic evidence abounds in the Cascadia Subduction Zone, Goldfinger pointed out. When a major offshore earthquake occurs, the disturbance causes mud and sand to begin streaming down the continental margins and into the undersea canyons. Coarse sediments called turbidites run out onto the abyssal plain; these sediments stand out distinctly from the fine particulate matter that accumulates on a regular basis between major tectonic events.

By dating the fine particles through carbon-14 analysis and other methods, Goldfinger and colleagues can estimate with a great deal of accuracy when major earthquakes have occurred. Over the past 10,000 years, there have been 19 earthquakes that extended along most of the Cascadia Subduction Zone margin, stretching from southern Vancouver Island to the Oregon-California border.

"These would typically be of a magnitude from about 8.7 to 9.2 – really huge earthquakes," Goldfinger said. "We've also determined that there have been 22 additional earthquakes that involved just the southern end of the fault. We are assuming that these are slightly smaller – more like 8.0 – but not necessarily. They were still very large earthquakes that if they happened today could have a devastating impact."

Provided by Oregon State University

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