Stress buildup precedes large Sumatra quakes

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The island of Sumatra, Indonesia, has shaken many times with powerful earthquakes since the one that wrought the infamous 2004 Indian Ocean tsunami. Now, scientists from the California Institute of Technology and the Indonesian Institute of Sciences are harnessing information from these and earlier quakes to determine where the next ones will likely occur, and how big they will be.

Mohamed Chlieh, the lead author of a new report, looked at the region during his postdoctoral studies at Caltech with Jean-Philippe Avouac, professor of geology and director of Caltech's Tectonics Observatory (TO) and Kerry Sieh, Sharp Professor of Geology. They found that in the time between great earthquakes, some portions of the fault zone locked up while others crept along steadily, and the portions that were locked in the past few decades coincided with portions that rupture to produce large-magnitude quakes. The correlation was especially strong for two temblors of magnitude 8.7 that struck the region in 1861 and again in 2005.

The study also reveals which part of the Sumatra megathrust is storing strain that will be released during future large earthquakes.

Earthquakes in Sumatra are the manifestation of a sudden release of strain that constantly builds as the plates beneath the Indian Ocean creeps steadily toward southeast Asia and dive into the subduction zone under the island. If the total tectonic plate motion in the region is not taken up by fault slip during earthquakes, then a deficit builds until the next earthquake rupture. The patch of the fault where slip is greatest during an earthquake and releases the most pent-up strain, known as an asperity, also gets stuck between quakes. The scientists were interested in what was happening at the land surface, above these asperities, between big earthquakes.

Investigations by Caltech scientists in the region began when Sieh and his students started documenting the history of subsidence and emergence of the islands offshore Sumatra using the record provided by coral heads. Later on, a network of geodetic stations was deployed by the TO. To measure how strain built up in the calm interseismic period between earthquakes, Chlieh and his colleagues analyzed GPS measurements collected since 1991 and annual banding in corals from the past 50 years.

Coral growth bands indicate vertical land motion because as the seafloor on which corals live shifts down or up, the creatures either grow to chase sunlight from below water or die back when elevated above water. Both the bands and the GPS data record small land-position shifts in interseismic periods. In contrast, they show drastic shifts during an earthquake, as the corals typically die when they are thrust high enough above or sunk too deep below sea level to survive.

The data provide a record of unevenly distributed deformation of the land surface directly above the subduction zone during the interseismic period. Modeling further indicates that this results from the asperities along the plate interface, while other parts remain smoothly slipping. These interseismic asperities are 10 times as wide--up to 175 kilometers--in the region where great earthquakes have occurred in the past.

"Our model shows asperities exactly at the same places that the 2005 Nias and the 1797 and 1833 earthquakes in the Mentawai islands occurred, indicating that aperities seem to be persistent features from one seismic cycle to another," Chlieh remarks. Avouac adds, "This is clear indication that the characteristics of large earthquakes are somewhat determined by properties of the plate interface that can be gauged in advance from measuring interseismic deformation.

"A priori, large earthquakes should not be expected where the plate interface is creeping, but are inescapable where it is locked. So it seems that we can, with interseismic observations, see these asperities before the earthquake occurs," he says. "The question now is, 'How well are we able to estimate the characteristics of the earthquakes that these asperities could produce?'"

The implications of the study are major, according to Chlieh. "Using the asperity locations, we may be able to construct some more realistic earthquake and tsunami models following different scenarios. Then we will have a good idea of the risk induced by these locked fault zones."

The study appears in the May issue of the *Journal of Geophysical Research*. Other authors on the paper are Danny Natawidjaja, a former Caltech grad student who is now at the Indonesian Institute of Sciences, and John Galetzka, staff geodesist with the TO.

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