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{Editors: Graphics and other information are available at http://www.tectonics.caltech.edu/sumatra/Science/index.html}

Fault That Produced Largest Aftershock Ever Recorded Still Poses Threat to Sumatra

PASADENA, Calif.—A mere three months after the giant Sumatra-Andaman earthquake and tsunami of December 2004, tragedy struck again when another great earthquake shook the area just to the south, killing over 2,000 Indonesians. Although technically an aftershock of the 2004 event, the 8.7-magnitude Nias-Simeulue earthquake just over a year ago was itself one of the most powerful earthquakes ever recorded. Only six others have had greater magnitudes.

In the March 31 issue of the journal *Science*, a team of researchers led by Richard Briggs and Kerry Sieh of the California Institute of Technology reconstruct the fault rupture that caused the March 28, 2005, event from detailed measurements of ground displacements. Their analysis shows that the fault broke along a 400-kilometer length, and that the length of the break was limited by unstrained sections of the fault on either end.

The researchers continue to express concern that another section of the great fault, south of the 2005 rupture, is likely to cause a third great earthquake in the not-too-distant future. The surface deformation they observed in the 2005 rupture area may well be similar to what will occur when the section to the south ruptures.

Briggs, a postdoctoral scholar in Caltech's new Tectonics Observatory, and his colleagues determined the vertical displacements of the Sumatran islands that are directly over the deeply buried fault whose rupture generated the 2005 earthquake. The main technique they used was the examination of coral heads growing near the shore. The tops of these heads stay just at the waterline, so if they move higher or lower, it indicates that there has been uplift or subsidence.

The researchers also obtained data on ground displacements from GPS stations that they had rushed into place after the 2004 earthquake. "We were fortunate to have installed the geodetic instruments right above the part that broke," says Kerry Sieh, who leads the Sumatran project of Caltech's Tectonics Observatory. "This is the closest we've ever gotten to such a large earthquake with continuously recording GPS instruments."

From the coral and GPS measurements, the researchers found that the 2005 earthquake was associated with uplift of up to three meters over a 400-kilometer stretch of the Sunda megathrust, the giant fault where Southeast Asia is overriding the Indian and Australian plates. This stretch lies to the south of the 1600-kilometer section of the fault that ruptured in 2004.

Actual slippage on the megathrust surface (about 25 kilometers below the islands) was over 11 meters. The data permitted calculation of the earthquake's magnitude at 8.6, nearly the same as estimates based on seismological recordings.

Most of the deaths in the 2005 earthquake were the direct result of shaking and the collapse of buildings. The earthquake did not trigger a disastrous tsunami comparable to the one that followed the 2004 event. In part, this was because the 2005 rupture was smaller—about one-quarter the length and one-half the slip.

In addition, the largest uplift lay under offshore islands, where there was no water to be displaced. Finally, by rising during the earthquake, the islands gained some instant, extra protection for when the tsunami reached them tens of minutes later.

The scientists were surprised to find that the southern end of the 2004 rupture and the northern end of the 2005 rupture did not quite abut each other, but were separated by a short segment under the island of Simeulue on which the amount of slip was nearly zero. They infer that this segment had not accumulated enough strain to rupture during either event—perhaps, they speculate, because it slips frequently and therefore relieves strain without generating large earthquakes.

Thus, this segment might act as a barrier to rupture propagation. A similar 170-kilometer "creeping" section of the San Andreas fault, between San Francisco and Los Angeles, separates the long section that produced Northern California's great 1906 earthquake from the long section that ruptured during Southern California's great 1857 earthquake.

The southern end of the 2005 rupture was at another short "creeping" segment or weak patch. "Both ends of the 2005 rupture seem to have been at the edges of a weak patch," Sieh explains. The 2005 event therefore probably represents a "characteristic earthquake" that has recurred often over geological time. In fact, old historical records suggest that a very similar earthquake was caused by a rupture of this segment in 1861.

Sieh suggests that installation of GPS instruments along the world's other subduction megathrusts could help more clearly to define those sections that creep stably versus the segments that are locked and thus more likely to break in infrequent, but potentially devastating, ruptures.

Previous work by the Caltech group and their Indonesian colleagues has shown that south of the southern creeping segment lies another locked segment, about 600 kilometers long, which has not broken since a magnitude 9.0 earthquake in 1833. Corals and coastlines along the southern segment record decades of continual, pronounced subsidence, similar to the behavior of the northern region prior to its abrupt uplift during the 2005 fault rupture.

“This southern part is very likely about ready to go again,” Sieh says. “It could devastate the coastal communities of southwestern Sumatra, including the cities of Padang and Bengkulu, with a combined population of well over a million people. It could happen tomorrow, or it could happen 30 years from now, but I’d be surprised if it were delayed much beyond that.”

Sieh and his colleagues are engaged in efforts to increase public awareness and preparedness for future great earthquakes and tsunamis in Sumatra.

The *Science* paper is titled “Deformation and slip along the Sunda megathrust in the great 2005 Nias-Simeulue earthquake.” The other authors are Aron Meltzner, John Galetzka, Ya-ju Hsu, Mark Simons, and Jean-Philippe Avouac, all at Caltech's Tectonics Observatory; Danny Natawidjaja, Bambang Suwargadi, Nugroho Hananto, and Dudi Prayudi, all at the Indonesian Institute of Sciences; Imam Suprihanto of Jakarta; and Linette Prawirodirdjo and Yehuda Bock at the Scripps Institution of Oceanography.

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