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Nature of the proto-décollement in the 2010 Mentawai tsunami earthquake rupture zone from full waveform inversion of seismic reflection data

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Since the beginning of the 21st century, three great interplate earthquakes (Mw >8.0) occurred in the Sumatran subduction zone. Although the 2004 Mw 9.2 Sumatra-Adaman earthquake generated a destructive tsunami, the 2005 Mw 8.6 Sumatra and 2007 Mw 8.4 Nias-Simeulue earthquakes did not. However, the 2010 Mw 7.9 Mentawai earthquake generated an unexpectedly powerful tsunami, and was interpreted as a tsunami earthquake. Although the mechanism of larger tsunami generation is not fully understood, rupture of the subduction front, supposed to be aseismic, is inferred to be the cause. In order to assess the tsunami risk in the locked zone of the Mentawai region, north of the 2007 rupture zone, seismic data were recorded in 2009 by CGG, using a 15-km-long streamer. Seismic line CGGV20, designed to cross the 2007 rupture zone, also crossed the southern part of the 2010 rupture zone.

We combined downward continuation, traveltime tomography and full waveform inversion on this 15-km-long streamer and low frequency seismic data. The downward continuation makes it possible to extrapolate the streamer seismic reflection data as it was recorded 200 m above the seafloor at more than 5 km depth. The resolution of the velocity model obtained by traveltime tomography was increased, particularly in the shallow subsurface compared to the conventional method. A reliable velocity model was obtained to use as starting model for the full waveform inversion. The velocity inversion results and the porosity computation highlight a low velocity ($\sim$ 1500 m/s), high porosity ($\sim$ 70%) layer, corresponding to a high amplitude reverse polarity reflector in pelagic sediments, interpreted as a proto-décollement. The up-dip limit of the seismogenic zone might be located at the toe of the accretionary wedge, where the porosity drops to 23% into the decollement. The décollement might allow frontal rupture, which could propagate along active landward and seaward-vergent thrust faults, generating a powerful tsunami by moving the seafloor at depth.