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Direct evidence of frontal rupture during the 2010 Mentawai earthquake, offshore Central Sumatra

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Until very recently, it was commonly accepted that the frontal portions of subduction systems slip aseismically, incapable of rupturing in large or great earthquakes – a paradigm that was challenged during the 2011 Mw=9.0 Tohoku earthquake where up to 70 m of slip occurred near the subduction front (but no faults were imaged on the seafloor). Furthermore, tsunami earthquakes have been suggested to deform the frontal section of subduction zones anelastically, without faulting. Using high-resolution bathymetry, seafloor back-scatter imagery and seismic reflection data, here we report the discovery of a seafloor trace of the 2010 Mentawai earthquake (Mw=7.8), which produced a very large tsunami on Pagai Island, offshore Central Sumatra, and is classified as a tsunami earthquake. This seafloor trace of the rupture coincides with the landward vergent thrust fault (backthrust) of the frontal pop-up (bi-vergent) anticline and can be followed for about 24 km along the subduction front. Although slip on these backthrusts is small (<10 m), their steep dips (50-60º) allow them to be imaged on back-scatter data as fresh scarps. We find that the total vertical uplift along the two frontal pop-ups could be up to 800 m. We suggest that tsunami earthquakes rupture the frontal section of the subduction front, creating steeply dipping pop-up structures that subsequently uplift the water column in the deep trench, thus producing a large localized tsunami. The presence of pop-up structures near the subduction front could be used as a proxy for the tsunamigenic nature of the subduction zone, helping to mitigate tsunami risks.