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The limits of the seismogenic zone in the epicentral region of the 26 Dec. 2004 Great Sumatra-Andaman earthquake: results from a wide-angle seismic (OBS) survey and thermal modeling

F. Klingelhoefer (1), J.X. Dessa (2), M.A. Gutscher (3), D. Graindorge (3), H. Permana (4), A. Chauhan (5), S. Singh (5)

(1) Marine Geosciences, Ifremer, Plouzane, France, (2) Geosciences Azur, Villefranche-sur-mer, France, (3) UMR6538 CNRS/Univ. Bretagne Occidentale, IUEM, Plouzane, France, (4) LIPI, Bandung, Indonesia (5) Dept. of Marine Geosciences, IPG Paris

The 26th December 2004 great Sumatra earthquake (Mw=9.1) is among the 4 largest earthquakes ever recorded and the largest of the last 40 years. It initiated at a depth of 20-30 km and ruptured about 1300 km of the Indo-Australian/Sunda plate boundary, from the vicinity of Simeulue Island up to the north of Andaman Islands. During the SAGER-OBS cruise (R/V Marion Dufresne, July-Aug. 2006) 56 ocean-bottom seismometers were deployed along a SW-NE oriented profile just north of Simeulue Island, in the epicentral area. The profile is 252 km-long, resulting in a 4.6 km instrument interval. A seismic refraction source of 8,300 in3 was used to fire 2170 shots on the profile. Data quality is excellent with useful arrivals to distances up to 180 km from the shot position. A tomographic inversion of 33127 picked first arrivals provides constraints on the deep structure of the source region of the great earthquake.

At the seaward end of the model, 4-5 km of sediments seem to overlie the oceanic crust at the trench, most likely consisting of trench fill and older hemi-pelagic sediments. The subducting oceanic slab can be imaged down to a depth of 25 km, more than 100 km landward from the trench. Based on seismic velocities, there is no evidence of a crystalline backstop up to 120 km from the trench axis, below the fore-arc basin. Thus, a significant portion of the seismogenic interplate consists of a contact between ancient accreted sediments and the downgoing plate. A high velocity zone at the lower landward limit of the ray-covered domain, at about 23 km depth, may indicate a shallow continental/forearc Moho. This observation implies that the 2004 megathrust earthquake nucleated on a portion of the plate contact that lies between the upper surface of the downgoing plate and the fore arc mantle.

The deep crustal structure obtained from the seismic velocity model was used to construct a finite-element model of the fore-arc thermal structure. Thermal modeling was performed to predict the updip and downdip limits of the seismogenic zone. Model parameters included a 60 Ma old oceanic lithosphere, an orthogonal velocity of 3cm/yr) and induced convection in the mantle wedge. The upper limit (controlled by the 100-100˚C isotherms) is located close to the trench (within 10-50 km). This is due to the insulating effect of the thick sedimentary cover at the trench. This updip limit is in good agreement with the observation of numerous aftershocks with a shallow thrusting mechanism in this zone. The 350˚C and 450˚C isotherms, which are considered to correspond to the downdip limit, are located 220 km and 260 km, respectively, from the trench axis. Aftershocks are observed up to a distance of 220km from the trench, in the vicinity of the plate boundary fault plane. The thermally predicted downdip limit (at about 40 km depth), is well below the forearc crust. The thermal model together with the aftershock distribution and crustal model implies that a significant portion ($>$50 km) of the rupture occurred along the interface between the oceanic crust of the downgoing plate and the fore-arc mantle of the upper plate. The thermal model predicts a large downdip width of the seismogenic zone (about 200km), which can partly explain the great contribution to seismic moment, due to the large surface area of the fault.