Asperities and Barriers along the Sumatra Subduction Zone

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Abstract

Unique record of interseismic strain accumulation in the outer-arc Mentawai islands of West Sumatra is used to understand fundamental features of the Sunda megathrust seismogenic zone, creator of giant earthquakes. In the wake of the two giant 2004 and 2005 seismic ruptures, it is crucial to localize asperities on the southern adjacent Mentawai segment. The secular motion of the Sunda Shelf relative to the Australia plate is partitioned into 23 mm/yr trench-parallel and 42-48 mm/yr trench-normal motion absorbed respectively by the Great Sumatra Fault and the Sunda megathrust. Vertical rates of deformation recorded in coral microatolls growth rings over the past half-century and horizontal velocities measured by Global Positioning System (GPS) between 1991-2004 show high gradients of deformation in the area of the recent 2005 Nias earthquake and in the southern adjacent Mentawai segment. These gradients are well explained by a strong coupling around asperities in the seismogenic locked fault zone (LFZ) and its surrounding creeping areas. The width of the LFZ is at a minimum value of ~50 km near the Equator and increases to about 200 km farther south. We show that this lateral variation of the LFZ width is related to structural irregularities associated with the subduction of the Investigator Fracture Zone and steady state thermal structure of the megathrust. Using a kinematic model, we show how the age and the normal convergence rate of the subducting megathrust control the thermal structure and its variations. The brittle-ductile transition at the downdip end of the LFZ closely correlates with the 300-400ºC isotherms window. The width variations of the LFZ correlates also well with the past 300 years seismicity. The LFZ width is wider in the areas where great M_w~8-9 earthquakes occurred between the 17^{th} and 19^{th} centuries, than near the Equator where large M_w~7.2-7.7 earthquakes occurred in the 20^{th} century. The LFZ in the Nias segment correlates also well with the area that highly slips since the 28 March the 2005 M_w = 8.7 Nias earthquake. Since a complete seismic cycle occurred on Nias segment that already broke in 1861 in a similar event, the Mentawai segment did not break since the couplet of giant 1797 and 1833 events. The slip deficit accumulated since this couplet is about 7-10m. If it were released now in a single event, it could correspond to Mw ~ 9.0 earthquake.