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Other intraplate earthquakes in the India-Australia plate off Sumatra and Coulomb stress changes for a selection of possible intraplate faults.

Extensional events at the trench wall are located in positive Coulomb stress change areas for receiver faults striking parallel to the trench both off Nicobar Islands (~N180°E) and off Nias (~N135°E) (see Figure A1). Any Aceh or Nias slip distribution that has weak surface displacement does not predict a positive Coulomb stress change in these areas close to the trench toe.

These normal faults are active as a result of extensional bending stresses at the trench wall[46,47] that are unrelated to the NW-SE compression in the Wharton Basin. The strike of the nodal planes shown on Figure A1 is following the trench line orientation. These normal faults are neo-formed faults since the normal fault fabric (N105°E to N110°E) is not perpendicular enough to the trench-normal bending stresses to be reactivated (with the exception of the two southernmost events in 2005, in the Wharton fossil spreading ridge area). Slip on neo-formed reverse faults perpendicular to the NW-SE intraplate P-axis is not favoured by the Aceh and Nias earthquakes (Figure A1), which is in agreement with the historical style of deformation in the Wharton Basin. A minority of thrust faults mechanisms is recorded, while most of the events are strike-slip.

Figure A2 shows increased Coulomb stress change on N110°E oriented vertical planes (right-lateral slip) when compared to N15°E oriented vertical planes (left-lateral slip, Fig. 3) (see main text).

One can notice from figures 3 and A2 that no strike slip earthquake occurred off Nias although the area favours such earthquakes. Pre-existing fracture zones are also present off Nias, but unknown pre-megathrust state of intraplate stress and fault strength probably prevented strike-slip earthquake triggering there. The magnitude of the near-trench Coulomb stress change off Nias is also far from the extreme levels calculated off Aceh (4 to 5 bars).

Viscoelastic relaxation in the asthenosphere and the time delay between the April 2012 intraplate earthquake and the 2004 Aceh and 2005 Nias earthquakes.

If the Aceh (December 2004) and Nias (March 2005) subduction earthquakes triggered the April 2012 intraplate earthquakes, why should there be such a delay between the triggering events and the intraplate earthquakes? Post-seismic viscoelastic relaxation is a possible explanation for earthquakes triggering many years after the main event[48]. We suggest here an explanation based upon our observations of deformation of the upper plate on the other side of the trench, within the Sunda block.

Large subduction earthquakes such as the Aceh earthquake induce coseismic extension both in the overriding plate and in the subducting plate. In the overriding plate, it is possible to measure by GPS not only the coseismic deformation[27] but also the postseismic deformation [33,49,50,51]. For example the Northern tip of Sumatra (UMLH), Phuket and Bangkok had in 2008 SW velocities of respectively 13.5, 5 and 1.7 cm/yr [31]. These GPS observations clearly demonstrate that the Sunda plate continues to stretch during the postseismic phase i.e. that the deviatoric stress continues to increase within the Sunda block several years after the earthquakes.

Since no geodetic measurement is available on the subducting plate, one may rely on the physical model used to explain the postseismic data for the overriding plate. Fleitout et al.[33] and Satirapod et al.[50] use a 3D finite-element model to determine the rheological parameters which best explain post-seismic deformation in the Sunda plate. Models featuring viscoelastic relaxation in the asthenosphere plus some afterslip on the subduction interface during the months following the earthquake provide very good fits to the GPS data. The best fit is obtained for a viscosity in the asthenosphere of the order of $3x10^{18}$ Pas and a Burgers rheology is preferred (these values are close to those independently obtained by Panet et al.[49] or Hu & Wang[51]; see Methods for the complete description of the Burgers body) .

To illustrate in a simple way what may occur in the subducting plate, we present here the results of a 2D finite-element model (Figure A3) featuring rheological parameters similar to those used in the 3D Fleitout et al. simulations. The model considers not a single earthquake but a seismic cycle with periodic earthquakes[44,52], with a period chosen equal to 170 yrs. The velocities 2 and 5 years after the earthquake as a function of distance to the trench are plotted on figure A4. According to this model, not only the overriding plate but also the subducting plate continues to stretch several years after an earthquake. The deviatoric stresses in both plates increase. The horizontal stress at distances of 150 km (Mw 8.6 location) and 300 km (Mw 8.2 location) from the trench is represented on figure A5 as a function of time, during a seismic cycle. The deviatoric stress increases for about 10 years, then levels off before decreasing. In cases where a Maxwell instead of a Burgers rheology is used, the phase of extension of the lithosphere before the interseismic phase of compression is found to be somewhat longer. Note also that the peak in deviatoric stress occurs later for points further away from the trench.

This simple model suggests that shear and unclamping stresses onto N20°E faults in the region of the April 2012 earthquakes are expected to continue to grow for about 10 yrs after Aceh and Nias earthquakes as a consequence of viscoelastic relaxation in the asthenosphere. The stress induced by a subduction earthquake in the overriding and subducting plates is predicted to be maximum several years after the earthquake and this may be the most favourable period to trigger an intraplate earthquake.

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Supplementary Figures:

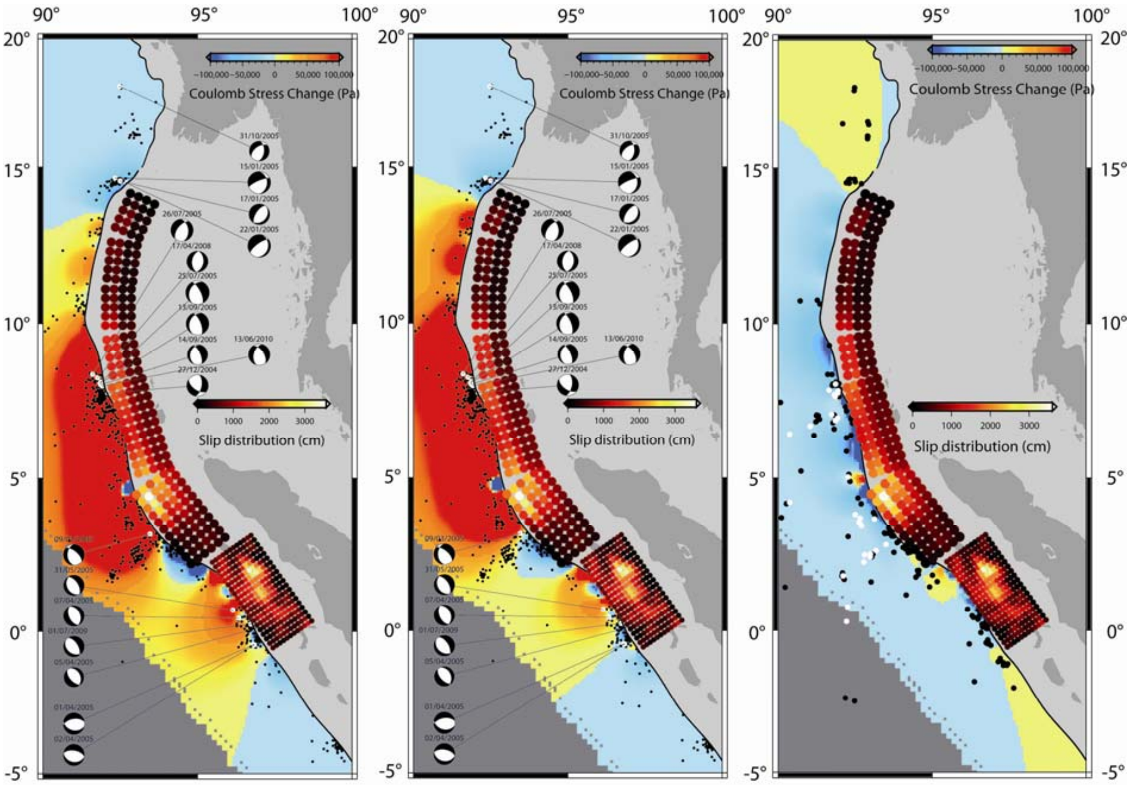

Figure A1 : Coulomb stress change calculations performed for N135°E oriented normal faults with a 60° dip (left), N180°E oriented normal faults with a 60° dip (center) and for N45°E oriented reverse faults with a 45° dip (right).

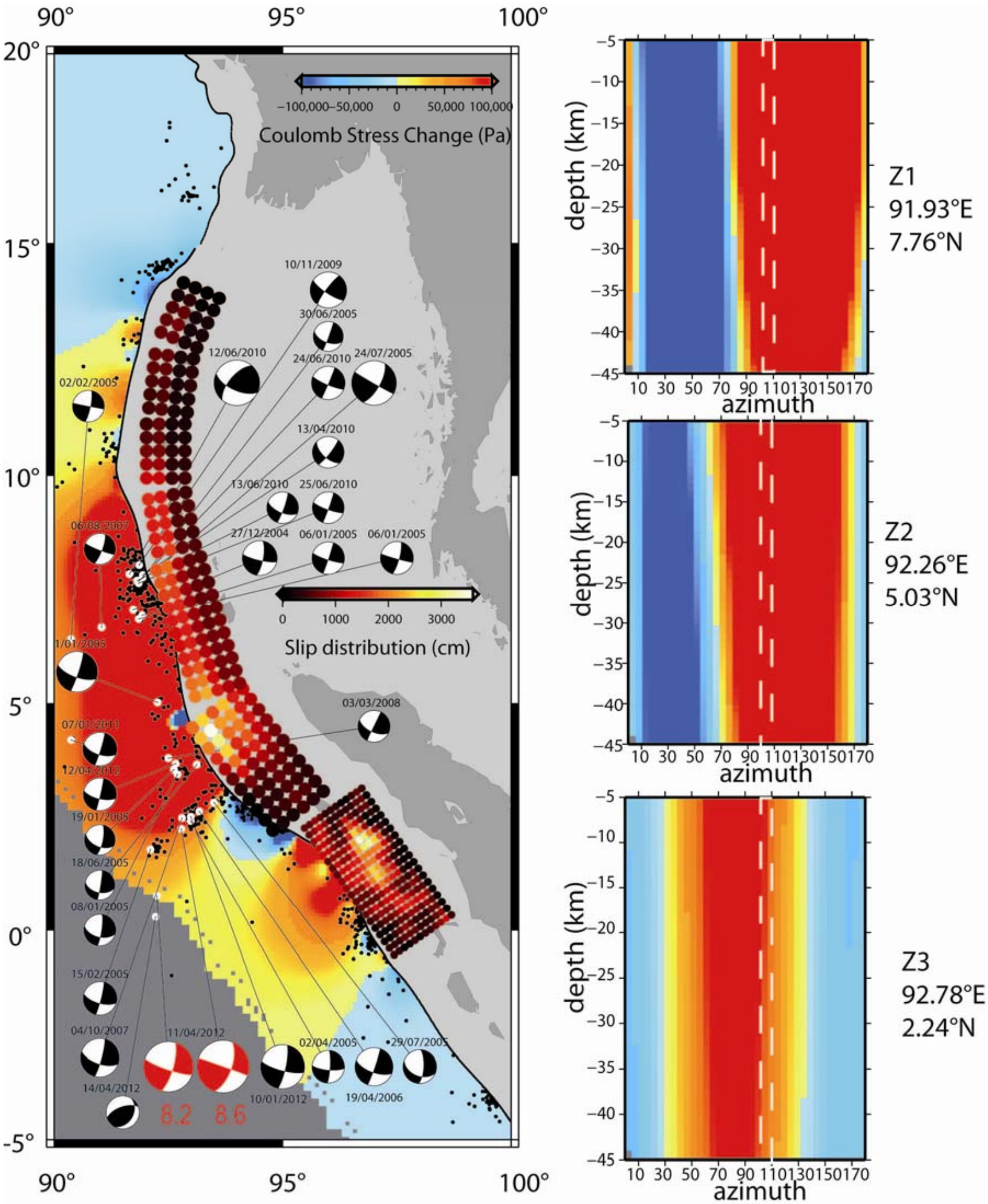

Figure A2: Coulomb stress change calculations performed for N110°E striking vertical planes with dextral motion. Preliminary seismological models show slip on the second nodal plane of the April 2012, Mw 8.6 event. This calculation shows Coulomb stress changes at the April 11th 2012 Mw 8.6 event location that are much higher than for N20°E oriented planes (Figure 3).

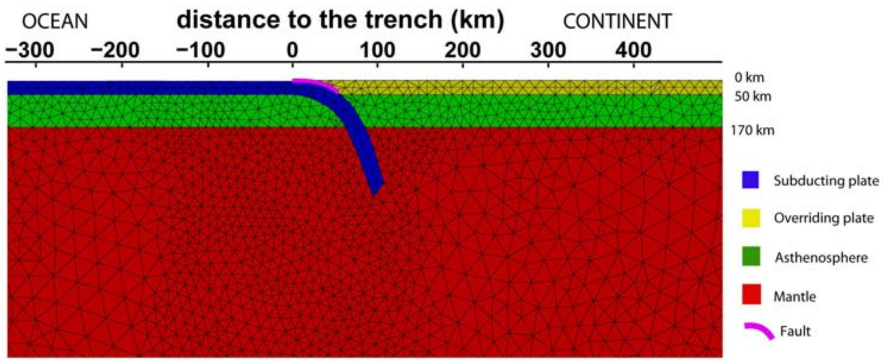

Figure A3: 2D finite element model used to compute the evolution of stresses as function of time in the subducting plate. The earthquake is modelled as a 10 m sudden displacement over the subduction interface (pink line). The elastic lithosphere (blue and yellow) is 50 km thick, and the asthenosphere 120 km thick.

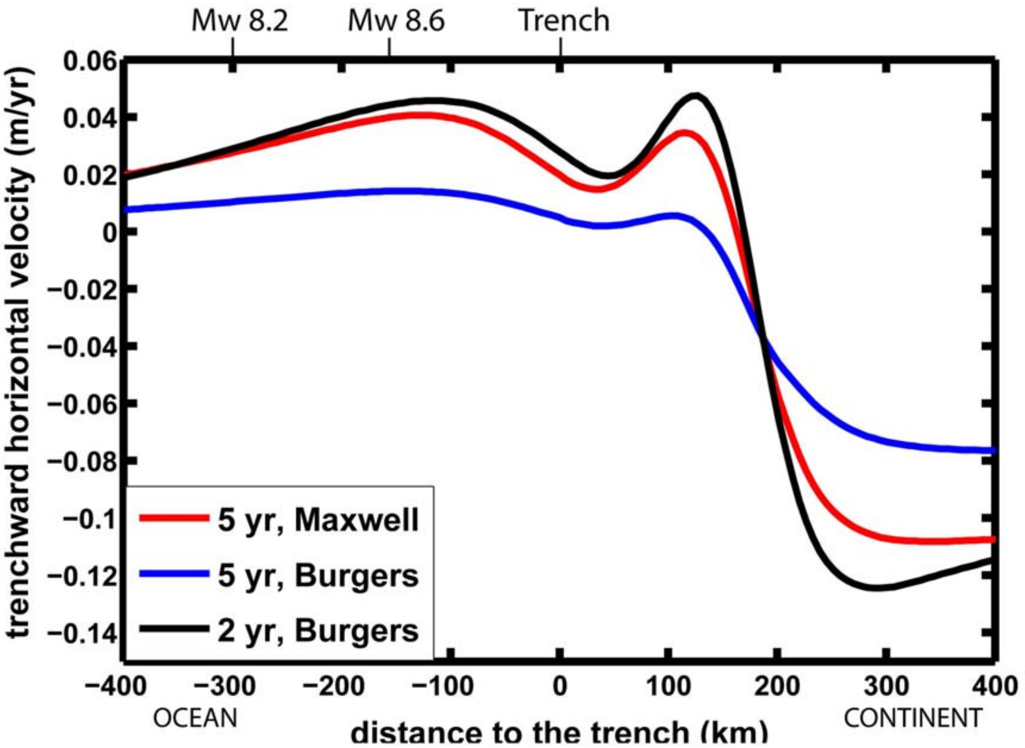

Figure A4: Horizontal velocity as function of distance to the trench 2 and 5 years after the earthquake. On the left portion of the figure (between -400 and -100km), the trenchward velocity increases i.e. the oceanic plate is stretched. Approximate distances to the trench corresponding to the April 2012 Mw 8.6 (150 km) and Mw 8.2 (300 km) earthquakes are indicated. Evolution of stresses through time at these locations are shown in Figure A5.

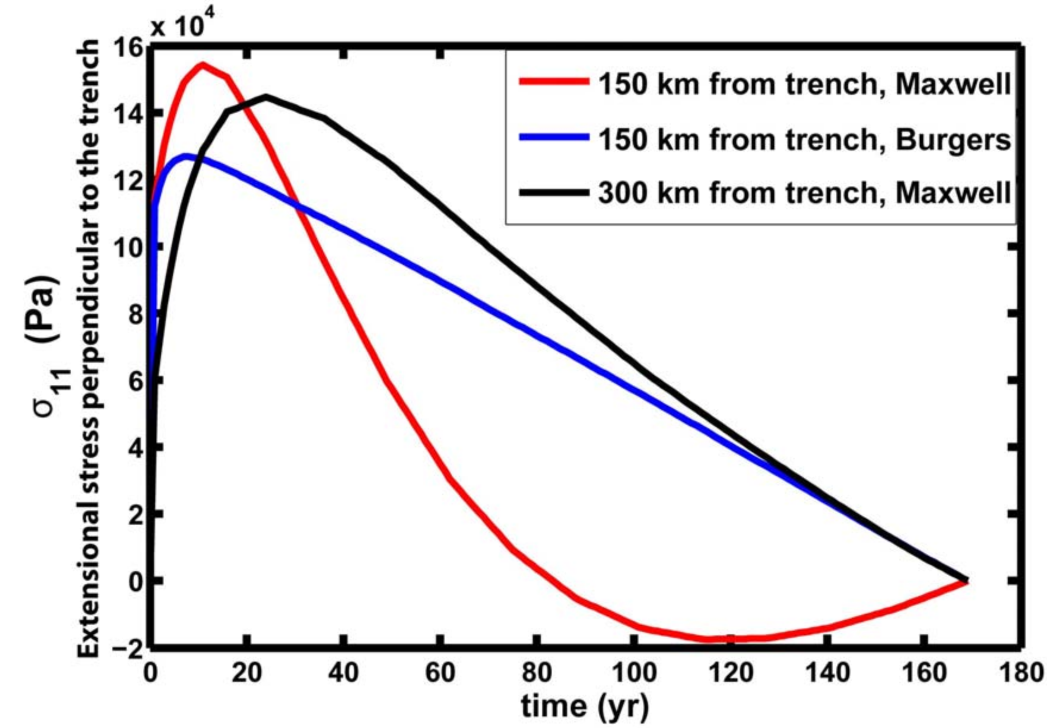

Figure A5: Trench perpendicular extensional stress as function of time at distances of 150 km (approximate location of Mw 8.6 event) and 300 km from the trench (approximate location of the Mw 8.2 event) during a seismic cycle.