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Shallow coseismic slip deficit due to large (M7) strike-slip earthquakes

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Inversions of space geodetic data (in particular, Interferometric Synthetic Aperture Radar and Global Positioning System) from several large (moment magnitude ~7) strike-slip earthquakes indicate that coseismic slip in the middle of the seismogenic layer (at depth of 4—5 km) is systematically larger than slip at the Earth's surface. Fig. 1 shows an example of slip inversion from the April 4, 2010, M7.2 El Mayor (Mexico) earthquake, and Fig. 2 shows a compilation of slip inversions from severa well-documented events [Fialko et al., 2005], including our recent results for the El Mayor earthquake.

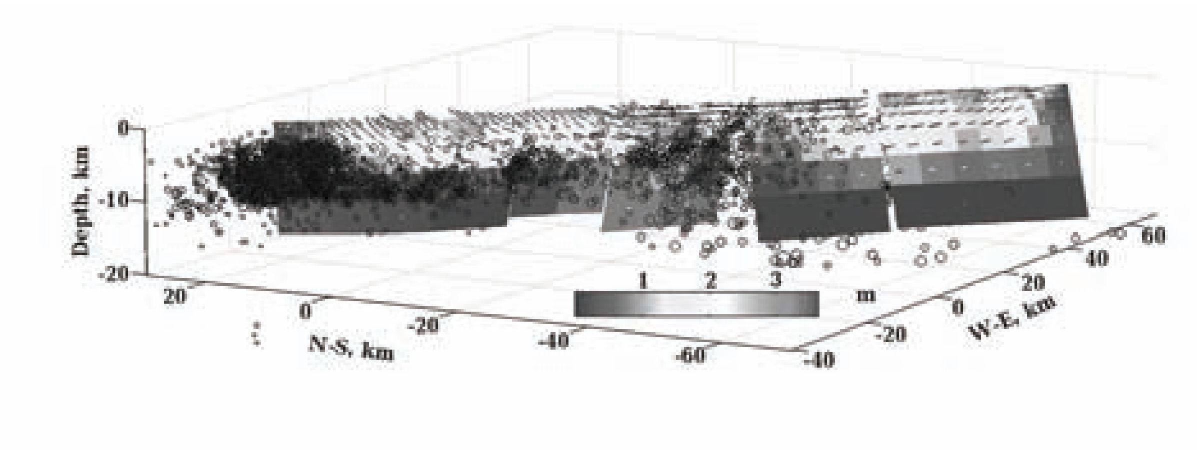

Fig. 1. Coseismic slip model of the El Mayor earthquake derived from inversion of InSAR and GPS Figure data. Colors denote the slip magnitude and arrows denote the sense of slip on the west side of the fault. Black circles denote precisely relocated hypocenters of aftershocks from the time period of 2 months following the mainshock (courtesy of Egill Hauksson).

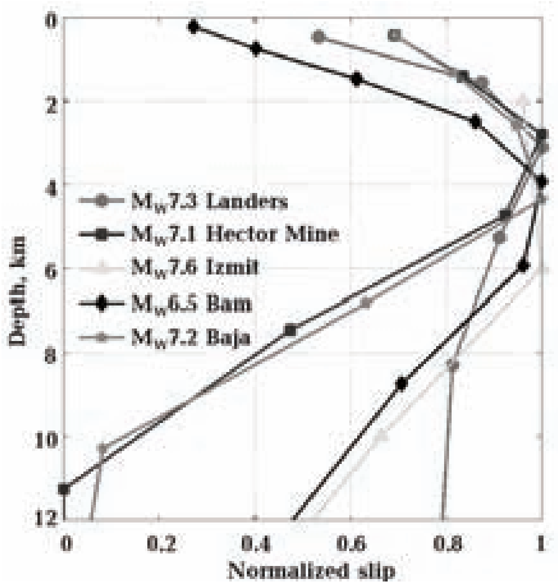

Fig. 2. Along-fault averaged distribution of slip for several large strike-slip earthquakes well constrained by the space geodetic data [Fialko et al., 2005]. The slip distribution from the El Mayor earthquake (magenta curve) follows the general pattern, with slip maximum in the middle of the seismogenic layer and shallow coseismic slip deficit.

This decrease in slip toward the surface, termed “shallow slip deficit”, appears to be consistent with the idea that the uppermost brittle layer is velocity-strengthening, as suggested by experimental data [Marone, 1998; Scholz, 1998], there remain a question of how the coseismic slip deficit is accommodated throughout the earthquake cycle [Fialko et al., 2005]. To the best of our knowledge, events included in Fig. 2 were not associated with either shallow interseismic creep or robust shallow afterslip (in the amount sufficient to remove the coseismic slip deficit in the shallow crust) [Jacobs et al., 2002; Fialko, 2004; Fialko et al., 2005; Fielding et al., 2009]. We explore a possibility that the shallow slip deficit is associated with immature and/or infrequently slipping faults and is caused by the bulk inelastic yielding of the host rocks in the shallow part of the brittle crust.

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The onset of plate tectonics on super-Earth's using a damage rheology

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Numerical simulations of mantle convection with a damage — grainsize feedback are used to develop scaling laws to predict conditions at which super-Earths would have plate tectonics. In particular, we introduce a new criterion for the onset of plate tectonics on terrestrial planets: that the viscosity of the lithosphere must be reduced to some critical value, which we assume to be the mantle viscosity. We formulate this criterion using the viscosity ratio between the pristine lithosphere and underlying mantle (μ_0/μ_1). These conditions are mapped out in regime diagrams of μ_0/μ_1 versus the damage fraction (f_a). The regime diagrams show that the transition from stagnant lid to mobile surface occurs for higher μ_0/μ_1 as f_a increases, with a power law relationship between those two variables; moreover, decreasing the healing constant (k_a) at the surface shifts the transition boundary to higher μ_0/μ_1. A scaling law is developed assuming that the transition between regimes occurs when damage, driven by convective stresses, reduces the viscosity in the lithosphere to a viscosity comparable to the mantle viscosity. This scaling law explains the numerical results well and can be applied to terrestrial planets. For the Earth, damage is efficient in the lithosphere, and viscosity can be reduced by 10 orders of magnitude with grains being reduced to a size on the order of a micron. When applied to super-Earth's, we find that larger planets are capable of larger viscosity reductions, but the viscosity ratio increases with planetary size at roughly the same rate. Therefore, contrary to previous results [e. g. O'Neill, Lenardic, 2007; Valencia et al., 2007], we find that the size of the planet has little effect on the convective regime that planet lies in. Factors such as surface temperature and thermal evolution may be more important in explaining the convective style of terrestrial planets.

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