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Numerical modeling of the Indo-Australian intraplate deformation

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The Indo-Australian plate is perhaps the best example of wide intraplate deformation within an oceanic plate. The deformation is expressed by an unusual level of intraplate seismicity, including magnitude Mw > 8 events, large-scale folding and deep faulting of the oceanic lithosphere and reactivation of extinct fracture zones. The deformation pattern and kinematic data inversions suggest that the Indo-Australian plate can be viewed as a composite plate made of three rigid component plates – India, Capricorn, Australia - separated by wide and diffuse boundaries undergoing either extensional or compressional deformation.

We tested this model using the SHELLS numerical code (Kong & Bird, 1995). The Indo-Australian plate is modeled by a mesh of 5281 spherical triangular finite elements. Mesh edges parallel the major extinct fracture zones so that they can be reactivated by reducing their friction rates. Strength of the plate is defined by the age of the lithosphere and seafloor topography. Model boundary conditions are only defined by the plate velocities predicted by the rotation vectors between rigid components of the Indo-Australian plate and their neighboring plates. Since the mesh limits all belong to rigid plates with fully defined Euler vectors, no conditions are imposed on the location, extent and limits of the diffuse and deforming zones.

Using MORVEL plate velocities (DeMets et al., 2010), predicted deformation patterns are very consistent with that observed. Pre-existing structures of the lithosphere play an important role in the intraplate deformation and its distribution. The Chagos Bank focuses most of the extensional deformation between the Indian and Capricorn plates. Agreement between models and observation improves by weakening fossil fracture zones relative to the surrounding crust; however only limited sections of FZ's accommodate deformation. The reactivation of the Eocene FZ's in the Central Indian Basin (CIB) and Wharton Basin (WB) explains the drastic change in the deformation style between these basins across the Ninetyeast ridge. The highest slip rates along the WB FZ's are predicted where two major strike-slip faulting earthquakes occurred in April 2012 (Mw=8.6 and 8.2). The best model is obtained when adding a local HF anomaly in the center of the CIB (proxy for weakening the lithospheric strength), consistent with evidence of mantle serpentinization in the CIB where deep seismics image a series of N-S dipping thrust faults reaching Moho depths. The rates of extension or shortening, inferred from the predicted strain rates, are consistent with previous estimates based on different approaches. This finite element modeling confirms that oceanic lithosphere, like the continental lithosphere, can slowly deform over very broad areas (> 1000 x 1000 km).