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Earthquake ruptures tied to long-lived plate interface deformation

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Predicting the spatial extent of mega-earthquakes is an essential ingredient of earthquake hazard assessment. In subduction zones, this prediction mostly relies on geodetic observations of interseismic coupling. However, such models face spatial resolution issues and are of little help to predict full or partial ruptures of highly locked patches. Coupling models are interpreted in the framework of the rate-and-state friction laws. However, these models are too idealized to take into account the effects of a geometrically or rheologically complex plate interface. In this study, we show, from the critical taper theory and a mechanical analysis of the topography, that all recent mega-earthquakes of the Chilean subduction zone are surrounded by distributed interplate deformation emanating from either underplating or basal erosion. This long-lived plate interface deformation builds up stresses ultimately leading to earthquake nucleation. Earthquakes then propagate along a relatively smooth surface and are stopped by segments of heterogeneously distributed deformation. Our results are consistent with long-term features of the subduction margin, with observed short-term deformation as well as physical parameters of recovered subducted fragments. They also provide an explanation for the apparent mechanical segmentation of the megathrust, reconciling many seemingly contradictory observations on the short- and long-term deformation. Consequently, we propose that earthquake segmentation relates to the distribution of deformation along the plate interface and that slip deficit patterns reflect the along-dip and along-strike distribution of the plate interface deformation. Topography would therefore mirror plate interface deformation and could serve to improve earthquake rupture prediction.