Partial Rupture of Locked Segments: The Role of Fault Morphology

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Assessment of seismic hazard relies on estimates of how large an area of a tectonic fault could potentially rupture in a single earthquake. Vital information for these forecasts includes which areas of a fault are locked and how the fault is segmented. Much research has focused on exploring downdip limits to fault rupture from chemical and thermal boundaries, and along-strike barriers from subducted structural features, yet we regularly see only partial rupture of fully locked fault patches that could have ruptured as a whole in a larger earthquake. Here we draw insight into this conundrum from the 25 April 2015 Mw 7.8 Gorkha (Nepal) earthquake. We invert geodetic data with a structural model of the Main Himalayan thrust in the region of Kathmandu, Nepal, showing that this event was generated by rupture of a décollement bounded on all sides by more steeply dipping ramps. The morphological bounds explain why the event ruptured only a small piece of a large fully locked seismic gap. We then use dynamic earthquake cycle modeling on the same fault geometry to reveal that such events are predicted by the physics. Depending on the earthquake history and the details of rupture dynamics, however, great earthquakes that rupture the entire seismogenic zone are also possible. These insights from Nepal should be applicable to understanding bounds on earthquake size on megathrusts worldwide.