Surface Cracks as a Long-term Record of Seismic Segmentation along the Andean Margin

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The characteristic earthquake model of seismic recurrence suggests that a given fault segment ruptures repeatedly in earthquakes of similar magnitude and areal extent. While some historical and paleoseismic records support this model, it is unclear whether these segments are truly long-lived, because the geologic indicators of distinct earthquakes usually only persist for a few thousand years (e.g., up to about 10 events). To assess the longevity of the segmented nature of seismicity, we require data that reflect coseismic deformation caused by 100s to 1000s of repeated earthquakes. Here we present maps of meter-scale surface cracks in the northern Chile and southern Peru forearc that provide such a record. These cracks have been observed to form during and/or shortly after strong subduction earthquakes, are preserved for very long time periods throughout the Atacama Desert, demonstrate evidence for multiple episodes of reactivation, and show changes in orientation over spatial scales similar to the size of earthquake segments. Our observations and models of recent earthquakes show that crack orientations are consistent with dynamic and static coseismic stress fields. While localized structural and topographic processes influence some cracks, the strong preferred orientation over large regions indicates that cracks are dominantly formed by plate boundary-scale stresses, namely repeated earthquakes. We invert the crack-based strain data for slip on the well-known Iquique seismic gap segment of the margin and find consistency with gravity anomaly-based inferences of long-term earthquake slip patterns. We suggest that the meter-scale cracks can be used to map characteristic earthquake rupture segments that persist over many seismic cycles. This information about the longevity of plate boundary segmentation encourages future study of cracks and other small-scale structures to constrain better the persistence of asperities in other arid, tectonically active regions.

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