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Small earthquakes on the San Andreas fault that have magnitudes controlled by slip alone

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Ordinarily, earthquake magnitude is controlled by both rupture length and slip variation. Here we show that a special population of earthquakes has a constant rupture length, but varying slip. We compare the source time function pulse widths of 25 earthquakes on the San Andreas fault, and 11 earthquakes on surrounding secondary faults to show that the earthquakes on the San Andreas fault near Parkfield have an approximately constant duration in this group with magnitudes ranging from 1.4 to 3.7. We determine the source time function of the earthquakes via an empirical Green's function deconvolution. Examination of the direct P-wave arrivals in the raw data confirms the constant duration observation determined by the empirical Green's function method. In contrast, earthquakes on secondary faults indicate the more usual source parameter scaling suggestive of a constant stress drop, i.e. they have an increase in duration with magnitude. The earthquakes on the San Andreas fault are located approximately 20 km to the northeast of the 1966 mainshock epicenter, along the fault, to approximately 5 km south of the 2004 epicenter. Unlike previously studied repeating sequences, the magnitudes are not constant, nor is the repeat time regular. The secondary faults are located at distances of 5 km or greater from the trace of the San Andreas fault, and are almost certainly not part of the active or historically active plate boundary fault system. The constant source duration observation for the earthquakes on the San Andreas fault suggests that fault area stays constant over the magnitude range of our data set.

A repetitive rupture of a small, locked asperity in a creeping fault can explain the constant duration. The dimension of the asperity could pre-determine the fault area. Therefore the observation directly measures the scale of the heterogeneities on the fault. We observe heterogeneities of 120, and 160 m in diameter.

Calculated stress drop values of the earthquake population on the San Andreas fault range from 0.18 MPa to 58 MPa, and values on secondary faults range from 0.76 MPa to 14 MPa. The differences in duration scaling between the events on the San Andreas fault and on secondary faults suggest that earthquakes on the San Andreas fault are inherently different. Cumulative slip values on the secondary faults are negligible in comparison to cumulative slip values on the San Andreas fault. We speculate that faults with more cumulative displacement have earthquakes which may rupture differently. Differences in rupture dynamics between the two populations might be explained by differences in fault surface roughness.