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The Parkfield Section of the San Andreas Fault, California: Characteristic or Complementary Earthquake Ruptures?

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The San Andreas Fault is the major fault in California; it accommodates right-lateral strike-slip motion between the Pacific Plate and the North American plate. Individual sections of the San Andreas Fault behave in seismically different ways – some sections of the fault are locked (they slip only co-seismically in large ~M8 earthquakes; e.g.: the 1857 M7.9 Fort Tejon earthquake, the 1906 M7.8 San Francisco earthquake), while others parts of the fault creep (they accommodate all the relative plate motion by slow steady-state slip; this is the case of the San Juan Bautista – Cholame segment). The North Anatolian Fault has no creeping section and exhibits an earthquake cascade pattern (consecutive earthquakes rupture neighboring sections of the fault). Despite the different patterns of occurrence of large mainshocks, a key aspect to understanding both the San Andreas and the North Anatolian fault systems is earthquake interaction. We approach this subject by looking at the Parkfield fault section of the San Andreas Fault. The Parkfield dataset allows us to study two consecutive earthquakes that ruptured the same fault section. Parkfield marks the transition between a creeping and a locked part of the San Andreas Fault. In the historical period (post 1850's) it has generated at least five ~M_W6 earthquakes. Based on similarity of waveforms from the 1922, 1934 and 1966 Parkfield earthquakes, Bakun and McEvilly (BSSA 1984) proposed the idea of characteristic earthquakes: a given fault segment would rupture repeatedly in earthquakes that would nucleate in the same hypocenter and generate slip on the same areas of the fault. Unlike previous Parkfield earthquakes, the 2004 Parkfield earthquake did not nucleate near Middle Mountain and rupture to the SE, but rather nucleated near Gold Hill and ruptured NW. Despite these differences, do the 1966 and 2004 slip distributions look similar? We compute a kinematic rupture model for the 1966 event by inverting the scarce co-seismic dataset (Figure 1). Only five strong motion instruments were nearby at the time of the 1966 mainshock; all were located perpendicular to the fault, near its SE end. Because the data coverage of the fault is poor, the resolution of the rupture model becomes an important question. To estimate the resolution of the 1966 rupture model, we use 3 different approaches: 1) we use synthetic slip distributions to generate waveforms at the 5 stations, and then invert the synthetic waveforms to see how well the initial slip distributions can be recovered; 2) we invert seismograms of the 2004 earthquake recorded at 5 stations coincident or close to the stations that were in place in 1966; we then compare the obtained rupture model with one obtained by inversion of a more complete dataset; 3) we invert the 1966 dataset applying the constrain that the slip amplitude distribution must be similar to the 2004 earthquake. The resolution tests indicate that the 1966 rupture model is poorly resolved; however, we can eliminate the hypothesis that the 1966 and 2004 Parkfield earthquakes slip distributions were identical.

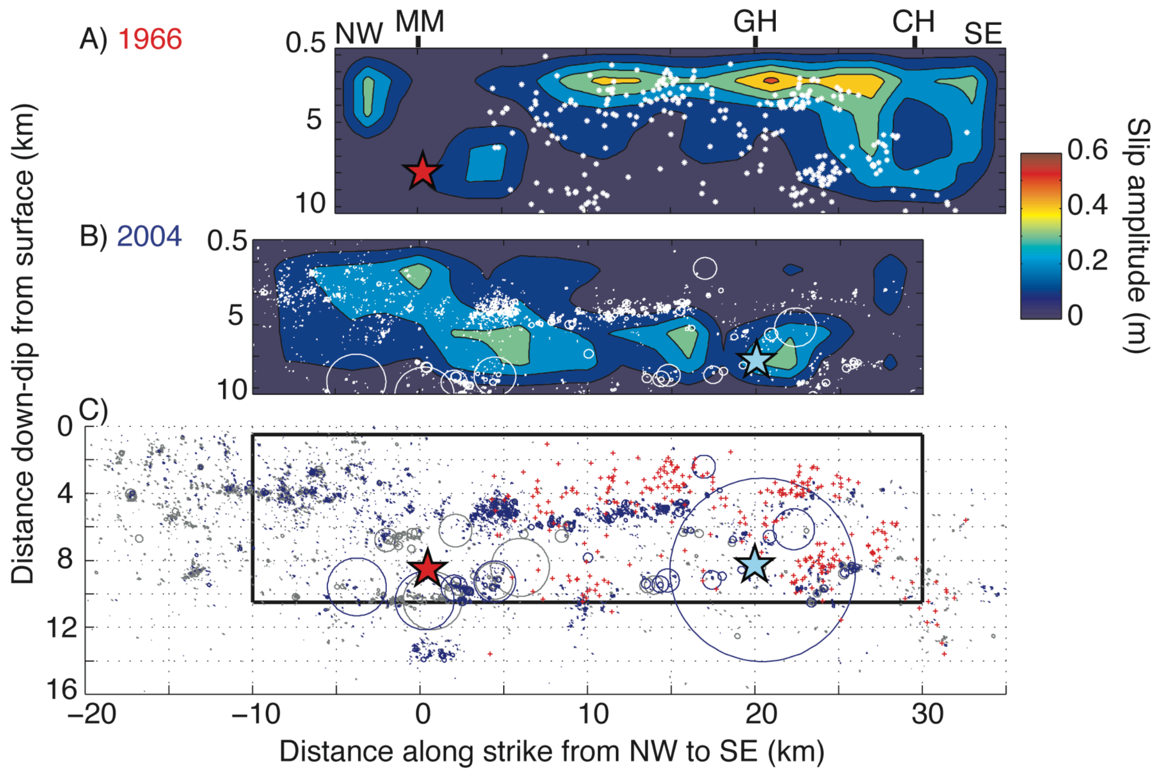

Figure 1 - Comparison between the rupture models for the 1966 and 2004 Parkfield earthquakes and microseismicity. According to our modeling of strong-motion seismic data, the two most recent Parkfield earthquakes (1966 and 2004) ruptured complementary parts of the fault plane. A) Slip amplitude and aftershocks of the 1966 earthquake. B) Slip amplitude and aftershocks of the 2004 earthquake. C) Aftershocks of the 1966 earthquake (red crosses), aftershocks of the 2004 earthquake (blue circles) and background seismicity from 1984 to the 2004 earthquake (gray circles) (Thurber et al., in press}. The size of the aftershocks (circles) is computed assuming a 3~MPa stress drop in a circular region. In the absence of information on the magnitudes of the 1966 aftershocks, we cannot compute their size; these aftershocks are represented by crosses. The rectangle indicates the position of the fault plane modeled for the 2004 earthquake. The red and blue stars mark the 1966 and 2004 hypocenters, respectively. MM - Middle Mountain; GH - Gold Hill; CH - Cholame.