An Updated San Andreas Fault Geometry in Parkfield, California

Adam Margolis[1], David Oglesby[1], Axel Periollat[1], Gareth Funning[1], Li-Chieh Lin[1]
[1] University of California, Riverside

Motivation

Publicly available 3D models of the San Andreas Fault (SAF) in the Parkfield region lack detail along strike and dip. Presently, the SCEC Community Fault Model (CFM) provides limited coverage in Parkfield. It does not discern the two dominate strands of the central SAF: the Southwest Fracture Zone (SWFZ) to the west of Parkfield and the SAF main trace which runs through the town. These strands and geometries may become important in understanding how ruptures propagate though the transition zone during moderate (M_w 6.0) events. The simplified geometry of the CFM provides a challenge for rupture simulation models which require the geometry to be well constrained. Here, we build a plausible SAF geometry for the Parkfield region based on the Waldhauser & Schaff Double-Difference (DD) Catalog [2] for the event data and the USGS Quaternary-fault (Q-fault) Catalog [3] to constrain the surface geometry. Then we run simple dynamic rupture simulations to determine possible rupture propagation paths.

Methods

We use the Waldhauser & Schaff double-difference catalog [2] with events from 1984 to 2011 and filter the data to include aftershocks in the 60 days after the 2004 M_w 6.0 Parkfield earthquake (28 September 2004 to 27 November 2004). The x, y, and z information is extracted from each event. We include events within 10 km south along strike of the 2004 earthquake hypocenter and 30 km north along strike. We apply a 0.75 km filter from the fault surface trace to remove events not associated with the SAF, and to ensure overlap is minimized between the two fault segments. After filtering, there are 515 and 2,349 events for the SWFZ and SAF main trace, respectively. The Q-fault surface data [3] is added to both datasets, which contains 68 and 330 surface points, respectively. We then generate a spline surface in Python using a linear radial basis function to fit the events (Fig 2). We then mesh the two surfaces in Gmsh [4] where the SWFZ is rotated 2.8º to the west (Fig 3). This is to ensure it intersects with the SAF main trace at roughly 5 km depth to the east. Lastly, we model the dynamics of rupture in DRDG-3D [5] with slip-weakening friction (μ_d = 0.2 and μ_s = 0.5) (Fig 4 & 5). Here, we are simply testing if our two-fault geometry can sustain and propagate rupture, rather than replicating any realistic

Results

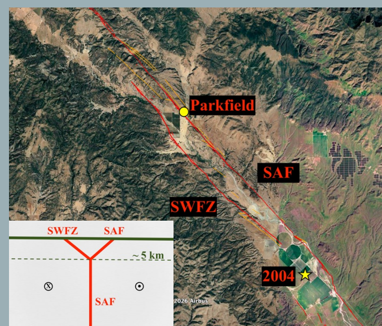

Figure 1 TOP: Google Earth satellite image of the San Andreas Fault (SAF) with mapped surface traces highlighted from Q-faults [3]. Red lines are well constrained fault strands, while orange is moderately constrained segments. A yellow star denotes the 2004 Parkfield earthquake epicenter [1]. The main trace of the SAF runs through Parkfield, while a secondary parallel strand, the Southwest Fracture Zone (SWFZ) is ~1.3 km southwest. BOTTOM: A cartoon interpretation that the Southwest Fracture Zone (SWFZ) and San Andreas Fault (SAF) intersect at ~5 km depth [6]. Note in Figures 2a and 2b our spline surfaces bend and straighten out at roughly this depth.

SWFZ

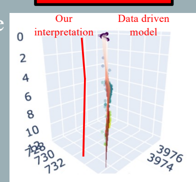

Figure 2a: The spline surface "oblong view" orientation (red) of the Southwest Fracture Zone (SWFZ) fit to the Q-fault [3] and the 60-day aftershock DD catalog data [2]. Note the dip in the fault towards the east between 0 and 6 km, in agreement with our interpretation (Fig 1 bottom) [6].

SAF-Main

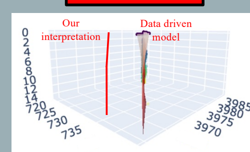

Figure 2b: The spline surface "oblong view" orientation (red) of the San Andreas Fault main trace (SAF) fit to the Q-fault [3] at the surface and the 60-day aftershock DD catalog data [2]. Note the dip in the fault towards the west between 0 and 6 km, in agreement with an interpretation like with Figure 1 bottom [6].

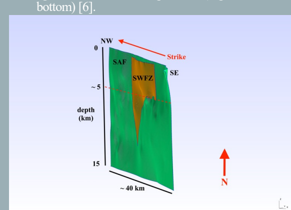

Figure 3: Our plausible two-fault geometry in Parkfield with the Southwest Fracture Zone (SWFZ) in brown and San Andreas Fault main trace (SAF) in green looking north along strike, meshed with 151,754 triangular elements in Gmsh [5]. Note the roughness of the surfaces. Here, the two faults intersect at about 5km depth.

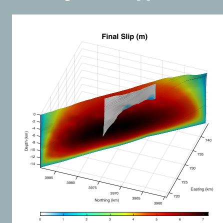

Figure 4: Final slip using our plausible two-fault geometry. This produces a max slip of ~7m and with a fault area of ~600 km^2, it equates to ~M_w 7.4. While we note this event is unlikely for the creeping segment, we show it is possible that our two-fault geometry can rupture as a proof of concept. Notice nearly all slip bypassed the SWFZ entirely.

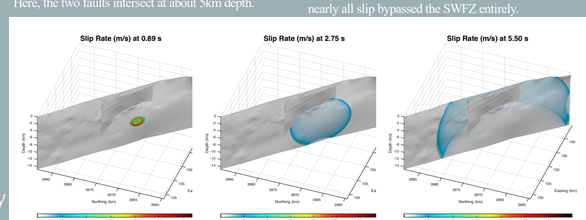

Figure 5: Three snapshots of the slip rate (a proxy for the rupture front) during different instances of time. Rupture initiates at the 2004 Parkfield epicenter and propagates bilaterally on the SAF main trace. It partially ruptures small portions of the base of the SWFZ before terminating and continuing to rupture the main trace behind it (or east of it).

Discussion

We show geometries for two major fault strands in the Parkfield region (Fig 2) based two catalogs [2 & 3]. We interpret our models intersect at ~5 km depth, below which form a single fault surface (Fig 1 bottom & Fig 2). We then mesh the resulting geometries in Gmsh [4] to create a plausible two-fault surface in Parkfield (Fig 3). As a proof of concept, we dynamically rupture the fault to test if our two-fault geometry can sustain and propagate rupture (Fig 4 & 5). We find that rupture prefers to take the SAF main trace, rather than both fault surfaces (Fig 5). This stems from a high S, or the strength excess, (~2-3) on the SWFZ along the sawtooth-like intersection at depth. Therefore, rupture bypasses the SWFZ altogether and mostly ruptures the SAF main trace.

Next Steps

Our eventual goal is to replicate the 2004 M_w 6.0 Parkfield earthquake with realistic parameters. Presently, we are implementing slip-weaking friction, and we plan on moving to rate and state friction. We also want to test nucleation points on the SWFZ and observe how it propagates on the main trace. In the future, we aim to extend our model south into the locked Carrizo Plain region to address the conditions that may allow a Parkfield earthquake to leak out and rupture in an ~M_w 7.9 1857-like event.

Summary

Here we show a plausible two-fault geometry for the Parkfield region and run simple dynamic rupture models. We will continue to make our model more realistic so that we can better test more complex questions such as whether a moderate (M_w 6.0) Parkfield earthquake could cause the next large event on the Southern San Andreas Fault.

References

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