2008 SCEC Annual Report

TITLE: What about the Bends?

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Category: (B) Integration and Theory

Science Objectives: A9, A10

In 2008 we have focused on computational models of faults with double bends, as illustrated in Figure 1. Such linked stepovers are present at a variety of length scales, from a few meters to the Big Bend in the San Andreas. An important question that arises in earthquake hazard assessment regions with linked fault stepovers is whether rupture will propagate across the stepover, leading to a large event, or terminate at the stepover. While various researchers have investigated the dynamics of strike-slip stepover systems (e.g., Segall and Pollard, 1980; Sibson, 1985; Wesnousky, 1988; Harris et al., 1991; Harris and Day, 1993; Kase and Kuge, 1998; Harris and Day, 1999; Kase and Kuge, 2001; Duan and Oglesby, 2006; Oglesby, 2008), until now there has been no systematic exploration of how the ability of earthquakes to rupture through a linked stepover varies with stepover length and linking fault strike angle.

The results of this recent research are summarized in parameter space in Figure 2. We see that for both compressional and extensional stepovers, small stepover angles and/or small stepover lengths allow rupture to propagate through the stepover. As stepover angle increases (and the linking segment becomes less favorable for rupture in the regional stress field), the maximum stepover segment length across which rupture can propagate shrinks, approaching an asymptotic critical length across which rupture can always propagate (or jump directly across the stepover). Conversely, as the stepover angle is reduced toward zero degrees, there exists a critical angle for which rupture can propagate across a stepover segment of unlimited length. The mechanism is the following: for large stepover angles, the pre-stress field on the stepover segment is unfavorable for spontaneous rupture; rupture tends to die out after propagating on the segment after a certain distance. This distance depends on both the static stress field on that linking segment, and on the dynamic stress field radiated from the larger strike-slip segment. Both these effects depend on the stepover angle. For small enough angles, though, the linking segment is favorable for rupture, and rupture can propagate essentially an infinite distance. For very large angles, the linking segment is very unfavorable for rupture, but slip on the main strike-slip faults can push rupture through very small stepovers anyway through dynamic effects. A key difference exists between the compressional and extensional stepovers. First, the pre-stress field on an extensional stepover is favorable for rupture on the linking fault segment for a wider range of angles. Second, on a compressional stepover, slip on the main strike-slip segments tends to clamp down the linking fault, while it tends to unclamp the linking fault on an extensional stepover. These two effects together result in extensional stepovers being more likely to produce through-going rupture than compressional stepovers. We further note that the maximum stepover length across which rupture may propagate with no restriction on stepover angle may be related to the size of the process zone near the crack tip, where dynamic stress perturbations are strong enough to cause fault failure through purely dynamic effects. Finally, preliminary experiments with fault systems of different scale (not shown) indicate that the width of stepover through which rupture may propagate does not scale linearly with the size of the fault system, consistent with the proposition that there is a finite-sized process zone at the crack tip. This work will make up one chapter of graduate Student Julian Lozos's Master's Thesis at UCR.

Due to constraints on Steve Wesnousky's time, we did not perform significant work on the observational side of this project—the comparison with real-world faulting data. For this reason, in our 2009 SCEC proposal we did not ask for funding for Wesnousky; rather, he will be in charge of the observational component this upcoming year.

Figures

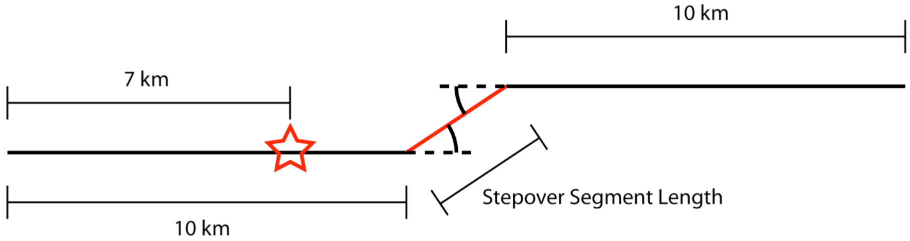

Figure 1. Cartoon model of linked stepover fault geometry. The linking fault is in red, and the stepover angle is marked with arc segments. Rupture is nucleated at the star.

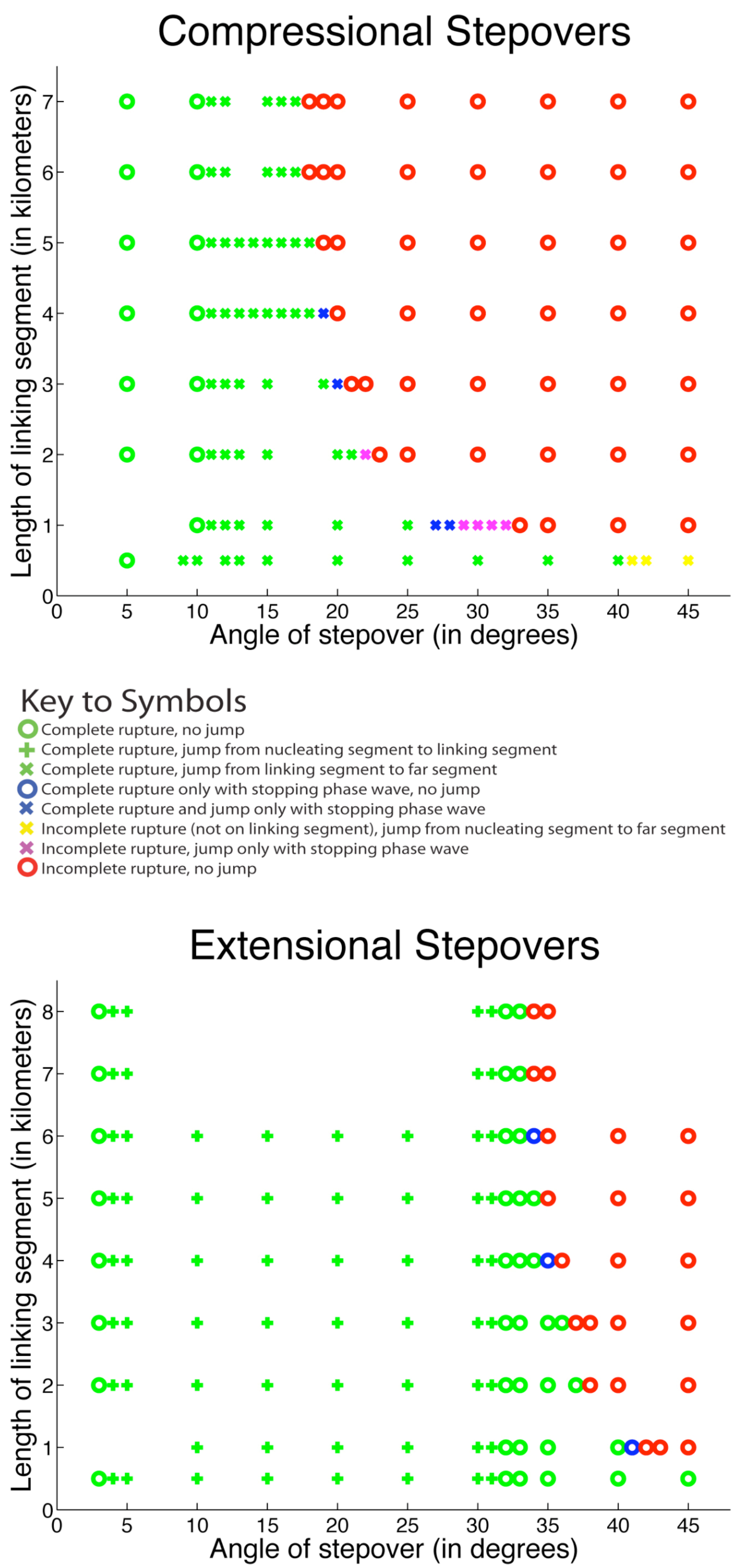

Figure 2. Ability of rupture to propagate through the linked stepover depicted in Figure 1, as a function of stepover angle and linking fault length, for both compressional (top) and extensional (bottom) stepovers. The most important symbols are the green vs. red colors; green represents rupture propagating through the stepover, and red represents ruptures that were stopped by the stepover. In some cases, rupture jumped discontinuously over portions of the fault system, as noted in the key to symbols. Overall, rupture can propagate across a wider range of angles and stepover lengths on extensional stepovers than compressional stepovers. In both cases, small angles and small stepover lengths favor through-going rupture, while large angles and large stepover lengths favor rupture termination at the stepover. In both types of stepover there exists a minimum angle, over which rupture may propagate across a stepover of any length, and a minimum stepover length, over which ruptures may propagate at any angle.

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