3-D rupture simulations for faults with complex geometric segmentation: Collaborative research with San Diego State University and University of California, Riverside
Award 02HQGR0009

David D. Oglesby
Department of Earth Sciences
University of California, Riverside
Riverside, CA 92521-0423
PH: (909) 787-2036
FAX: (909) 787-4324
david.oglesby@ucr.edu
Source characteristics

Investigations Undertaken

As a case study of a fault with complex geometrical segmentation, we chose the fault that was the source of the 1999 M 7.1 Hector Mine earthquake. This earthquake ruptured a complex fault system with a branched structure in the north (Figure 1). This fault geometry and slip pattern presents a puzzle, because the northwest branch of this system should be in the stress shadow of the north branch, upon which nucleation likely took place. We performed three-dimensional dynamic finite element models of this event to investigate how such a slip pattern could take place, and to explore general characteristics of branched fault systems.

Results

We show that the ability of rupture to propagate to the northwest branch depends crucially on the fact that rupture did not proceed to the surface on the north branch. This slip pattern leads to part of the northwest branch being brought above its failure stress, with subsequent rupture propagation and slip on that branch (Figure 2). A similar effect can be seen in the somewhat artificial case in which rupture is constrained not to propagate to the base of the north branch. Models with slip over the entire north branch do not produce rupture propagation and slip on the northwest branch (Figure 3). The results are robust with respect to details of the pre-stress pattern and hypocenter location. Great heterogeneity in the final stress pattern is a natural product of the models, even when the initial stress field is quite homogeneous. We also find that the interaction between fault geometry and stress pattern helps to explain other observations in this event, including slow rupture propagation on the northwest branch. The results help to show that three-dimensional dynamic effects may be crucial in determining the behavior of geometrically complex fault systems, although these effects may be hard to predict without detailed knowledge of the stress pattern and fault geometry prior to earthquakes.

Non-Technical Summary

The 1999 Hector Mine earthquake ruptured a fault with a branched structure. However, a simple stress analysis of the fault system implies that it should be very difficult to rupture both branches, since slip on one branch would appear to prevent slip on the other. Using computer models of this earthquake, we

find that the observed slip pattern occurs quite naturally as long as the slip does not proceed to the surface on one of the branches. The results help to explain why rupture propagates across fault branches in some fault systems, and not in others.

Reports Published

Oglesby, D. D., S. M. Day, Y.-G. Li, and J. E. Vidale (2002). The 1999 Hector Mine earthquake: the dynamics of a branched fault system, *Bull. Seism. Soc. Am.* In Preparation.

Data Availability

All simulation results are available upon request from the principal investigator:

David D. Oglesby
Department of Earth Sciences
University of California, Riverside
Riverside, CA 92521-0423
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FAX: (909) 787-4324
david.oglesby@ucr.edu

The finite element modeling code is also available to investigators who are members of the Lawrence Livermore Laboratory Methods Development Group collaboration program.

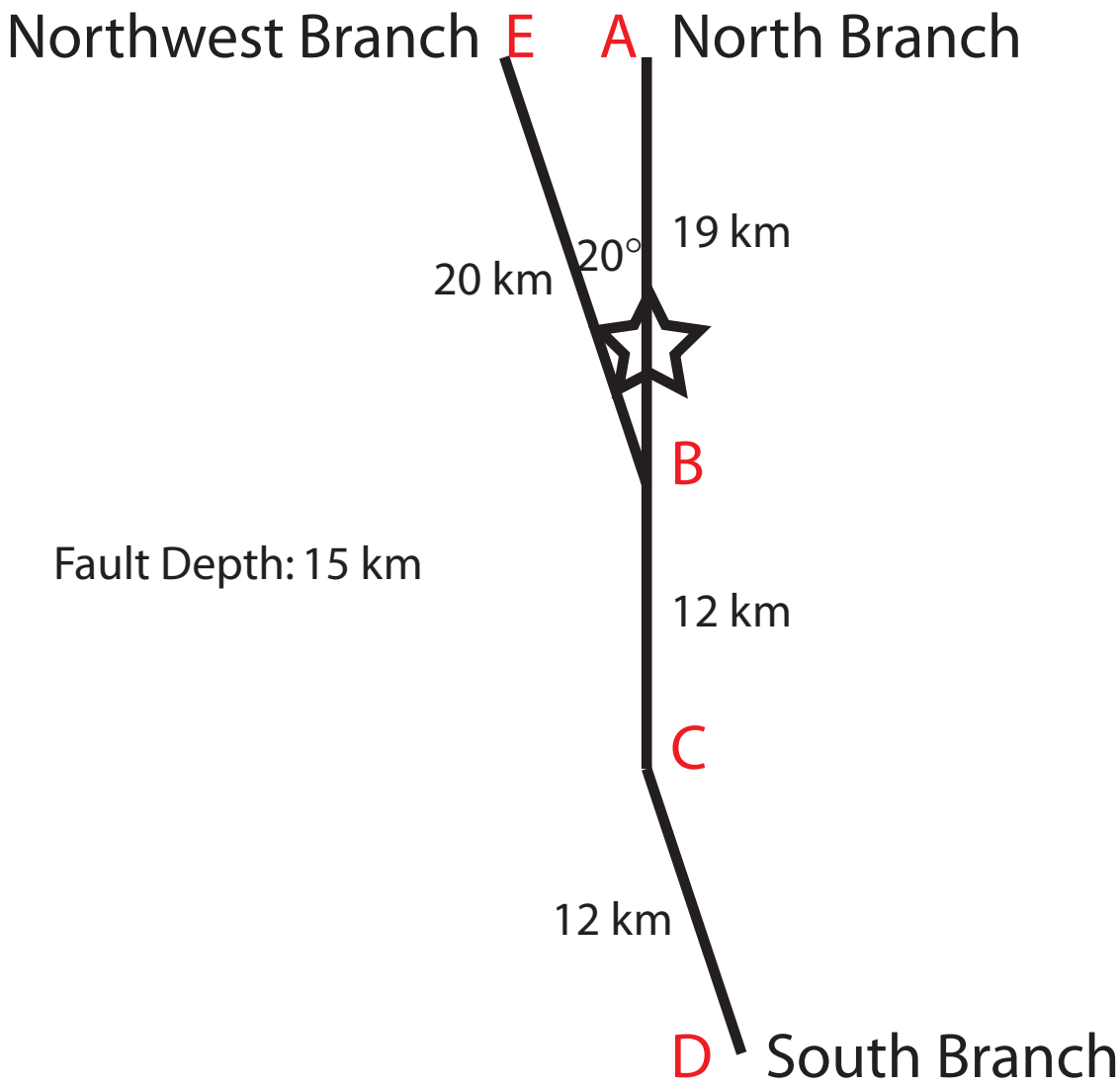

Figure 1. Fault geometry used in the dynamic models. Segment names are identified, with the hypocenter marked with a star.

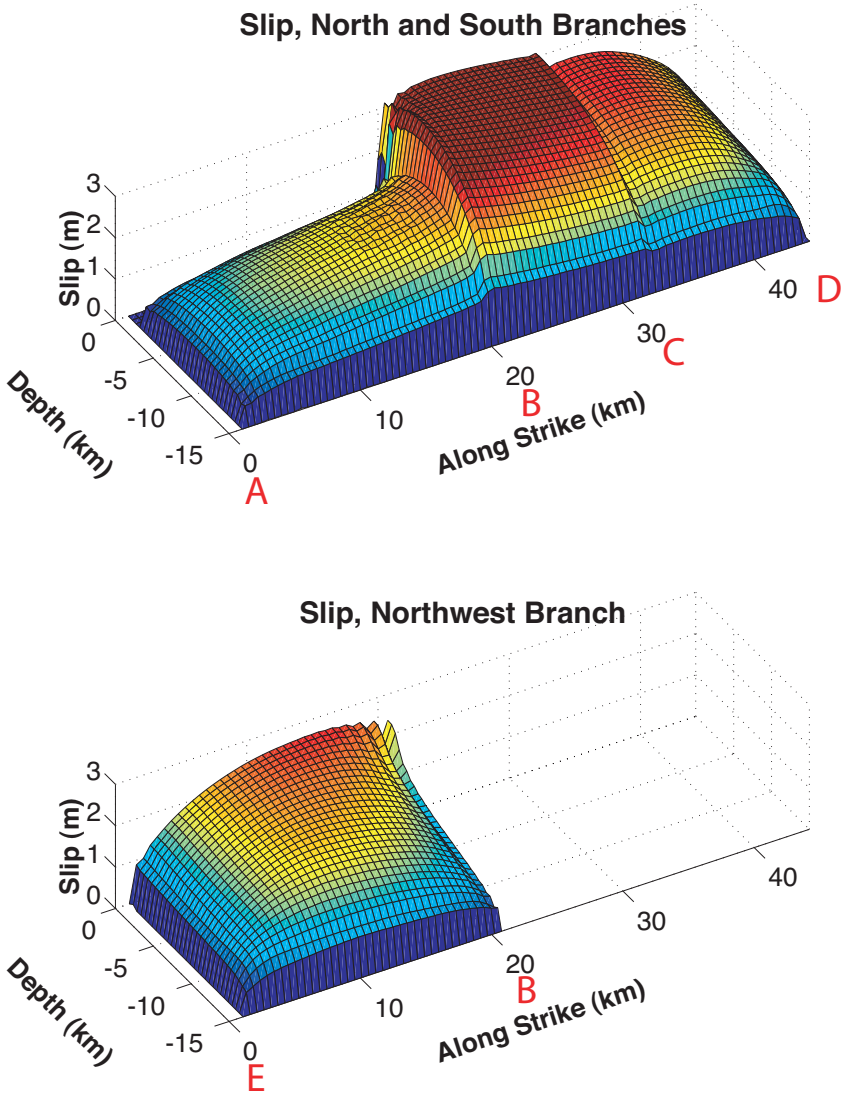

Figure 2. Slip resulting from a dynamic model of the Hector Mine earthquake in the case that slip does not propagate to the surface of the north branch. Note that in this case, slip propagates to the northwest branch. the letters on the fault segments correspond to the letters on the fault segments in Figure 1.

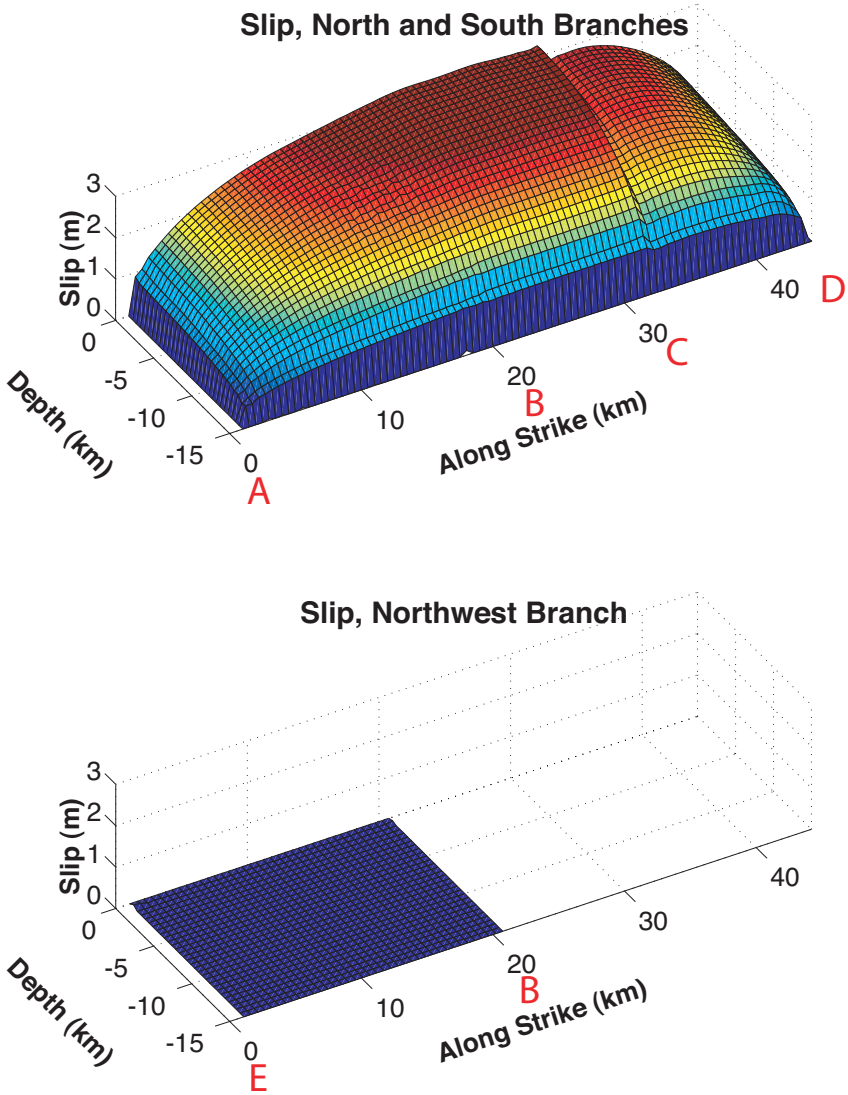

Figure 3. Slip resulting from dynamic model of Hector Mine earthquake in the case that slip propagates to the surface of the north branch. Note that in this case, slip does not propagate to the northwest branch. The letters on the fault segments correspond to the letters on the fault segments in Figure 1.