Workshop on San Gorgonio Pass:

Structure, Stress, Slip, and the Likelihood of Through-Going Rupture

Organizers: Doug Yule, Michele Cooke, David Oglesby
Date: Sept. 6, 2014
Location: Palm Springs Hilton
Participants: 54

Objective

This workshop explored recent research on the San Gorgonio Pass (SGP) region as part of SCEC's Special Fault Study Area (SFSA) program. Our goal was to bring together researchers from all areas in SCEC—geologists, seismologists, and others—to explore key issues surrounding earthquakes in this region. Specific topics included the geometry of active subsurface faulting, the potential for earthquakes on the complex fault system in this region, and the likelihood of a 'super-earthquake' that would propagate along the San Andreas system through the pass, leading to a very large-magnitude and damaging event. The workshop brought together geoscientists from a wide spectrum of interests including tectonic geomorphology, structural geology, mechanical modeling, rupture modeling, gravity and magnetic modeling, seismology, geochronology, geodesy, and fault and rock mechanics. The morning of the workshop consisted of a field trip to the western Coachella Valley to visit key paleoseismic sites, and the afternoon consisted of short presentations on recent scientific discoveries and important questions to be answered by future research. This SFSA has attracted the attention of public utilities and infrastructure managers, which may present opportunities for future collaboration and funding.

Workshop Agenda

September 6, 2014

08:00 sharp	Depart Hilton lobby	
08:30-09:15	Stop 1 - Mission Creek strand at Pushawalla Canyon	*Blisniuk et al.*
09:45-10:30	Stop 2 - Banning strand west of Hwy 62	*Behr et al.*
11:00-11:45	Stop 3 - Mission Creek strand at Mission Creek Preserve	*Kendrick et al.*
12:30	Return to Hilton lobby	
13:00-14:00	Lunch at Hilton	
14:00-14:10	Summary of field trip discussion and outline of talks and goals	*M. Cooke, D. Yule, D. Oglesby*
14:10-14:30	Fault activity in the San Gorgonio Pass	*K. Kendrick, J. Matti*
14:30-14:50	Megatrench Results *D. Yule, K. Scharer, D. Heermance*	
14:50-15:10	Observations of Activity of the Mill Creek Strand and Uplift of Yucaipa Ridge	*A. Morelan, M. Oskin, J. Chester*
15:10-15:30	GPS Analysis	*J. Spinler, R. Bennett S. McGill*
15:30-15:50	Shallow 3D Structure in the San Gorgonio Pass	*D. Oglesby*
15:50-16:10	Break	

16:10-16:30	Assessing Fault Geometry from Seismicity	*C. Nicholson*
16:30-16:50	Impact of Fault Geometry within the San Gorgonio Pass on Deformation	*M. Cooke*
16:50-17:10	Stress Patterns from Seismicity	*T. Goebel and E. Hauksson*
17:10-17:30	Dynamic Rupture Models along Irregular Faults	*Z. Shi*
17:30-17:50	How does the San Gorgonio Pass Fit into UCERF3?	*T. Dawson*
17:50-18:00	Discussion of the Future of San Gorgonio Pass SFSA	*All*

PARTICIPANTS

Nicolas	Barth
Whitney	Behr
Yehuda	Ben Zion
Scott	Bennett
Glenn	Biasi
Kim	Blisniuk
Rufus	Catchings
Judi	Chester
John	Conrad
Michele	Cooke
Tim	Dawson
Ian	Desjarlais
Daniel	Elizondo
Tom	Freeman
Gary	Fuis
Thomas	Gobel
Peter	Gold
Jessica	Granader
Alex	Hatem
Dick	Heermance
Ann	Hislop
Birttany	Huerta
Susanne	Janecke
Kaitlyn	Jones
Frank	Jordan
Katherine	Kendrick
Vicki	Langenheim
Julian	Lozos
David	Lynch
Betsy	Madden
Jon	Matti
Sally	McGill
Alex	Morelan
Corrie	Neighbors
Craig	Nicholson
David	Oglesby
Mike	Oskin
Robert	Powell
Chris	Rollins
Kate	Scharer
David	Schwartz
Gordon	Seitz
Jacob	Selandar
Warrren	Sharp
Zheqiang	Shi
Kerry	Sieh
Josh	Spinler
Kathleen	Springer
Aviel	Stern
Tarra	Thompson
Jerry	Treiman
Louis	Warren
Lisa	Wolf
Doug	Yule
Robert	Zinke

Summary of Discussions

We had a number of illuminating presentations and discussions on the day of the workshop, as well as a follow-up discussion on Tuesday evening of the regular SCEC meeting. Our discussions revolved around the following four questions:

1. **What is the probability of a through-going San Andreas rupture?**

   A definitive answer to this question has fundamental implications for forecasting the earthquake hazard in southern California. To answer this question, we require answers to the two following questions.

2. **What is the subsurface geometry of active faulting through the San Gorgonio Pass?**

   To best predict potential rupture through the San Gorgonio "knot" and ground motions related to such an event, additional information is needed about the active fault configuration to 25 km depth. A data gap between 0-7 km depths hinders linking the very complex surface mapped fault traces with the deeper, potentially through-going fault structures defined by seismicity in the region.

   - A number of alternative active fault models link the surface and subsurface; some incorporate structures that steepen with depth and others use structures that become less steep with depth. Many possibilities and alternative 3D fault representations are parameterized in the SCEC CFM 5.0.
   - The seismicity below 7 km near the possible location of a through-going fault tends to have a very high stress drop. Does this seismicity reflect volumetric strain on a family of small faults, or slip on a single master structure?
   - Some earthquakes in this volumetric strain zone appear to define discrete faults with multiple orientations. Which of these faults may represent a through-going master fault remains unclear, because some – if not many – of these deep faults may be second-order structures.
   - How does the oblique collision between the San Jacinto and San Bernardino mountains relate to the zone of high stress drop and fault complexity near the surface?
   - Along with the fault structure, the state of stress along active faults is also not well characterized, but is necessary for understanding the propagation of earthquake rupture and slip in the Pass.

3. **What is the earthquake potential in the San Gorgonio Pass region?**

   If fault geometry, stressing rates and slip rates are known, then we will be able to develop more accurate earthquake models, which will in turn produce better estimates of earthquake size, earthquake interactions, ground motion, and seismic hazard.

   - We have a number of new estimations of slip rates on various strands of faults in the SGP.
     - Roughly ten different on-going geologic investigations are providing much needed new insight on the slip history of the SGP. These new results support a preliminary model with steep along-strike gradients in slip rate as well as abrupt transfer of slip between overlapping fault strands. There are still some inconsistencies between strike-slip rate estimates, so the slip rate model for active faults in the SGP is still a work in progress.

    - Mechanical models testing two often hypothesized active fault configurations show that all of the observed slip rates cannot be matched with any one active fault configuration. The existing distribution of slip rate results could be further tested with measurements at additional sites, comparison within forward models that can test for consistency of self-consistency of the strike-slip rates, and ongoing geodetic inversions for slip rate distribution.
- We also have new information on paleoseismic ruptures in the SGP. The most geometrically complex region appears to have infrequent earthquakes.
    - These results support a model with infrequent, very large (M 7.5+) events in the SGP, with more smaller-sized events that tend to terminate on either side of the pass.
    - There may exist a >700 year recurrence of events with >4-7 m of slip, which would be almost impossible to be confined only to the pass and suggests large rupture through the SGP.
- We have filled in a number of data gaps in the past few years, but much strategic work still needs to be done.

Proposed Science Plan

For our proposed science plan, we wish to lay out some directed research priorities that help to answer our fundamental questions above, and are aligned with the priorities of SCEC 5 as outlined at the SCEC Annual Meeting.

We note that in the past few years, the geologic community has produced a great deal of progress in the geology of the SGP SFSA, building upon decades of successful research prior to the formation of the SGP SFSA. There have been a few notable successes on the geophysical (microseismicity and gravity in particular) side of the investigation, but in general geophysical analysis and modeling has not progressed as rapidly as the geology due to a lack of constraints on fault geometry. In particular, the lack of data linking the surface fault traces and deeply-buried (>7 km) structures at seismogenic depths has hindered the formulation of models that can directly address the likelihood of through-going rupture in the SGP. Therefore, the SFSA participants have proposed the following directed priorities:

1. Focused geophysical investigation of the upper 7 km of the SGP region to delineate the faults linking the surface to the deeper structures. For example, a passive-source, seismic tomography study could provide such crucial information.
2. Simultaneously, we wish to further develop numerical models that will lead toward answering the question of through-going rupture in the SGP. These models could include spatial and temporal domains ranging from long-term crustal deformation models of the entire region to short-term single-event models of portions of the SGP. The models should strive to use the most current observations available to constrain their inputs and test their results.

3. Targeting strategic data gaps in the geological slip rates and rupture record. These investigations could test slip rate gradients along strike and slip transfer between fault segments. More information on slip rates in different time intervals would help to constrain the evolving activity of this fault system.
4. Leveraging potential partnerships with utilities and other infrastructure organizations to help facilitate the priorities listed above.
5. We encourage other studies that address the three overarching questions established for the SGP SFSA.