San Gorgonio Pass Special Fault Study Area

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Small region within a large system

The San Gorgonio Pass comprises the southern Big Bend of the San Andreas fault

Field et al., 2014, UCERF3
The San Gorgonio Pass

(modified from McGill et al., GSA Bull. 2013)
Guiding questions

- What is the subsurface geometry of active faulting through the San Gorgonio Pass?
- What is the earthquake potential in the San Gorgonio Pass?
- What is the probability of a through-going San Andreas rupture?
Time line of activity

- **Start of SCEC4**
  - 2 day Workshop
  - 33 participants
  - Established as one of two SFSA

- **2012**
  - CFM v.4
  - Nicholson et al.

- **2013**
  - McGill et al., GSA Bull

- **2014**
  - Herbert, Cooke & Marshall, JGR
  - CFM v.5
  - Plesch et al.

- **2015**
  - 1 day workshop
  - 54 participants
  - 2015 annual meeting
  - Kendrick et al., JGR
  - McGill et al., JGR

- **2016**
  - Gold et al. JGR
  - Many future papers

San Gorgonio Pass SFSA, SCEC annual meeting 2015
Data and tools

Nicholson
Hauksson
Goebel
Carena

seismicity

geology

geophysics

Fuis
Langenheim
Oglesby

Spinler
McGill

Geodesy

Cooke
Crustal deformation models

Dynamic rupture models

Behr, Blisniuk, Brune,
Chester, Gold, Heermance,
Kendrick, Lifton, Matti,
McGill, Oskin, Scharer,
Sharp, Sieh, Rymer, Yule

Shi, Day,
Oglesby, Tarnowski
What is the active geometry of faults?

- SSIP seismic line 6 crosses within the SGP SFSA
- Reveals multiple NE dipping strands of the San Andreas

Fuis, Bauer, Goldman, Ryberg, Langenheim, Scheirer, Rymer, Stock, Hole and Catchings, submitted
What is the active geometry of faults?

CFM 5.0
Updated 3D Fault Set

Increasing fault complexity in SGP & adjacent areas defined by seismicity

Nicholson, Plesch and Hauksson
What is the active geometry of faults?
How is slip partitioned?

McGill et al., 2015

McGill, Spinler et al., unpublished
How is slip partitioned?

- Variable slip rates along the San Andreas through the San Gorgonio Pass.
- Mechanical models match this variability

(modified from Herbert & Cooke, BSSA 2012)

(McGill et al., GSA Bull. 2013)

(data gap)

(McGill et al., in prep)
How is slip partitioned?

- Active strands
  - Mill Creek-Mission Creek
  - Banning-Garnet Hill

(Gold, Behr et al., JGR 2015)
How is slip partitioned?

- No offset of Holocene/Latest Pleistocene alluvial deposits at Upper Raywood Flats

- The Pinto Mountain fault offsets the Mill Creek strand

(Kendrick et al., JGR. 2015)
How is slip partitioned?

- Lidar scarp analysis suggests that slip may by-pass upper Raywood flats via the Galena Peak fault.
- Fault kinematics consistent with slip transfer

(Morelan, Oskin, Chester and Elizondo, in prep)
How is slip partitioned?

- Offset alluvial fan reveals relatively slow slip rates $\sim (4-5$ mm/yr) along the Banning fault
- Slip rate at SE end of Indio Hills (Scharer) is also 2-6 mm/yr

*Holocene rate: 3.9+2.3/-1.6 to 4.9+1.0/-0.9 mm/yr*

*Gold, Behr et al., JGR 2015*
How is slip partitioned?: Banning strand & San Gorgonio Pass thrust

Heermance and Yule, in prep

new $^{10}$Be ages ★
- Qt4: 8900 $^{+11600}_{-7300}$ y.b.p.
- Qt3: 8300 $^{+10300}_{-6800}$ y.b.p.

new cumulative slip rate: 4.0-5.9 mm/yr
(~30-70% of total SAF slip)

take home points:
1) low SAF slip rate and long (>600 yrs) eq recurrance in San Gorgonio Pass
How is slip partitioned?:

**Mission Creek strand**: 22-25 mm/yr (~90 ka, ~70 ka, & ~25 ka)
**Banning strand**: 4-6 mm/yr since ~6ka

- 2.1 to 2.4 km offset since 88 $^{+11/-7}$ ka: $25^{+4/-3}$ mm/yr
- 1.3 to 1.7 km offset since 69 $^{+2/-2}$ ka: $22^{+3/-3}$ mm/yr
- 0.6 to 0.9 km offset since 25 $^{+5/-4}$ ka: $27^{+8/-6}$ mm/yr

Blisniuk, Scharer, Sharp, Burgmann in prep
How is slip partitioned?  

- Strike slip is transferred to the Mill Creek strand.
  - San Jacinto and Banning have slower slip rates

Cooke, in prep.
How is slip partitioned?

Slip partitioning is sensitive to active fault geometry through the pass

San Bernardino  Mill Creek – Mission Creek  Banning  Coachella

Cooke, \textit{in prep.}

San Gorgonio Pass SFSA, SCEC annual meeting 2015
What is the stress state?

- Insights from microseismicity
  - Large stress drops within the San Gorgonio Pass

*Goebel et al., JGR 2015*
What is the stress state?

- Insights from crustal deformation models
  - Off-fault deformation matches better the stress inversions from focal mechanisms than interseismic stressing rates

Cooke, in prep.
Correlation to stress drops in SGP

Regions of large stress drops correlate with compressive mean stress of off-fault deformation

Stress drop may relate to fault geometry rather than material contrast at step in base of seismicity

Goebel et al., JGR 2015
Can earthquakes rupture through the Pass?  

*Paleoseismology*

- Only 4 earthquakes in 5500 years
- Complex slip patterns: 0.5 – 2.5 m uplift in single event
- Most recent event was ~1400 A.D.

*Yule, Scharer in prep*
Can earthquakes rupture through the Pass? Dynamic rupture

Candidate SCEC CSMs as Reference of Stress Input

- The initial stress field dominates rupture behavior, compared to other factors including small-scale fault geometric complexities.
- Different stress models in their present forms will lead to vastly different rupture scenarios regarding the likelihood of through-going rupture along SGP.
Can earthquakes rupture through the Pass?

- Ruptures starting on the Banning strand can pass to the San Bernardino strand.
- Ruptures from the San Bernardino strand are less likely to pass to the Banning.

Tarnowski, Kyriakopoulos, and Oglesby
Can earthquakes rupture through the Pass?

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Tarnowski, Kyriakopoulos, and Oglesby
San Gorgonio Pass SFSA outcomes

- Some but not all ruptures can pass through the SGP as large events.
- The region hosts slow slip rates, low strain rates and unusually high stress drops, which owe to fault geometry.
- Activity distributed among multiple strands rather than along one dominate structure.
- Cross-disciplinary discussions and collaborations
- Leveraging for projects funded by USGS and NSF.
Thank you!

Photo along the Mill Creek strand of the San Andreas fault