# Prospective Testing of Fault Segmentation Models

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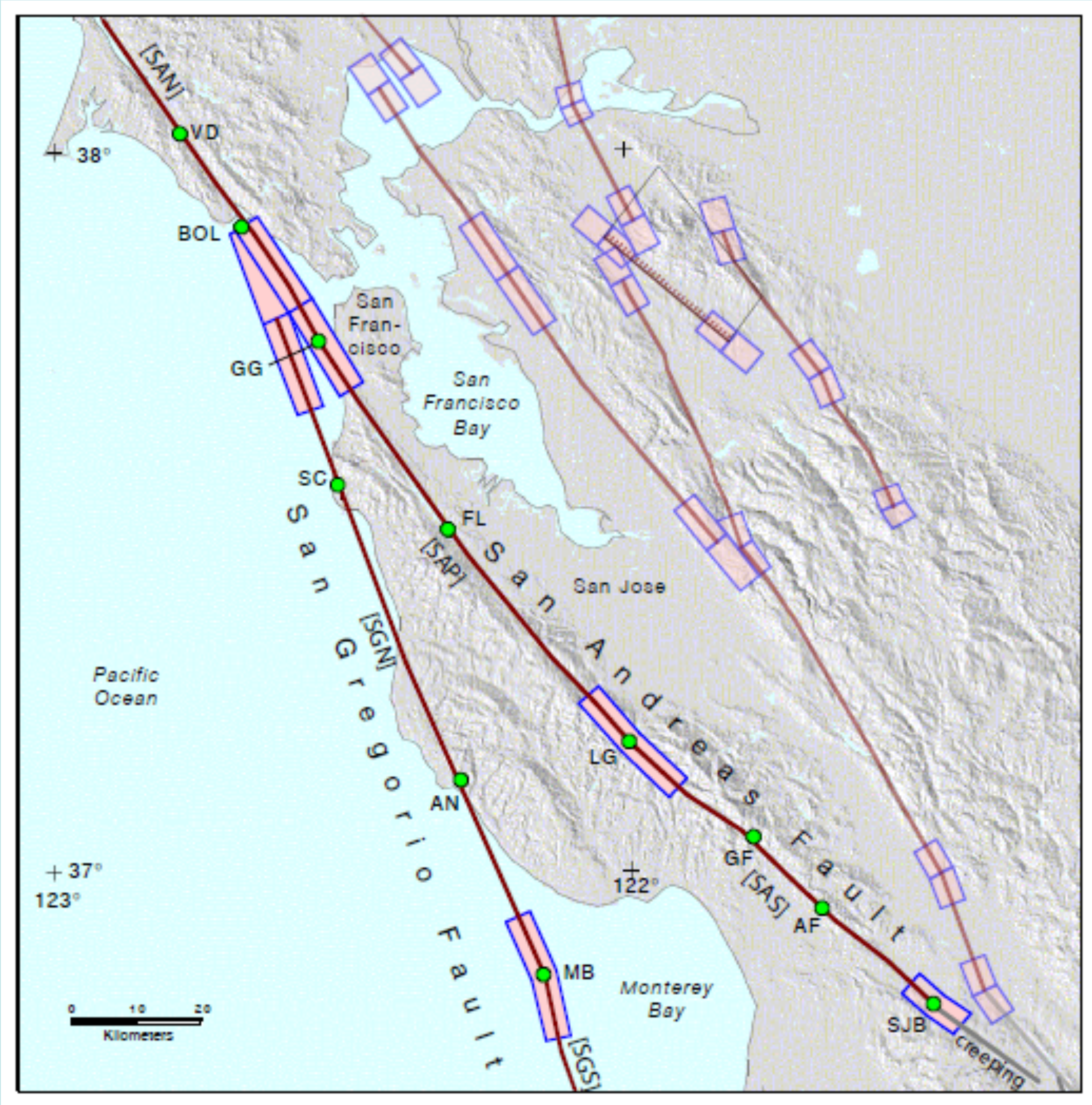
# Faults modeled in the 2002 Working Group on California Earthquake Probabilities Report, with boxes to show segment boundaries with their uncertainty.



# Hypotheses

- Test Hypothesis H1: If earthquake rupture enters a segment boundary polygon as shown in Figure 1 from outside, it will stop within that polygon with probability p, which is greater than the probability q for a similar sized random polygon spanning the fault.

- Null Hypothesis H0: $p \leq q$.

- Comments: Strict segmentation requires $p = 1$ (any rupture that gets to the boundary stops within the polygon. Moderate success requires $p > 2*q$ by my criterion.

# Cascade scenarios from WGCEP 2002, with implied frequencies of stopping or proceeding

| Scenario | Rate/yr. | SAS/SAP | SAP/SAN | SAN/SAO |
|---|---|---|---|---|
| SAS | 0.00070 | Stop | | |
| SAP | 0.00050 | Stop | Stop | |
| SAN | 0.00010 | | Stop | Stop |
| SAO | 0.00020 | | | Stop |
| SAS+SAP | 0.00100 | Go | Stop | |
| SAP+SAN | 0.00000 | Stop | Go | Stop |
| SAN+SAO | 0.00120 | | Stop | Go |
| SAS+SAP+SAN | 0.00002 | Go | Go | Stop |
| SAP+SAN+SAO | 0.00010 | Stop | Go | Go |
| SAS+SAP+SAN+SAO | 0.00260 | Go | Go | Go |
| | | | | |
| Stop rate | | 0.00130 | 0.00280 | 0.00032 |
| Go rate | | 0.00362 | 0.00272 | 0.00390 |
| | | | | |
| Stop Probability | | 0.264 | 0.507 | 0.076 |

# WGCEP 2008 Segment Model for Southern California

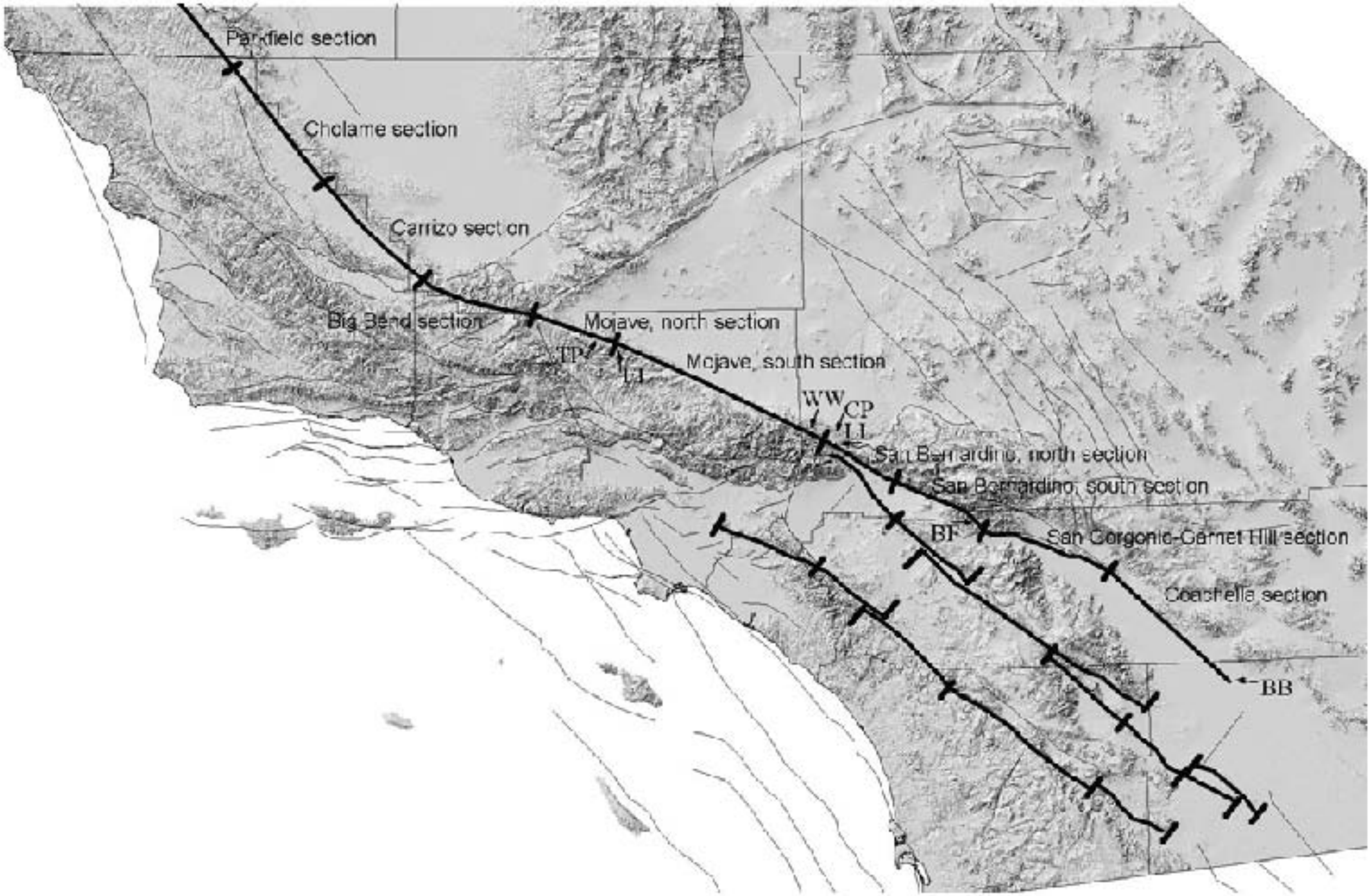



**Figure 5.** Sections of the southern San Andreas, San Jacinto, and Elsinore faults, showing new section names for the southern San Andreas. Annotated localities are Plieto thrust fault (PT), Three Points (TP), Elizabeth Lake (EL), Wrightwood (WW), Cajon Pass (CP), Lost Lake (LL), Burro Flats (BF), and Bombay Beach (BB).

# Null hypothesis for conditional stopping probability

**Assumptions**

- Ground-rupturing earthquakes distributed randomly along infinitely long fault
- Gutenberg Richter magnitude distribution, $6.5 < m < 8.5$
- Rupture length scaled as cube root of seismic moment (see next slide)

**Results**

For fixed magnitude, $P = B / (L+B)$

$P$ = conditional stopping probability

$B$ = length of segment boundary zone

$L$ = rupture length

Integrated for magnitudes $6.5 < m < 8.5$

**$P = 0.184$ for $B = 20$ km**

# Simple scaling model for length, width, and slip VS. magnitude

Assuming the self=similarity implied by the Kagan result, we adopted the following forms for average length (L), average down-dip width (W) and average slip (D) as a function of moment magnitude (m):

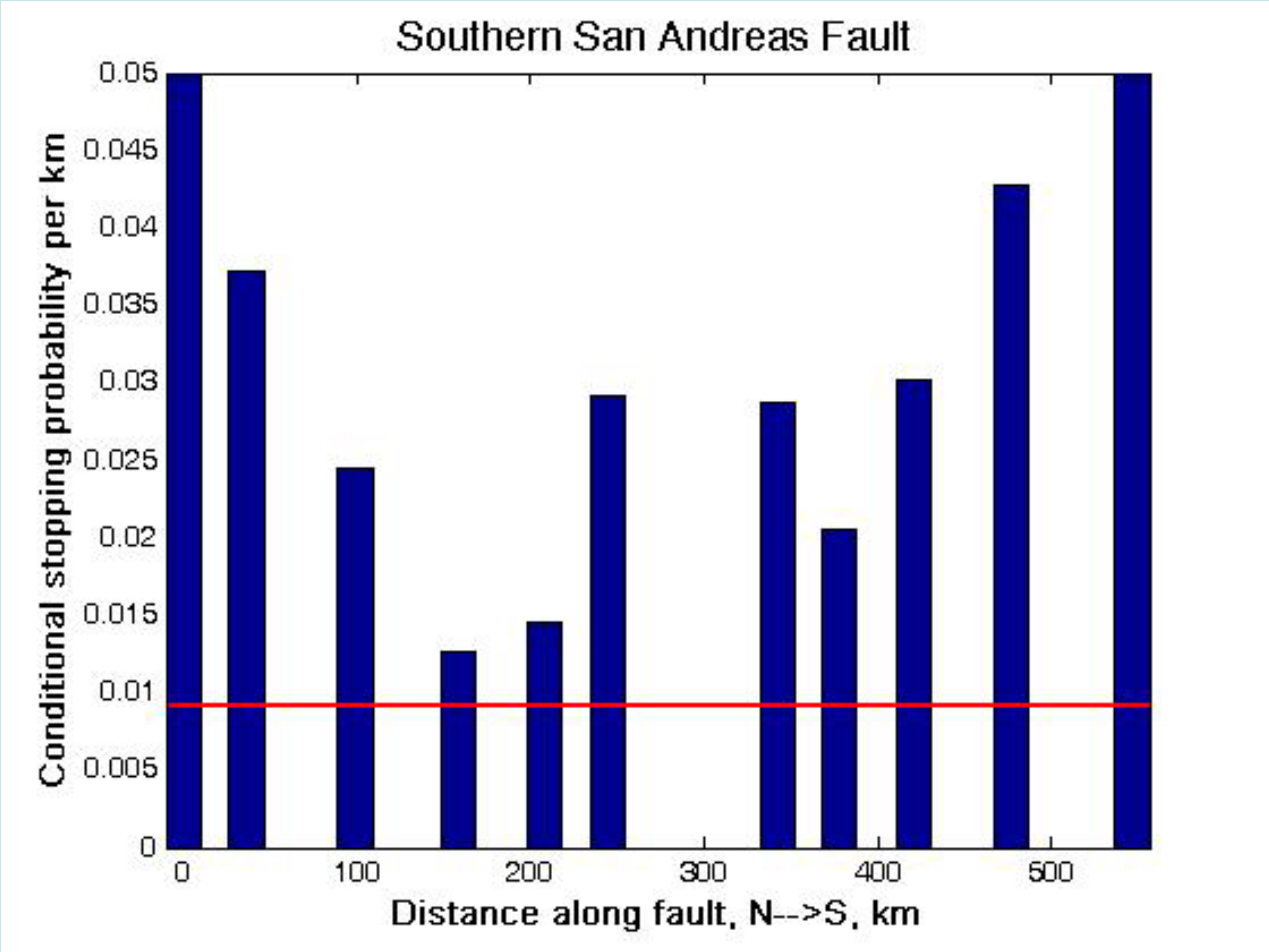
- Log10(L) = a + 0.5*m  L in km;  a = -1.65 from Kagan [2002]
- Log10(D) = c + 0.5*m  D in m; c = -3.50 from Wells and Coppersmith [1994]
- Log10(W) = b + 0.5*m  W in km;  b = -2.55 from m*L*W*D = 10^(1.5*m+9)

- We took m to be $5*10^{10}$ Nm. The sum a + b = -4.2 represents the area scaling, and it coincidentally equals the value used in the "Ellsworth B" magnitude-area relationship. The results:

# Simple Scaling Relationship

| Moment Magnitude | Length | Width | Slip | Moment | Area |
|---|---|---|---|---|---|
| 6.5 | 39.81 | 5.02 | 0.56 | 5.62E+18 | 200 |
| 7 | 70.79 | 8.93 | 1 | 3.16E+19 | 632 |
| 7.5 | 125.89 | 15.89 | 1.78 | 1.78E+20 | 2000 |
| 8 | 223.87 | 28.25 | 3.16 | 1.00E+21 | 6324 |
| 8.25 | 298.54 | 37.67 | 4.22 | 2.37E+21 | 11246 |
| 8.5 | 398.11 | 50.23 | 5.62 | 5.62E+21 | 19999 |
| 9 | 707.95 | 89.33 | 10 | 3.16E+22 | 63241 |
| 9.5 | 1258.93 | 158.85 | 17.78 | 1.78E+23 | 199986 |

# Conditional Stopping Probability, UCERF2



## Likelihood test for San Francisco Earthquake, 1906

| **WGCEP 08** | | N. end SAO | SAO-SAN | SAN-SAP | SAP-SAS | S. End SAS |
|---|---|---|---|---|---|---|
| Conditional Stopping Probability | | 1.00 | 0.24 | 0.82 | 0.42 | 1.00 |
| Outcome Probability | | 1.00 | 0.76 | 0.18 | 0.58 | 1.00 |
| Log Likelihood | | 0.00 | -0.12 | -0.75 | -0.23 | 0.00 |
| ***Total Log Likelihood*** | ***-1.11*** | | | | | |

| **Null Hypothesis** | | | | | | |
|---|---|---|---|---|---|---|
| Conditional Stopping Probability | | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| Outcome Probability | | 0.18 | 0.82 | 0.82 | 0.82 | 0.18 |
| Log Likelihood | | -0.74 | -0.09 | -0.09 | -0.09 | -0.74 |
| ***Total Log Likelihood*** | **-1.74** | | | | | |

## Likelihood test for Ft. Tejon Earthquake, 1857

| | | PK-CH | CH-CC | CC-BB | BB-NM | NM-SM | SM-NSB |
|---|---|---|---|---|---|---|---|
| **WGCEP 08** | | | | | | | |
| Conditional Stopping Probability | | 0.74 | 0.49 | 0.25 | 0.29 | 0.58 | 0.58 |
| Outcome Probability | | 0.74 | 0.51 | 0.75 | 0.71 | 0.42 | 0.58 |
| Log Likelihood | | -0.13 | -0.29 | -0.13 | -0.15 | -0.38 | -0.24 |
| ***Total Log Likelihood*** | ***-1.32*** | | | | | | |
| | | | | | | | |
| **Null Hypothesis** | | | | | | | |
| Conditional Stopping Probability | | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| Outcome Probability | | 0.18 | 0.82 | 0.82 | 0.82 | 0.82 | 0.18 |
| Log Likelihood | | -0.74 | -0.09 | -0.09 | -0.09 | -0.09 | -0.74 |
| ***Total Log Likelihood*** | ***-1.82*** | | | | | | |

# Conclusions

1. A segment test requires advance specification of segment boundaries and conditional probability of rupture stopping within boundary zone.
2. The 2002 and 2008 WGCEP reports give info from which conditional stopping probabilities can be derived.
3. A simple null hypothesis assumes random locations, GR magnitudes, and length proportional to the cube root of seismic moment. For magnitude 6.5+, the conditional stopping probability is about 0.009 per km of segment boundary.
4. In a retrospective test on the 1906 and 1857 earthquakes, the WGCEP segmentation model beats the null hypothesis, but only because segment boundaries were drawn at the assumed ends of those ruptures.
5. Definitive test of WGCEP models could take 100 years.