

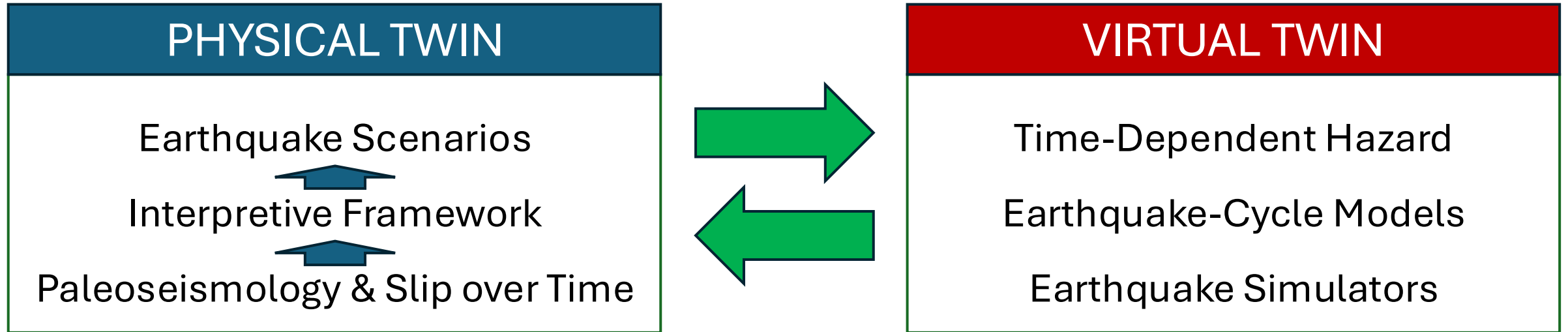
# UNREST TAG Proposal

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+ Tim Dawson, Belle Philibosian, Ian Pierce, Gordan Seitz, Lisa Grant-  
Ludwig, Kate Scharer, Genya Ishigaki, Ramon Arrowsmith (Project  
Collaborators)

+ Any/all of you here!

# UNREST *vision: Digital Twin Fault System*



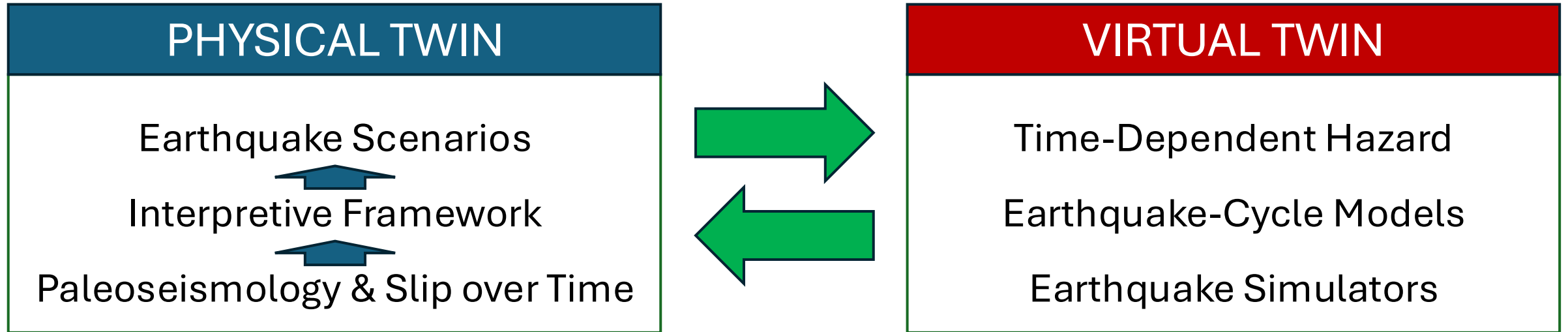
The ***Physical Twin*** is constructed from point observations along a fault, e.g.,

- Paleoseismic event sequences (trench data)
- Slip over time (within sequence) & long-term slip rates
- Other information (fault geometry, regional time markers, etc.)

The ***Interpretive Framework*** correlates point observations to build ***Earthquake Scenario Models*** of the natural earthquake cycle.

(a.k.a. stringing pearls, but with improved algorithm)

# UNREST *vision: Digital Twin Fault System*

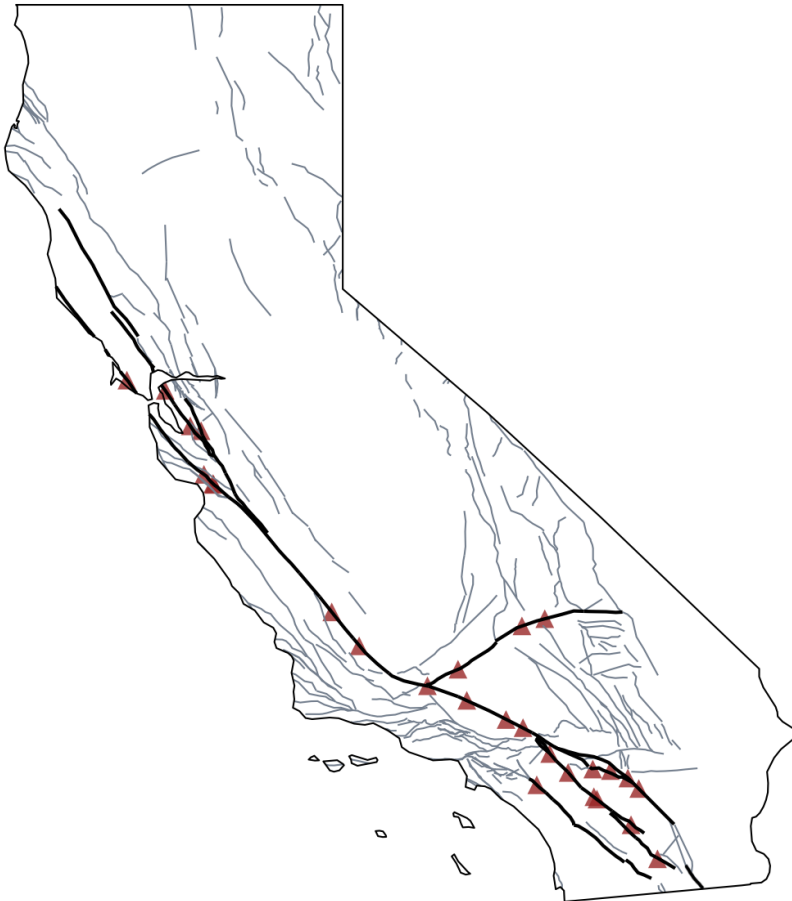


The ***Virtual Twin*** is a container for earthquake-cycle models , e.g.,

- Statistical Models (BPT, Weibull, Long-Term Fault Memory, etc.)
- Earthquake Cycle Models (full physics basis with evolving stress conditions)
- Earthquake Simulators (reduced physics basis with complex fault network)

The ***Digital Twin Feedback Loop*** allows for *model-derived insight* to Influence the physical twin through the interpretive framework layer, e.g., less plausible earthquake pairs may be removed and scenarios re-evaluated.

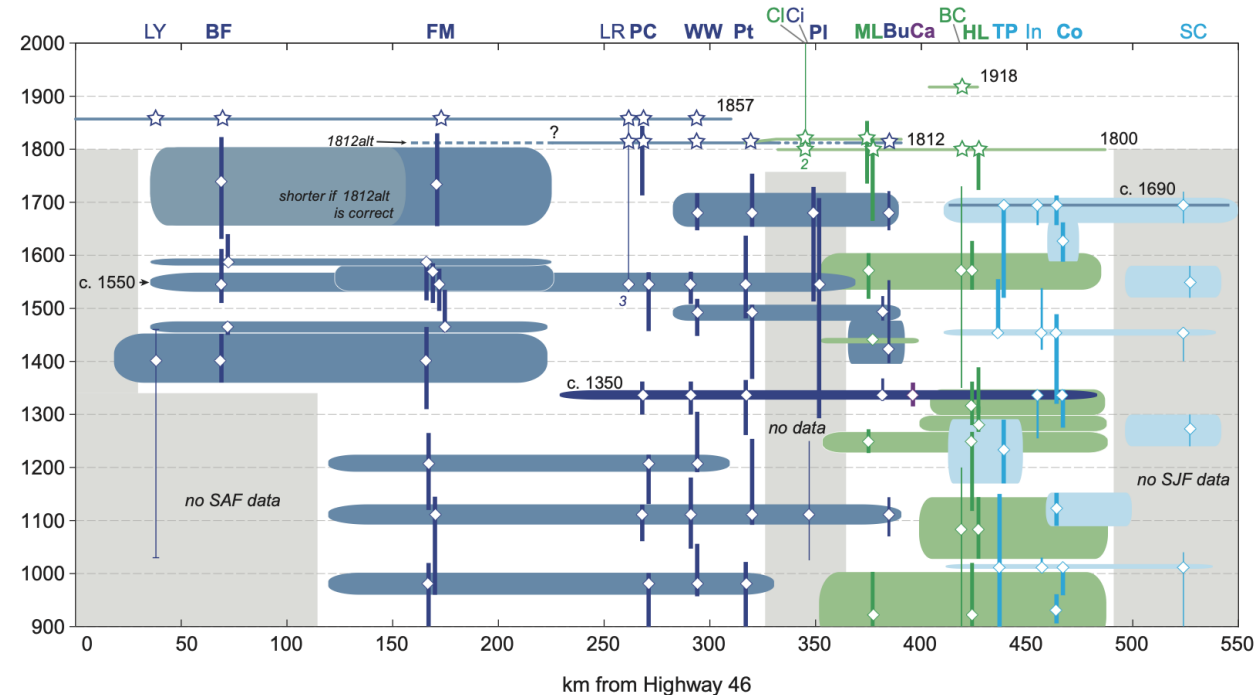
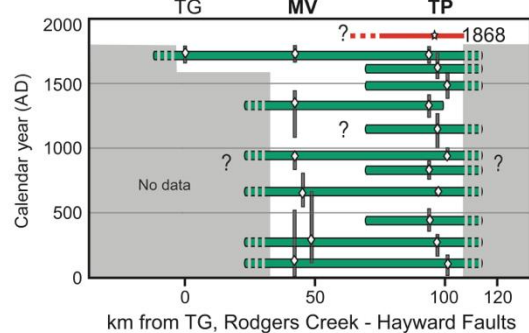
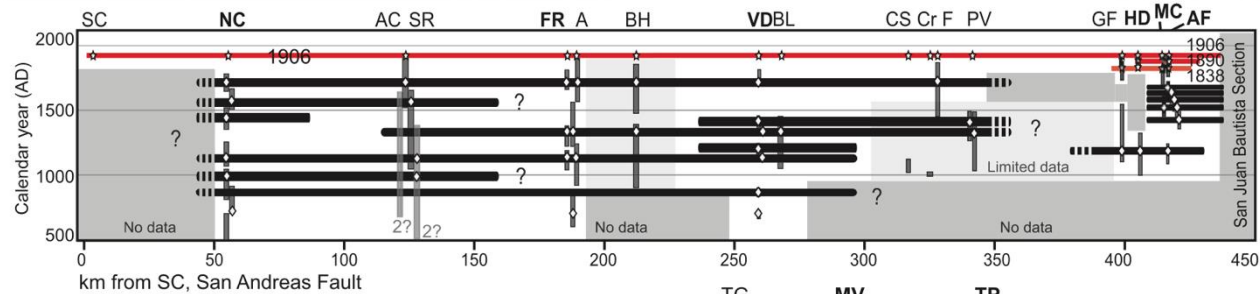
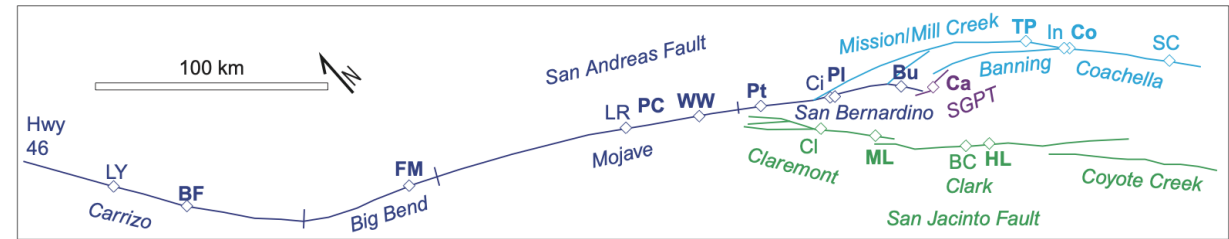
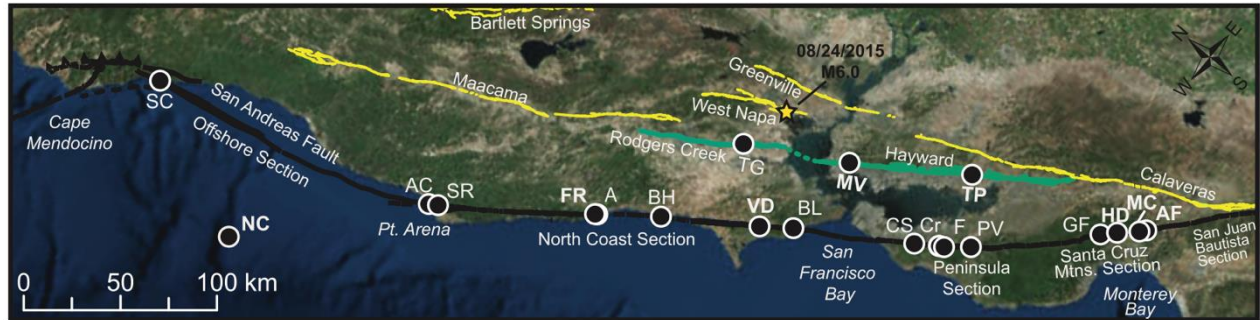
# Project scope: Primary plate-boundary transform faults (slip rate $\geq 5$ mm/yr)



- Northern California:
  - Northern San Andreas
  - Calaveras-Hayward-Rodgers Creek-Maacama
- Southern California
  - Southern San Andreas
  - Garlock
  - San Jacinto
  - Elsinore
  - Imperial

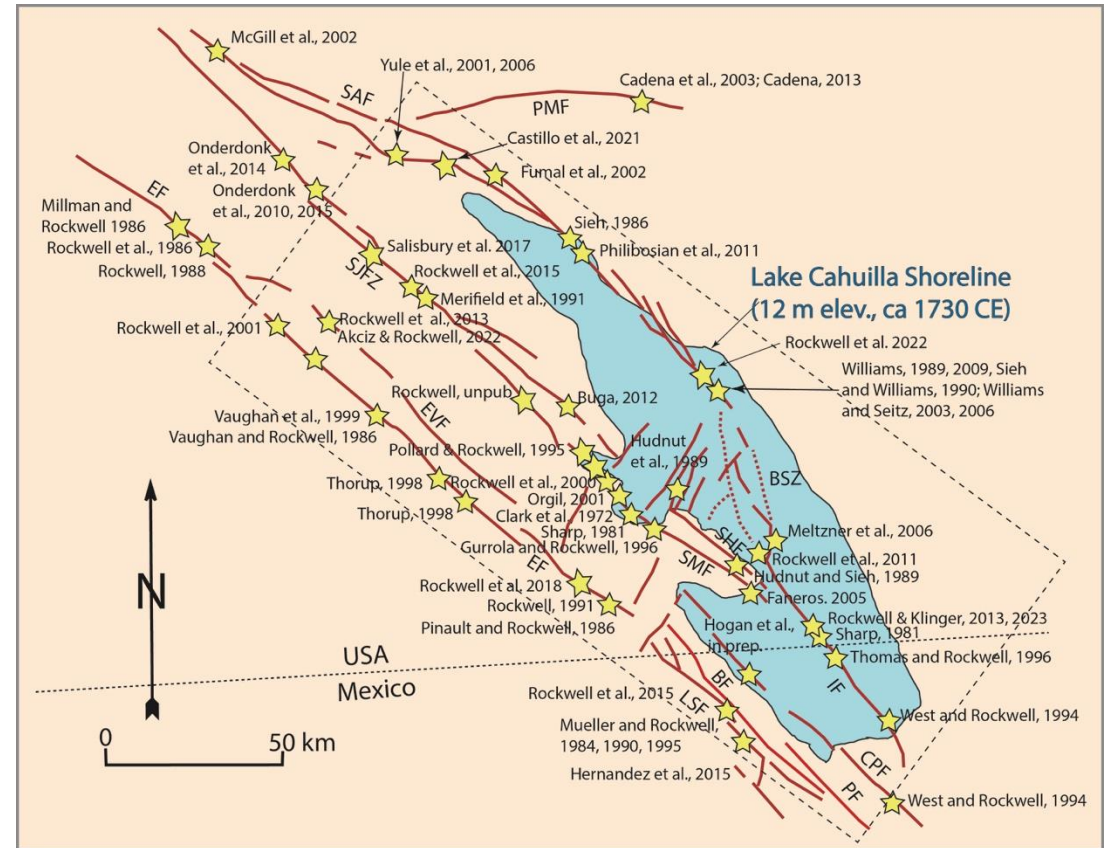
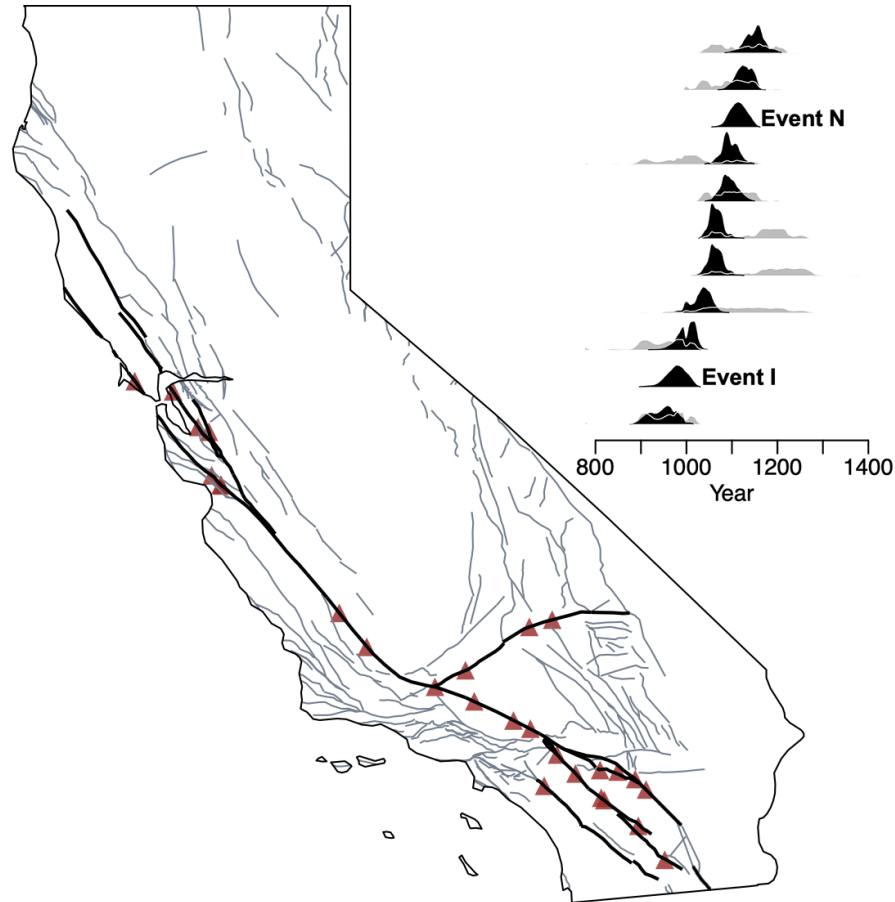
# Earthquake-Cycle Scenario Models

*UNREST vision: Automatic, Mutable Scenario Generation*



Maximum Rupture Scenario Models from Scharer & Streig (2019)

# Abundant data exists from which to build scenario models.



Paleoseismic trench sites with archived oxcal sequence models (mostly UCERF2 era; needs updating)

Compilation of paleoseismic data from Rockwell et al., submitted manuscript.

# Oxcal Sequence Models

- Oxcal scripts encode logic of event age interpretation and show what data were used.
- Age PDFs needed for rigorously computing inter-event times.
- Age PDFs especially important for computing joint probability across multiple trench sites!
- Much work needs to be done to collect/reconstruct models from literature & reports.

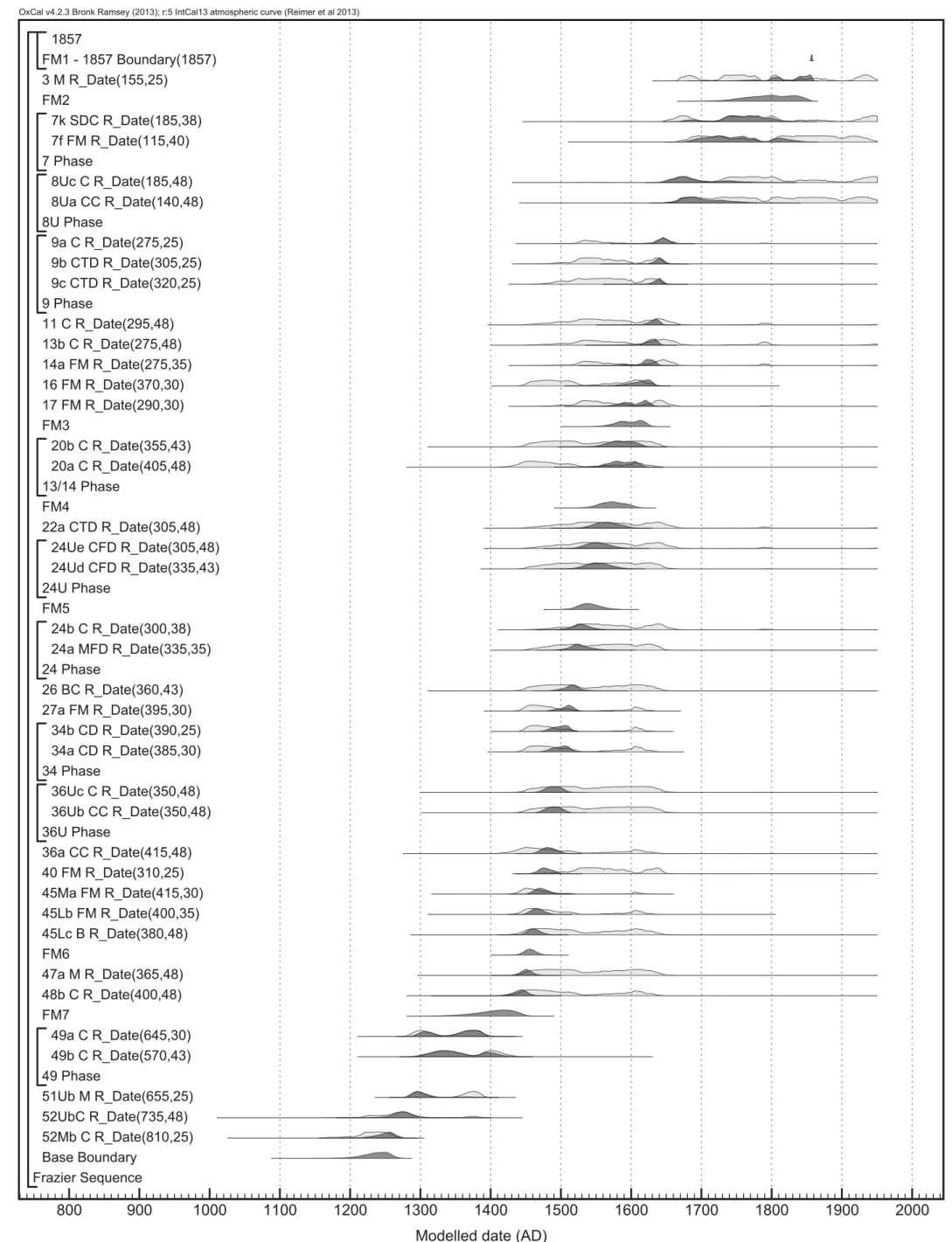
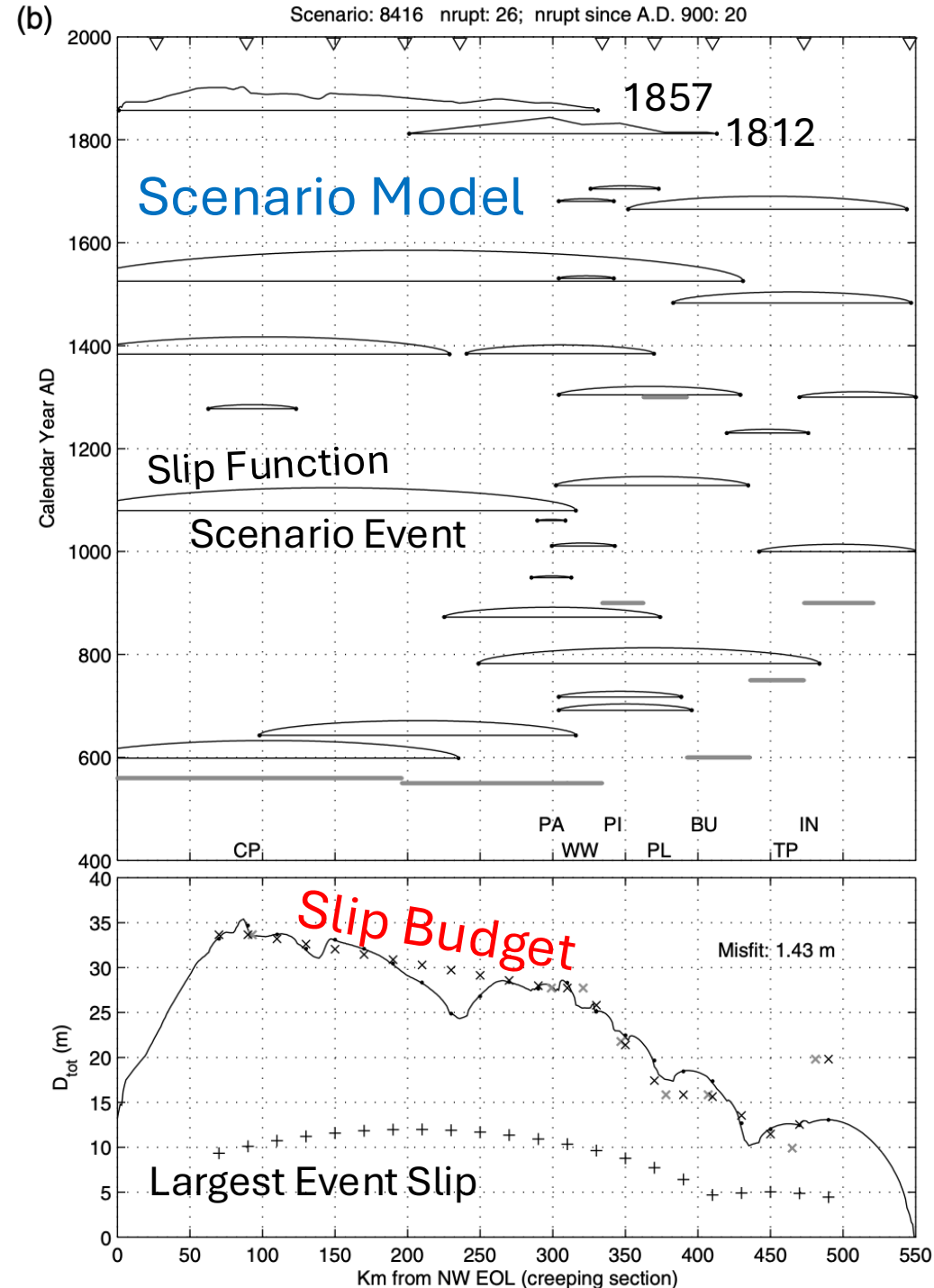
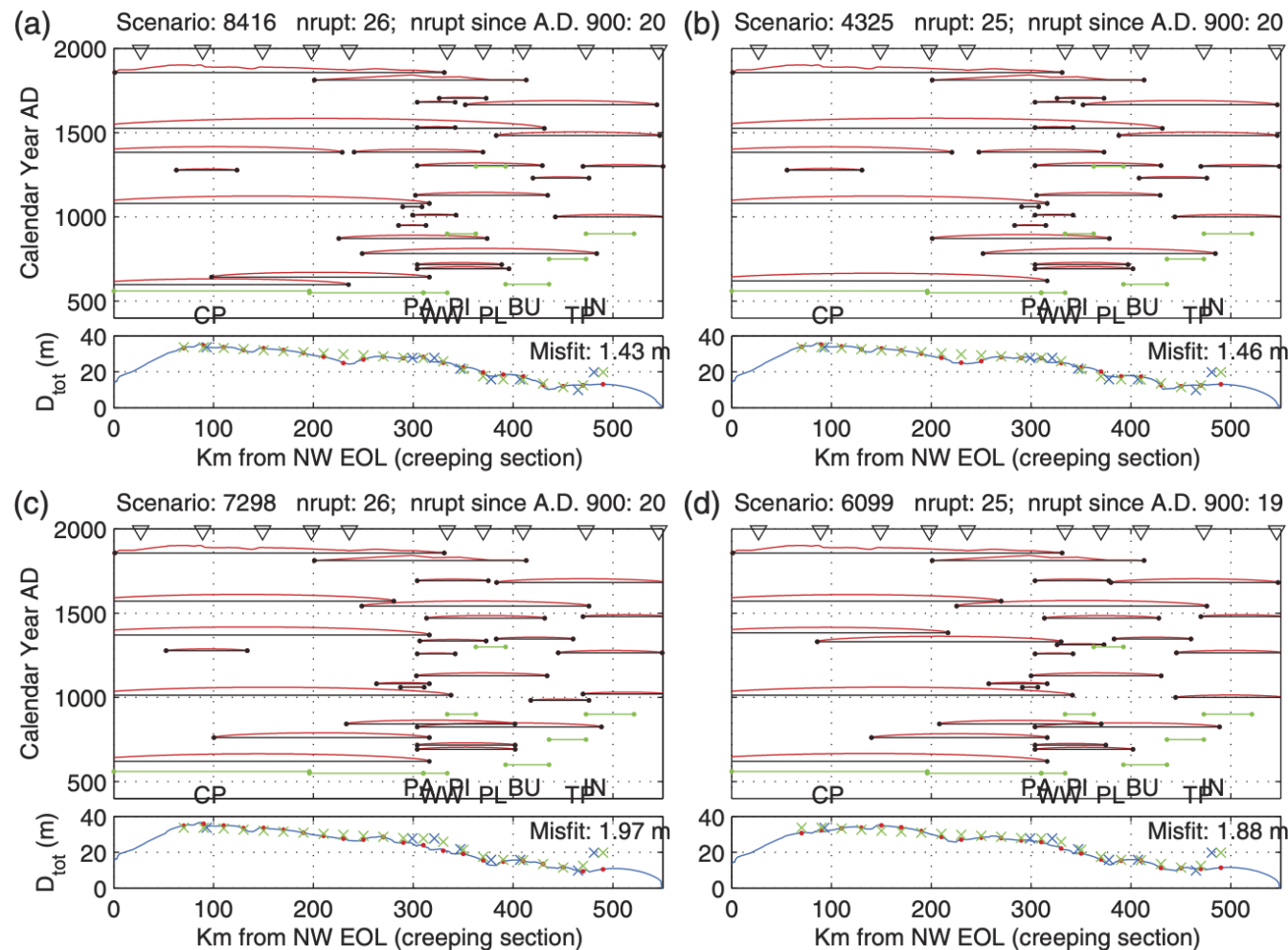


Figure S2 from Scharer et al. (2010)

# San Andreas Fault Rupture Scenarios from Multiple Paleoseismic Records: Stringing Pearls

by Glenn P. Biasi and Ray J. Weldon II

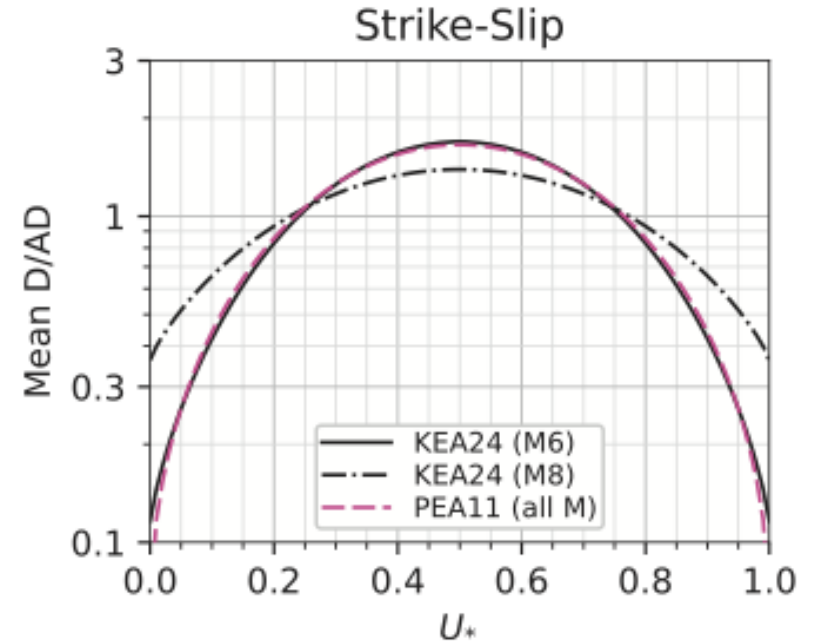
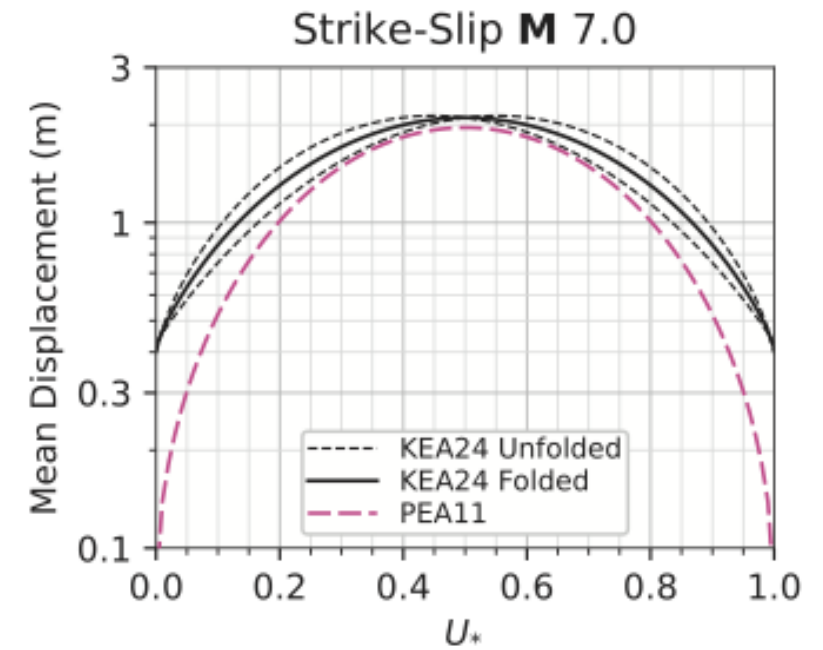
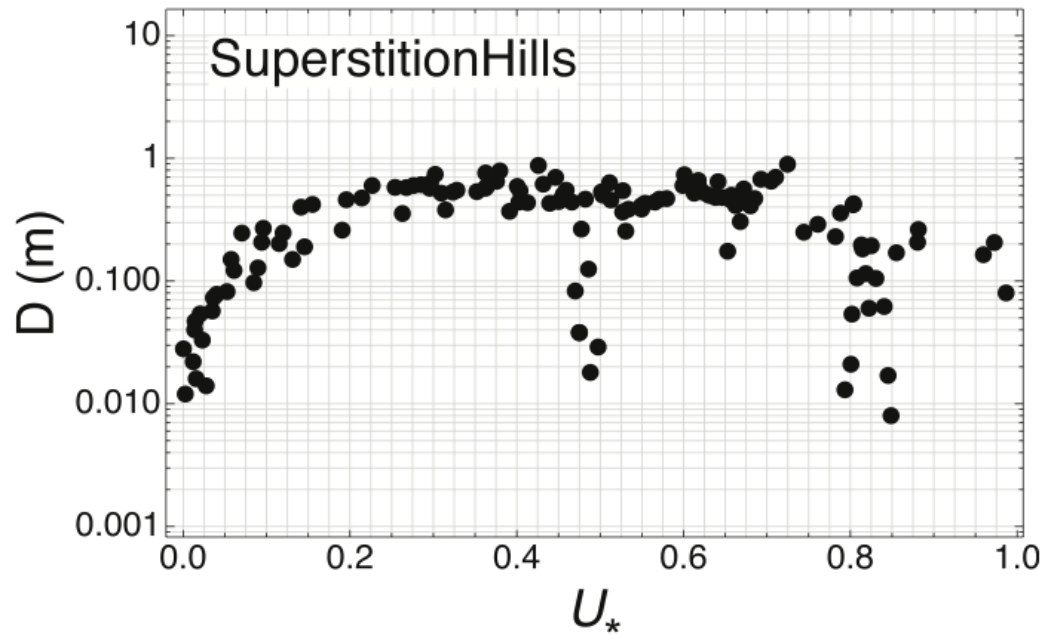


# A Fault Displacement Model Based on the FDHI Database

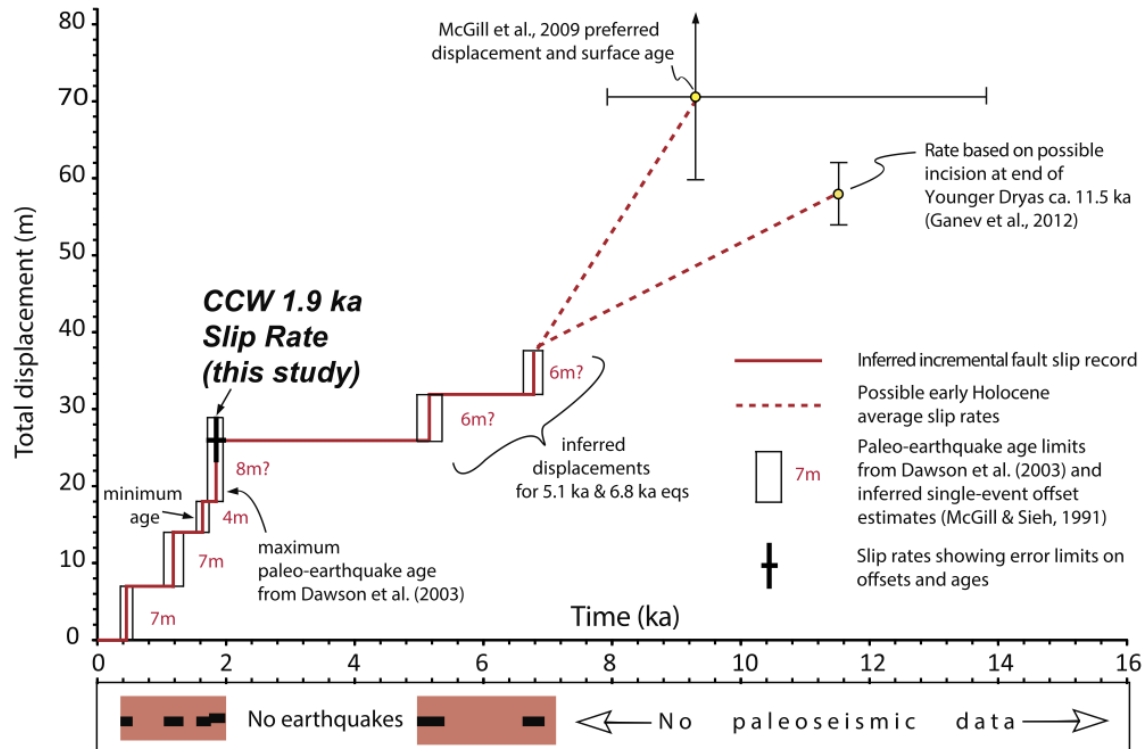
Earthquake Spectra  
2025, Vol. 41(4) 2783–2805  
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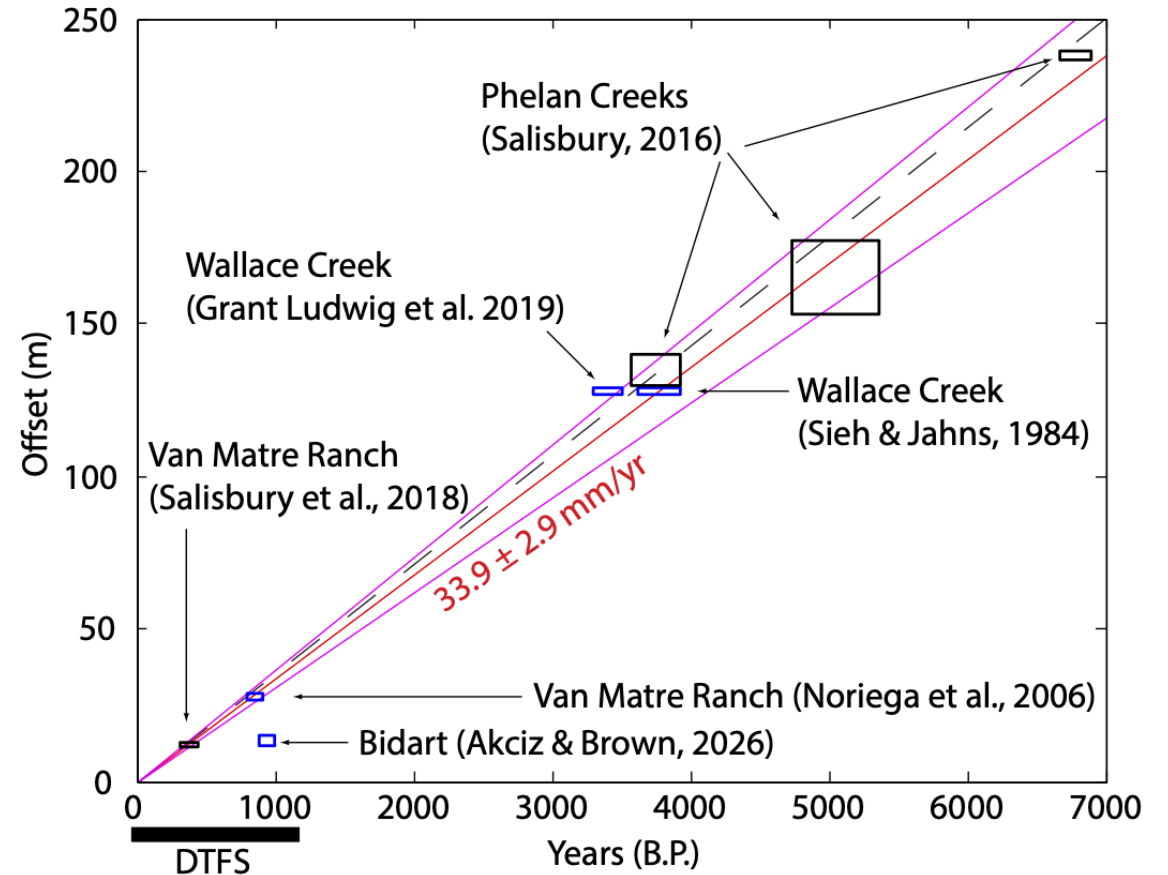
Nicolas M Kuehn<sup>1</sup> , Albert R Kottke, M.EERI<sup>2</sup> ,  
Alexandra C Sarmiento<sup>1,3</sup> , Christopher M Madugo<sup>2</sup>,  
and Yousef Bozorgnia, M.EERI<sup>1</sup> 



# Slip rate, Slip Budget, and Slip over Time

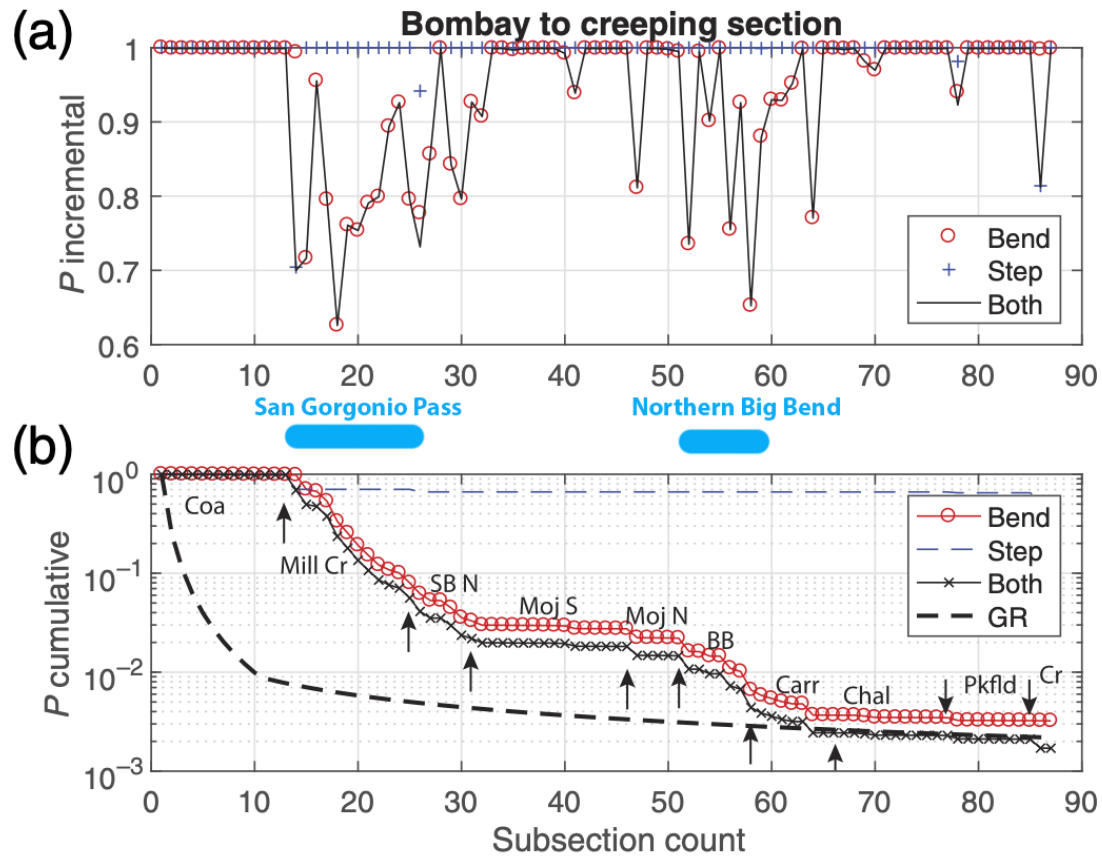


Garlock Fault: Dolan et al. (2016) Figure 8

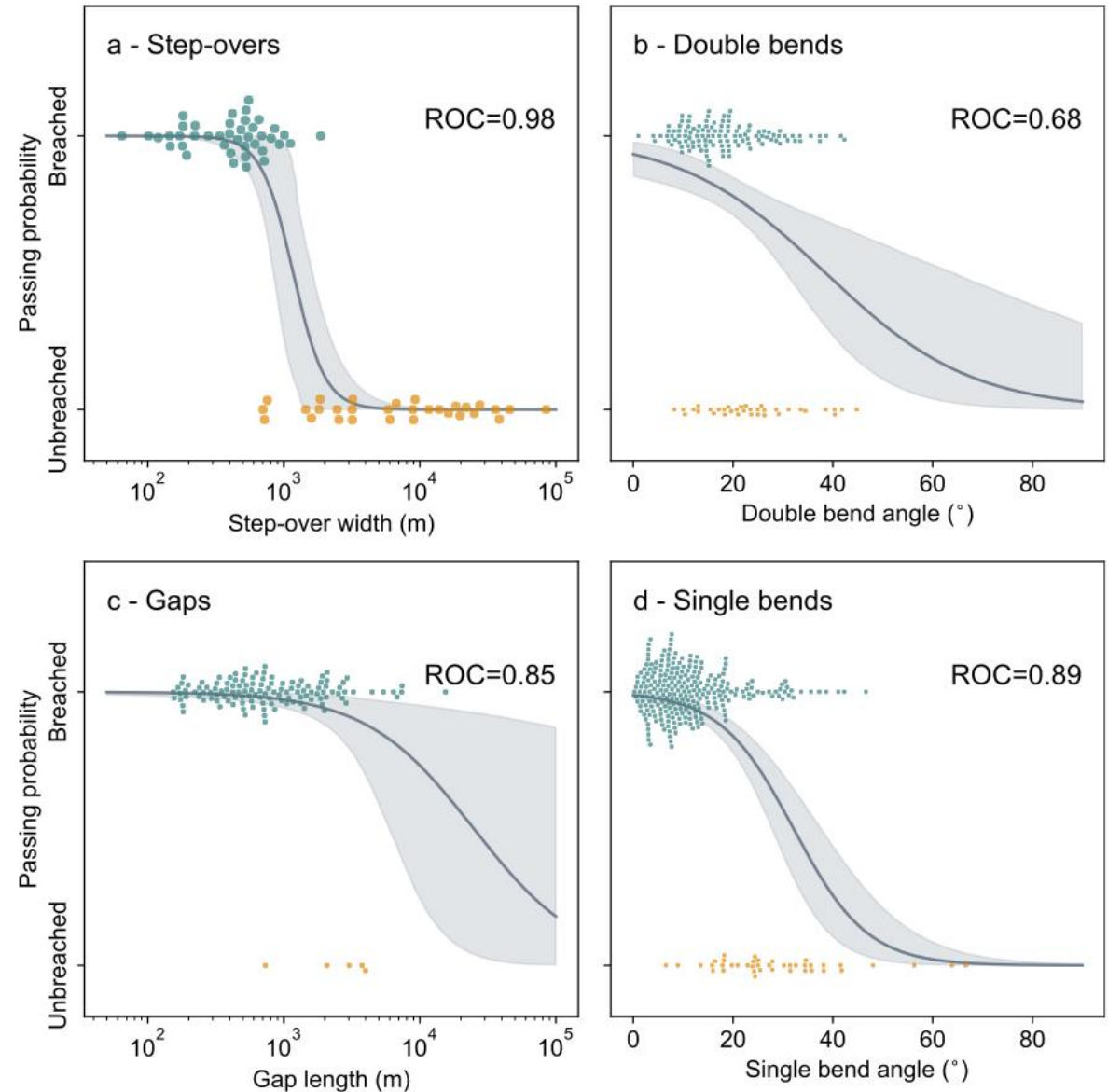


San Andreas Fault: Modified from Salisbury (2016)

# Rupture Termination Probability

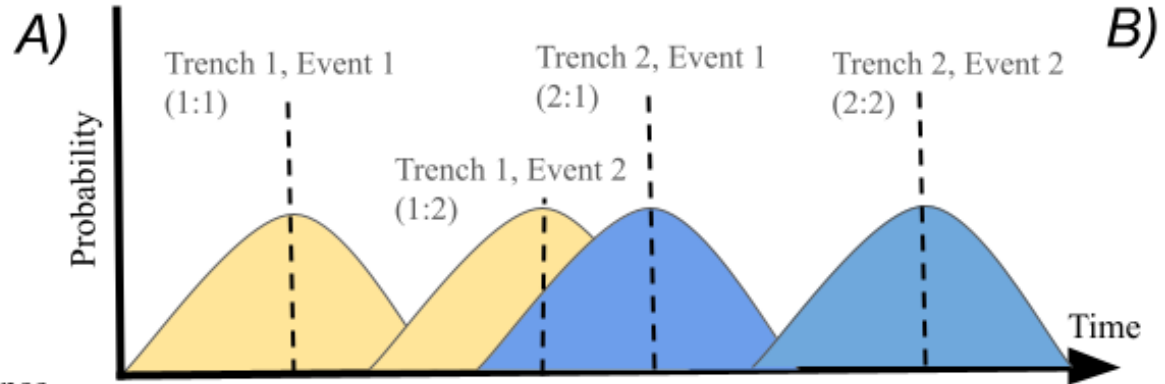
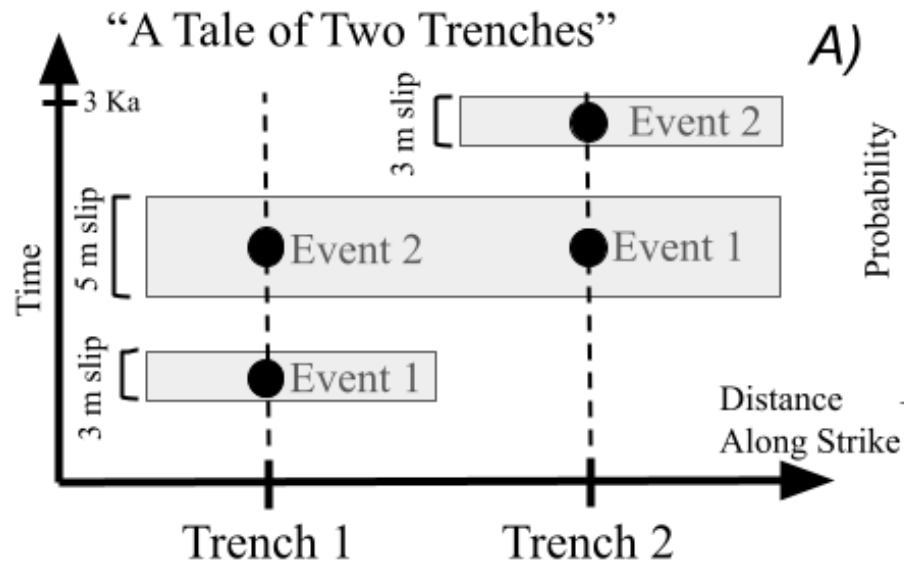


Modified from Biasi and Wesnousky (2021) Figure 7



Rodriguez Padilla et al. (20124) Figure 3

# Stringing Pearls with Integer Linear Programming



Trench 1 Modeled Slip =  $(3 \text{ m})(\mathbf{X}_1) + (3 \text{ m})(\mathbf{X}_2) + (5 \text{ m})(\mathbf{X}_3)$

Trench 2 Modeled Slip =  $(5 \text{ m})(\mathbf{X}_4) + (3 \text{ m})(\mathbf{X}_5) + (3 \text{ m})(\mathbf{X}_6)$

Trench 1 Post-3Ka Observed Slip = 7 m

Trench 2 Post-3Ka Observed Slip = 8.5 m

Constraints:  $\{\mathbf{X}_1 + \mathbf{X}_2 = 1\}$ ,  $\{\mathbf{X}_3 + \mathbf{X}_4 = 1\}$ ,  $\{\mathbf{X}_1 = 1\}$ ,  $\{\mathbf{X}_5 = 1\}$

Trench 1:  $3\mathbf{X}_1 + 3\mathbf{X}_2 + 5\mathbf{X}_3 -$

$7 \leq d$ ,  $3\mathbf{X}_1 + 3\mathbf{X}_2 + 5\mathbf{X}_3 - 7$

$\geq -d$

Trench 2:  $5\mathbf{X}_4 + 3\mathbf{X}_5 + 3\mathbf{X}_6 -$

$8.5 \leq d$ ,  $5\mathbf{X}_4 + 3\mathbf{X}_5 + 3\mathbf{X}_6 -$

$8.5 \geq -d$

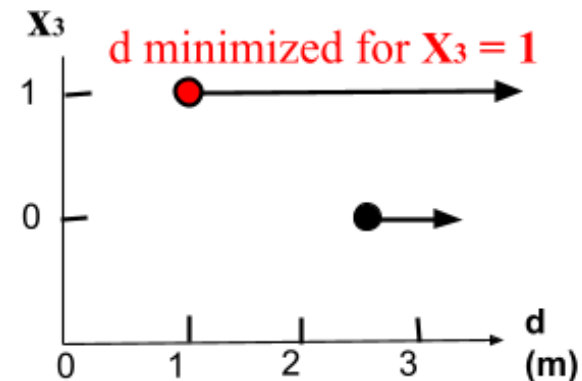
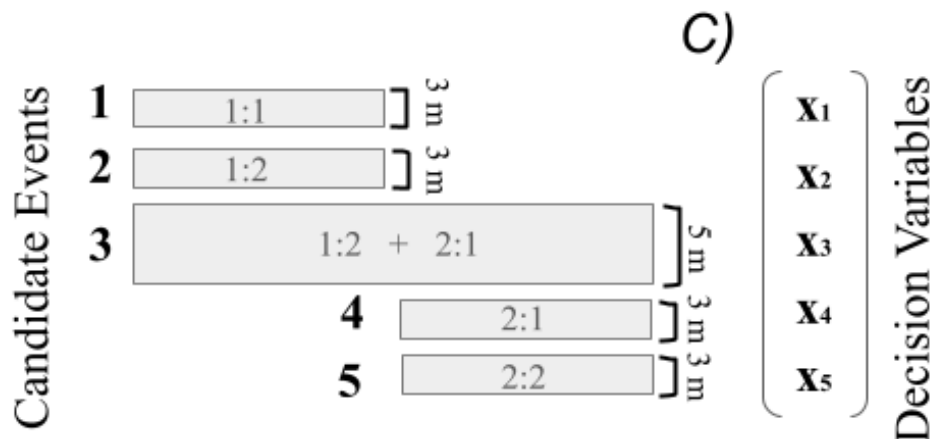
(Substitute constraints,

simplify): Trench 1:  $2\mathbf{X}_3 - 1$

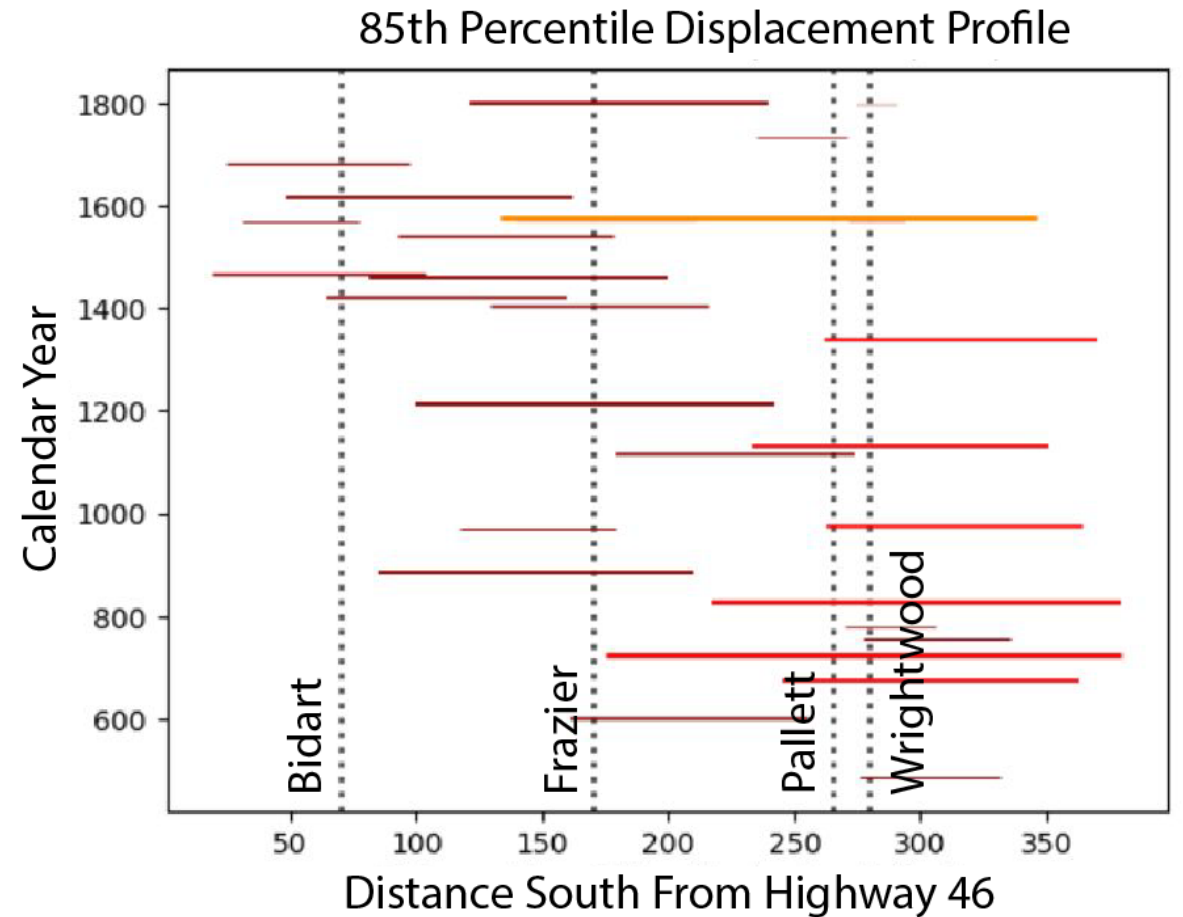
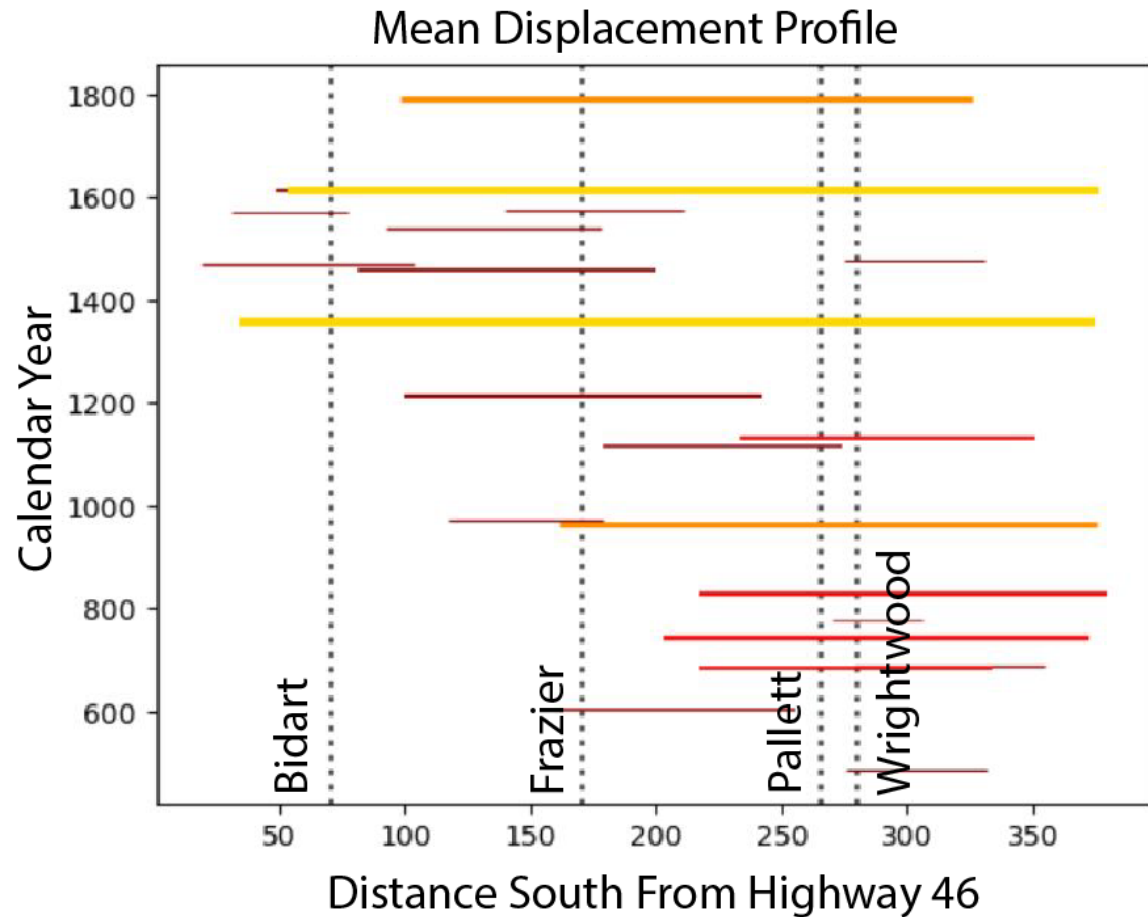
$\leq d$ ,  $2\mathbf{X}_3 - 1 \geq -d$  Trench

2:  $2\mathbf{X}_3 - 2.5 \leq d$ ,  $2\mathbf{X}_3 - 2.5 \geq$

$-d$



# Rapid Scenario Development & Exploration



# UNREST Proposal Tasks & Milestones

- Paleoseismic data synthesis and curation
  - **Year 1:** Compile Oxcalf-formatted sequence models for all paleoseismic sites on target faults
  - **Year 2:** Populate *Community Paleoseismology Database* with these data
- Resolving Fault Slip over Time [for target faults]
  - **Year 1:** Constrain slip history of the central San Andreas fault, Carrizo Plain
- Quantifying Geometric Fault Properties [for target faults]
  - **Year 1:** Southern California
  - **Year 2:** Northern California
- Build Interpretive Framework
  - **Year 1:** Core data constraints: Event sequences, slip rate, slip over time
  - **Year 2:** Extended data constraints: Fault geometry, uncertain events, proxy event size, multi-fault ruptures, external chronology (lacustrine, climate)
- Digital Twin Fault System
  - **Year 1:** Test statistical renewal models with earthquake scenario models
  - **Year 2 & 3:** Migrate digital twin system into ML computational environment