Surface Faulting and Deformation

Assessment & Mitigation

Summary of a Shlemon Specialty Conference sponsored by the Association of Environmental & Engineering Geologists convened on February 19 & 20, 2009

for the PEER Workshop on Surface Fault Displacement Hazard

Jerome A. Treiman California Geological Survey May 20, 2009





Speakers

History of the Alquist Priolo Fault Zoning Act	Bill Bryant
Significant Issues Being Considered in the Current Review of the A-P Act	Stephen Testa
Fault Rupture & Surface Deformation: Defining the Hazard	Jerry Treiman
Earthquake Surface Fault Rupture Design Considerations	Jonathon Bray
Structural Mitigation of Seismically Induced Permanent Ground Deformation	Craig Comartin
Obtaining Sufficient Field Data for Engineering Design to Mitigate Secondary Surface Fault Deformation	William Page
Case Study: Assessment of Surface-Fault Rupture Hazard and Analysis of Fault Displacement – Green Valley Fault	Stephen Thompson
Determining Fault Rupture Parameters for Dams	William Fraser
Determining Relative Age of Faulting Using Soil Stratigraphy in Fault Investigations	Glenn Borchardt
Challenges in Peer Review of Fault-Rupture Hazard Studies	Thomas Blake

A Mid-Holocene Age for "Hazardous Faults":

Acceptable Risk for Surface-Fault Rupture

Roy Shlemon









critical questions:

1. Where should fault rupture and deformation be anticipated?

- 2. How much slip and in what sense, should be anticipated?
- 3. How do we anticipate the hazard based on incomplete data?
- 4. What can be done about the hazard?

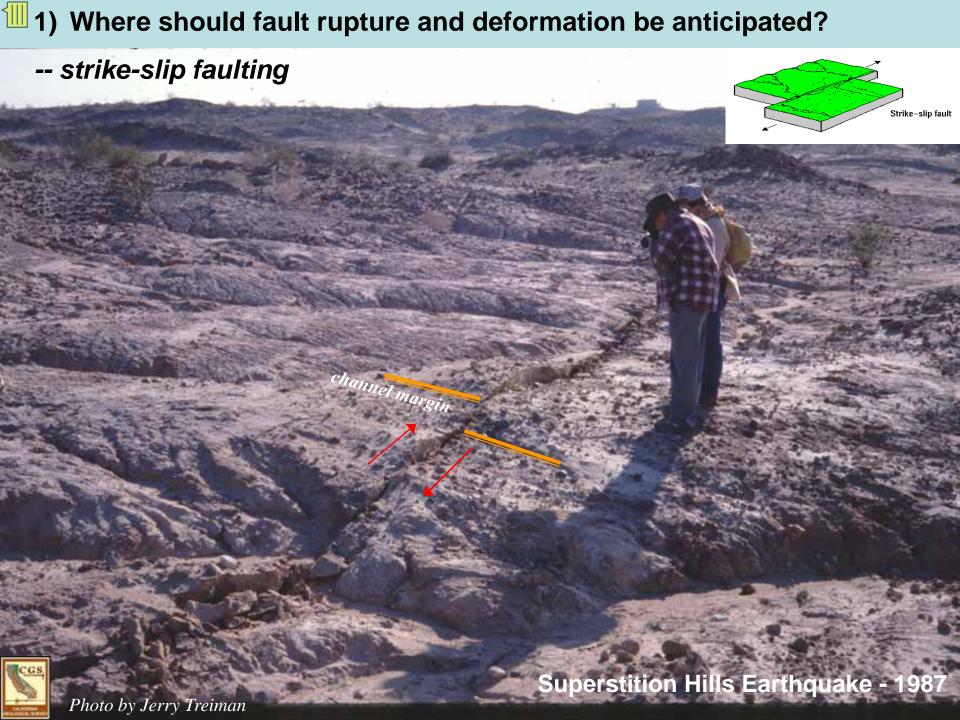


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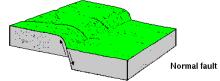
... not just the simple location, but the geometry, style, distribution, and complexity of faulting





1) Where should fault rupture and deformation be anticipated?

-- normal faulting





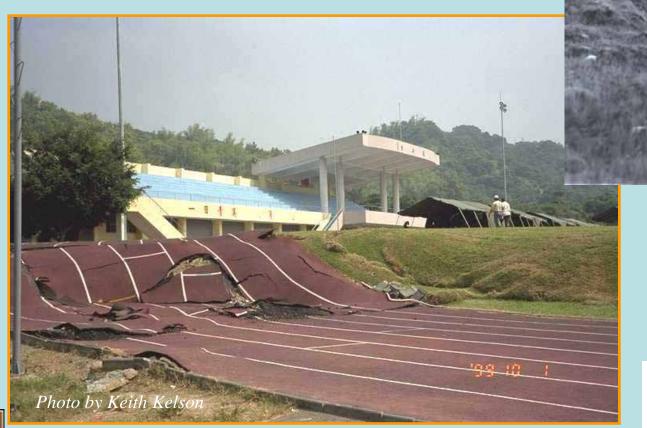




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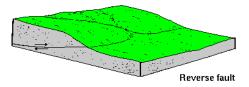
-- reverse and thrust faulting

Chi Chi Earthquake -- 1999



San Fernando -- 1971

photo by James Kahle







Single Fault Trace





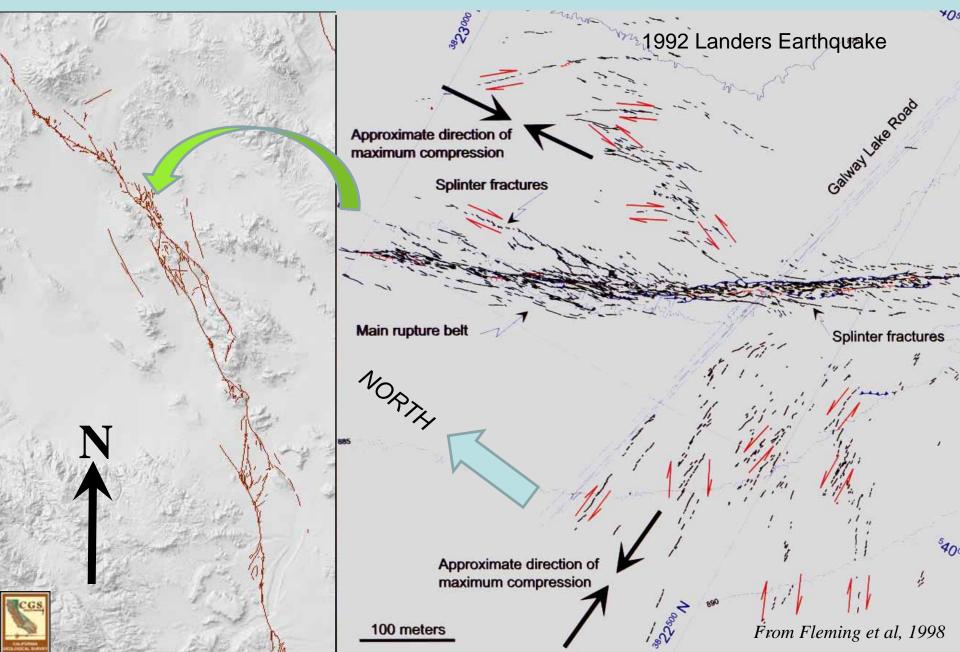


Complex Faulting



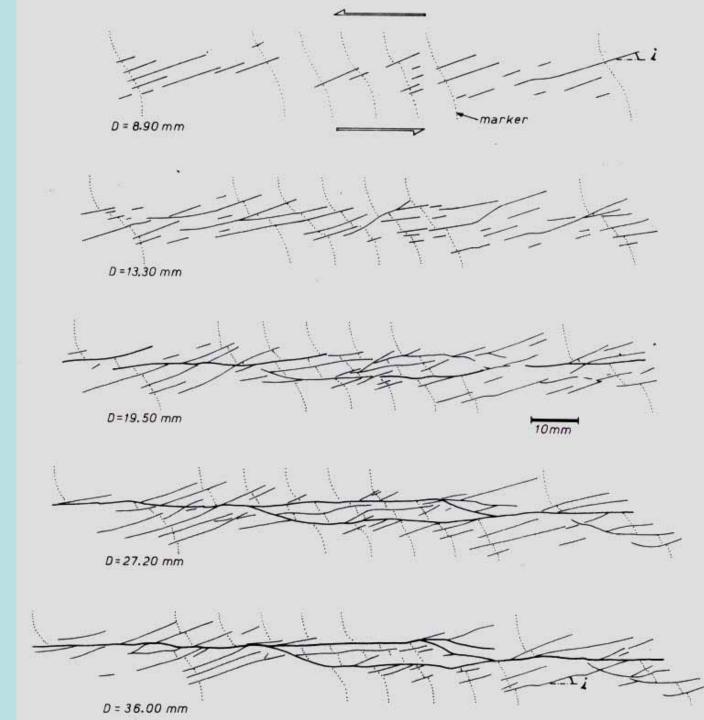


In reality, rupture commonly is more complex.





Strike Slip – integration of en echelon faults







Fault patterns at different scales

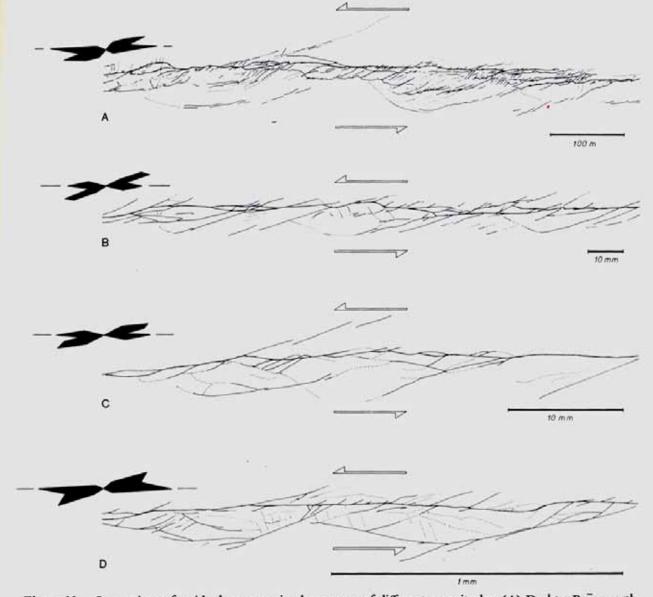
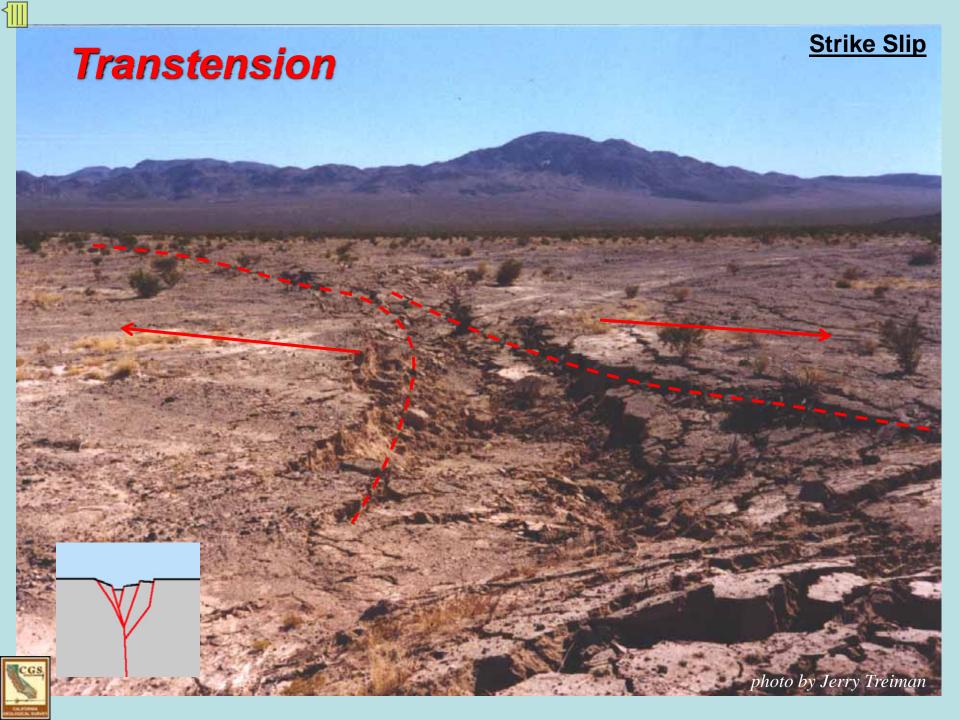
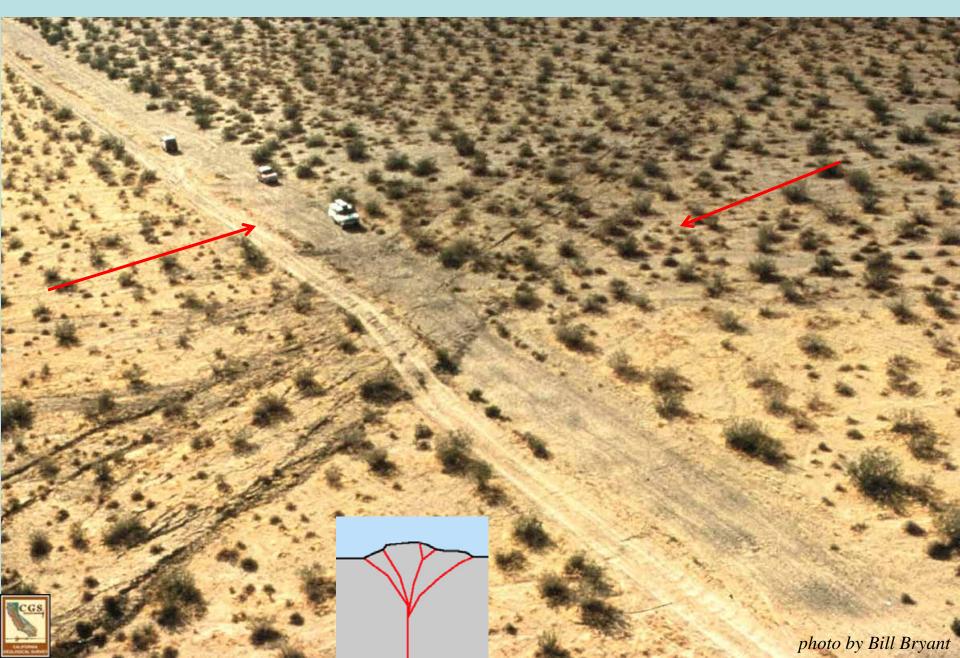


Figure 11. Comparison of residual structure in shear zones of different magnitudes. (A) Dasht-e Bayaz earth-quake fault (after Tchalenko and Ambraseys, 1970, Fig. 5). (B) Riedel experiment. (C) entire shear box sample (see also Fig. 8A). (D) detail of shear box sample. Total displacements are given in the text. Dotted lines indicate less prominent shears. The structures plotted in the form of rose diagrams show Riedel, P shear and principal displacement shear directions.



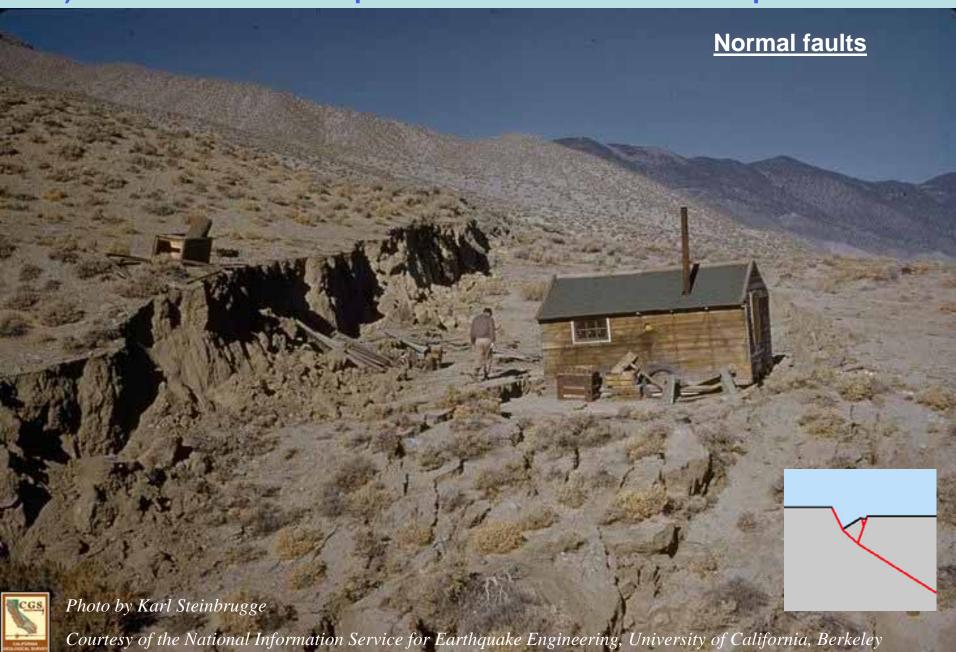


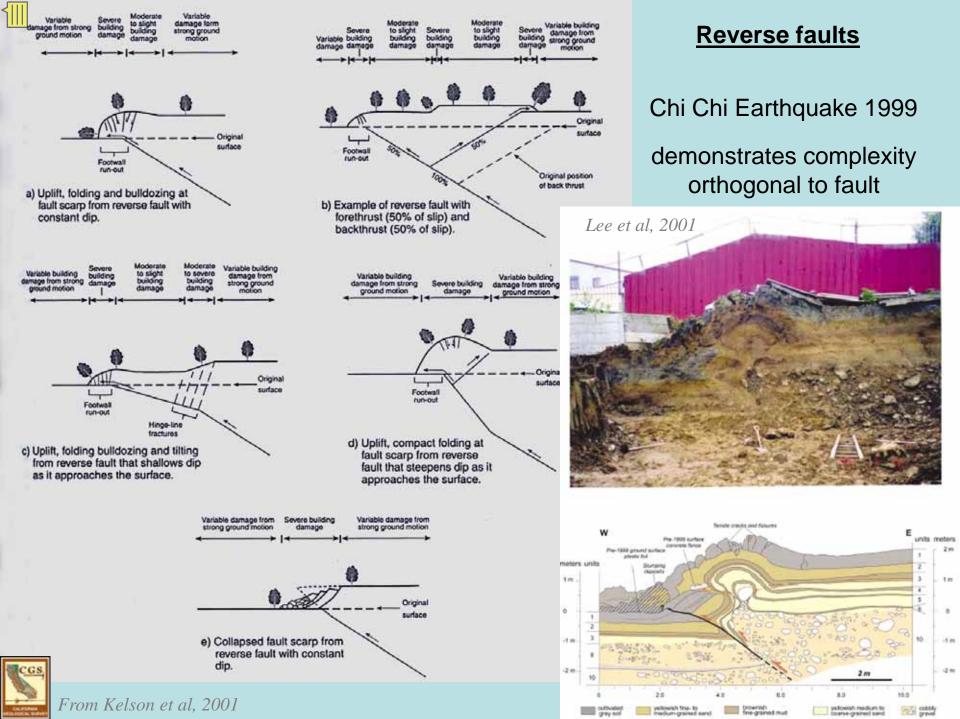
Transpression





1) Where should fault rupture and deformation be anticipated?







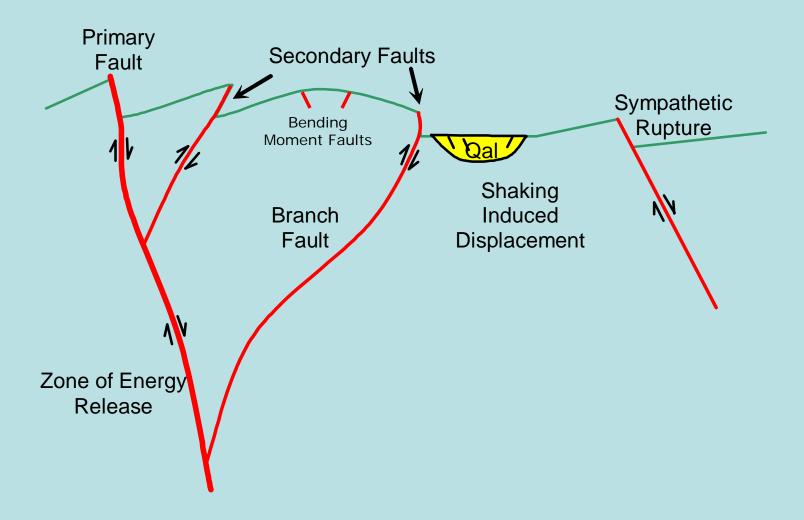
Definition of Terms

- Primary fault- the trace where the majority of coseismic displacement occurs
- Secondary or Branch fault a subordinate trace that connect to the primary fault in either map view or at depth, where minor co-seismic rupture occurs
- Bending moment fault
- Sympathetic fault rupture
- Shaking induced displacements





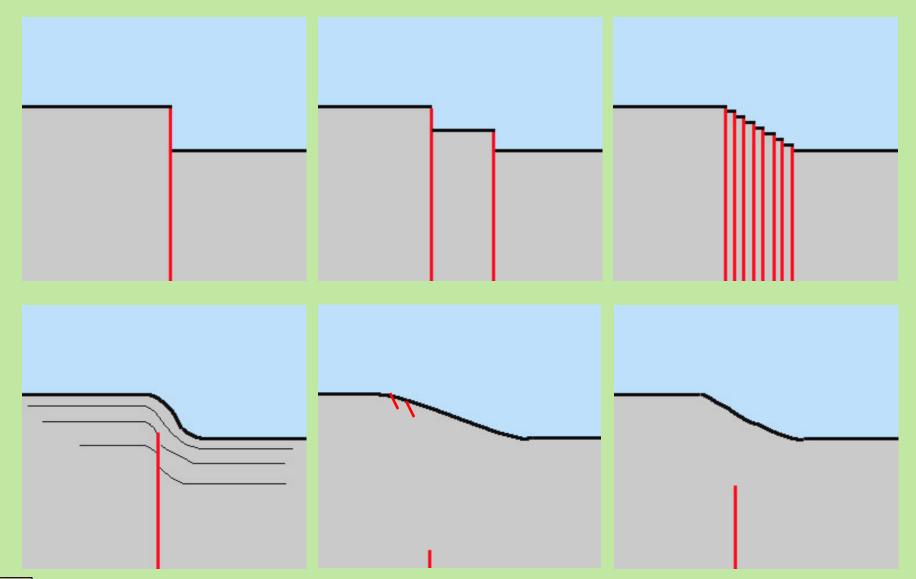
Definition of Terms







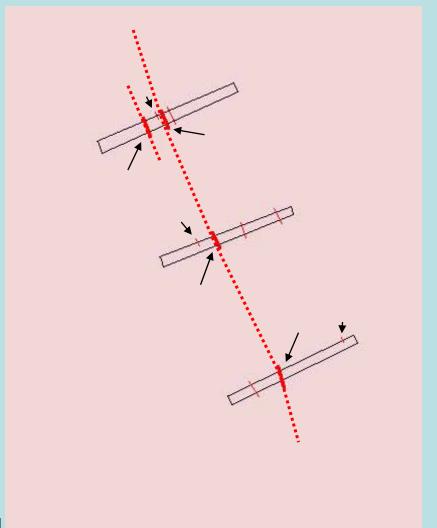
1) Fault rupture to fault deformation – what is a surface fault?

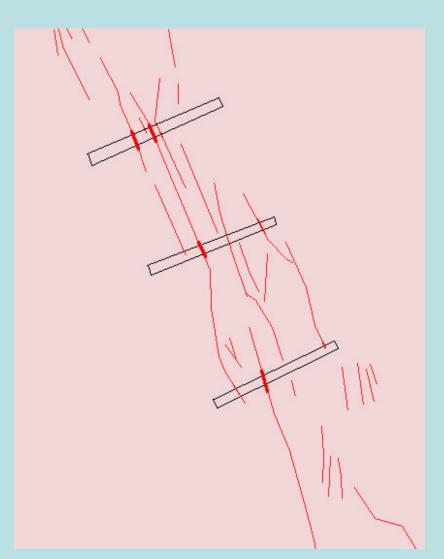






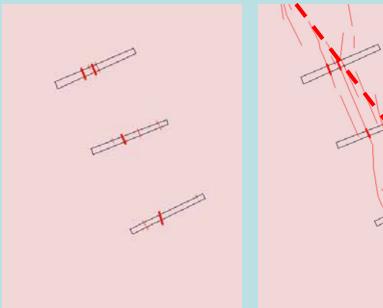
Since much of our site information comes from trenches we may not see the full expression of prior rupture at the site.











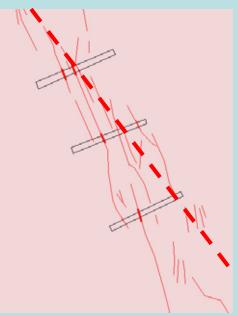
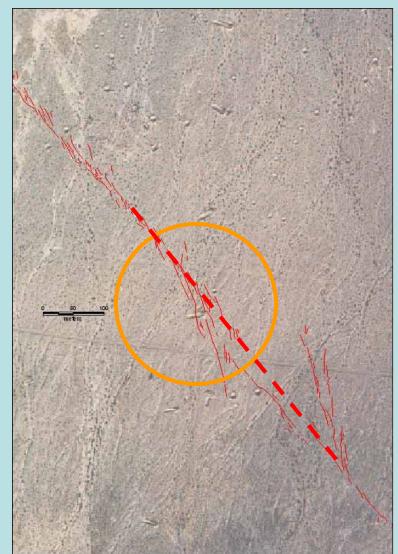




photo by Jerry Treiman



... the next rupture may be part of the evolution of the fault zone.



2. How much slip, and in what sense, should be anticipated?





2. How much slip and in what sense, should be anticipated?

We looked at two dimensions of variability in slip:

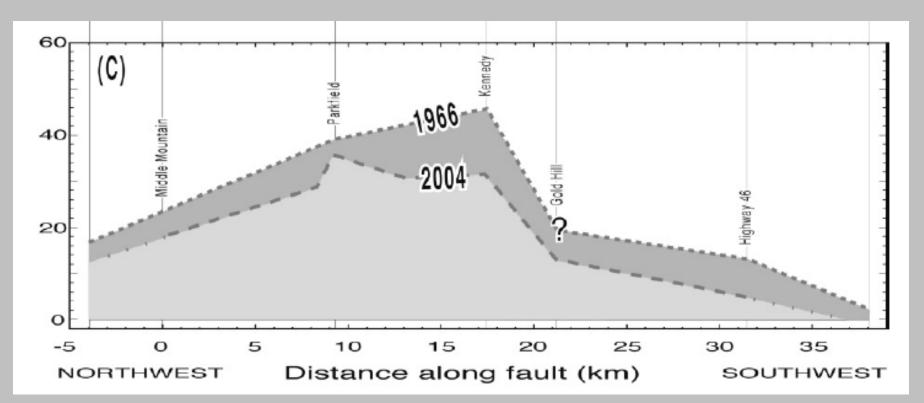
- temporal variation from one earthquake to the next
- spatial variation along a fault zone in any one event

photo by Jerry Treiman





Comparison of total slip for the 1966 and 2004 Parkfield earthquakes



from Lienkaemper and others, 2006

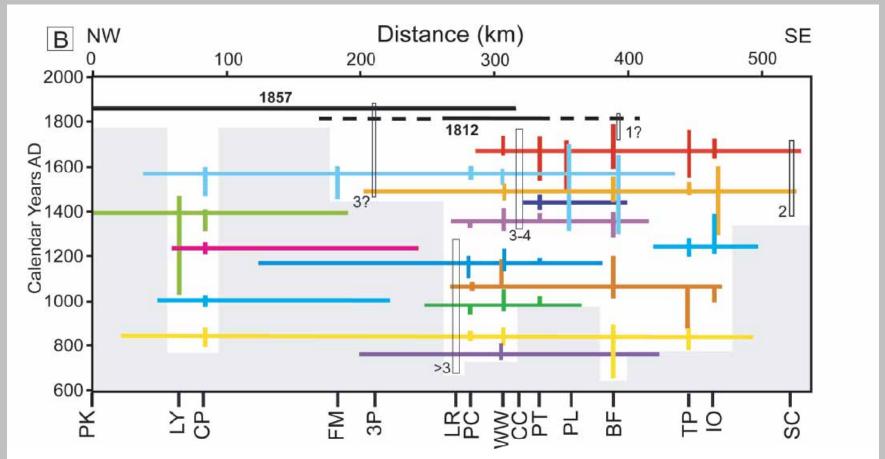




Overlap of rupture events on the southern San Andreas Fault

Parkfield to Salt Creek

-- one possible history --

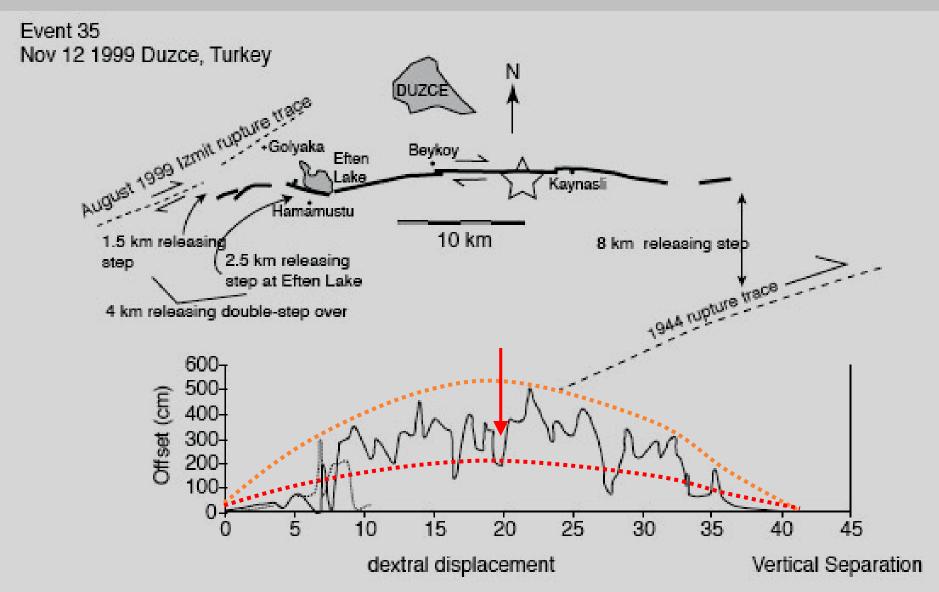




Slip will vary from one quake to the next based on:

- variabilty of short-term slip rate
- difference in interval/accumulated strain since last event (strain rate x time since last event)
- % of strain release in an event
- rupture of shorter/longer segment
- where you are in a rupture segment
- shift of slip distribution between strands









Characteristics of Surface Rupture Depend on:

- fault type
- inclination of fault plane
- amount of fault displacement
- fault definition
- geometry of overlying material
- nature of overlying material







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Fault Activity

Is a fault active?

- How do we define "active"?
- Somewhat arbitrary there can be no absolute assurance that a fault is "dead".
- Commonly based on time frame (e.g. Holocene)
- Better approach may be based on slip-rate and fault history, where you have the data.





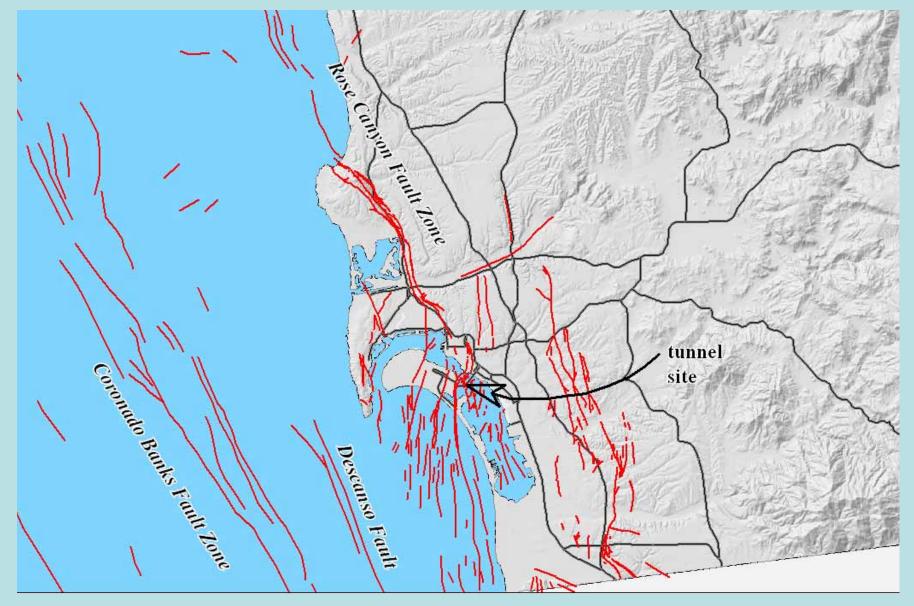
Understanding the style of faulting





Coronado bridge/tunnel – San Diego, CA







Coronado bridge/tunnel - San Diego, CA



4) What can be done about the hazard?

Basically the only way to avoid damage from surface rupture and associated deformation is through application of a buffer around those uncertainties.



- Spatial buffer -- physical setback -- look beyond your trench data to the big picture of the mechanism/style of faulting in order to avoid faults and associated significant deformation.
- <u>Design buffer</u> -- develop realistic estimates of sense and magnitude of displacement with generous margins of error. Requires good science, not guesswork.





 AEG conference focused on engineering projects that may have a choice of avoidance.

 Lifelines do not have that luxury (although you may have some choice in where to cross faults).

Proper characterization is key.



