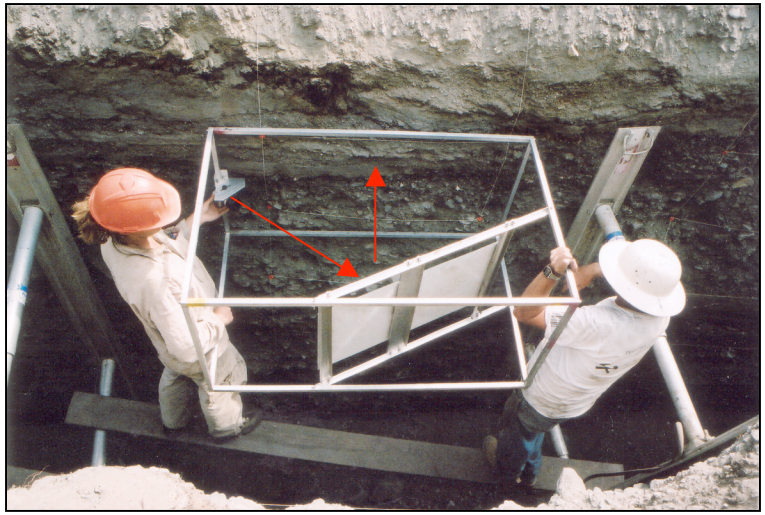
Modern deformation: Izmit 1999 (M7.4)

Cracks = fissures

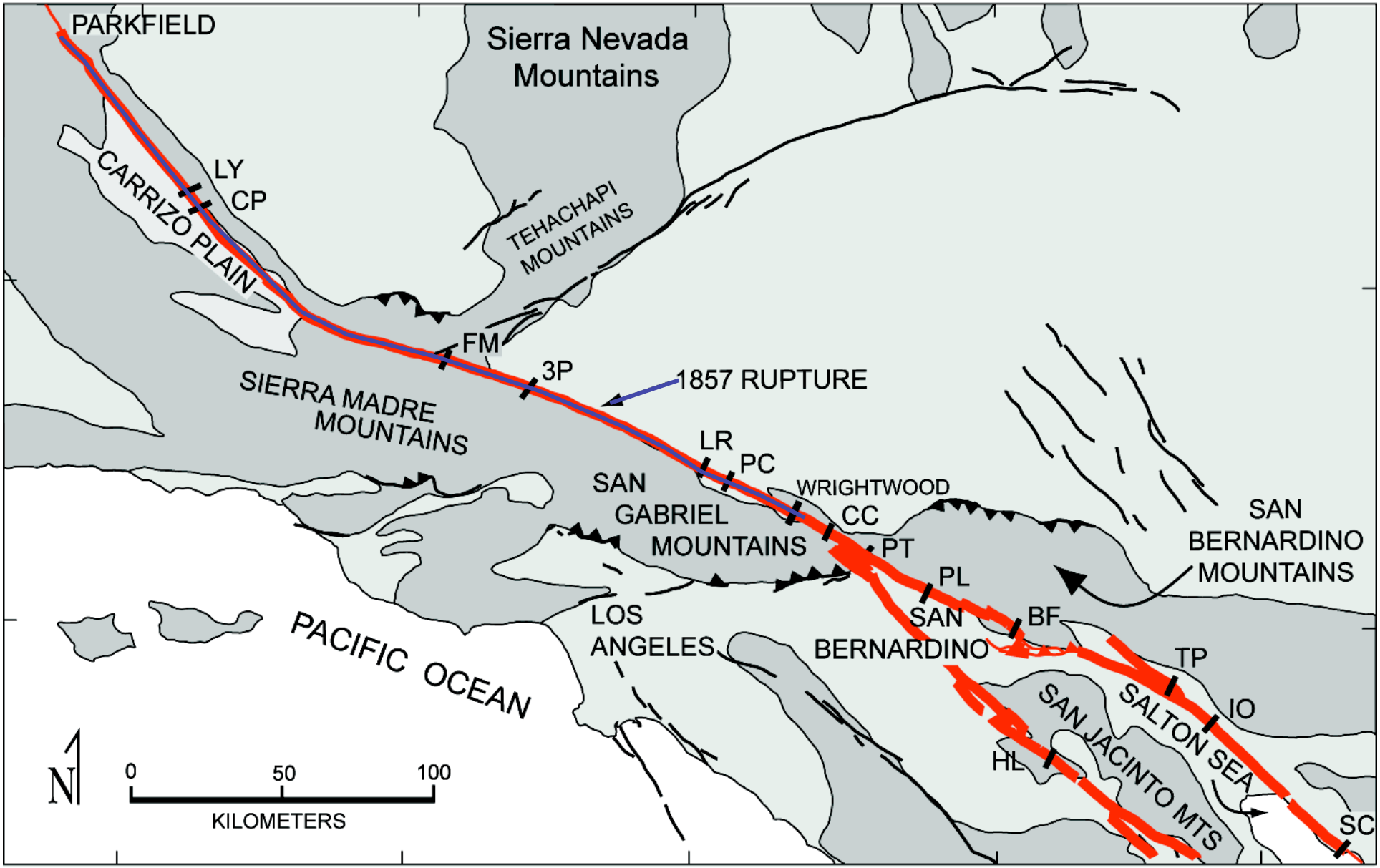
Folds = growth strata

Excavating

Cleaning and gridding



Photographing


PARKFIELD
Sierra Nevada Mountains
LY
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1857 RUPTURE
SIERRA MADRE MOUNTAINS
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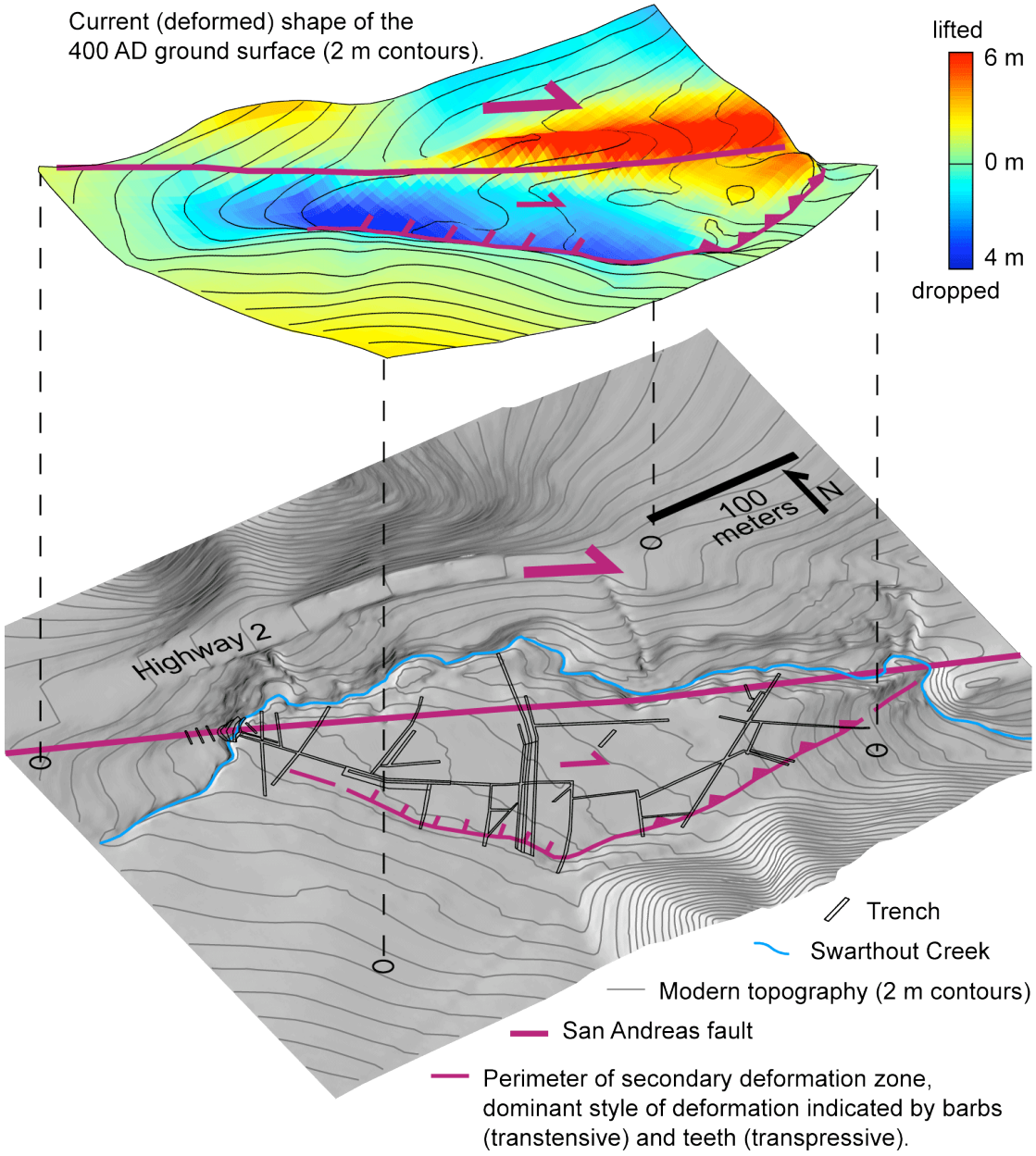
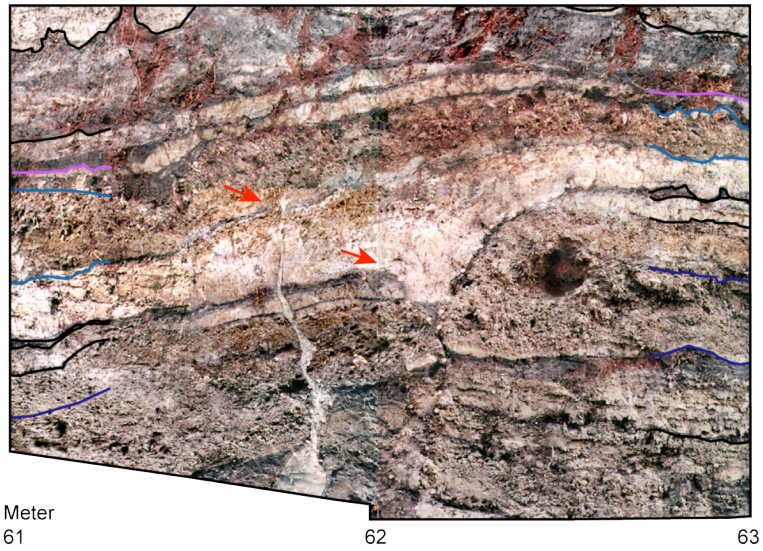
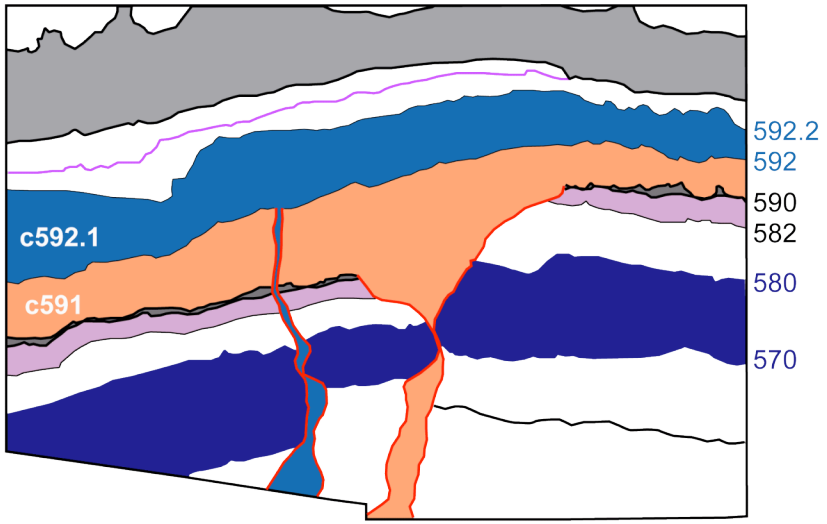
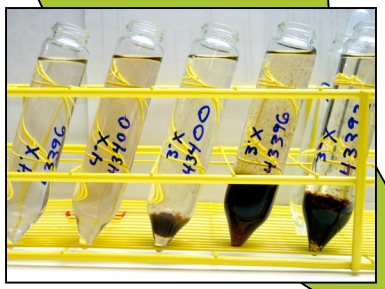
SC
PACIFIC OCEAN
N
0
50
100
KILOMETERS

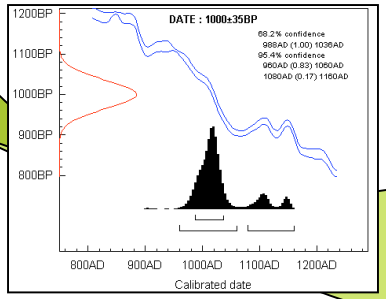

Current (deformed) shape of the
400 AD ground surface (2 m contours).
lifted
6 m
0 m
4 m
dropped
100
meters
N
Highway 2
Trench
Swarthout Creek
Modern topography (2 m contours)
San Andreas fault
Perimeter of secondary deformation zone,
dominant style of deformation indicated by barbs
(transtensive) and teeth (transpressive).

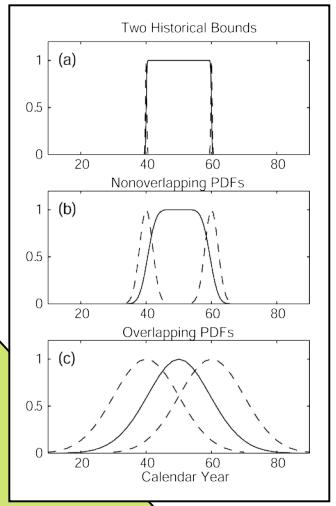


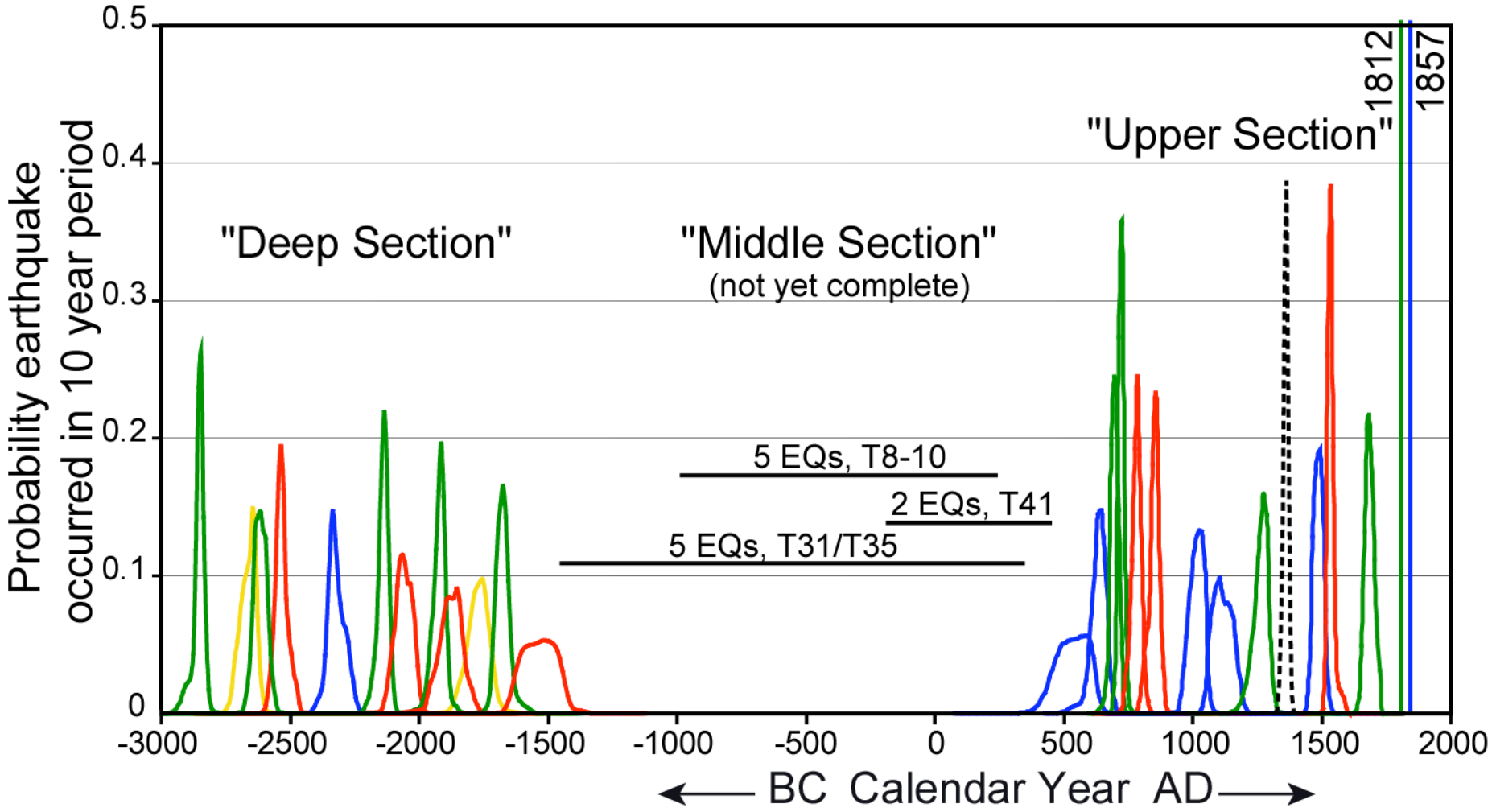


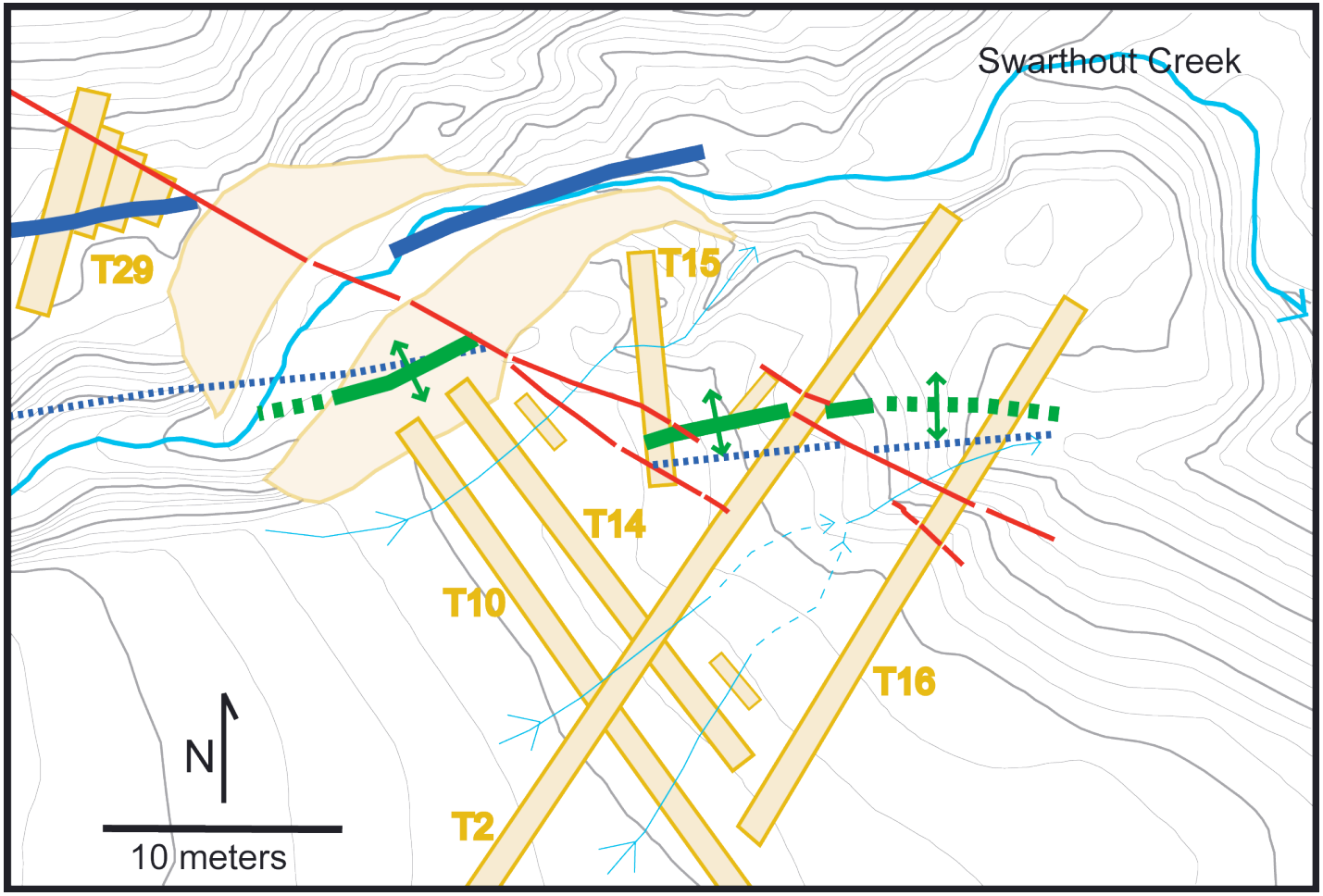
Timing of Earthquakes








Probability earthquake occurred in 10 year period
0.5
0.4
0.3
0.2
0.1
0
"Deep Section"
"Middle Section"
(not yet complete)
"Upper Section"
1812
1857
5 EQs, T8-10
2 EQs, T41
5 EQs, T31/T35
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
BC Calendar Year AD

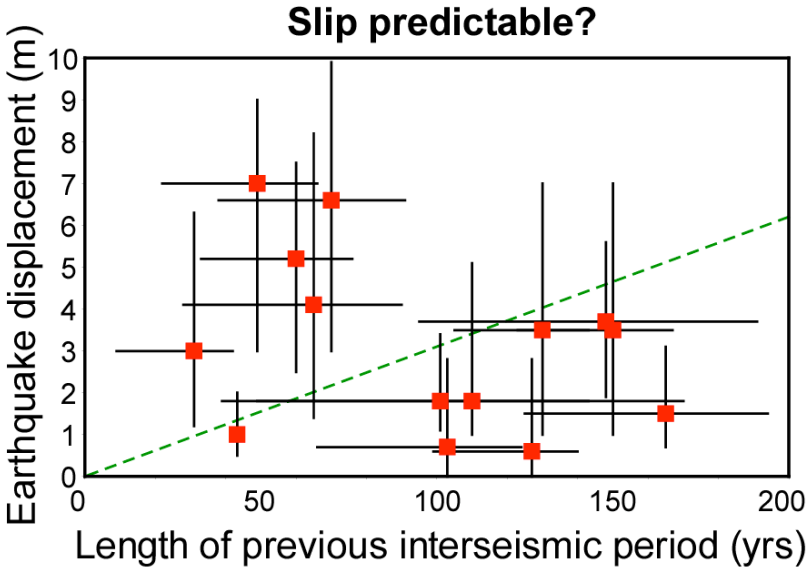


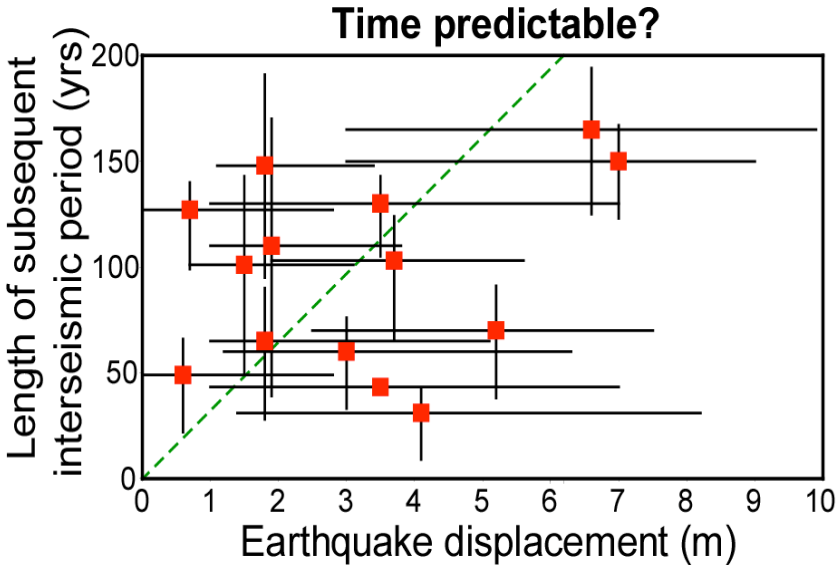
Weldon et al., 2002, *Structure and earthquake offsets on the San Andreas Fault at the Wrightwood, California, Paleoseismic site*, BSSA 92, 7, 2704-2725

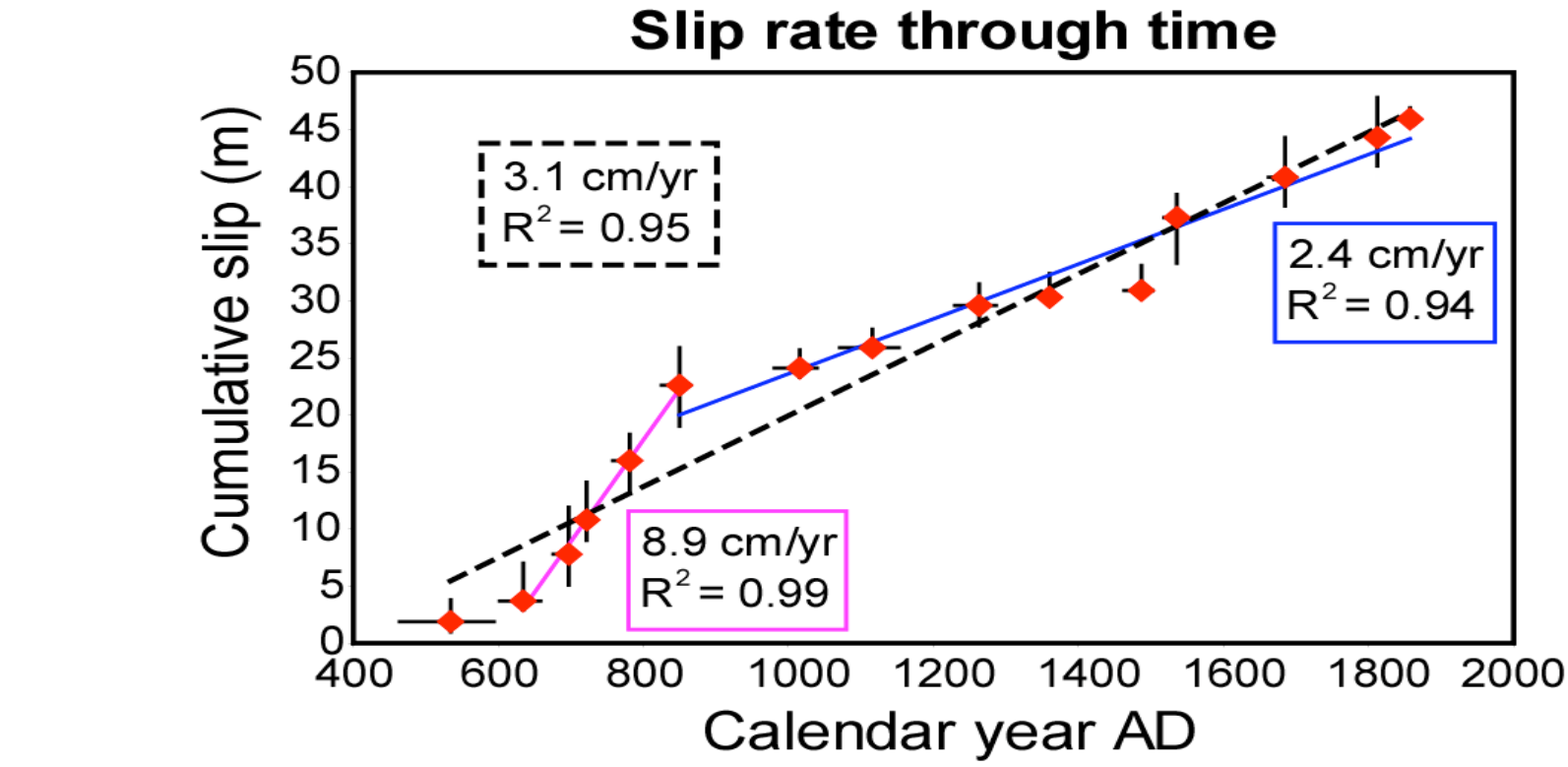
Fumal et al., 2002, *Evidence for large earthquakes on the San Andreas Fault at the Wrightwood, California, Paleoseismic site*, BSSA, 92, 7, 2726-2760.

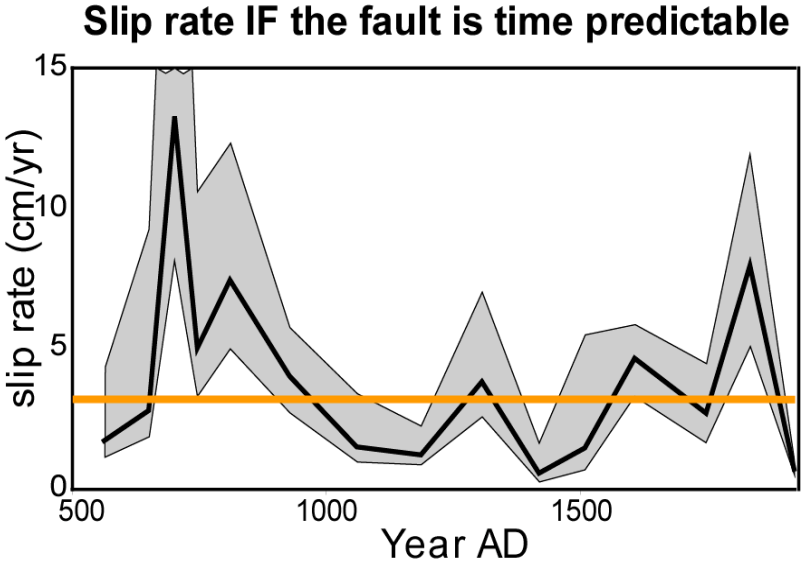
Biasi et al., 2002, *Paleoseismic event dating and the conditional probability of large earthquakes on the Southern San Andreas Fault, California*, BSSA, 92, 7, 2761-2781.

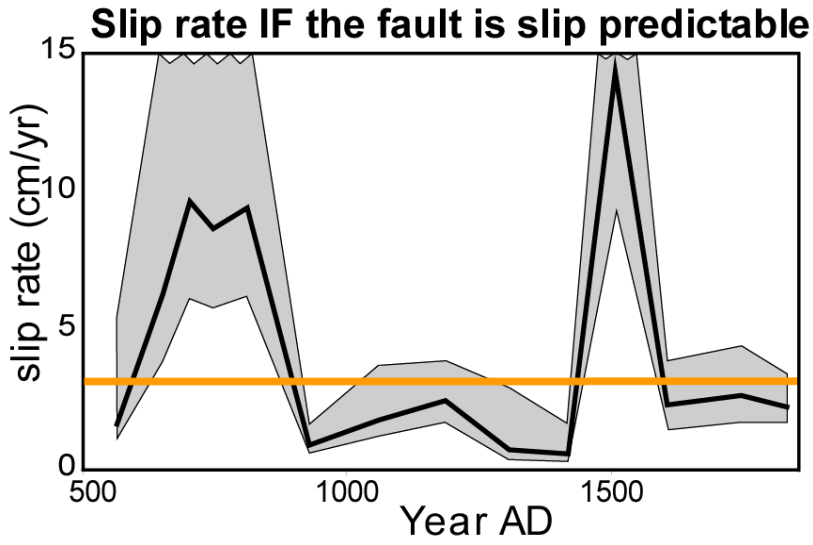
- Ask questions about basic fault behavior.



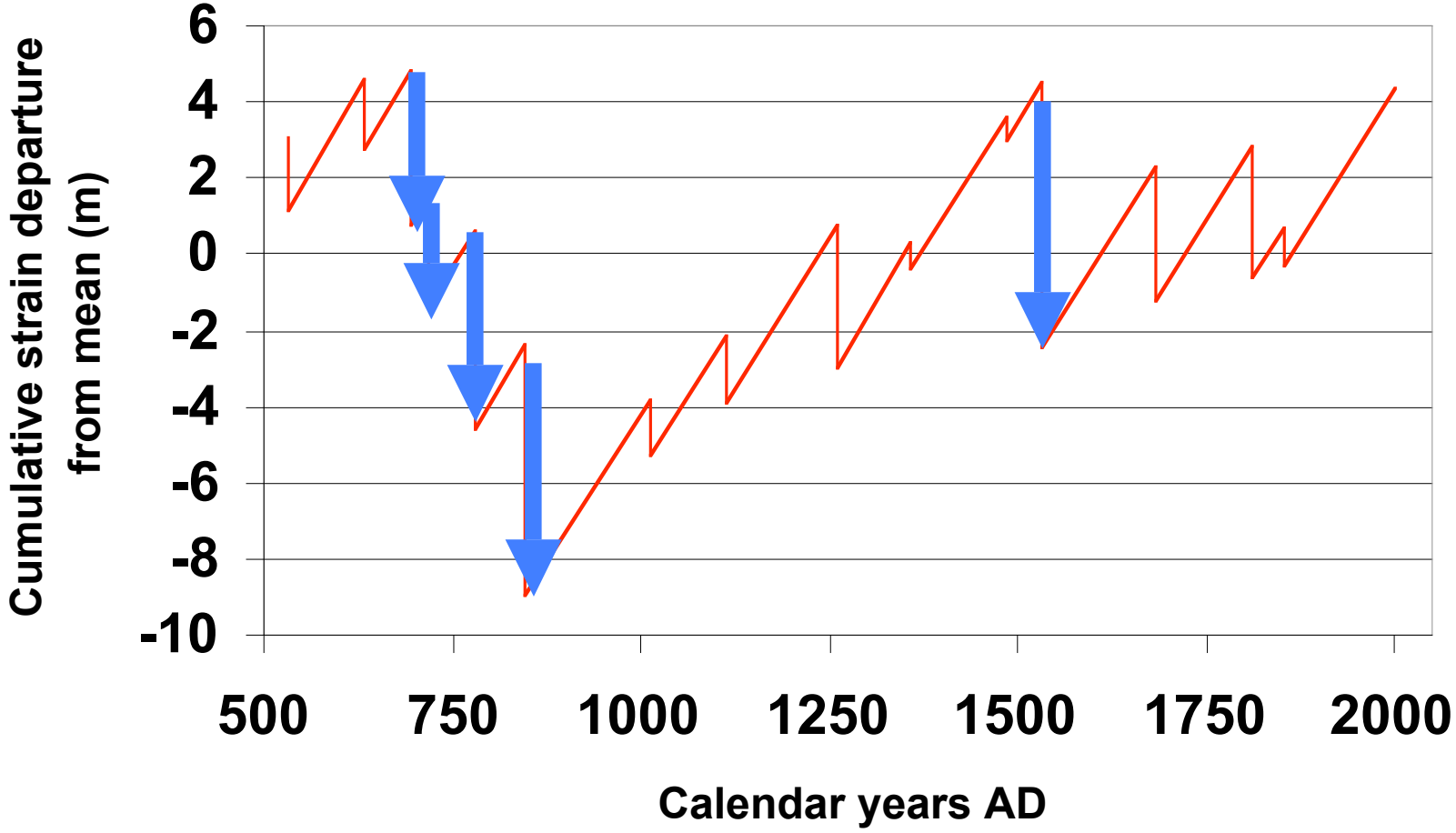



Slip rate through time
Cumulative slip (m)
Calendar year AD
3.1 cm/yr
R2 = 0.95
2.4 cm/yr
R2 = 0.94
8.9 cm/yr
R2 = 0.99
0
5
10
15
20
25
30
35
40
45
50
400
600
800
1000
1200
1400
1600
1800
2000


Slip rate IF the fault is time predictable
slip rate (cm/yr)
Year AD
0
5
10
15
500
1000
1500

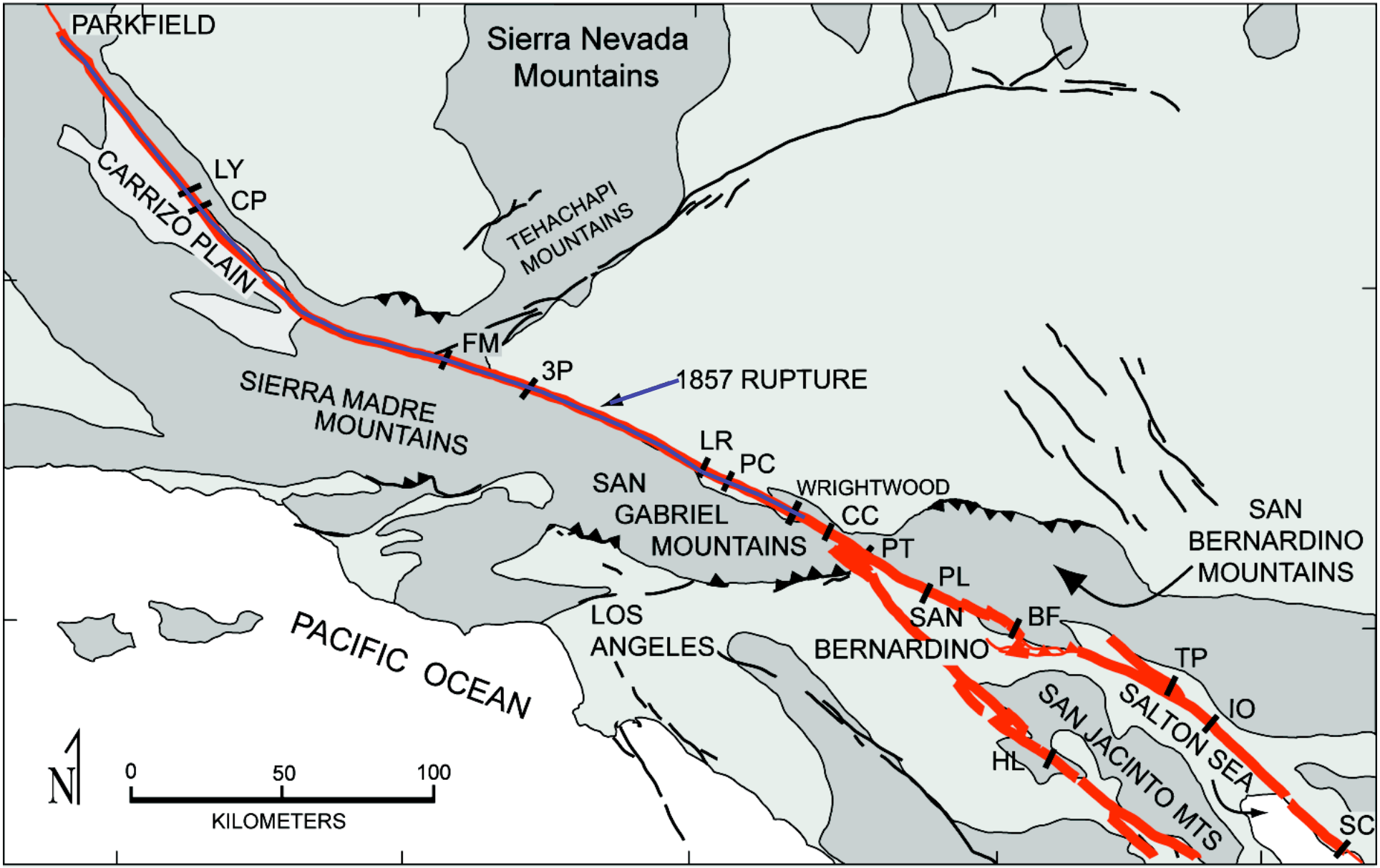

Slip rate IF the fault is slip predictable
slip rate (cm/yr)
Year AD
0
5
10
15
500
1000
1500

Are there cycles longer than the earthquake cycle and what does this mean for how faults work and seismic hazards?



Strain release and accumulation curve, Upper Section, Wrightwood

See: **GSA Today** September 2004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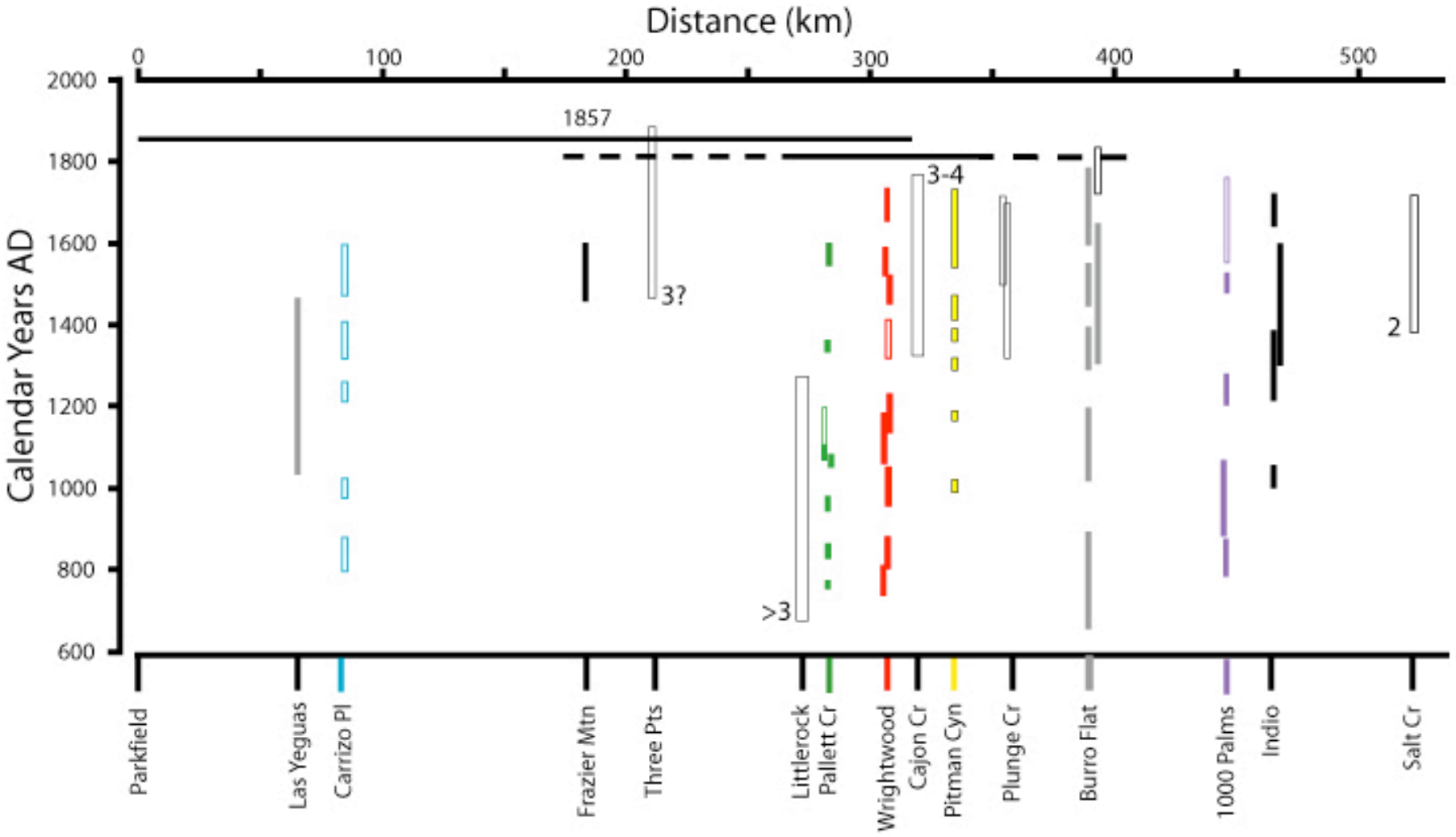
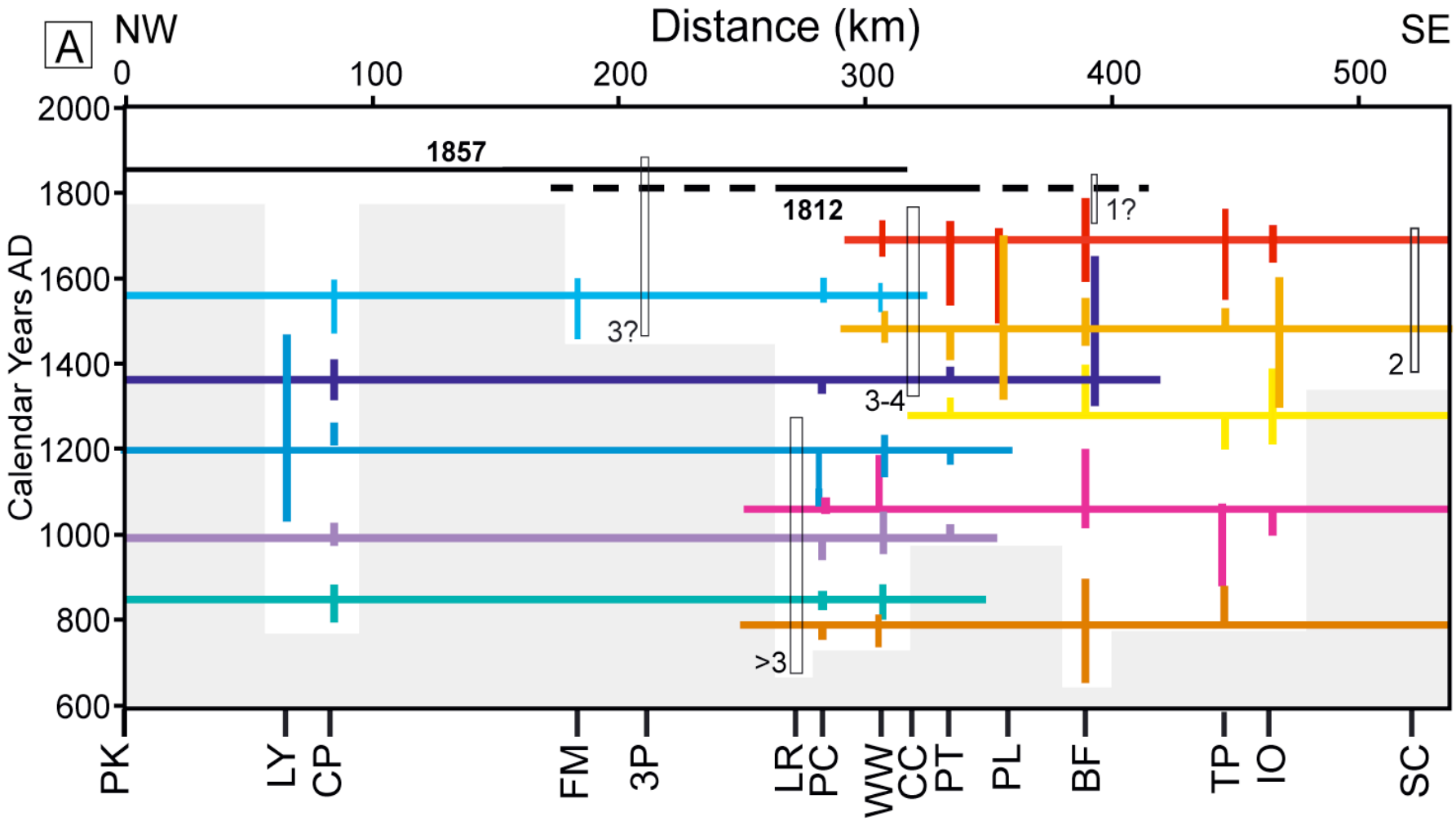
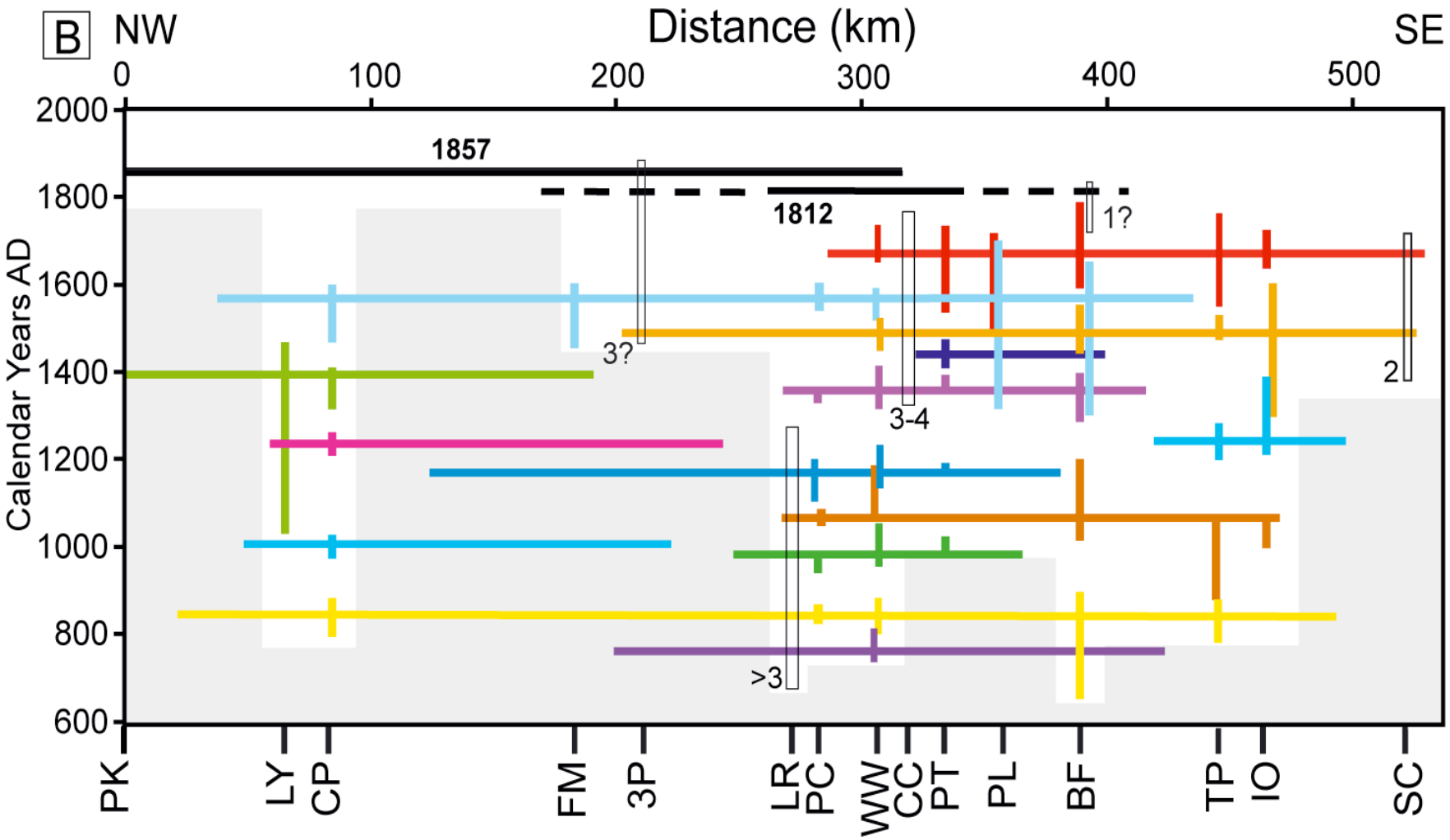

Distance (km)
0
100
200
300
400
500
Calendar Years AD
2000
1800
1600
1400
1200
1000
800
600
1857
3?
3-4
>3
2
Parkfield
Las Yeguas
Carrizo Pl
Frazier Mtn
Three Pts
Littlerock
Pallett Cr
Wrightwood
Cajon Cr
Pitman Cyn
Plunge Cr
Burro Flat
1000 Palms
Indio
Salt Cr


A
NW
Distance (km)
SE
0
100
200
300
400
500
2000
1800
1600
1400
1200
1000
800
600
Calendar Years AD
1857
1812
1?
3?
2
3-4
>3
PK
LY
CP
FM
3P
LR
PC
WW
CC
PT
PL
BF
TP
IO
SC


B
NW
Distance (km)
SE
0
100
200
300
400
500
2000
1800
1600
1400
1200
1000
800
600
Calendar Years AD
1857
1812
1?
3?
2
3-4
>3
PK
LY
CP
FM
3P
LR
PC
WW
CC
PT
PL
BF
TP
IO
SC

Conditional Probabilities Depend on Scenario

For 30 years:

Poisson model with fewest quakes:	~20%
Maximum likely Poisson model:	~40%
Periodic (lognormal) model:	
North Bend event:	~10%
South Bend event:	~60%

Conclusions

1) ≥ 12 M7 to M8 earthquakes in 1300 years.
2) Age control favors > 12 earthquakes, but displacement data allow few (if any) more.
3) Conditional probabilities depend upon rupture scenarios.
4) To improve our hazard estimates we must:
   - Greatly expand the displacement data set.
   - Improve the age control for existing and future sites.
   - Reevaluate existing sites and develop 2-3 new keystone sites to confirm and link existing sites.
   - Use of sites with event count or displacement spanning multiple events.

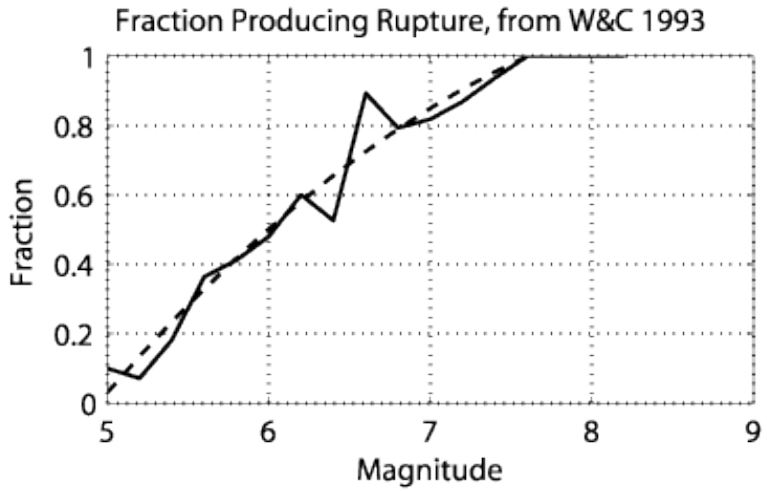
Bayesian Inverse of Displacement Variability

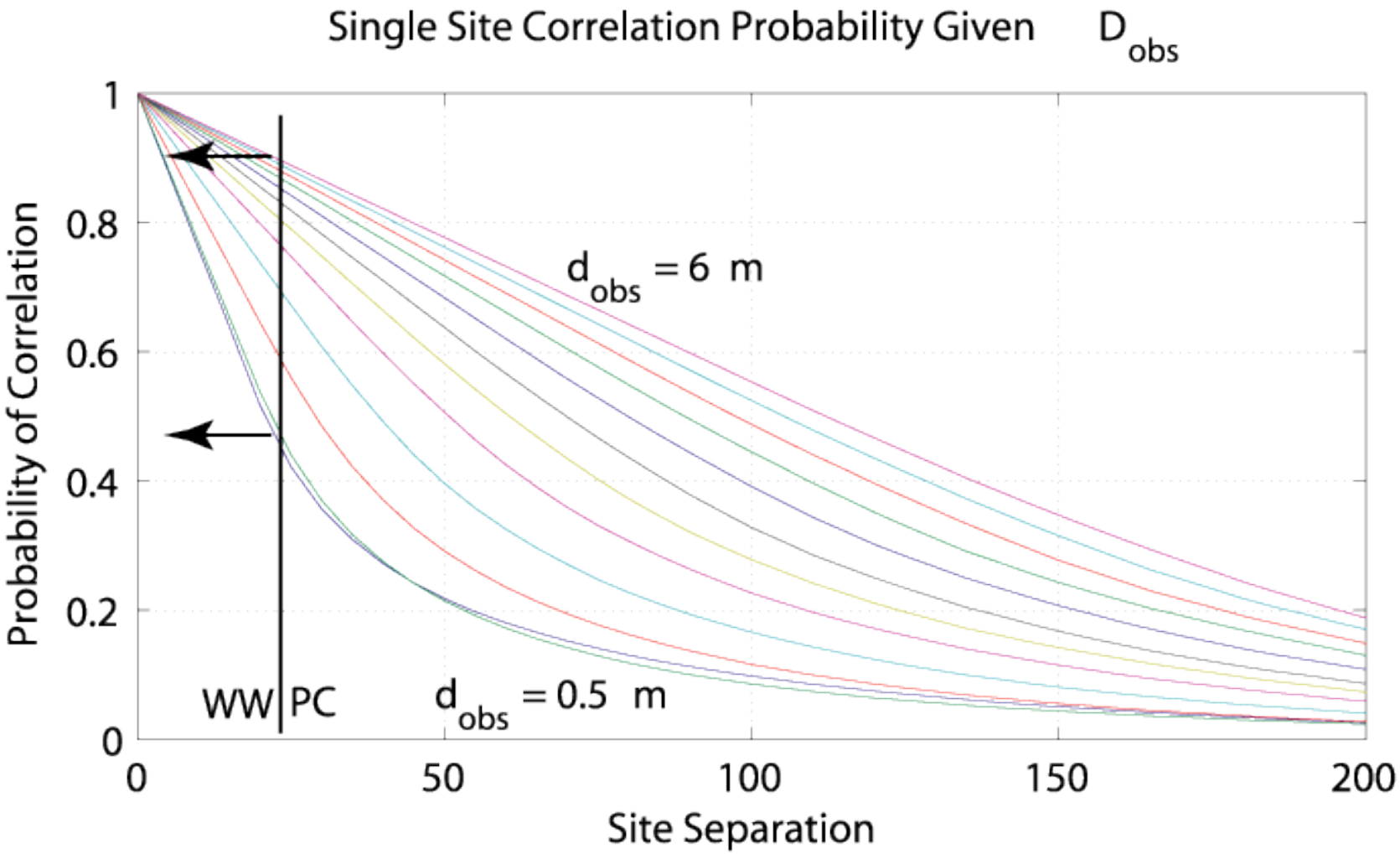
A priori distribution of magnitudes. Uniform, GR, and Average Displacement

Probability that the observed displacement was caused by an event of magnitude M. Get from scaled rupture variability.

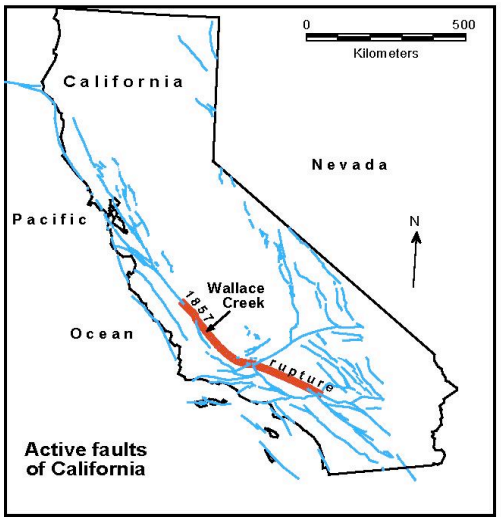
$$p(M|d) = \frac{p(M)*P(d_{obs}|M)}{\sum p(M_i)*P(d_{obs}|M_i)} *P(Rupture|M)$$

Normalization. Means that with P=1, the rupture was caused by an event in the considered magnitude range



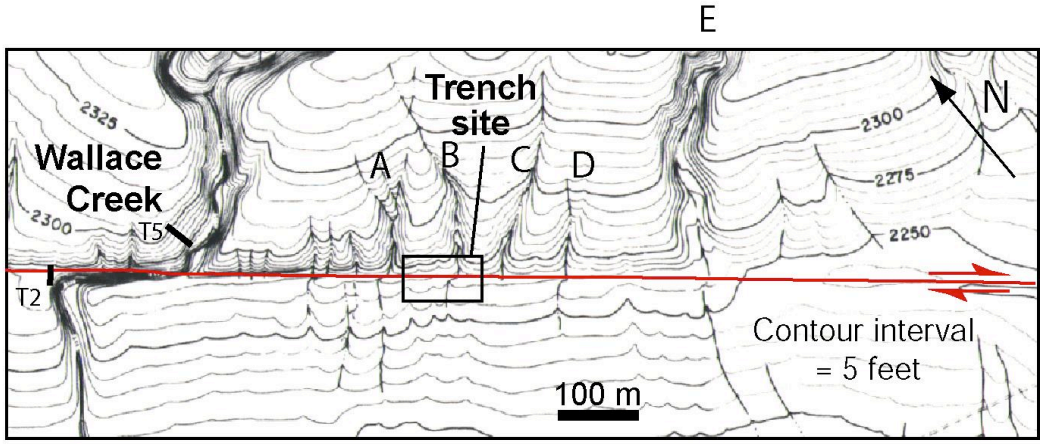

Single Site Correlation Probability Given D obs
Probability of Correlation
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
Site Separation
d obs = 6 m
d obs = 0.5 m
WW
PC

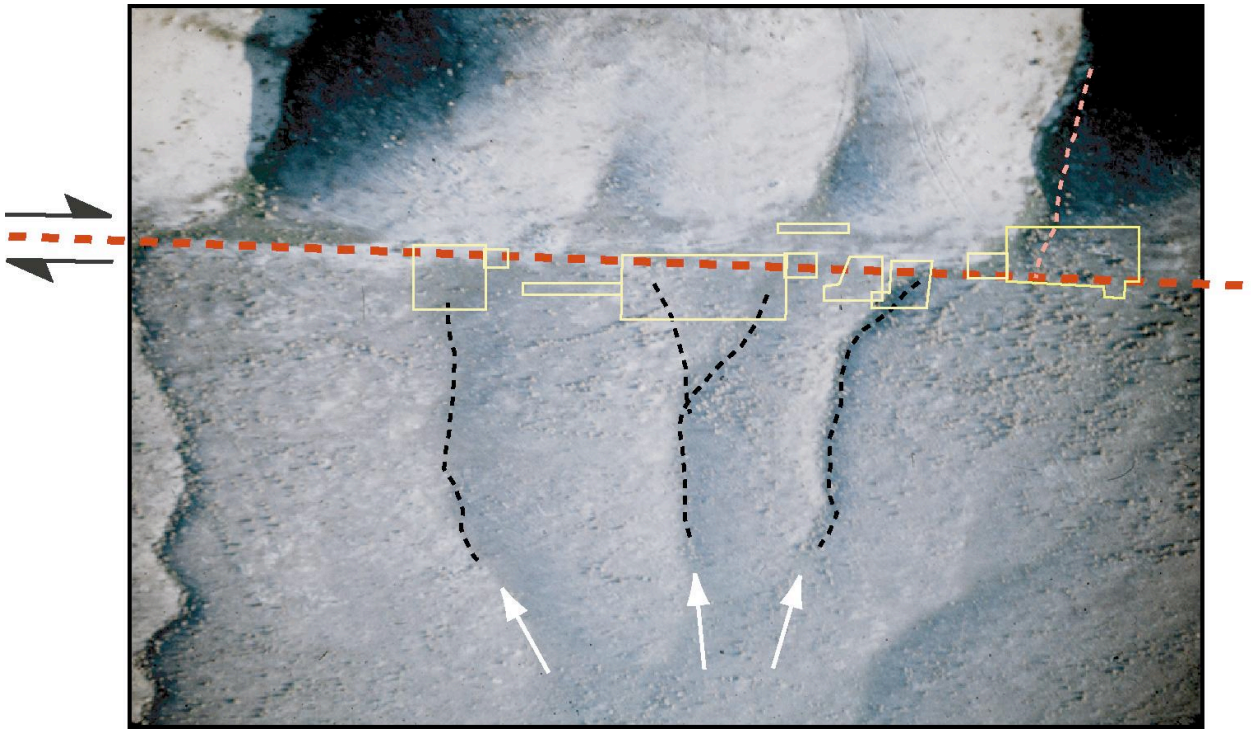
(a)

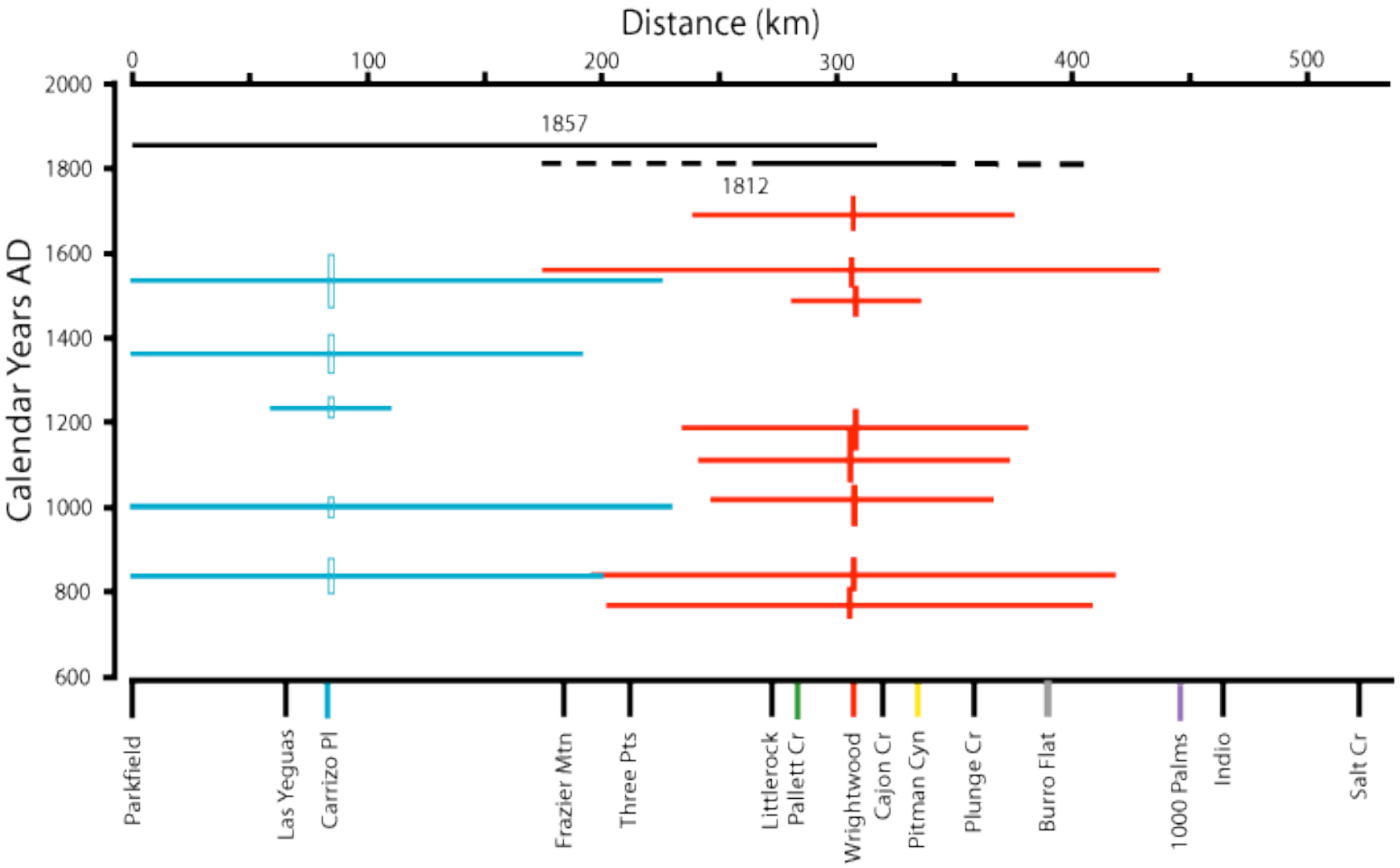


See Liu et al. Geology 2004 for details

(b)






Distance (km)
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Wrightwood
Cajon Cr
Pitman Cyn
Plunge Cr
Burro Flat
1000 Palms
Indio
Salt Cr

Conclusions:

1) There is a lot of site specific data and we have a good handle on how to characterize their uncertainties.

2) We can convert site specific data into ruptures.

    a) unfortunately, there are many possible ruptures

    b) fortunately, we can weight them with their consistency with the data.

3) We can use the rupture scenarios to determine conditional probabilities.

4) Using the weighting of the rupture scenarios we can combine the individual conditional probabilities into a single estimate of the conditional probability.