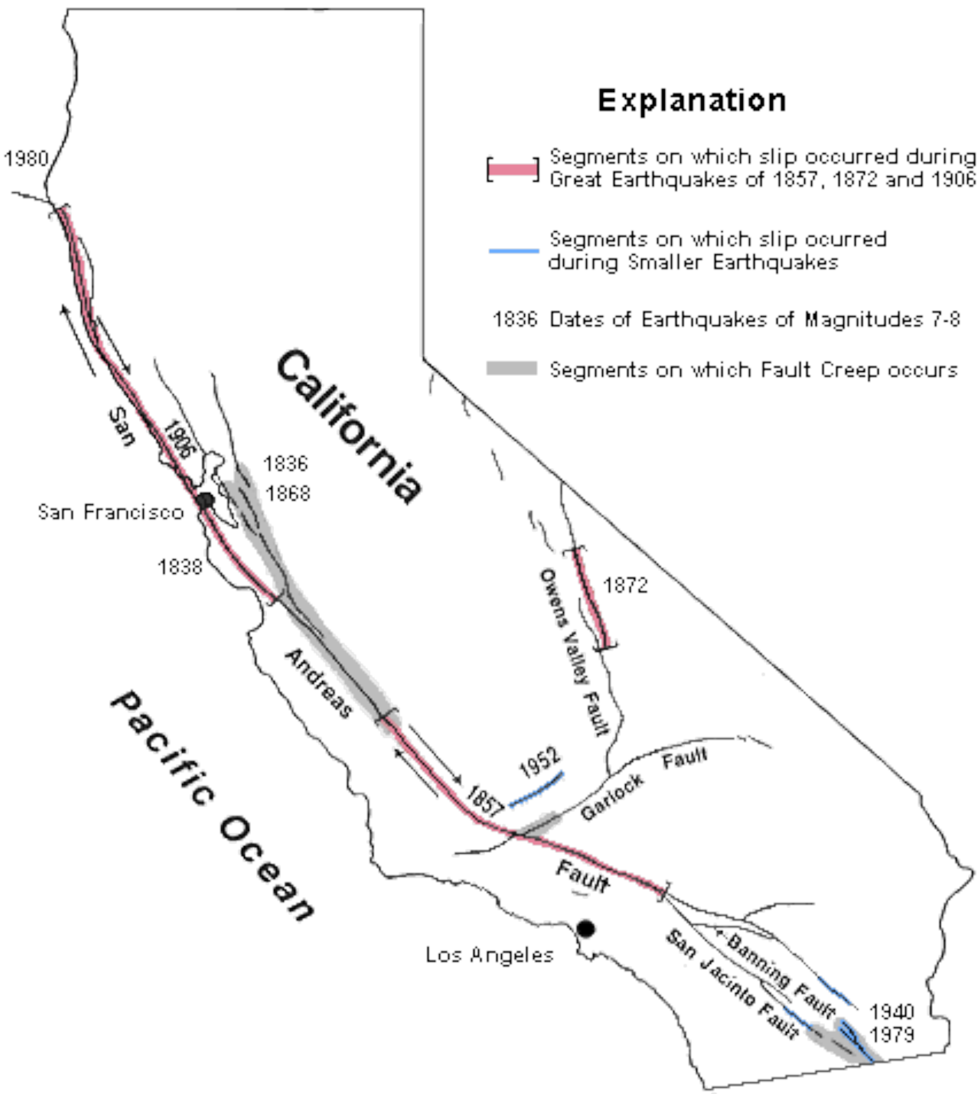
<u>Deep creep</u>, seismicity, and earthquake potential along the southern San Andreas Fault System

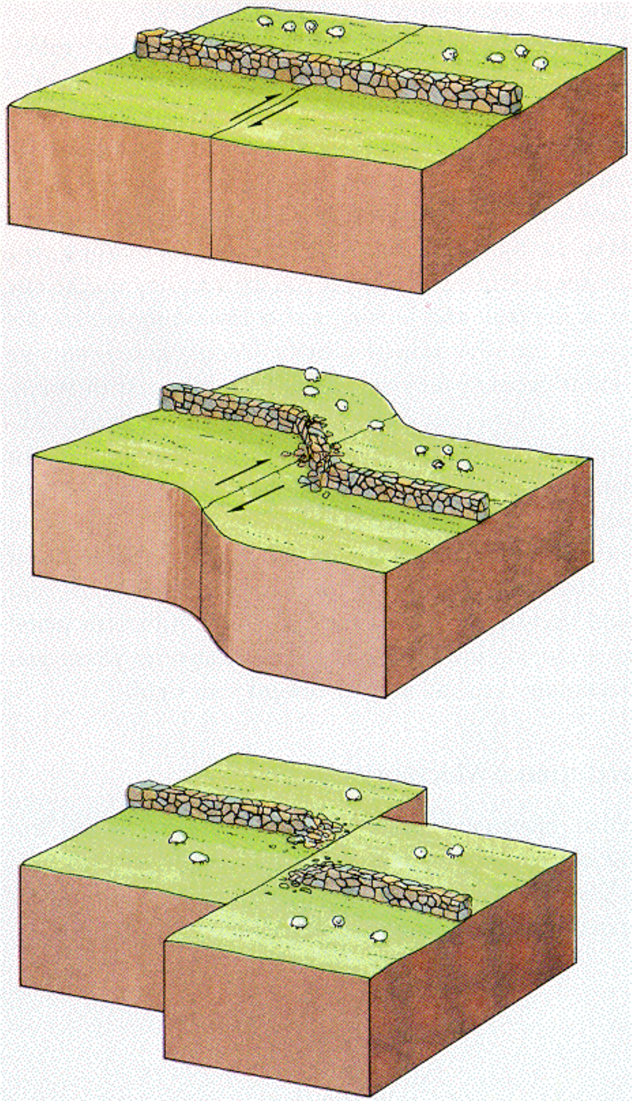
Shimon Wdowinski

The San Andreas Fault System



Major fault segments

Earthquake-induced deformation



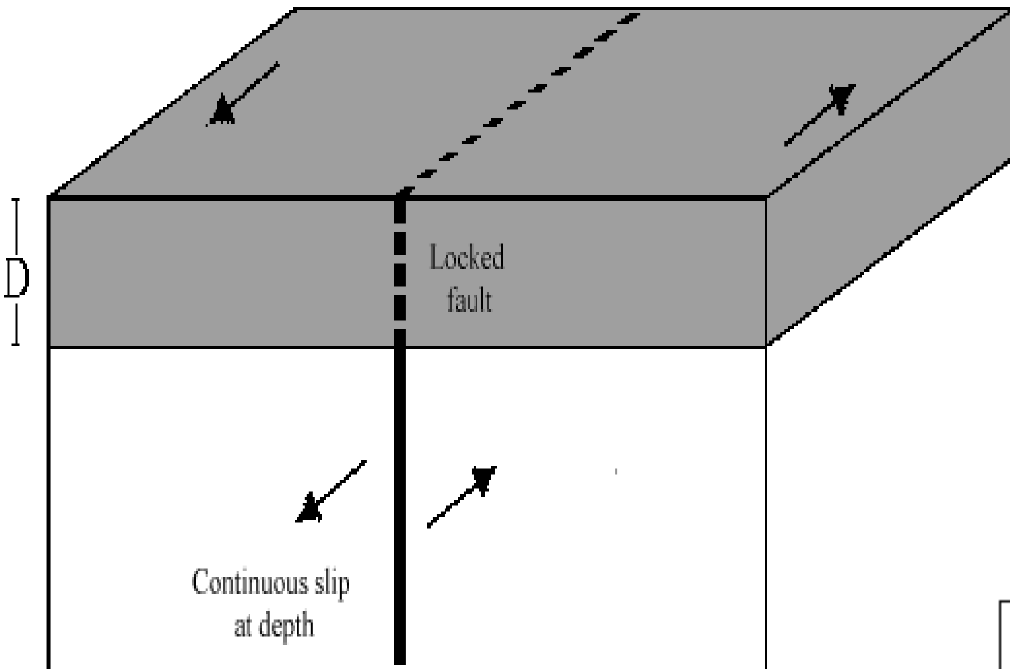
<u>Elastic rebound theory (Read, 1910)</u>

- Elastic strain accumulation
- Strain release during large Earthquakes

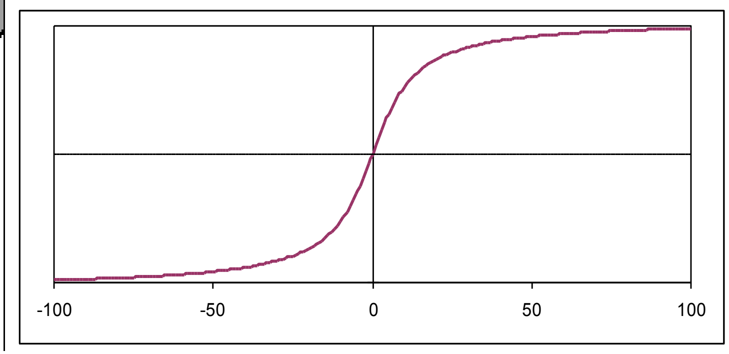
<u>The earthquake deformation cycle</u>

- Co-seismic: large EQ
- Post-seismic
- Inter-seismic
- Pre-seismic

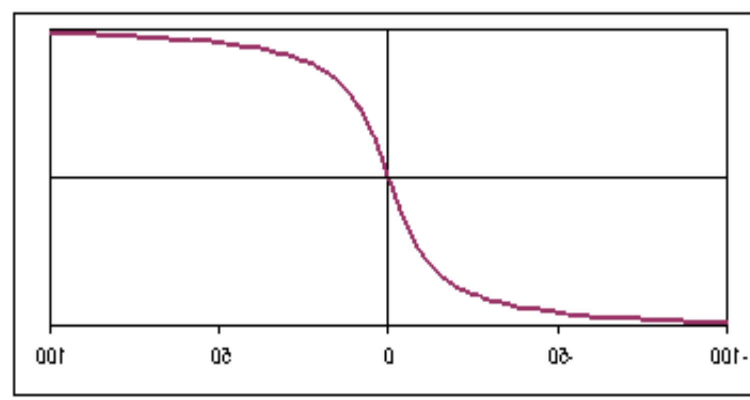
Locked fault model



Velocity field

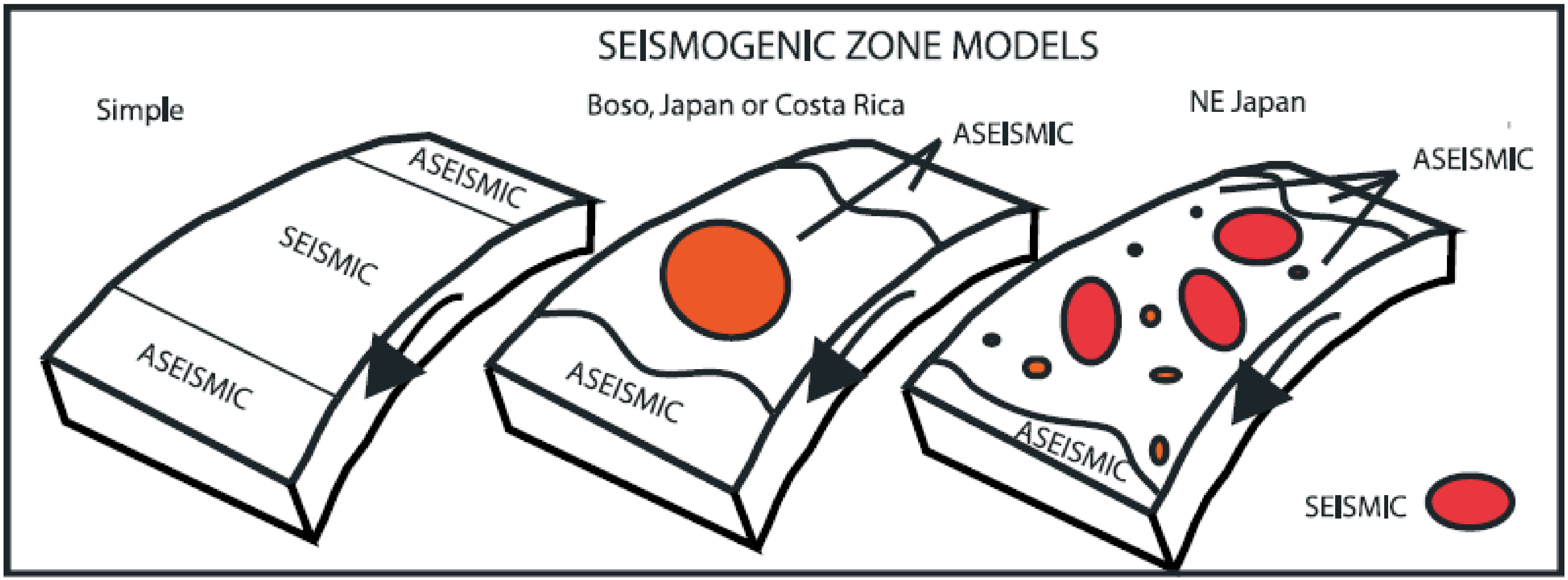


Distance from the fault



$$V(x) = V_1 + V_0 \frac{1}{\pi} \arctan(\frac{x}{D})$$

More complex models



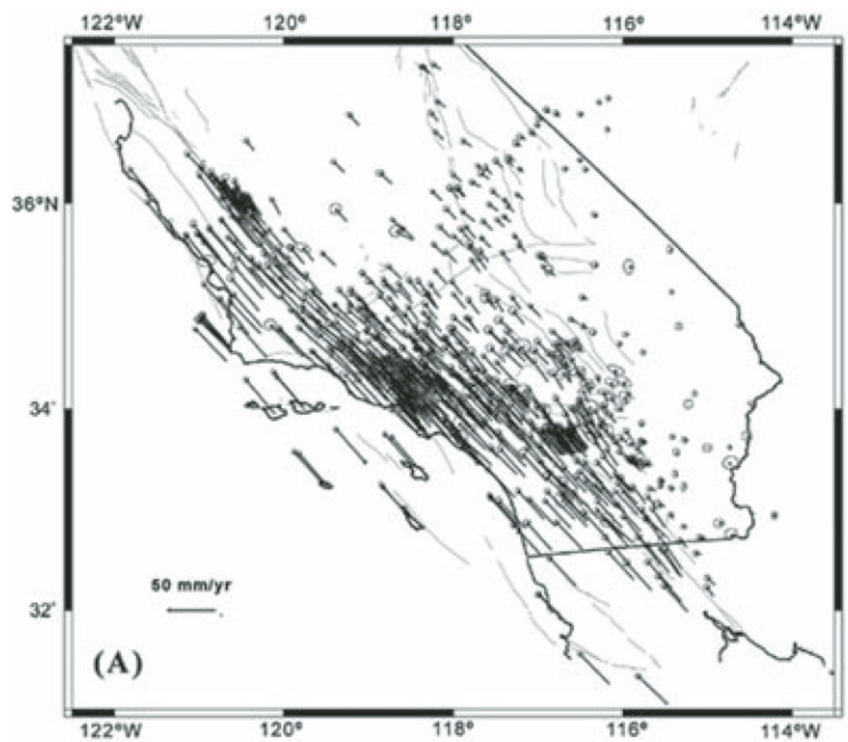
Schwartz and Rokosky (2007)

Geology, April 2007; v. 35; no. 4; p. 311–314;

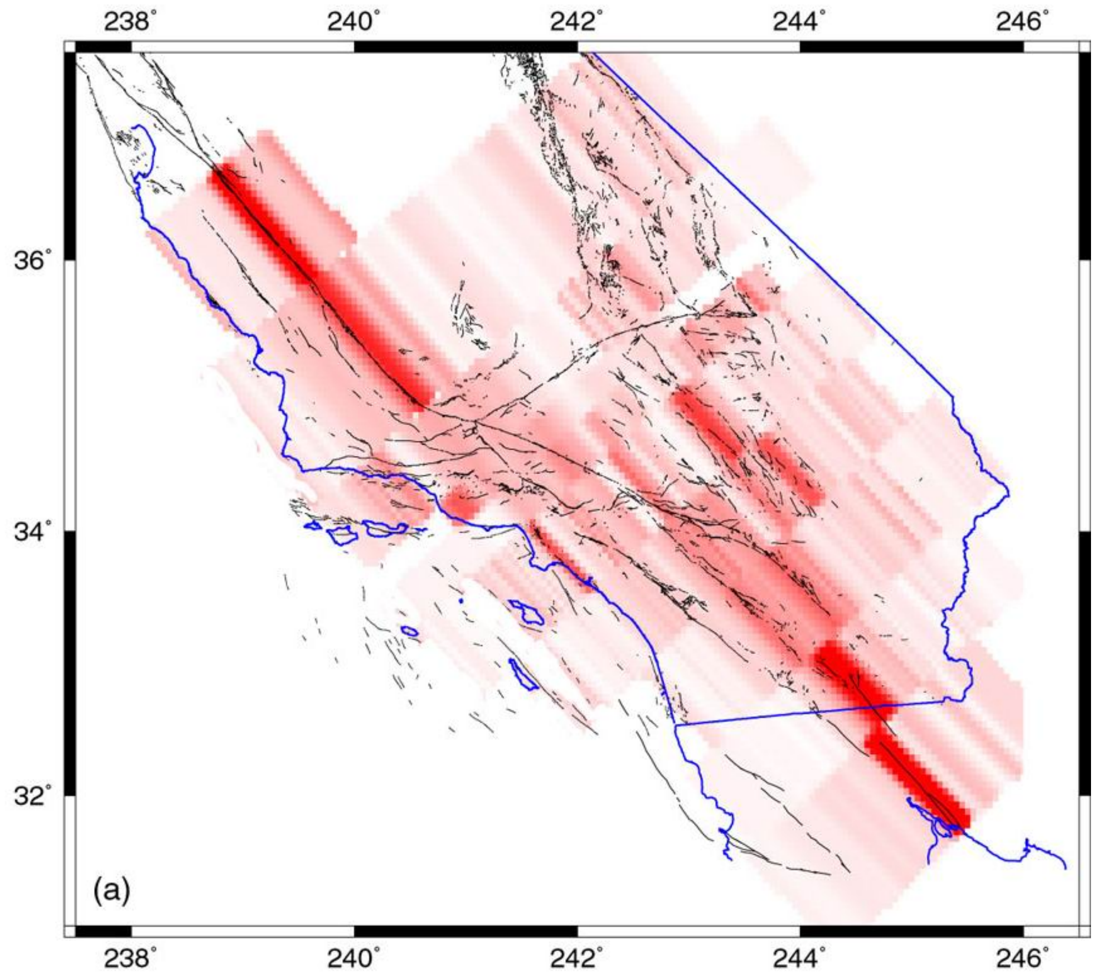
Diffuse interseismic deformation across the Pacific–North America plate boundary

Shimon Wdowinski — Division of Marine Geology and Geophysics, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149-1098, USA

Bridget Smith-Konter
Yehuda Bock
David Sandwell
— Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, La Jolla, California 92093-0210, USA

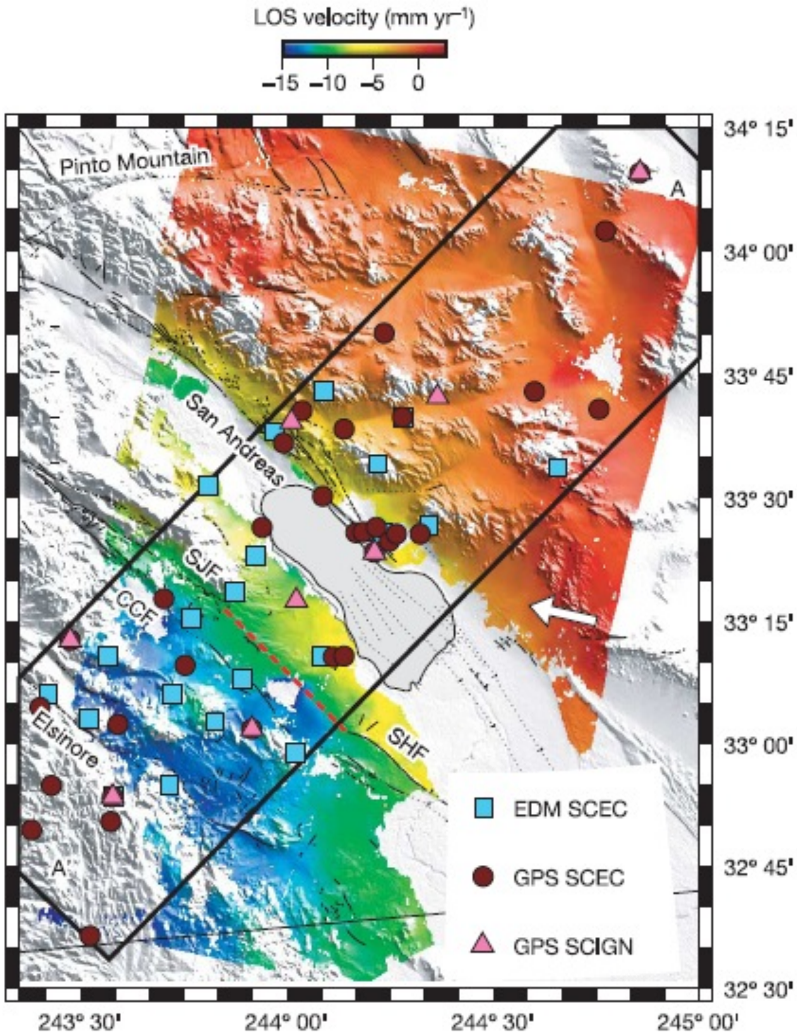


Maximum horizontal shear



San Jacinto Fault
Locking depth - 9-12 km
Slip rate – 15-18 mm/yr

S. San Andreas Fault
Locking depth – 17-20 km
Slip rate – 22-24 mm/yr



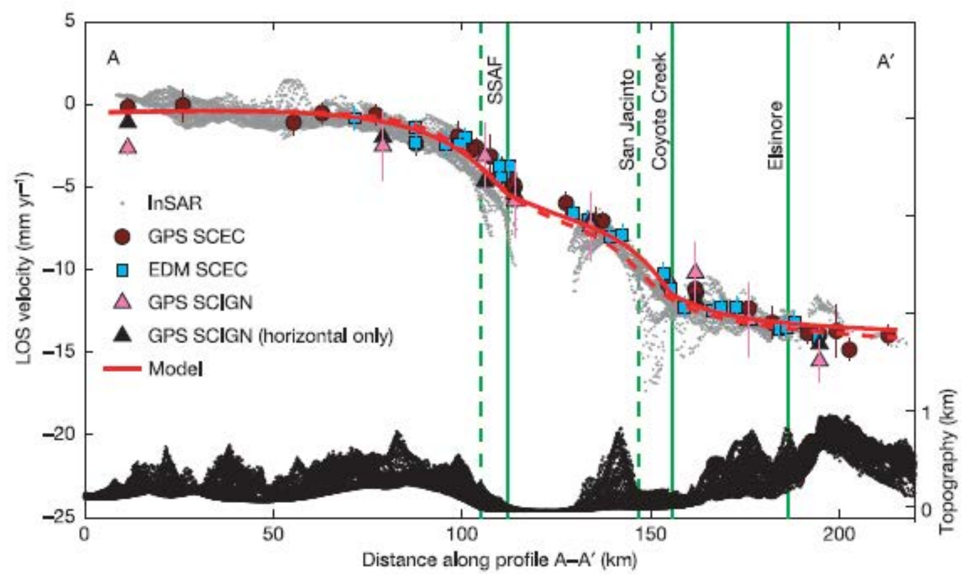
San Jacinto Fault

Locking depth - 9-12 km
Slip rate – 17-21 mm/yr

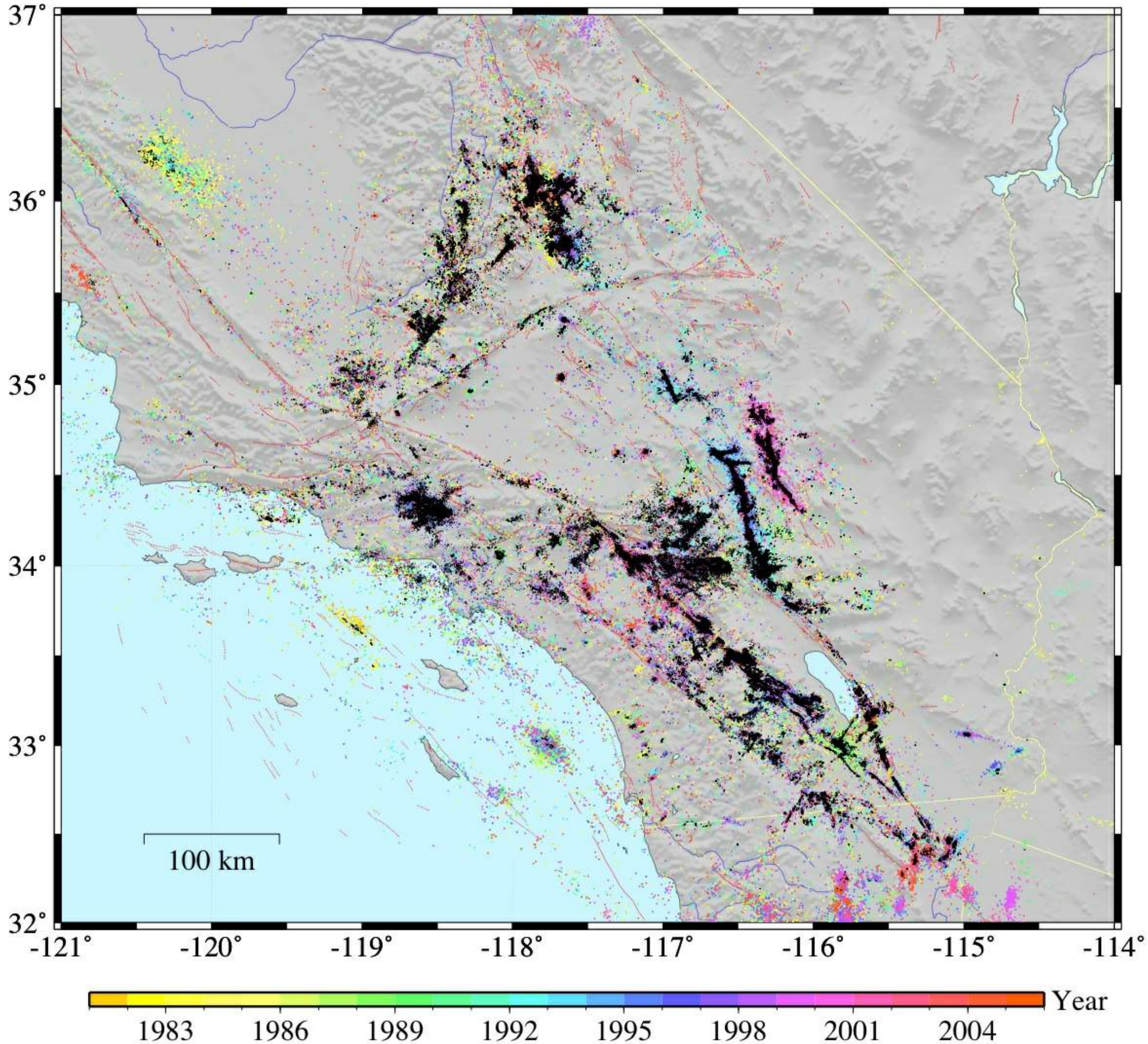
S. San Andreas Fault

Locking depth – 17-20 km
Slip rate – 24-28 mm/yr

Fialko (2006)



Relocated earthquake catalog

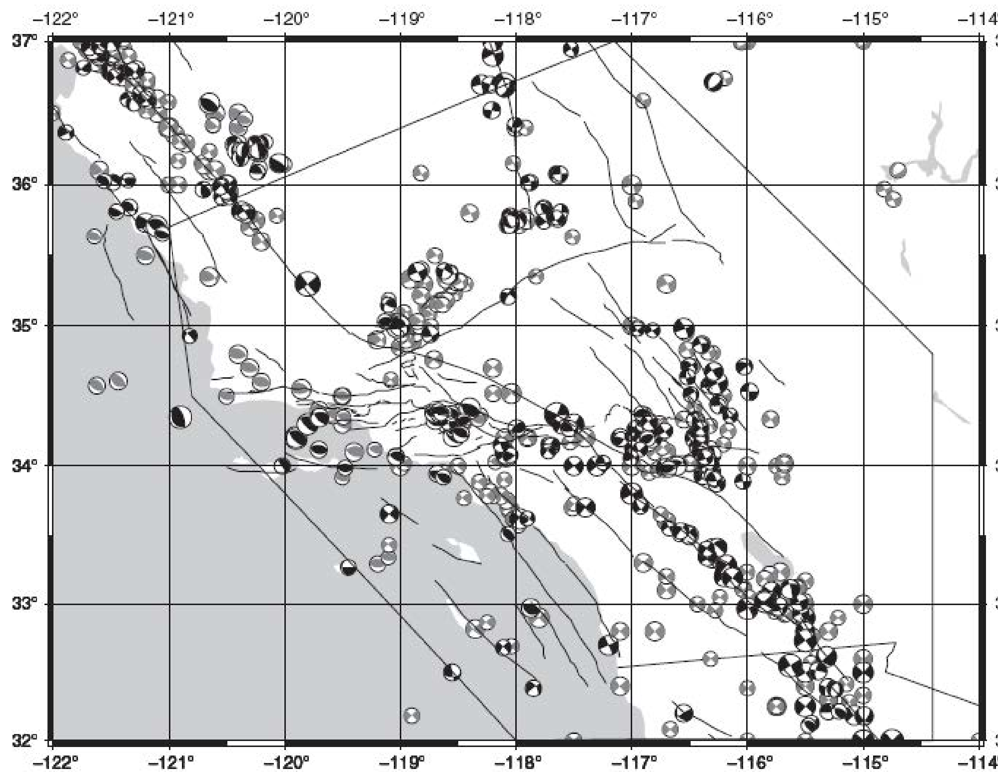


Lin et al. (2007)

A New Catalog of Southern California Earthquakes, 1800–2005

Yan Y. Kagan and David D. Jackson
Department of Earth and Space Sciences, University of California

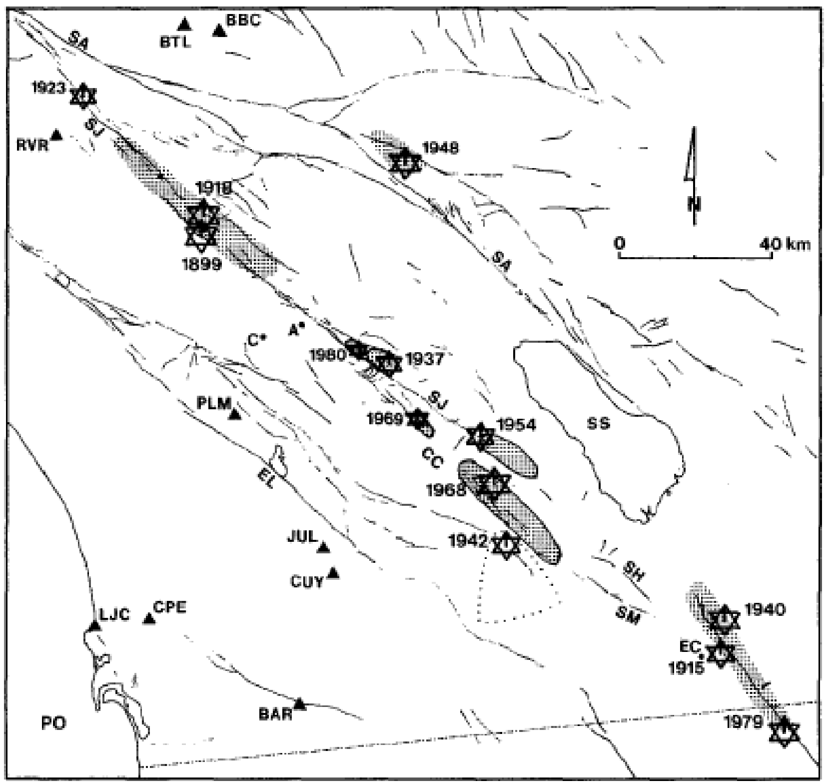
Yufang Rong
AIR-worldwide Corporation, Boston, Massachussets

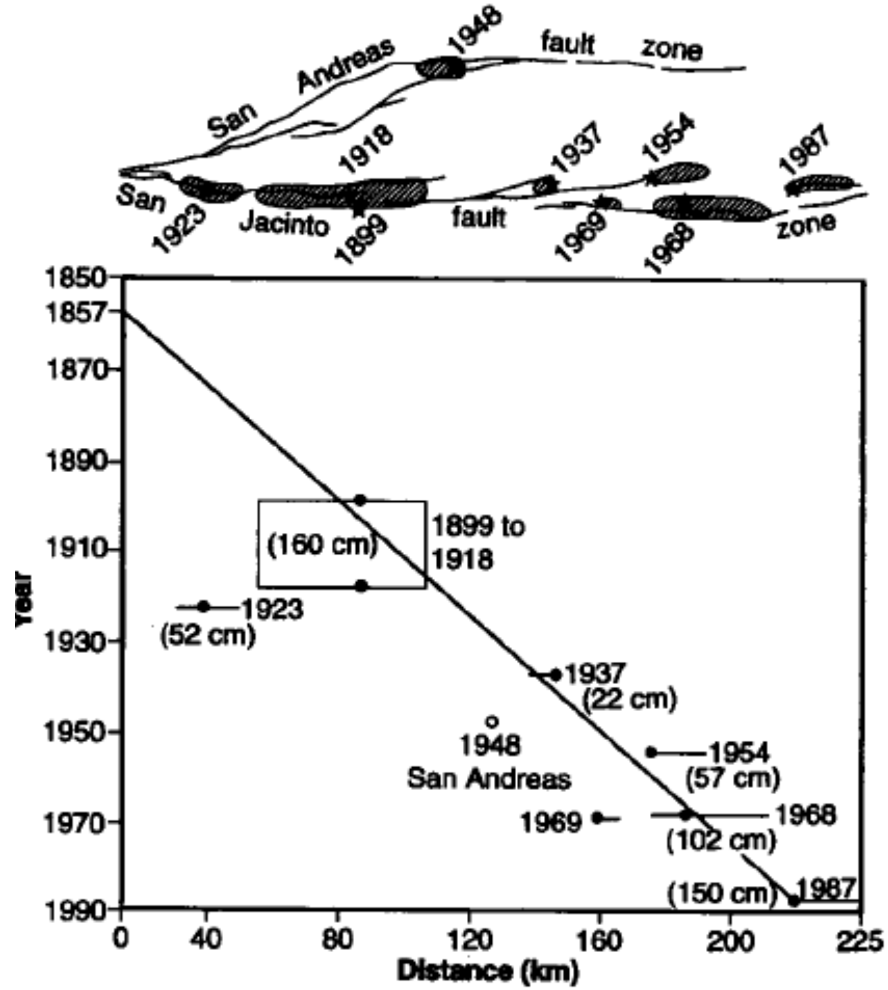


▲ **Figure 1.** Epicenter distribution of earthquakes in southern California, 1800-2005. Black beach balls—known solutions; gray beach balls—imputed solutions, obtained through interpolation from known focal mechanisms. A 6-point box (Equation 2) is shown. Earthquake distribution is considered to be reasonably homogeneous and complete in this box for the CalTech catalog (L. M. Jones, private communication, 2002).

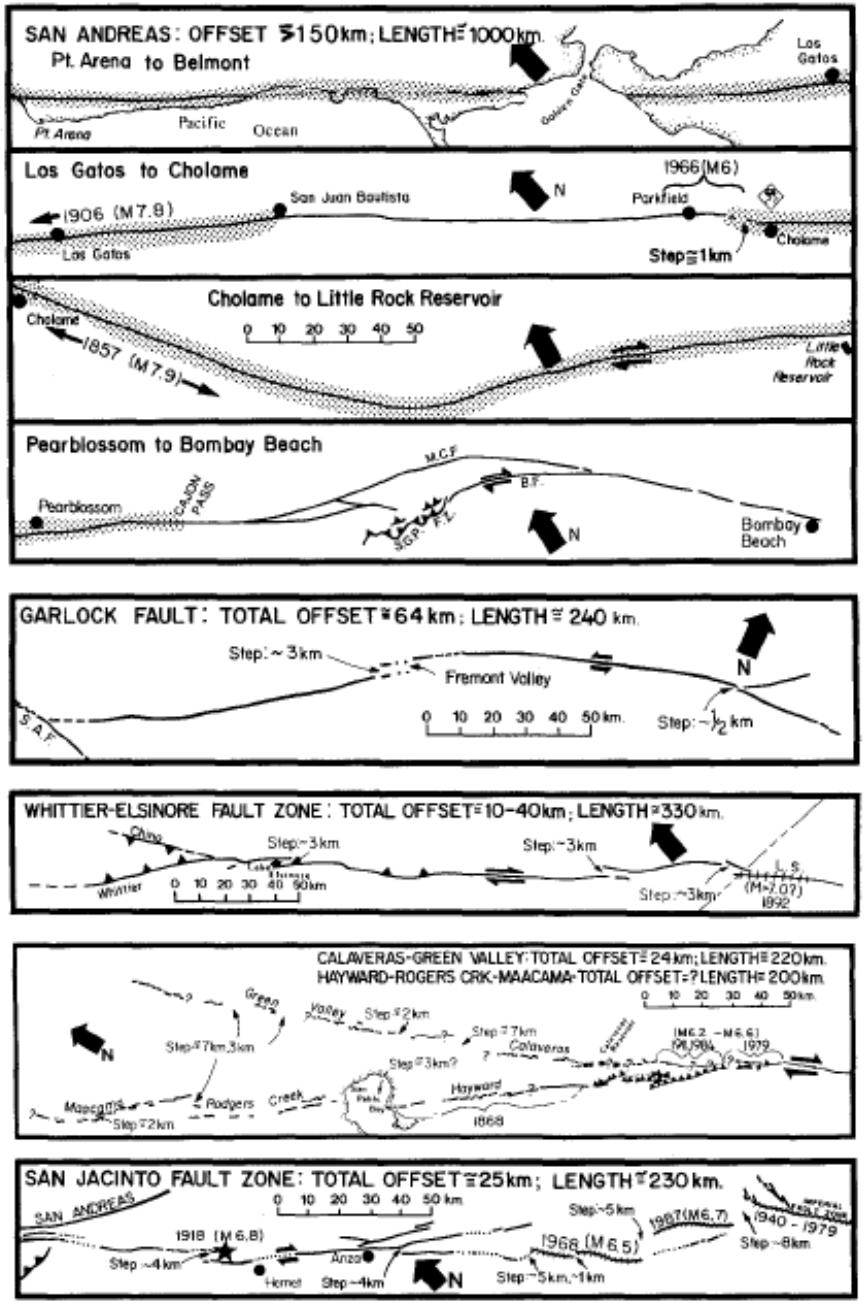
Interaction of the San Jacinto and San Andreas Fault Zones, Southern California: Triggered Earthquake Migration and Coupled Recurrence Intervals

Christopher O. Sanders





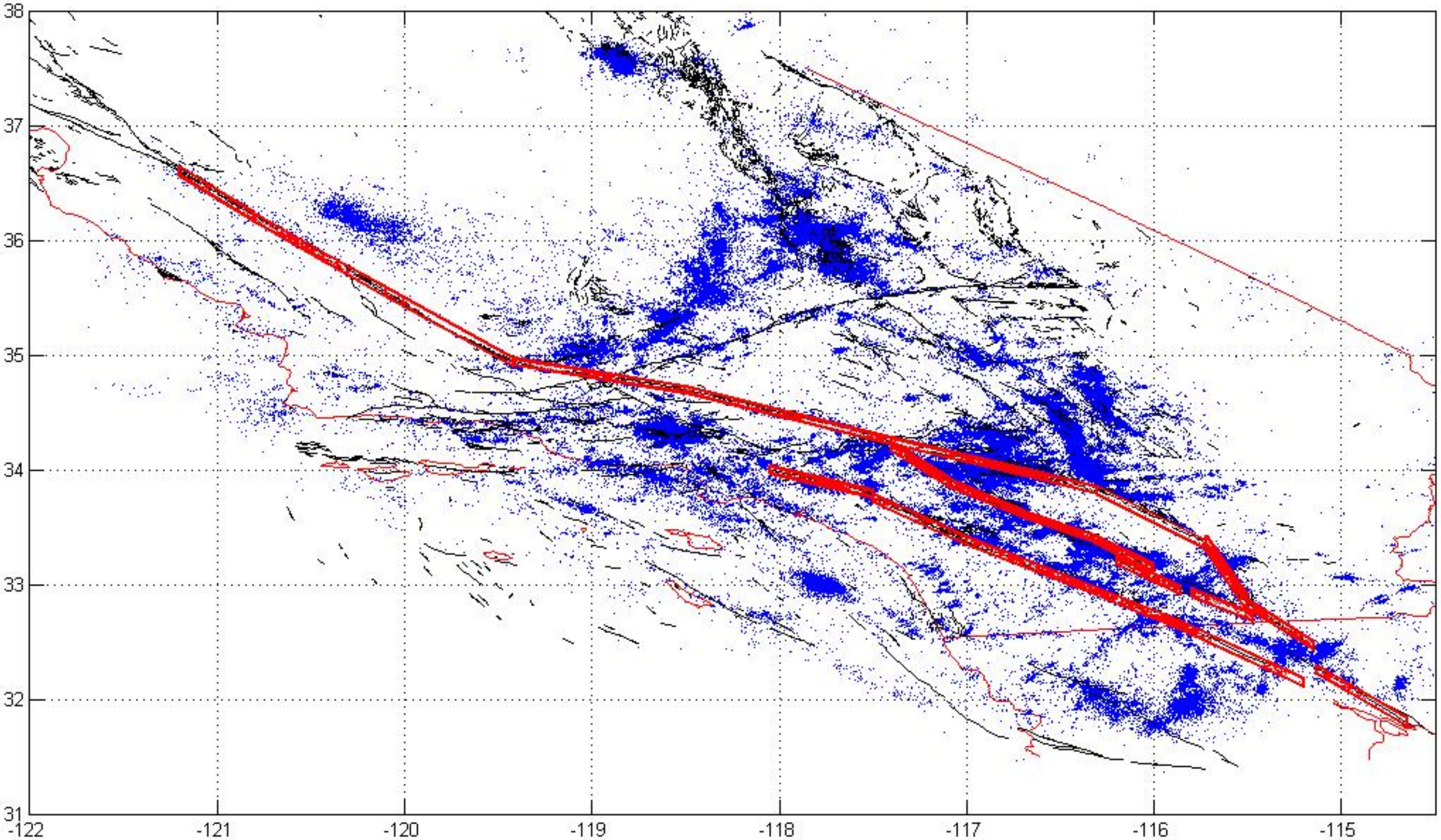
Sanders et al. 1987



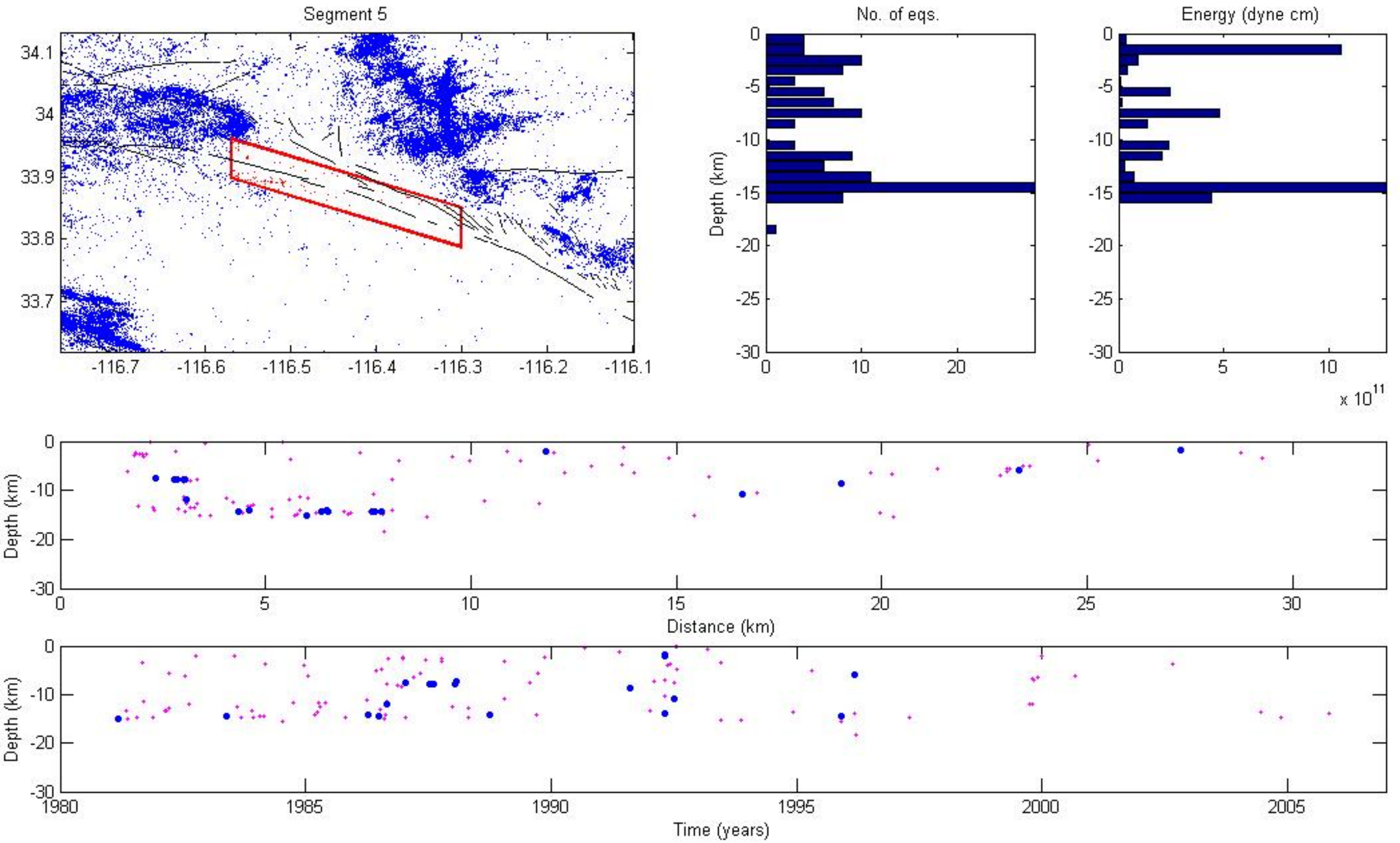
Accepted explanation for high seismic level along the SJF:

Wesnousky (1990): seismic productivity is controlled by structural complexity of fault systems

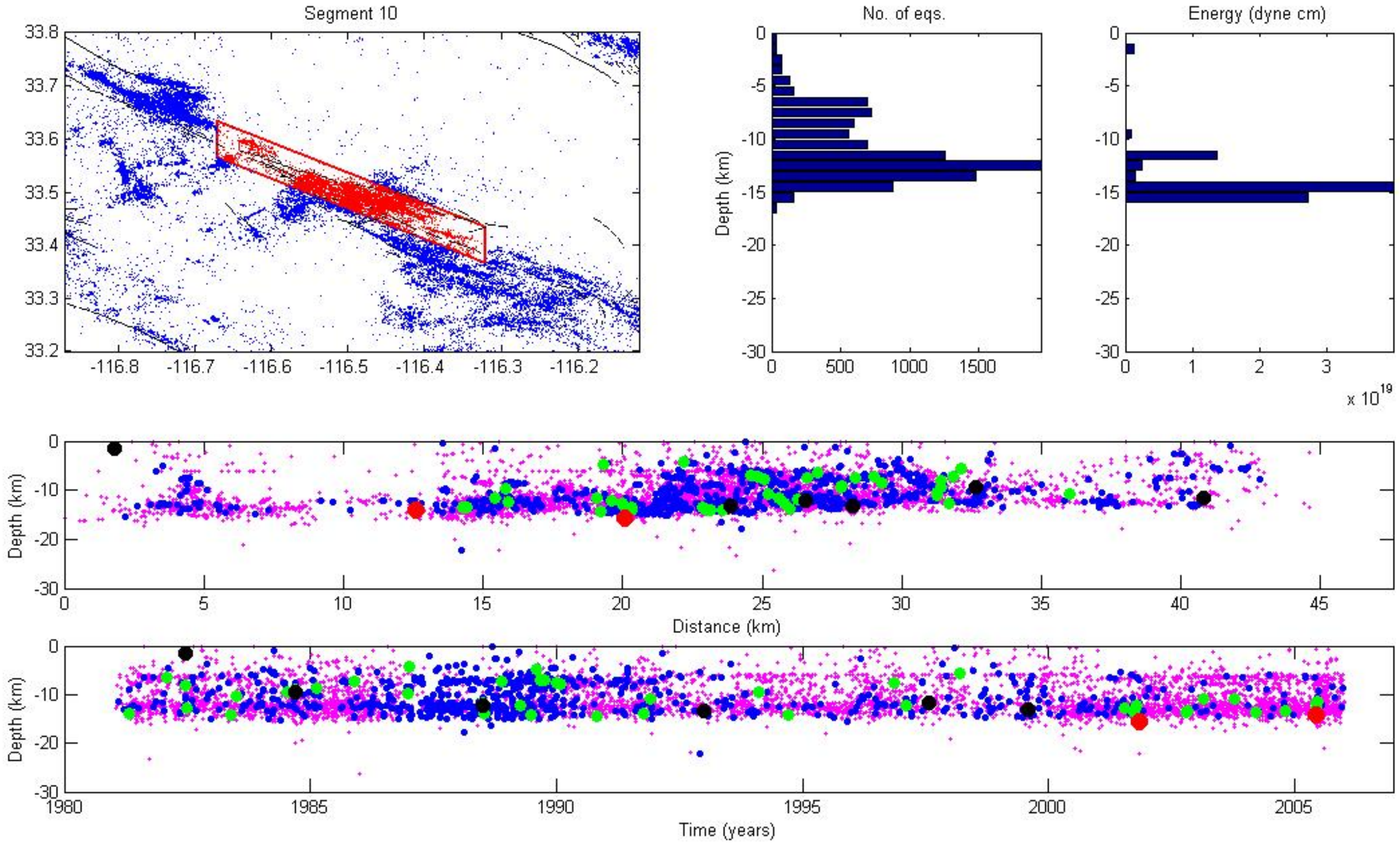
Main fault segments



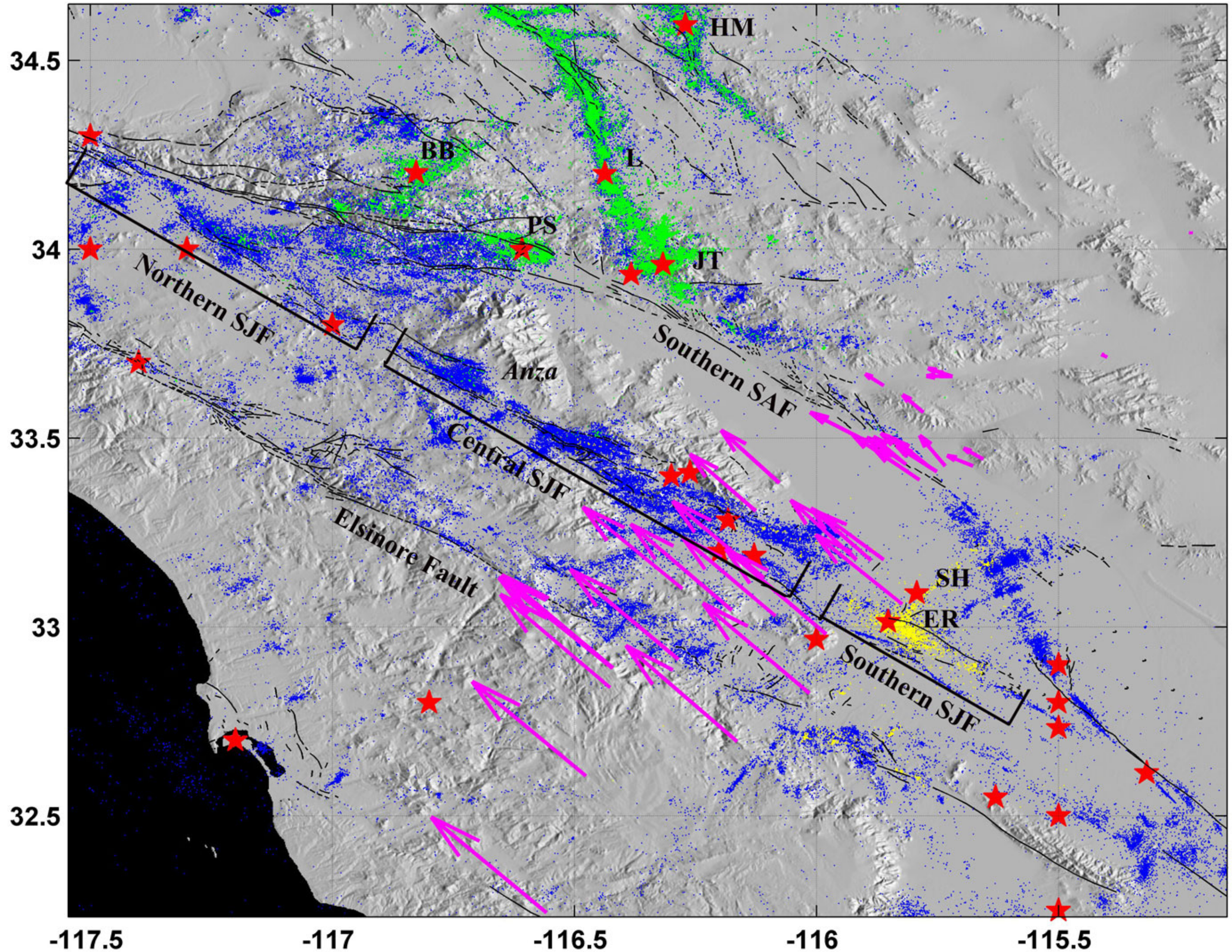
S. San Andreas Fault



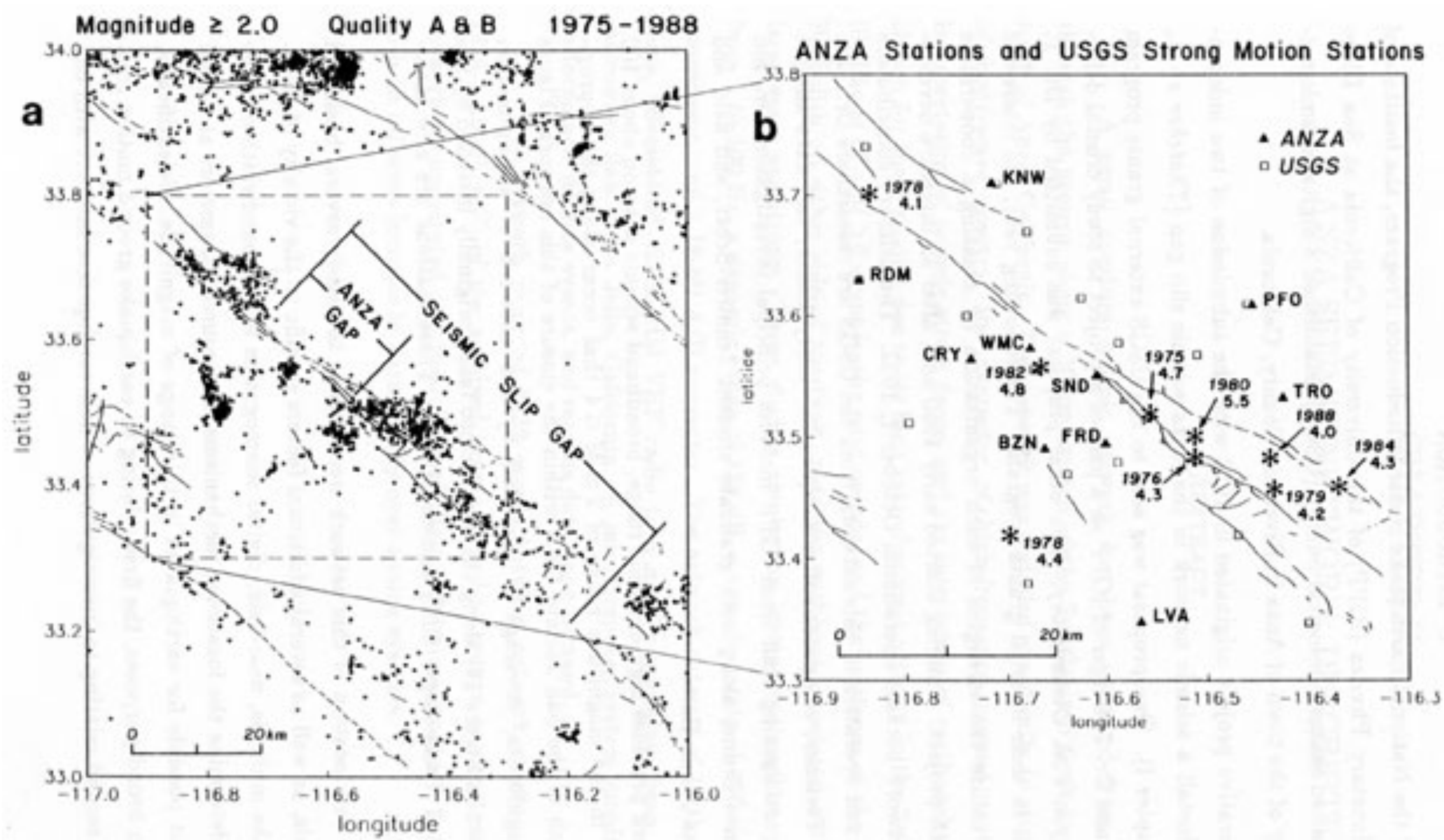
Central San Jacinto Fault



Seismicity + Geodesy

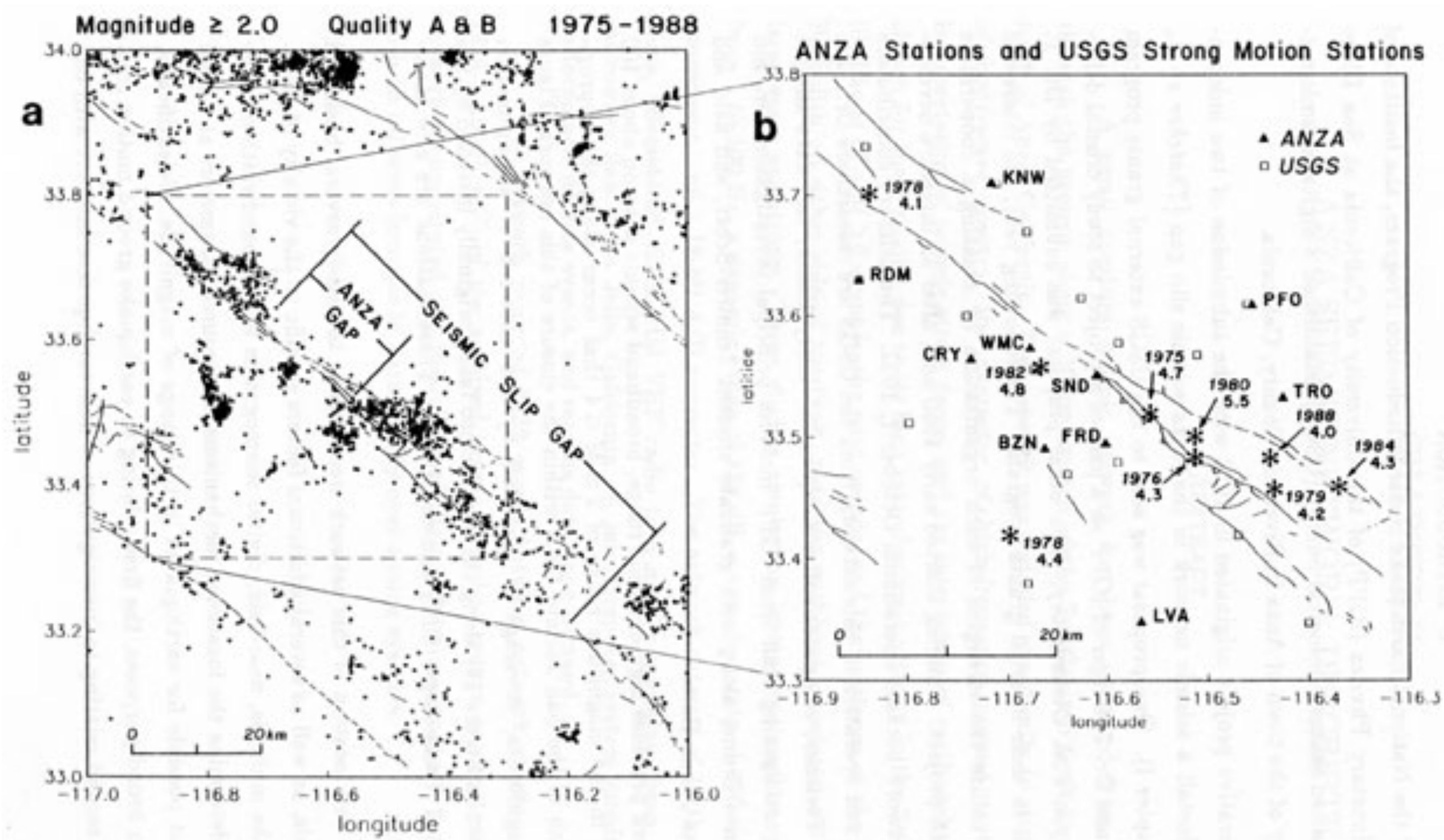


The Anza Gap



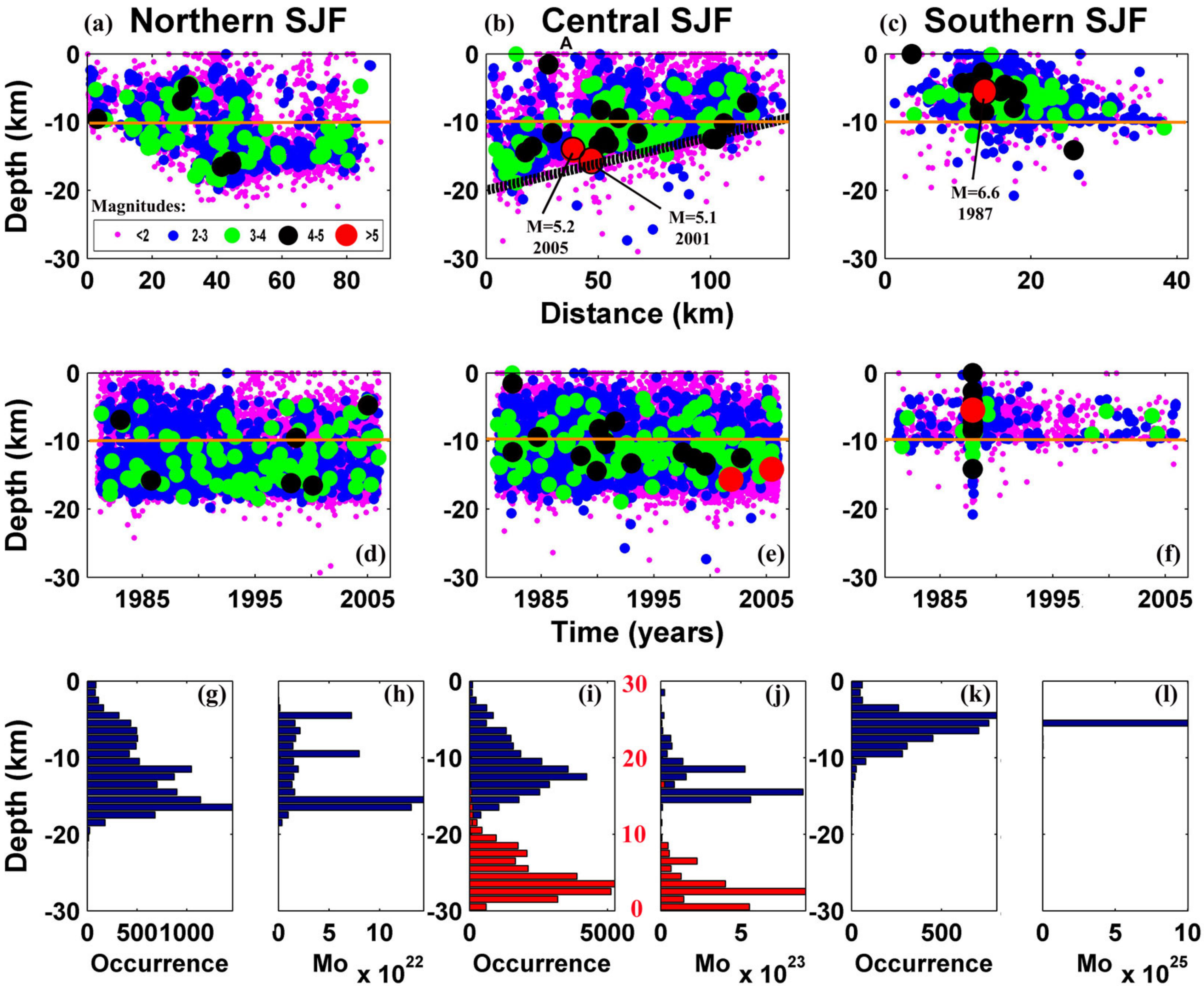
Magnitude ≥ 2.0 Quality A & B 1975-1988
a
ANZA GAP
SEISMIC SLIP GAP
20km
latitude
longitude
b
ANZA Stations and USGS Strong Motion Stations
ANZA
USGS
KNW
RDM
PFO
CRY
WMC
SND
TRO
BZN
FRD
LVA
1978 4.1
1982 4.8
1975 4.7
1980 5.5
1988 4.0
1984 4.3
1976 4.3
1979 4.2
1978 4.4
20km
latitude
longitude

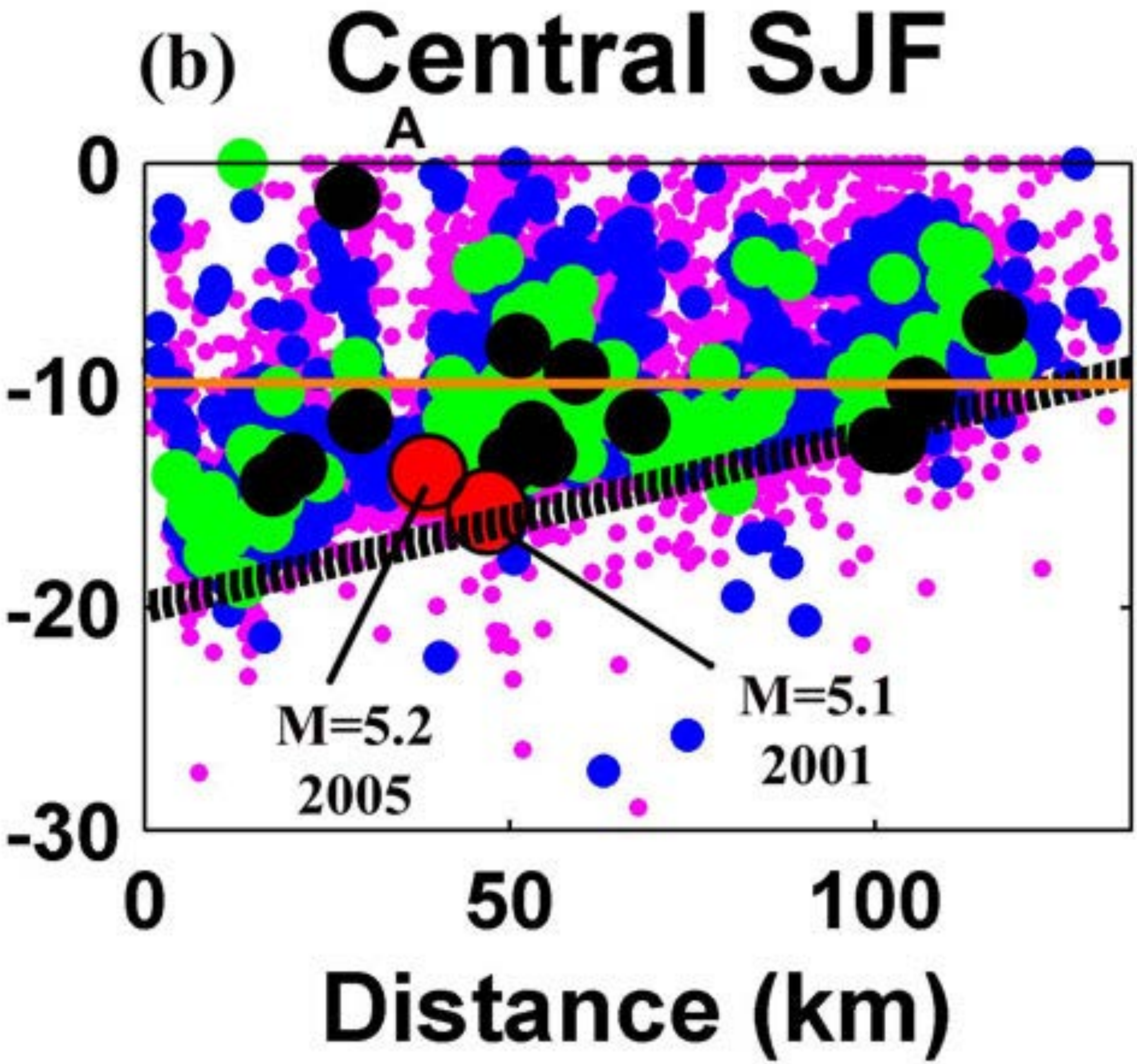
The Anza Gap

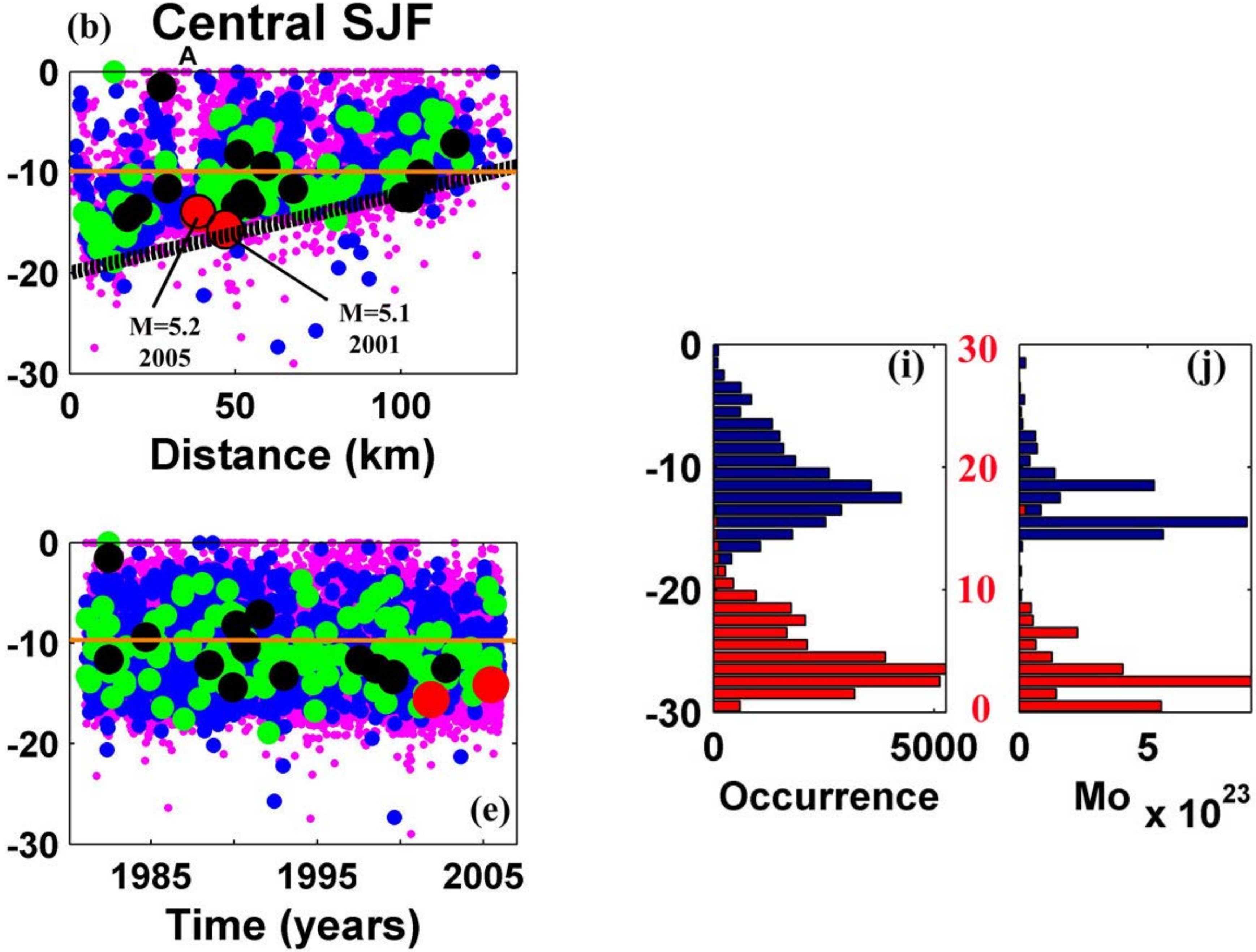


Magnitude ≥ 2.0 Quality A & B 1975-1988
a
ANZA GAP
SEISMIC SLIP GAP
20km
latitude
longitude
ANZA Stations and USGS Strong Motion Stations
b
ANZA
USGS
KNW
RDM
PFO
CRY
WMC
SND
TRO
BZN
FRD
LVA
1978 4.1
1982 4.8
1975 4.7
1980 5.5
1988 4.0
1984 4.3
1976 4.3
1979 4.2
1978 4.4
20km
longitude

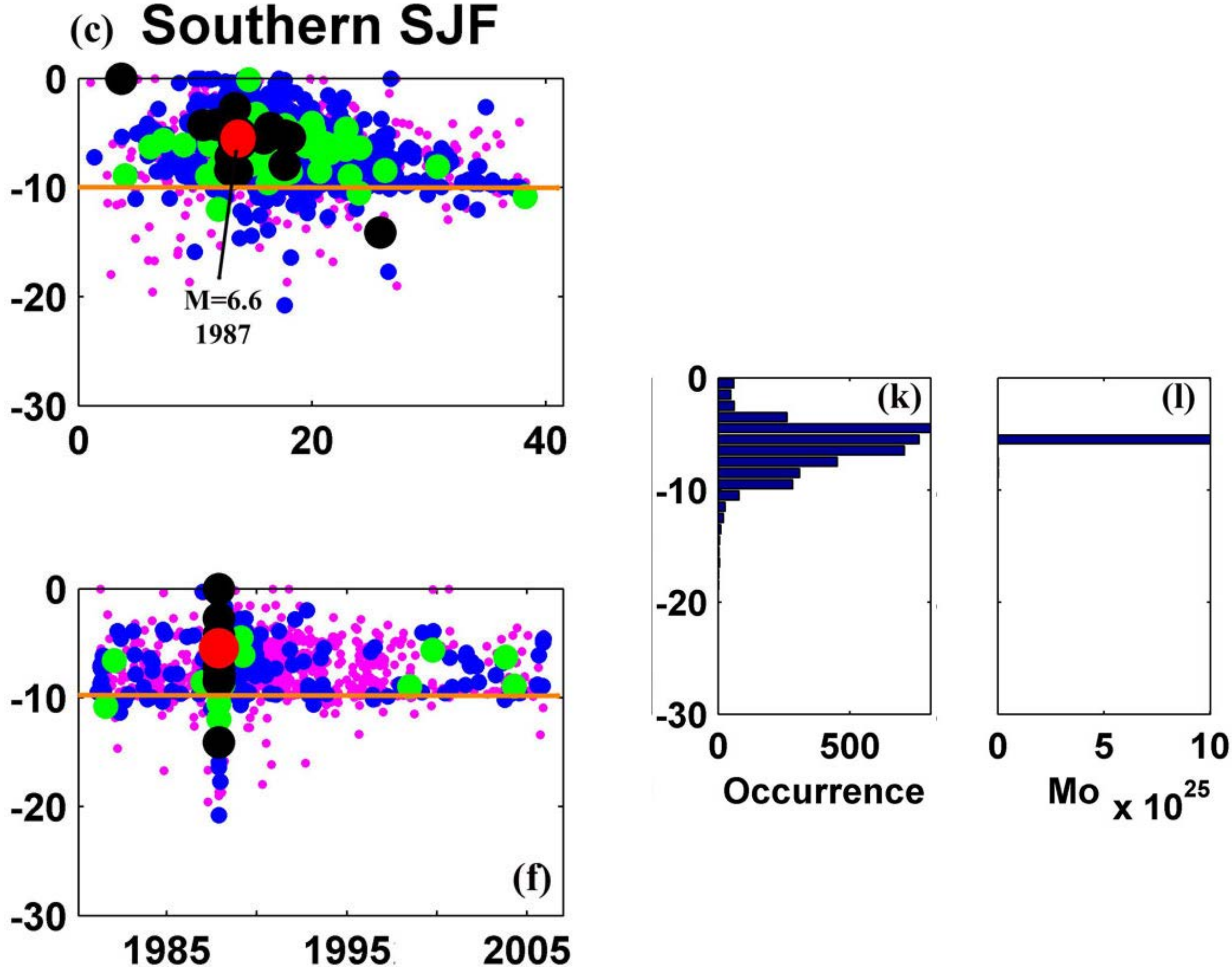
San Jacinto Fault

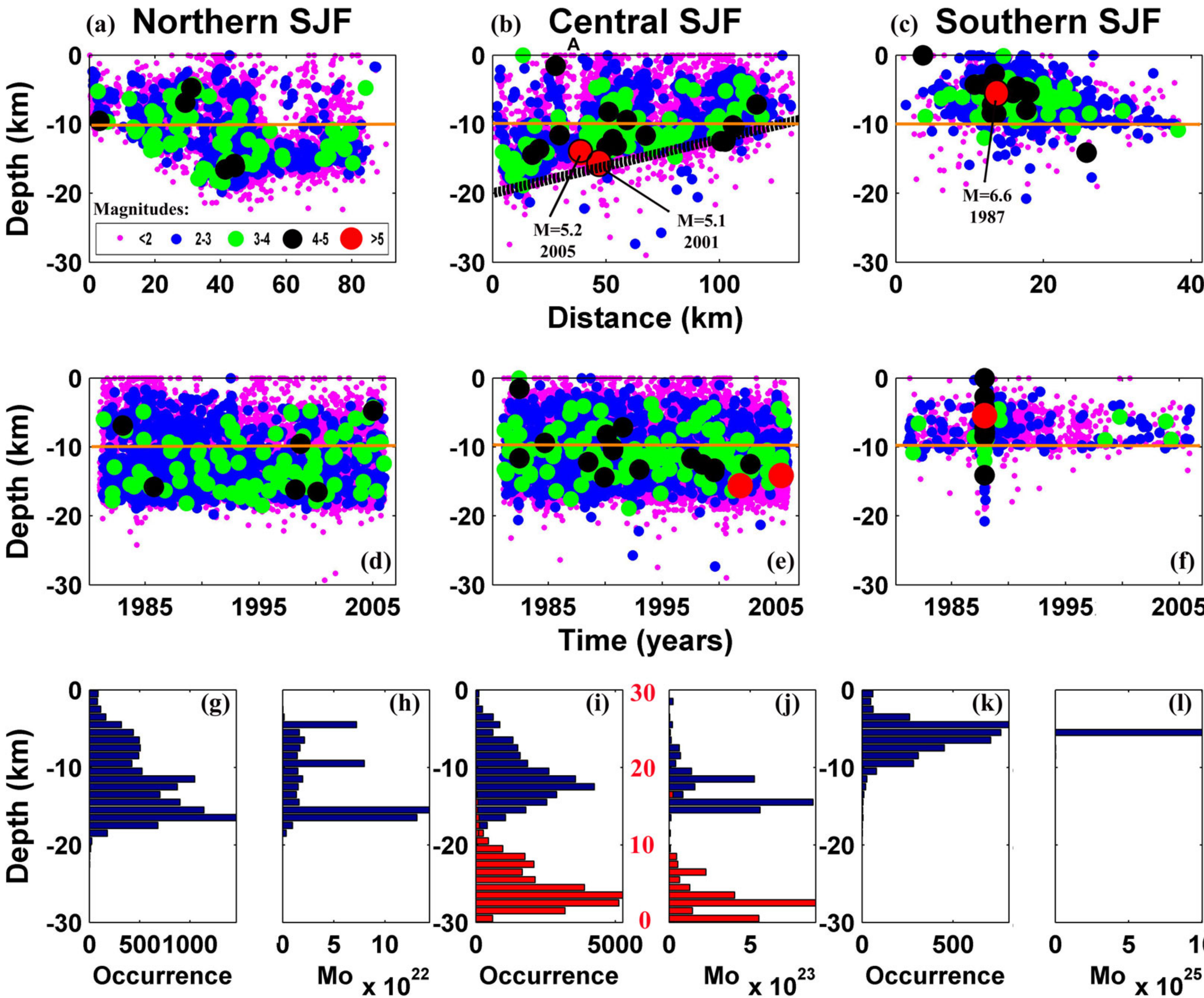



(b)
Central SJF
A
0
-10
-20
-30
M=5.2
2005
M=5.1
2001
0
50
100
Distance (km)



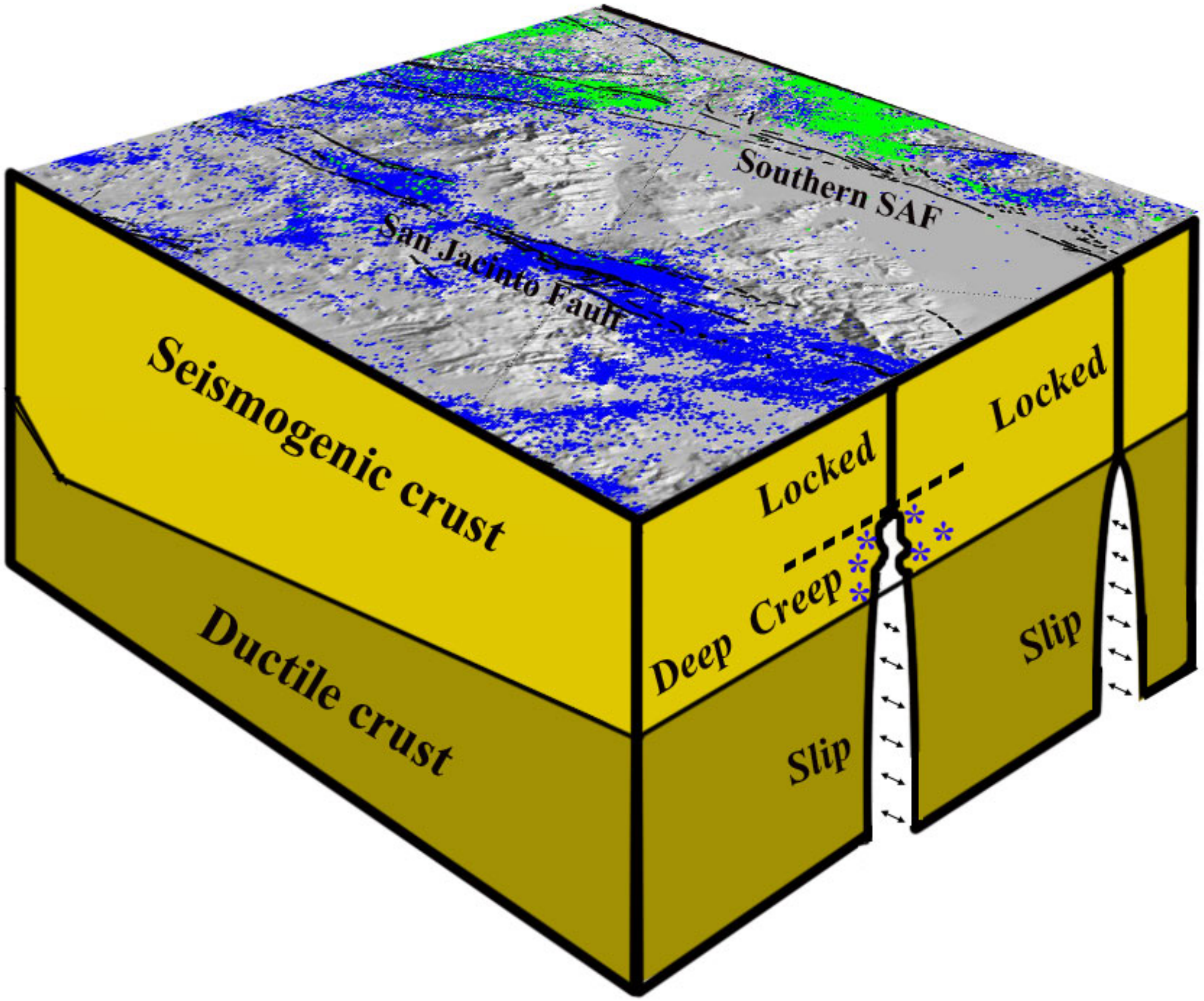
(b)
Central SJF
A
0
-10
-20
-30
0
50
100
M=5.2
2005
M=5.1
2001
Distance (km)
(e)
1985
1995
2005
Time (years)
(i)
(j)
30
20
10
0
5000
5
Occurrence
Mo x 10^23


(c) Southern SJF
0
-10
-20
-30
0
20
40
M=6.6
1987
0
-10
-20
-30
1985
1995
2005
(f)
0
-10
-20
-30
0
500
Occurrence
(k)
0
5
10
Mo x 10^25
(l)



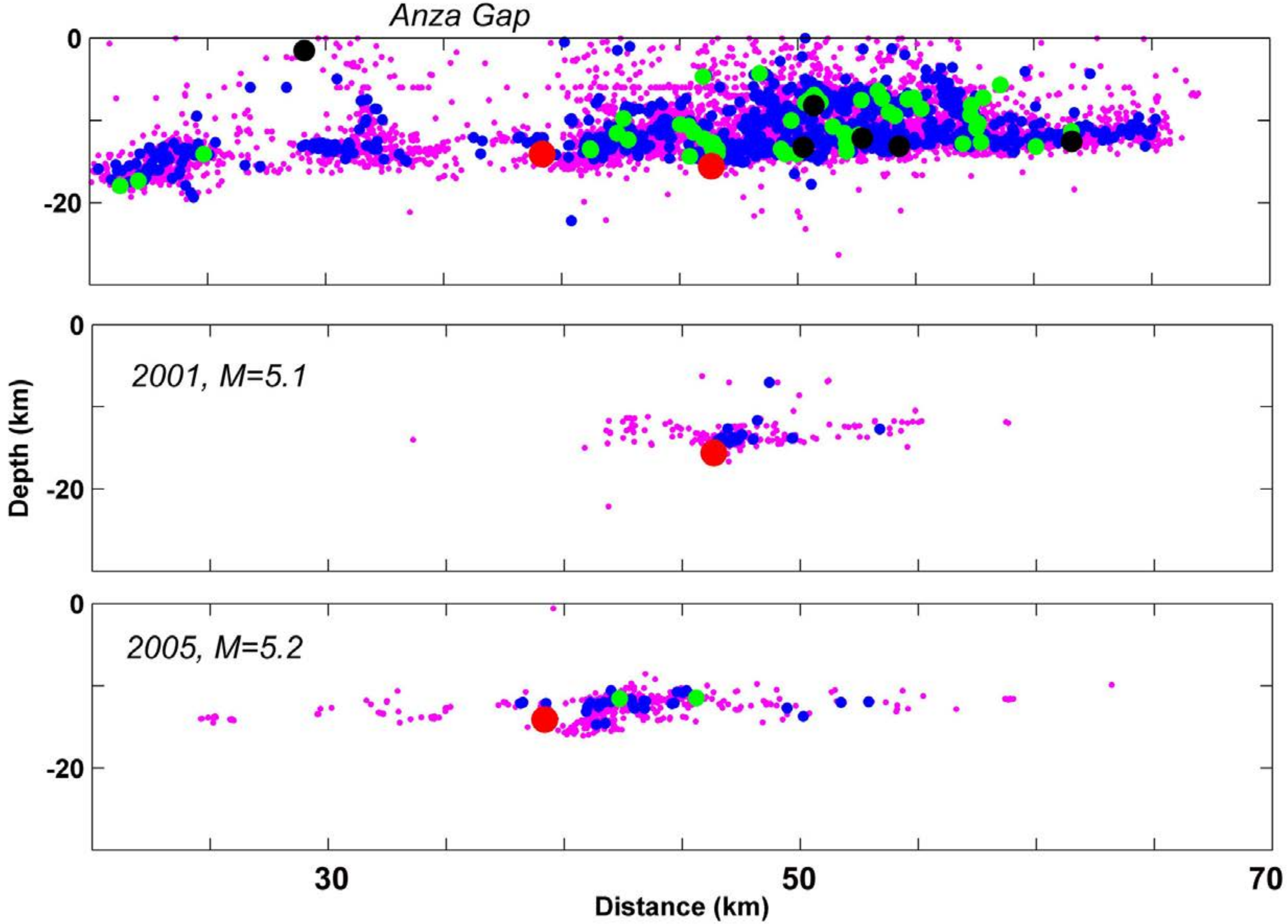
(a) Northern SJF
(b) Central SJF
(c) Southern SJF
Depth (km)
Magnitudes:
<2
2-3
3-4
4-5
>5
A
M=5.2
2005
M=5.1
2001
M=6.6
1987
Distance (km)
(d)
(e)
(f)
Time (years)
(g)
(h)
(i)
(j)
(k)
(l)
Occurrence
Mo x 10^22
Mo x 10^23
Mo x 10^25

Deep Creep



Southern SAF
San Jacinto Fault
Seismogenic crust
Ductile crust
Locked
Locked
Deep Creep
Slip
Slip

Aftershock sequence

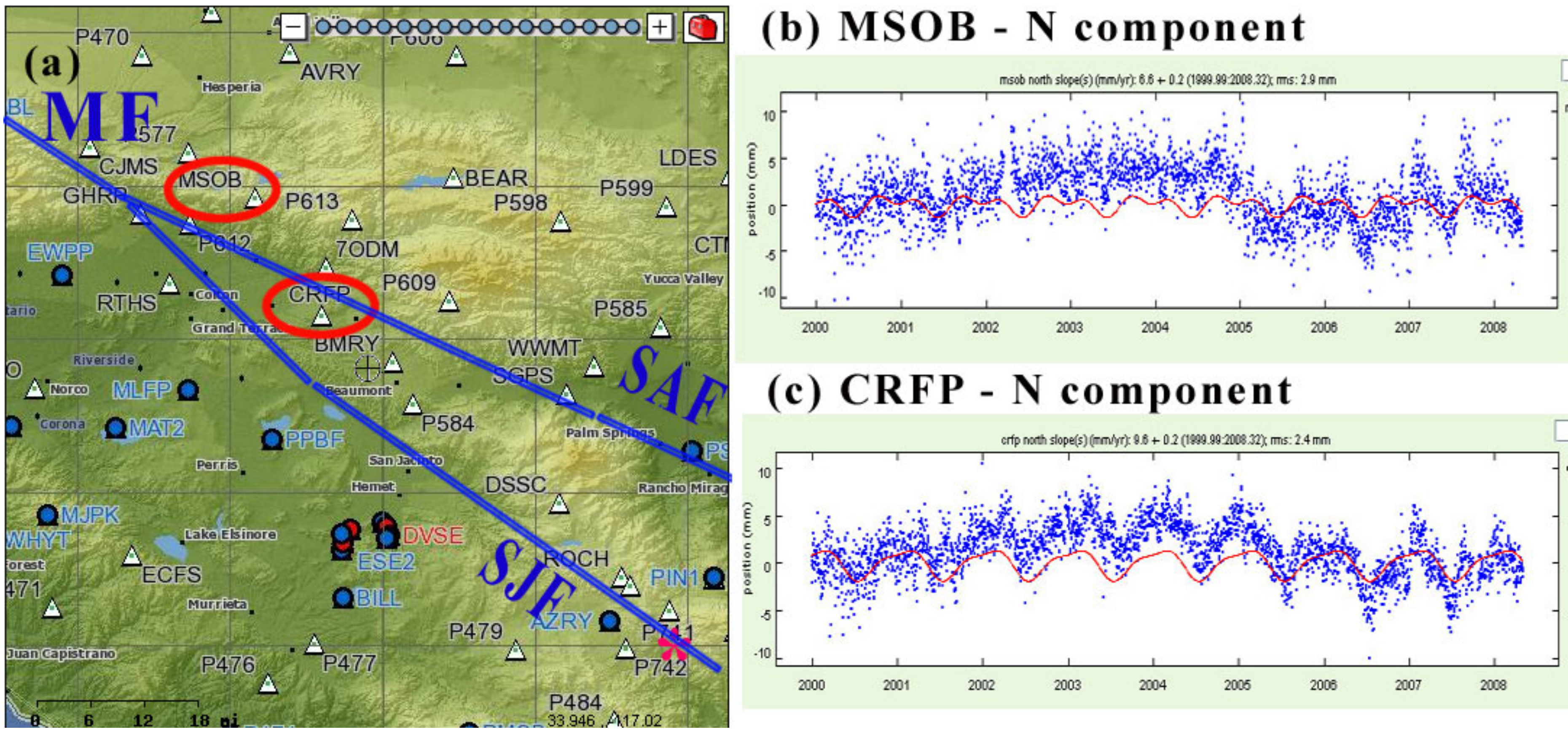


Possible Triggered Aseismic Slip on the San Jacinto Fault

(Agnew and Wyatt, 2005)

- We report evidence for deep aseismic slip following a recent earthquake on the San Jacinto fault (12 June 2005, 15:41:46.27, or 2005:163.654), based on data from long-base strainmeters at Pinon Flat Observatory (PFO).
- This magnitude 5.2 shock occurred within a seismic slip gap, but in in a region of abundant small and moderate earthquakes that lie to the SE of a 15-km section of fault that is relatively aseismic (a seismicity gap).

Transient deformation



Implications for seismic hazard assessments

New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement

by Donald L. Wells and Kevin J. Coppersmith

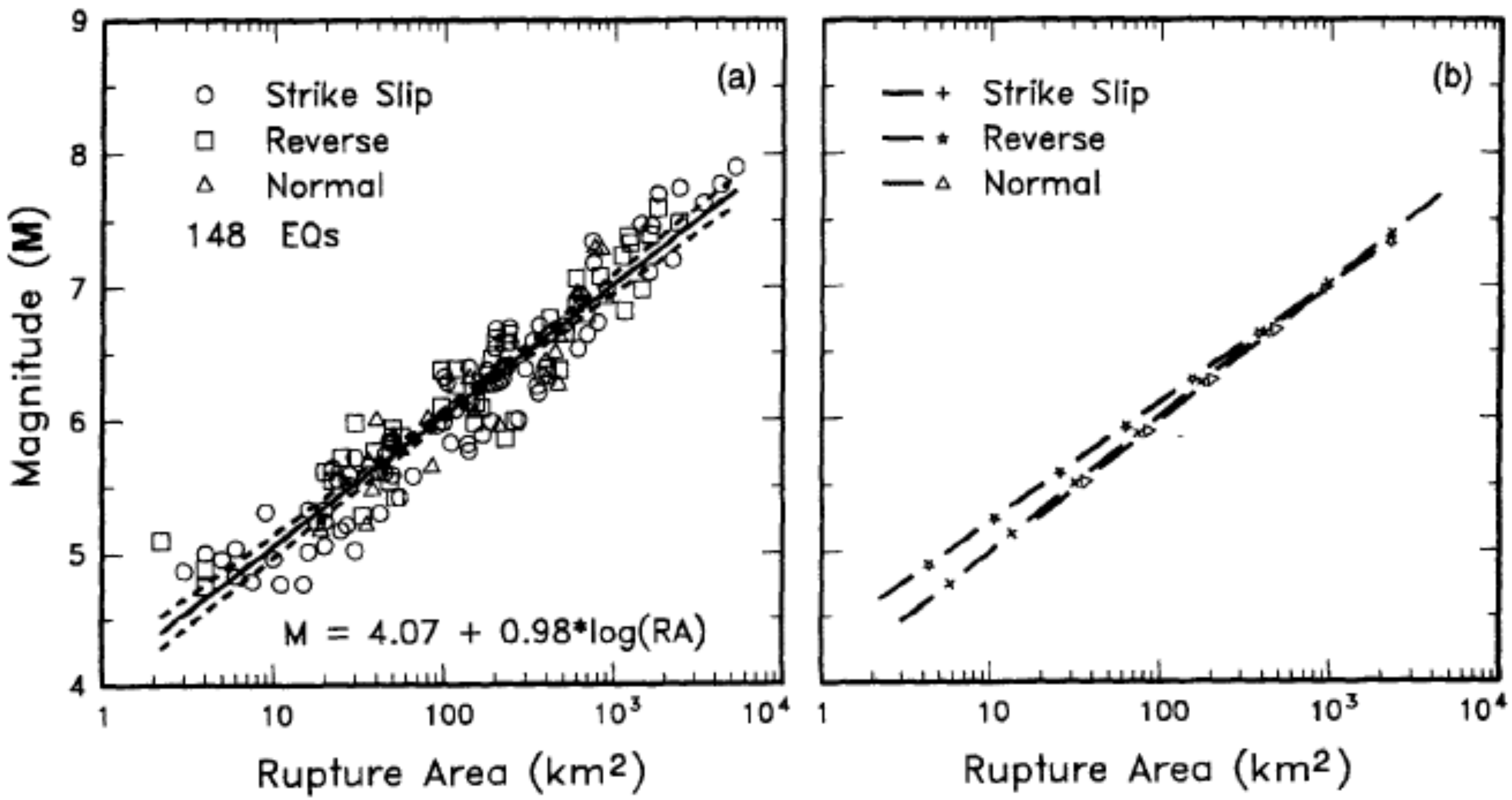


Table 2A

Regressions of Rupture Length, Rupture Width, Rupture Area, and Moment Magnitude (**M**)

Equation*	Slip Type†	Number of Events	Coefficients and Standard Errors *a*(sa)	*b*(sb)	Standard Deviation *s*	Correlation Coefficient *r*	Magnitude Range	Length/Width Range (km)
M = *a* + *b* * log (SRL)	SS	43	5.16(0.13)	1.12(0.08)	0.28	0.91	5.6 to 8.1	1.3 to 432
	R	19	5.00(0.22)	1.22(0.16)	0.28	0.88	5.4 to 7.4	3.3 to 85
	N	15	4.86(0.34)	1.32(0.26)	0.34	0.81	5.2 to 7.3	2.5 to 41
	All	77	5.08(0.10)	1.16(0.07)	0.28	0.89	5.2 to 8.1	1.3 to 432
log (SRL) = *a* + *b* * **M**	SS	43	−3.55(0.37)	0.74(0.05)	0.23	0.91	5.6 to 8.1	1.3 to 432
	R	19	−2.86(0.55)	0.63(0.08)	0.20	0.88	5.4 to 7.4	3.3 to 85
	N	15	−2.01(0.65)	0.50(0.10)	0.21	0.81	5.2 to 7.3	2.5 to 41
	All	77	−3.22(0.27)	0.69(0.04)	0.22	0.89	5.2 to 8.1	1.3 to 432
M = *a* + *b* * log (RLD)	SS	93	4.33(0.06)	1.49(0.05)	0.24	0.96	4.8 to 8.1	1.5 to 350
	R	50	4.49(0.11)	1.49(0.09)	0.26	0.93	4.8 to 7.6	1.1 to 80
	N	24	4.34(0.23)	1.54(0.18)	0.31	0.88	5.2 to 7.3	3.8 to 63
	All	167	4.38(0.06)	1.49(0.04)	0.26	0.94	4.8 to 8.1	1.1 to 350
log (RLD) = *a* + *b* * **M**	SS	93	−2.57(0.12)	0.62(0.02)	0.15	0.96	4.8 to 8.1	1.5 to 350
	R	50	−2.42(0.21)	0.58(0.03)	0.16	0.93	4.8 to 7.6	1.1 to 80
	N	24	−1.88(0.37)	0.50(0.06)	0.17	0.88	5.2 to 7.3	3.8 to 63
	All	167	−2.44(0.11)	0.59(0.02)	0.16	0.94	4.8 to 8.1	1.1 to 350
M = *a* + *b* * log (RW)	SS	87	3.80(0.17)	2.59(0.18)	0.45	0.84	4.8 to 8.1	1.5 to 350
	R	43	4.37(0.16)	1.95(0.15)	0.32	0.90	4.8 to 7.6	1.1 to 80
	N	23	4.04(0.29)	2.11(0.28)	0.31	0.86	5.2 to 7.3	3.8 to 63
	All	153	4.06(0.11)	2.25(0.12)	0.41	0.84	4.8 to 8.1	1.1 to 350
log (RW) = *a* + *b* * **M**	SS	87	−0.76(0.12)	0.27(0.02)	0.14	0.84	4.8 to 8.1	1.5 to 350
	R	43	−1.61(0.20)	0.41(0.03)	0.15	0.90	4.8 to 7.6	1.1 to 80
	N	23	−1.14(0.28)	0.35(0.05)	0.12	0.86	5.2 to 7.3	3.8 to 63
	All	153	−1.01(0.10)	0.32(0.02)	0.15	0.84	4.8 to 8.1	1.1 to 350
M = *a* + *b* * log (RA)	SS	83	3.98(0.07)	1.02(0.03)	0.23	0.96	4.8 to 7.9	3 to 5,184
	R	43	4.33(0.12)	0.90(0.05)	0.25	0.94	4.8 to 7.6	2.2 to 2,400
	N	22	3.93(0.23)	1.02(0.10)	0.25	0.92	5.2 to 7.3	19 to 900
	All	148	4.07(0.06)	0.98(0.03)	0.24	0.95	4.8 to 7.9	2.2 to 5,184
log (RA) = *a* + *b* * **M**	SS	83	−3.42(0.18)	0.90(0.03)	0.22	0.96	4.8 to 7.9	3 to 5,184
	R	43	−3.99(0.36)	0.98(0.06)	0.26	0.94	4.8 to 7.6	2.2 to 2,400
	N	22	−2.87(0.50)	0.82(0.08)	0.22	0.92	5.2 to 7.3	19 to 900
	All	148	−3.49(0.16)	0.91(0.03)	0.24	0.95	4.8 to 7.9	2.2 to 5,184

*SRL—surface rupture length (km); RLD—subsurface rupture length (km); RW—downdip rupture width (km), RA—rupture area (km^2).
†SS—strike slip; R—reverse; N—normal.

Earthquake potential

	San Jacinto	S. San Andreas
Locking depth (rupture width)	9-12 km	17-20 km
Magnitude	6.3-6.8	7.4-7.6
Rupture length	15-20 km	100-120 km
Average Displacement	1.5-3 m	4-7 m
Slip rate	15-21 mm/yr	22-28 mm/yr
Repeat time	105-170 yrs	200-300 yrs

The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2)

By 2007 Working Group on California Earthquake Probabilities*

USGS Open File Report 2007-1437
CGS Special Report 203
SCEC Contribution #1138
Version 1.0

2008

Participation Probabilities

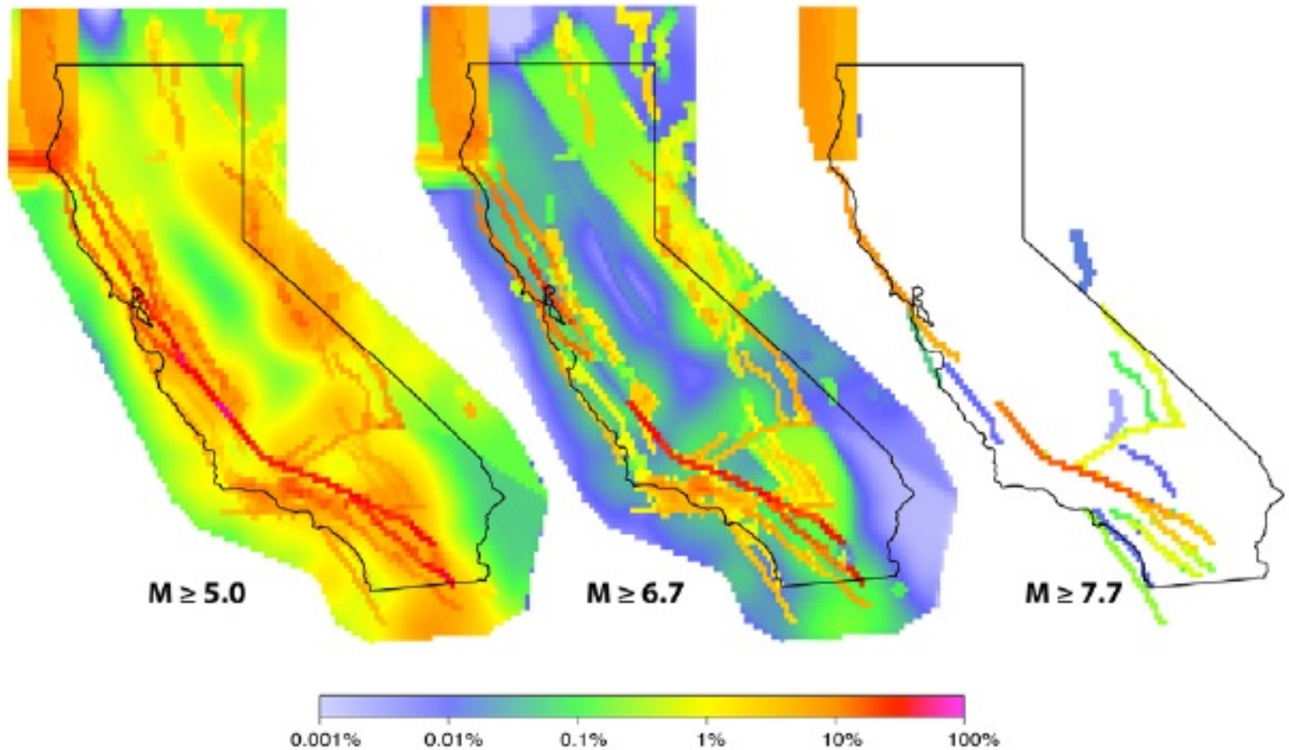


Table A. 30-year probability of M • 6.7 events on the Type-A faults, rounded to the nearest percent.

Fault	WGCEP (2007) Mean [Min-Max]	WGCEP (2003) Mean [2.5% and 97.5%]	WGCEP (1995) Mean
S. San Andreas	59% [22-94]		53%
Hayward-Rodgers Creek	31% [12-67]	27% [10-58]	
San Jacinto	31% [14-54]		61%
N. San Andreas	21% [6-39]	23% [3-52]	
Elsinore	11% [5-25]		24%
Calaveras	7% [1-22]	11% [3-27]	
Garlock	6% [3-12]		