Surface Rupture Earthquakes

Displacement and geometrical characteristics of earthquake surface ruptures: Issues and implications for seismic hazard analysis and the earthquake rupture process.

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STRIKE-SLIP (22)

1906 San Andreas, CA
1891 Neo-Dani, Japan
1930 Kita-Izu, Japan
1939 Ercincan, Turkey
1940 Imperial Valley, CA
1942 Erbaa-Niksar, Turkey
1943 Tosya, Turkey
1943 Tottori, Japan
1944 Gerede-Bolu, Turkey
1967 Mudurnu, Turkey
1968 Borrego Mtn, CA
1979 Imperial Valley, CA
1981 Sirch, Iran
1987 Superstition Hills, CA
1990 Luzon, Philippines
1992 Landers, CA
1999 Fandoqa, Iran
1999 Hector Mine, CA
1999 Izmit, Turkey
1999 Duzce, Turkey
2001 Kunlun, China
2002 Denali, AK

NORMAL (7)

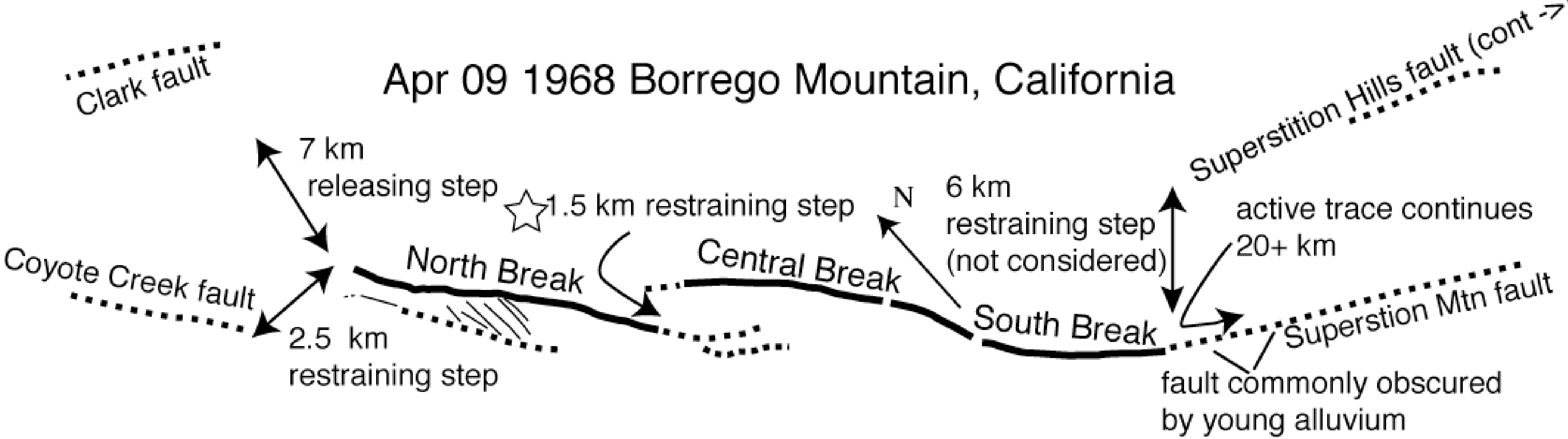
1887 Sonora, MX
1915 Pleasant Valley, NV
1954 Fairview Peak, NV
1954 Dixie Valley, NV
1959 Hebgen Lake, MT
1983 Borah Peak, ID
1987 Edgecumbe, NZ

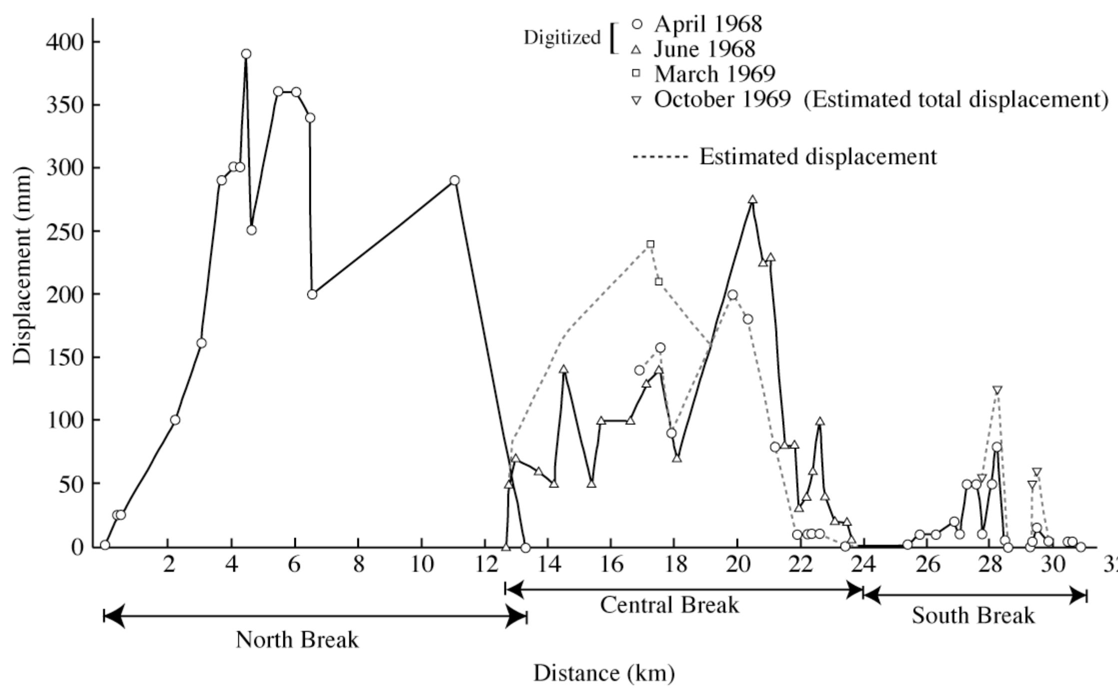
REVERSE (8)

1896 Rikuu Japan
1945 Mikawa, Japan
1971 San Fernando
1979 Cadoux, Australia
1980 El Asnam
1986 Maryat, Australia
1998 Tenant Creek, Australia
1999 Chi-Chi, Taiwan

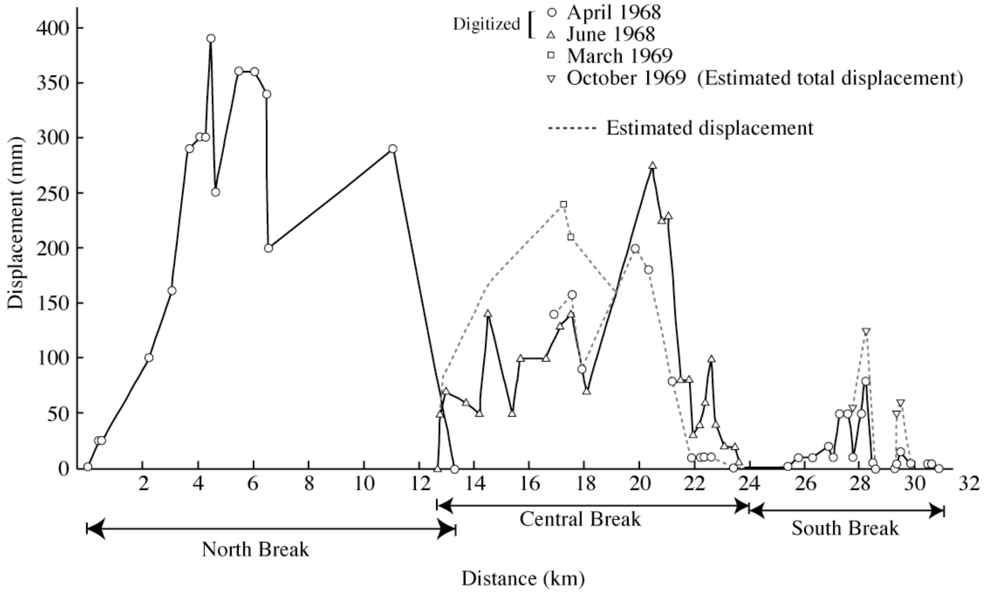
37 Earthquakes

Apr 09 1968 Borrego Mountain, California

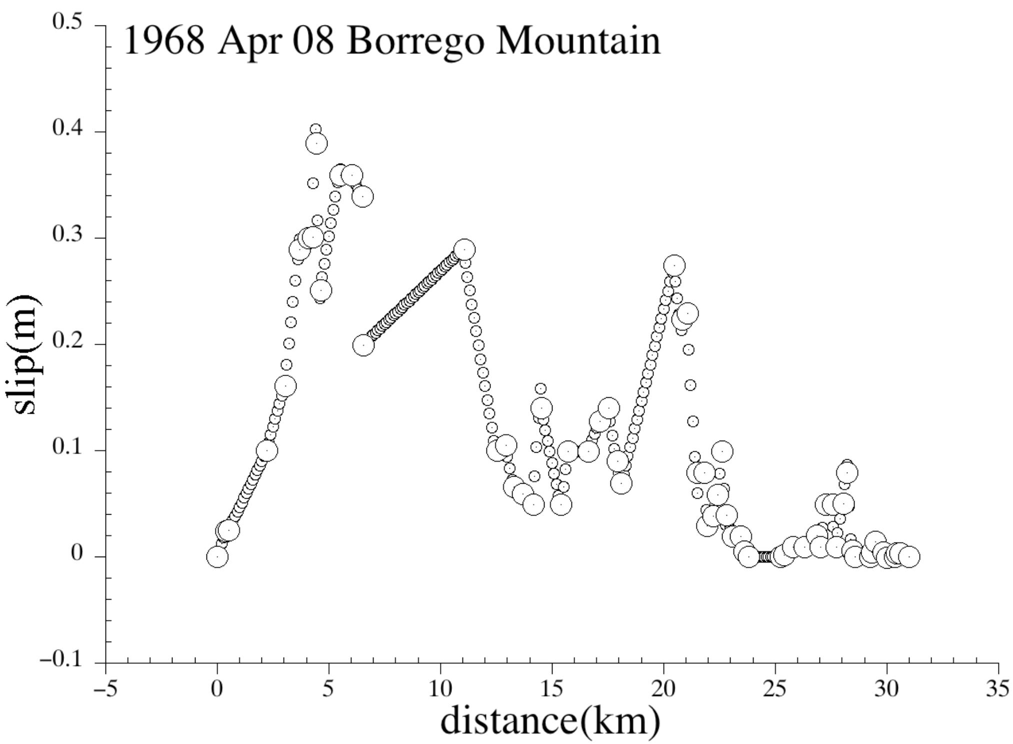




Measured and Published



Digitized and Interpolated



Interpolated **Digitized**

distance(km) interpolated	slip(m) interpolated	distance(km) digitized	slip(m) digitized
0.10000	0.0062074	0.0000	0.0000
0.20000	0.012415	0.39557	0.024554
0.30000	0.018622	0.50633	0.025347
0.40000	0.025270	2.2310	0.10020
0.50000	0.025985	3.0538	0.16119
0.60000	0.029687	3.7025	0.28951
0.70000	0.034027	4.0981	0.30020
0.80000	0.038367	4.2880	0.30059
0.90000	0.042707	4.4620	0.38970
1.0000	0.047047	4.6519	0.25109
1.1000	0.051387	5.5063	0.35921
1.2000	0.055727	6.0443	0.35960
1.3000	0.060067	6.5032	0.33941
1.4000	0.064407	6.5506	0.19921
1.5000	0.068747	11.060	0.28951
1.6000	0.073087	12.532	0.099802
1.7000	0.077427	12.927	0.10495
1.8000	0.081767	13.291	0.065743
1.9000	0.086107	13.703	0.059010
2.0000	0.090447	14.193	0.049109
2.1000	0.094787	14.525	0.13980
2.2000	0.099127	15.411	0.049109
2.3000	0.10761	15.712	0.099010
2.4000	0.11502	16.630	0.099010
2.5000	0.12244	17.136	0.12792
2.6000	0.12985	17.532	0.13980
2.7000	0.13726	17.927	0.089901
2.8000	0.14467	18.117	0.068911
2.9000	0.15209	20.490	0.27406
3.0000	0.15950	20.823	0.22376
3.1000	0.18097	21.076	0.22891
3.2000	0.20075	21.519	0.079604
3.3000	0.22053	21.820	0.079604
3.4000	0.24031	21.962	0.029703
3.5000	0.26009	22.215	0.038416
3.6000	0.27987	22.421	0.058614
3.7000	0.29965	22.627	0.099010
3.8000	0.29221	22.801	0.039208
3.9000	0.29491	23.101	0.019010
4.0000	0.29761	23.465	0.019010
4.1000	0.30041	23.623	0.0051485
4.2000	0.30062	23.829	0.00039604
4.3000	0.35179	25.237	0.0000
4.4000	0.40299	25.396	0.0015842
4.5000	0.31670	25.791	0.0095050
4.6000	0.24370	26.298	0.0095050
4.7000	0.26374	26.851	0.020198
4.8000	0.27640	27.041	0.0095050
4.9000	0.28905	27.263	0.049109
5.0000	0.30171	27.563	0.049109
5.1000	0.31436	27.753	0.0095050
5.2000	0.32701	28.054	0.049901
5.3000	0.33967	28.212	0.078812
5.4000	0.35232	28.449	0.0055446
5.5000	0.36497	28.576	0.0000
5.6000	0.35928	29.272	0.0000
5.7000	0.35936	29.335	0.0039604
5.8000	0.35943	29.478	0.014653
5.9000	0.35950	29.858	0.0043564
6.0000	0.35958	30.016	-0.00039604
6.1000	0.35520	30.348	0.0000
6.2000	0.35080	30.427	0.0035644
6.3000	0.34640	30.601	0.0035644
6.4000	0.34200	31.000	0.0000
6.5000	0.33759		
6.6000	0.20121		
6.7000	0.20321		
6.8000	0.20522		
6.9000	0.20722		
7.0000	0.20922		
7.1000	0.21122		
7.2000	0.21323		

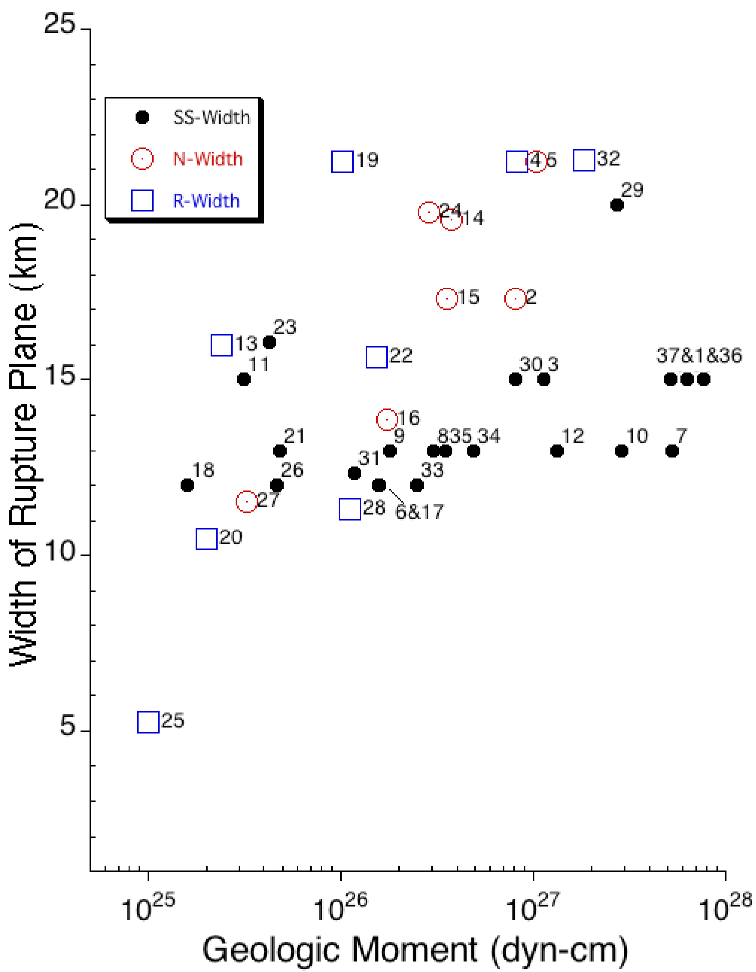
Table 1: Geological Observations

#	Date	Location	Type	Length (km)	Average Slip (m)	Max Slip (m)	Depth (km)	rigidity 10^{11} dyn/cm^2	Geologic Moment 10^{26} dyn-cm	Potency 10^{15}	M_w^g	Ref	Notes
29	1998-Mar-14	Fandoqa, IRN	ssn/54	25	1.1 [1.1]	3.1 [3.1]	10	3.3	1.2	.36	6.6	50	ag
30	1999-Sep-21	Chi-Chi, Taiwan	r/70	72	3.5 [4.0]	12.7 [16.4]	20	3.0	18.4	6.1	7.3	23	ad
31	1999-Oct-16	Hector Mine, CA.	ssr	44	1.45-1.6	5.2-5.2	12	3.0	2.9	1.0	6.9	57	an
32	1999-Aug-17	Izmit, TUR	ssr	107 (145)	1.1	5.1	13	3.2	4.9	1.6	7.1	47	ae
33	1999-Nov-12	Duzce, TUR	ssr	40	2.1	5.0	13	3.2	3.5	1.1	7.0	24	af
34	2001-Nov-14	Kunlun, China	ssl	421	3.3	8.7	15	3.0	62.1	18.8	7.8	53	al
35	2002-Nov-03	Denali, AK	ssr	302	3.6	8.9	10	3.2	33.5	10.5	7.6	52	ak

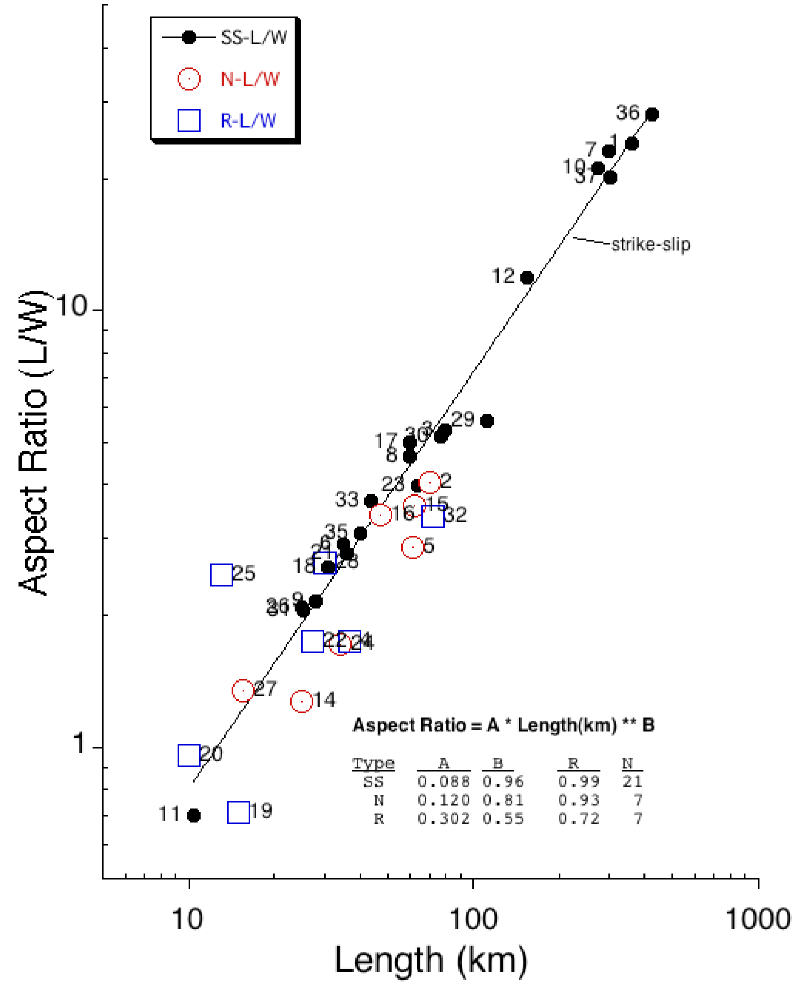
Table 2: Seismological Observations

#	Date	Location	Type	Seismic Moment 10^{26} dyn-cm				Potency (Mo/				Ref	Notes
				body	long-period	geodetic	range	body	long-period	geodetic	range		
29	1998-Mar-14	Fandoqa, IRN	ssn	0.91(3.3)	**0.95 (4.4)**	1.2(3.4)	1.05±0.145	.28	.22	.35	.284±.069	50	bag
30	1999-Sep-20	Chi-Chi, Taiwan	r/70	29(2.1) 41(3.0)	**34(4.4)**	27(3)	34±7	13.8 13.7	7.7	9.0	10.8±3.04	26	bad
31	1999-Oct-16	Hector Mine,CA	ssr	6.2(3*)	**6.0(4.4)**	6.8(3*) 5.9(3*) 7.0(3.1)	6.45±0.55	2.1	1.4	2.3 2.0 2.3	1.8±0.45	58	bal
32	1999-Aug-17	Izmet, TUR	ssr	22(3.3) 15(3.5)	**28.8(4.4)**	24(3.3) 18(3.3) 26(3.4)	21.9±6.9	6.7 4.3	6.6	7.3 5.4 7.7	5.97±1.7	38	bae
33	1999-Nov-12	Duzce, TUR	ssr	5.0(3*)	**6.7**H**(4.4)**	5.4(3.0)	5.4±1.3	167	1.52	1.80	1.66±.14	37	baf
34	2002-Nov-14	Kunlun, China	ssl	46(3) 50(3.0)	**59(4.4)**	71(3 *)	58.5±12.5	15.3 16.7	13.4	23.6	18.5±5.1	55	bai
35	2002-Nov-03	Denali, AK	ssr	68(3.3) 38(3*) 49(3*) 56(3)	**75(2.6)**		56.5±18.5	20.1 12.7 16.3 18.7	28.8		20.7±8.1	54	baj

CHARACTERISTICS OF DATA SET



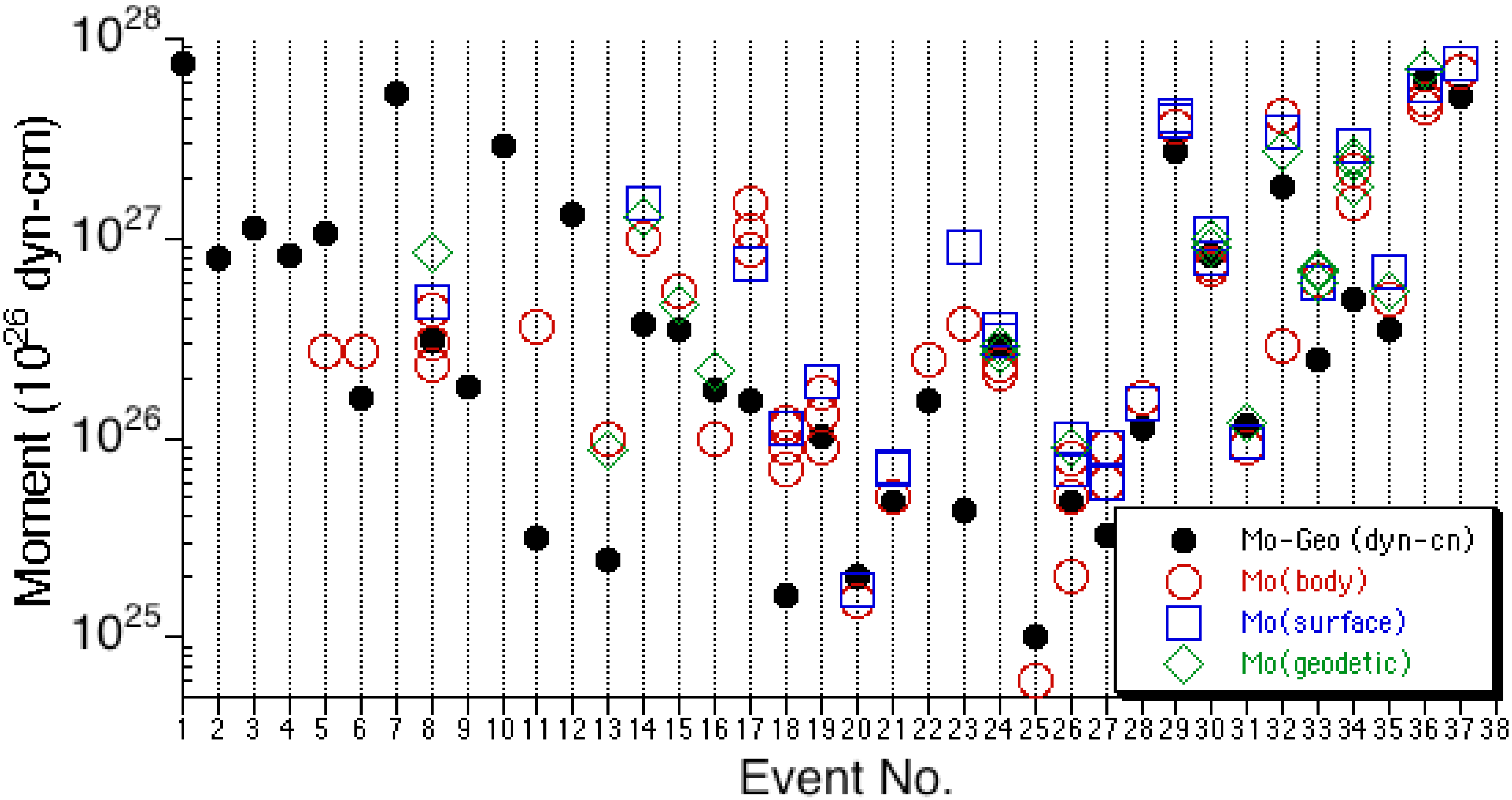
W versus L



Aspect Ratio (L/W) versus L

(Slope of 1 if constant W)

COMPARISON OF MOMENT ESTIMATES FROM DIFFERENT METHODS



Geologic Mo - Black

Body Wave Mo - Red

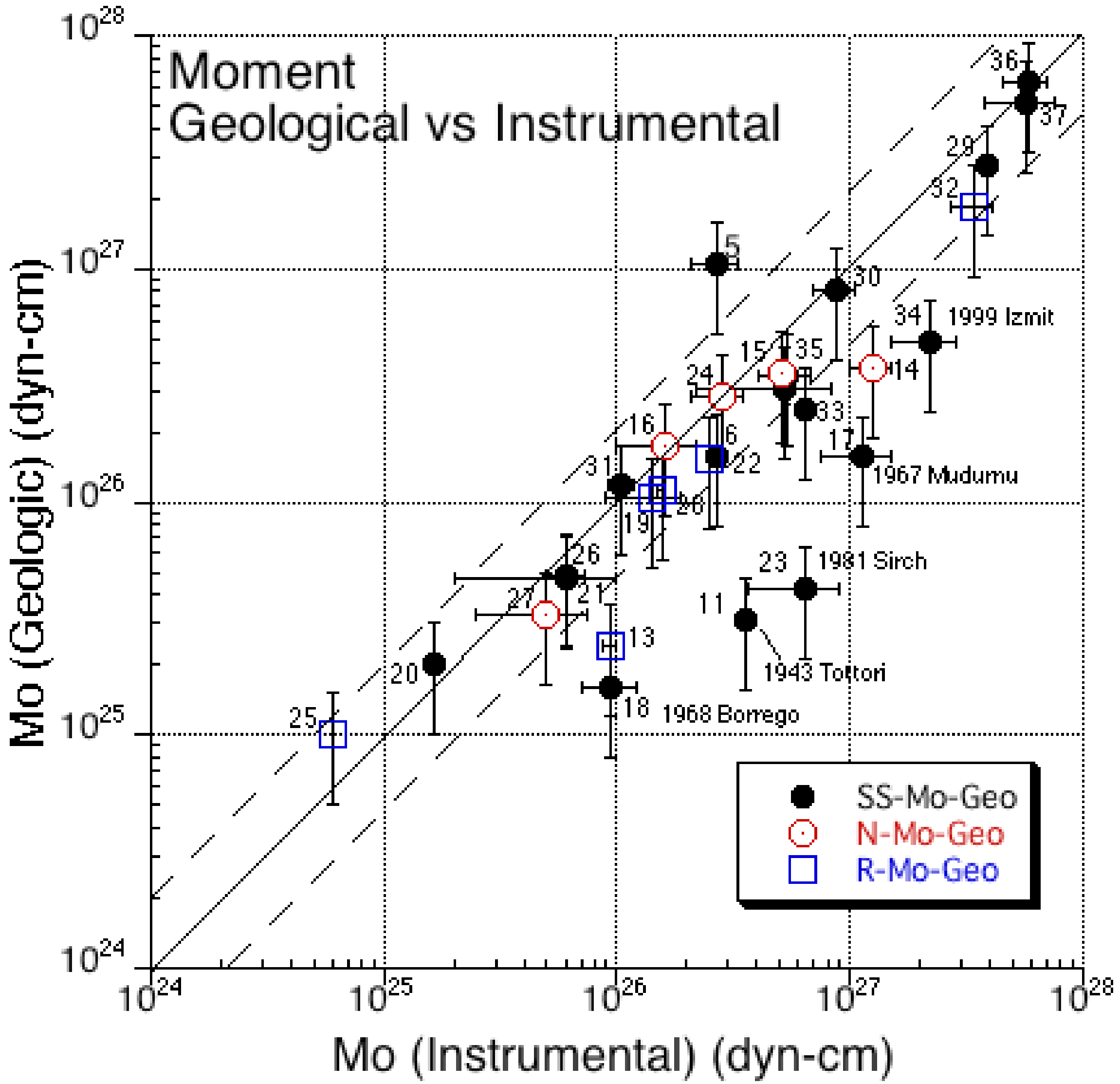
Surface Wave Mo - Blue

Geodetic Mo - Green

Tendencies

Geo Mo similar to Instr for many, but not all…

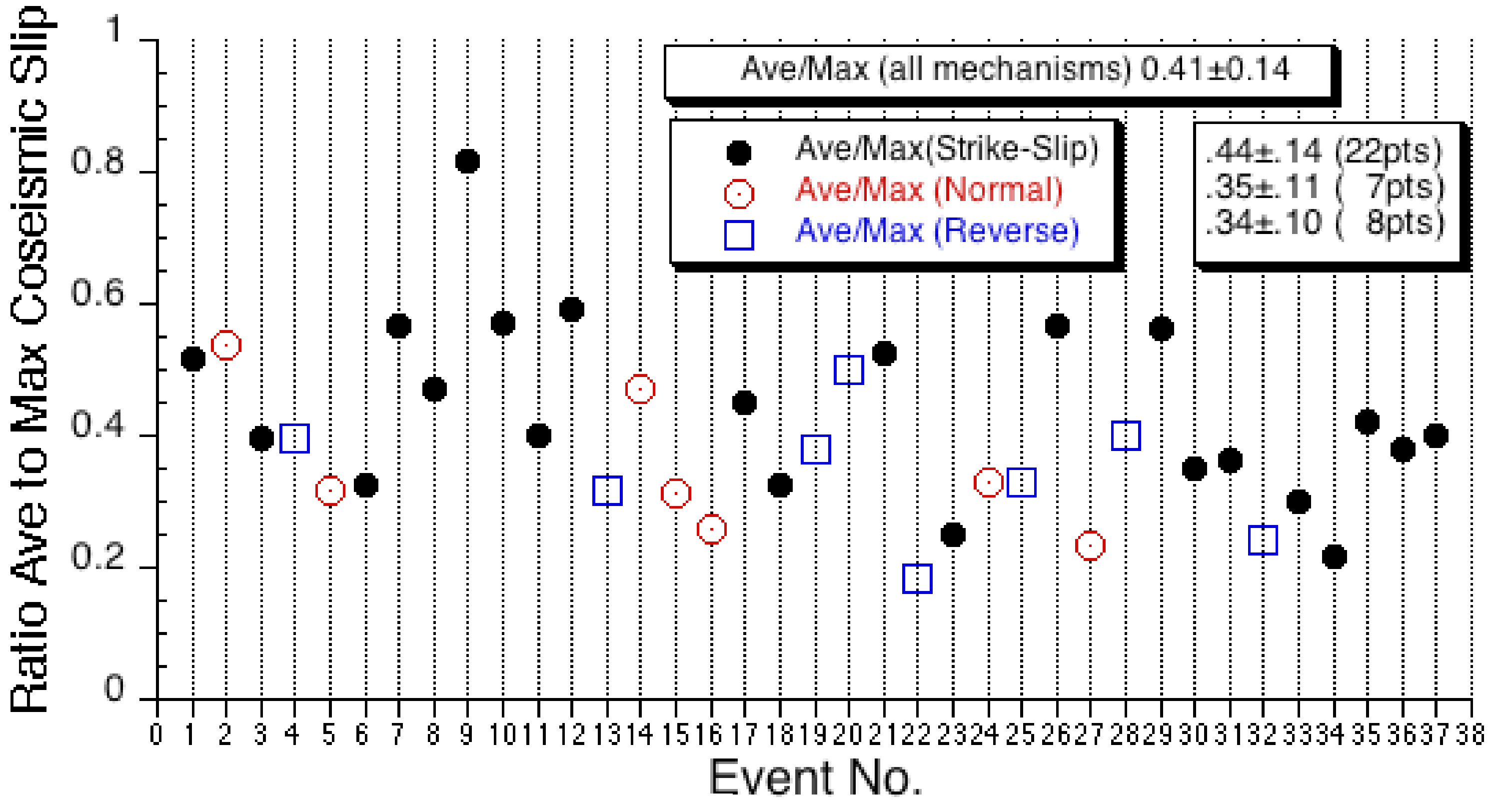
Green(Geodetic) not consistently on top

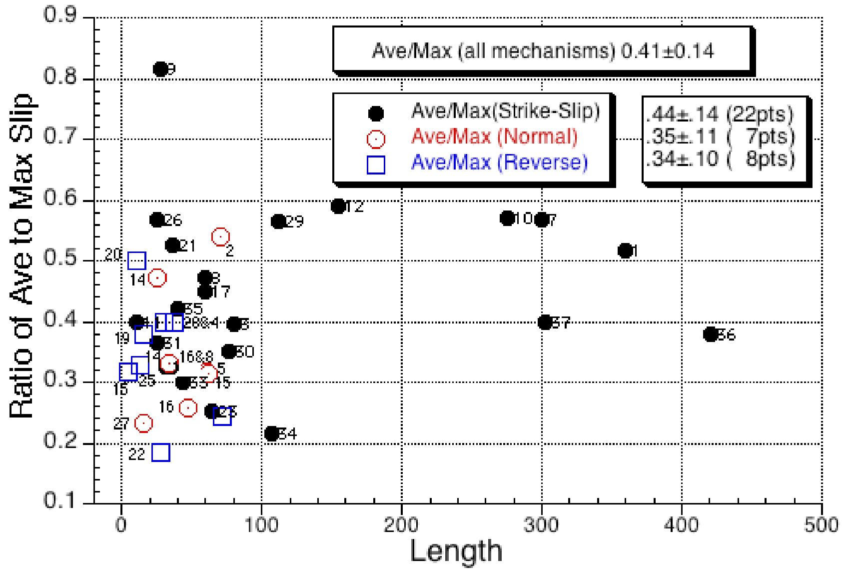


Geologic estimates generally within ~factor of 2 given uncertainties.

Vertical error bar is factor of 3 of value - assumed for refrence

Horizontal error bar is range of estimates of moment determined from various instrumental methods

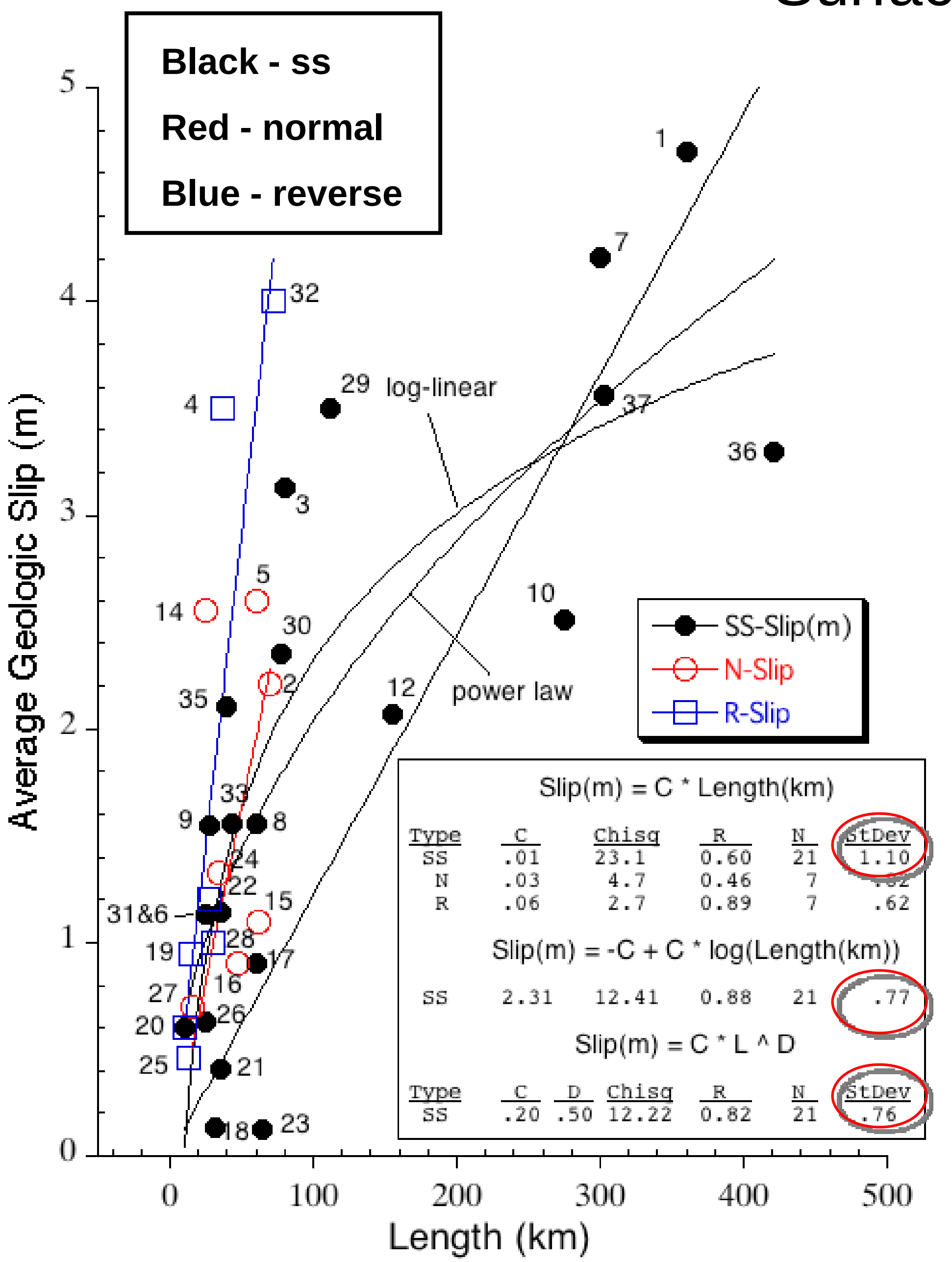




Formalization of Average to Maximum Values of Surface Slip

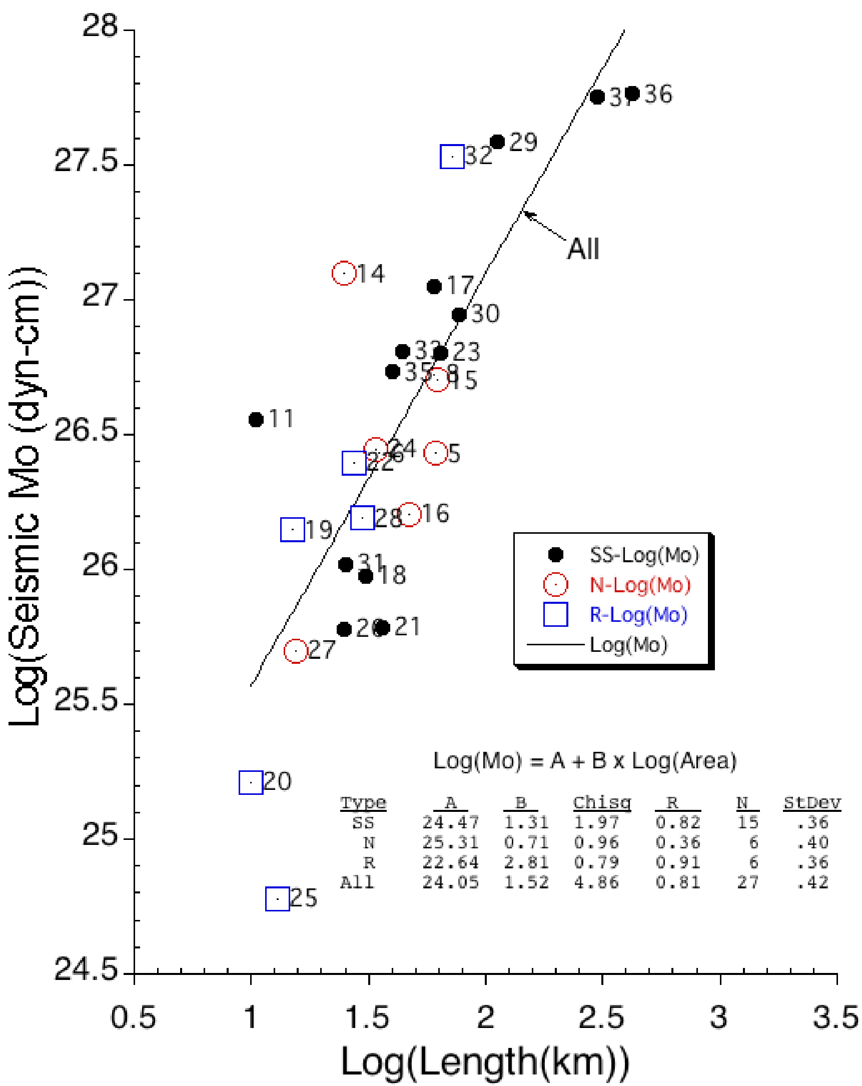
(0.41±.14)

Surface Slip versus Rupture Length



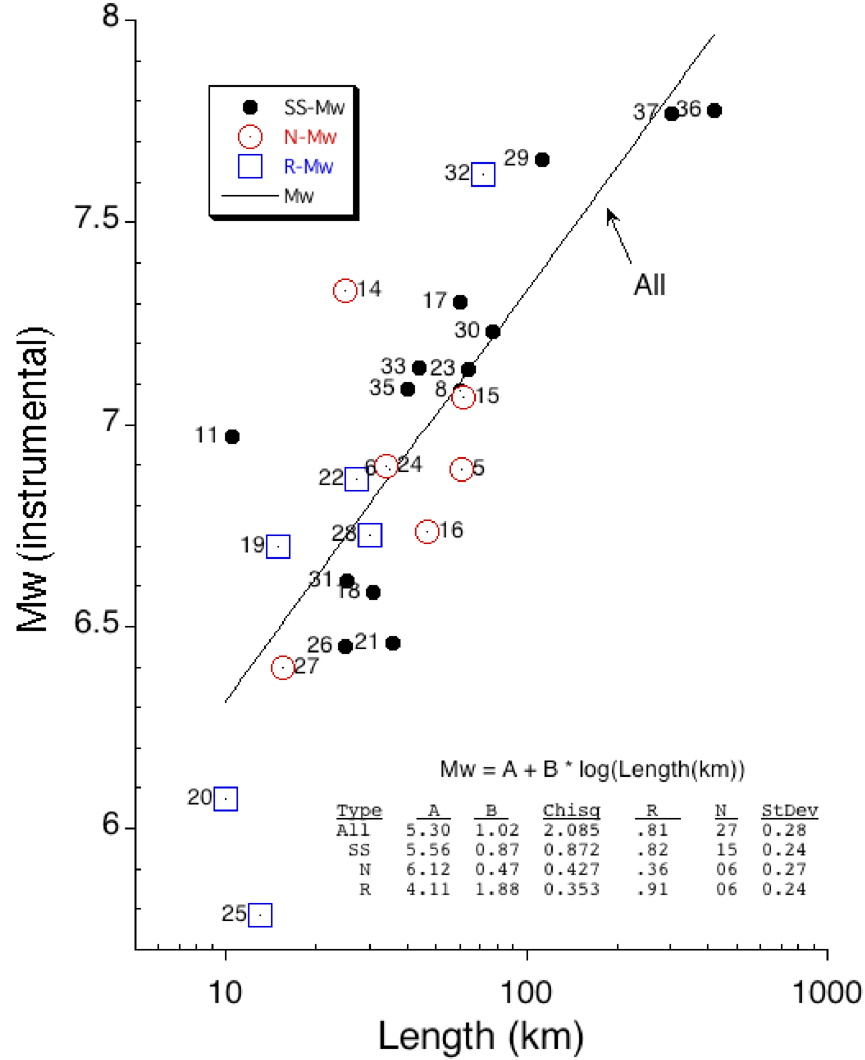
Relationship for reverse and normal may be linear but may NOT so for strike-slip

Mo vs L



Type	A	B	Chisq	R	N	StDev
SS	24.47	1.31	1.97	0.82	15	.36
N	25.31	0.71	0.96	0.36	6	.40
R	22.64	2.81	0.79	0.91	6	.36
All	24.05	1.52	4.86	0.81	27	.42

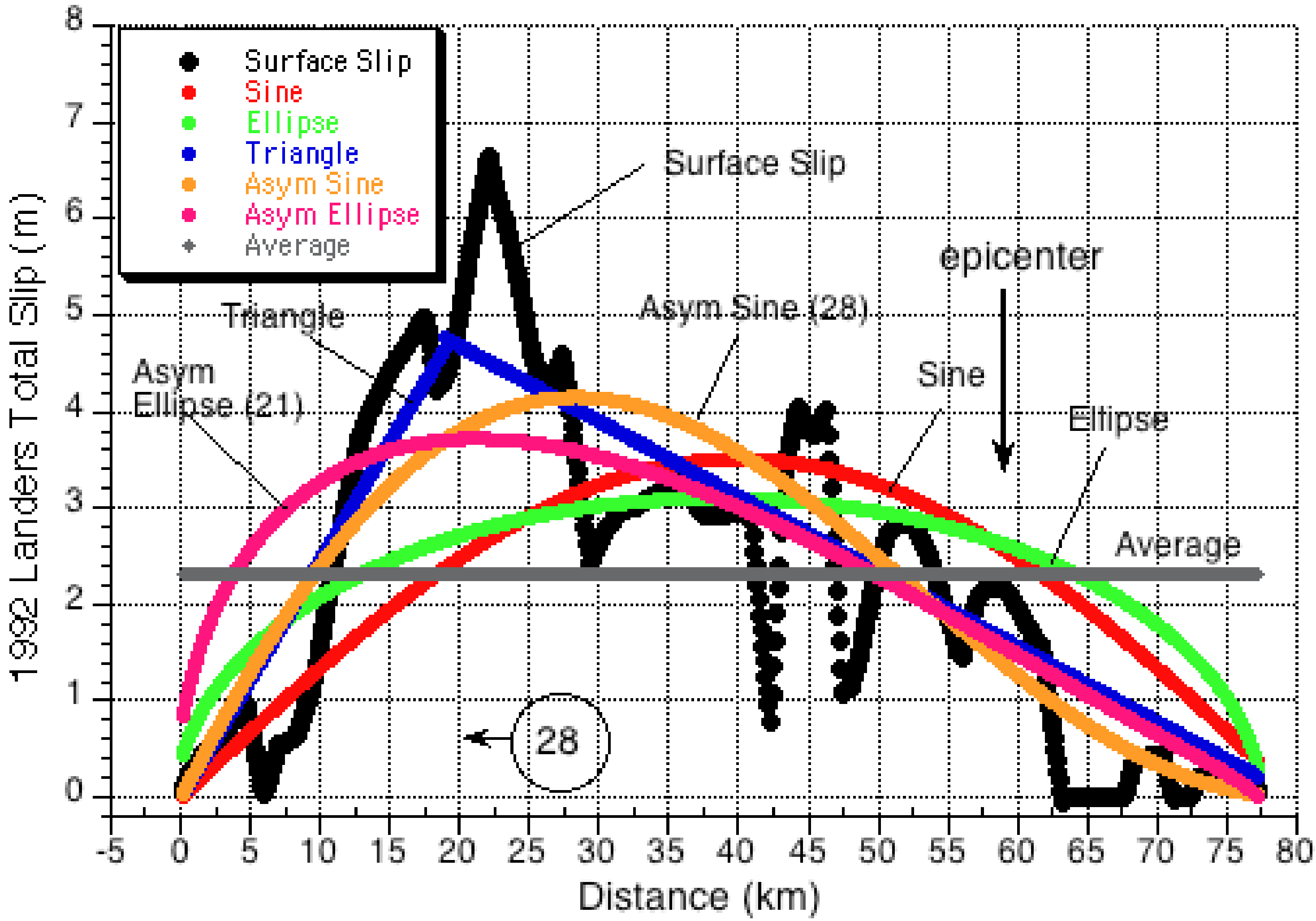
Mw vs L



Type	A	B	Chisq	R	N	StDev
All	5.30	1.02	2.085	.81	27	0.28
SS	5.56	0.87	0.872	.82	15	0.24
N	6.12	0.47	0.427	.36	06	0.27
R	4.11	1.88	0.353	.91	06	0.24

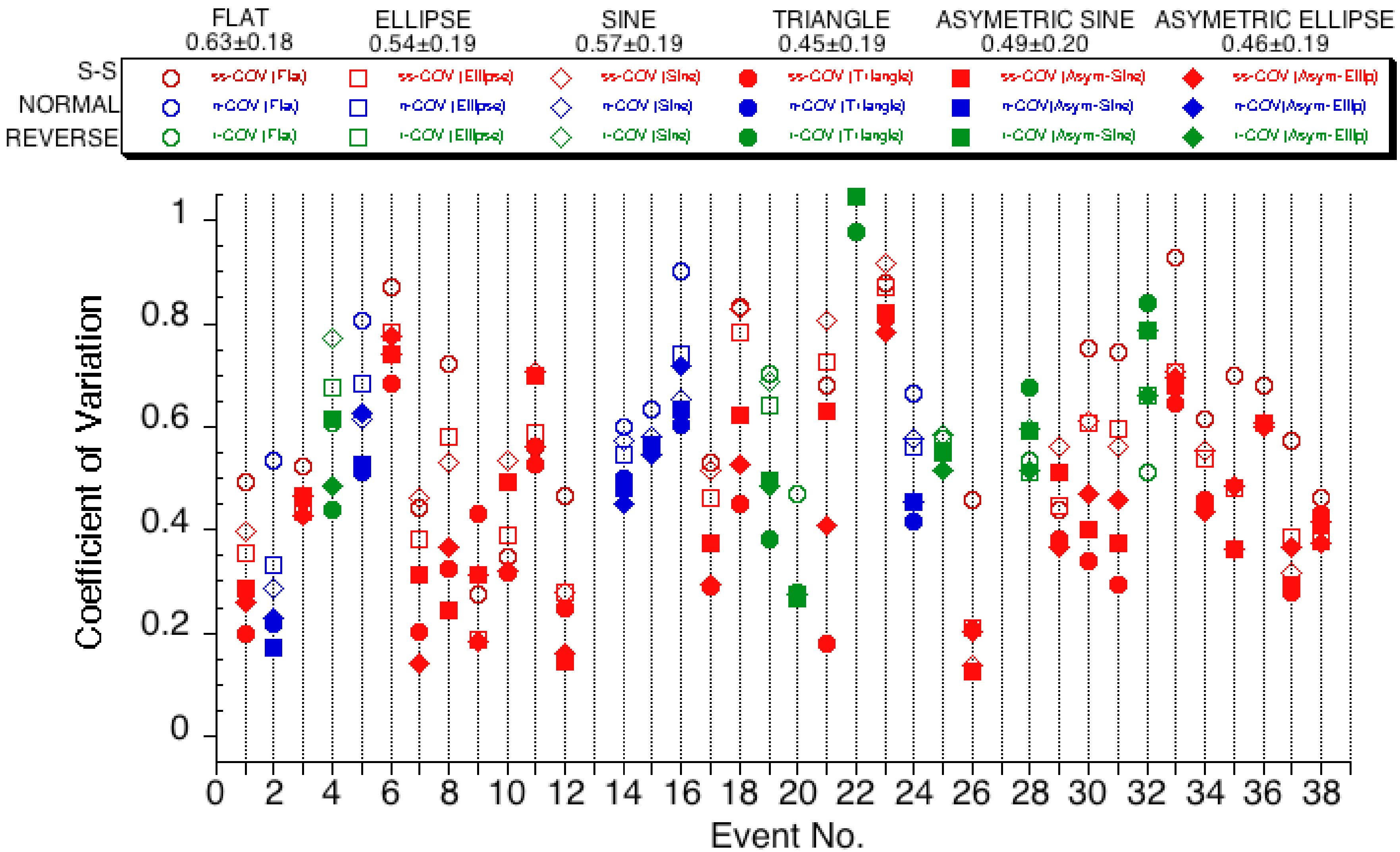
Regressions of size to length limited to surface rupture quakes

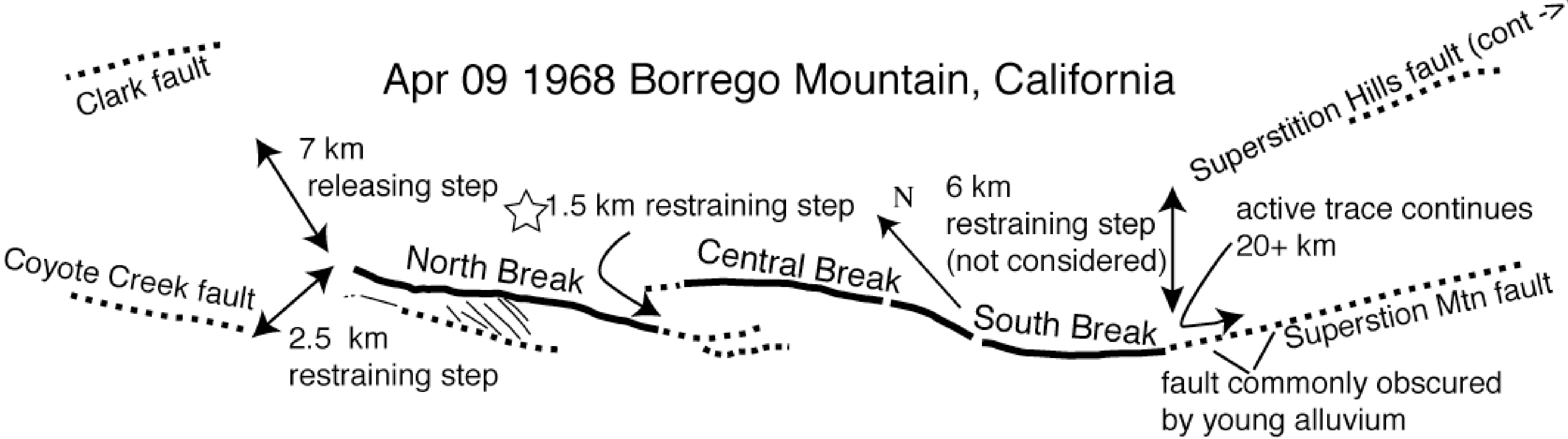
Towards quantifying the shape of Slip distributions and estimating the amount of slip expected at a site on a fault of given length



Coefficient of Variation

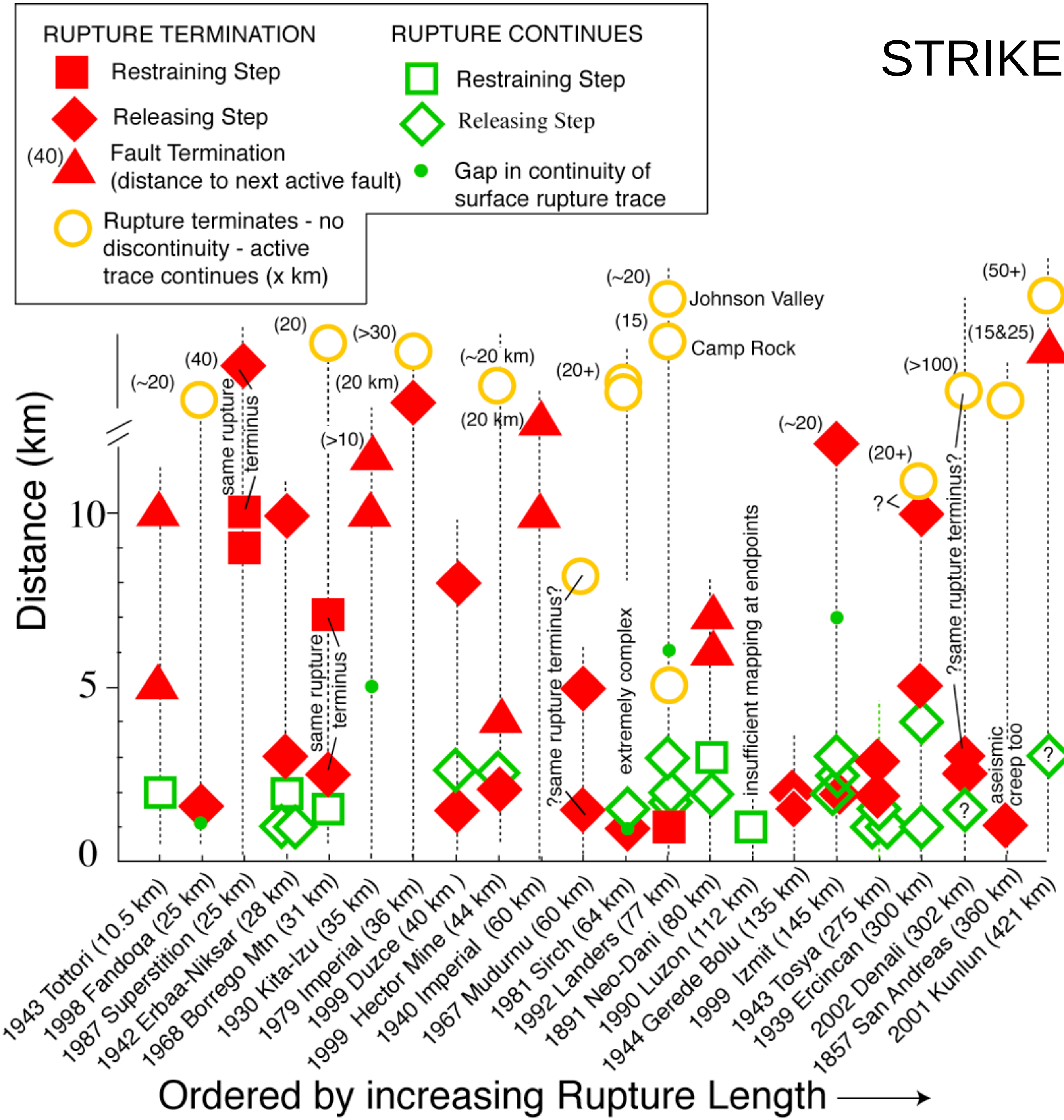
Standard deviation of particular curve-fit to observed slip and then divided by average value of slip



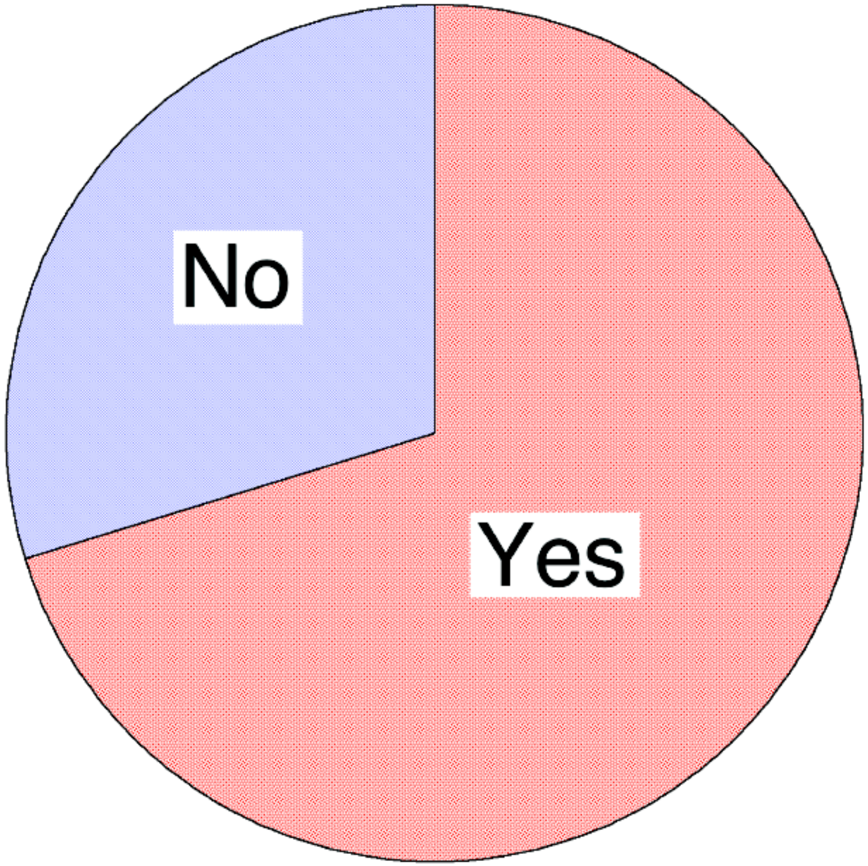


Turn attention back to fault geometry

STRIKE-SLIP

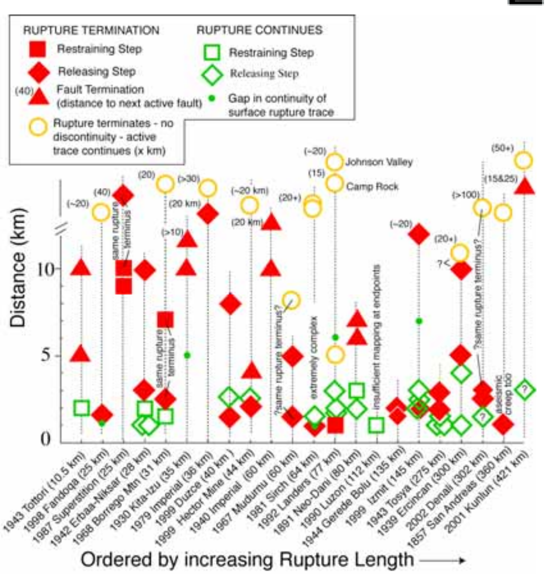

RUPTURE TERMINATION
Restraining Step
Releasing Step
(40) Fault Termination (distance to next active fault)
Rupture terminates - no discontinuity - active trace continues (x km)
RUPTURE CONTINUES
Restraining Step
Releasing Step
Gap in continuity of surface rupture trace
Distance (km)
0
5
10
Johnson Valley
Camp Rock
same rupture terminus
?same rupture terminus?
extremely complex
insufficient mapping at endpoints
?same rupture terminus?
aseismic creep too
1943 Tottori (10.5 km)
1998 Fandoqa (25 km)
1987 Superstition (25 km)
1942 Erbaa-Niksar (28 km)
1968 Borrego Mtn (31 km)
1930 Kita-Izu (35 km)
1979 Imperial (36 km)
1999 Duzce (40 km)
1999 Hector Mine (44 km)
1940 Imperial (60 km)
1967 Mudurnu (60 km)
1981 Sirch (64 km)
1992 Landers (77 km)
1891 Neo-Dani (80 km)
1990 Luzon (112 km)
1944 Gerede Bolu (135 km)
1999 Izmit (145 km)
1943 Tosya (275 km)
1939 Ercincan (300 km)
2002 Denali (302 km)
1857 San Andreas (360 km)
2001 Kunlun (421 km)
Ordered by increasing Rupture Length

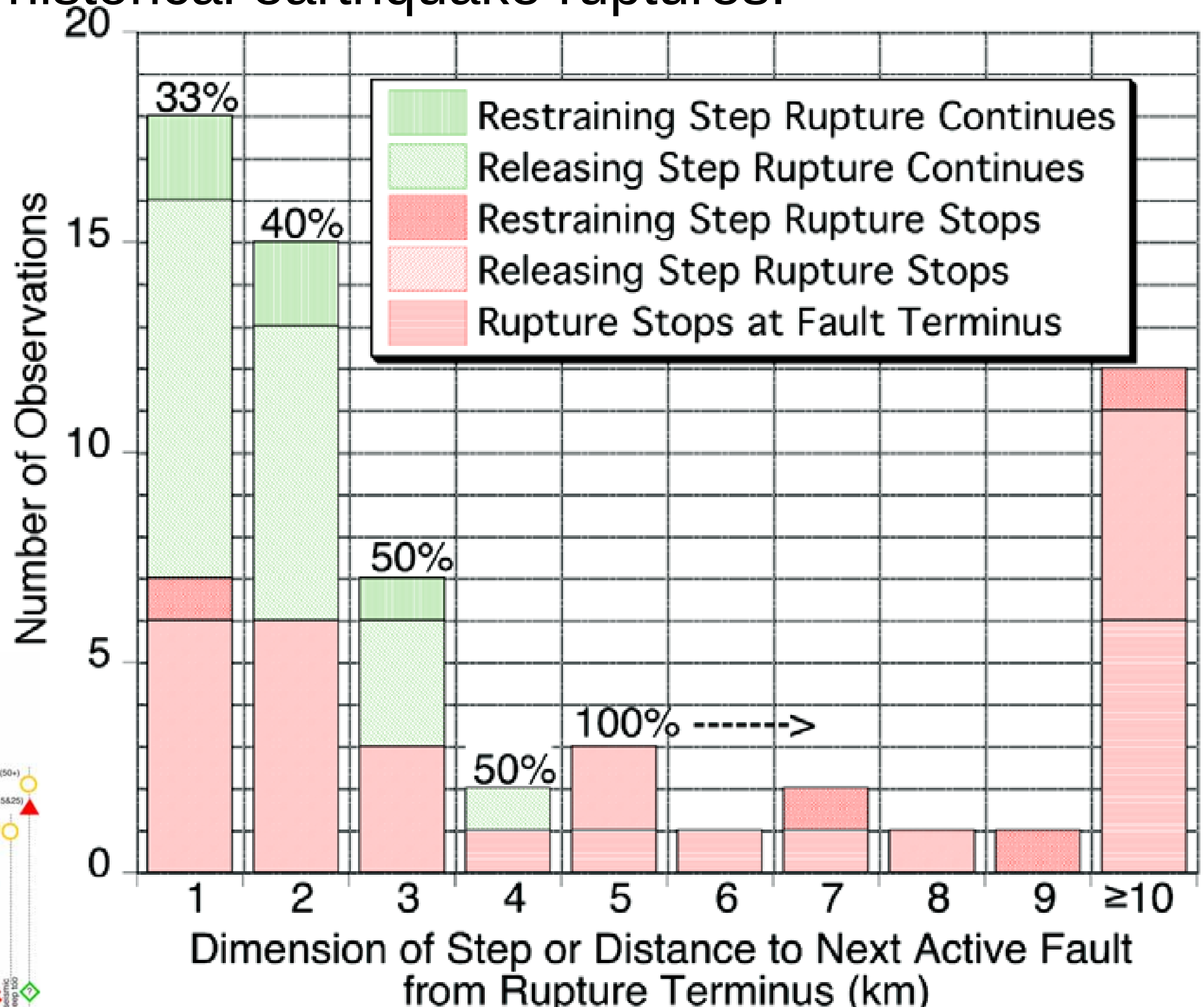
Is termination of STRIKE-SLIP rupture associated with step in fault trace of dimension >=1km or end of active fault trace ?



Pie chart of total number of rupture endpoints divided between whether (red-yes) or not (blue-no) endpoints are associated with a geometrical discontinuity (step or termination of rupture trace). About 2/3 of time rupture endpoints are associated with such discontinuities. The remainder appear to simply die out along an active fault trace. Sample Size is 46.

Summary of behavior of all discontinuities along strike of historical earthquake ruptures.

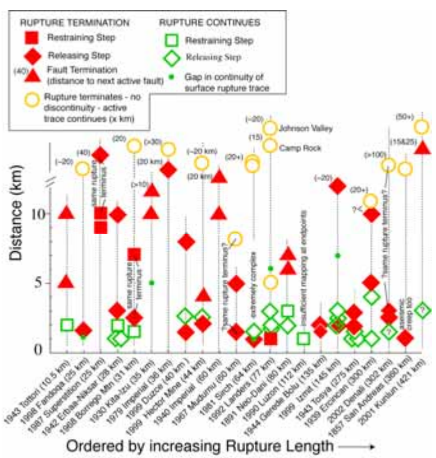




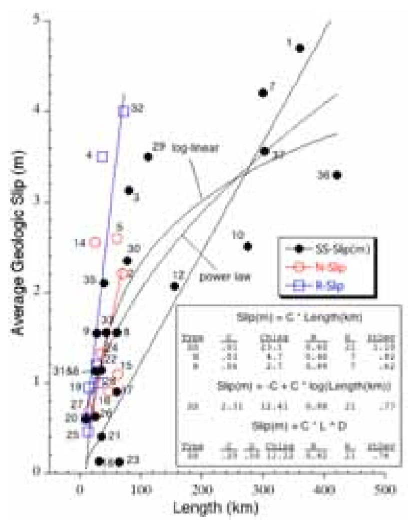
Histogram of the total number of geometrical discontinuities located along historical strike-slip ruptures binned as a function of size (≥1, ≥2, etc) and color-coded/shaded according to whether the particular step occurred at the endpoint of rupture (red) or was broken through by the rupture (green).

So all the basics (at least for strike-slip faults) are here to estimate amount of surface displacement at a site.

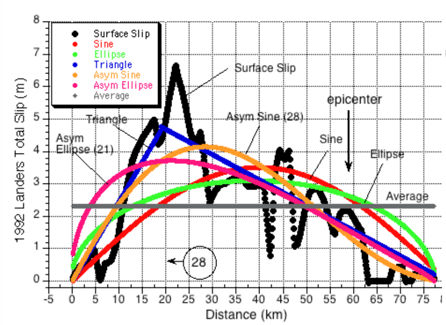
Define expected rupture length



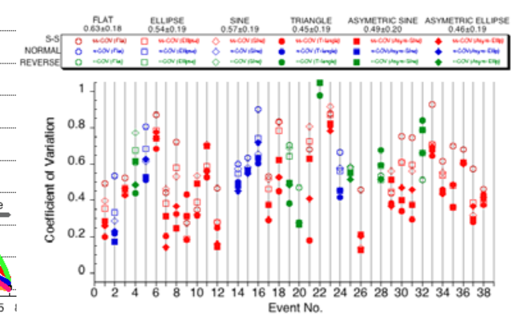
Estimate expected average slip



Choose shape of slip distribution and estimate slip at point along fault



Use coefficient of variation to estimate uncertainty (std) at respective point



Wesnousky, S. G., (2008) Displacement and geometrical characteristics of earthquake surface ruptures: Issues and implications for seismic hazard analysis and the earthquake rupture process, Bulletin of the Seismological Society of America, 98, 4, 1609-1632

Wesnousky, S. G. (2006), Predicting the endpoints of earthquake ruptures, Nature, 444, 358-360, doi:10.1038/nature0525)

Both with data and appendices can be downloaded at

http://neotectonics.seismo.unr.edu