Magnitude limits for faults

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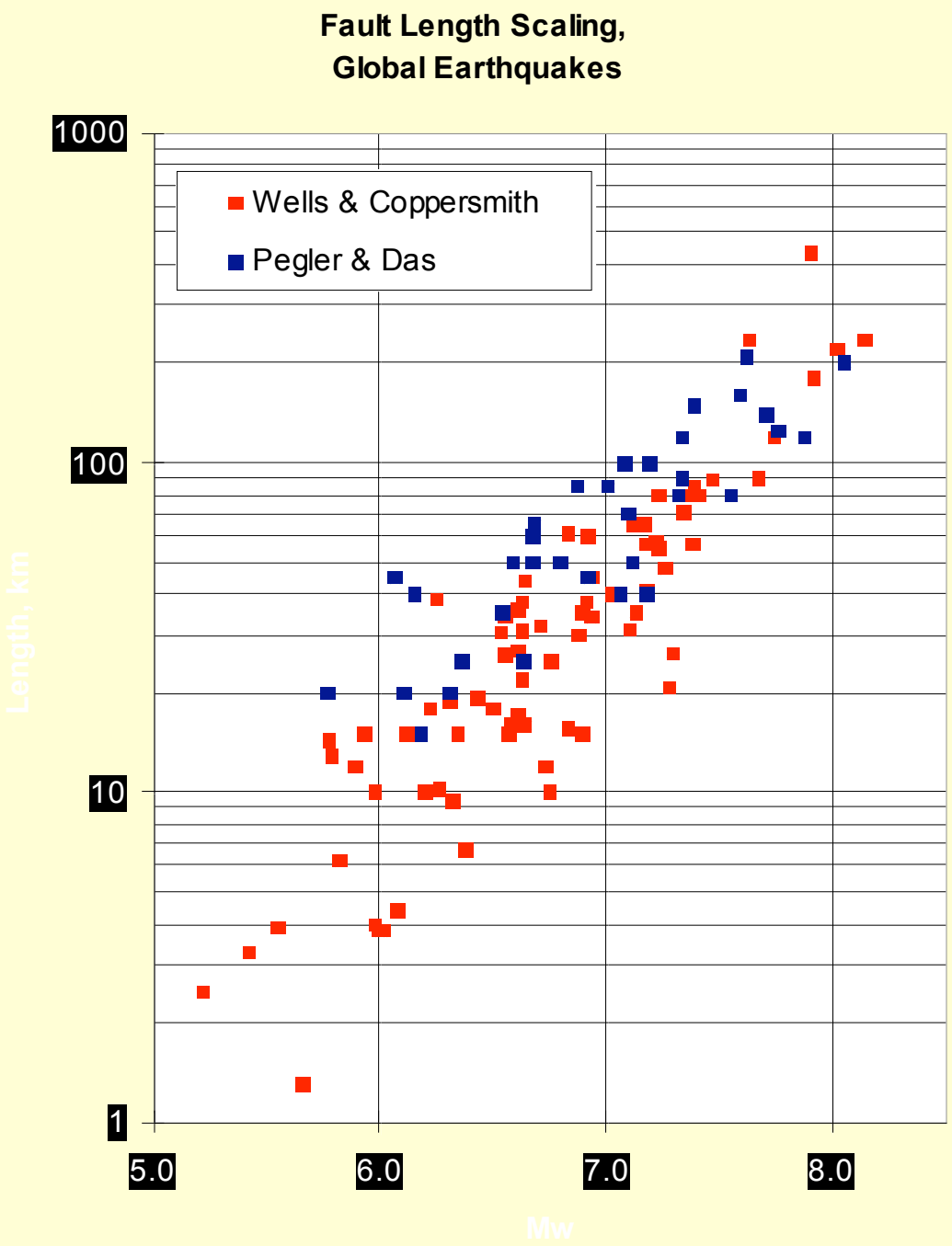
Standard recipe for hazard estimation

- Determine maximum magnitude from fault geometry.
- Estimate relative magnitude distribution (characteristic, Gutenberg-Richter, etc.).
- Set earthquake rate to match fault slip rate.
- Adjust for cascades, time dependence, etc.
- Estimate probable shaking for each hypothetical quake.

Raw data from Wells and Coppersmith, 1994

EQN	Earthquake	Date	Mw	Surf. Len.	Subs. Len.	Width	Area
240	Landers	1992/06/28	7.34	71	62	12	744
227	Loma Prieta	1989/10/18	6.92		40	16	640
241	Big Bear	1992/06/28	6.68		20	10	200
86	San Fernando	1971/02/09	6.64	16	17	14	238
71	Borrego Mountain	1968/04/09	6.63	31	40	10	400
216	Superstition Hills	1987/11/24	6.61	27	30	11	330
144	El Centro	1979/10/15	6.53	30.5	51	12	612
170	Coalinga	1983/05/02	6.38		27	15	405
203	Chalfant Valley	1986/07/21	6.31	-16	20	11	220
178	Morgan Hill	1984/04/24	6.28		26	8	208
239	Joshua Tree	1992/04/23	6.27		15	13	195
63	Parkfield	1966/06/28	6.25	38.5	35	10	350
215	Elmore Ranch	1987/11/24	6.20	10	30	12	360
201	North Palm Springs	1986/07/08	6.13	-9	16	9	144
189	Kettleman Hills	1985/08/04	6.09		20	8.3	166

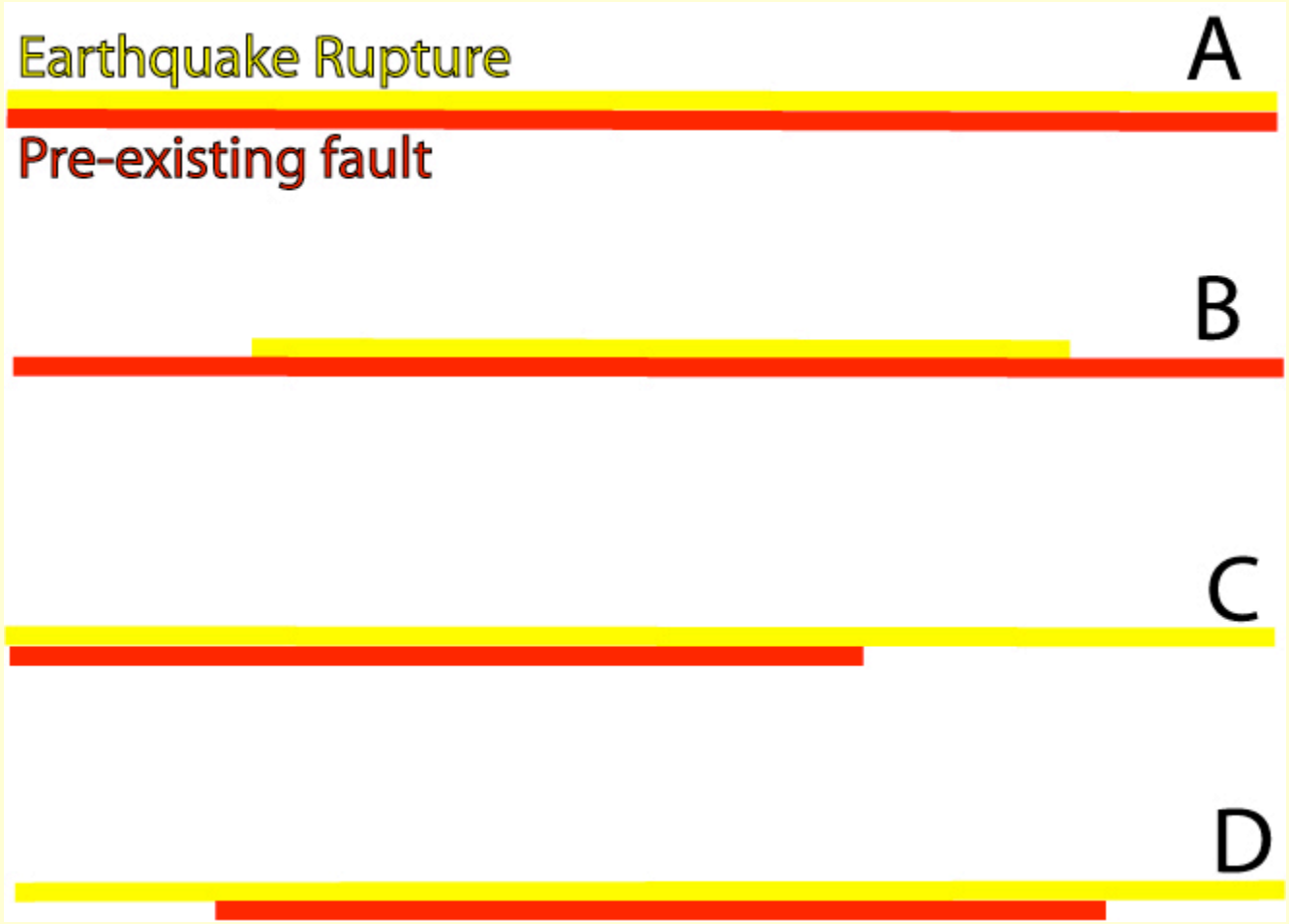

Fault Length Scaling,
Global Earthquakes
Wells & Coppersmith
Pegler & Das
1000
100
10
1
Length, km
5.0
6.0
7.0
8.0
Mw

The Problem

- Regressions of magnitude on fault dimensions (as in Wells and Coppersmith) use rupture length, unknown before quake.
- Future magnitude limits are inferred from prior mapped fault length.
- Equivalence assumes that
  - »rupture length is limited by prior fault length, and
  - »magnitudes for fault-limited earthquakes behave the same as those for ordinary earthquakes (as used by Wells and Coppersmith)
- Few or none of Wells and Coppersmith quakes were limited by fault dimension.

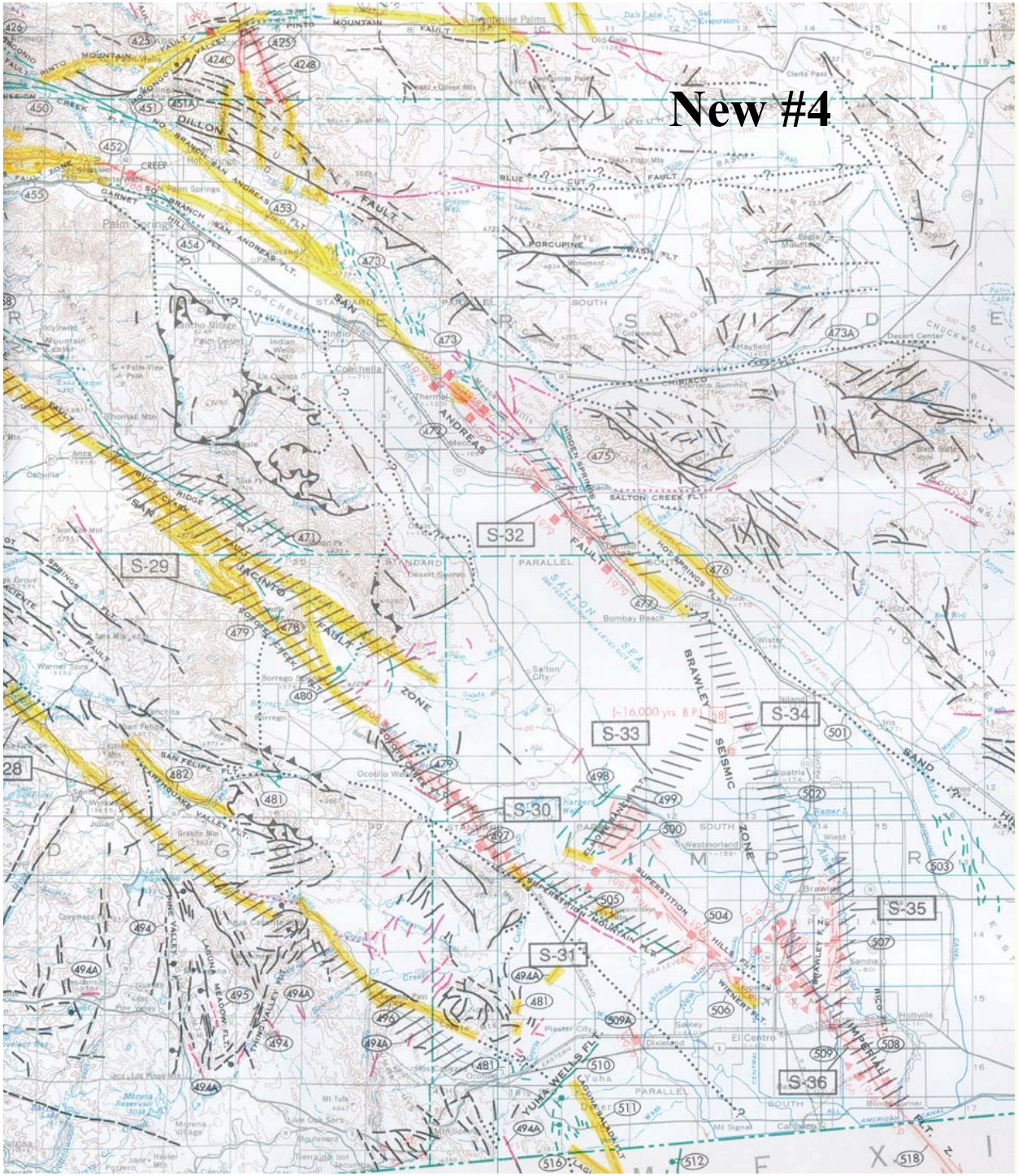
Procedures

- Establish selection criteria
  - California
  - Mw>5.5
  - Prior fault map (implies after 1975)
  - In Wells & Coppersmith, +Hector
- Estimate fault length from prior fault map
- Compare prior fault length with rupture length (from Wells and Coppersmith).
- Correlate Mw with prior fault length

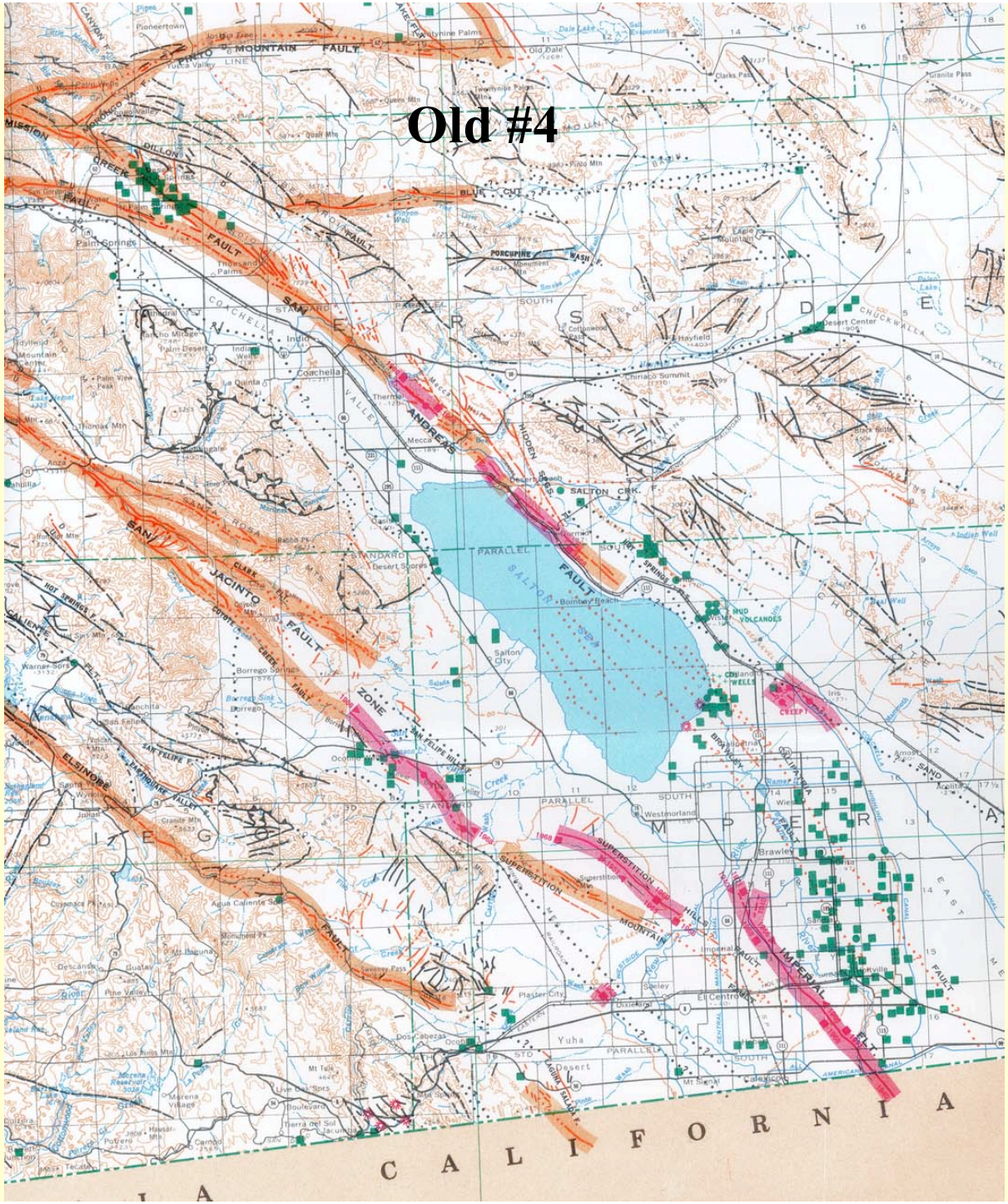

Earthquake Rupture
Pre-existing fault
A
B
C
D

Name	Date	Type	Primary Fault Name	Prior Length, km	Mw	Map	W/C Length, km
San Simeon	1905		Oceanic-W. Huasna	120	6.5	94 Jennings	N/A
Hector Mine*	1999	D	Lavic Lake	5	7.1	94 Jennings	N/A
Landers*	1992	D	Johnson Valley	38	7.3	75 Jennings	71
Superstition Hills	1987	B	Superstition Hills	44	6.6	75 Jennings	27
Elmore Ranch*	1987	D	Elmore Ranch	3	6.2	75 Jennings	10
Chalfant Valley	1986	B	White Mountains	36	6.3	75 Jennings	16
No. Palm Springs	1986	B	San Andreas Southern	533	6.1	75 Jennings	9
Coalinga*	1983	D	Nunez	2	6.4	75 Jennings	3
Greenville	1980	B	Greenville	28	5.8	75 Jennings	6
El Centro	1979	B	Imperial	41	6.5	75 Jennings	31
Coyote Lake	1979	B	Calaveras	123	5.8	75 Jennings	14
Homestead Valley	1979	B	Homestead Valley	27	5.6	75 Jennings	4
San Fernando*	1971	D	Sierra Madre (San Fernando)	14	6.6	69 Los Angeles	16
Borrego Mountain	1968	B	San Jacinto-Borrego	45	6.6	66 Santa Ana	31
Parkfield	1966	B	Parkfield Segment, San Andreas	619	6.3	65 San Luis Obispo	39
Does not include eqrthquakes not on mapped faults							

New #4


S-29
S-30
S-31
S-32
S-33
S-34
S-35
S-36
SAN ANDREAS FAULT
BRAWLEY SEISMIC ZONE
SALTON SEA
SALTON CREEK FLT.
HOT SPRINGS FLT.
SUPERSTITION MOUNTAIN FLT.
SUPERSTITION HILLS FLT.
YUHA WELLS FLT.
SAN JACINTO FAULT ZONE
SAN FELIPE FLT.
EARTHQUAKE VALLEY FLT.
PINTO MOUNTAIN FAULT
DILLON
BLUE CUT FAULT
PORCUPINE WASH FLT.
CHIRIACO SUMMIT
RIDGEN SPRINGS FAULT
Palm Springs
Indio
Coachella
Mecca
Bombay Beach
Westmorland
Brawley
El Centro
Calipatria
Holtville
Niland
Salton City
Borrego Springs
Ocotillo Wells
Julian
Warner Springs
Anza
Cahuilla
Mt Signal
Calexico
Mexicali
Yuma
Desert Center
Clark Pass
Twentynine Palms
Old Dale
Sand Hills
Sand Dunes
Imperial Valley
Coachella Valley
Salton Sea
Chuckwalla Mts
Eagle Mountains
Orocopia Mts
Chocolate Mts
Pinto Mts
Coyote Mts
Superstition Mts
Jacinto Mts
San Jacinto Mts
Santa Rosa Mts
Vallecito Mts
Laguna Mts
Cuyamaca Mts
Peninsular Range
Salton Trough
Imperial Valley
Mexicali Valley
Sand Hills
Sand Dunes
Salton Sea

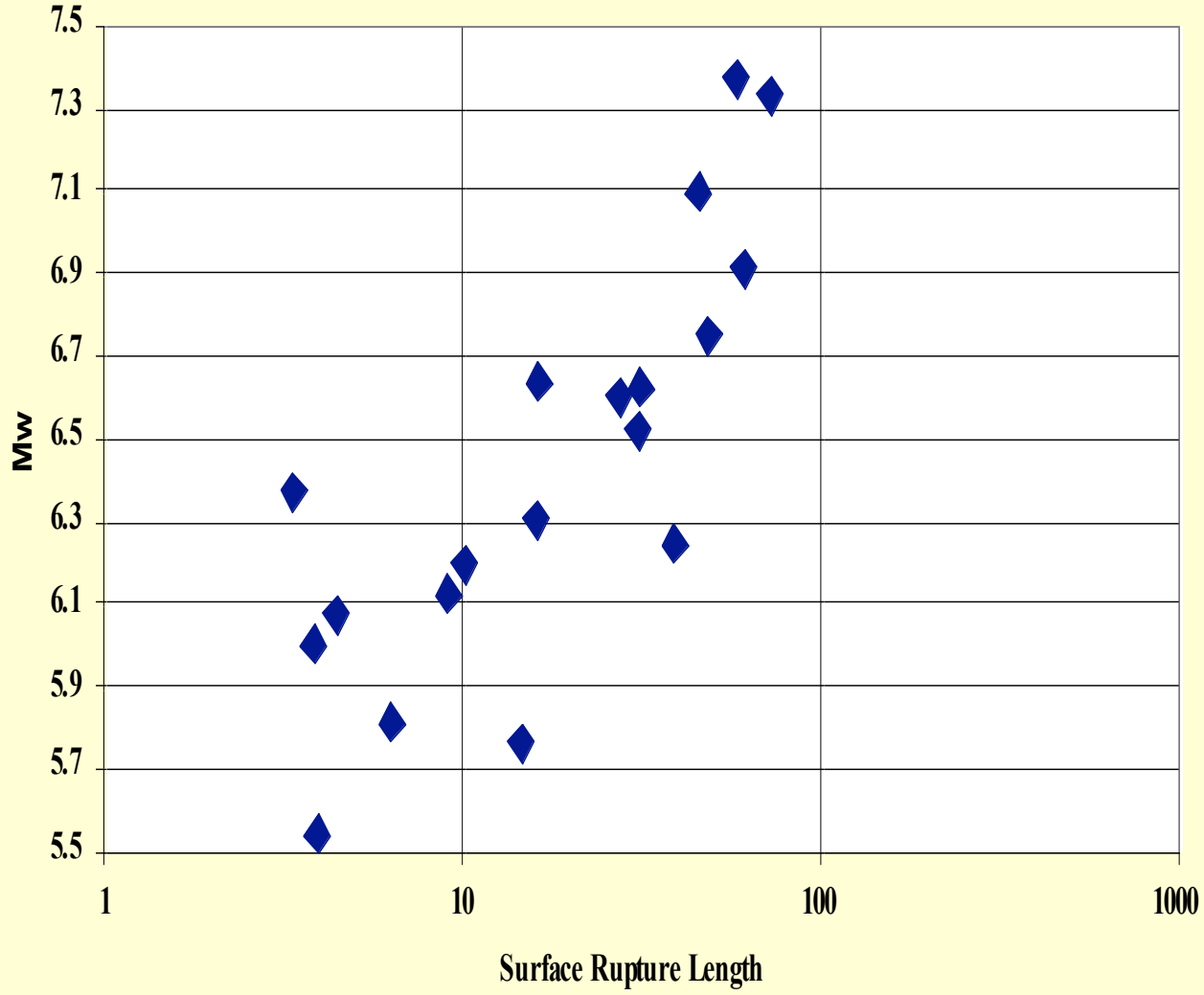
Old #4


MOUNTAIN FAULT
MISSION CREEK FAULT
DILLON
BLUE CUT
PORCUPINE WASH
SAN ANDREAS FAULT
COACHELLA VALLEY
Palm Springs
Thousand Palms
Indio
Coachella
Mecca
Desert Center
Chuckwalla
Hayfield
Chiriaco Summit
HIDDEN ANDREAS
SALTON CRK.
SALTON SEA
Bombay Beach
Salton City
MUD VOLCANOES
Desert Shores
SAN JACINTO FAULT
CLARK FAULT
Borrego Springs
Borrego Sink
SAN FELIPE HILLS
ELSINORE FAULT
EARTHQUAKE VALLEY
Warner Springs
Julian
Agua Caliente Spr
Westmorland
Brawley
SUPERSTITION MOUNTAIN
SUPERSTITION HILLS
IMPERIAL FAULT
El Centro
Imperial
Seeley
Plaster City
Yuha Desert
Mt Signal
Calexico
Mt Talk
Boulevard
Tecate
Potrero
Carmo
Morena Reservoir
Morena Village
Dos Cabezas
Mt Stevens
Live Oak Spgs
Tierra del Sol
La Rumorosa
Pine Valley
Descanso
Guatay
Cuyamaca
Mt Laguna
Monument Pk
Granite Mtn
Los Rios Mtn
Anza
Thomas Mtn
Palm Desert
Indian Wells
La Quinta
Cabazon
Twentynine Palms
Pioneertown
Yucca Valley
Joshua Tree
Old Dale
Clarks Pass
Granite Pass
Eagle Mountain
Chocolate Mtn
Indian Well
Bear Well
Iris
Niland
Calipatria
Westmorland
Brawley
Imperial
Holtville
Calexico
SOUTH PARALLEL
STANDARD
CALIFORNIA
MEXICO
DIEGO
IMPERIAL
EAST

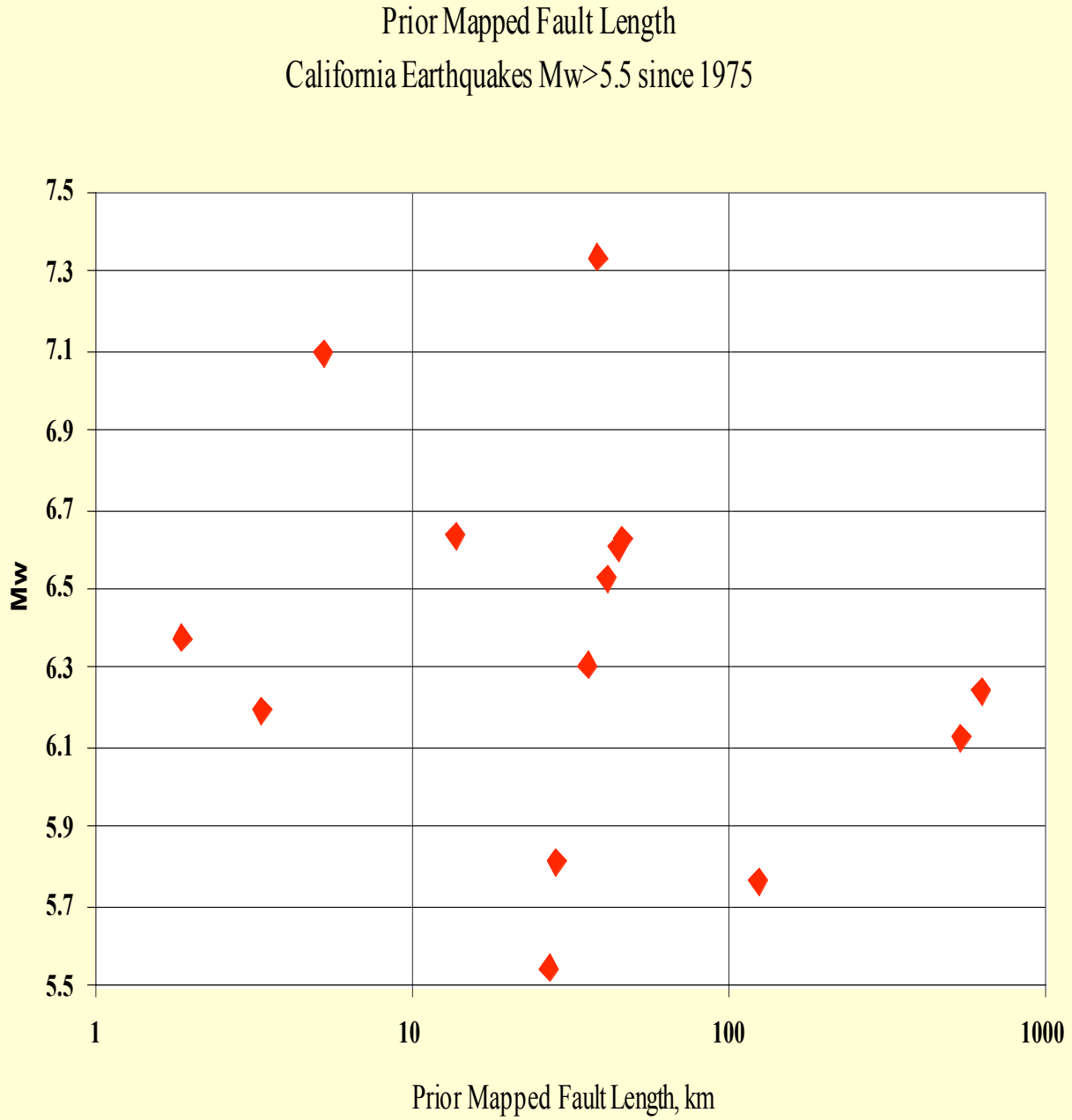
Mw vs. Surface Rupture Length

Wells & Coppersmith Data

California Earthquakes Mw>5.5 since 1975



Mw Vs. Prior Mapped Fault Length

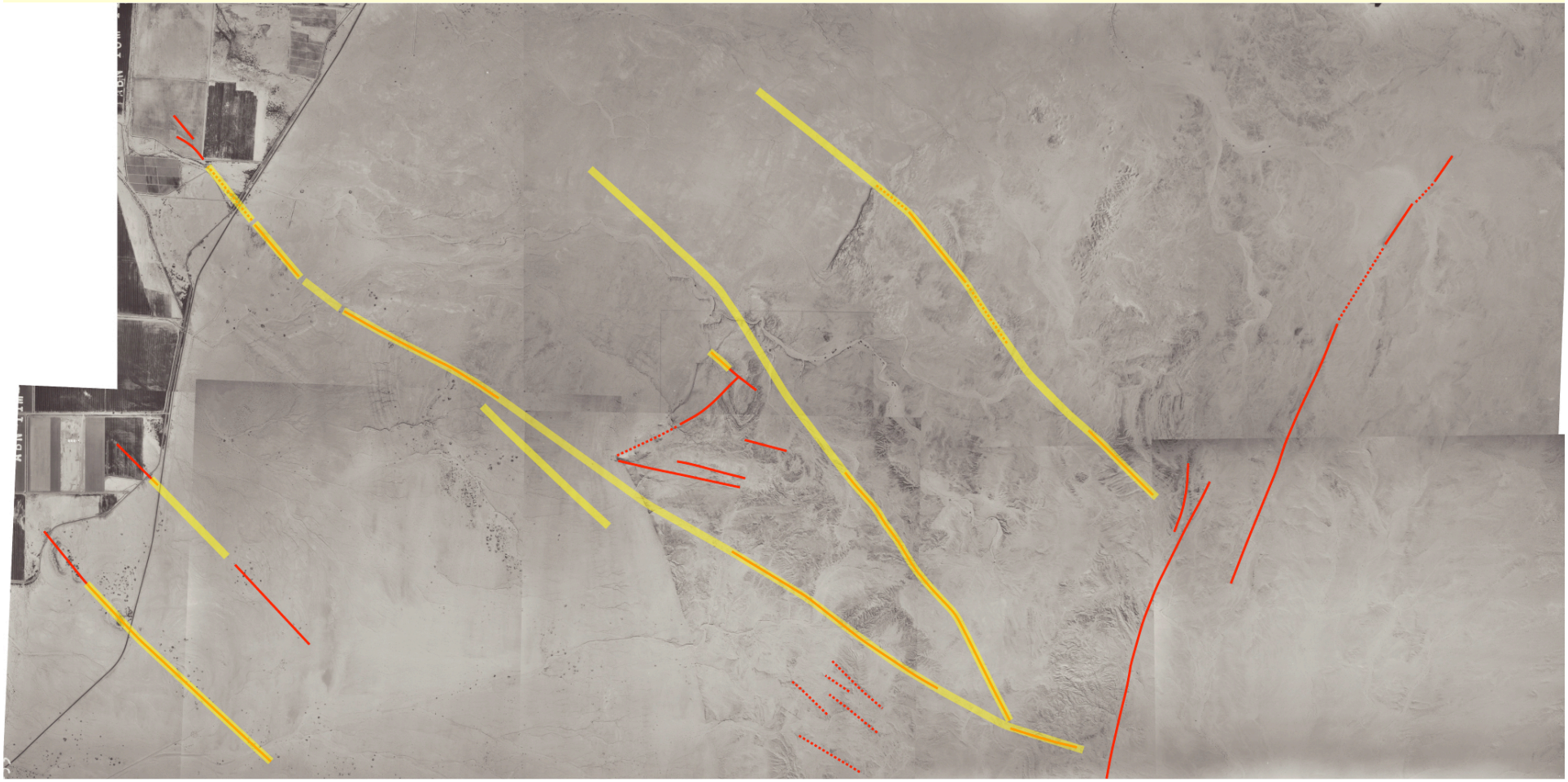


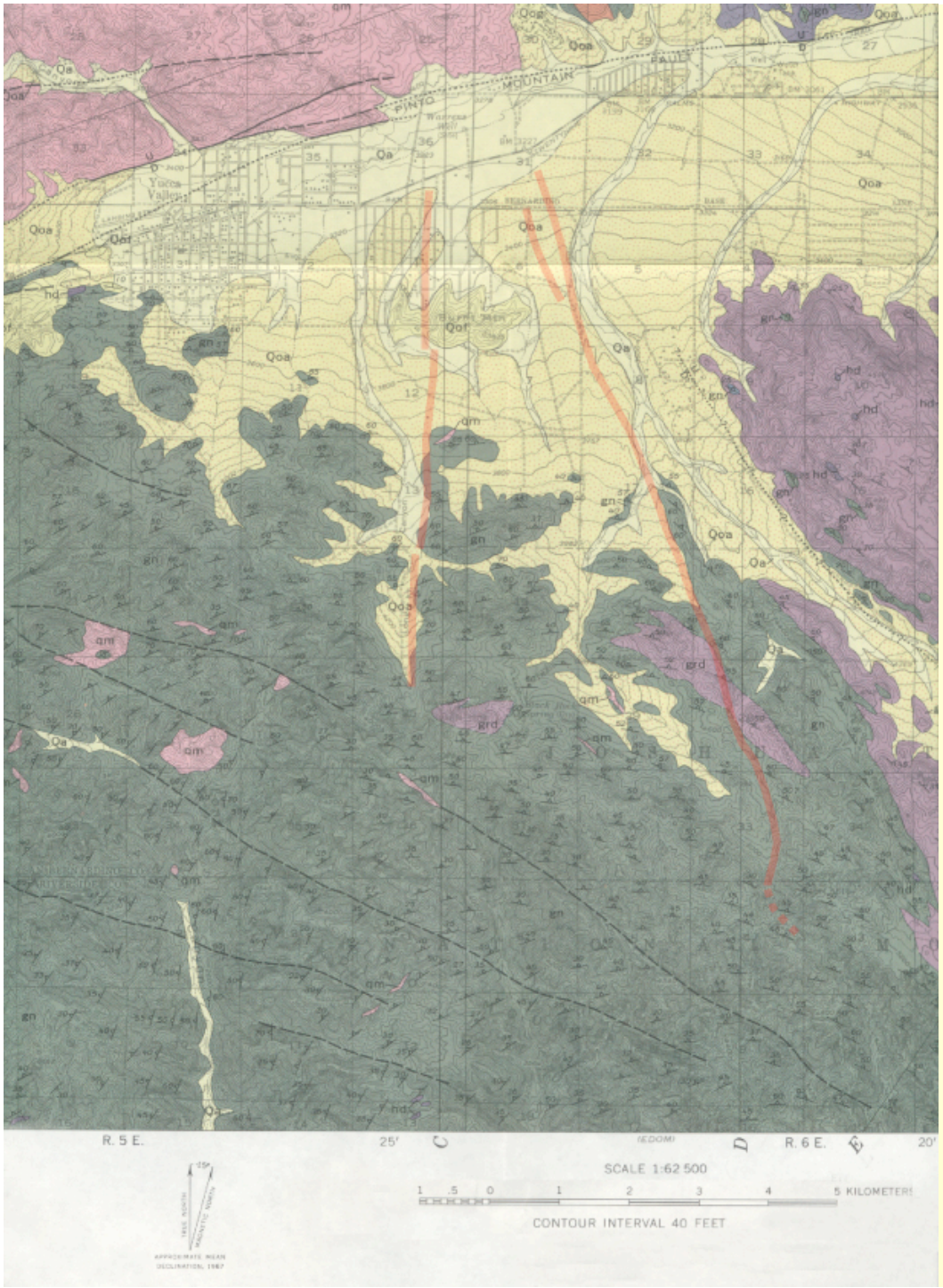
Elmore Ranch Earthquake, 1986

Prior mapped faults in red

Recent rupture in orange

Based on pre-quake air photo





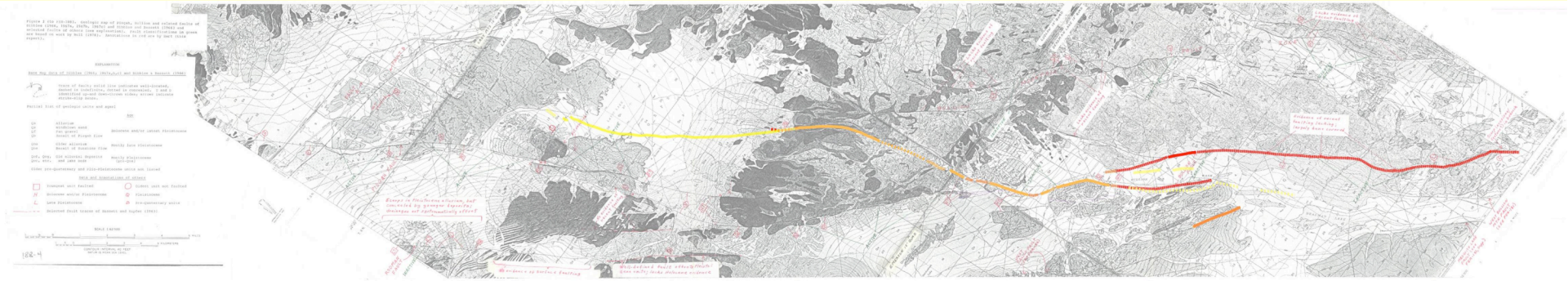
South end Landers Earthquake, 1992.

Hector Mine Earthquake 1999

Pre-mapped faults in red

Recent rupture in orange

From CDMG Fault Evaluation Report

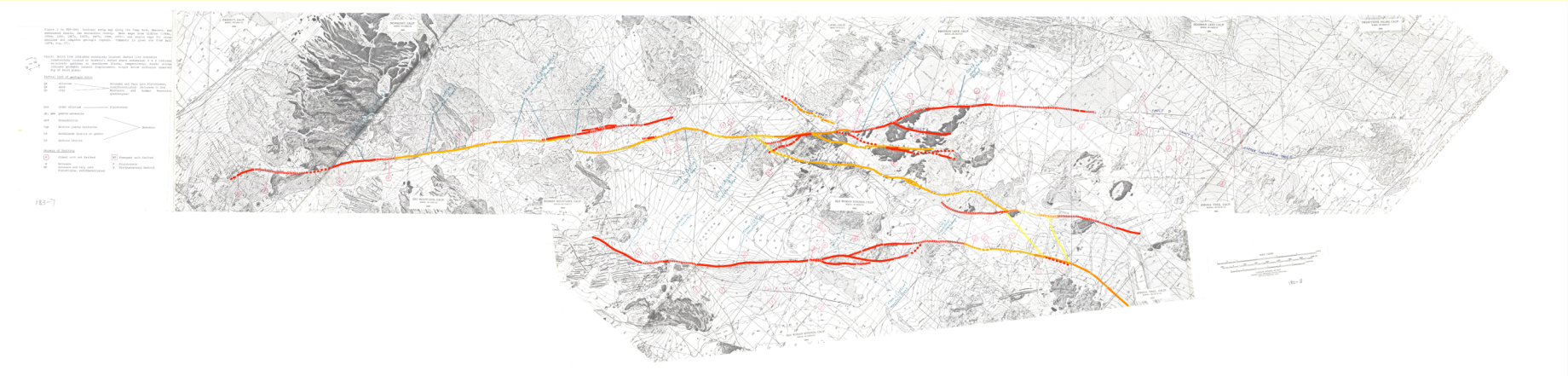


Landers Earthquake, 1992

Pre-mapped faults in red

Recent rupture in orange

From CDMG Fault Evaluation Report



EQ Name	Date	Fault(s)	Prior Fault Length (Mapped)	Rupture Length (Total)	Unmapped Fault Rupture	Rupture Type
Elmore Ranch	1987	Elmore Ranch	3.7 km (Diblee, 1953) 10.52 km w/a 3.13 km gap (Air Photo)	10.92 km (Hudnut et. al., 1989)	7.55 km 3.43 km	D
Superstition Hills	1987	Superstition Hills	22.2 km +21km dashed (Jennings, 1975) 29.84 km (Diblee, 1953)	27 km		B
Landers	1992	S Jonhson Valley	50 km (FER 180, 1986)	18 km (FER 234, 1992; Hart et. al., 1993)		B
		Kickapoo	0.5 km (Sowers et. al, 1994)	5.83 km (Sowers et. al, 1994)	5.33 km	D
		Homestead Valley	32 km (FER 180 &183, 1986)	29 km (FER 234, 1992; Hart et. al., 1993)		B
		Emerson	46 km	32.6 km		B
		Fault A	10 km	6.3 km		B
		Galway	5.3 km (dashed)	5.3 km		A
		Camp Rock	20 km	13.5 km		B
		Burnt Mtn	0 km (FER 181, 1986; Dibblee, 1967)	5 km (FER 230, 1992)	5 km	D
		Eureka Peak	0 km	8.5 km	8.5 km	D
Hector Mine	1999	Lavic Lake	17 km (FER 188, 1987)	32 km (Treiman, 2002)	14 km	C
		W Bullion	58 km	16 km		B
San Fernando	1971	Santa Susan and Sierra Madre Fault Zones	14 km (Los Angeles Co., 1969)	19 (E-W) 6 (N-S) km (Proctor et. al., 1972)	5 km	D
Northridge	1994	Northridge	16.5 km +2.5 km dashed (Barnhart and Slosson, 1973)	15 km (Science, 1994)		B

Conclusions

- California earthquakes commonly (5/15) rupture past mapped fault ends; mapped fault length is not a good predictor of quake size limit. Other earthquakes occur where no fault is even mapped.

- Simulations of earthquakes limited to mapped faults clearly inadequate; whether most quakes stay on existing faults is presently uncertain.

Conclusions

- Fault lengths inferred from low-resolution maps (like the Jennings map for California) will not be a guide to ultimate rupture length.
- Maximum magnitudes based on those lengths, and magnitude-rupture length regressions, will underestimate maximum magnitudes.
- Fault lengths inferred from high resolution maps **may** do better, but allowance must be made for
  - Faults obscured by sediments
  - Ability of rupture to jump 5 km or more
- How often do quakes break virgin rock? Unresolved.