WGUEP MEETING #7

February 16 & 17, 2012

Bear River fault scarp in Utah south of Evanston, Wyoming

WELCOME

ONCE AGAIN

UTAH GEOLOGICAL SURVEY

WGUEP MEETING 7 AGENDA
Thursday, February 16, 2012

8:00 – 8:30	Continental Breakfast	
8:30 – 8:45	Overview of Agenda and Review of Last Meeting's To Do List	Ivan
8:45 – 9:30	Update on Consensus Wasatch Front Earthquake Catalog	Walter/Jim
9:30 – 10:00	Multi-Segment Ruptures on Normal Faults	David
10:00 – 10:15	Break	
10:15 – 11:15	Wasatch Central Segment Final RIs, Time-Dependent/Time Independent Weights, M_{max}	Chris/Nico
11:15 – 11:45	Wasatch End Segments Final Slip Rates and M_{max}	Mike/Chris
11:45 – 12:30	Lunch	
12:30 – 1:30	O-GSLFZ Parameters	Susan/Jim
1:30 – 2:15	Other Faults Final Parameters	Bill/Susan
2:15 – 2:45	Final Recurrence Models and Weights	Ivan
2:45 – 3:15	Final Seismogenic Thicknesses	Jim
3:15 – 3:30	Break	
3:30 – 4:15	Update on Geodetic Analysis	Jim/Mark/David
4:15 – 5:00	Evaluation of Geodetic Models in Northern California	Ivan
8:00 – 8:30	Continental Breakfast	
8:30 – 8:45	Overview of Agenda and Review of Last Meeting's To Do List	Ivan
8:45 – 9:30	Update on Consensus Wasatch Front Earthquake Catalog	Walter/Jim

WGUEP MEETING 7 AGENDA
Friday, February 17, 2012

8:00 – 8:30	Continental Breakfast	
8:30 – 9:15	Background Seismicity Parameters	Mark/Ivan
9:15 – 10:00	Antithetic Fault Parameters	Mike
10:00 – 10:15	Break	
10:15 – 12:00	Preliminary Forecast	Patricia
12:00 – 1:00	Lunch	
1:00 – 2:00	Path Forward	All
2:00	Adjourn	

IVAN'S TO DO LIST

1. Complete revision of the historical earthquake catalog (Walter/Jim).
2. Decluster catalog and calculate recurrence for background seismicity correcting for magnitude bias (Mark/Walter/Ivan).
3. Finalize selection of recurrence models and weights (Ivan).
4. Finalize COV and uncertainties for WFZ – asymmetric or symmetric (Chris).
5. Finalize RIs for single and multi-segment ruptures on central WFZ (Chris/Nico).
6. Finalize slip rates for end segments of WFZ (Mike/Chris).
7. Finalize rupture model, RIs, slip rates, and COV for O-GSLFZ (Susan/Jim).
8. Finalize M_{max} procedures (Susan).
9. Finalize seismogenic crustal thicknesses for west and east of WFZ (Jim/Ivan).
10. Finalize parameters for "Other Faults" (Bill).

IVAN’S TO DO LIST CONTINUED

11. Finalize parameters for antithetic rupture of Hansel Valley fault (Mike/Bill).
12. Finalize weights of time-dependent versus time-independent models for WFZ and O-GSLFZ (Chris/Susan/Jim).
13. Finalize average displacements for calculating M for central WFZ (Chris/Susan).
14. Compare geologic horizontal slip rates with geodetic rates across Wasatch Front (David/Jim/Mark).
15. Finalize approach for background seismicity (Ivan/Mark).

Tasks

1. Complete revision of the historical earthquake catalog (Walt/Jim).
2. Decluster catalog and calculate recurrence for background seismicity correcting for magnitude bias (Mark/Walter/Ivan).
3. Finalize selection of recurrence models and weights (Ivan).
4. Finalize COV and uncertainties for WFZ – asymmetric or symmetric (Chris).
5. Finalize RIs for single and multi-segment ruptures on central WFZ (Chris/Nico).
6. Finalize slip rates for end segments of WFZ (Mike/Chris).
7. Finalize rupture model, RIs, slip rates, and COV for OGSL (Susan/Jim).
8. Finalize Mmax procedures (Susan).

Tasks

9. Finalize seismogenic crustal thicknesses for west and east of WFZ (Jim/Ivan).
10. Finalize parameters for "Other Faults" (Bill).
11. Finalize parameters for antithetic rupture of Hansel Valley fault (Mike/Bill).
12. Finalize weights of time-dependent versus time-independent models for WFZ and OGSL (Chris/Susan/Jim).
13. Finalize average displacements for calculating **M** for central WFZ (Chris/Susan).
14. Compare geologic horizontal slip rates with geodetic rates across Wasatch Front (David/Jim/Mark).
15. Finalize approach for background seismicity (Ivan/Mark).

Update on Consensus Wasatch Front Catalog

Walter Arabasz and Jim Pechmann

UNIVERSITY OF UTAH
SEISMOGRAPH STATIONS
THE UNIVERSITY OF UTAH

WGUEP
February 16, 2012

Outline

I. Information items

II. Data set of moment magnitudes for Utah region

III. Work on magnitude conversions & uncertainties (historical: $M_{L\ (I_o)}$; instrumental: M_L, M_C, and M_W)

IV. Update on unifying UUSS and NSHM catalogs (and magnitudes)
   — Historic catalog (1850–1962)
   — Instrumental catalog (1962–2010)

V. Target for passing catalog to URS/USGS "analysts"

I. Information Items

- The UUSS earthquake catalog is being used by industry consultants as part of a seismic evaluation for a proposed nuclear power plant near Green River, Utah

  — WJA and JCP are both providing technical advice on use of the UUSS catalog for the "Blue Castle" project

  — Requirements for deriving earthquake rate information from the UUSS catalog are similar for both the WGUEP and Blue Castle projects

- The final report for the "CEUS SSC Project," which contains abundant details on the state of practice for seismic source characterization (including use of earthquake catalogs and paleoseismological data), has been published. See:

  http://www.ceus-ssc.com/

II. Data Set of Moment Magnitudes for ~100 events in the Utah Region

Reliable measurements of M_w — useful not only for selected events but also critical for assessing the relation between M_L , M_C in the UUSS catalog with M_w

- **pre-1962:** N=2 (Hansel Valley m'shock and a'shock)
- **1962-1980:** N=7 (Pechmann, unpub. compilation; ~same sources as Pancha et al., 2006; Doser and Smith, 1982, values excluded)
- **1981-2003:** N=52 (Pechmann et al., 2007, 2010), nine overlap with Whidden and Pankow (2012)
- **1997-2011:** N=48 (Whidden and Pankow, 2012), 25 overlap with Herrmann et al. (2011)

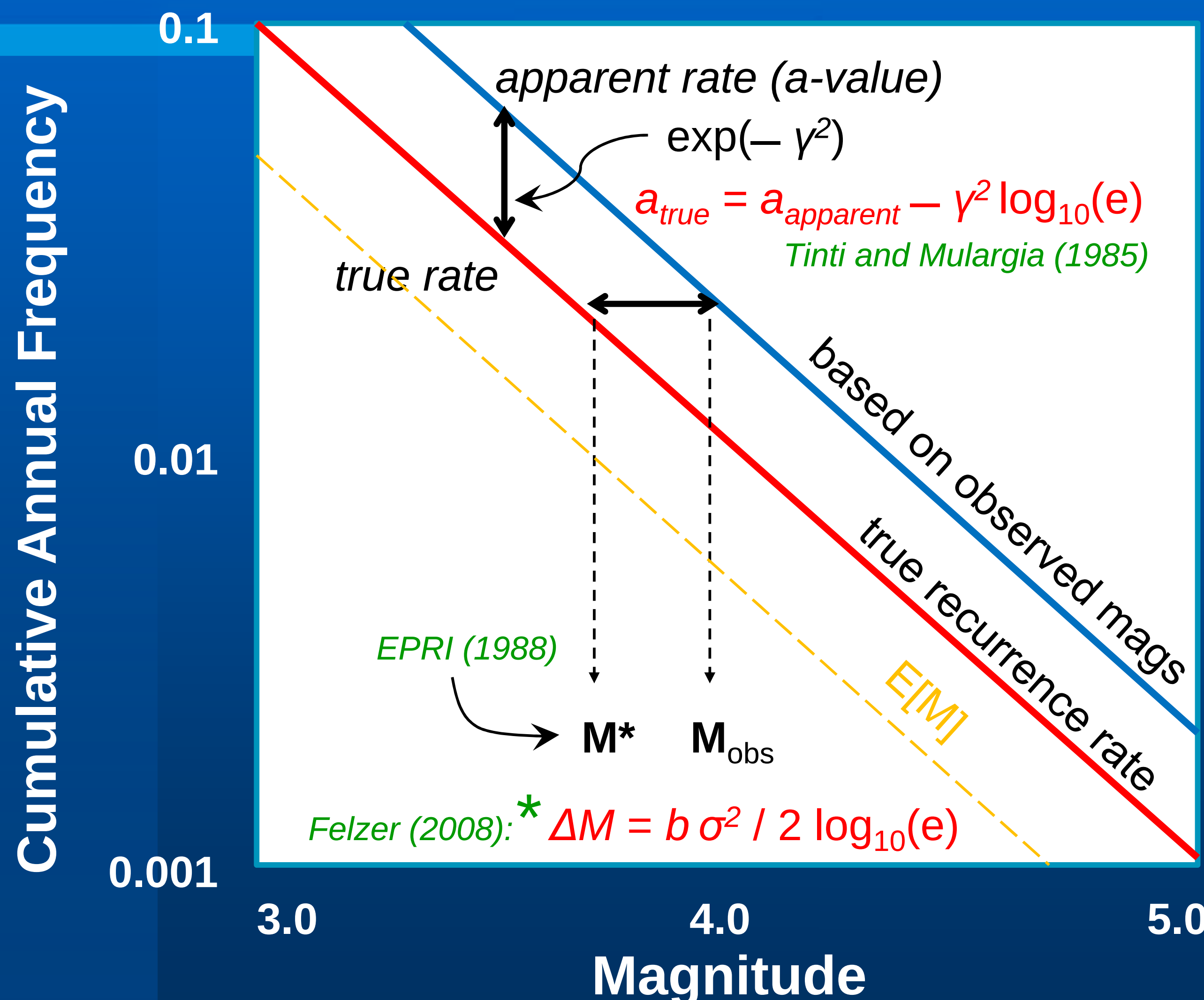
  N=29 (Herrmann et al., 2011)

III. Work on magnitude conversions and uncertainties

Why uncertainties are important (review)

- Recurrence calcs for rigorous hazard and risk analyses require an adjustment for magnitude uncertainties because they introduce bias (*a*-values are systematically overestimated)
- Bias arises because errors in magnitude estimates are normally distributed while earthquake counts in magnitude bins are exponentially distributed
- Magnitude uncertainties come from: (1) statistical average of measurements made at a number of stations and (2) conversion from one magnitude scale to another; errors also from rounding

Equivalent approaches to ensuring unbiased recurrence rates (review)



$\gamma^2 = \beta^2 \sigma^2 / 2$

where $\beta = b / \log_{10}(e)$

Fine point:
E[M] = expected value of the true magnitude

See: http://www.ceus-ssc.com/PDF/Chapter3.pdf
Figure 3.3-1

**** Published equation incorrectly shows b²***

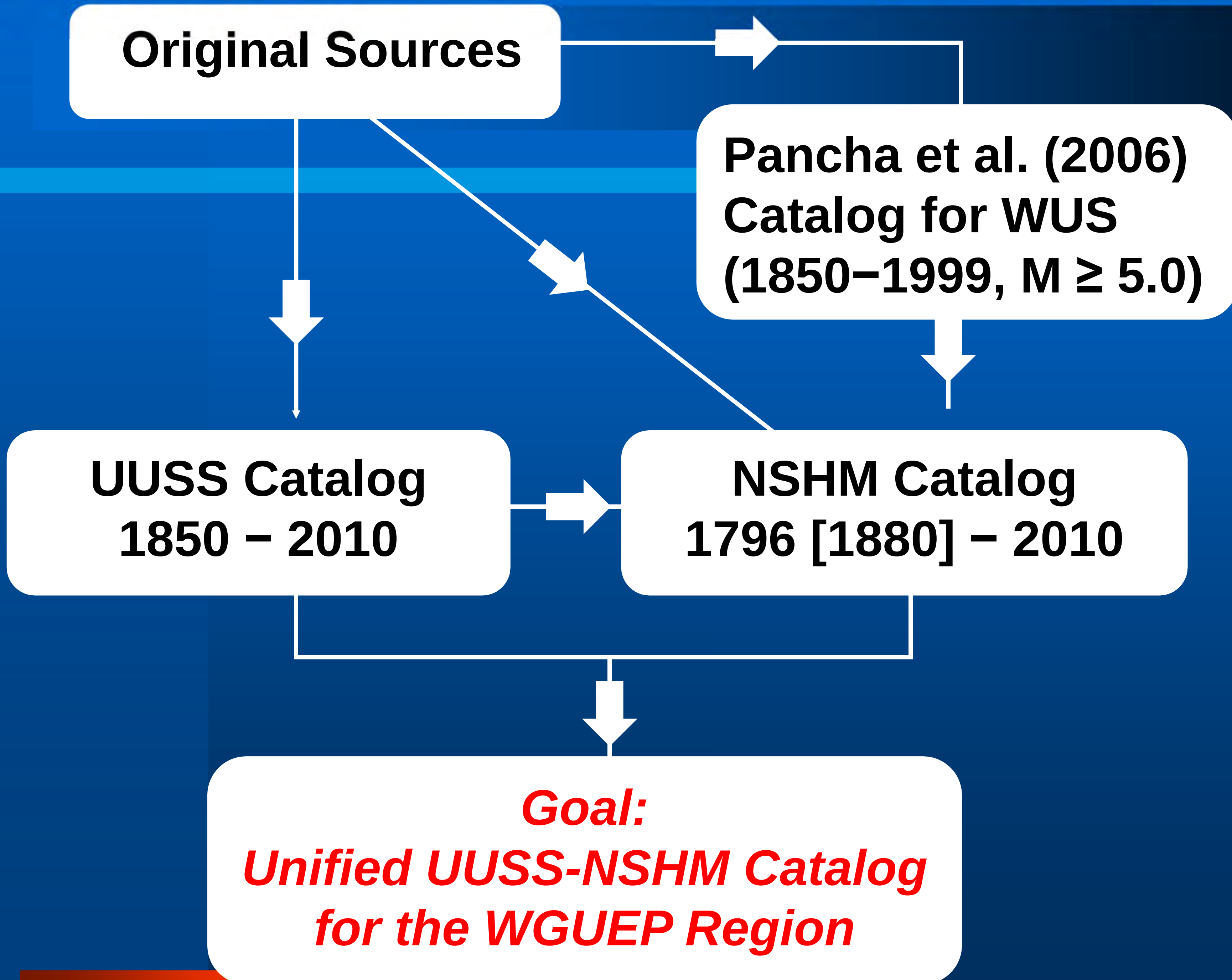
Need σ and *b*-value for the bias correction (review)

- For an adopted scale (say M_W or $M_L \approx M_W$) and for observed magnitudes: need to know $\sigma_{stations}$, the standard error of estimate of magnitude based on measurements at multiple stations.
- When converting from one magnitude scale to another, need to know $\sigma_{regression}$, the std error of estimate for the regression.

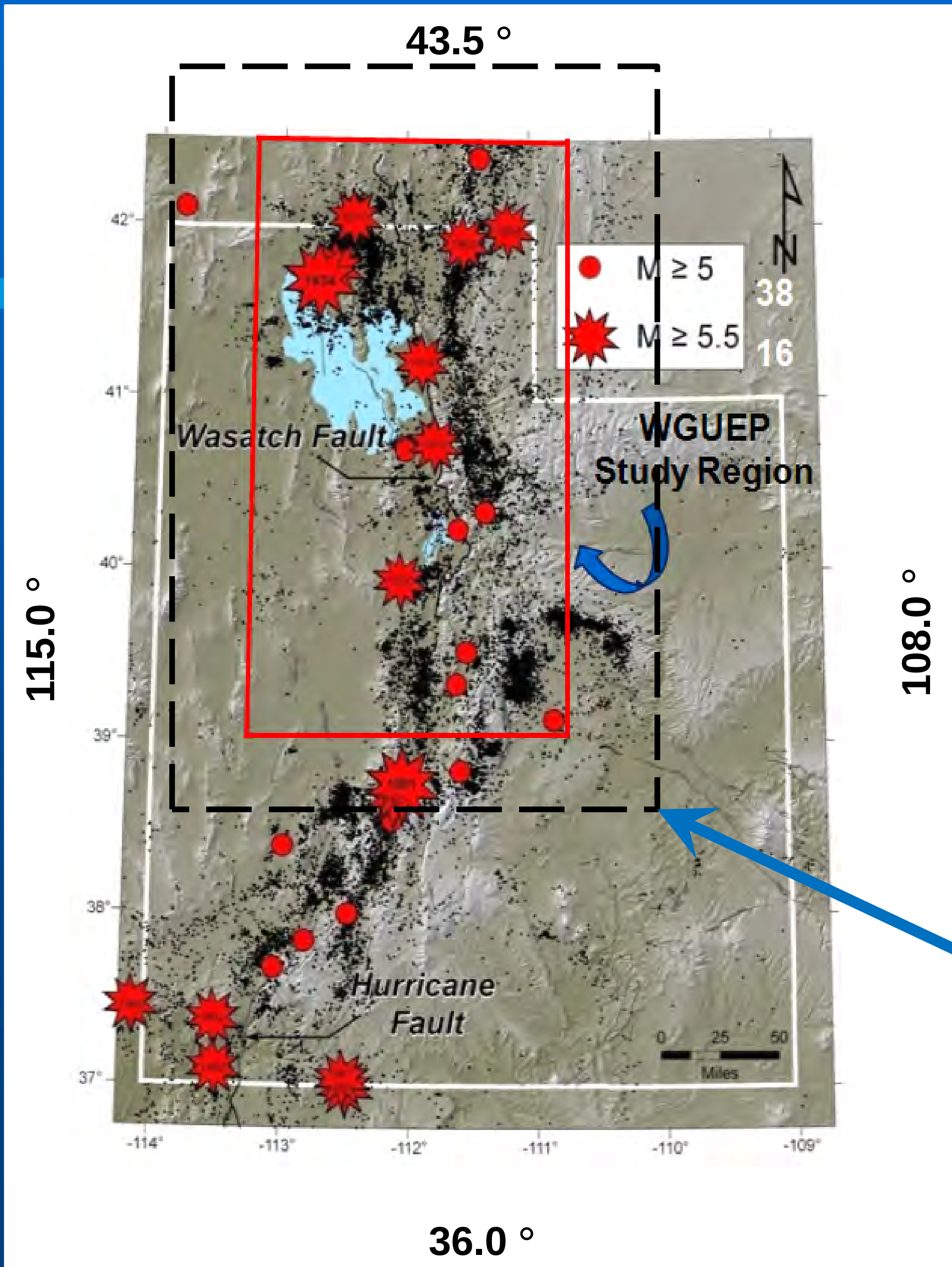
  In this case, for the normally-distributed magnitude errors

$$\sigma = \sqrt{\sigma_{regression}^{\ 2} - \sigma_{stations}^{\ 2}}$$

Unifying UUSS and NSHM Catalogs (1 of 3)



Unifying UUSS and NSHM Catalogs (2 of 3)



"extended Utah region"

Buffer zone for declustering

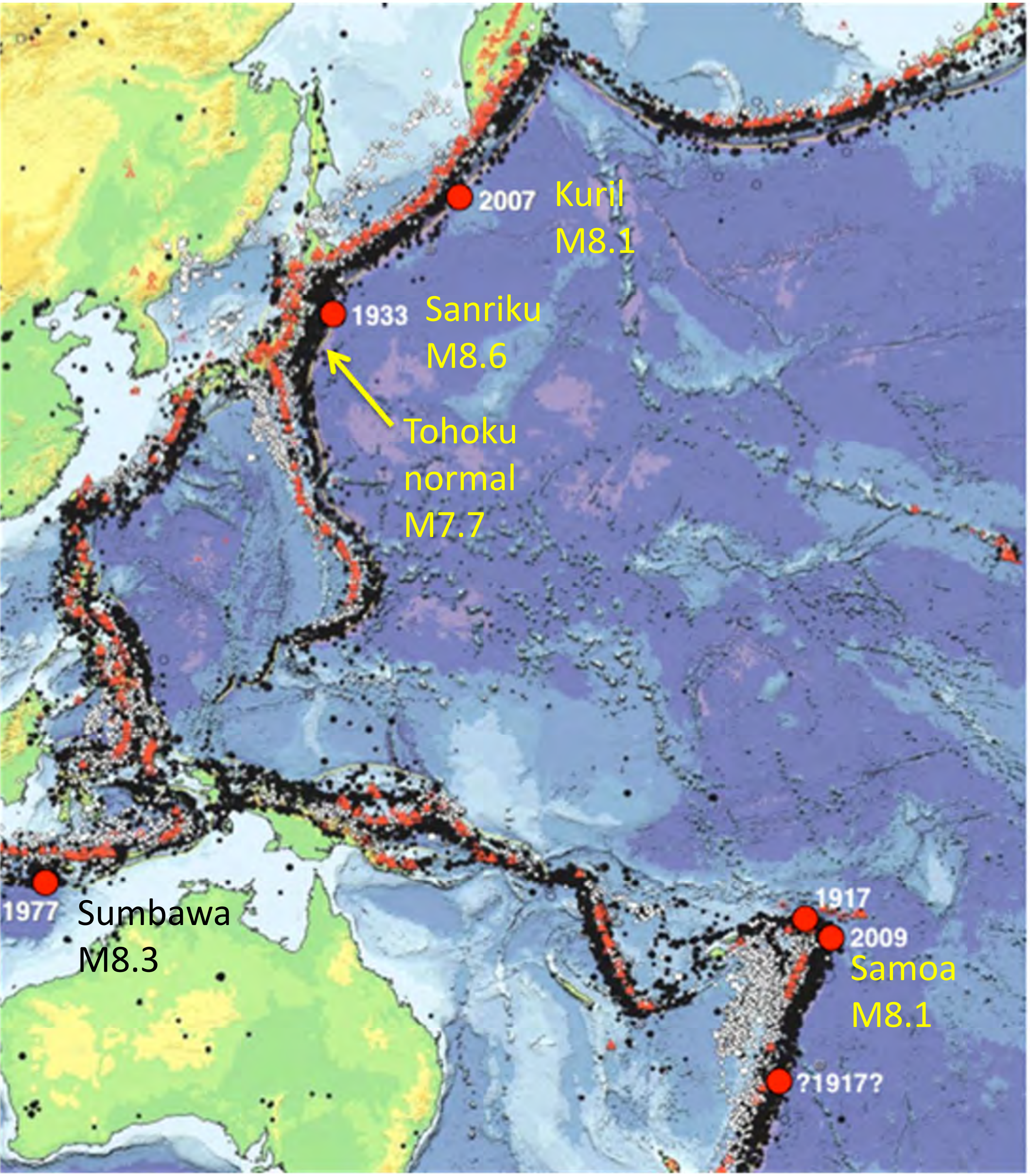
Unifying UUSS and NSHM Catalogs (3 of 3)

Time Period	UUSS	NSHM	Pancha et al.
1850-JUN1962 No. of Events	462 307 (M_{int}) 140 (no mag)	143 Reconciling Mags	68
JUL 1962-SEP 1974	866 M_C, M_L (347 ≥ M2.5)	226 mbneic, M_L Variance weighting?	22
OCT 1974-DEC 1980	5,256 M_C, M_L (452 ≥ M2.5)	47 Mostly M_L (reliant on UUSS) ←	5
JAN 1981-DEC 2010	49,737 M_C, M_L, M_W (3,337 ≥ M2.5)	371 ←	19

Target for passing catalog to URS/USGS “analysts”

- Attempting to complete before mid-March
- Decision on declustering method to be made by analysts

end



Features Common to these M ≥ 8 Earthquakes

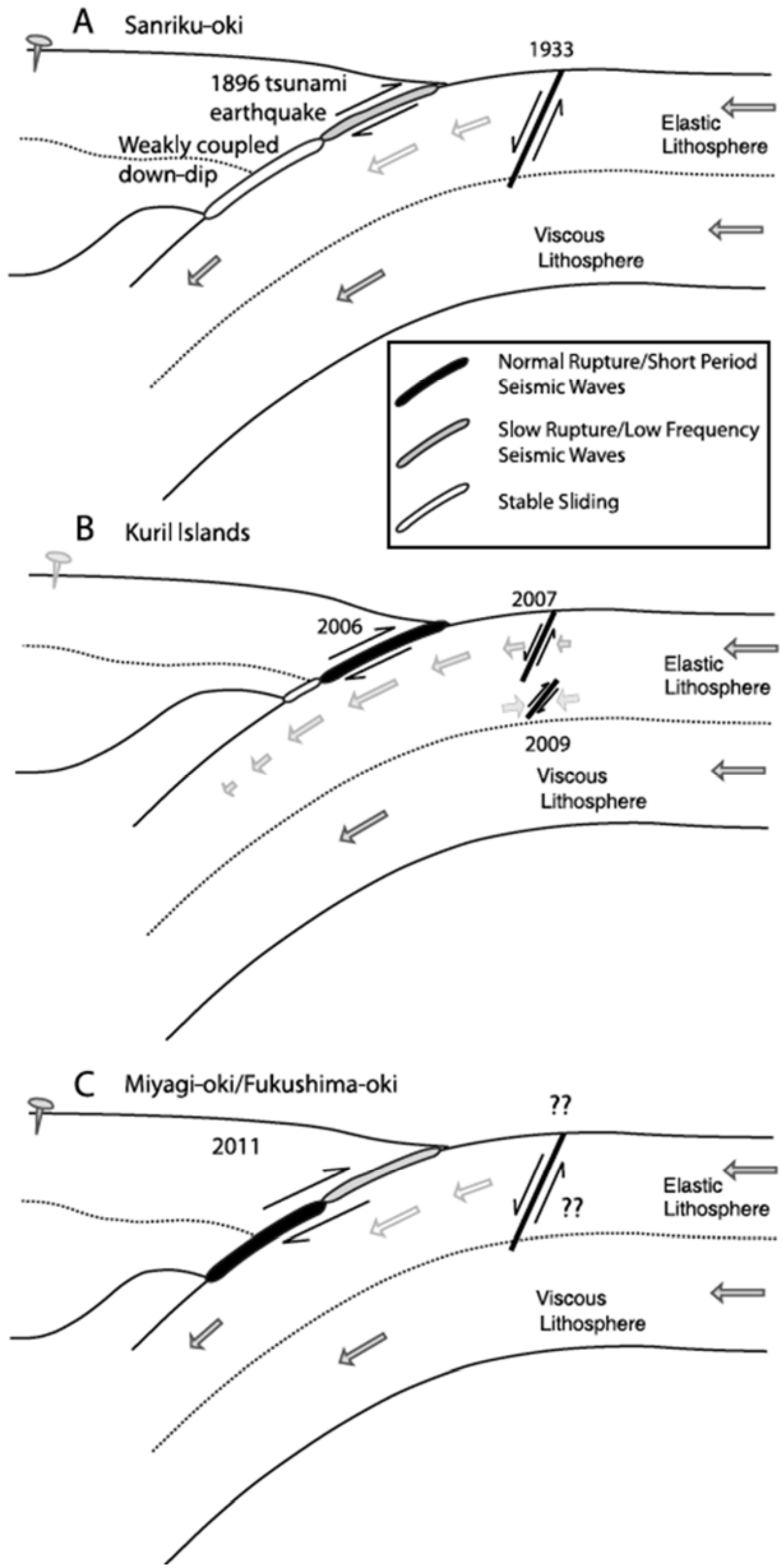
*Incoming plate is Mesozoic in age and hence thermally mature and thick. High stress.

*Where focal mechanisms are known and/or swath maps are available, rupture planes cross-cut seafloor spreading fabric at high angles (> 30°).

*Well-located great earthquakes occur where outer-rise gravity anomalies are positive and large.

*Dip angles on rupture planes are high compared to megathrust earthquakes.

*Combined with the large ocean depths in the epicentral areas, such events should produce bigger tsunamis for a given Mo than megathrust EQ's of similar moment.



Lay et al. (2011)

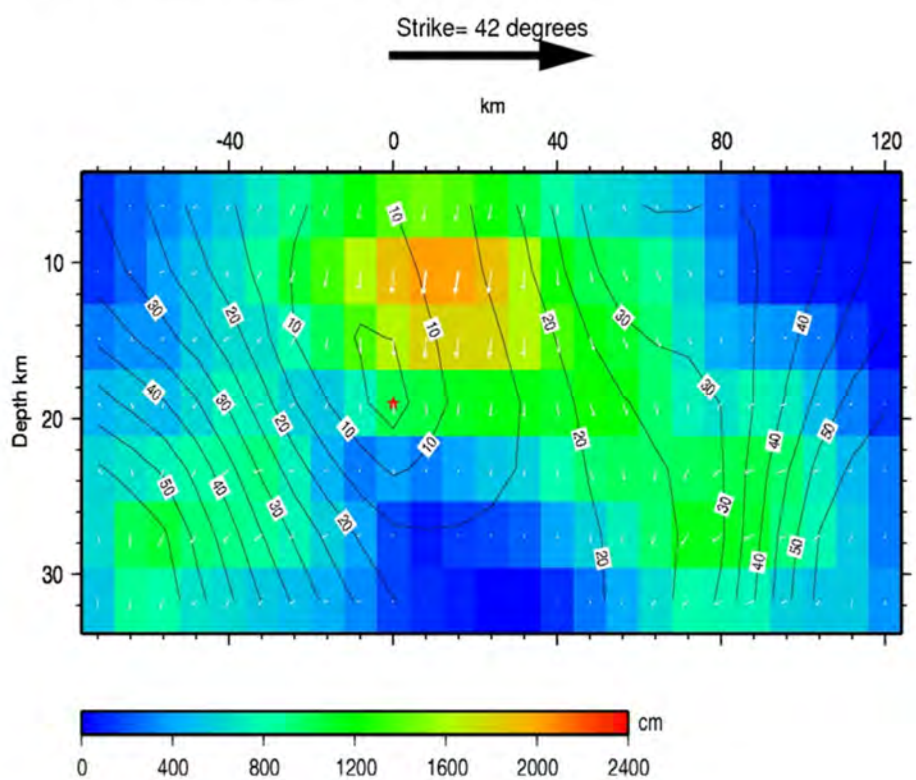
		Mw	Hypo Depth	Length	Width	Dav	Dmax	Dip
1933	Sanriku	8.6 8.7		~280 220	~50 35	11 17		45 45
1977	Sumbawa	8.2-8.4	29	200				45
2007	Kuril	8.1-8.2	18	200	35	9	20	57.8
2009	Samoa	8.1	18	~165			14	57.1
2011	Tohoku	7.6,7.7	21					

2007 Kuril

Result

We selected the high angle nodal plane (dip =57.89 deg., strike=42 deg.) as preferred fault plane based upon aftershock distribution. Its dimension is 200 km (along strike) by 35 km, which is further divided into 175 subfaults (8 km by 5 km). The seismic moment release of this model is $1.9x10^{21}$ N.m and its peak slip is about 20 m using a 1D PREM model.

Cross-section of slip distribution



Samoa 2009

Result

After comparing the waveform fits based on two planes, we find that the nodal plane (strike=342.5 deg., dip=57.1 deg.) fits the data better. The seismic moment release based upon this plane is 1.63E+028 dyne.cm using a 1D crustal model interpolated from CRUST2.0 (Bassin et al., 2000).

Cross-section of slip distribution

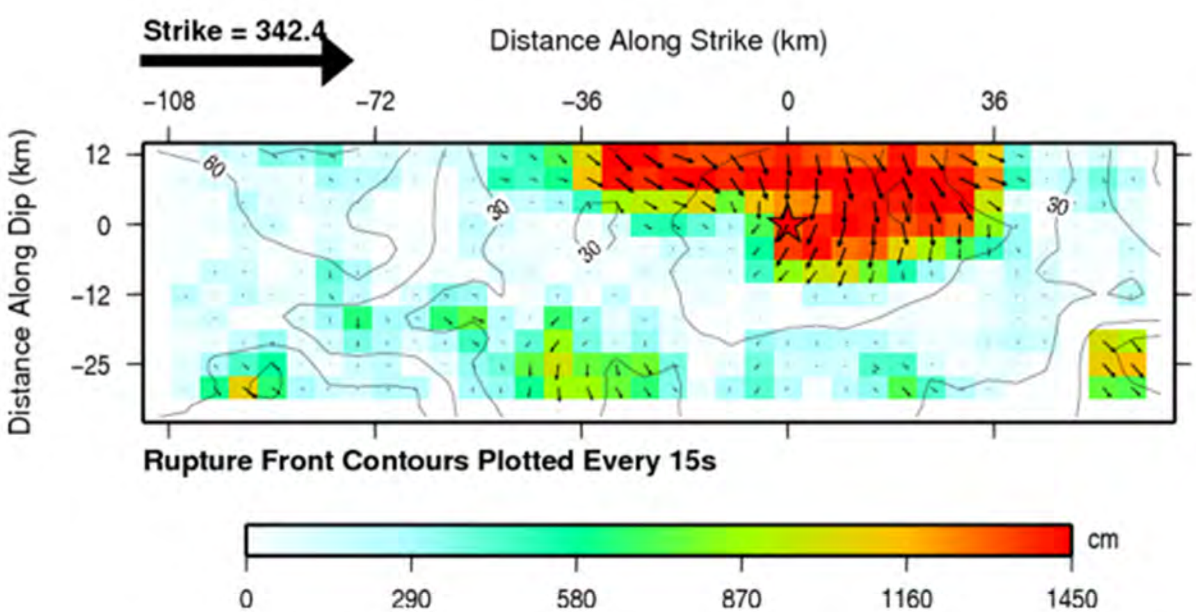
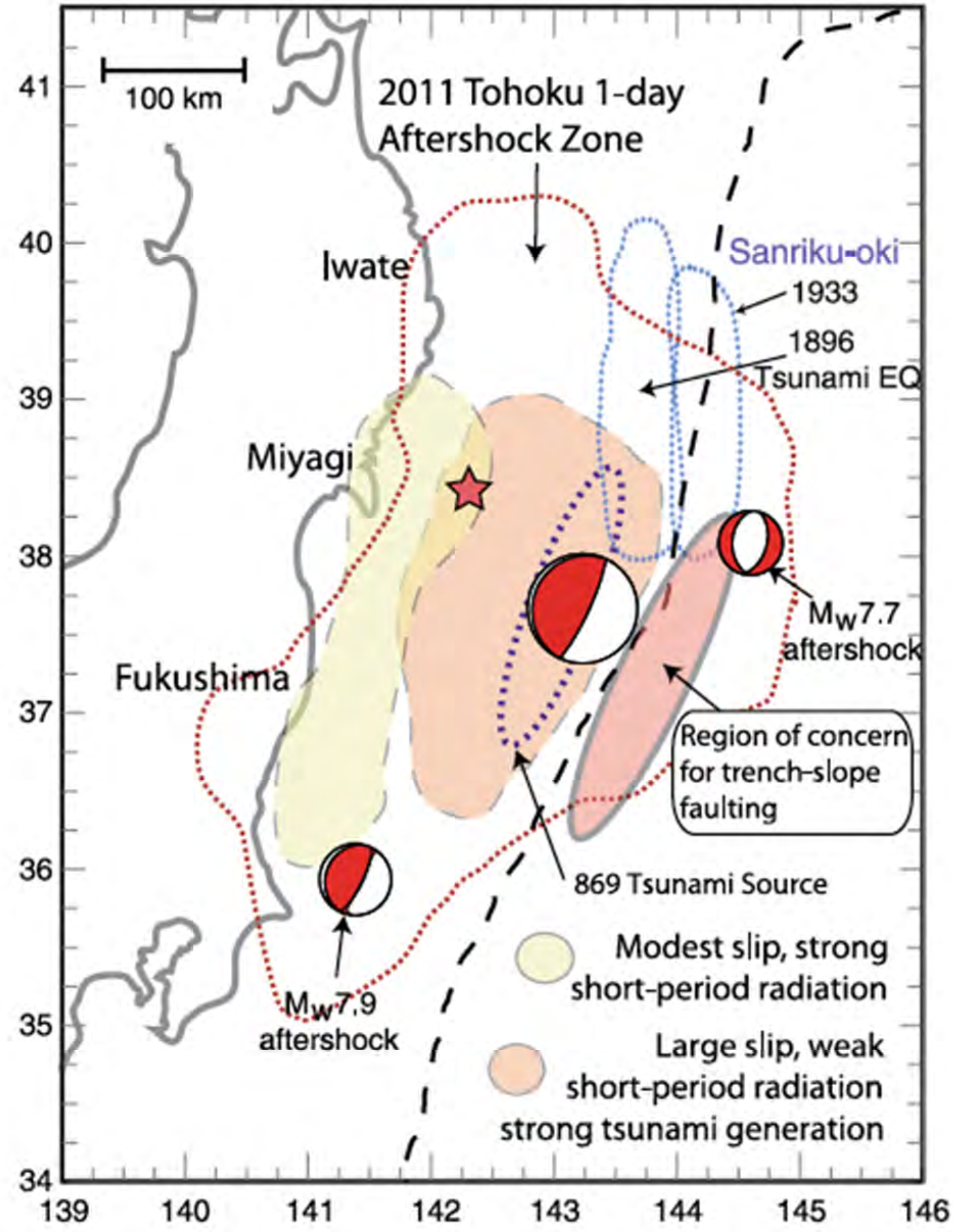


Figure 1. Cross-section of slip distribution. The strike direction of fault plane is indicated by the black arrow and the hypocenter location is denoted by the red star. The slip amplitude are showed in color and motion direction of the hanging wall relative to the footwall is indicated by white arrows. Contours show the rupture initiation time in seconds.



Lay et al. (2011)

Comparison of Slip Rates for Normal Faulting with Average Megathrust (MT) Slip Rates

- Megathrust average slip rate (PA:OK): 80 mm/a or *80 km/Ma*
- Normal faulting OR/OTS:
  - *Total cumulative slip on scarps nearest trench: scarps, $S \approx 500$ m
  - *Time interval for normal faulting over the outer trench slope of 100 km width:
    T = 100 km/80 km/Ma = 1,250,000 years = 1.25 Ma

Average slip rate = 0.5 km/1.25 Ma = *0.4 km/Ma = 0.4 mm/a* or <u>0.005 of the megathrust slip rate => very slow average slip rate [*But the MT boundary has a very different structure and faulting behavior*]</u>

If most of the slip on these scarps occurs by great OR/OTS earthquakes with average slip, $s \approx 10$ m, then a rough average regional return time would be:

$\Delta T = 10^4$ mm/(0.4 mm/year)/(20 scarps) = 1250 years (a minimum interval, since it neglects the slip contributions of smaller earthquakes and possible fault creep or afterslip).

The Wasatch Fault Zone End Segments

(Malad City, Clarkston Mountain, Collinston, Levan, & Fayette)

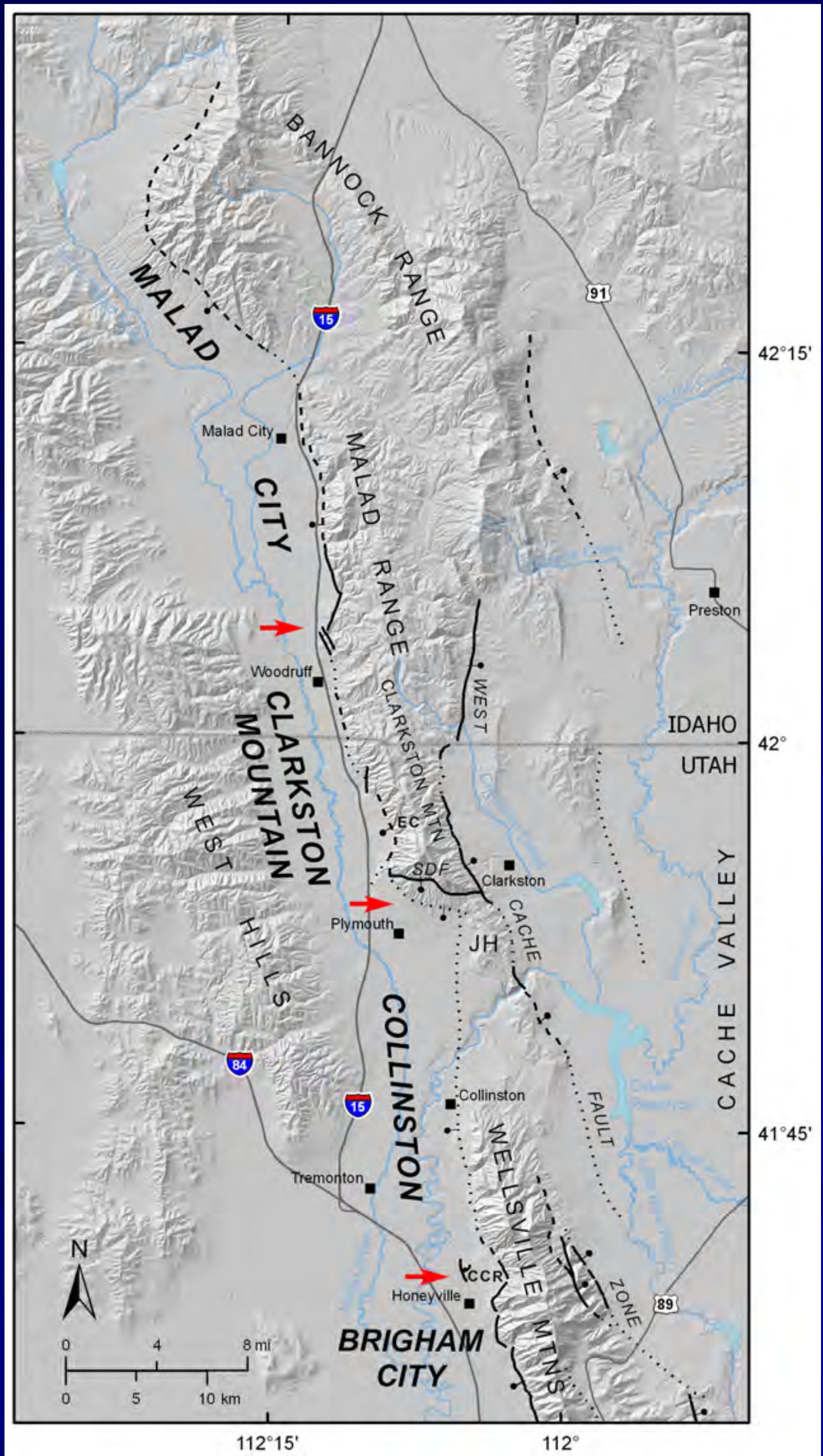
Slip Rate and Length – Model Distributions and Weights

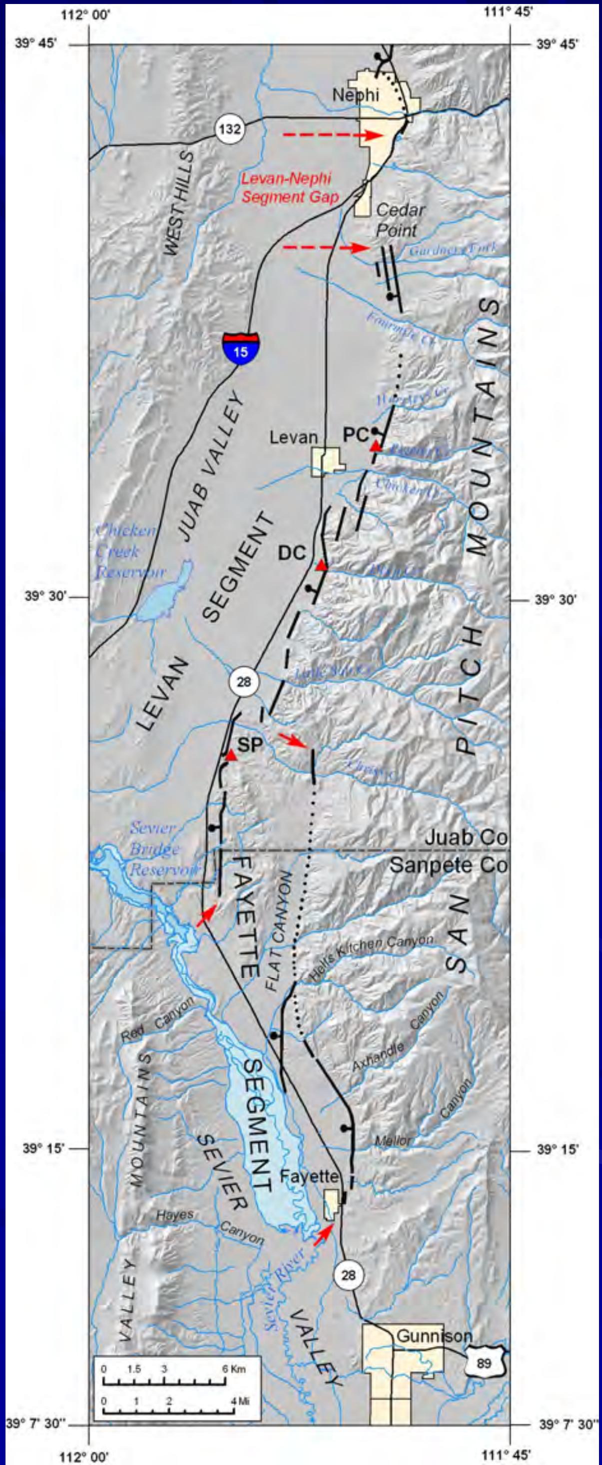
Mike Hylland
Utah Geological Survey

Working Group on Utah Earthquake Probabilities – February 2012

Northern Segments

Southern Segments





The Wasatch Fault Zone End Segments

Summary of Earthquake Parameters

(presented at February 2011 WGUEP meeting)

Segment	***MRE Timing***	***Displacement/ Surface Offset (m)***	***Time Interval (kyr)***	***Est. SR (mm/yr)***	***Recommended SR (mm/yr)***	***RI (kyr)***
Malad City	Late Pleistocene	≤1.5 (est.)	>18	<0.08	0.01–0.1	NA
Clarkston Mountain	Late Pleistocene	2	>18	<0.1	0.01–0.1	NA
Collinston	Late Pleistocene	≤2 (est.) <12	>18 300	<0.1 <0.04	0.01–0.1	NA
Levan	≤1000 cal yr B.P. 1000–1500 cal yr B.P.	1.8 1.8–3.0 4.8	>4.8–9.8 >1.3–3.3 100–250	<0.2–0.4 <0.5–2.3 <0.3±0.1* 0.1–0.6** 0.02–0.05	0.1–0.6	>3 & <12**
Fayette	Early(?) Holocene (SW strand) Latest Pleistocene (SE strand)	0.8–1.6 0.5–1.3 3	<11.5 <18 100–250	>0.07–0.1 >0.03–0.07 0.01–0.03	0.01–0.1	NA

*Hylland and Machette, 2008

** UQFPWG (Lund, 2005)

The Wasatch Fault Zone End Segments

Strawman Model Parameters

Segment	Length (km)	Length Uncertainty (km)	Length Range (km)	Length Distribution (5th, 50th, 95th) (0.2–0.6–0.2)	Slip Rate Consensus Range (mm/yr)	Slip Rate Distribution (5th, 50th, 95th) (0.2–0.6–0.2)
Malad City	40	+/-6	34 – 46	34 – 40 – 46	0.01 – 0.1	0.01 – 0.05 – 0.1
Clarkston Mountain	19	+/-6	13 – 25	13 – 19 – 25	0.01 – 0.1	0.01 – 0.05 – 0.1
Collinston	30	+/-6	24 – 36	24 – 30 – 36	0.01 – 0.1	0.01 – 0.05 – 0.1
Levan	32	+/-6	26 – 38	–	0.1 – 0.6	0.1 – 0.3 – 0.6
Levan (mapped Holocene rupture)	25	+/-6	19 – 31	–	–	–
Levan (incl. faults in L-F step-over)	37	+/-6	31 – 43	–	–	–
Levan – ***Length range to consider***	–	–	19 – 43	19 – 31 – 43	–	–
Fayette	22	+/-6	16[1] – 28	17.5 – 22 – 28	0.01 – 0.1	0.01 – 0.05 – 0.1
Levan + Fayette (multi-segment rupture)[2]	46[3]	+/-6	40 – 52	40 – 46 – 52	–	–

[1] *Use default minimum length to generate M 6.5 earthquake (17.5 km).*
[2] *WGUEP recommends giving 0.5 weight to this model.*
[3] *End-to-end combined length; avoids double-counting length of overlap that would occur from simply summing individual segment lengths.*

Oquirrh Great Salt Lake Fault Zone Revisited

Susan Olig (URS Corporation)
Jim Pechmann (UUSS)

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OGSLFZ

Rozelle - 25 km

Promontory – 25 km

Fremont Is.- 25 km

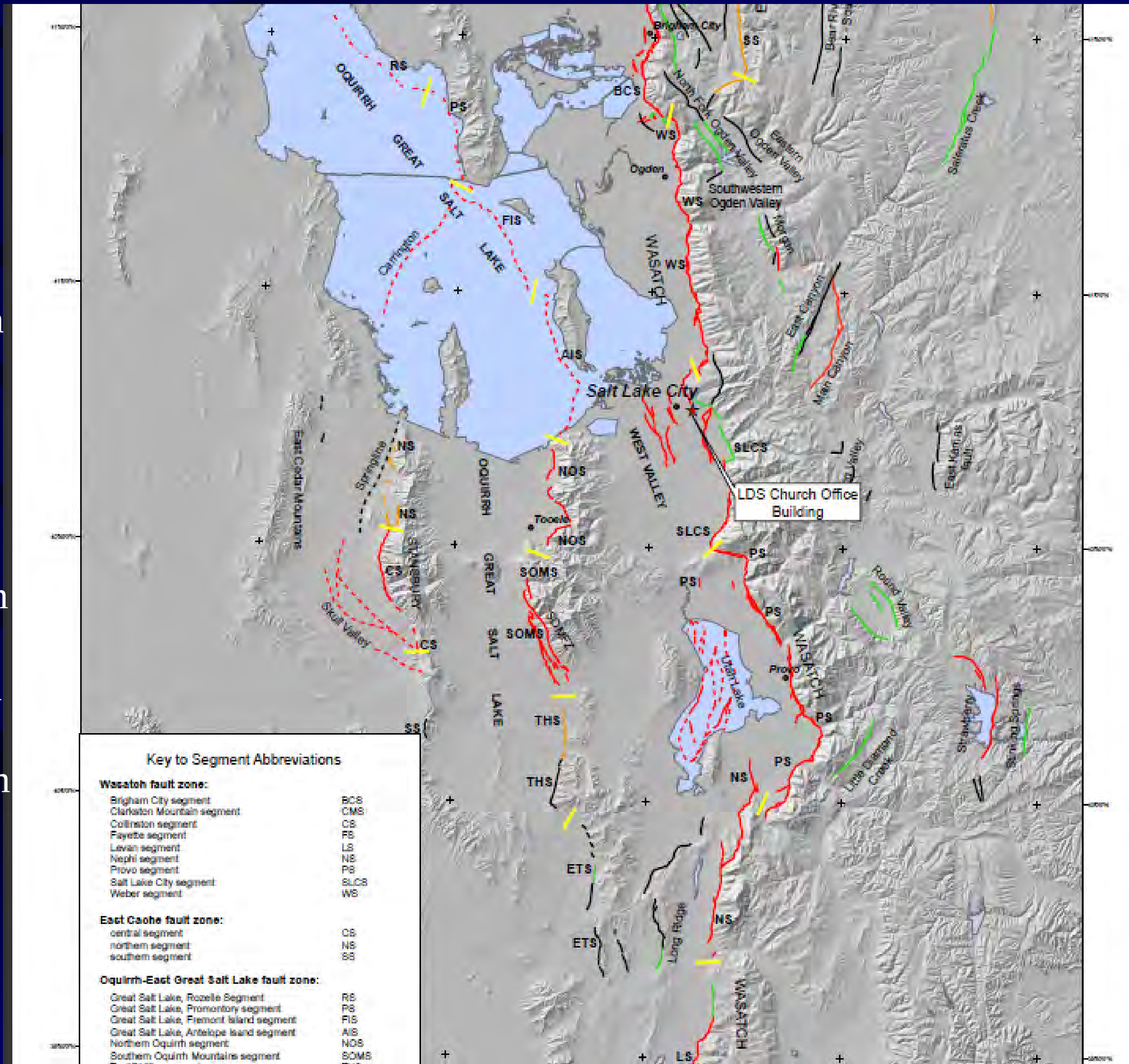
Antelope Is.- 35 km

No. Oquirrh – 30 km

So. Oquirrh – 31 km

Topliff Hills – 26 km

East Tintic - 35 km



Paleoseismic Timing Data

Table 3

Ages of Youngest Surface-Faulting Along Segments of the Oquirrh-Great Salt Lake Fault Zone[1]

	Fault Segment	Youngest Event	Penultimate Event	Older Events?[3]
Great Salt Lake fault[2]	Rozelle (RZ)	Holocene?	?[3]	?[3]
	Promontory (PY)	Holocene?	?[3]	?[3]
	Fremont Island (FI)	3,150 (+240, -210)	6,410 (+210, -210)	< 11,430 (+610, -450)
	Antelope Island (AI)	590 (+200, -240)	6,170 (+240, -230)	9,900 (+250, -300)
	Northern Oquirrh (NO)[4]	6330 (4960 to 7650)	20,300 - 26,400	> > 33,000
	Southern Oquirrh (SO)[5]	1,300 to **4,830**[6]	20 to 50 ka[6]	shortly after 42 ± 8; shortly after 75 ± 10 ka; ca. 92 ± 14 ka[6]
	Topliff Hills (TH)	> 15,000[7] or < 15,000[8]	?[3]	?[3]
	East Tintic (ET)	> > 15,000 (middle to late Pleistocene)[9]	?[3]	?[3]

Rupture Models & Weights for OGSLFZ

Rupture Scenarios		Old Strawman 2 Weights (Mtg. #6)	New Strawman 3 Weights
1	RZ, PY, *FI, AI,* NO+SO, TH, ET	0.25	0.15
2	RZ, PY, *FI, AI,* NO, SO, TH, ET	0.4	0.5 (or 0.45?)
3	RZ, PY, FI+AI, NO, SO, TH, ET	0.1	0.1
4	RZ, PY, *FI, AI,* NO, SO+TH, ET	0.1	0.1
5	Unsegmented (floating)	0.15	0.15 (or 0.2?)

**Yellow italics* indicates time-dependent model considered

Supporting Data & Considerations [Contradictions]

1. RZ, PY, FI, AI, NO+SO, TH, ET

- Ages of PE and APE overlap for NO and SO [but uncertainties are large]
- Displacements per event are very large for both NO (2.2-2.7 m) and SO (1.3-2.2 m) given their individual lengths of only 21 and 24 km, respectively
- Late Quaternary displacement profiles (from scarp profile data) do not taper but stay large near the NO-SO segment boundary
- NO and SO have similar late Quaternary slip rates of 0.1-0.2 mm/yr

2. RZ, PY, FI, AI, NO, SO, TH, ET

- Gaps and step-overs of late Quaternary scarps and ranges
- Age of MREs different (for those that are reasonably constrained)
- Basin geometry (except SO & TH and FI &AI)

Supporting Data & Considerations -continued

3. RZ, PY, FI+AI, NO, SO, TH, ET

- Age of Penultimate events of FI and AI overlap
- Similar slip rates for FI and AI
- Traces overlap and geometrical step-over is small
- Large displacements/event for AI for length 32 km

4. RZ, PY, FI, AI, NO, SO+TH, ET

- Basin Geometry (continuous and deepest at SO-TH boundary)
- Large displacements per event for SO
- Permissable that ages of events overlap [data poor on TH]

5. Unsegmented

- Large uncertainties (particularly for RZ, PY, TH, ET)
- Accounts for scenarios with weight < 0.1

Supporting Data & Considerations -continued

Why AI+NO weight considered <0.1

- Large difference between the rates of activity on the AI and NO (rates on AI are 2x to 4x higher than NO)
- The major right-step and change in strike between AI and NO fault traces
- Basin and range geometry
- Large uncertainty in age of MRE on NO (6330, 4960 to 7650) argues against the significance of the overlap between this age and that of the PE on AI (6170, +240, -230)

  {sum of the 2-sigma uncertainty limits is
  (7650 yr - 4960 yr) + (240 yr + 230 yr)= 3160 years,
  which is 75% (56% to 113%) of the estimated average single-segment recurrence interval for the southern GSLF of 4200 +/- 1400 years}

Rupture Models & Weights for OGSLFZ

Rupture Scenarios		Old Strawman 2 Weights (Mtg. #6)	New Strawman 3 Weights
1	RZ, PY, *FI, AI,* NO+SO, TH, ET	0.25	0.15
2	RZ, PY, *FI, AI,* NO, SO, TH, ET	0.4	0.4
3	RZ, PY, FI+AI, NO, SO, TH, ET	0.1	0.15
4	RZ, PY, *FI, AI,* NO, SO+TH, ET	0.1	0.1
5	Unsegmented (floating)	0.15	0.2

**Yellow italics* indicates time-dependent model considered

Rates and Other Parameters

Rates

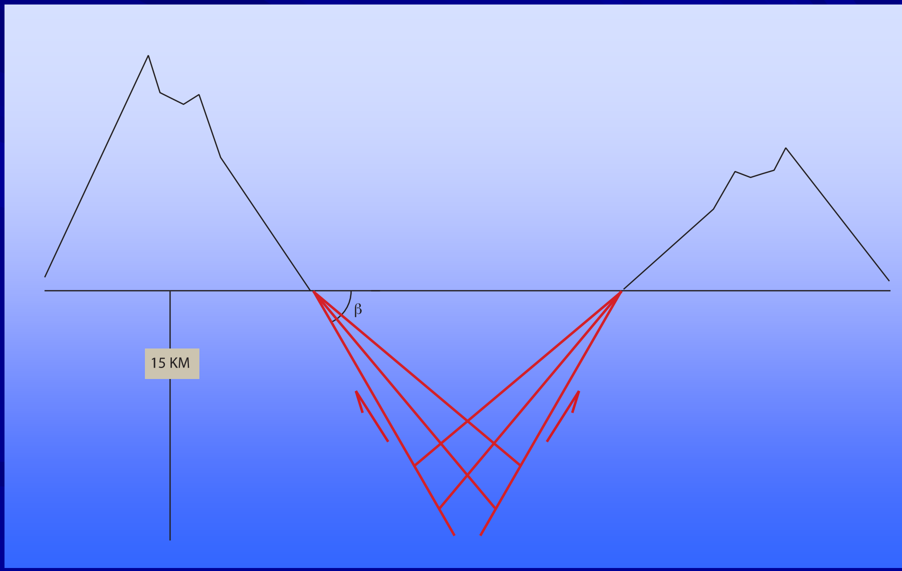
- Use UQFPWG recurrence intervals for GSLF:
  1,800 yrs (0.2)
  4,200 yrs (0.6)
  6,600 yrs (0.2)
- Use UQFPWG (vertical) slip rates for NO and SO:
  0.05 mm/yr (0.3)
  0.15 mm/yr (0.4)
  0.3 mm/yr (0.3)
- Use lower rates for TH and ET (based on scarp profile data):
  0.05 mm/yr (0.3)
  0.1 mm/yr (0.4)
  0.2 mm/yr (0.3

Other Parameters

- COV: Use WFZ COVs
- Unsegmented model: approach generally consistent with WFZ – float M 6.75 to Mchar(using average segment length X 3) ruptures; b=0.8
- Strawman weight on time-dependent: 50--50

Antithetic Fault Parameters

Mike Hylland
Utah Geological Survey



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How should antithetic fault pairs be modeled? (BRPEWGII issue G2) Depending on fault dip and distance between faults, one fault likely truncates the other within seismogenic depths. But which is the master and which is the subsidiary (i.e., truncated) fault?

BRPEWGII recommendations:

Explore using metrics (such as Length, Topographic Relief, Overlap) to guide selection of master and subsidiary faults.

- Evaluate dataset for overlapping relations to select master fault based on Length
- Evaluate using aspect ratio (Length/Width) for individual fault pairs
- Where data allow, structural throw should be used rather than Topographic Relief
- Evaluate using Length x Throw as a parameter for selecting master fault

Subsurface data (e.g., seismic reflection) should be used to guide master fault selection, where available.

Where available data do not give a clear indication of master vs. subsidiary fault, model both alternatives using a logic tree approach.

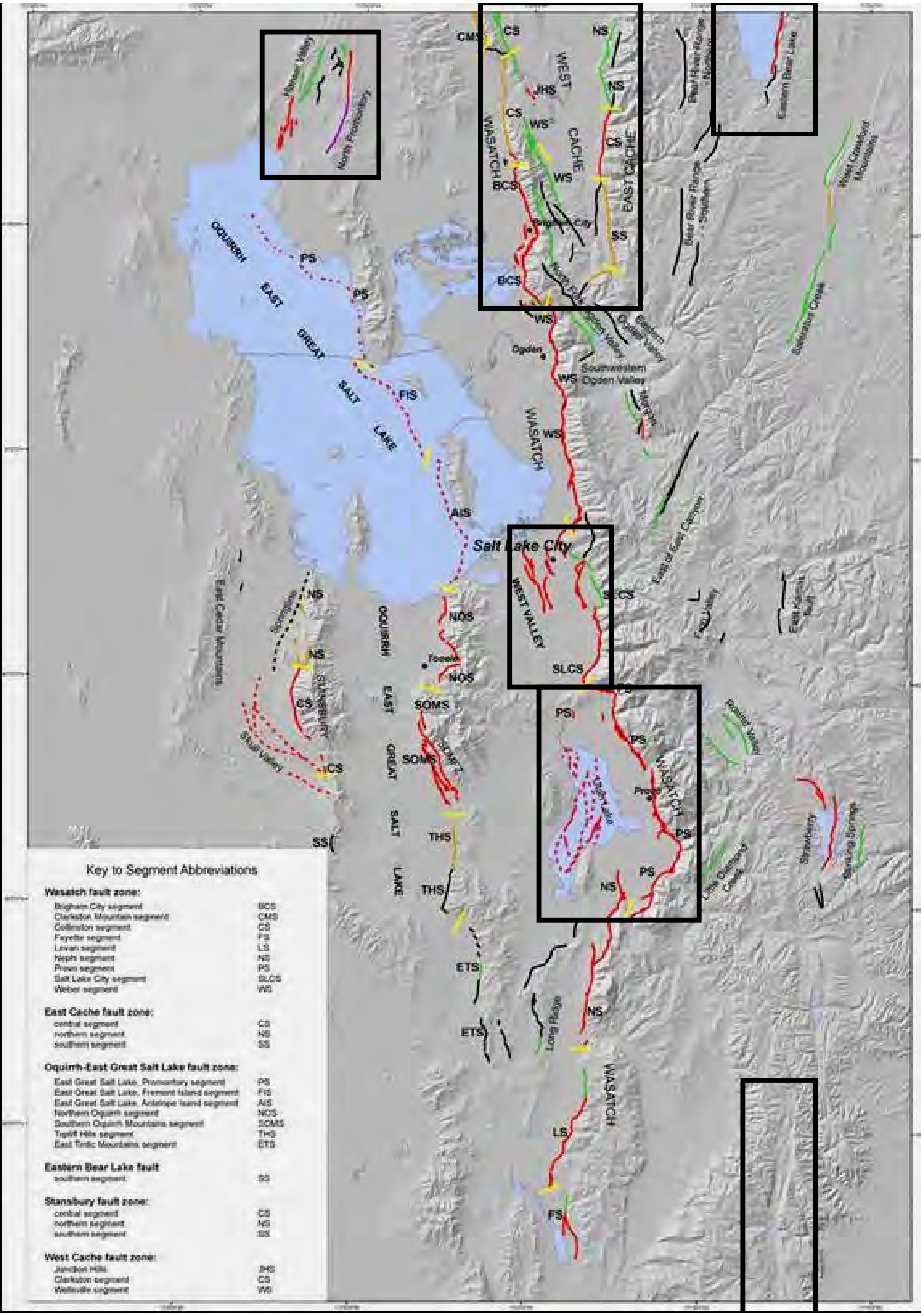
How should antithetic fault pairs be modeled? (BRPEWGII issue G2) Depending on fault dip and distance between faults, one fault likely truncates the other within seismogenic depths. But which is the master and which is the subsidiary (i.e., truncated) fault?

Approach:

- Evaluated fault metrics for six antithetic pairs in the WGUEP study region, including length, percent overlap, maximum and “average” topographic relief, and length x relief
- Selected three master faults based on fault metrics, two master faults based on subsurface data, and used a logic tree approach for one fault pair
- Assigned preliminary 5th – 95th percentile dip distribution for each fault, with weights
- Assigned preliminary weights for independent vs. coseismic (vs. non-seismogenic) behavior

Questions:

- Do master fault selections seem reasonable?
- Are dip distributions and weightings appropriate?
- Are assigned weights for independent vs. coseismic (vs. non-seismogenic) behavior appropriate?
- Should the antithetic modeling approach be applied to other fault pairs in the WGUEP study region?



Fault pairs evaluated:

- West Valley fault zone – Salt Lake City segment
- Utah Lake faults – Provo segment
- Hansel Valley + Hansel Mountains (east side) + Hansel Valley (valley floor) faults – N. Promontory fault
- West Cache fault – East Cache + James Peak faults
- Western Bear Lake + Bear Lake (west side) faults – Eastern Bear Lake fault
- Joes Valley faults (east and west sides)

Should other fault pairs also be evaluated?

- East Canyon – Main Canyon faults
- Round Valley faults
- Other Wasatch Plateau faults
    - Pleasant Valley fault zone
    - Gooseberry graben
    - Snow Lake graben

Metrics for Selecting Master and Subsidiary Faults

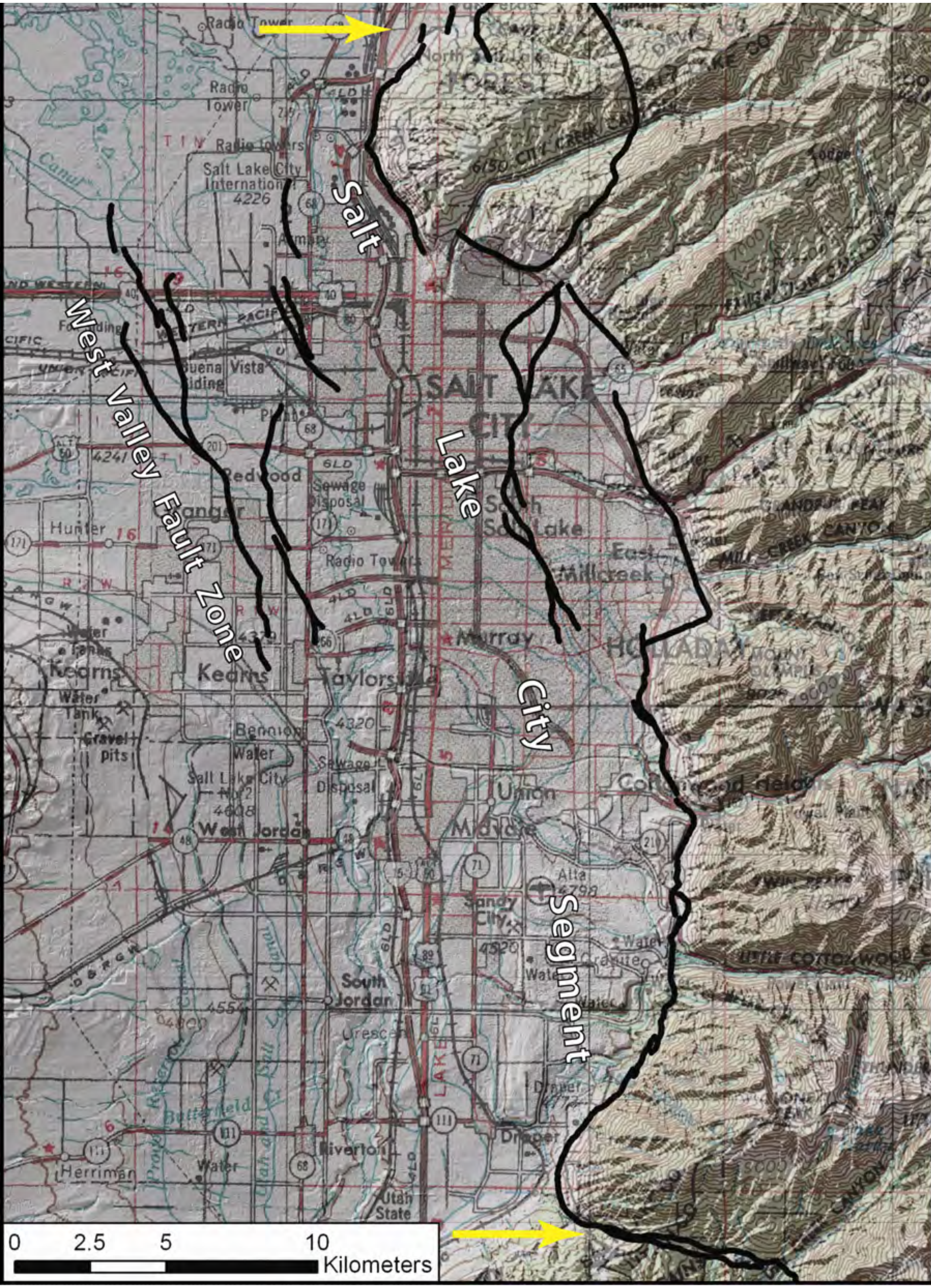
Fault Length* – proxy for fault maturity

Topographic Relief – proxy for long-term slip rate

Percent Overlap – comparative indicator of controlling structure

(Haller and Harmsen, 2011)

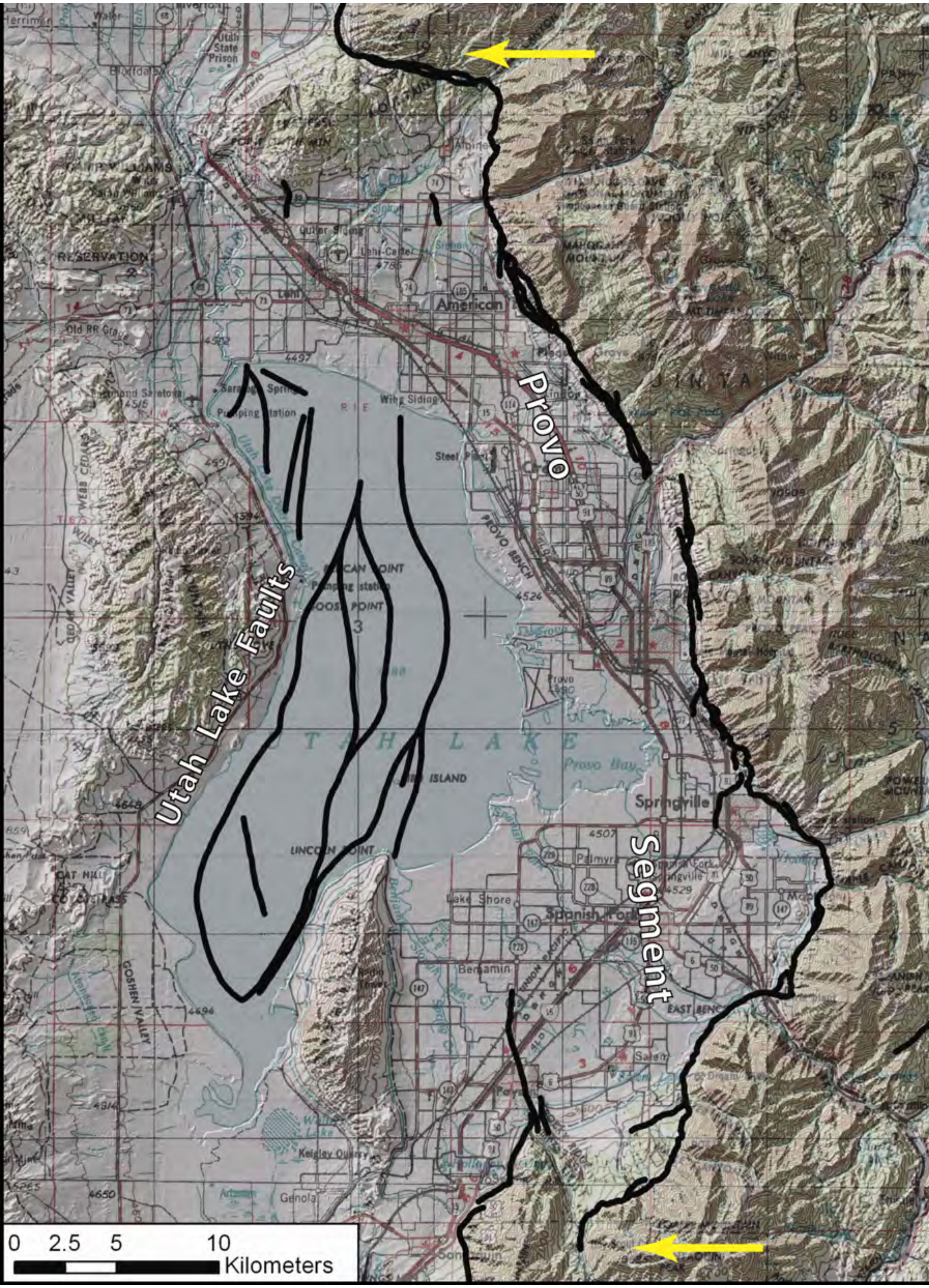
*Lengths used in this analysis may include multiple faults or fault sections, to represent a basin-bounding structure as a whole, and were measured as straight-line distances in Google Earth. Therefore, lengths used to select master vs. subsidiary faults may differ from lengths assigned as model parameters to calculate M.



West Valley Fault Zone – Salt Lake City Segment

WVFZ	SLCS
Length (km)	
16	40
Percent Overlapped	
100	40
Topographic Relief (m)	
6 (max.)	1950
2 (ave.)	1070
Length x Relief (km^2)	
0	43

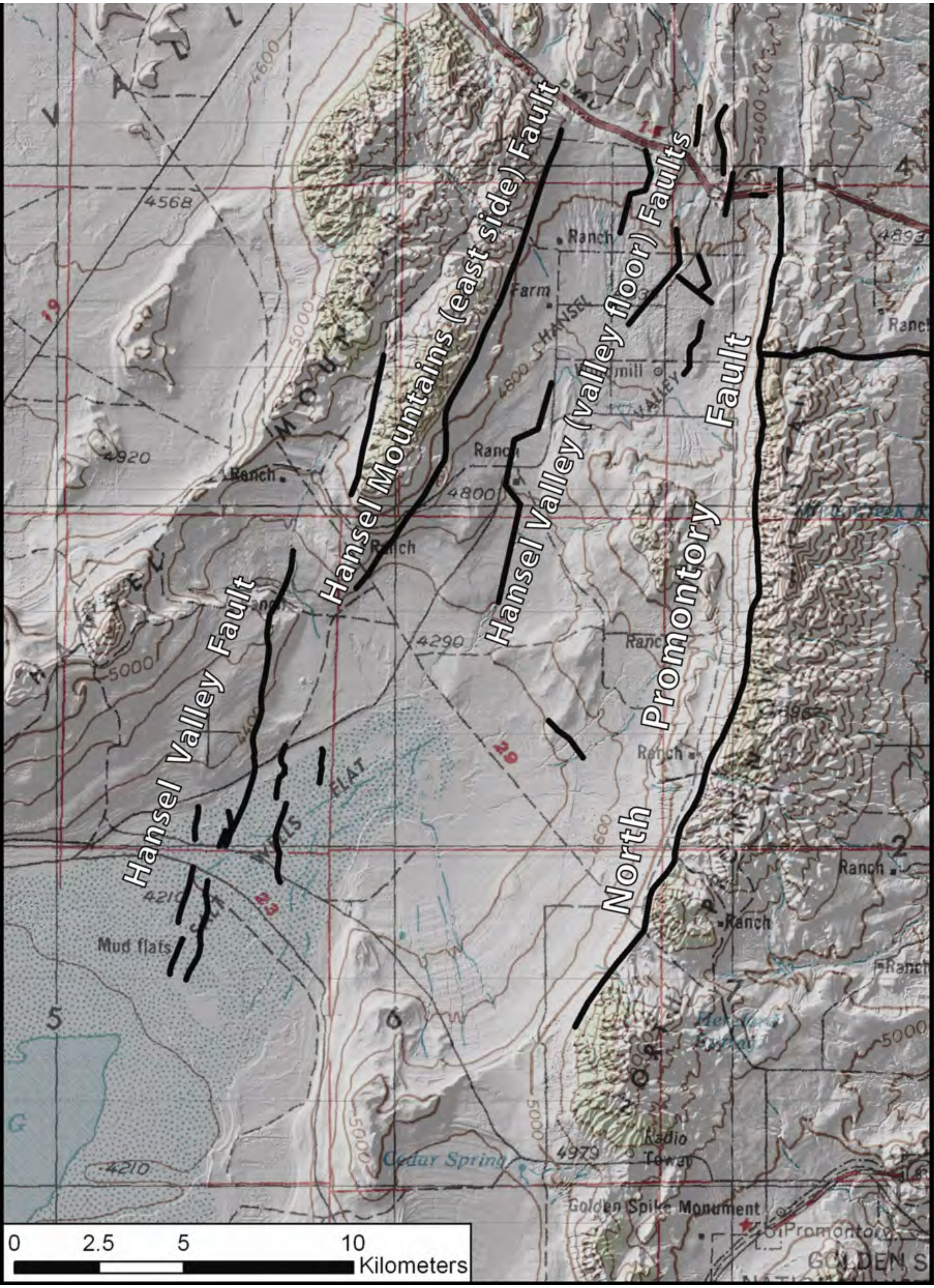
Master fault – Salt Lake City segment



Utah Lake Faults – Provo Segment

ULF	PS
Length (km)	
31	59
Percent Overlapped	
100	50
Topographic Relief (m)	
5 (max.)	1880
4 (ave.)	960
Length x Relief (km^2)	
0	57

Master fault – Provo segment

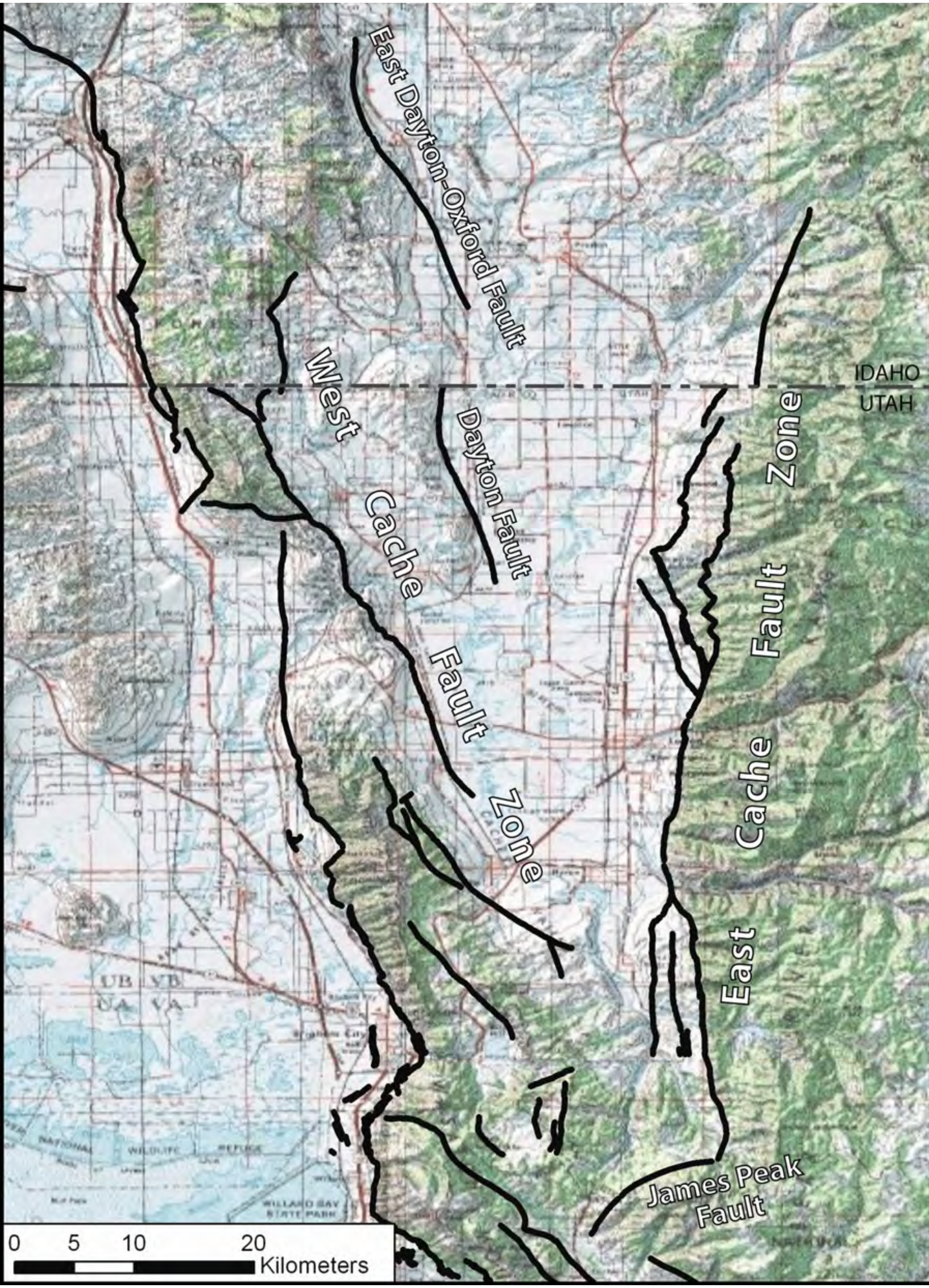


Hansel Valley Faults* – North Promontory Fault

HVF	NPF
Length (km)	
30	26
Percent Overlapped	
83	100
Topographic Relief (m)	
480 (max.)	420
250 (ave.)	220
Length x Relief (km^2)	
8	6

Master fault – [Hansel Valley, etc.]

*Includes Hansel Valley fault, Hansel Mountains (east side) fault, and Hansel Valley (valley floor) faults

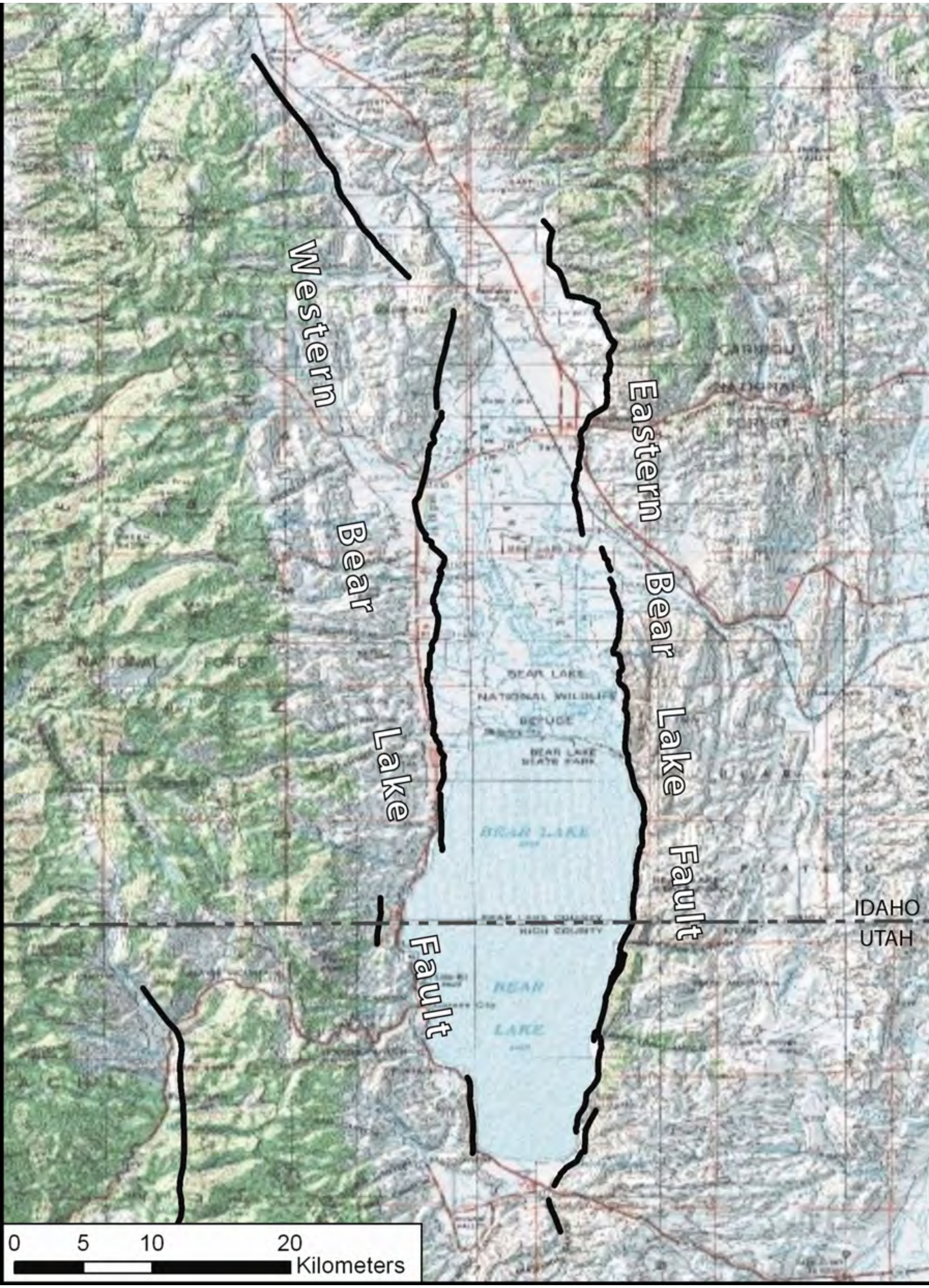


West Cache Fault – East Cache Fault*

WCF	ECF
Length (km)	
59	83
Percent Overlapped	
100	71
Topographic Relief (m)	
1250 (max.)	1440
530 (ave.)	860
Length x Relief (km^2)	
31	71

Master fault – East Cache fault

*Includes James Peak fault



Western Bear Lake Fault* – Eastern Bear Lake Fault

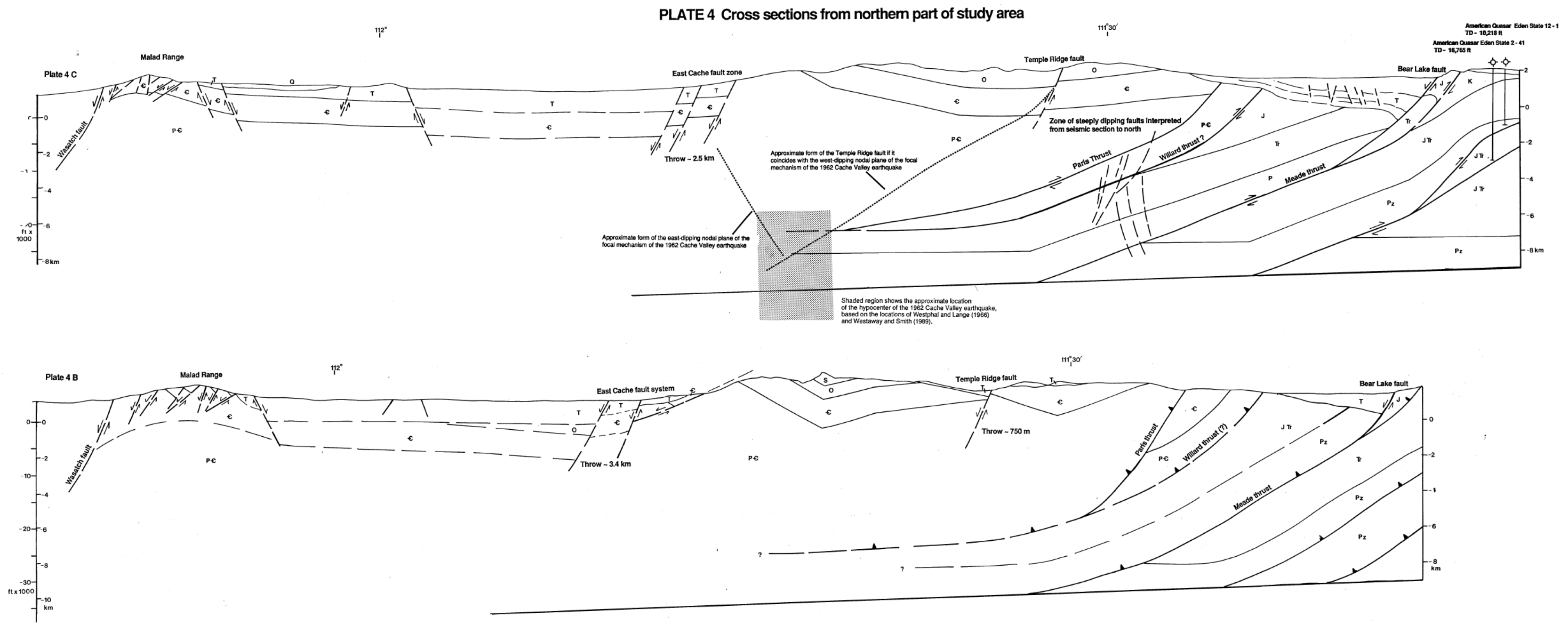
WBLF	EBLF
<u>Length (km)</u>	
82	73
<u>Percent Overlapped</u>	
82	92
<u>Topographic Relief (m)</u>	
900 (max.)	600
740 (ave.)	370
<u>Length x Relief (km^2)</u>	
61	27

Master fault – [Western Bear Lake fault]

*Includes Bear Lake (west side) fault

Western Bear Lake Fault – Eastern Bear Lake Fault

Fault metrics suggest that the Western Bear Lake fault is the master fault, but interpreted seismic reflection data indicate that the Eastern Bear Lake fault is the master fault.



From Evans (1991)

Joes Valley Faults (west side) – Joes Valley Faults (east side)

WJVF	EJVF
Length (km)	
84	84
Percent Overlapped	
100	100
Topographic Relief (m)	
1000 (max.)	630
710 (ave.)	360
Length x Relief (km^2)	
60	30

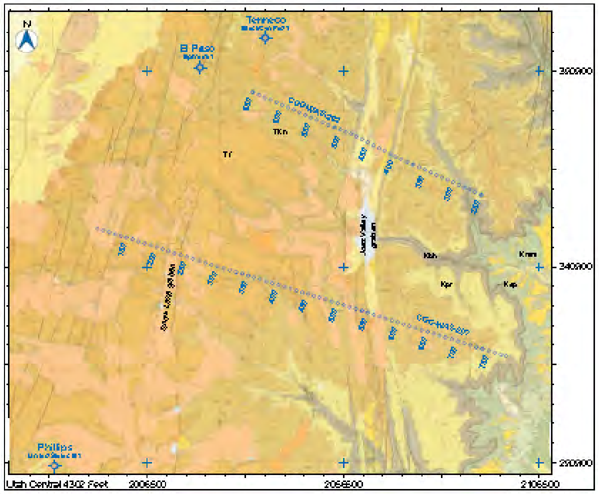
Master fault – [west side faults]

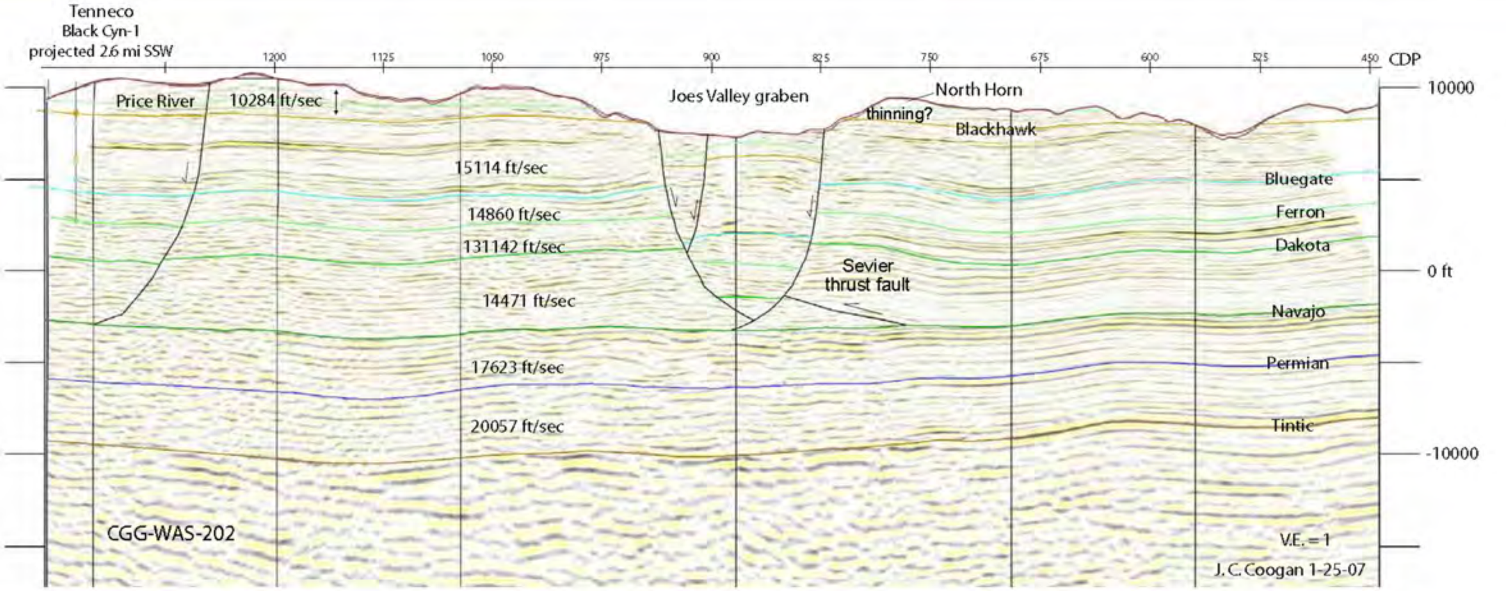
Fault metrics suggest that the western Joes Valley fault system comprises the master fault, but interpreted seismic reflection data indicate that the eastern fault system comprises the master fault.

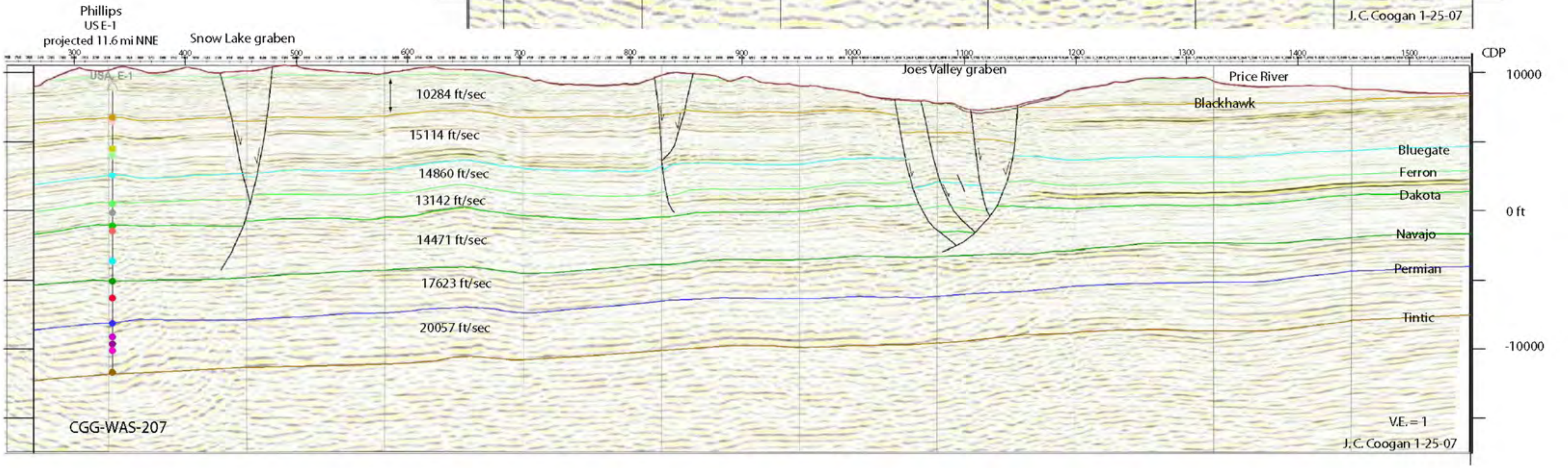
Joes Valley Faults

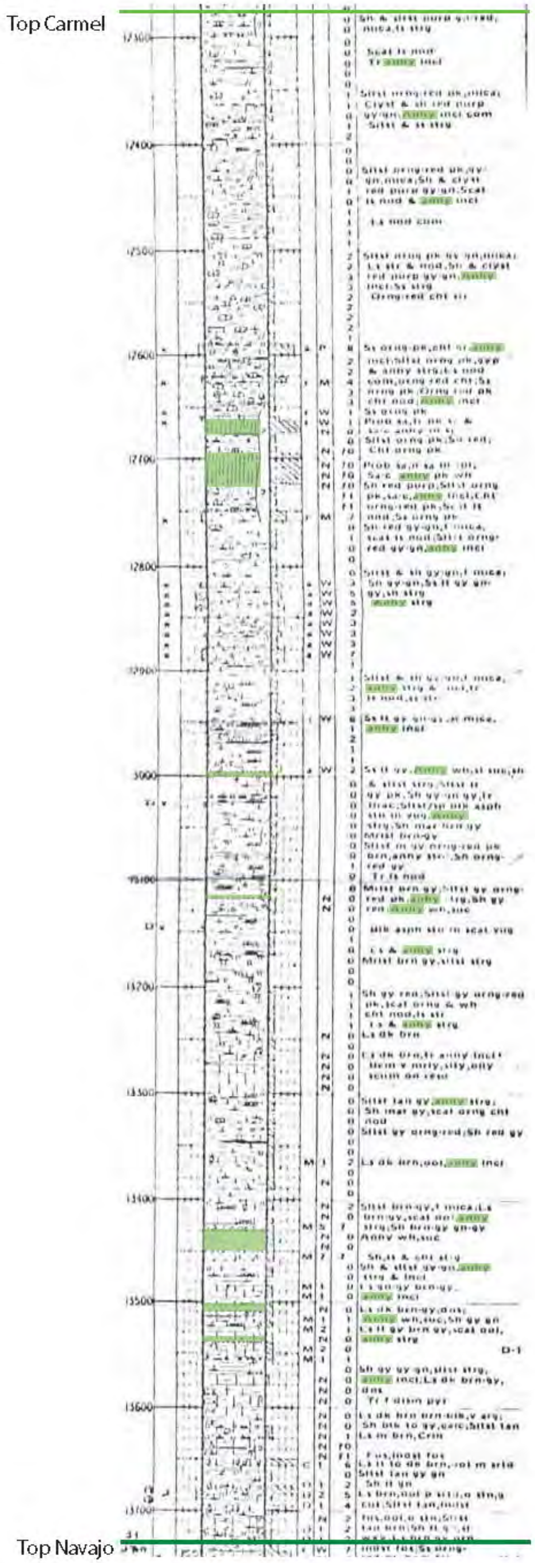
Vert. displacement of lower T and Upper K strata across main graben-bounding faults is 600–900 m.

Depth-migrated seismic reflection profiles (Coogan, 2008, *in* Anderson, 2008)









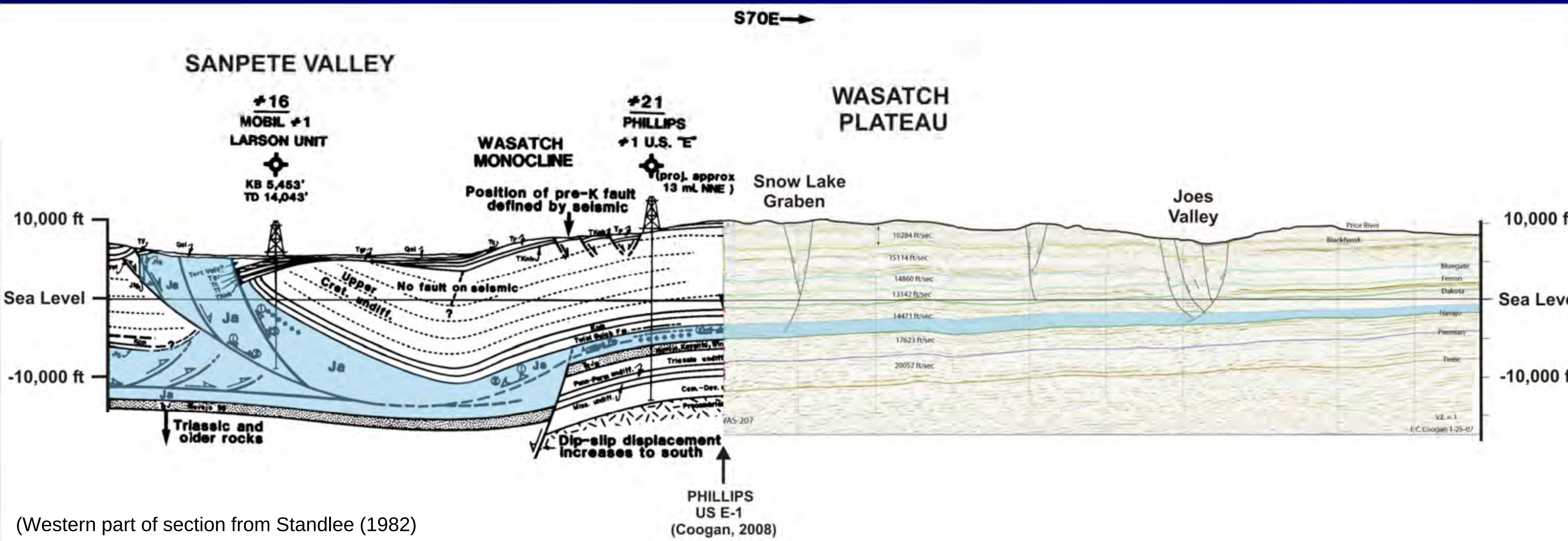
Joes Valley Faults

<u>Phillips US E-1 Well</u>

- Carmel Formation 1456 ft (444 m) thick
- Contains anhydrite throughout (highlighted in green)
- 5–40 ft thick (1.5–12 m) beds in middle 900 ft (275 m) of formation

(Coogan, 2008, *in* Anderson, 2008)

Joes Valley Faults



(Western part of section from Standlee (1982)

From Anderson (2008)

Master/Subsidiary Fault Classification

Master/Subsidiary Fault Classification for Antithetic Fault Pairs in the WGUEP Study Area.

Fault	Length	Overlap	Relief	Length X Relief	Classification
West Valley fault zone	S	S	S	S	**S**
Salt Lake City segment	M	M	M	M	**M**
Utah Lake faults	S	S	S	S	**S**
Provo segment	M	M	M	M	**M**
Hansel Valley–Hansel Mtns (east side) faults	[M]	[M]	M	M	**M** (0.25)
North Promontory fault	[S]	[S]	S	S	**M**[1] (0.75)
West Cache fault	S	S	S	S	**S**
East Cache fault (incl. James Peak fault)	M	M	M	M	**M**
Western Bear Lake fault	S	[S]	M	M	**S**
Eastern Bear Lake fault	M	[M]	S	S	**M**[2]
Joes Valley faults (west side)	—	—	M	M	**S**
Joes Valley faults (east side)	—	—	S	S	**M**[3]

M, master fault; S, subsidiary fault.
Brackets indicate <10% difference in parameter values.
[1] *Likelihood for master fault based on regional pattern of half-graben structure.*
[2] *Master fault based on interpreted seismic reflection data (Evans, 1991).*
[3] *Master fault based on interpreted seismic reflection data (Anderson, 2008); neither fault penetrates deeper than about 3.4 km.*

Several examples where fault metrics provide clear indication of master fault
- Salt Lake City segment, Provo segment, East Cache fault zone

Several examples where fault metrics provide somewhat ambiguous results
- Hansel Valley – North Promontory, Western – Eastern Bear Lake faults, Joes Valley faults

Strawman Model Parameters for Antithetic Fault Pairs in the WGUEP Wasatch Front Study Region

Fault	Classification[1]	Dip[2] (degrees) (5th, 50th, 95th) (0.3–0.4–0.3)	Independent vs. Coseismic (vs. non-seismogenic)[3]
West Valley fault zone	S	35–50–65	0.55, 0.45
Salt Lake City segment	M	35–50–65	0.55, 0.45
Utah Lake faults	S	35–50–65	0.4, 0.3 (0.3)[4]
Provo segment	M	35–50–65	0.55, 0.45
Hansel Valley + Hansel Mtns (east side) faults	M (0.25)	35–50–90[5]	0.55, 0.45
North Promontory fault	M (0.75)	35–50–65	0.55, 0.45
West Cache fault	S	35–50–65	0.7, 0.3[6]
East Cache fault + James Peak fault	M	35–50–65	0.8, 0.2[6]
Western Bear Lake fault	S	35–50–65	0.55, 0.45
Eastern Bear Lake fault	M	35–50–65	0.55, 0.45
Joes Valley faults (west side)	S	55–70–85[7]	0.3, 0.4 (0.3)[8]
Joes Valley faults (east side)	M	55–70–85[7]	0.4, 0.3 (0.3)[8]

1 *M, master fault; S, subsidiary fault (truncated at depth by master fault).*
2 *Default WGUEP dip distribution (50° ± 15°) except where noted.*
3 *Preliminary WGUEP recommended range except where noted.*
4 *Potential non-seismogenic character of the fault weighted 0.3 after S. Olig (p[a] = 0.7; written communication).*
5 *Preliminary WGUEP recommended range.*
6 *Higher weights for independent behavior relative to other fault pairs based on greater average separation distance between the West and East Cache fault; higher weight for East Cache fault being independent relative to West Cache fault based on higher likelihood of East Cache fault being the master fault.*
7 *Range based on interpreted seismic reflection data (Anderson, 2008).*
8 *Potential non-seismogenic character of the faults weighted 0.3 after S. Olig (p[a] = 0.7; written communication); higher weight for east side fault being independent relative to west side fault based on higher likelihood of east side fault being the master fault.*

Final Recurrence Models

Working Group on Utah Earthquake Probabilities

Ivan G. Wong
Seismic Hazards Group
URS Corporation
Oakland, CA

Salt Lake City, UT 16 February 2012

Final Models

- Wasatch and Oquirrh-Great Salt Lake Faults
  0.9 Maximum Magnitude (Mmin 6.75)
  0.1 Truncated Exponential (Mmin 6.75)

- Other Faults
  0.8 Maximum Magnitude (Mmin 6.75)
  0.2 Truncated Exponential (Mmin 6.75)

- Background Seismicity (also includes earthquakes that may be on faults)
  1.0 Truncated Exponential (**M** 5.0 to Mmax 7.0)

- For faults that have Mmax < 6.75, only the Maximum Magnitude will be used.

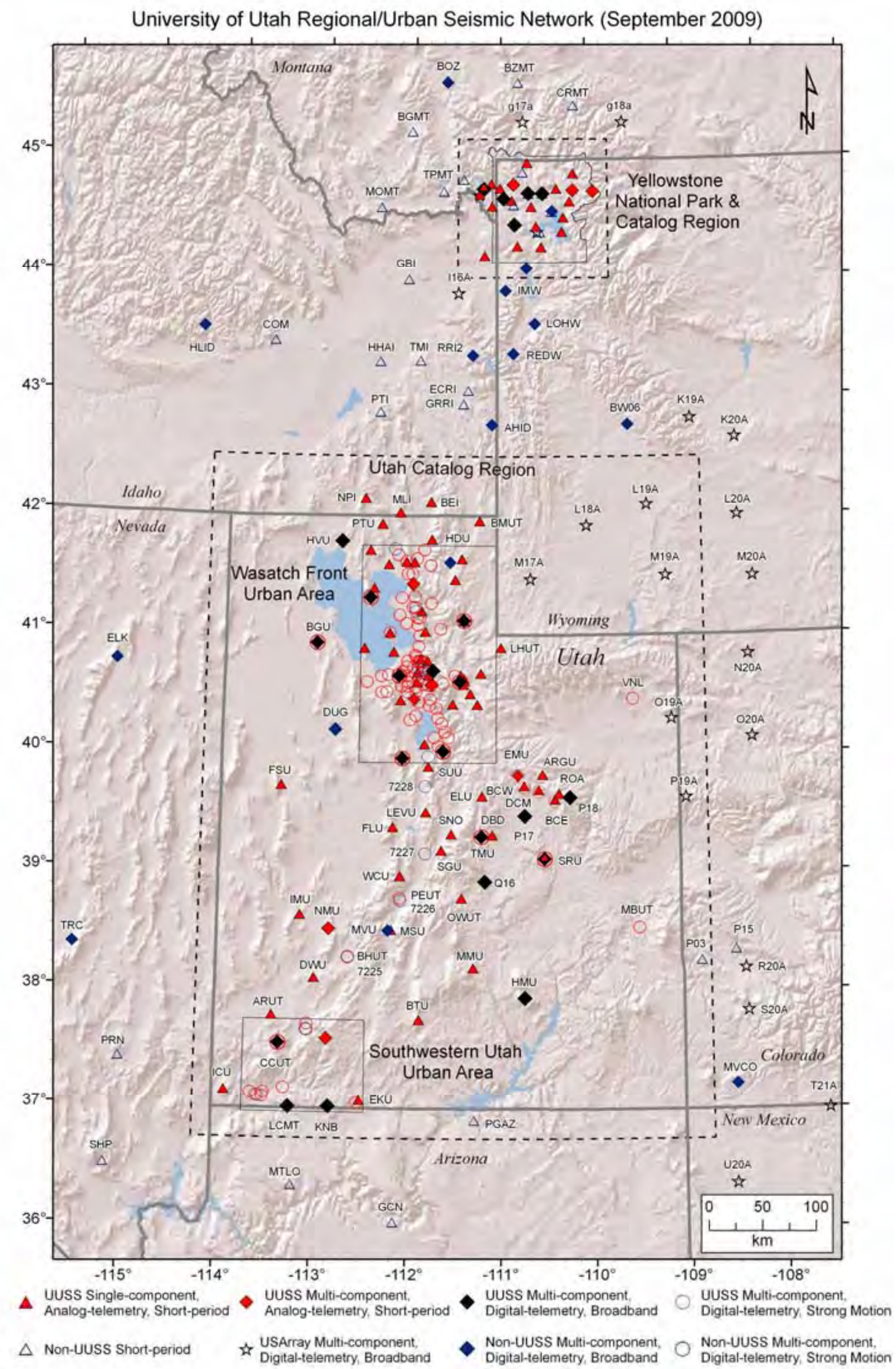
Maximum Earthquake Focal Depths in the WGUEP Wasatch Front Region

by

James C. Pechmann
University of Utah, Salt Lake City, Utah

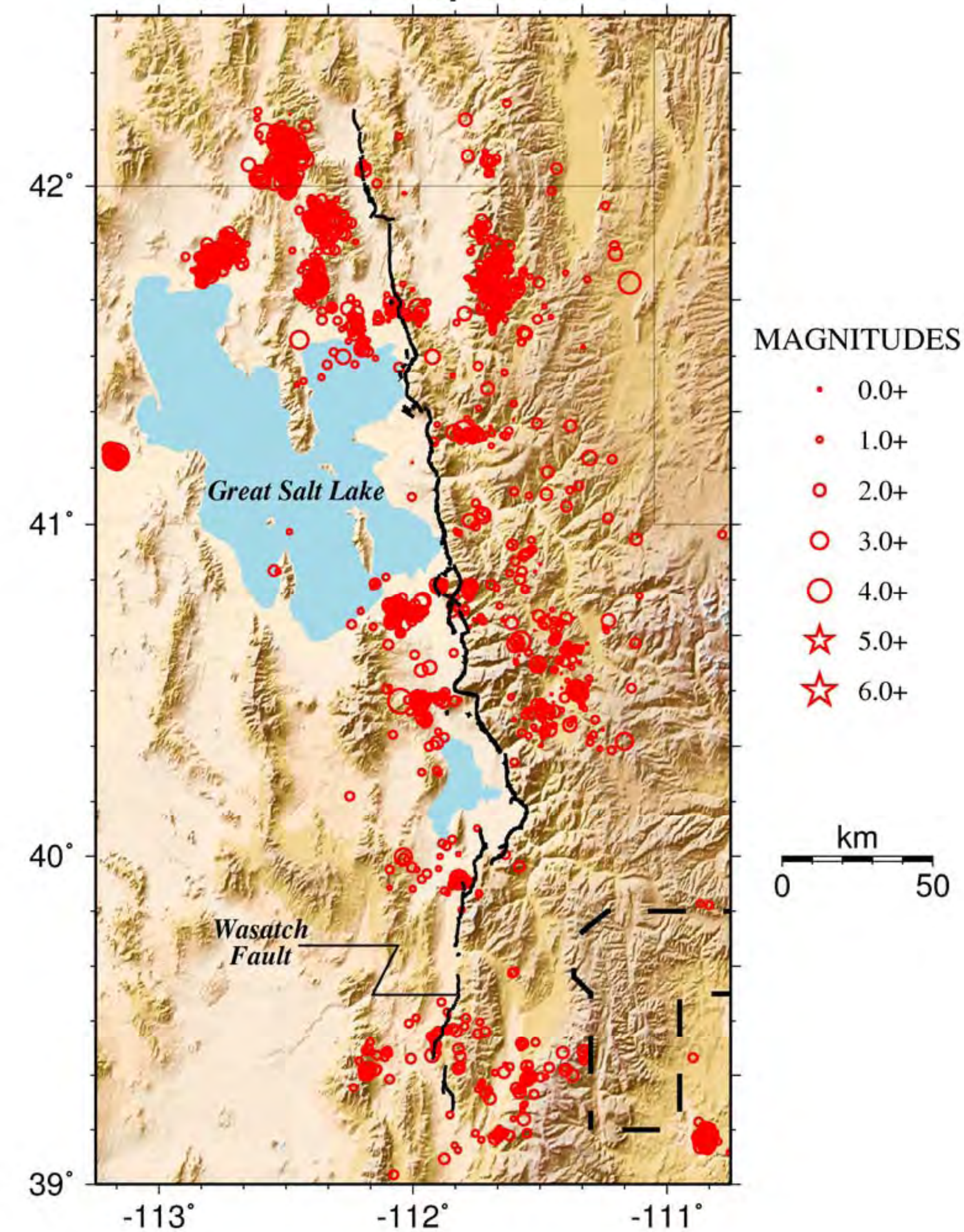
Focal Depth Quality Criteria

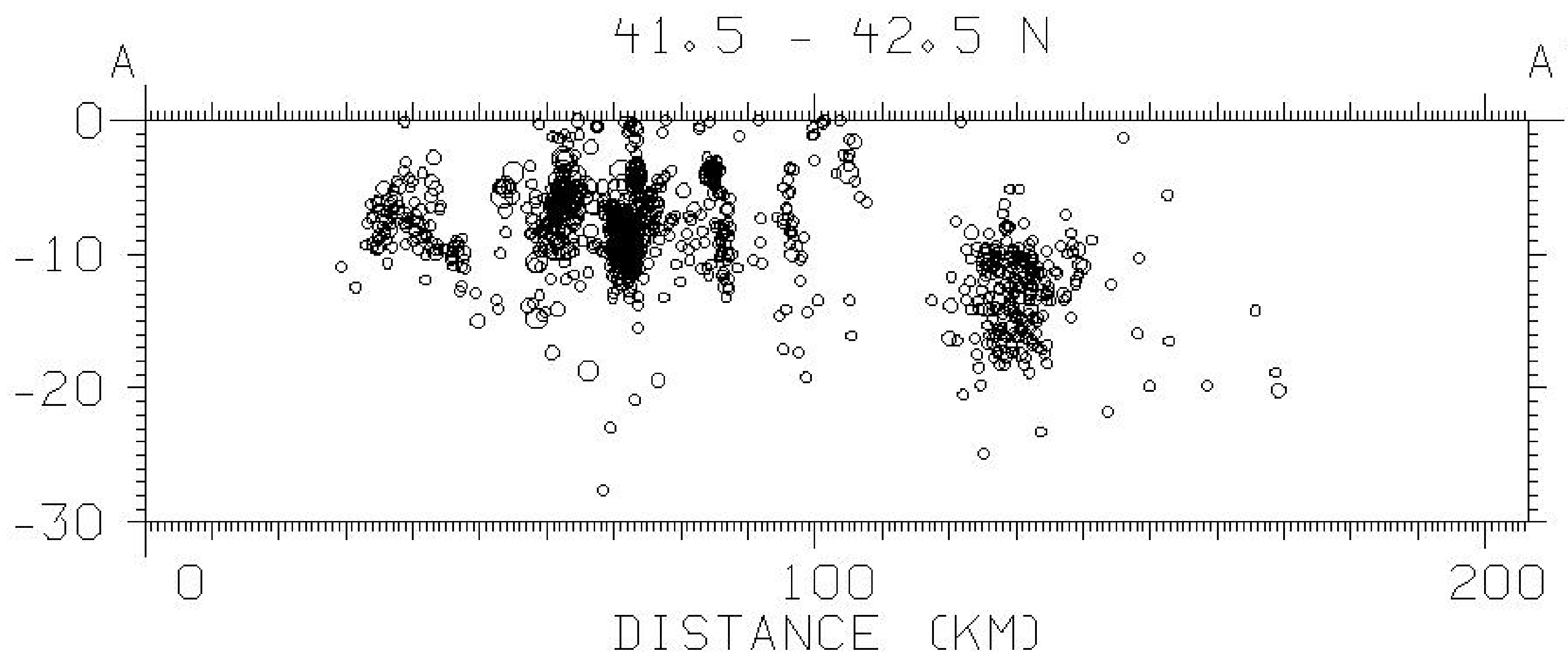
- Epicentral distance to the nearest station less than or equal to the focal depth or 5 km, whichever was larger, and
- Standard vertical hypocentral error (ERZ) of 2 km or less, as calculated by the location program

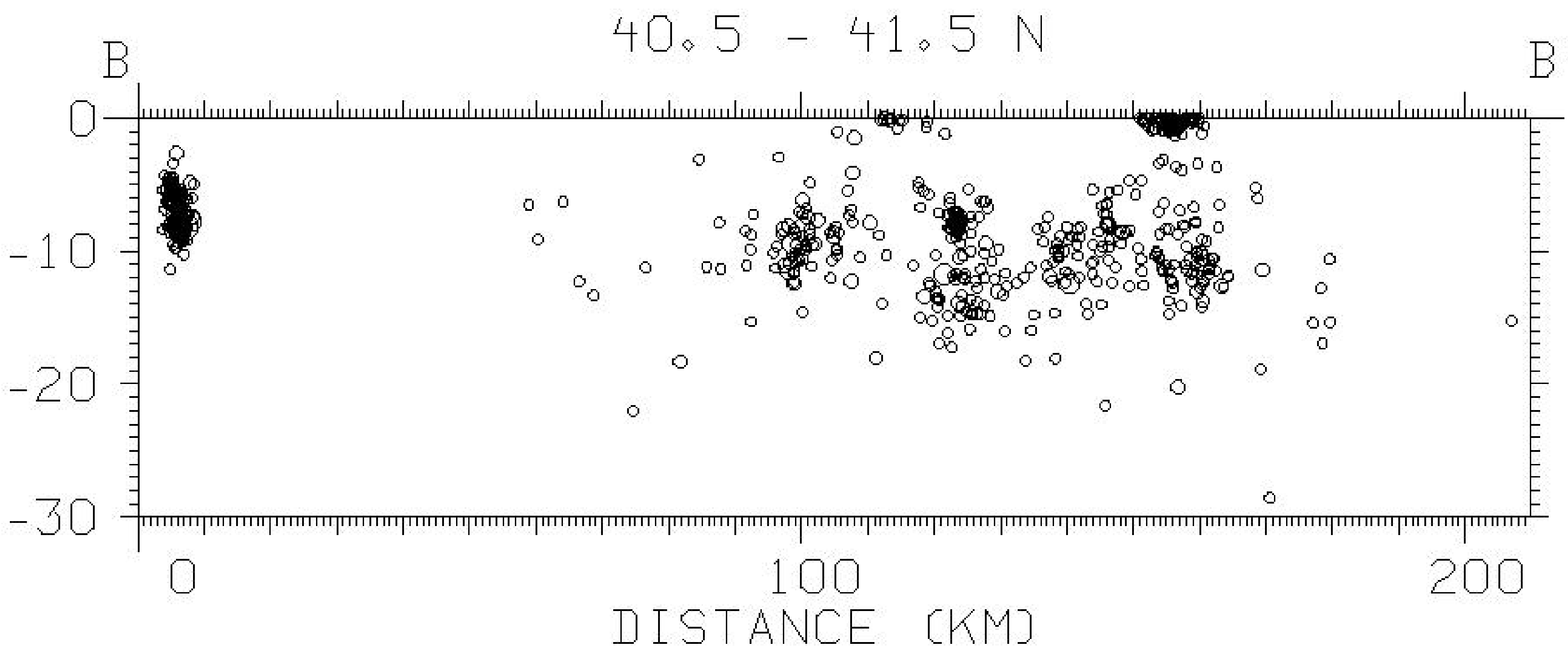


UUSS Network September 2009

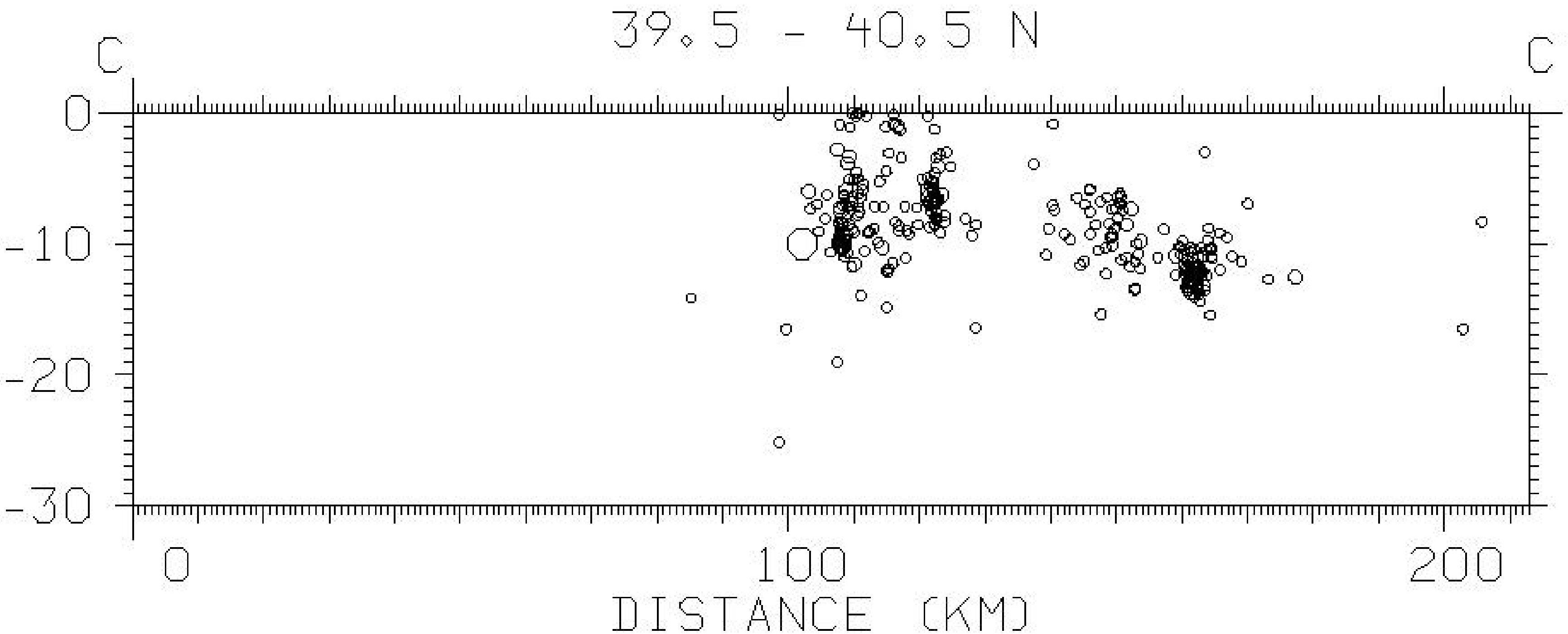
October 1974 - September 2011



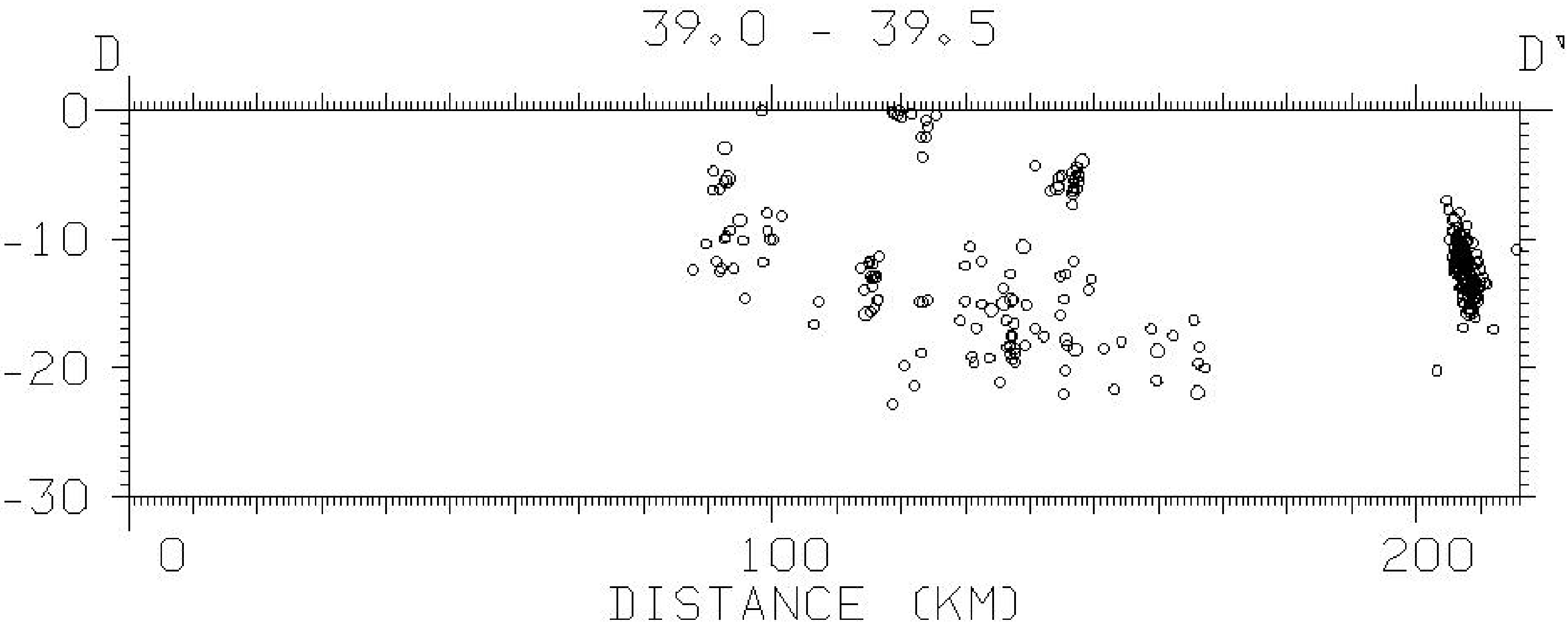

41.5 - 42.5 N
A
A'
0
-10
-20
-30
0
100
200
DISTANCE (KM)

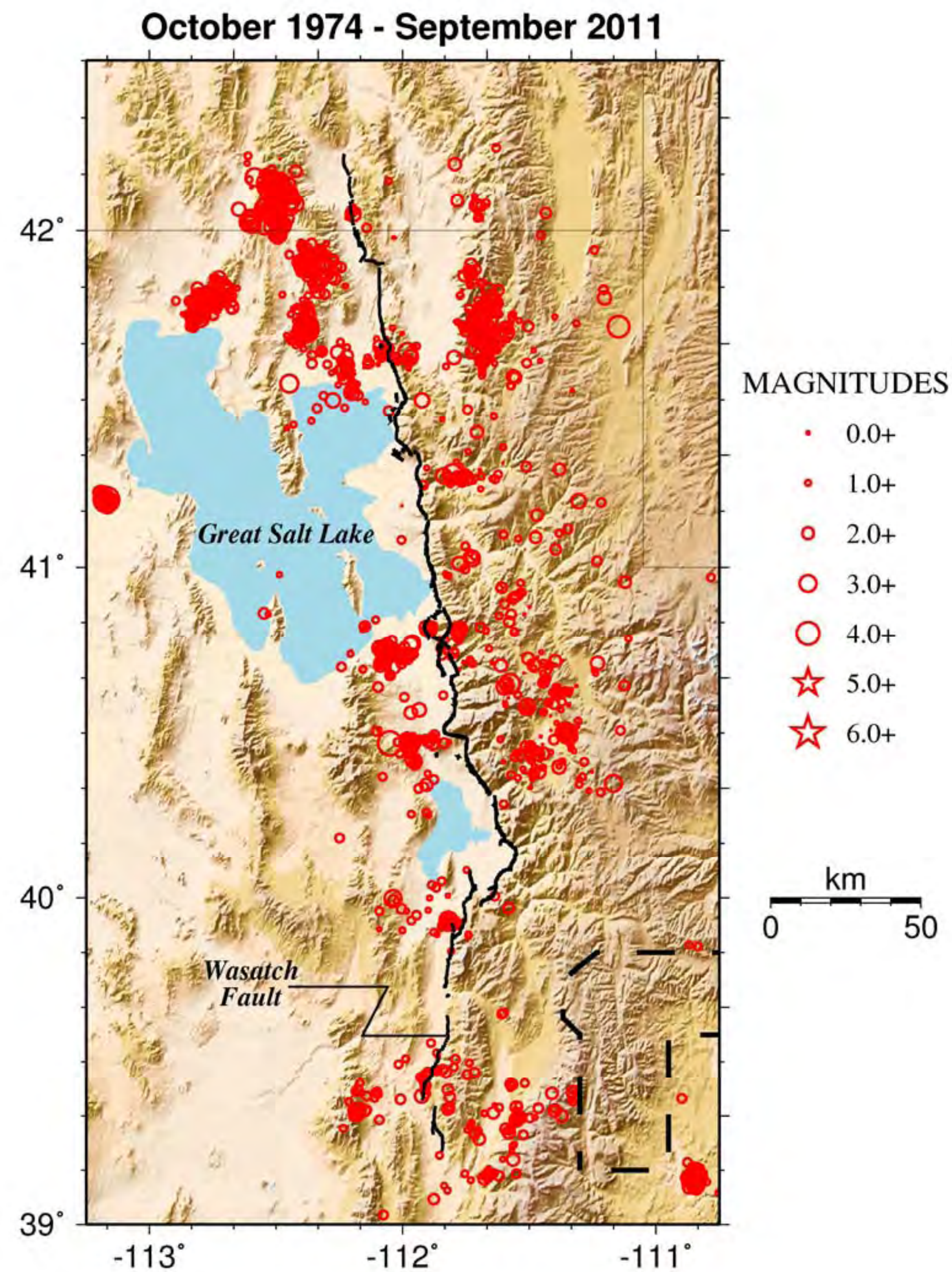


40.5 - 41.5 N
B
B'
0
-10
-20
-30
0
100
200
DISTANCE (KM)



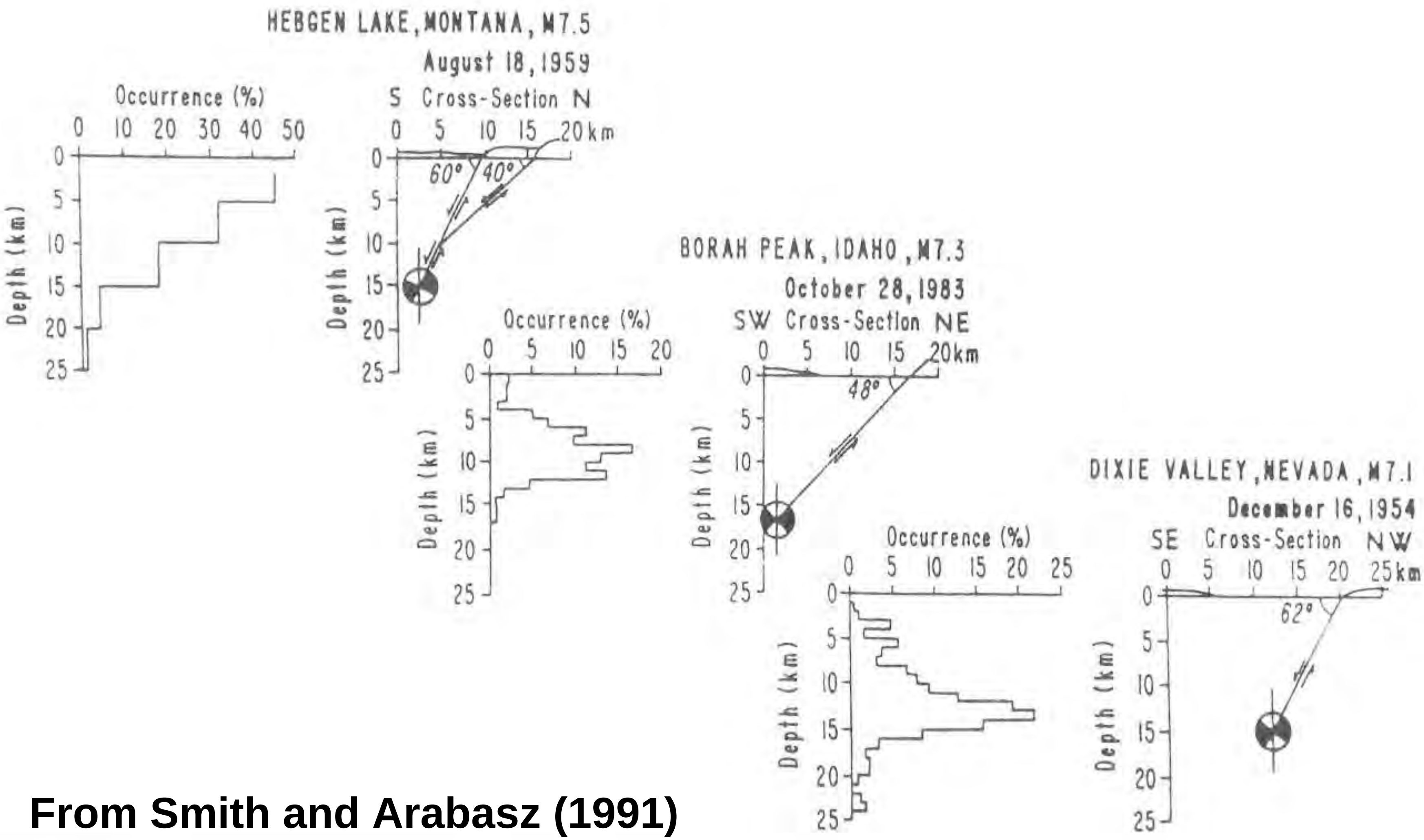
39.5 - 40.5 N
C
C'
0
-10
-20
-30
0
100
200
DISTANCE (KM)


39.0 - 39.5
D
D'
0
-10
-20
-30
0
100
200
DISTANCE (KM)

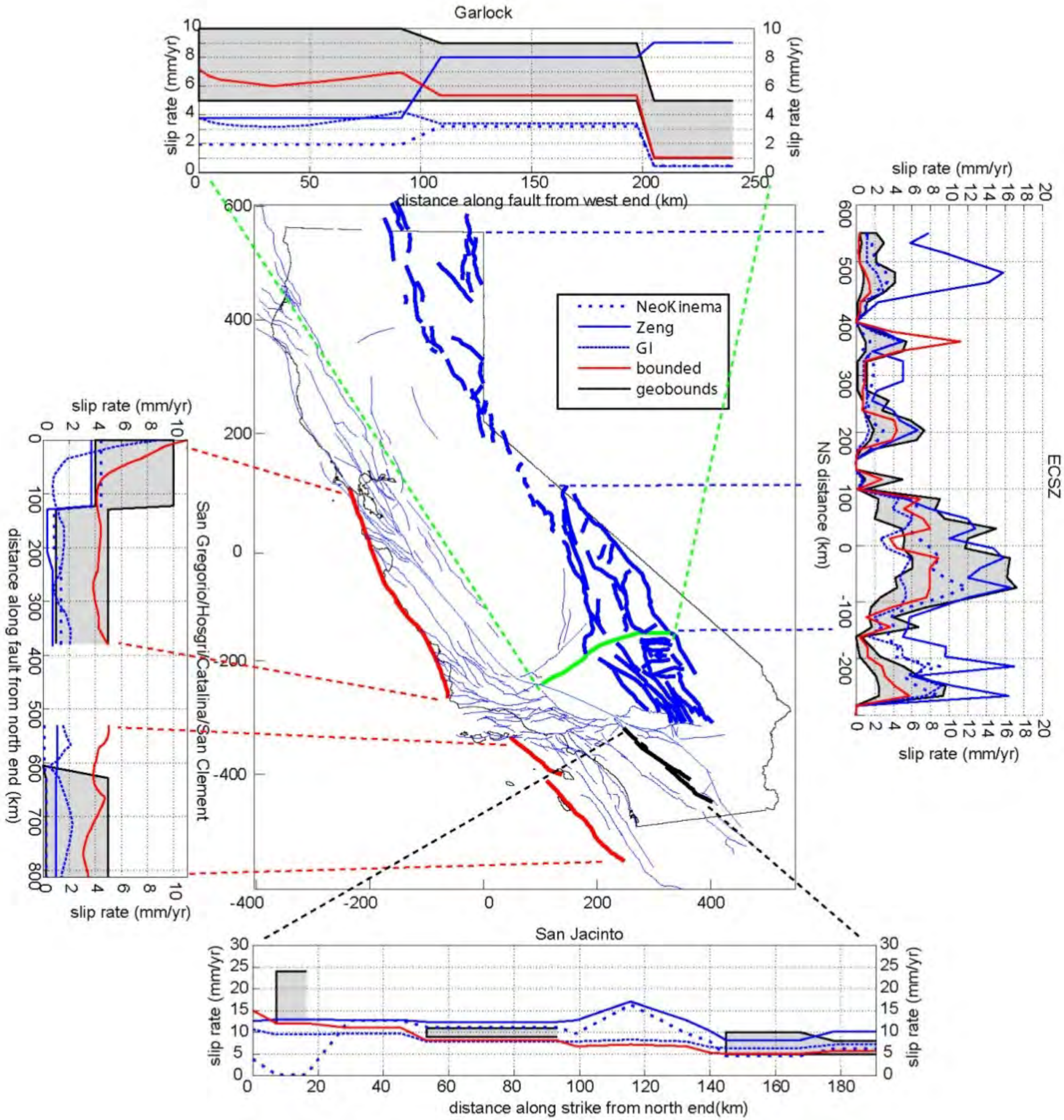

October 1974 - September 2011
42˚
41˚
40˚
39˚
-113˚
-112˚
-111˚
Great Salt Lake
Wasatch
Fault
MAGNITUDES
0.0+
1.0+
2.0+
3.0+
4.0+
5.0+
6.0+
km
0
50

Focal Depth Percentiles

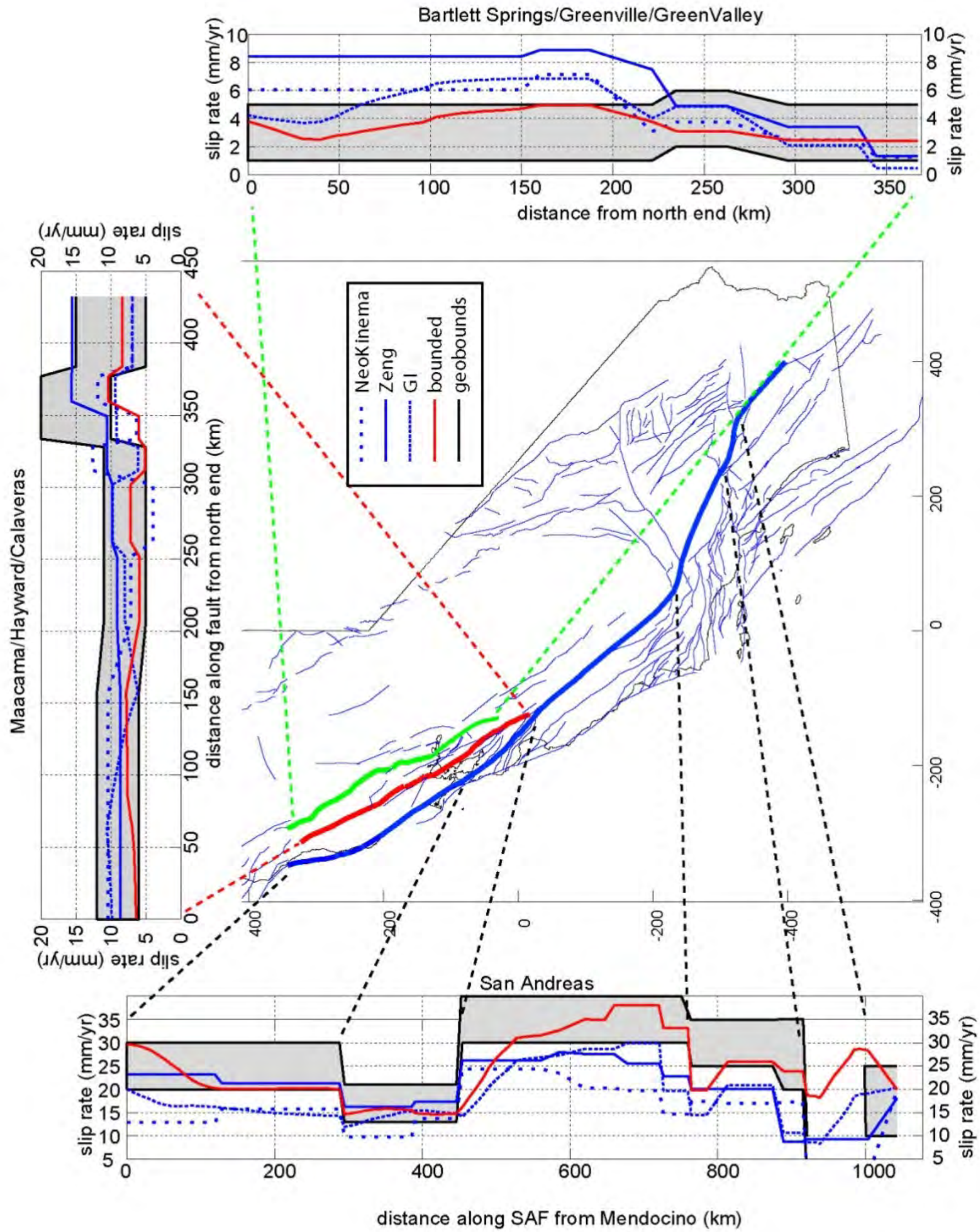
	West of 111° 50´	East of 111° 50´	Entire Region
Number of Events	1505	1018	2523
90th Percentile Depth	11.1 km	16.2 km	14.1 km
95th Percentile Depth	12.4 km	18.0 km	16.0 km



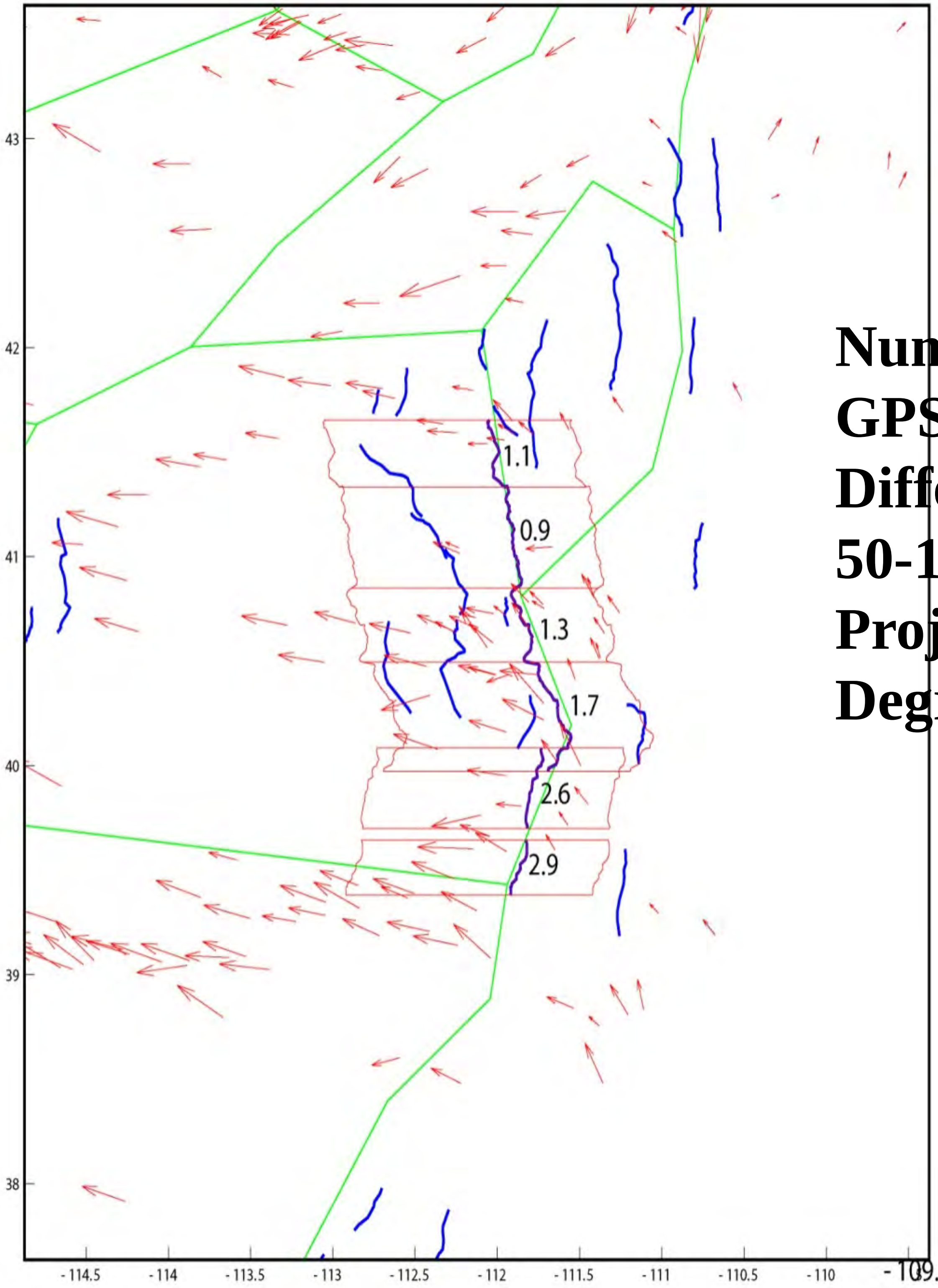
From Smith and Arabasz (1991)



Garlock
slip rate (mm/yr)
distance along fault from west end (km)
NeoKinema
Zeng
GI
bounded
geobounds
ECSZ
NS distance (km)
slip rate (mm/yr)
San Gregorio/Hosgri/Catalina/San Clement
distance along fault from north end (km)
San Jacinto
distance along strike from north end(km)

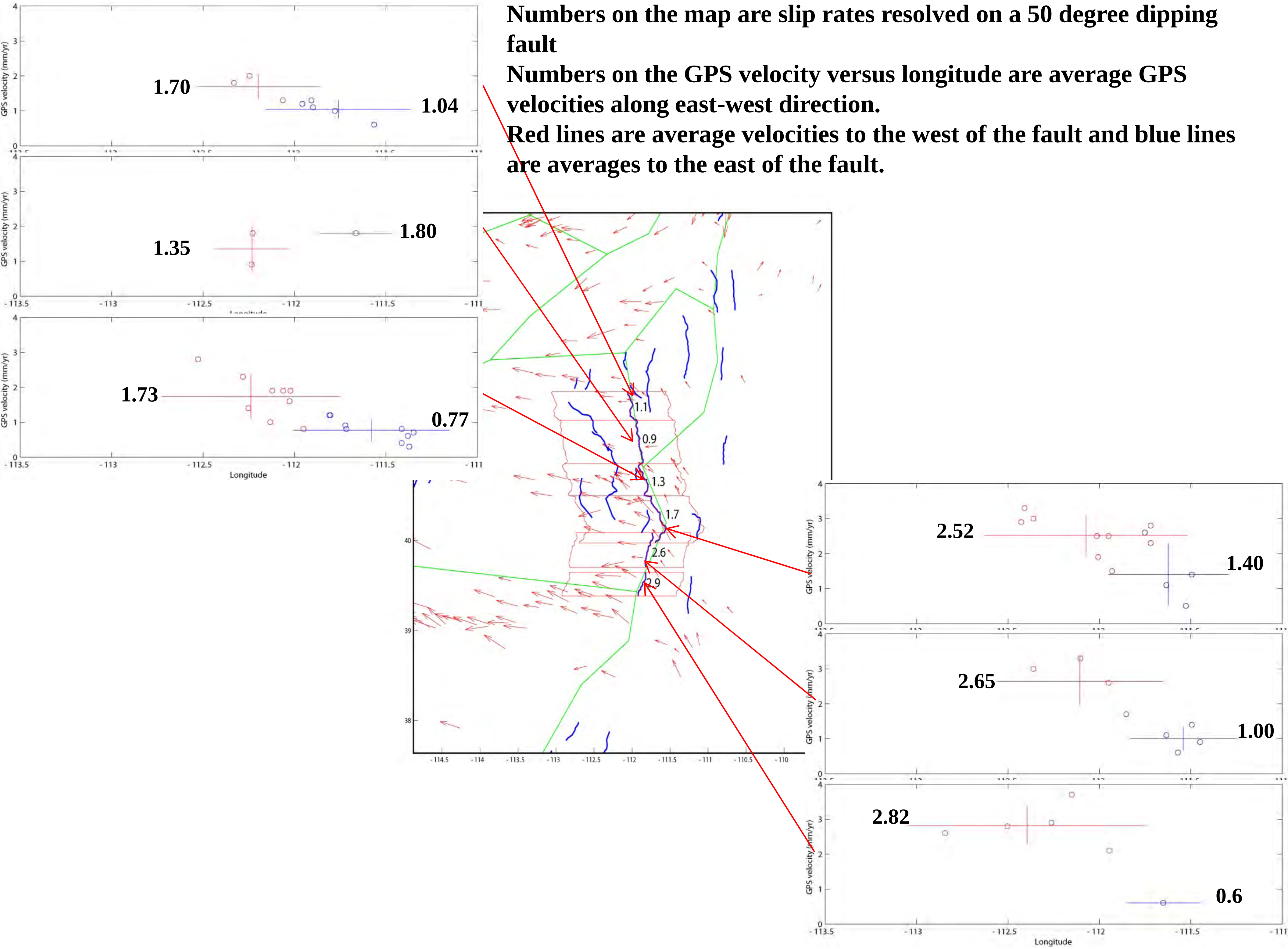


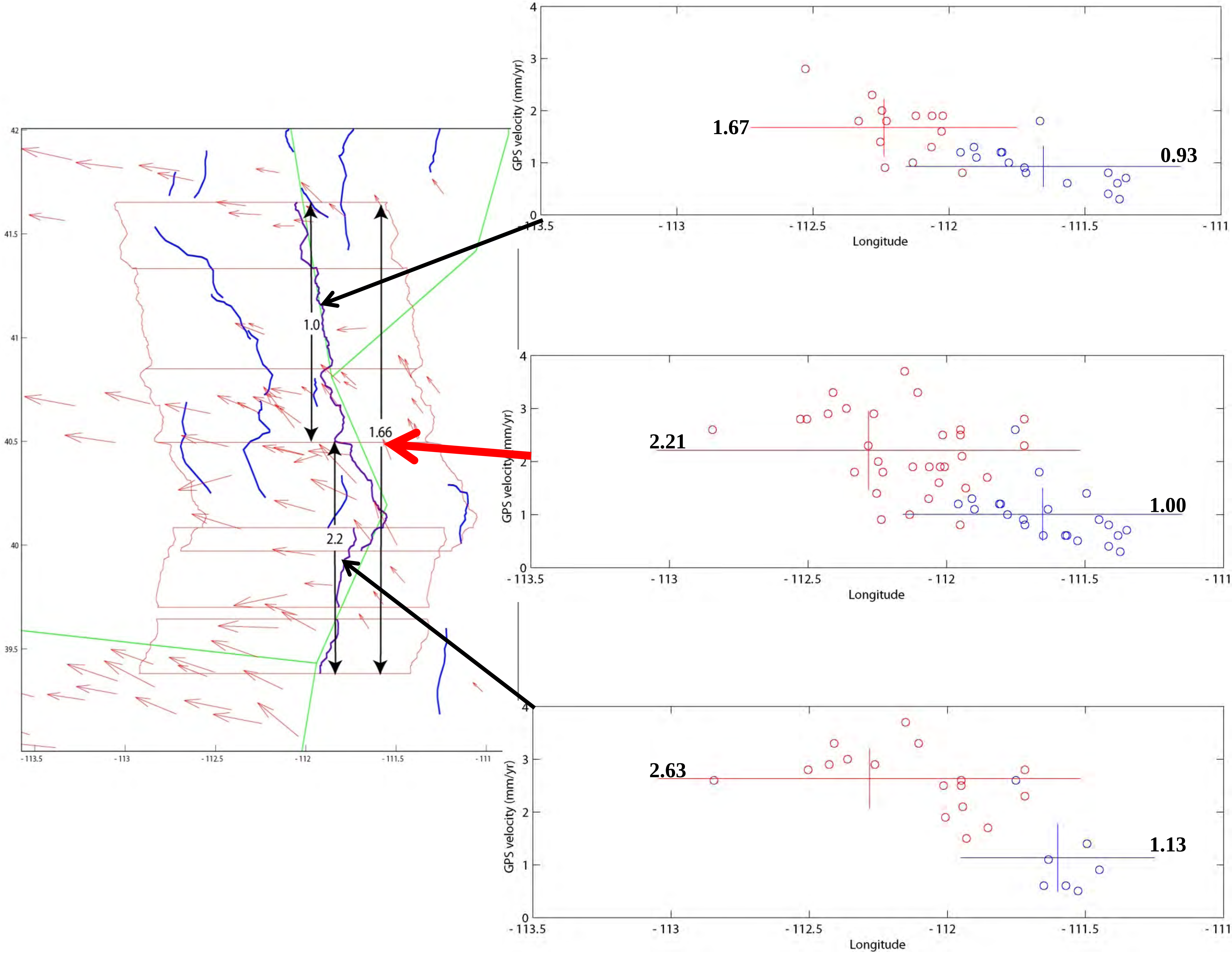
Bartlett Springs/Greenville/GreenValley
slip rate (mm/yr)
distance from north end (km)
Maacama/Hayward/Calaveras
distance along fault from north end (km)
NeoKinema
Zeng
GI
bounded
geobounds
San Andreas
distance along SAF from Mendocino (km)



Numbers are total GPS Vector Differences within 50-100 km from fault Projected on a 50 Degree fault.

Numbers on the map are slip rates resolved on a 50 degree dipping fault
Numbers on the GPS velocity versus longitude are average GPS velocities along east-west direction.
Red lines are average velocities to the west of the fault and blue lines are averages to the east of the fault.





1.0
1.66
2.2
1.67
0.93
2.21
1.00
2.63
1.13
GPS velocity (mm/yr)
Longitude
- 113.5
- 113
- 112.5
- 112
- 111.5
- 111
42
41.5
41
40.5
40
39.5

UCERF3 Evaluation of Geodetic Models in California

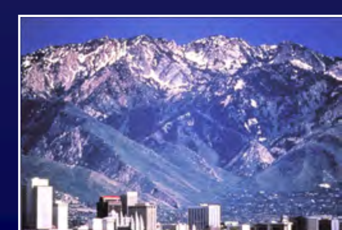
Working Group on Utah Earthquake Probabilities

Ivan G. Wong
Seismic Hazards Group
URS Corporation
Oakland, CA

Salt Lake City, UT 16 February 2012

Observations

- Presentation by Kaj Johnson, University of Michigan at 2012 Northern California Earthquake Hazards Workshop
- Systematic misfits: geodetic rates were to high along northern San Andreas and too low along southern San Andreas. Match was good along central San Andreas (SF Bay area).
- High bias to low slip rates – Tim Dawson
- Expect bias to be opposite – Ray Weldon



Observations

- Possible explanations
  - Geologic rates overestimated?
  - Deformation models inadequate?
  - Missing postseismic deformation?
  - Temporal variation in velocity field?
  - Some time-dependent mantle flow?
  - Internal block deformation?
- Reduce block size to improve match?
- Effect of locking depth is small

Observations

- How to evaluate block model assumption?
- None of the models fit the data – Kaj Johnson
- Pushing rigid block models too far? – Paul Segall
- Choice of block geometry subjective – Wayne Thatcher
- Don’t rely on a single model – Kaj Johnson
- Careful model validations are needed – Kaj Johnson