UTAH GROUND SHAKING WORKING GROUP

Annual Meeting #4: Introduction

27 February 2007

2004 GSWG Plan

- Develop a community velocity model (CVM)
  - V_S30, R1, R2
- Evaluate seismic source and propagation path characteristics of Utah earthquakes, and site amplification and geotechnical characteristics of Utah soils
  - Stress drops, slip distributions, rupture processes
  - Hanging wall effects and directivity
  - Q and kappa
  - Non-linear dynamic soil properties

2004 GSWG Plan (cont.)

- Perform 3D modeling using CVM to evaluate the importance of basin structure on strong ground motions
  – Depth to R2, basin-edge/steep boundary effects
- Prepare large-scale Wasatch Front ground-shaking maps
  – Incorporate site conditions and basin effects

RESULTS OF 2006 MEETING: PRIORITIES FOR 2007

- Collect additional shallow Vs30 data for Weber/Davis/Utah Counties (pending analysis of 2005 data).
- Collect additional and/or re-analyze deep-basin-structure data (gravity, seismic, geologic).
- Continue laboratory dynamic soil testing to assess the appropriateness of shear modulus reduction and damping curves.

RESULTS OF 2006 MEETING: PRIORITIES FOR 2007 (cont.)

- Complete development and verification of the CVM and perform additional verification studies to assess sensitivity to basin parameters and determine whether velocity- and basin-structure data are adequate for use in developing urban hazards maps.
- Consider passive instrumental monitoring to model basin effects.

GOALS OF THE 2007 MEETING

- Present results of 2005-2006 research
- Discuss changes to NSHMs in Utah resulting from 2007 USGS update
- Discuss progress on CVM development and refinement

GOALS OF THE 2007 MEETING (cont.)

- Develop project plan for preparing Wasatch Front urban seismic hazard maps
  - Source characterization
  - Site-amplification and basin models
  - Attenuation
  - Schedule
- Identify 2008 research priorities

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UTAH GROUND SHAKING WORKING GROUP

Tuesday, February 27, 2007
Utah Department of Natural Resources Building, Room 1060
1594 W. North Temple, Salt Lake City

7:30 Continental breakfast

8:10 Introduction, overview of meeting and review of last year's priorities
Ivan Wong, Gary Christenson

8:30 Technical presentations of work completed

- 8:30 – Bill Stephenson, Rob Williams, USGS; 2006 USGS deep P-wave seismic imaging in Mapleton and Provo
- 9:00 – Brad Wilder, Ken Stokoe, NEES-UTA – Results of "Liquidator" intermediate and deep SASW surveys in Salt Lake Valley
- 9:30 - Greg McDonald, UGS; Jim Bay, USU – Site conditions map for the Wasatch Front

10:00 Break

10:20 Technical presentations of work completed (continued)

- 10:20 – Ivan Wong, URS, UU; Mark Petersen, USGS - update on PEER Next Generation of Attenuation Models results
- 10:40 – Mark Petersen, USGS – Use of BRPEWG recommendations and changes to Utah ground shaking levels in the 2007 draft NSHMs
- 11:20 – Harold Magistrale, Kim Olsen, SDSU; Jim Pechmann, UUSS - Wasatch Front community velocity model (CVM) demonstration and plans for verification - Discuss keeping CVM up-to-date with new data, availability for use in other research, and final resting place.

12:00 Lunch

A G E N D A

1:15	Discussion - Planning for preparing Wasatch Front seismic hazard maps Develop lists of parameters needed to produce hazard maps. Are data adequate?	
1:20	Seismic source characterization	Gary Christenson
1:40	Site amplification models	Ivan Wong
2:20	Basin-effects models	Mark Petersen
3:00	**Break**	
3:20	Discussion - Planning for preparing Wasatch Front seismic hazard maps (cont.)	
3:20	Attenuation relations	Ivan Wong, Mark Petersen
3:50	Set target completion dates and estimate schedule to produce maps	
4:00	Priorities for 2008 research	
5:00	**Adjourn**	

Update on USGS High-Resolution Seismic Imaging Investigations along Wasatch Front

W. Stephenson, R. Williams, J. Odum, D. Worley, R. Dart (USGS)
J. McBride (BYU)

Overview of Presentation

– USGS Open File Report describing S-wave minivibe, Vs30's in Salt Lake and Utah Valleys near release!!!

– P-wave minivibe seismic reflection in Utah Valley

– Planned field work for summer, 2007

(Acquire microtremor data from Portable arrays to derive deeper S-velocity)

USGS
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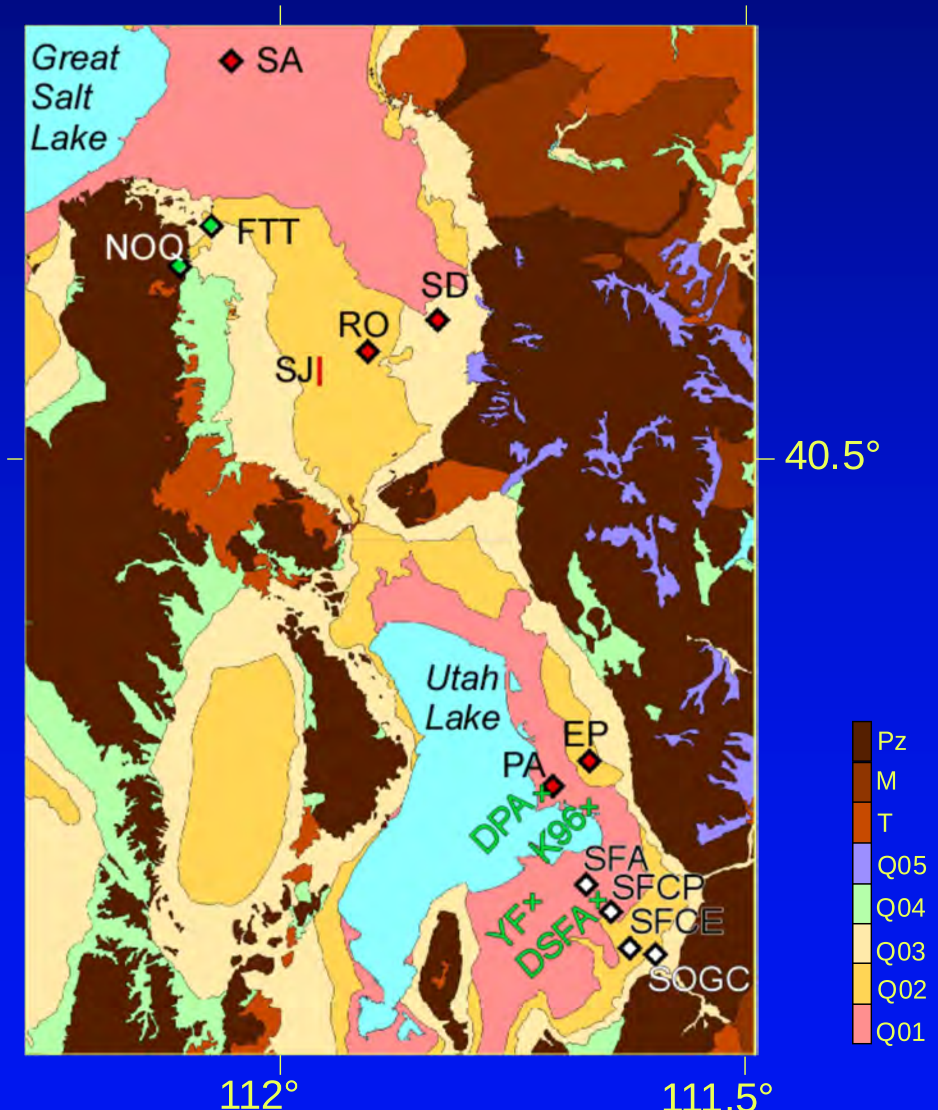
Soon-to-be-Released O.F. Report

"Miscellaneous High-Resolution Seismic Imaging Investigations in the Salt Lake and Utah Valleys for Earthquake Hazards"

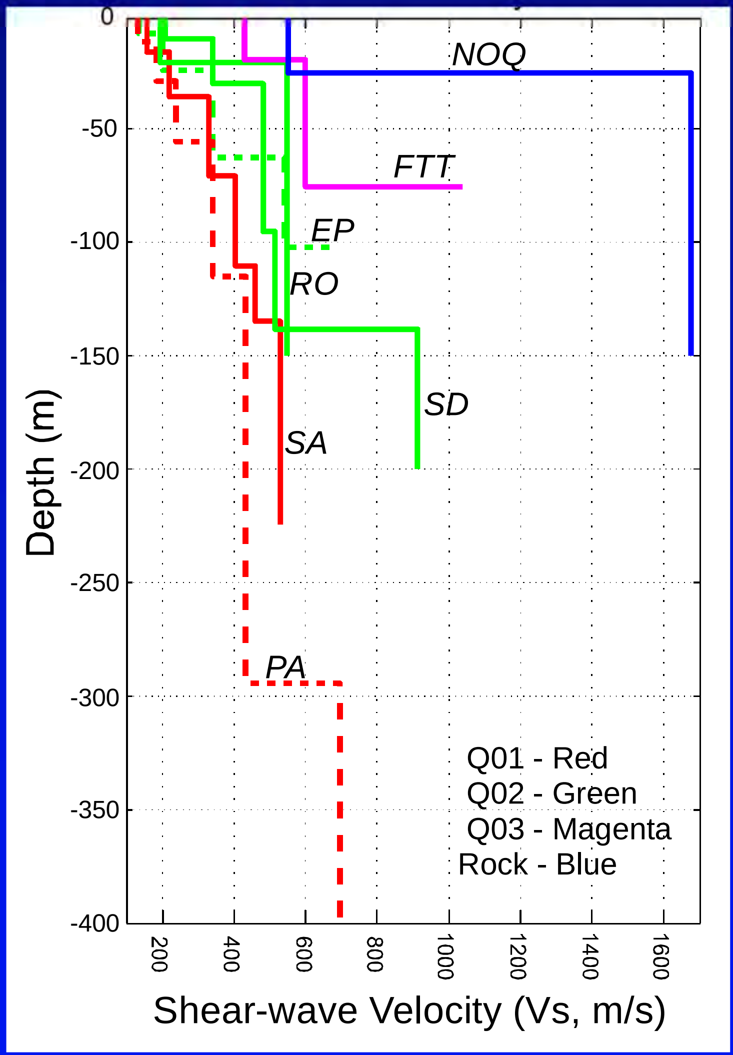
- ◆ Station w/ minivibe and hammer S-wave data
- ◇ Station w/ hammer S-wave data
- ◆ Station w/ minivibe S-wave data
- + Downhole S-wave
- I P-wave seismic reflection profile



–map modified from Solomon et al., 2004

Report Highlights

S-wave Minivibe Vs Soundings in Salt Lake and Utah Valleys

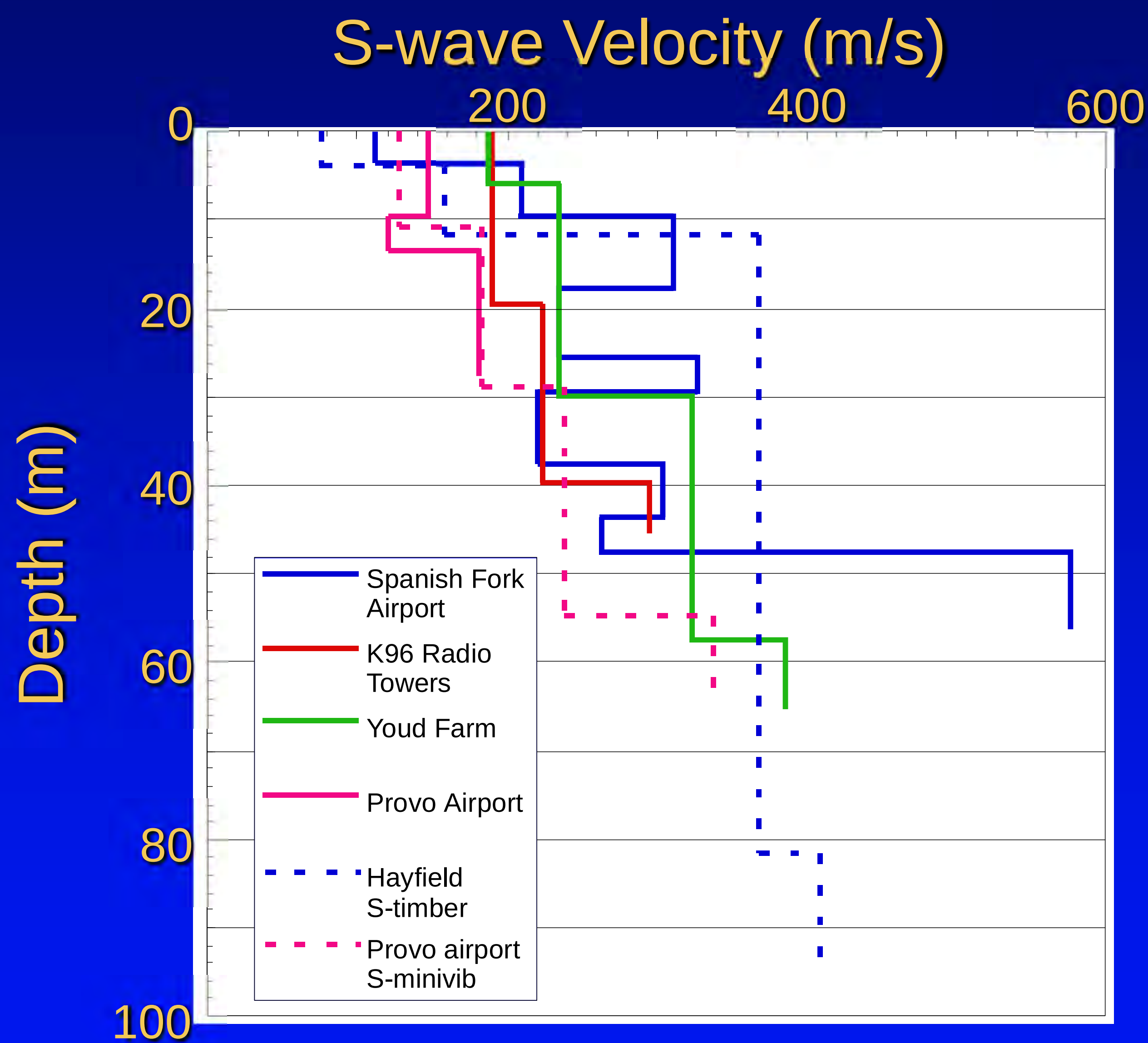


Sites

EP=Exchange Park
FTT= Fire Training Tower
NOQ= NOQ
PA= Provo Airport
RO= River Oaks
SA= Saltair
SD= Siesta Drive

Report Highlights

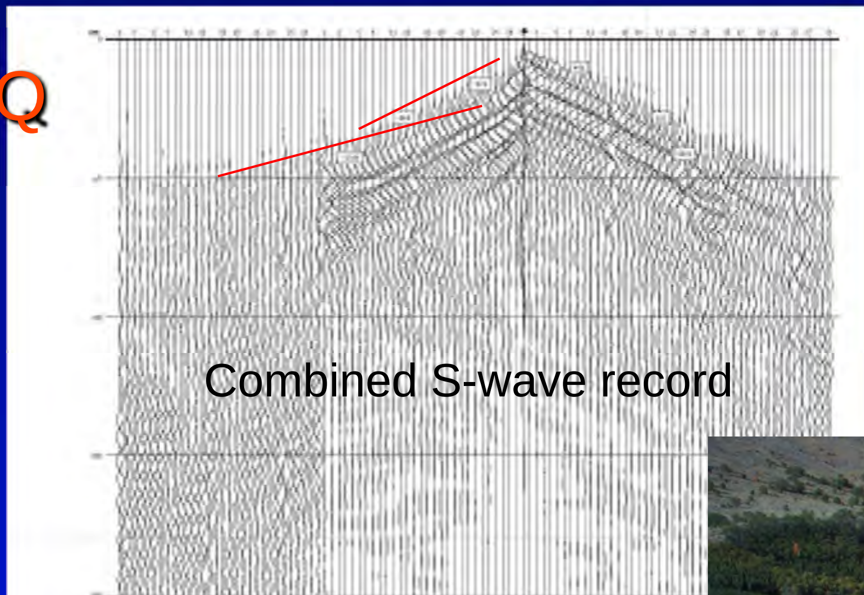
Four newly-released downhole Vs logs from Utah Valley

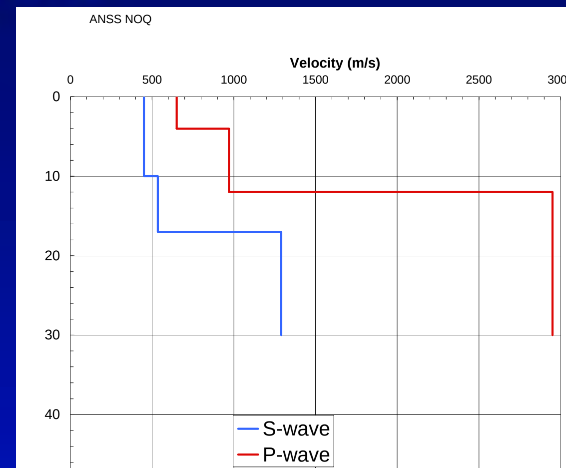


Report Highlights

Refraction Vs30 results

NOQ





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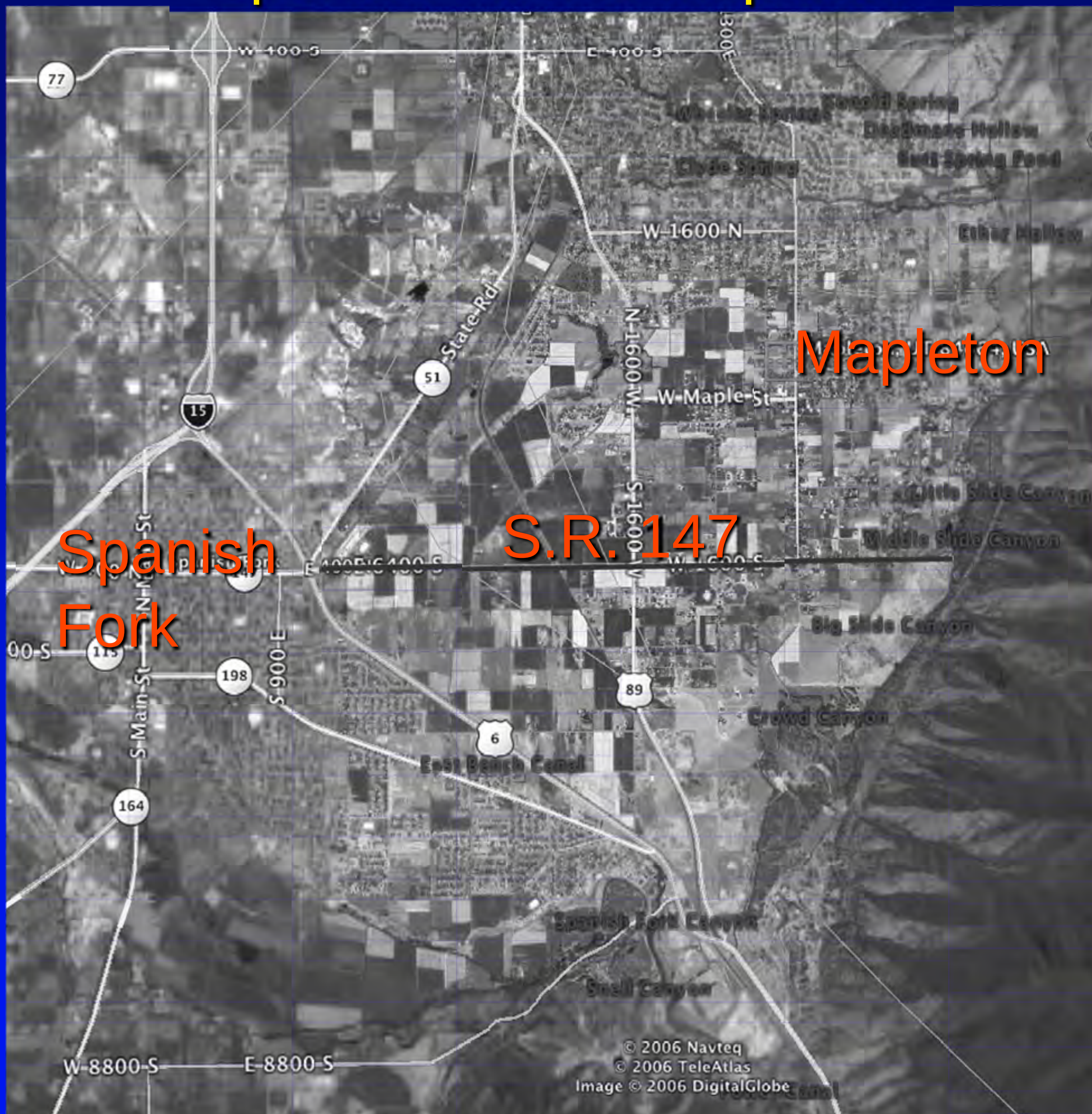
P-wave Seismic Reflection Imaging

Spanish Fork to Mapleton



– ~5.6 km

– 5 m source / receiver spacing

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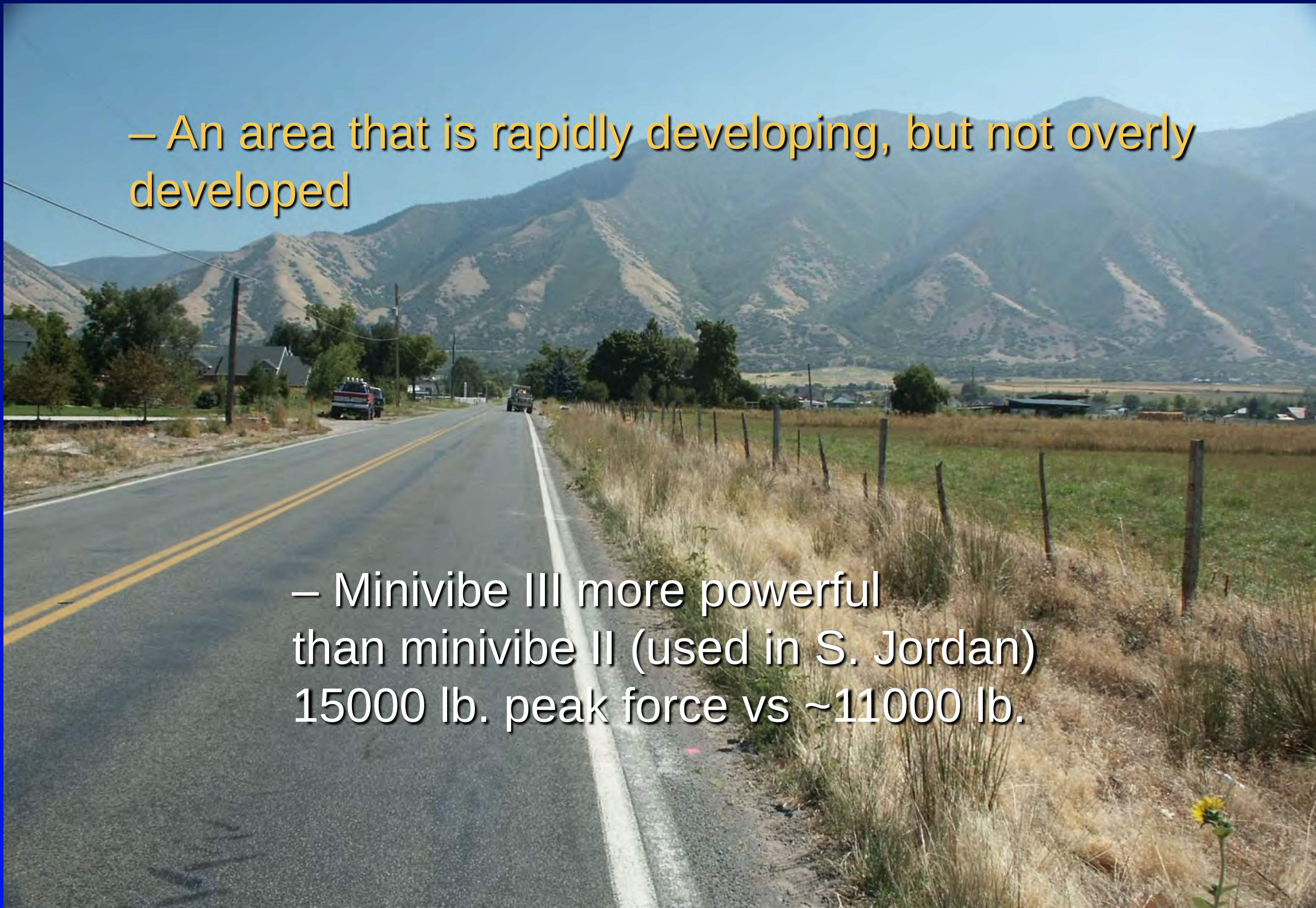

– An area that is rapidly developing, but not overly developed

– Minivibe III more powerful than minivibe II (used in S. Jordan) 15000 lb. peak force vs ~11000 lb.

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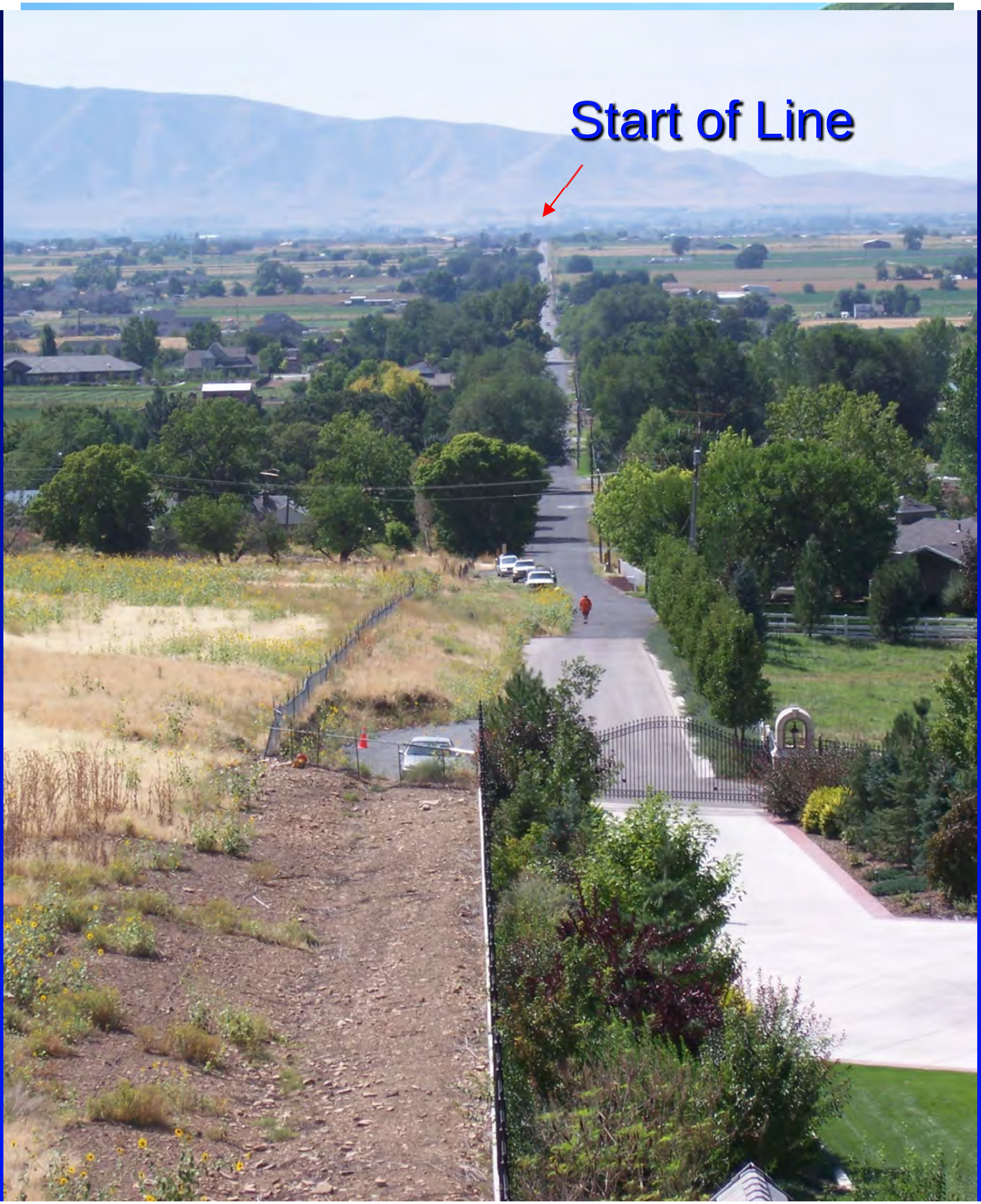
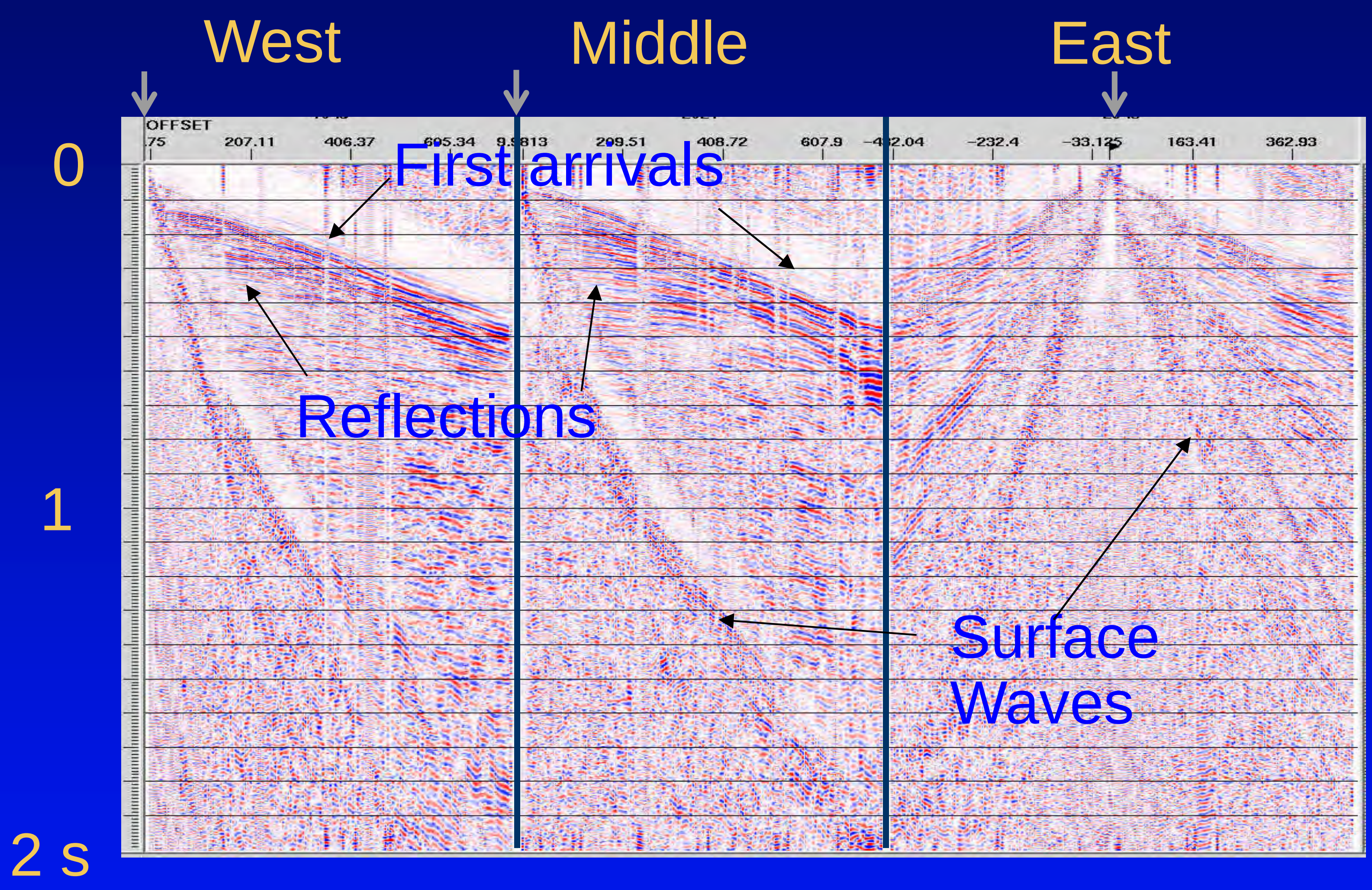
RAIL
CROSSIN
ROAD
USGS


USGS


Start of Line

Spanish Fork-Mapleton P-wave Field Records



- Records displayed with AGC and bandpass.

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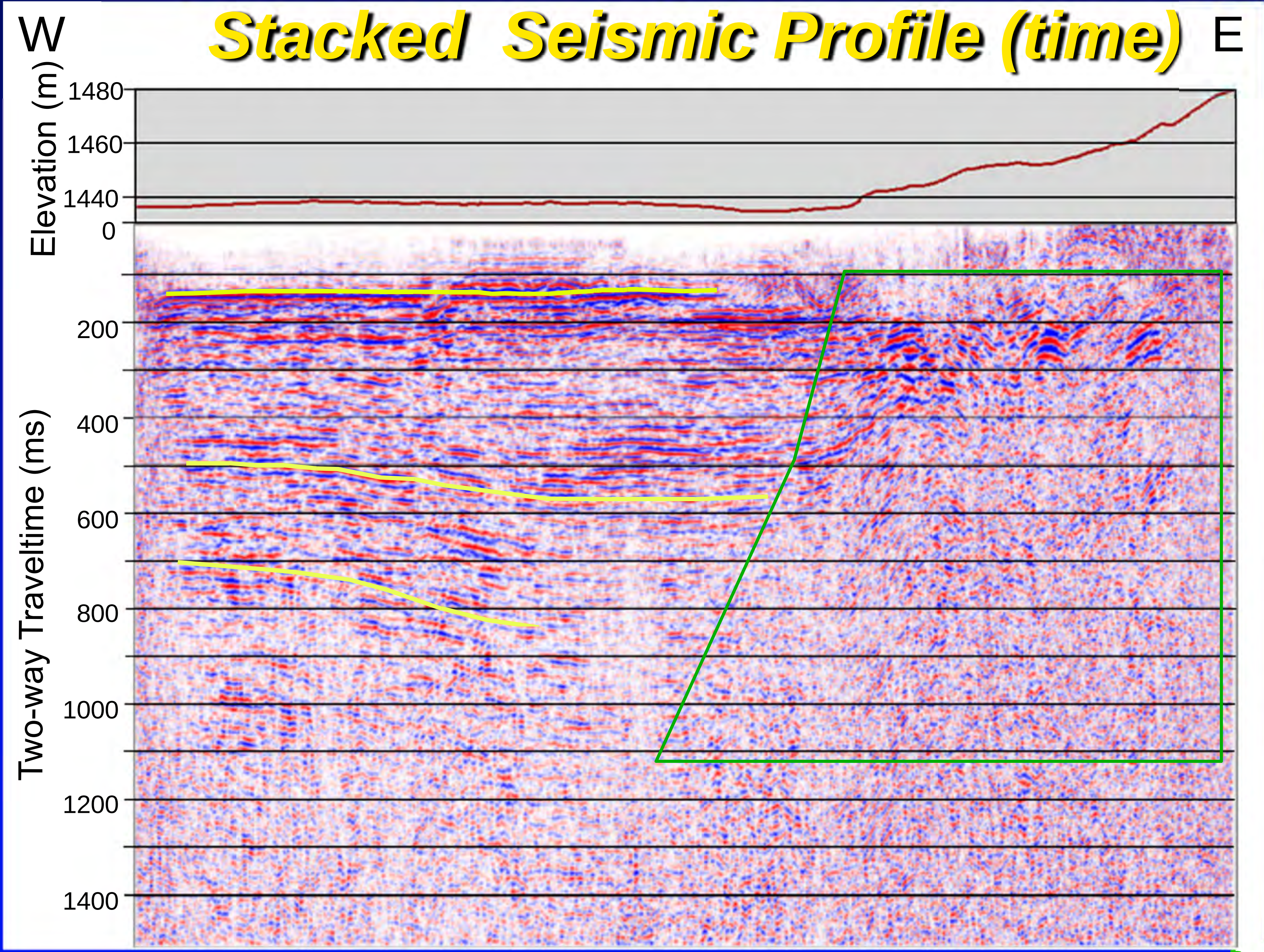
Spanish Fork-Mapleton Preliminary Stacked Seismic Profile (time)



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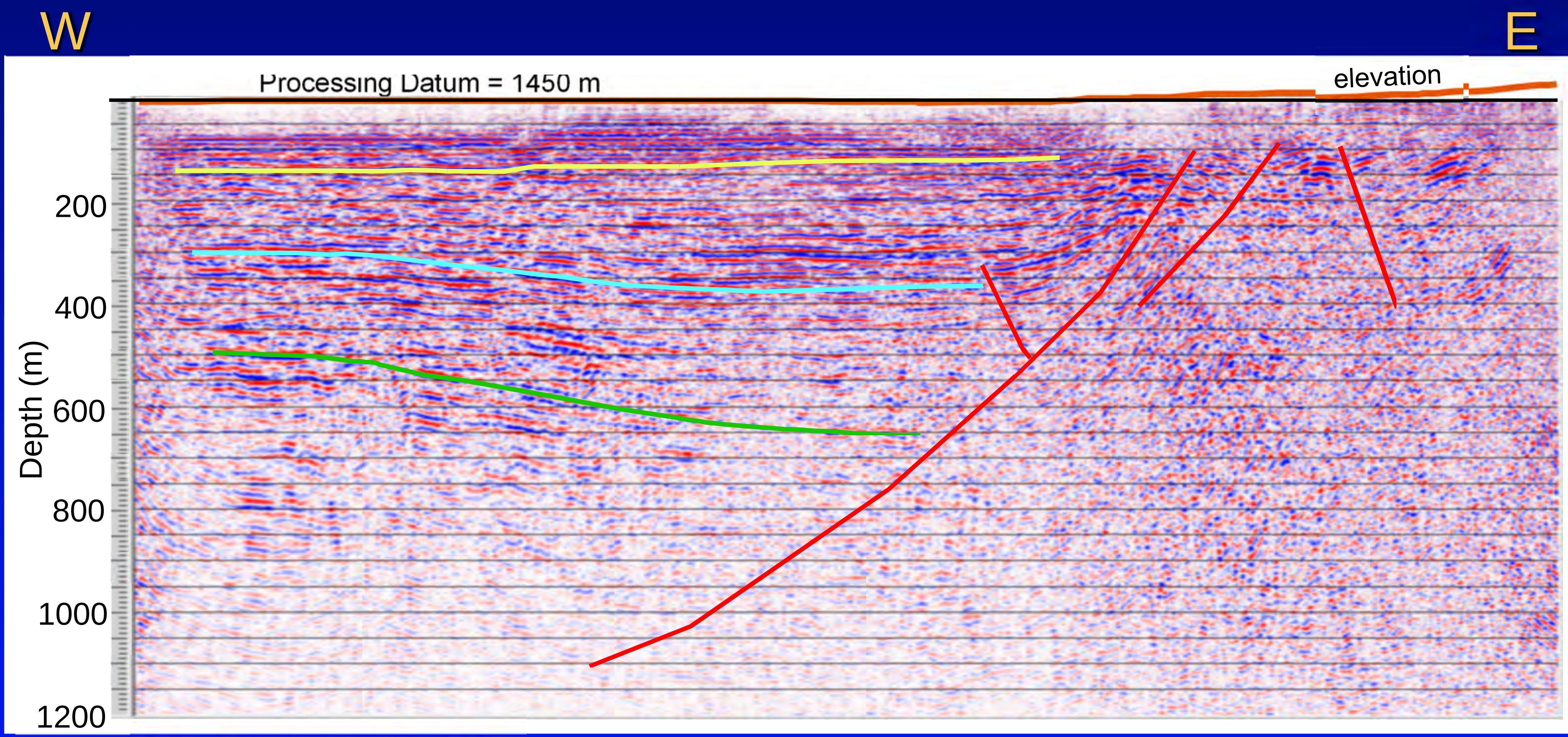
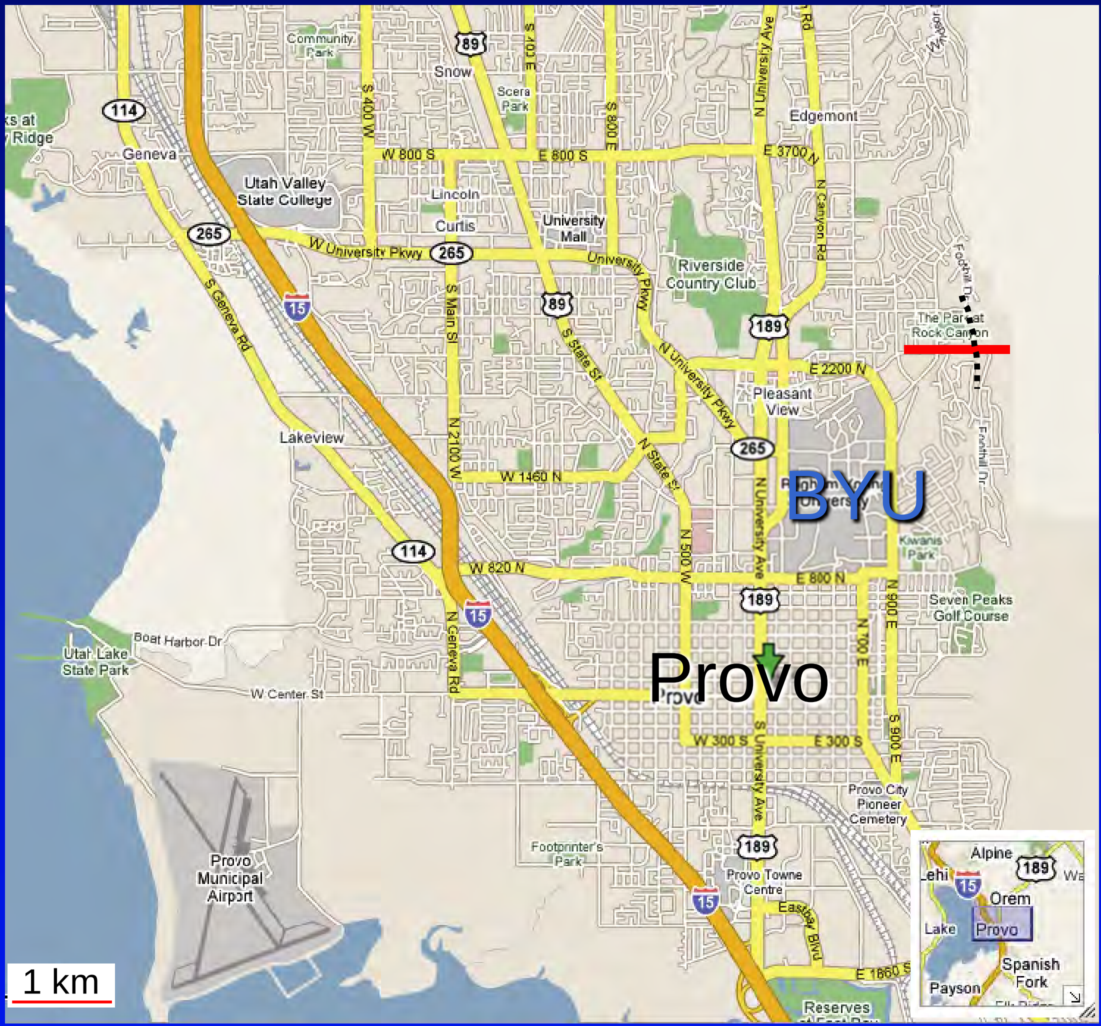
Spanish Fork-Mapleton Preliminary Stacked Migrated Seismic Profile (depth)



Vertical exag. 2:1

Rock Canyon, Provo



~1.2 km long

Base map from Google Maps

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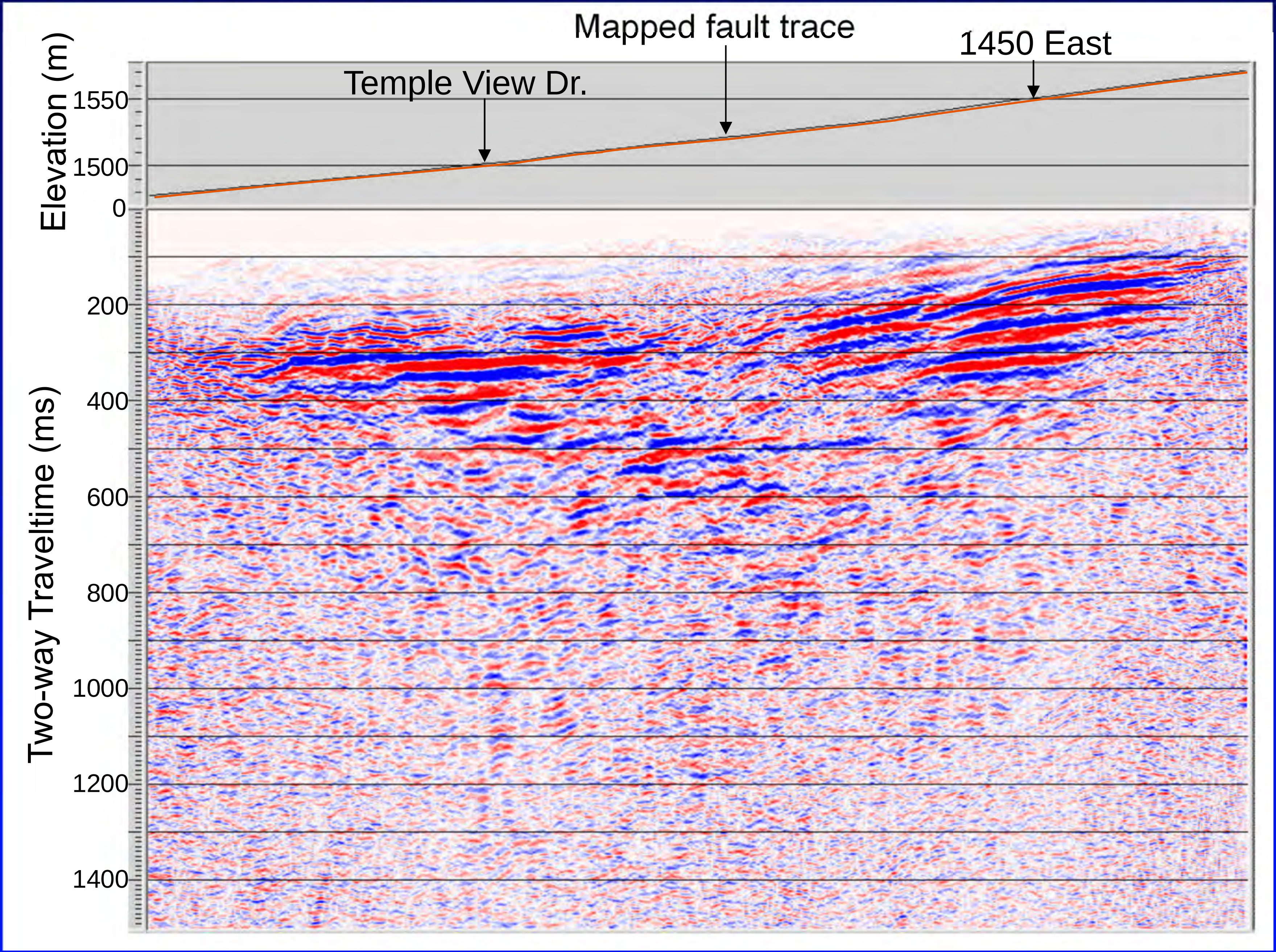
USGS

Rock Canyon Preliminary Stacked Seismic Profile (time)



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Field Work for Summer 2007

– Focus: Derive Vs to depths greater than 30 m

– Community Input Needed on siting, etc.

Surface Methods for S-wave Velocity Determination

Active	Passive
SASW	ReMi
CXW	FK
MASW	SPAC
Reflection/Refraction	H/V (Nakamura)
	Interferometry

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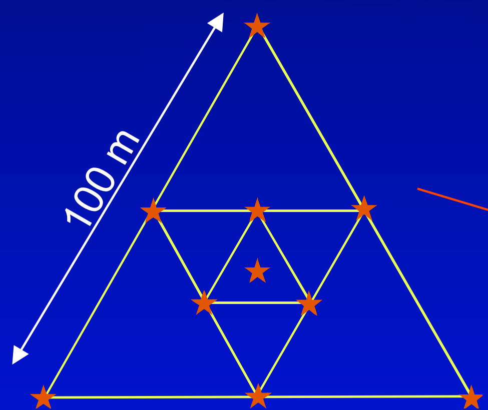
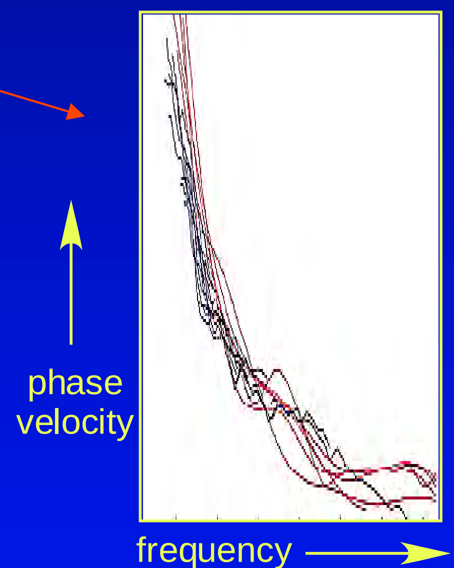
SPAC Methodology

SPAC = SPatial AutoCorrelation (Aki, 1957)

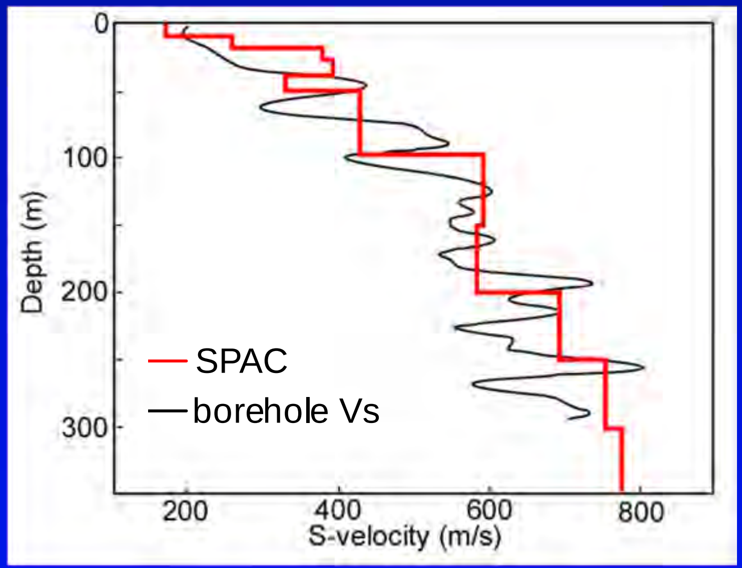
– Record microtremors (surface waves) w/ array and analyze data for Vs



array w/ sensors at stars



Dispersion curve



From Hartzell et al., 2005

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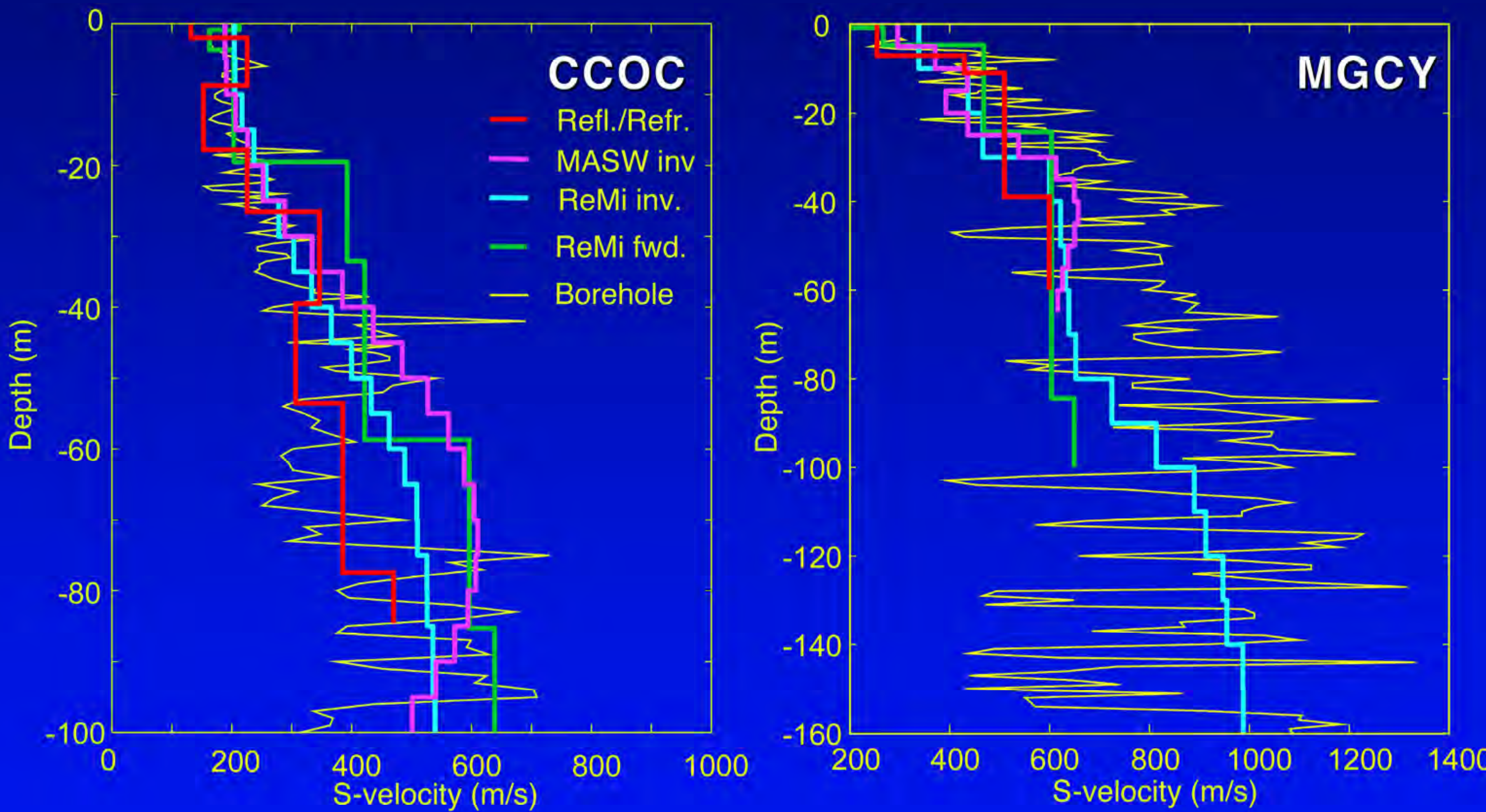
Borehole vs Surface Method Vs

– Example of blind study from Santa Clara Valley, CA



Thanks for your time!

THE UNIVERSITY OF TEXAS AT AUSTIN

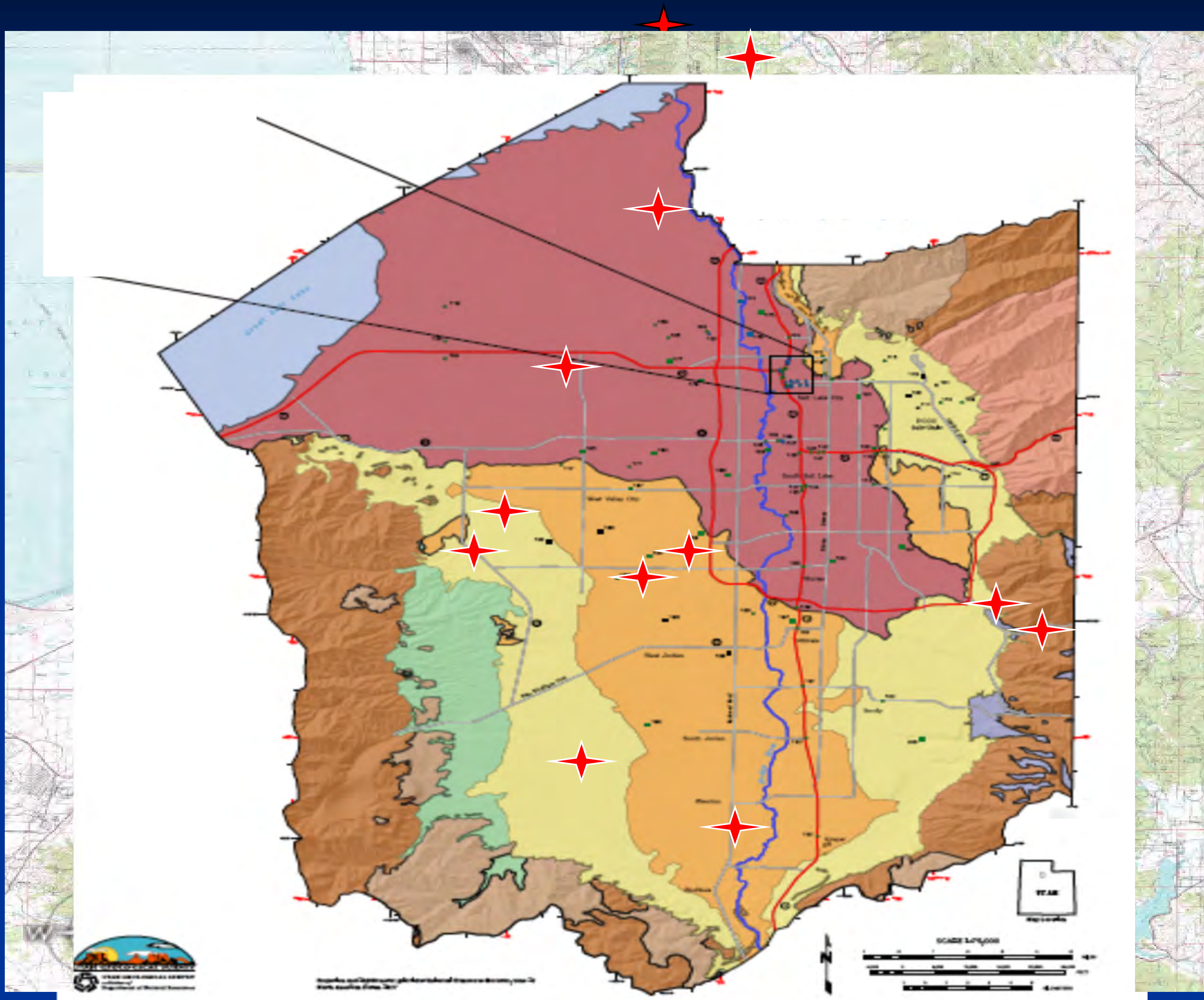
SASW Testing with “Liquidator” in Salt Lake Valley

Presented By:

Dr. Kenneth H. Stokoe II

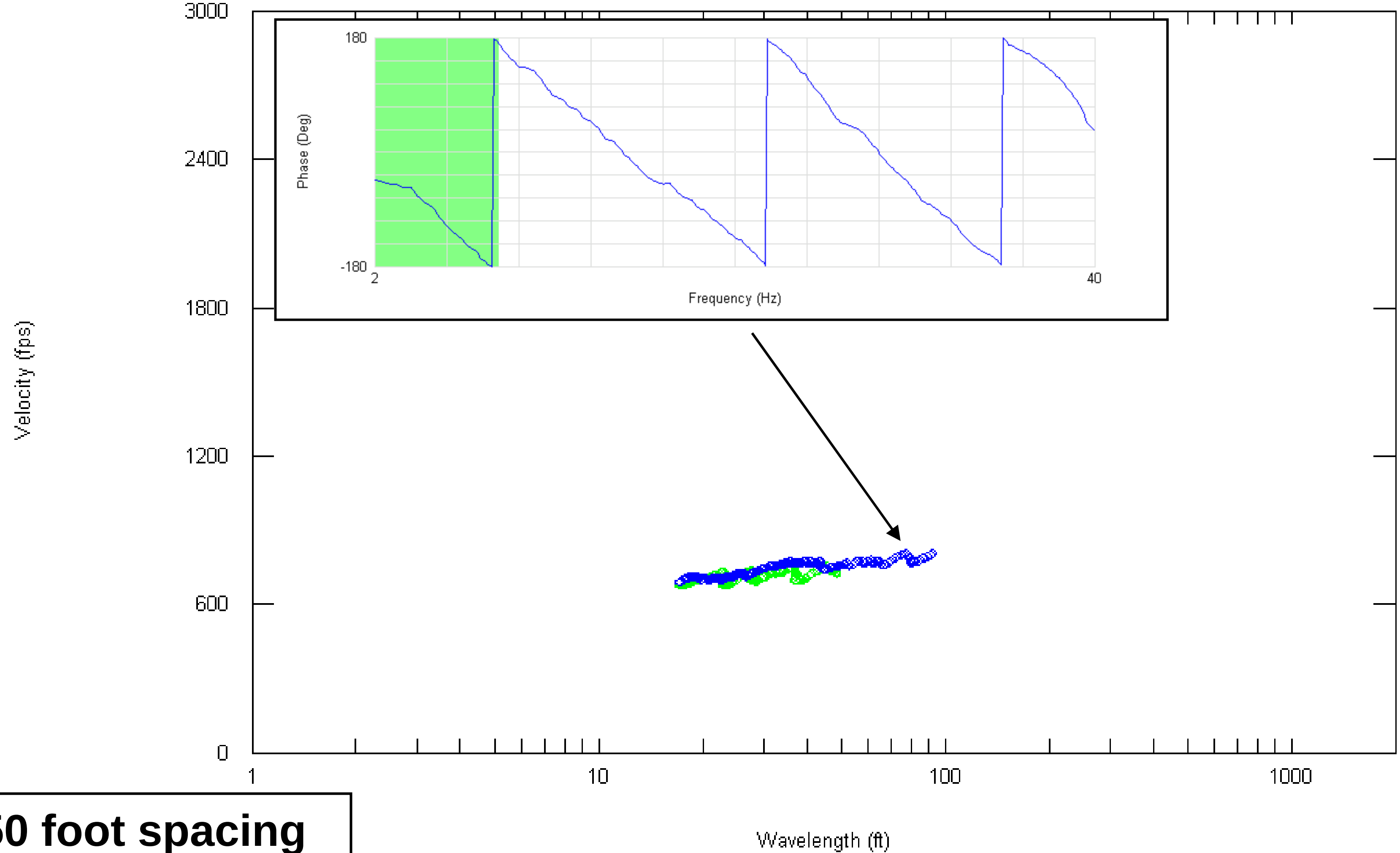
Brad Wilder

11 Locations



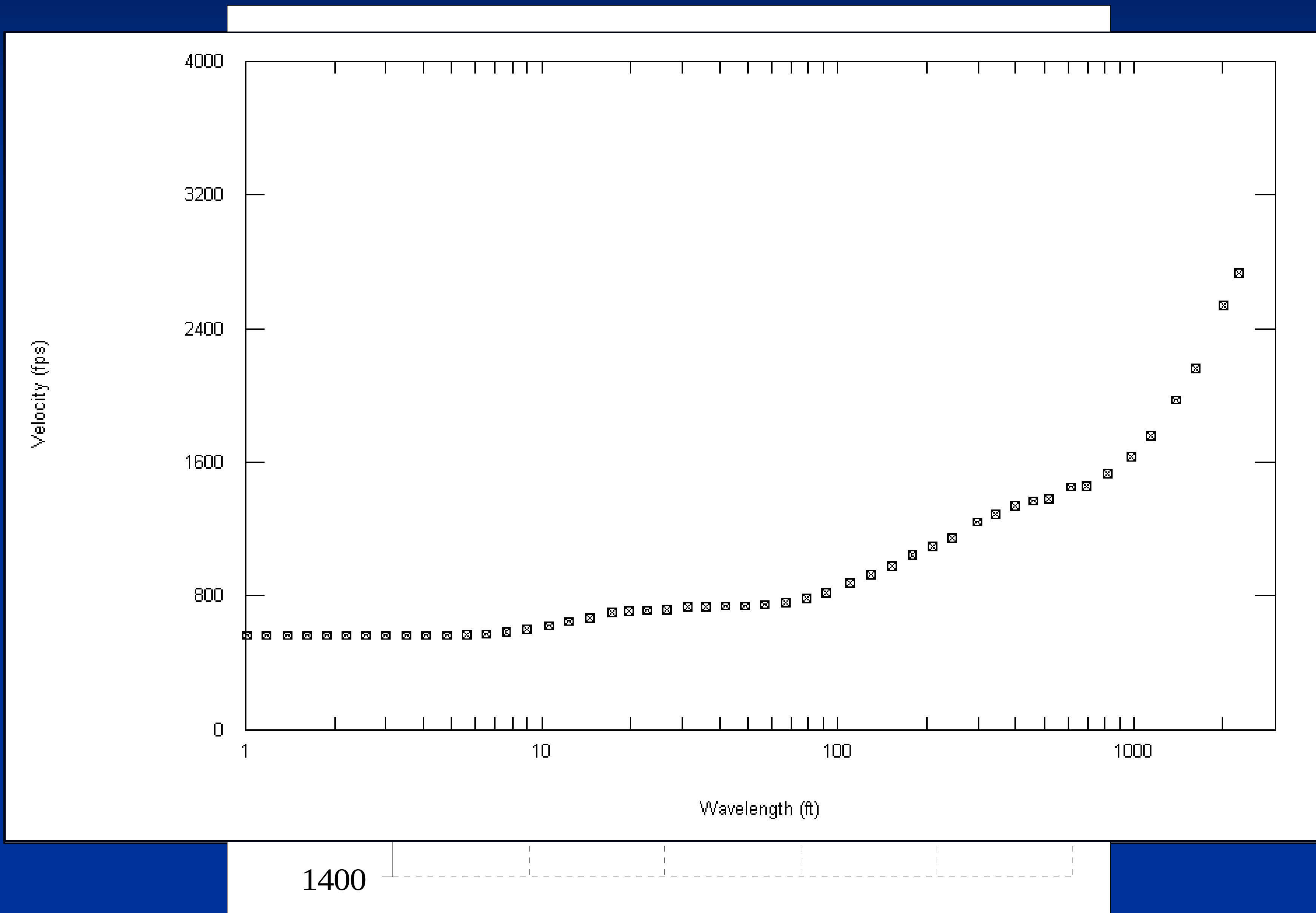
SASW Method

Field Dispersion Curves

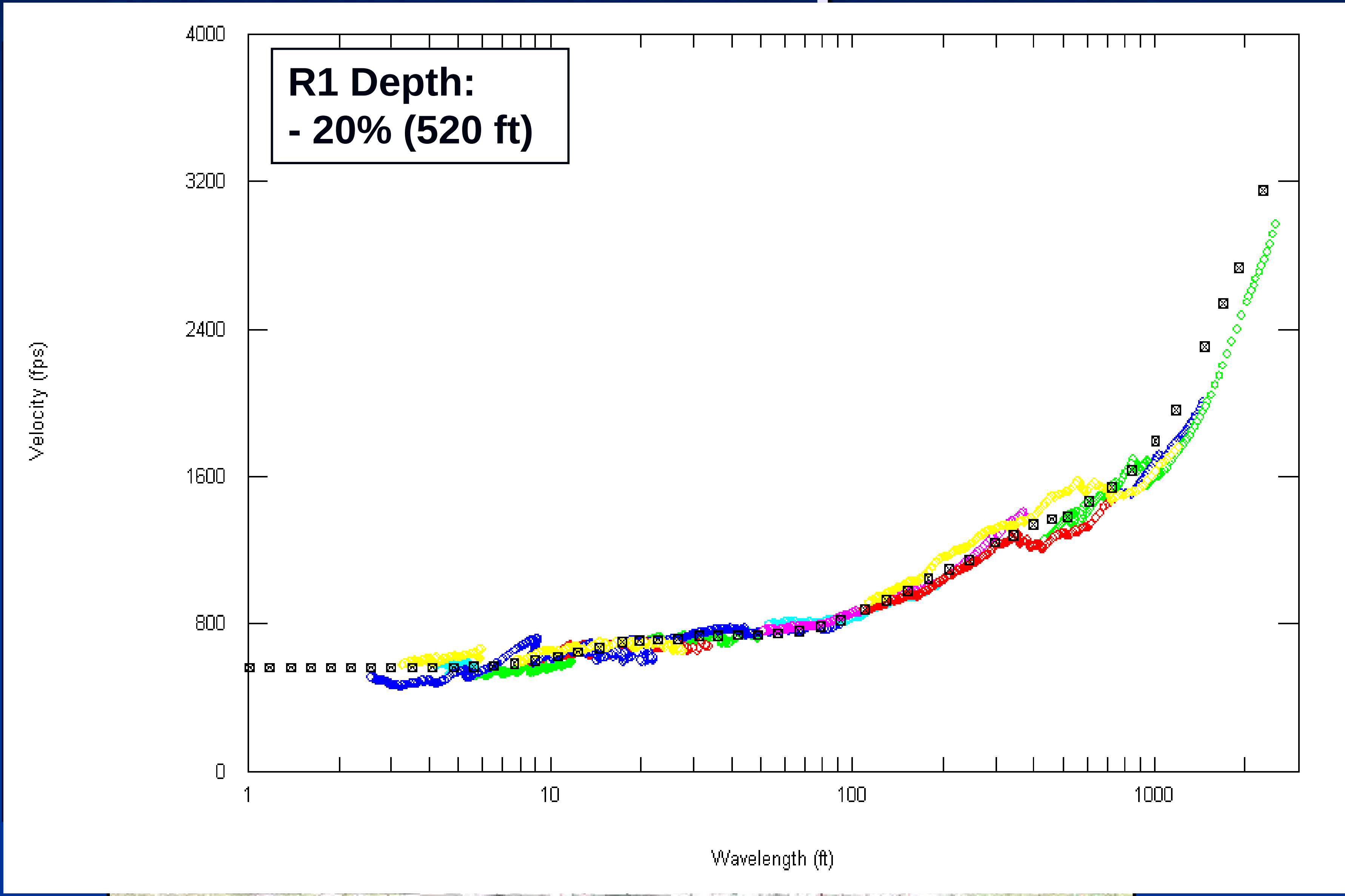


50 foot spacing

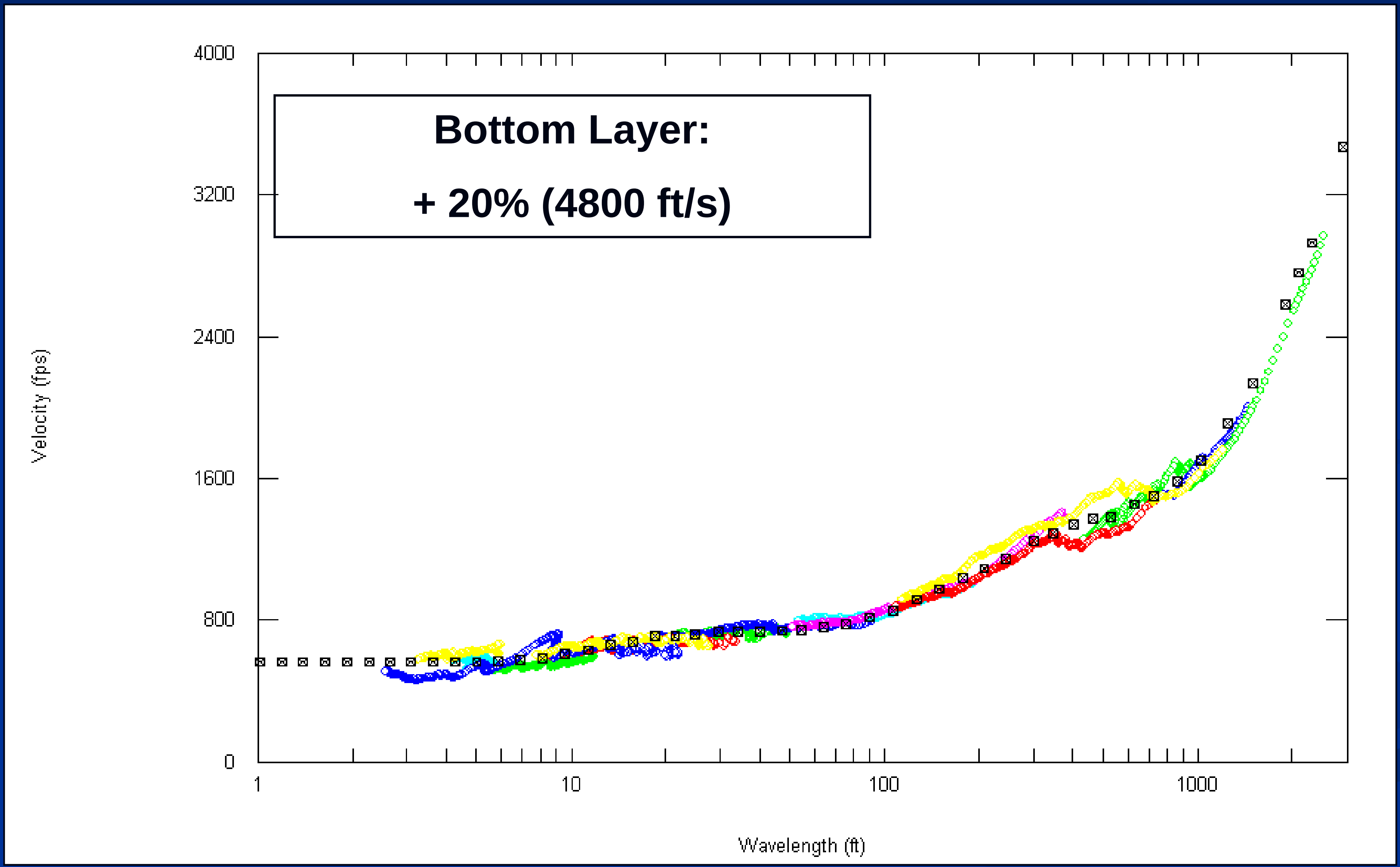
Forward Modeling



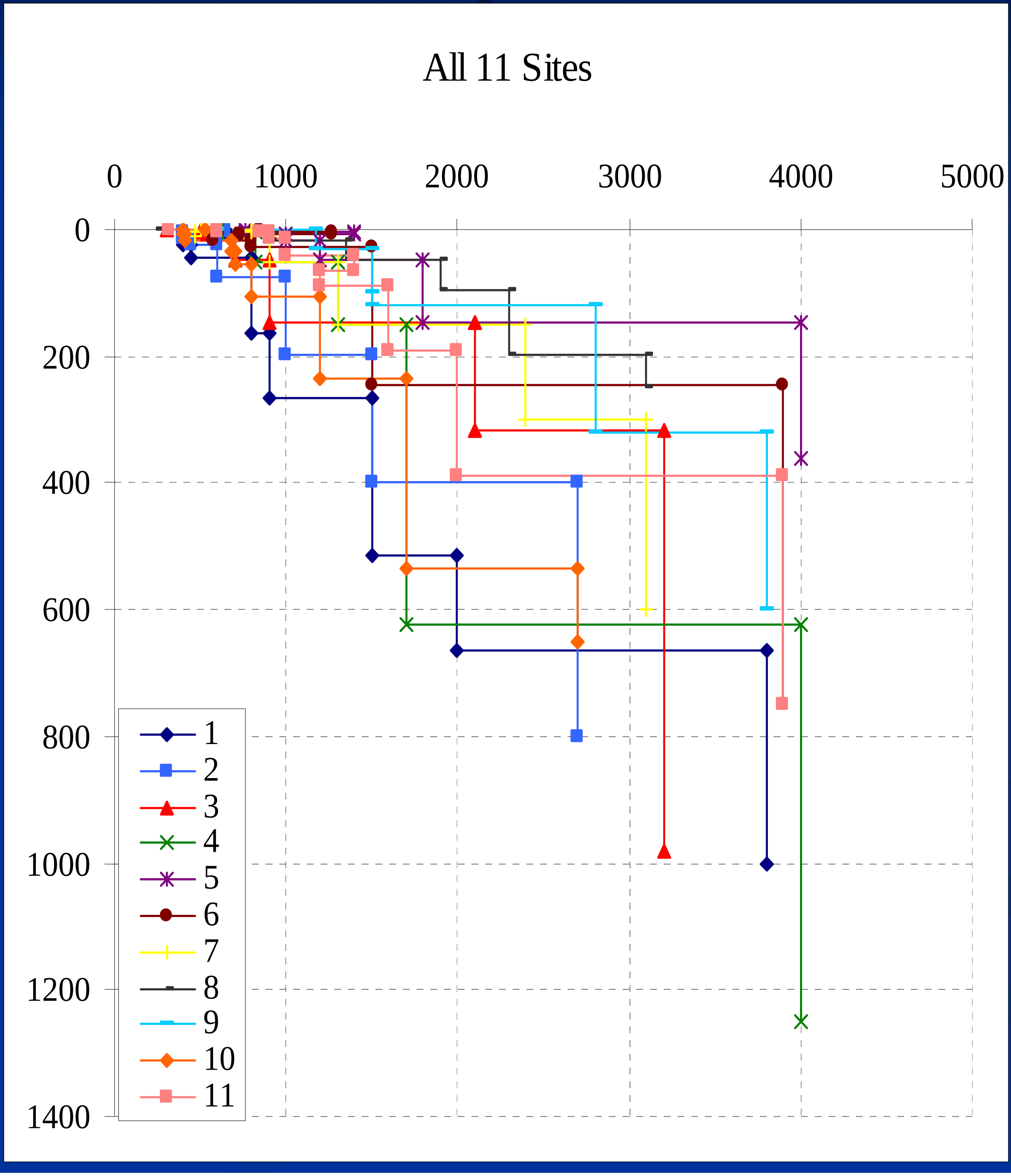
Resolution of Depth to R1



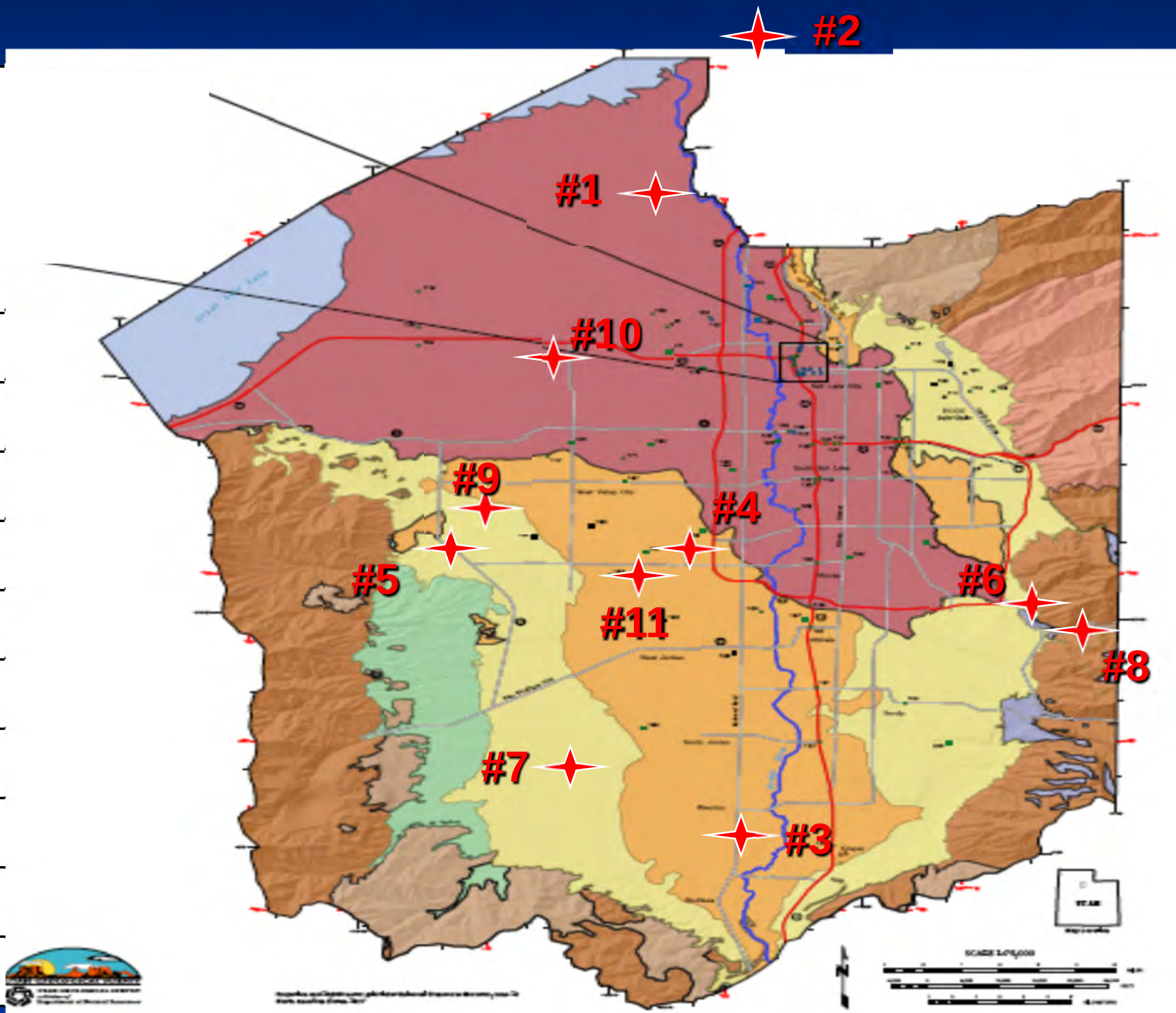
Resolution of Velocities



Velocity Profiles

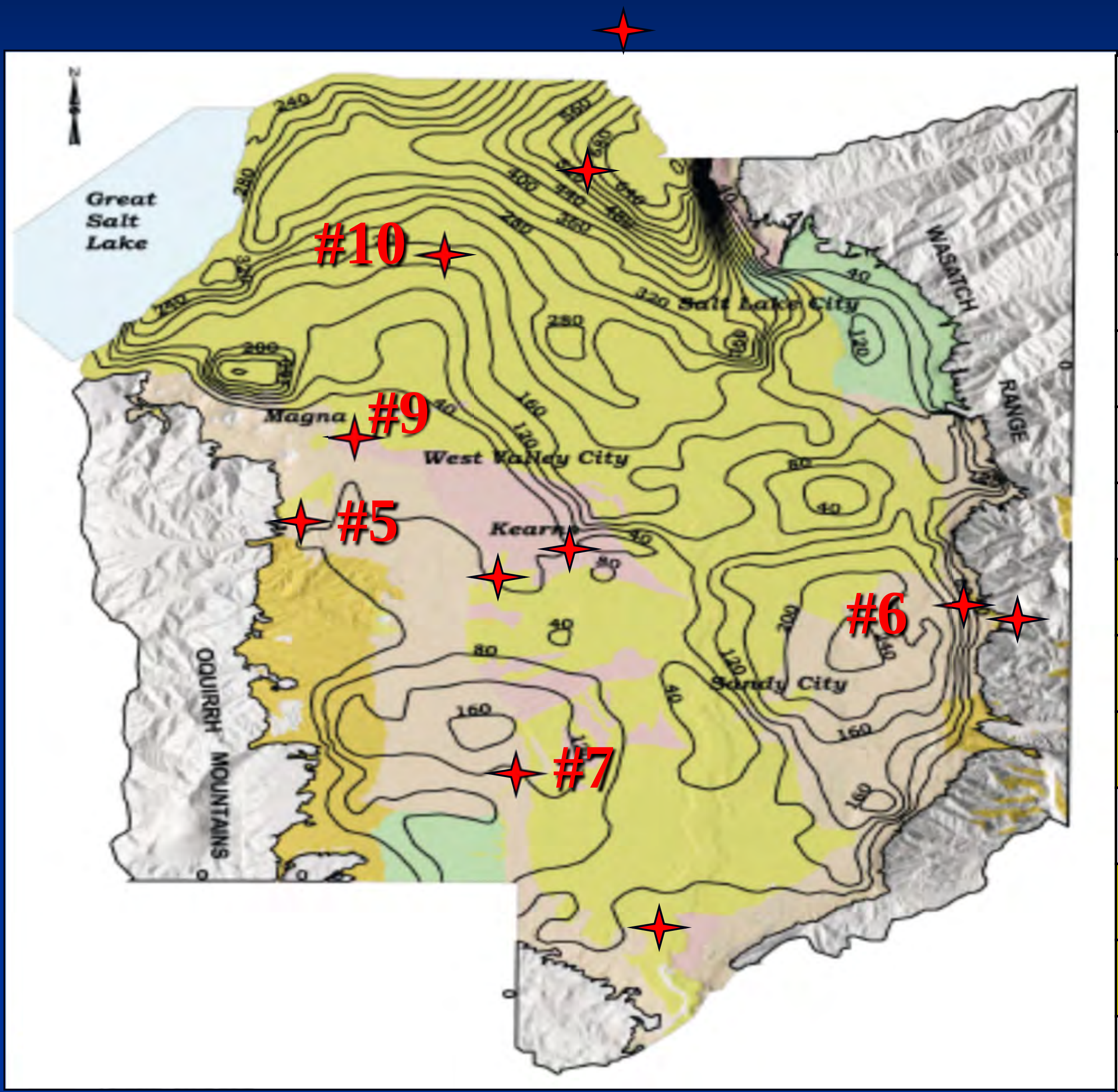


Comparison of Vs30



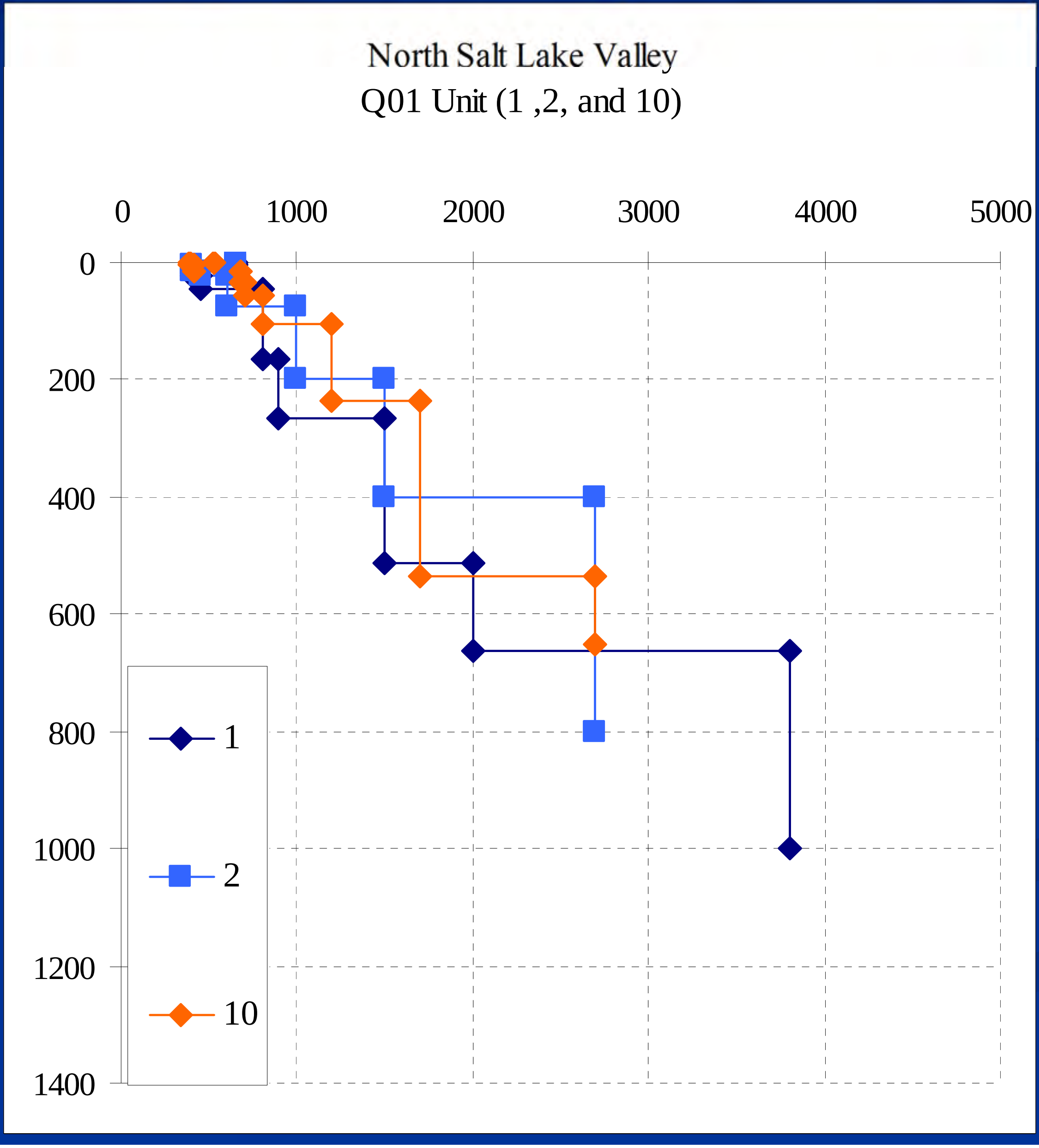
Site	BC Site Class
1	E
2	D
3	D
4	D
5	C
6	C
7	D
8	C
9	C
10	D
11	D

Depth to R1 Interface

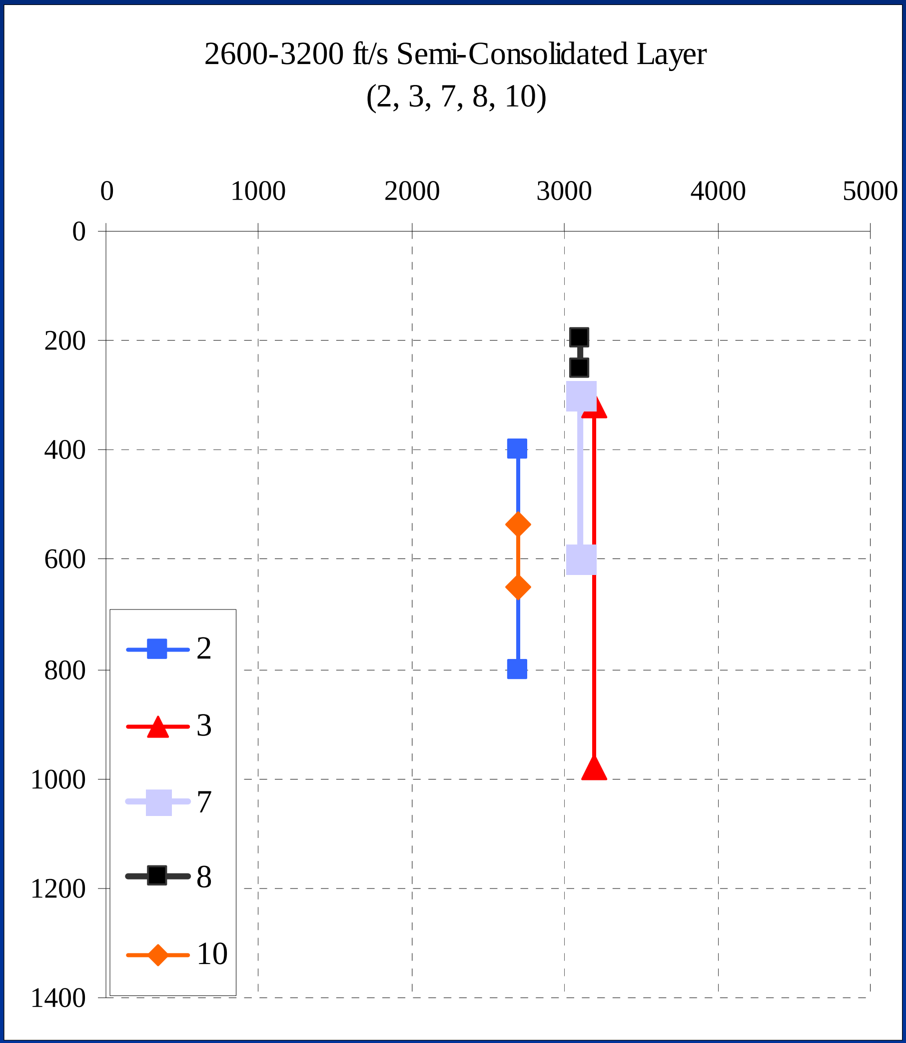


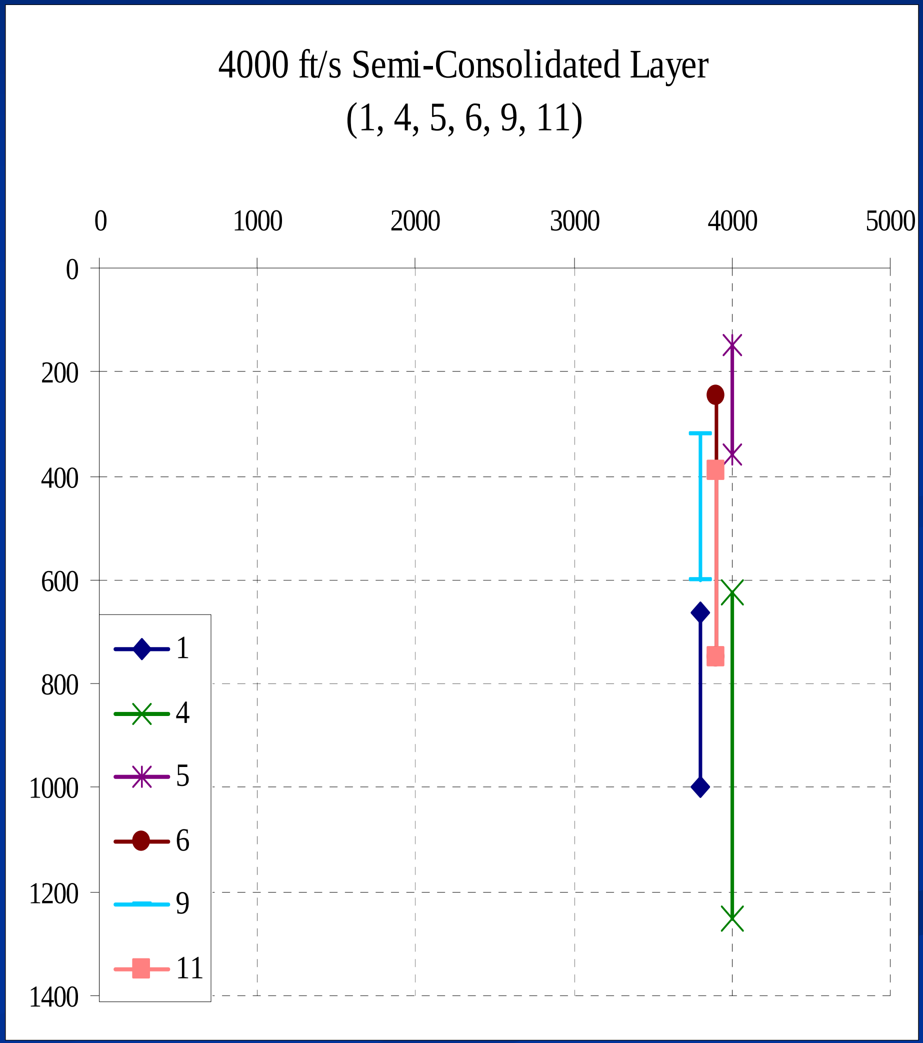
Depth to R1 (ft)		
SITE #	Map	SASW
1	1400-2000	665
2	x	400
3	150	317
4	120-360	625
5	<150	148
6	200-400	246
7	200-400	300
8	<150	197
9	50-150	120
10	400-600	536
11	100-200	390

Correlations Based on Quaternary Units

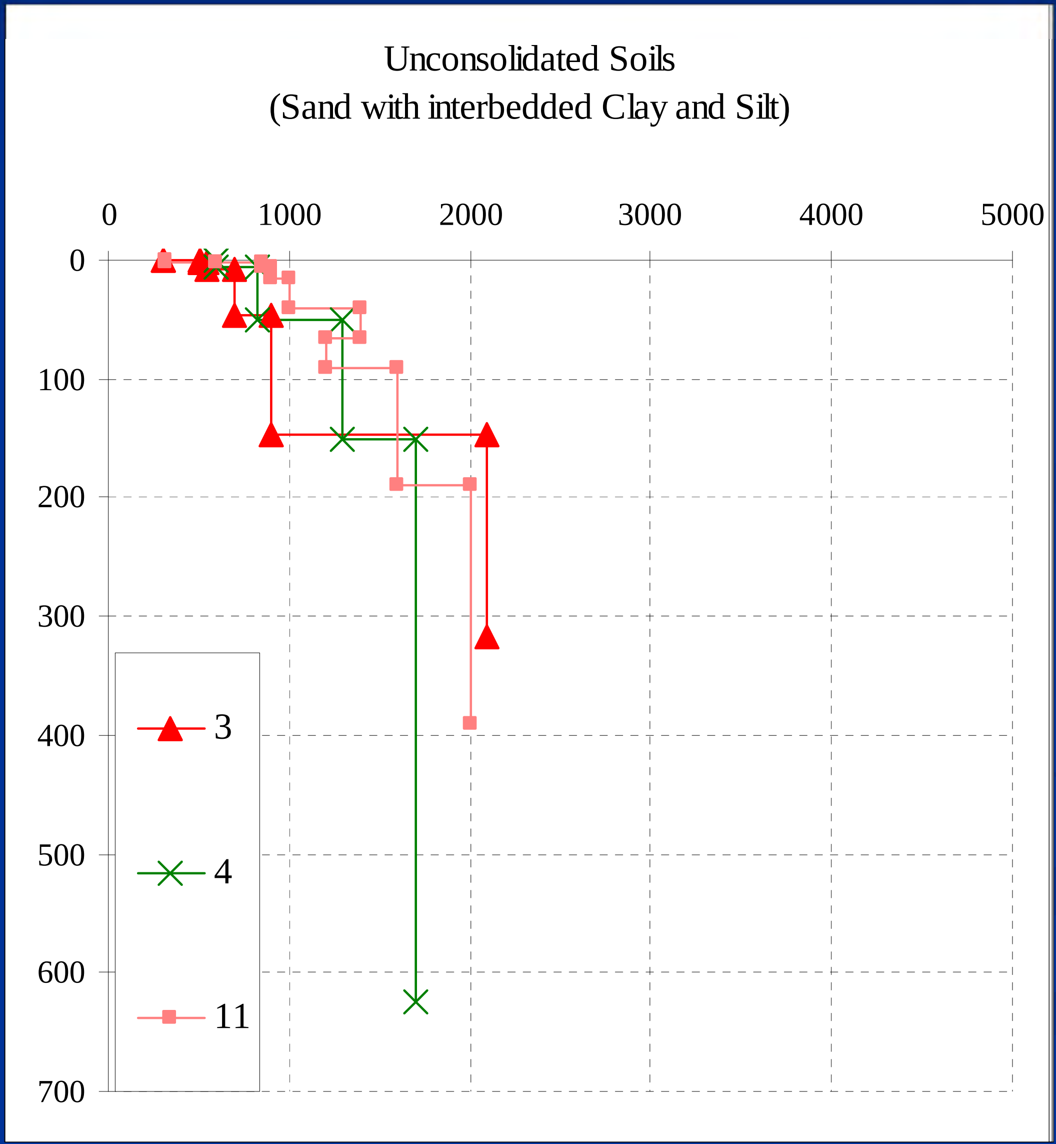


Correlations Based on Velocity of Semi-Consolidated Layer





Correlations Based on Unconsolidated Velocity

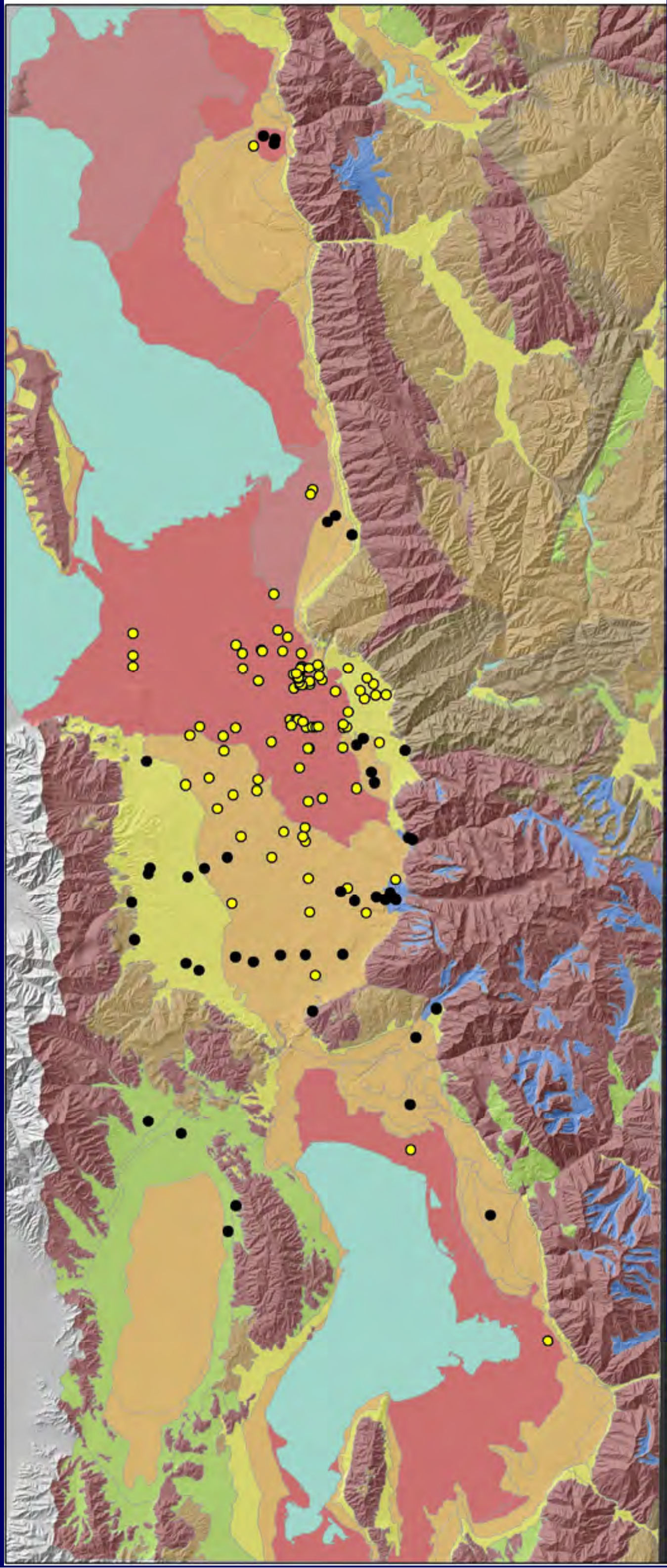


QUESTIONS?

Wasatch Front urban corridor Vs testing and site-conditions mapping update

Greg McDonald, Francis Ashland
Utah Geological Survey

James Bay, Jeff Gilbert, Jeff Berry
Utah State University

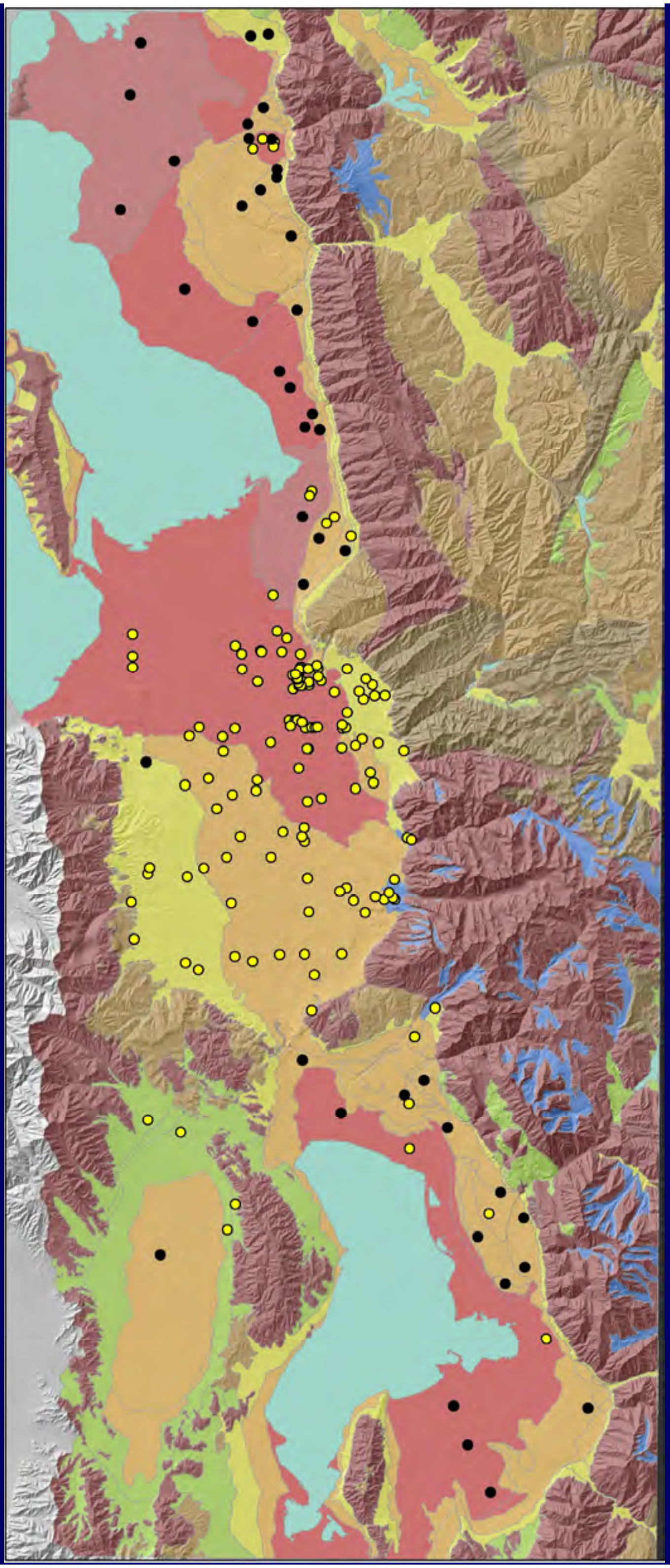


USU – Gilbert and Bay (2003)

44 sites

- 30 - Salt Lake basin
- 3 - Weber basin
- 3 - Davis basin
- 4 - Utah basin
- 4 - Cedar Valley

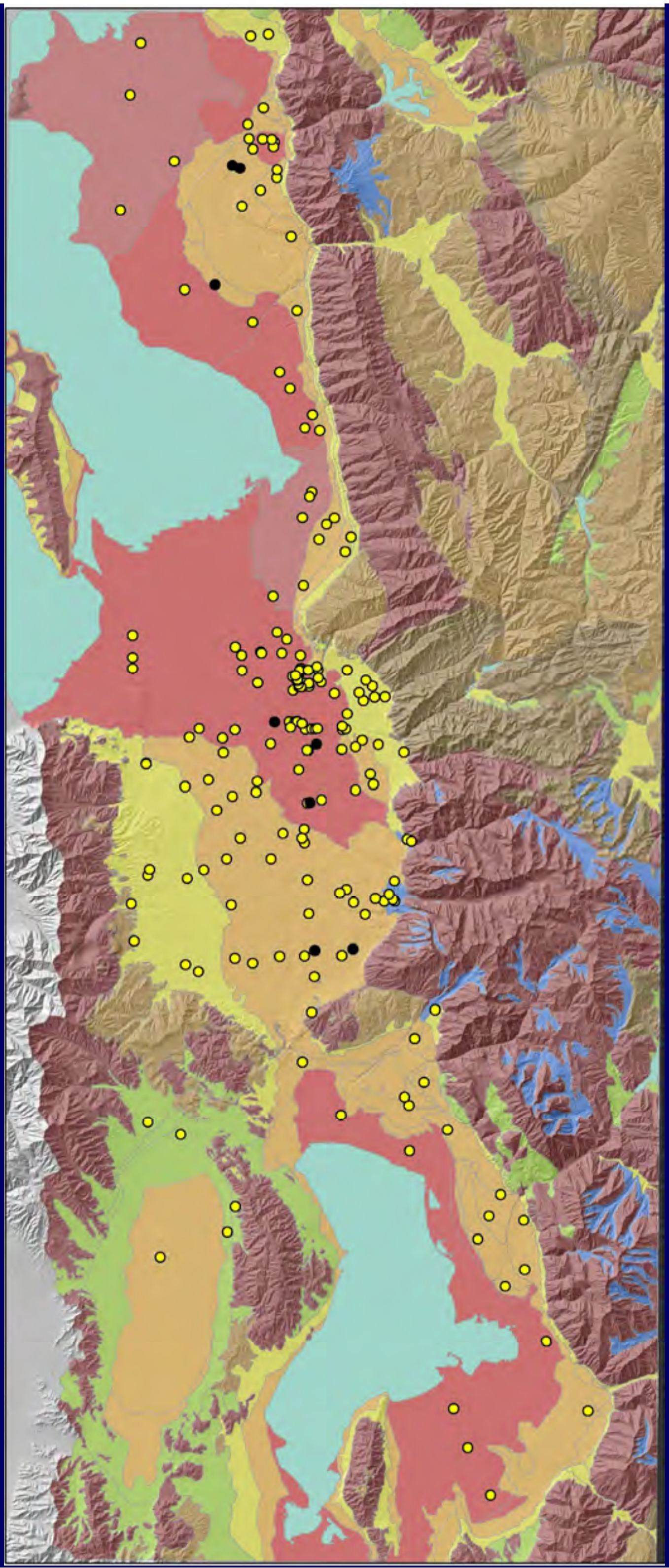
SL Valley site-conditions map (Ashland and others (2005)



USU – Berry and Bay (2005)

45 sites

- 3 - Salt Lake basin
  - 2 ANSS “bedrock” (NOQ, CTU)
  - FTT retest
- 15 - Weber basin
- 12 - Davis basin
- 14 - Utah basin
- 1 - Cedar Valley

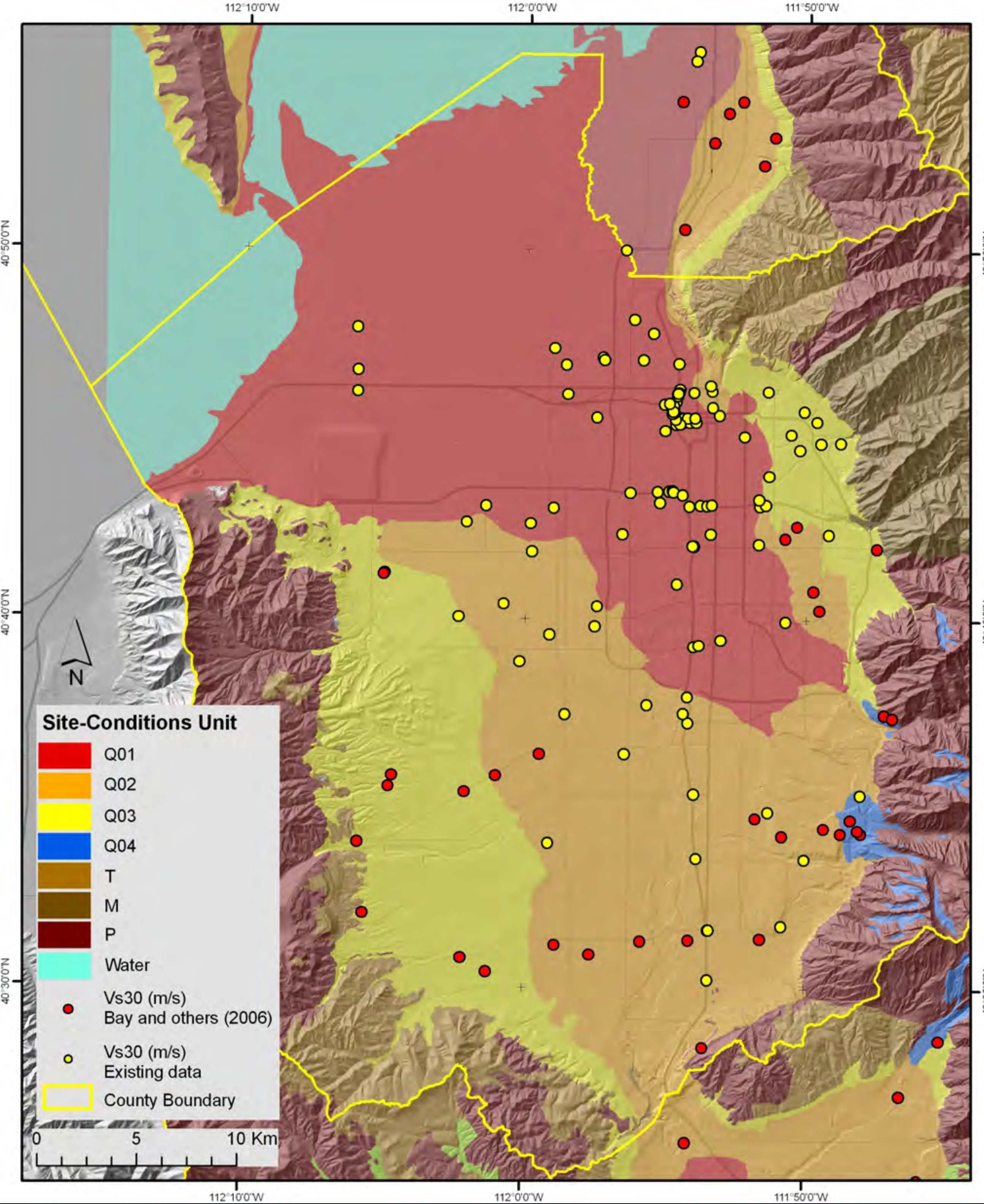


USU – Bischoff

CPT data - 9 sites

6 - Salt Lake basin
3 – Q01
3 – Q02

3 - Weber basin
3 – Q02

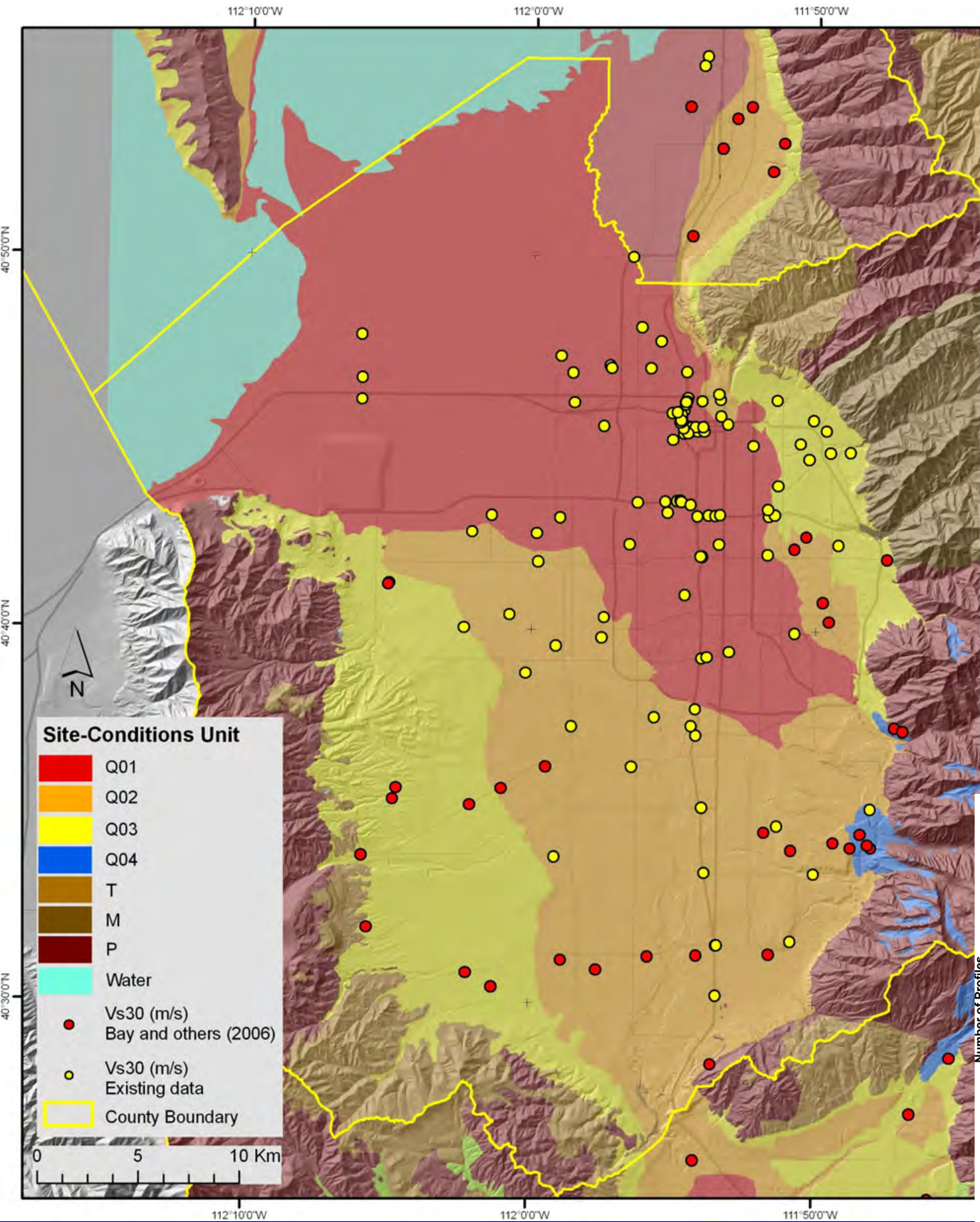


Salt Lake basin

139 profiles
(68% of WF total)

Mapped/characterized by Ashland and others (2005)

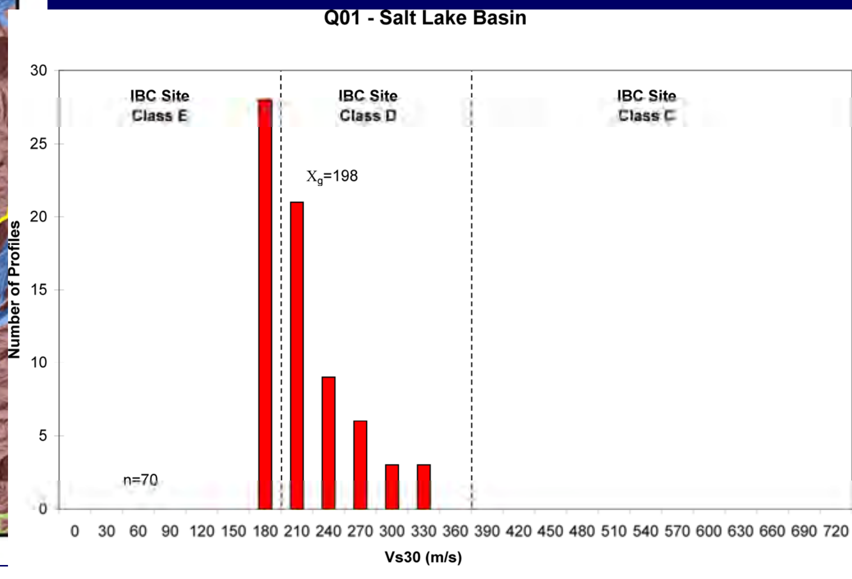
4 Quaternary site-conditions units

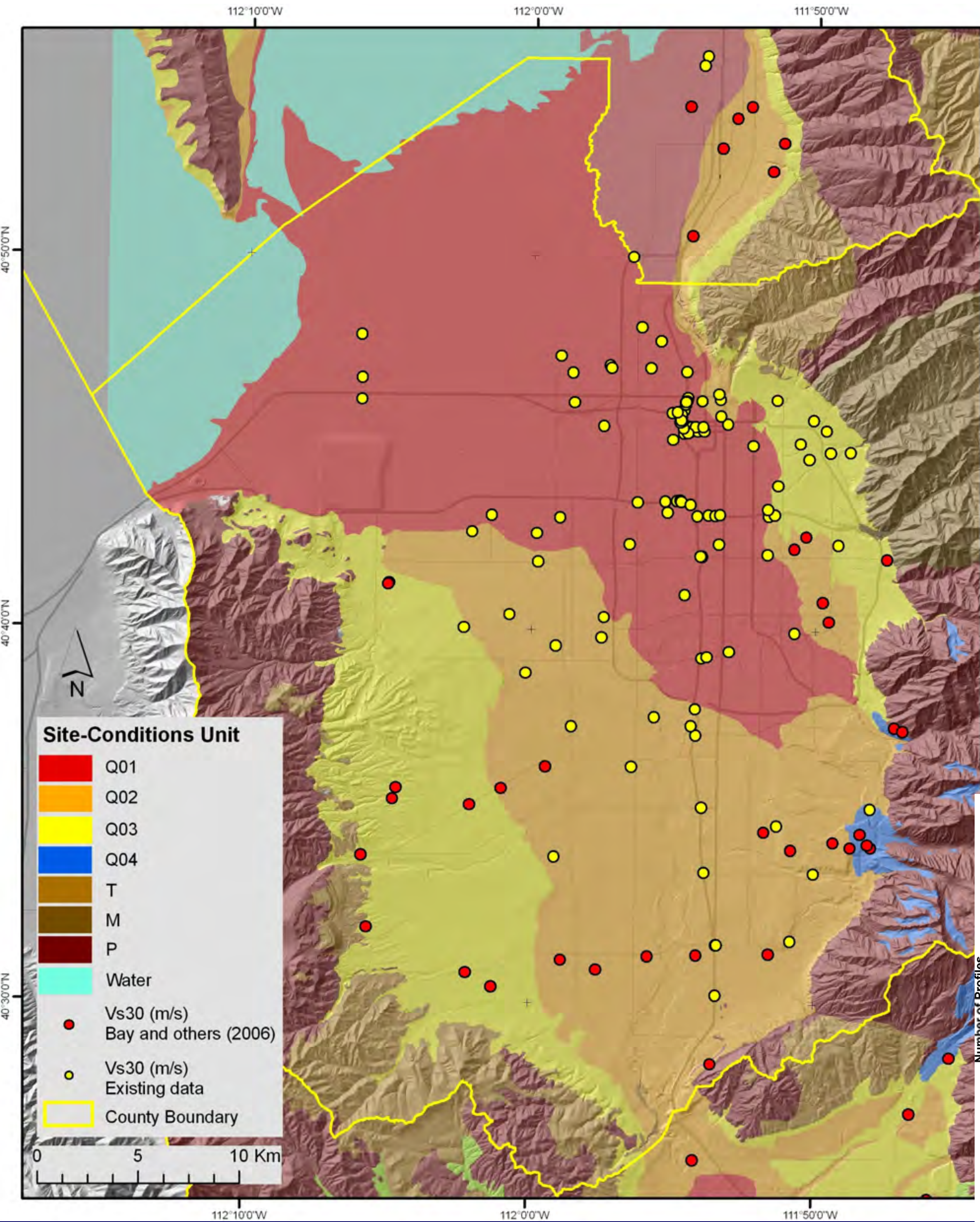


Salt Lake basin

Q01 – Lacustrine and alluvial clay, silt and fine sand

Xg=198 m/s
n=70

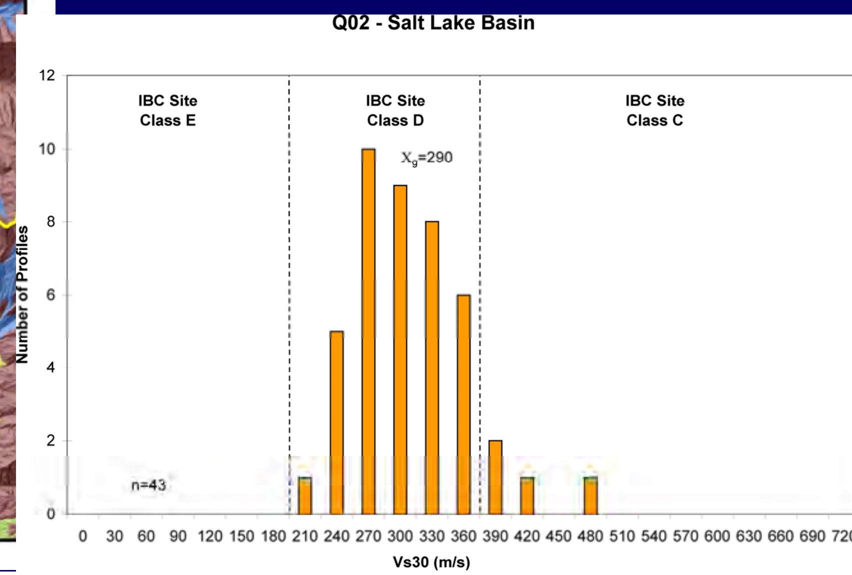




Salt Lake basin

Q02 – Lacustrine sand, silt and fine gravel and young alluvial-fan deposits

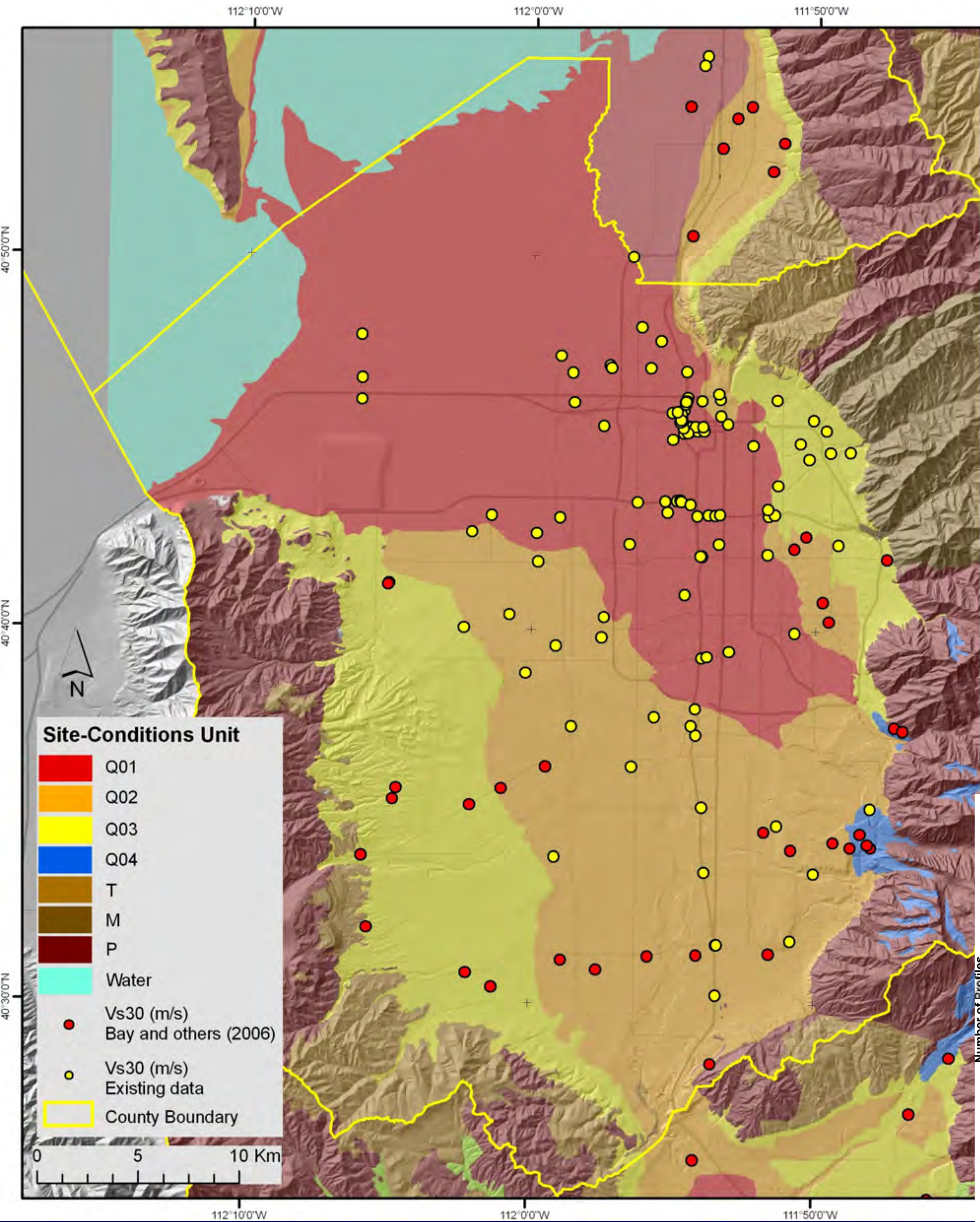
Xg=290 m/s
n=43

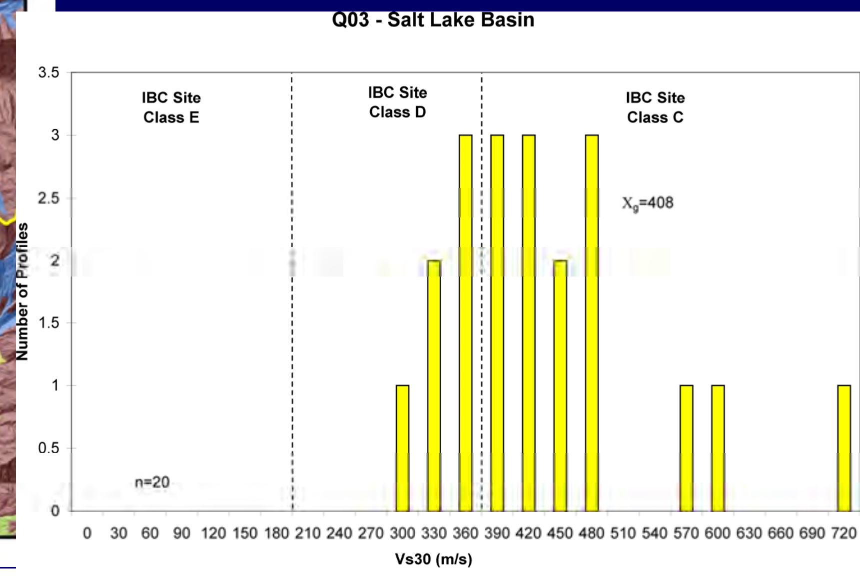


Salt Lake basin

Q03 – Gravel-dominated lacustrine and alluvial deposits; includes deltaic and older fan deposits

Xg=408 m/s
n=20

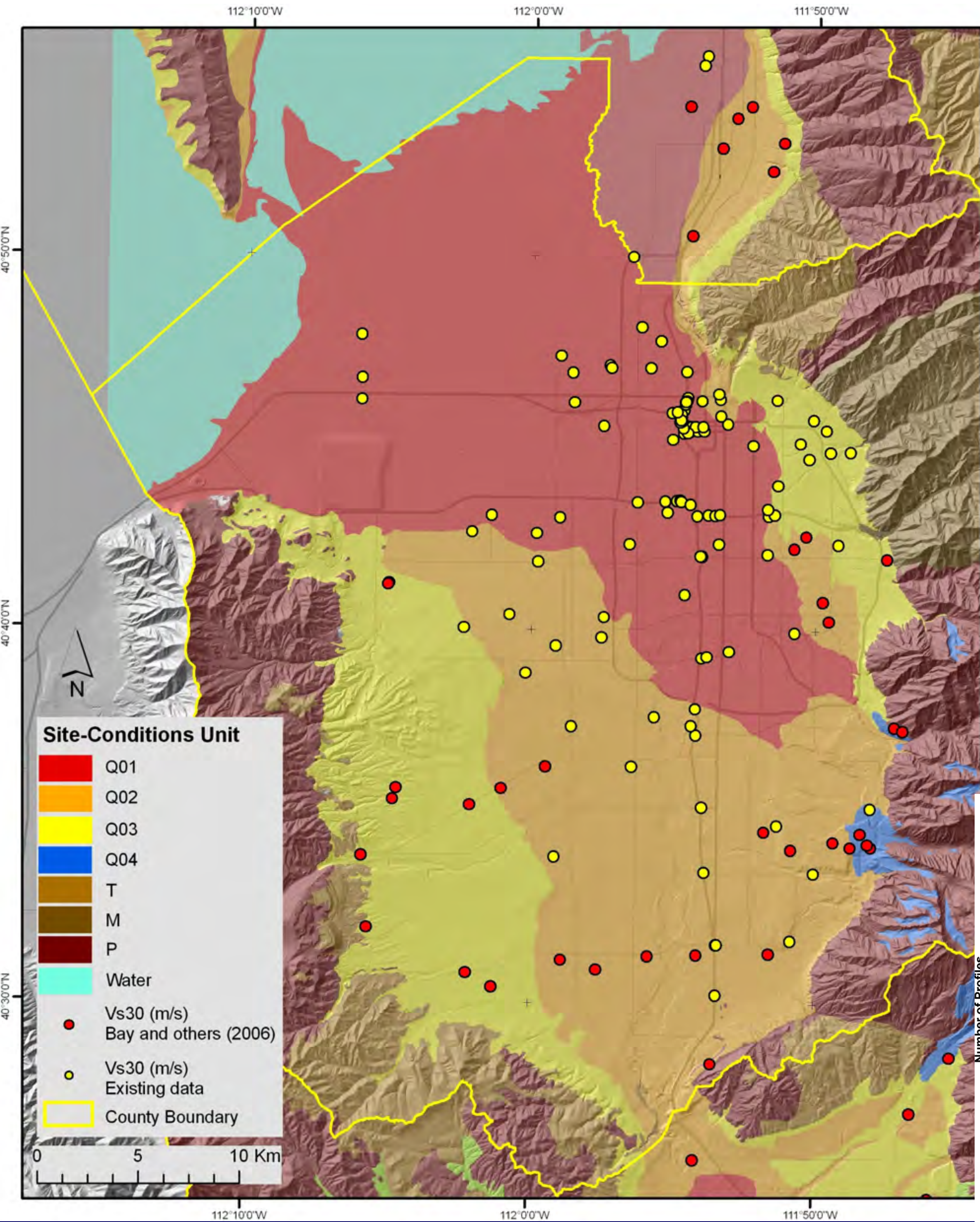


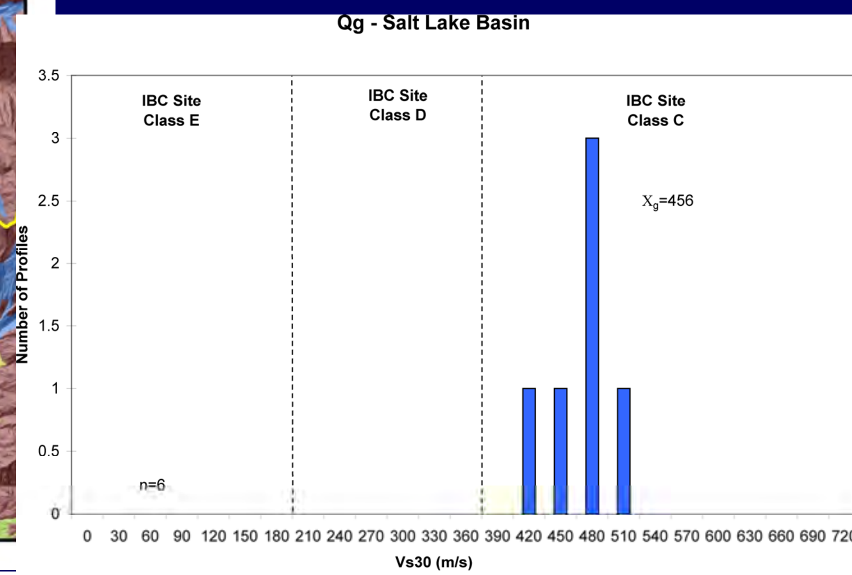


Salt Lake basin

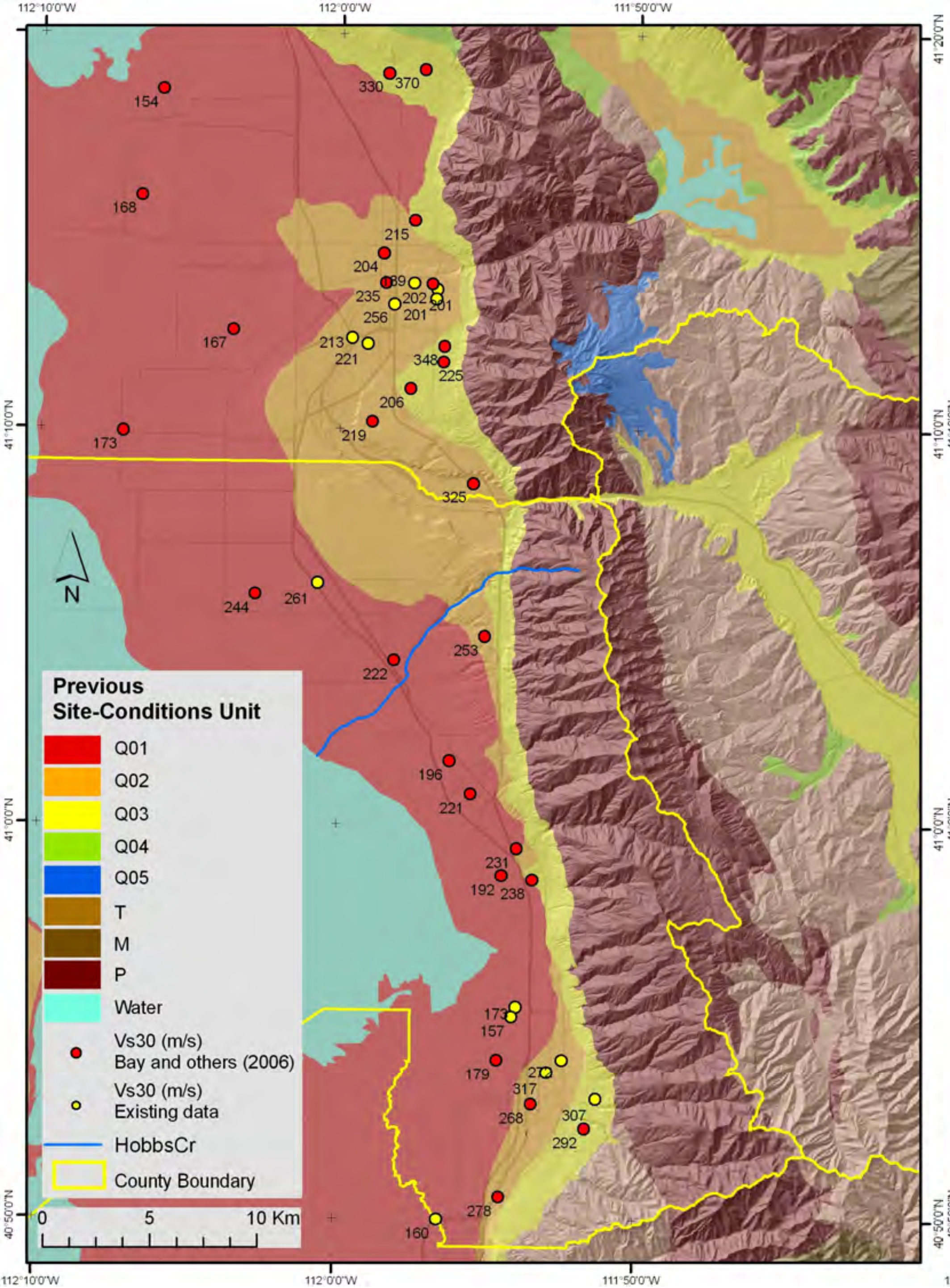
Q04 – Glacial deposits

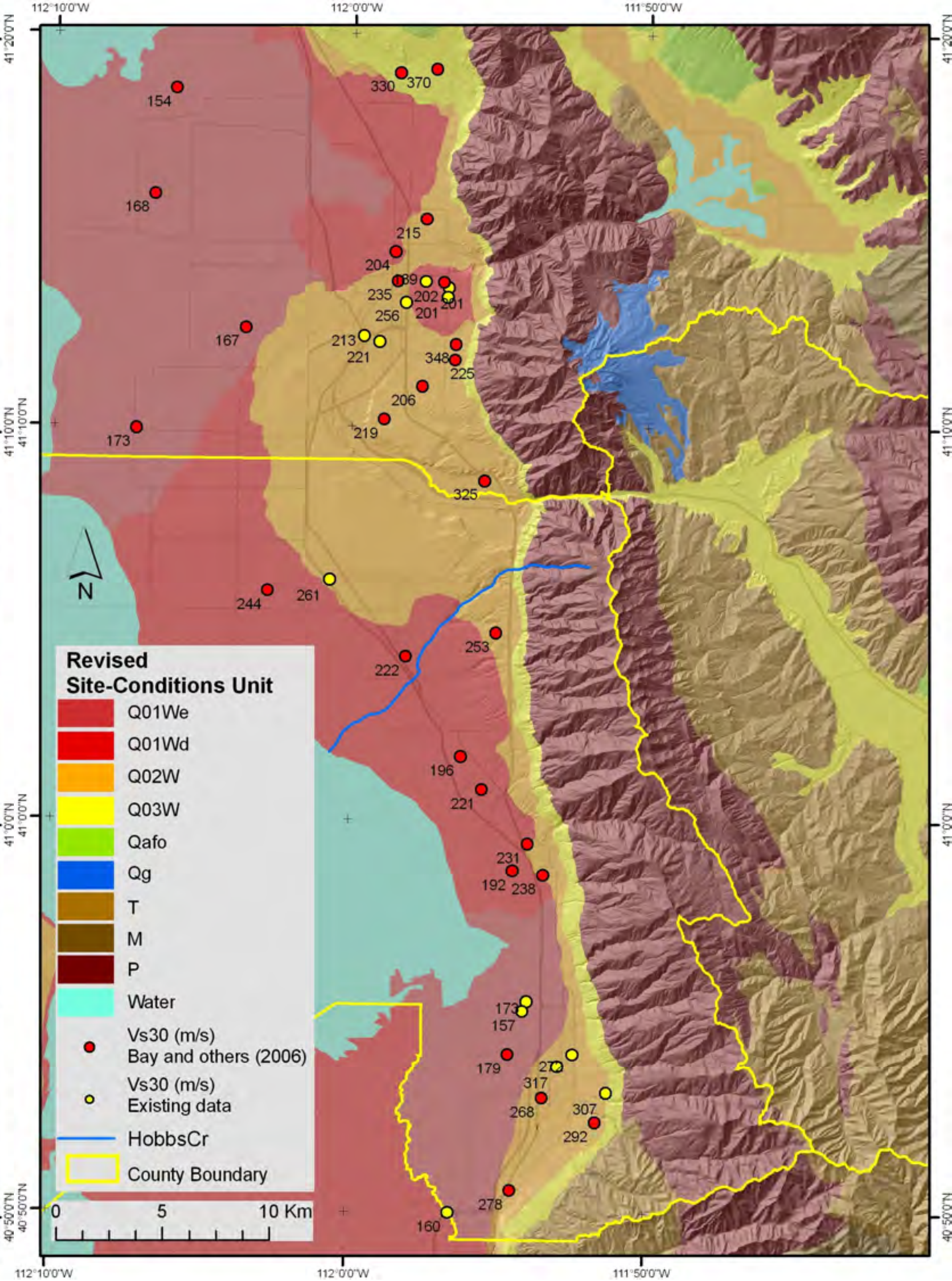
Xg=456 m/s
n=6





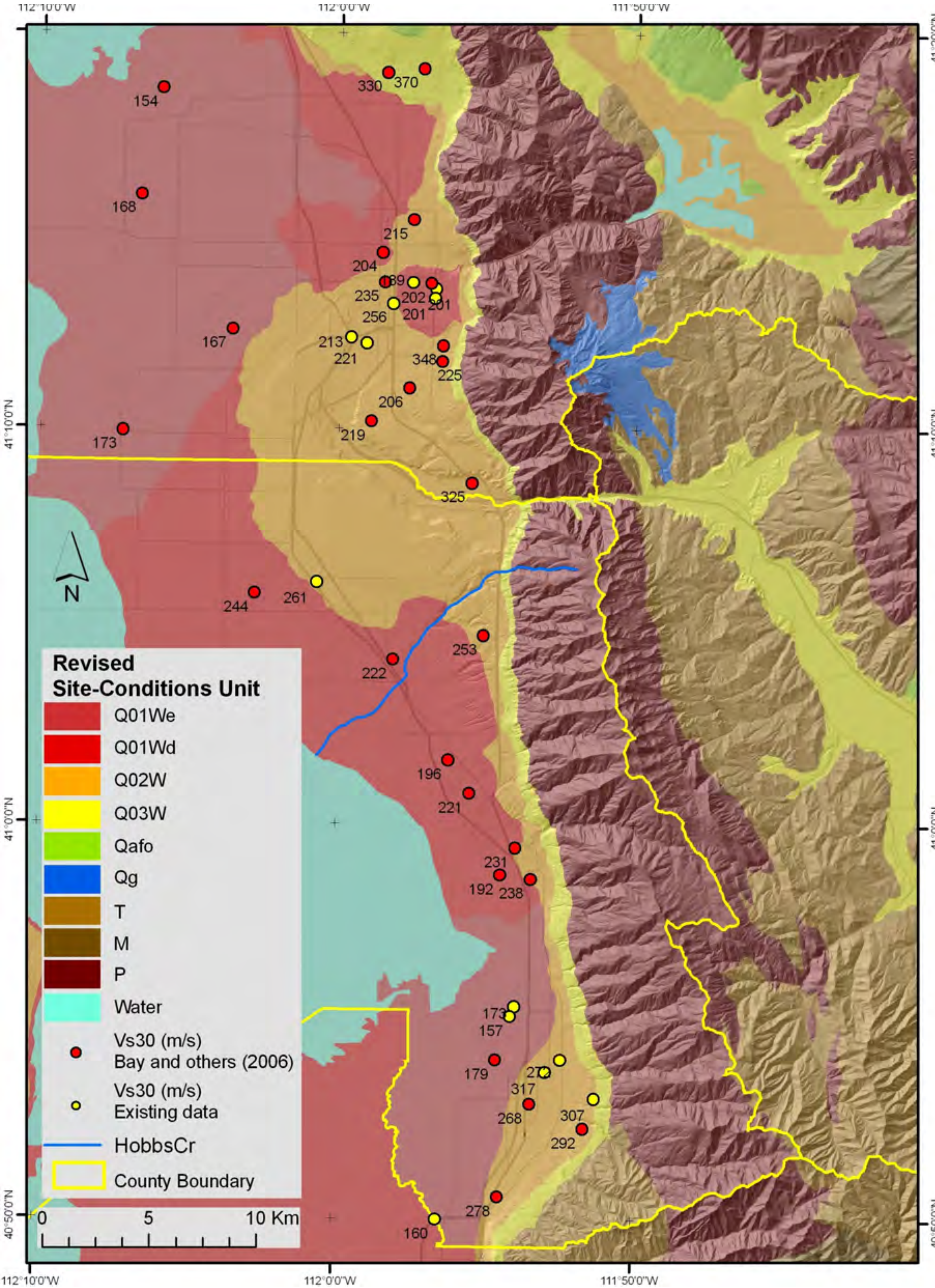
Weber-Davis composite basin

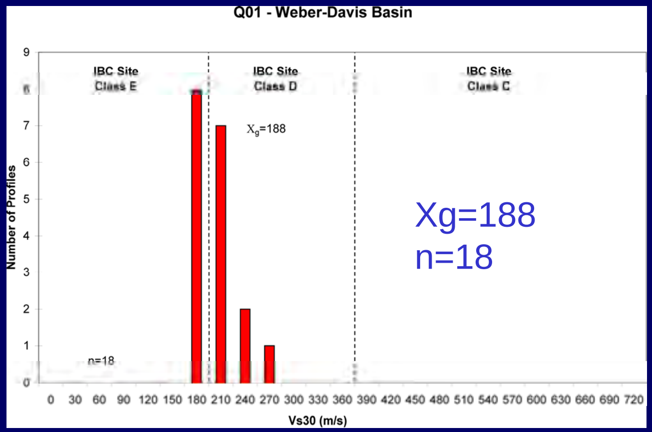


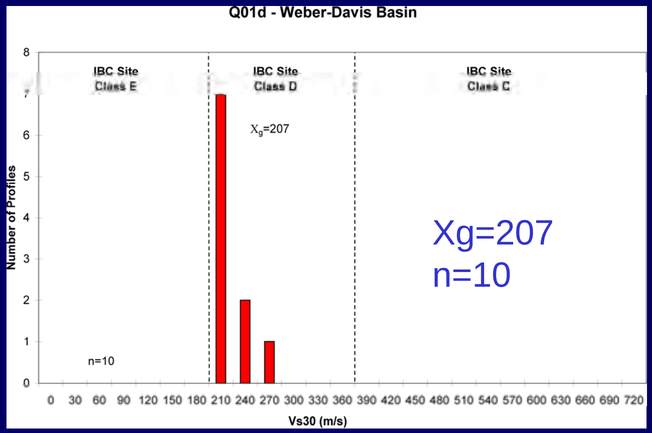


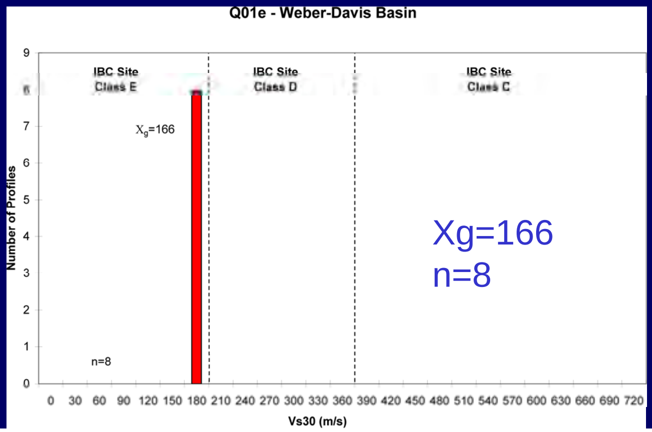
Weber-Davis composite

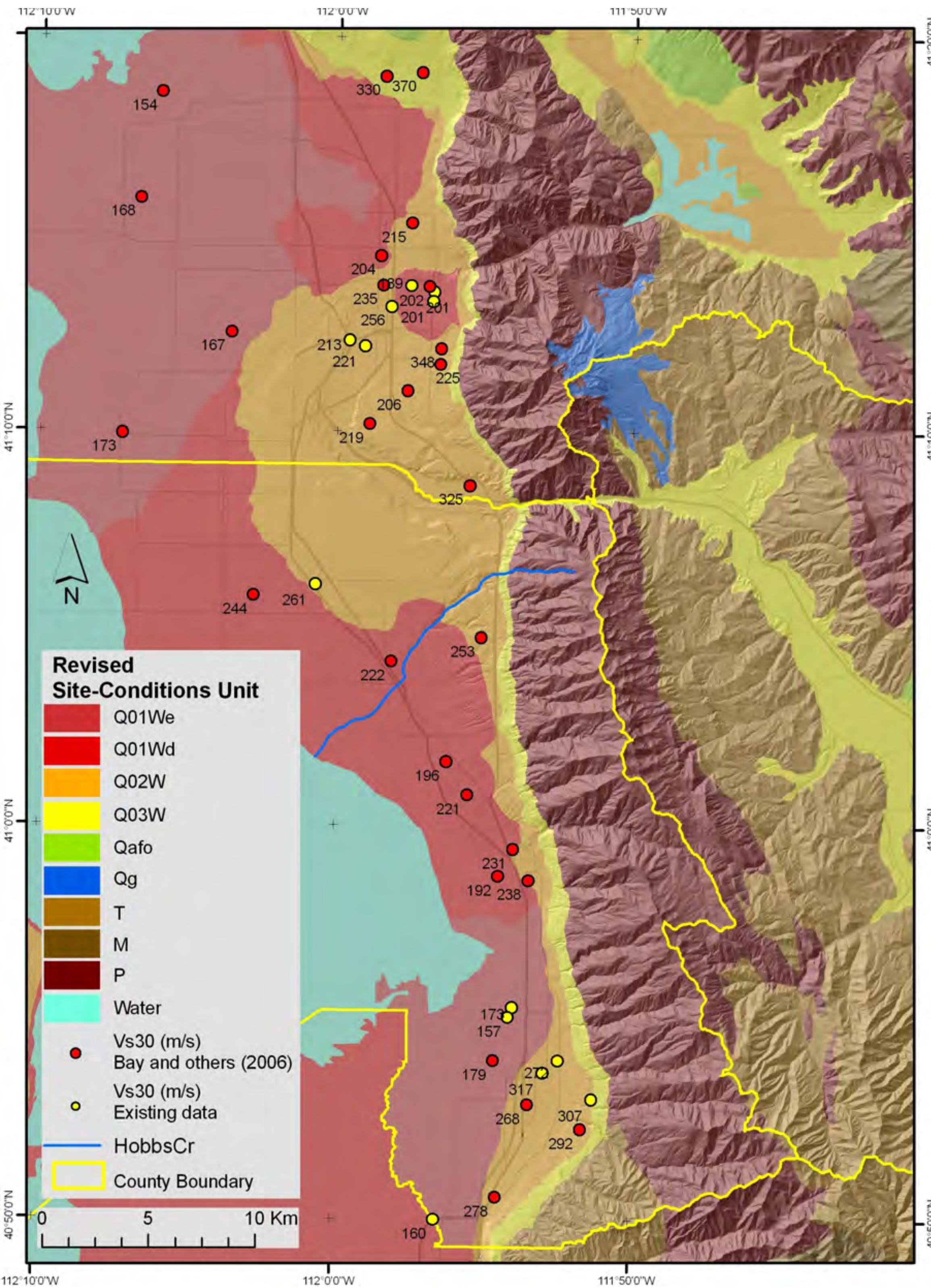
IBC site class D and E subunits





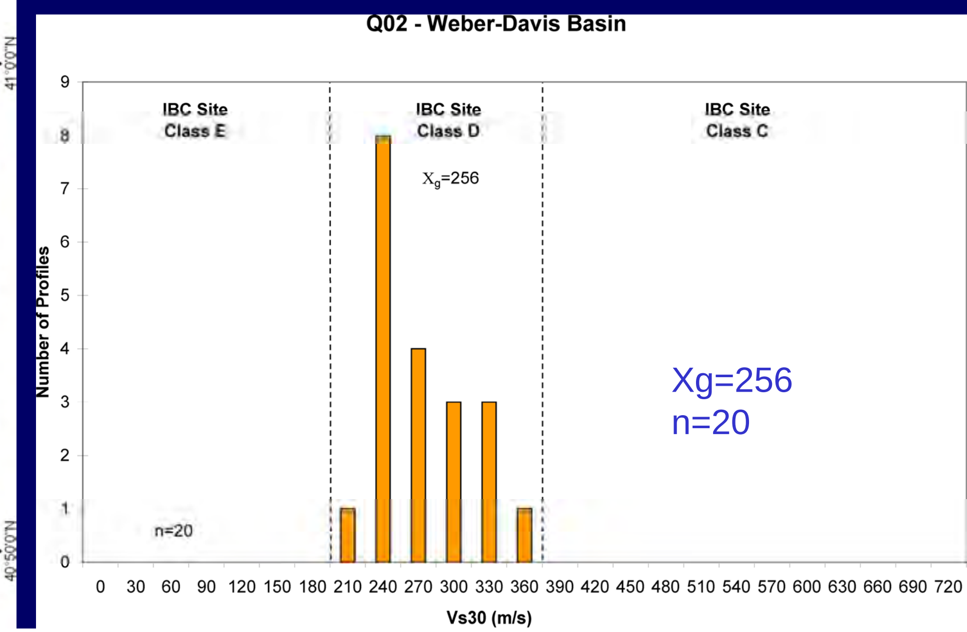


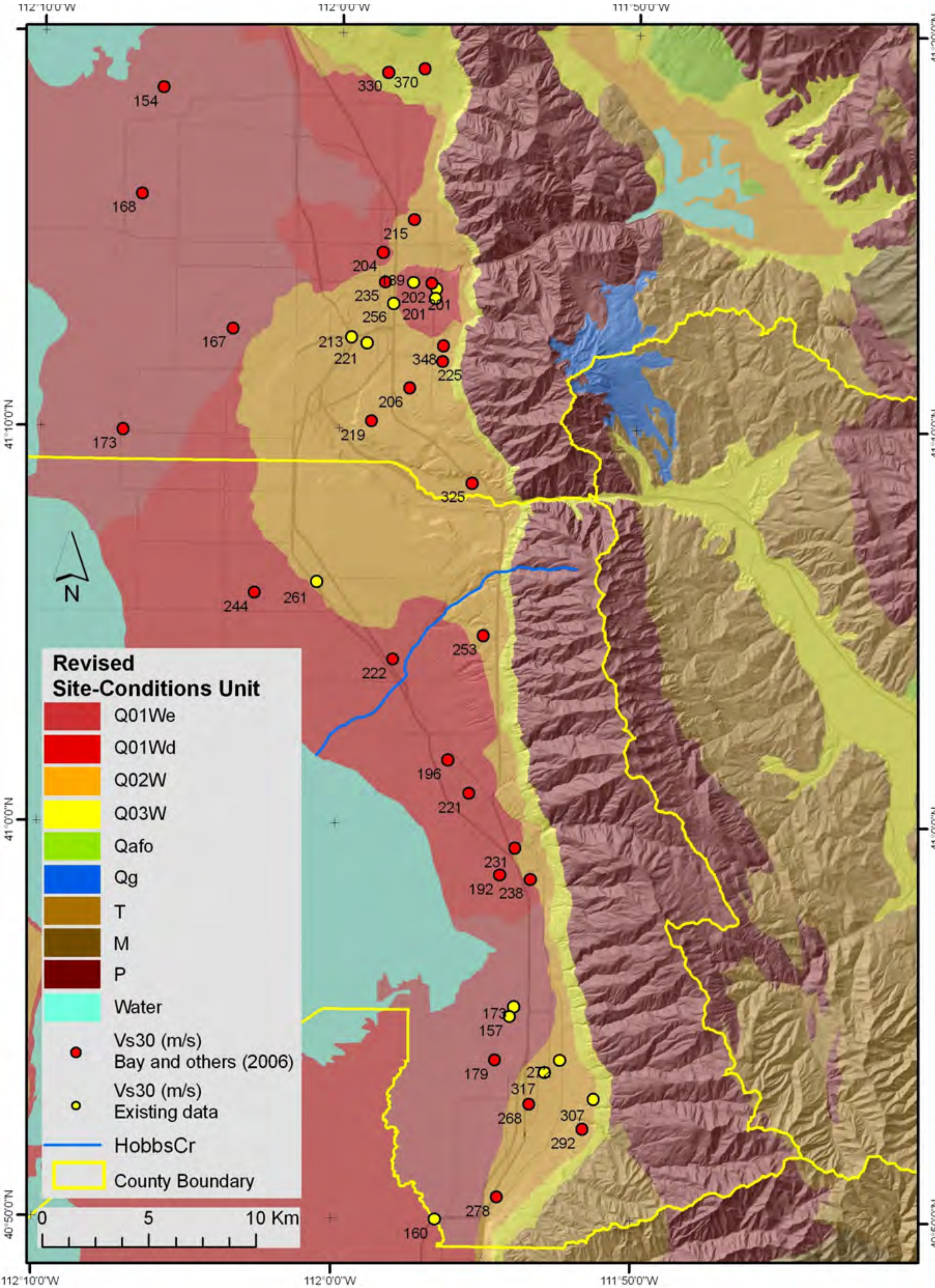




Weber-Davis composite

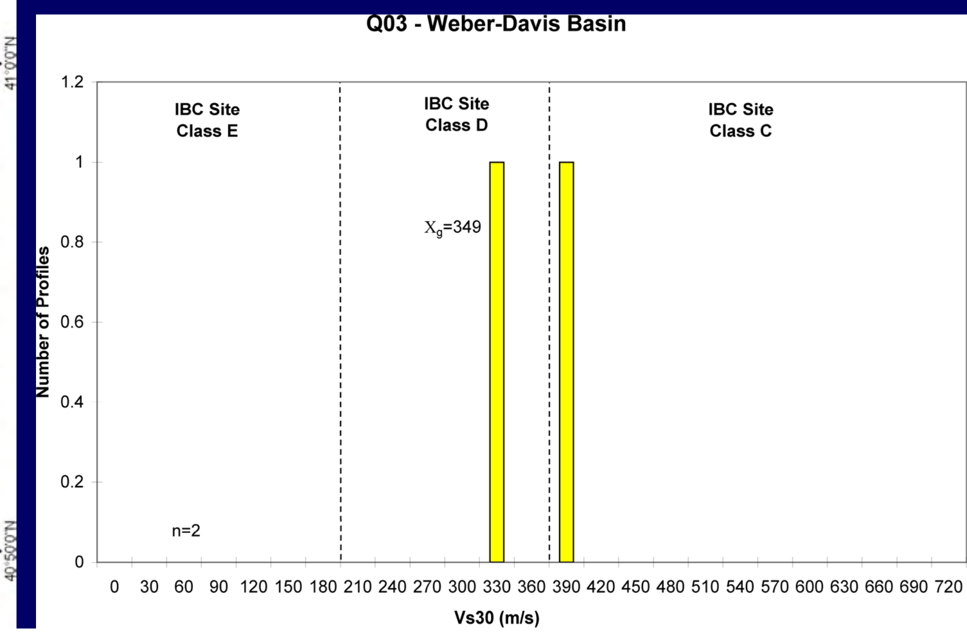
- Q02WD – Sand-dominated deltaic/nearshore, younger alluvial deposits

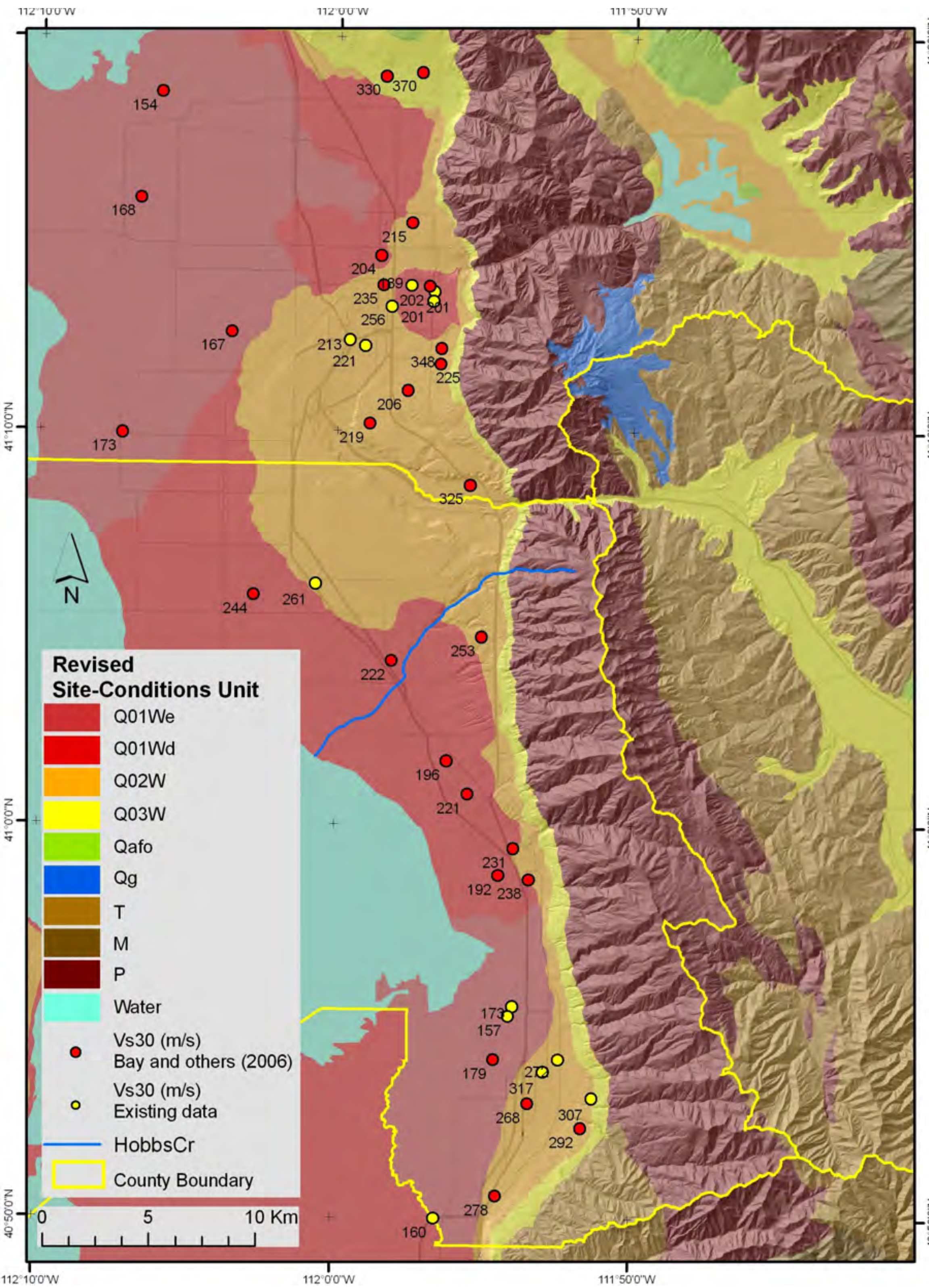




Weber-Davis composite

- Q03WD – Narrow band of gravel-dominated deposits on footwall of WF & in NE basin

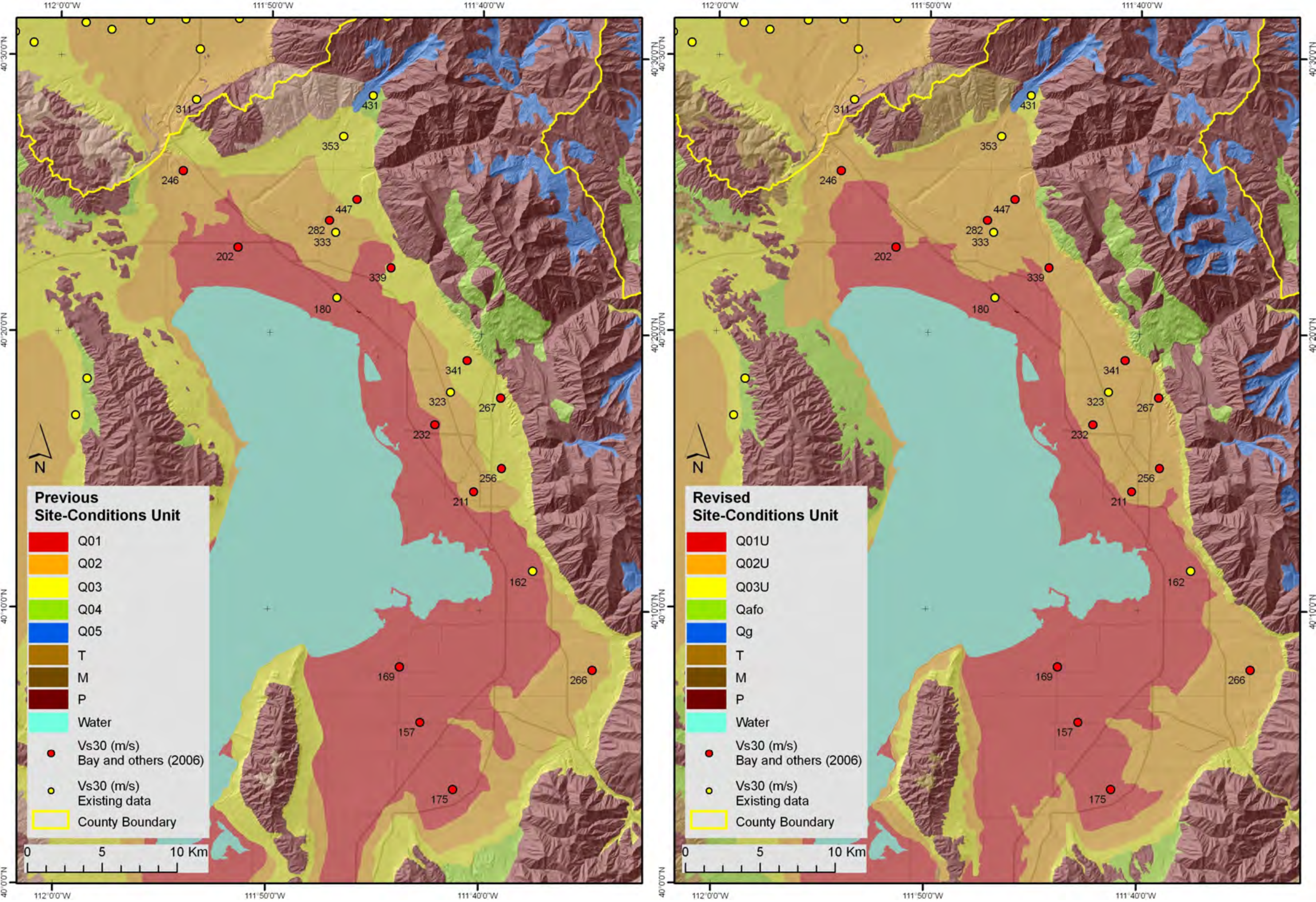




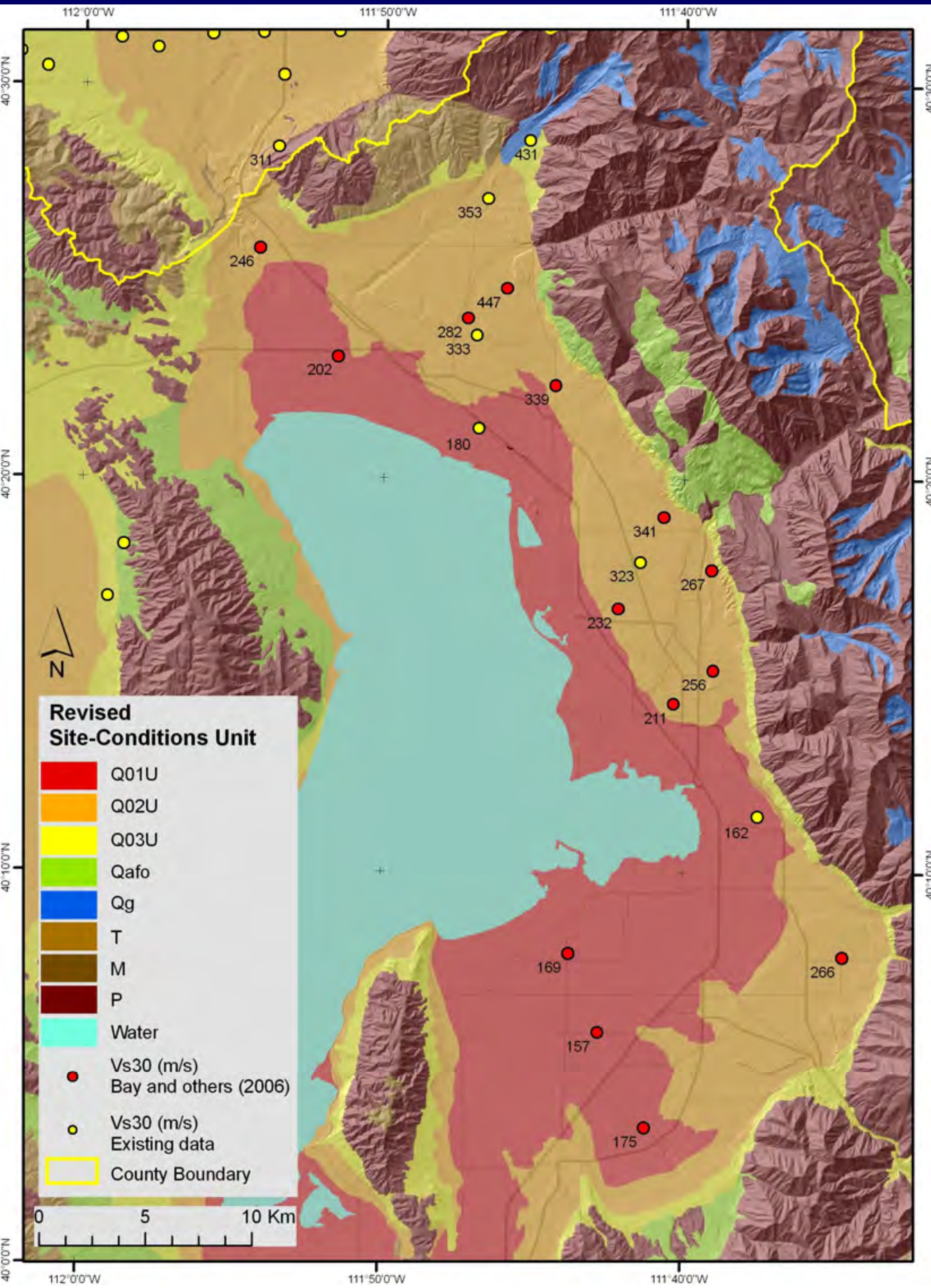
Weber-Davis composite

- QafoWD – Older alluvial-fan deposits only mapped in NE part of basin; no profiles

Utah Valley

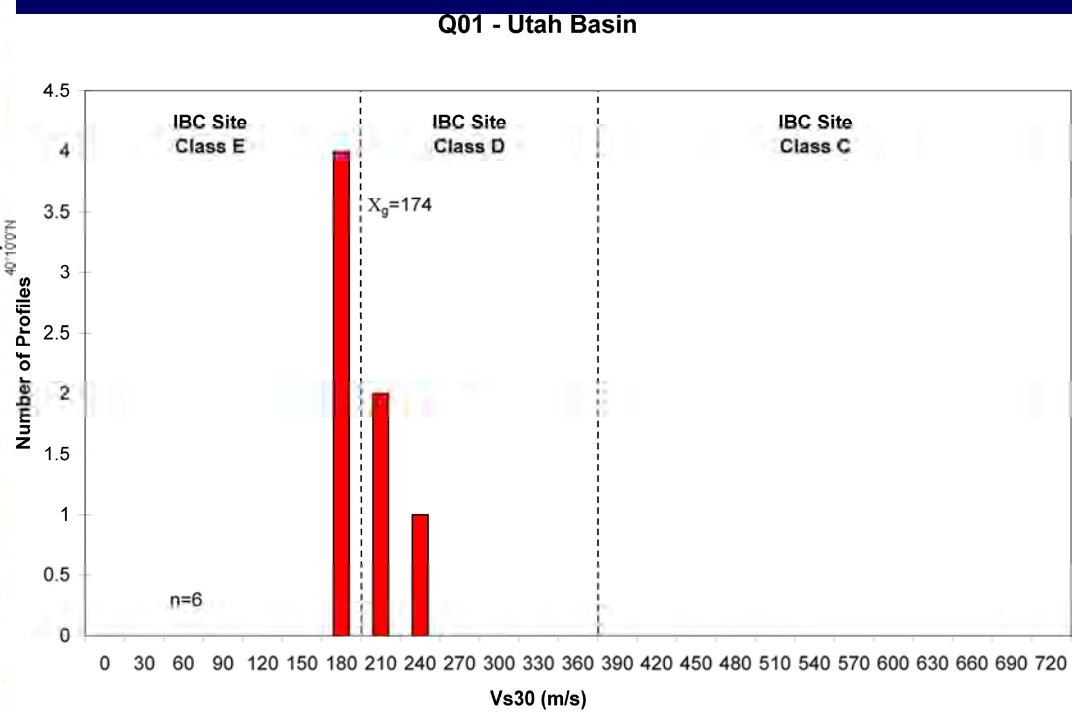

112°0'0"W
111°50'0"W
111°40'0"W
40°30'0"N
40°20'0"N
40°10'0"N
40°0'0"N
311
431
353
246
447
282
333
202
339
180
341
323
267
232
256
211
162
169
266
157
175
N
Previous
Site-Conditions Unit
Q01
Q02
Q03
Q04
Q05
T
M
P
Water
Vs30 (m/s)
Bay and others (2006)
Vs30 (m/s)
Existing data
County Boundary
0
5
10 Km
Revised
Site-Conditions Unit
Q01U
Q02U
Q03U
Qafo
Qg
T
M
P
Water
Vs30 (m/s)
Bay and others (2006)
Vs30 (m/s)
Existing data
County Boundary
0
5
10 Km

Utah Valley

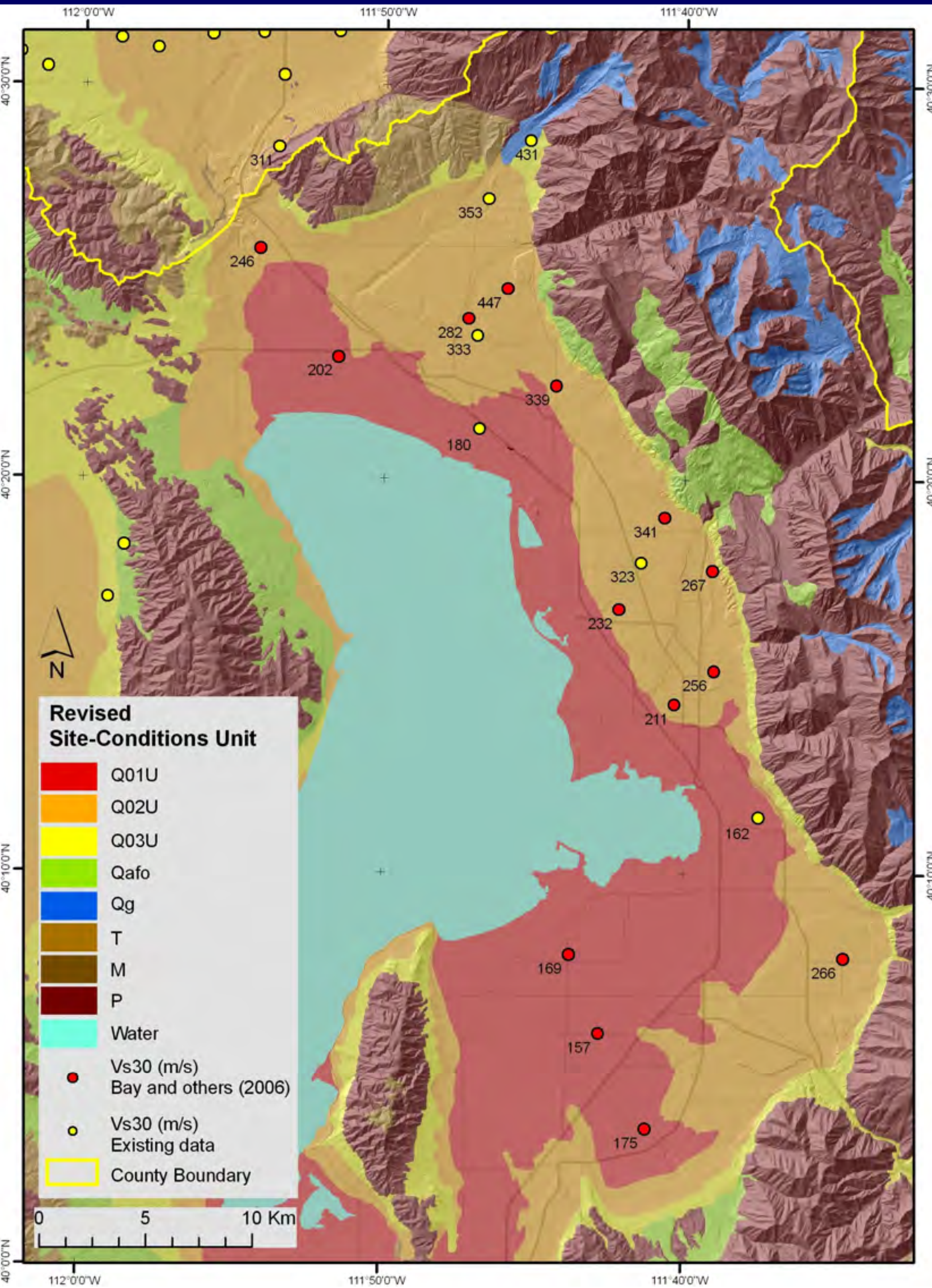


- Q01U – Silt and clay-dominated deposits

Xg=174 m/s
n=6

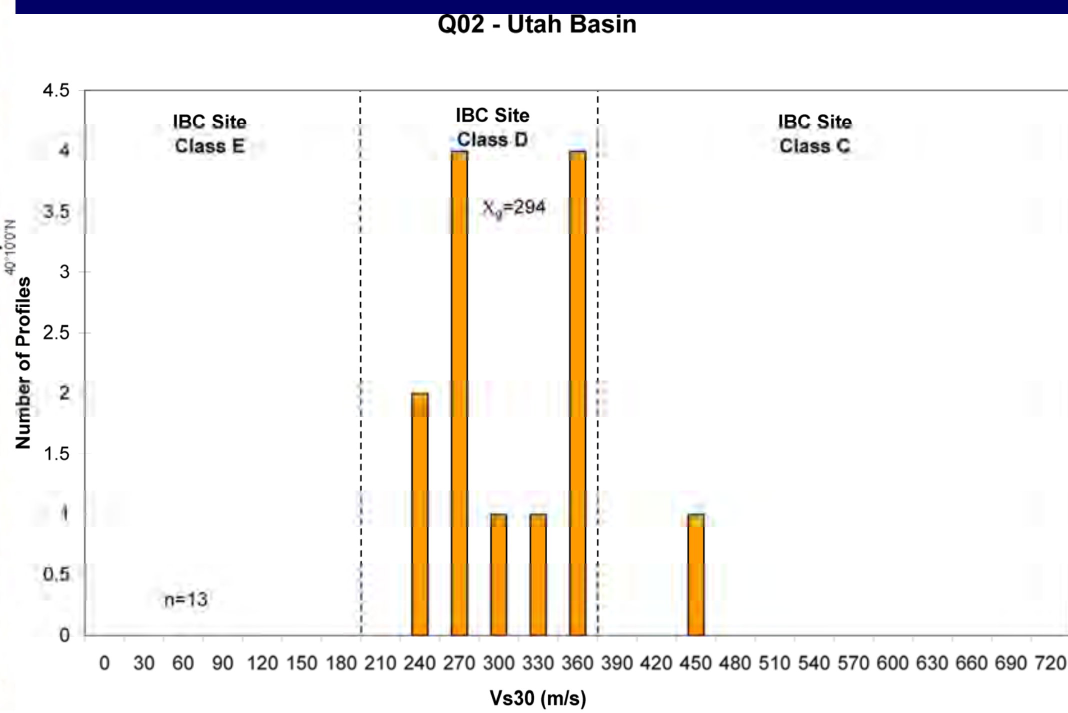


Utah Valley

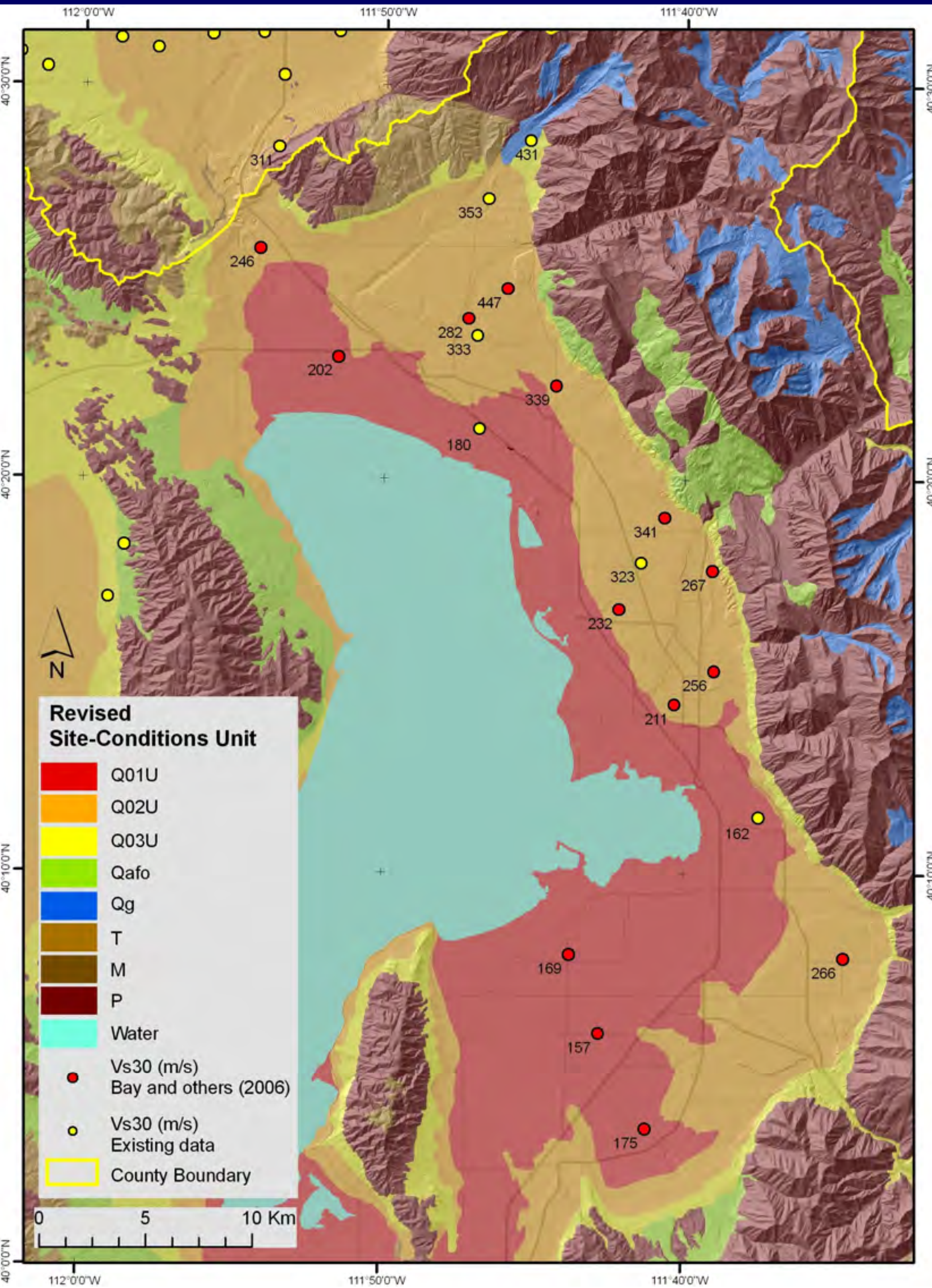


- Q02U – Sand-dominated deltaic/nearshore, younger alluvial deposits

Xg=294 m/s
n=13

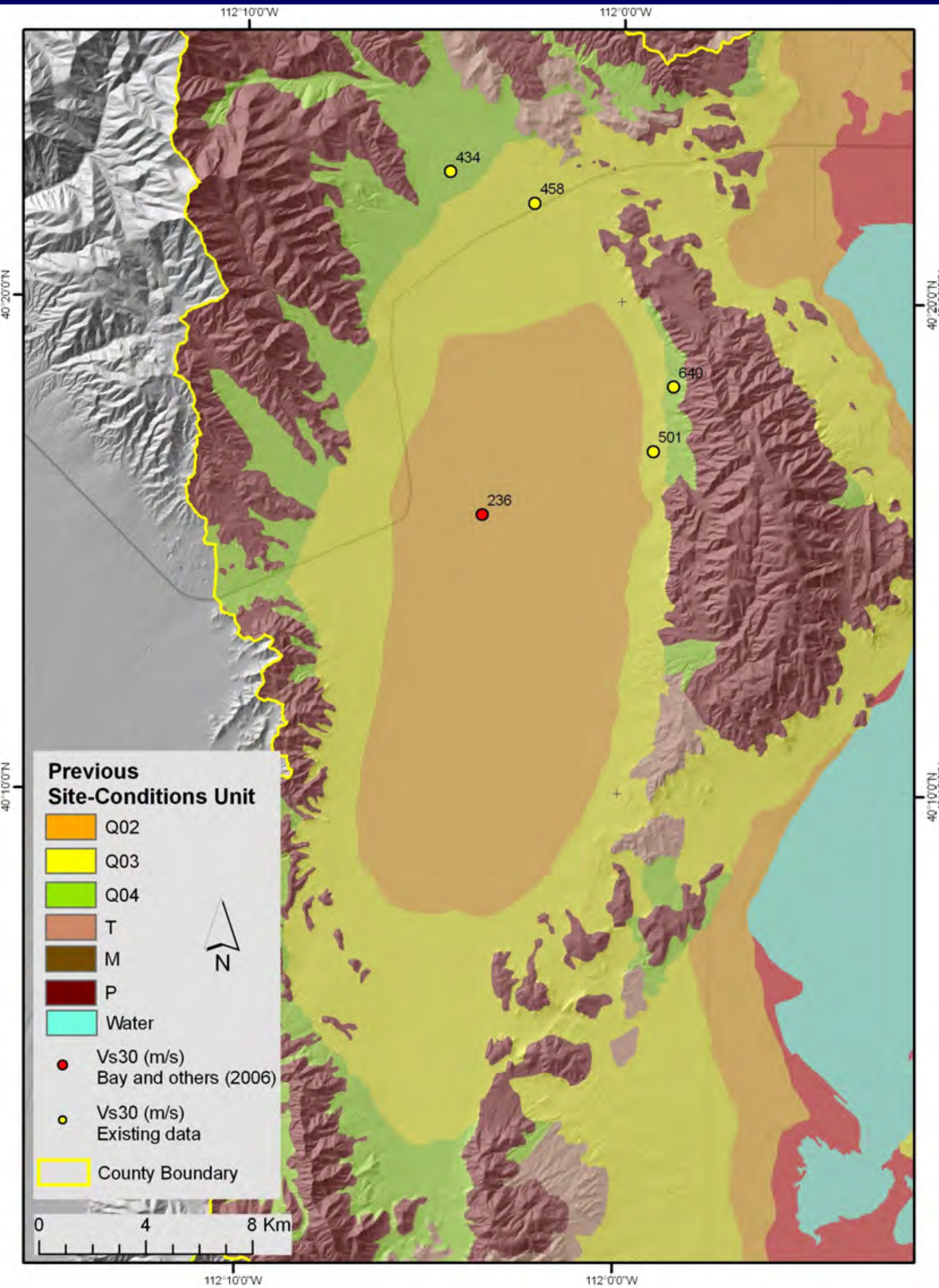


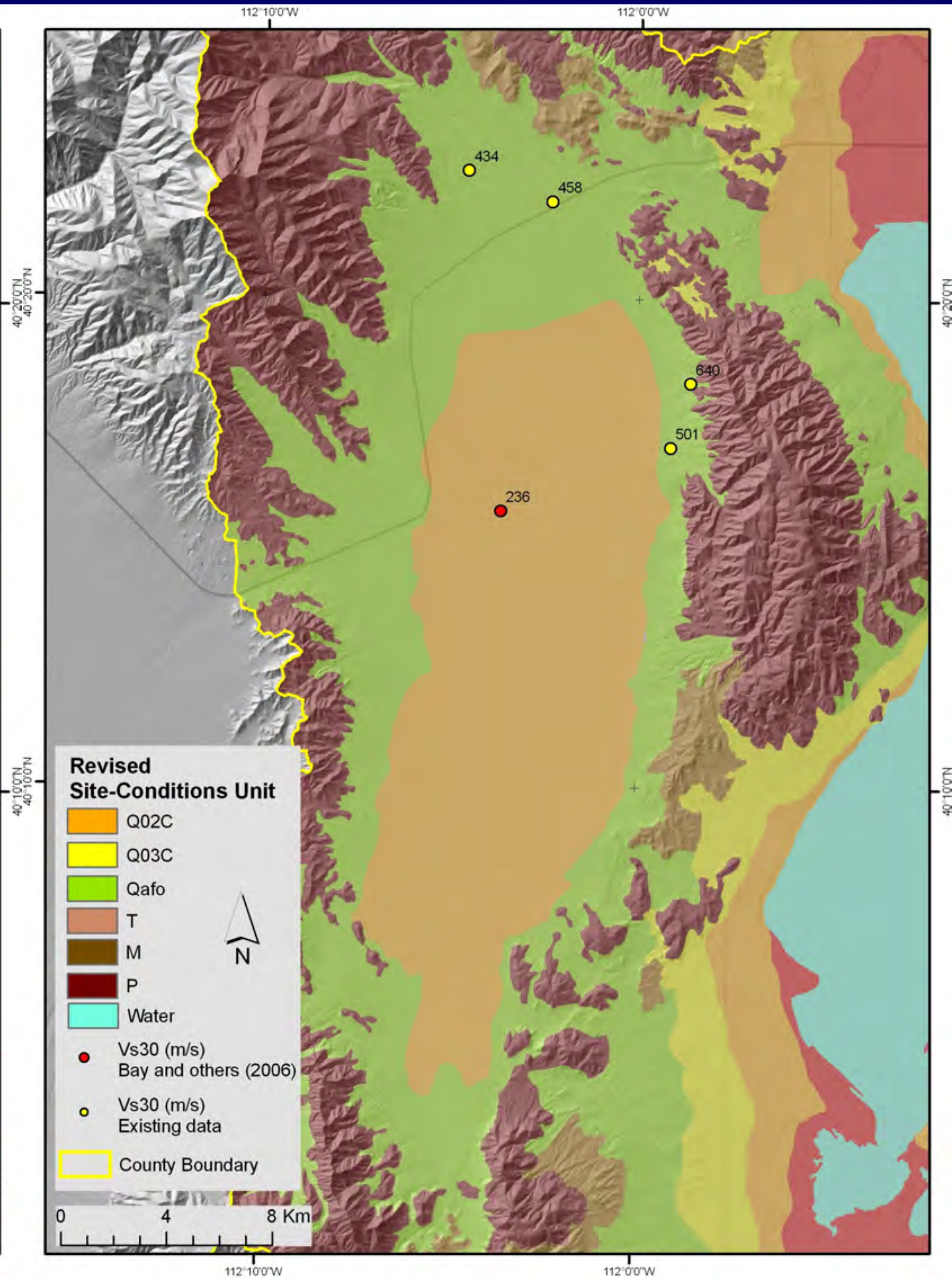
Utah Valley



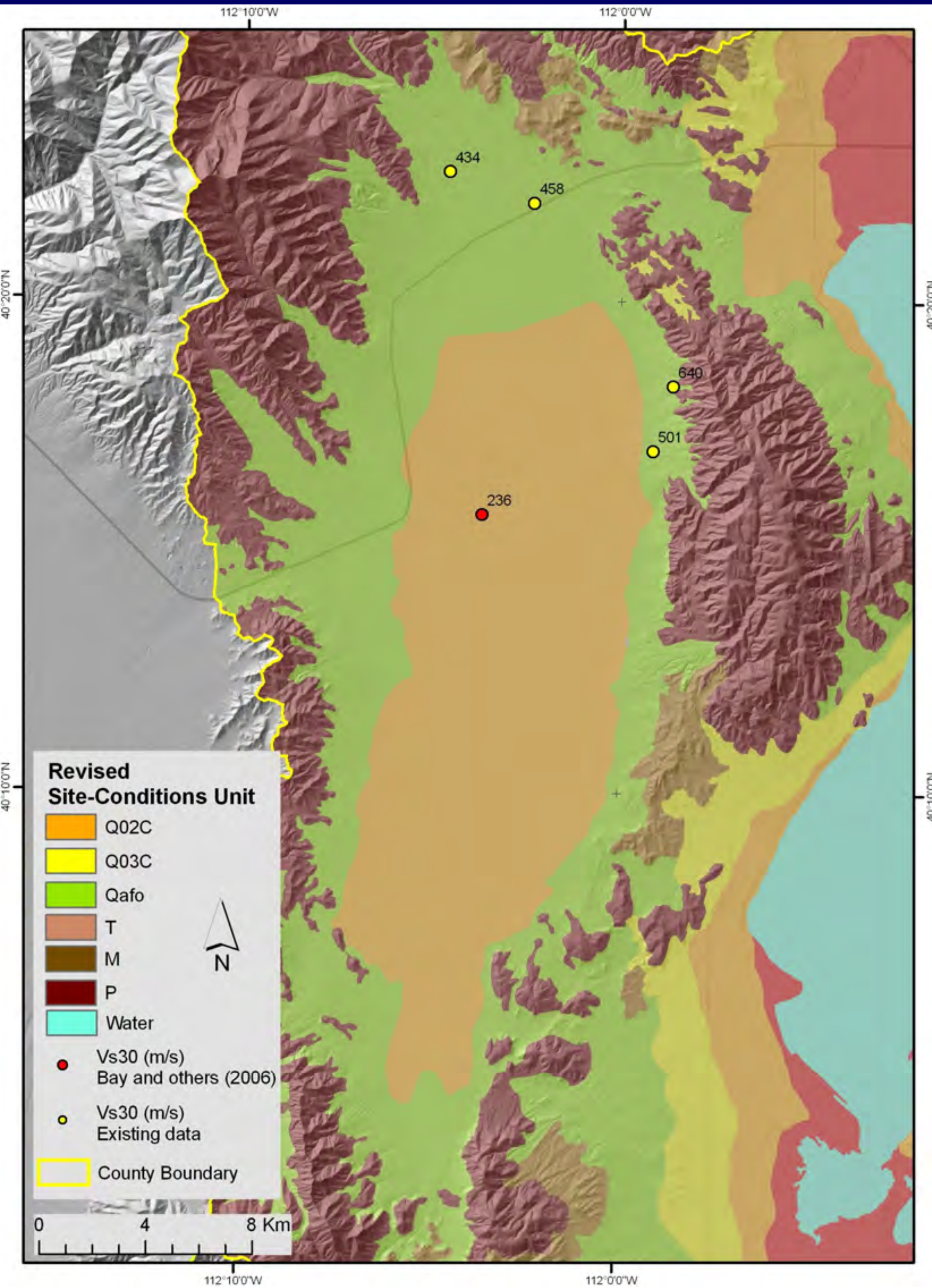
- Q03U – Narrow band of gravel-dominated deposits on footwall of WF; no profiles
- QafoU – Older alluvial-fan deposits. Includes large landslide complexes; no profiles
- QgU – Glacial deposits. One profile 431 m/s (SL mean 456 m/s)

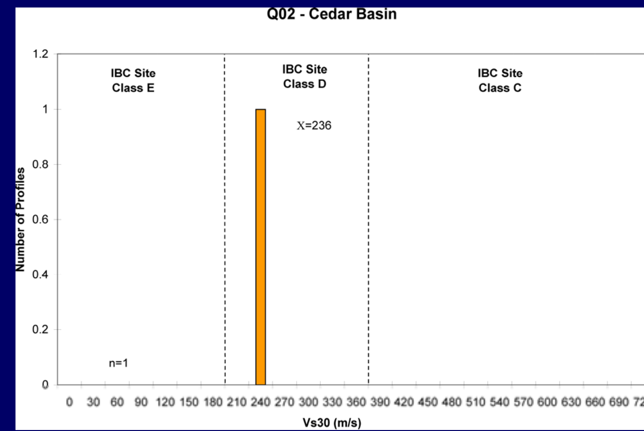
Cedar Fort basin

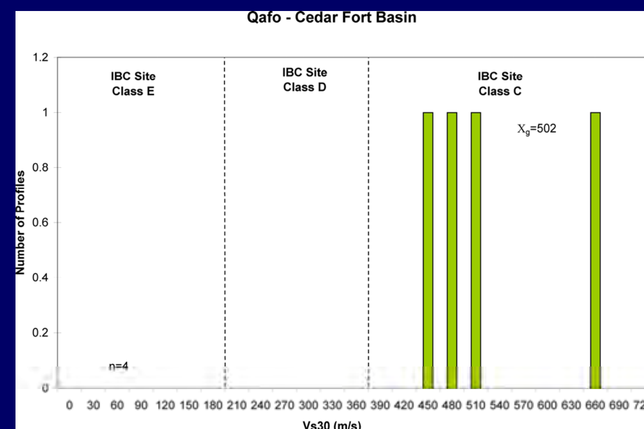


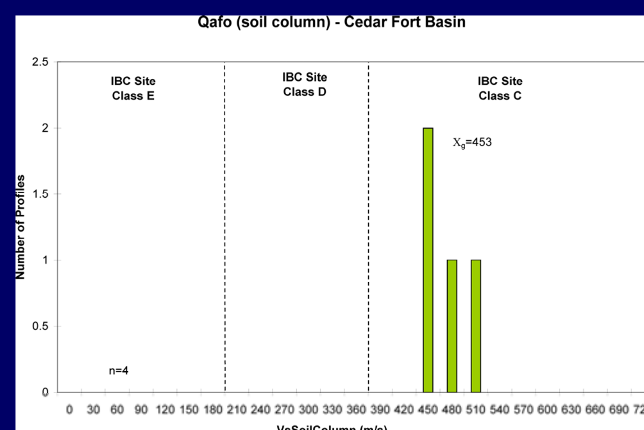


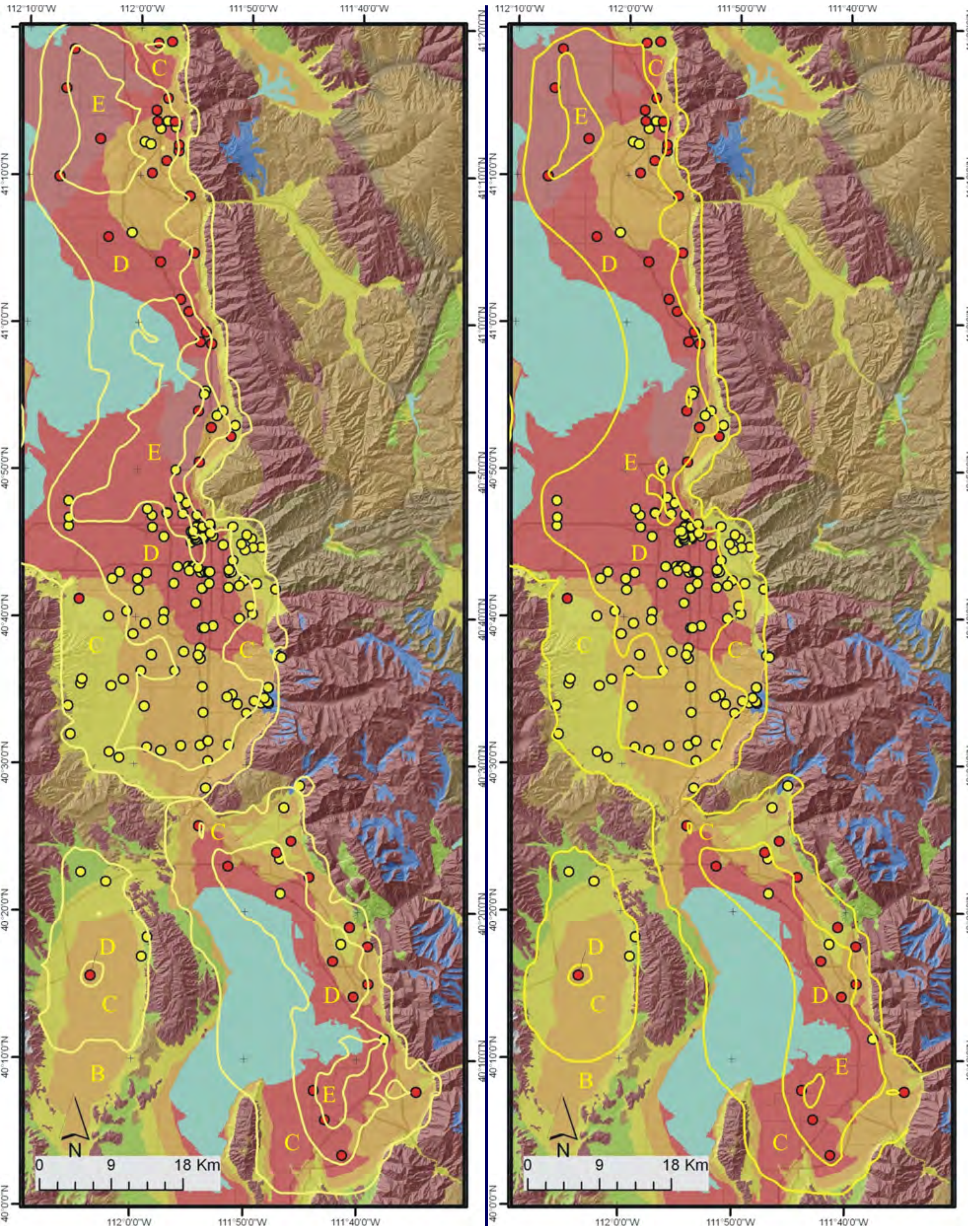
Cedar Fort basin









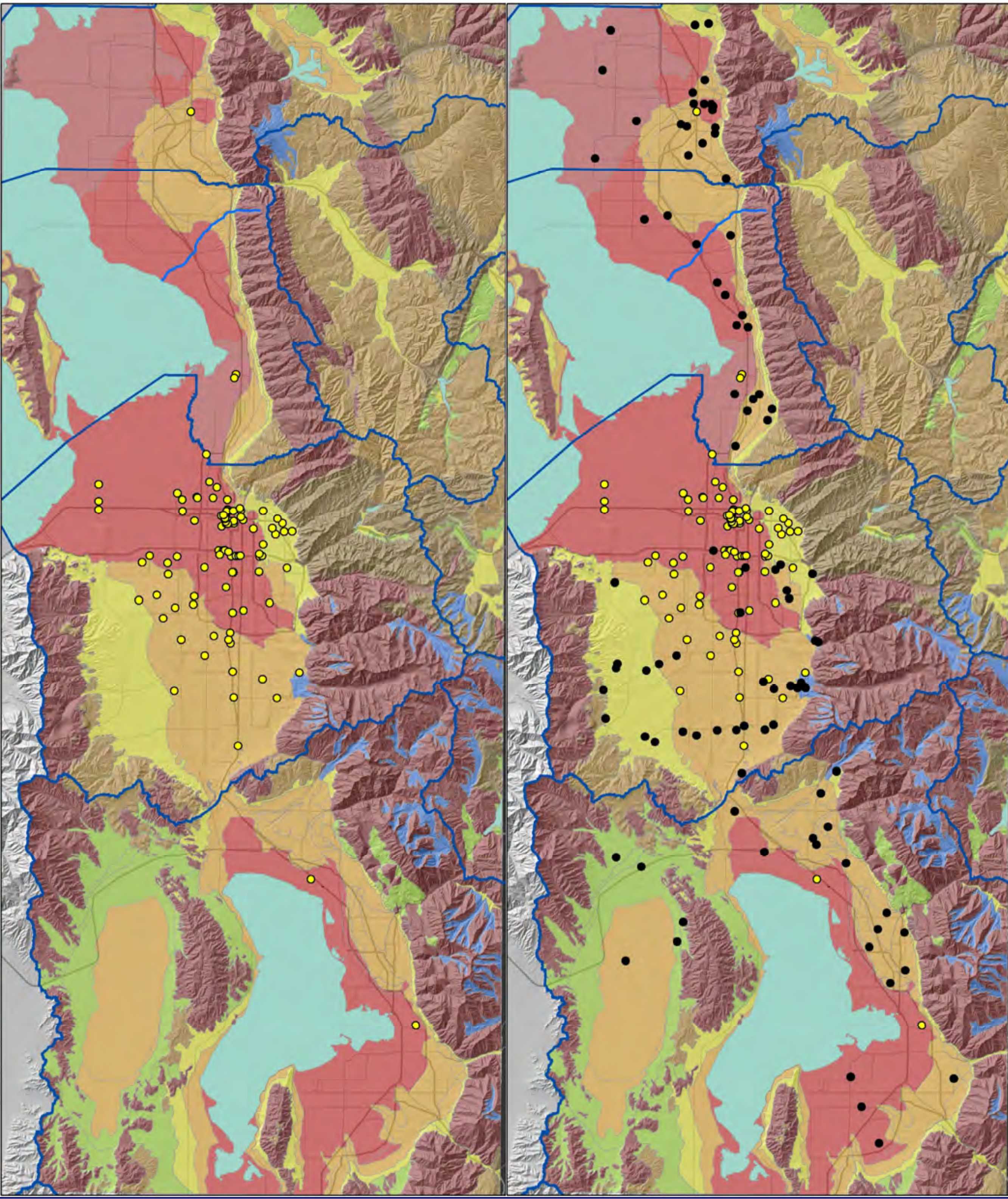


Contoured Vs30 data

Krig
Natural neighbor

Q/bedrock contact 760 m/s
(IBC B-C boundary)

Variable spatial distribution
Too few data



New Vs data

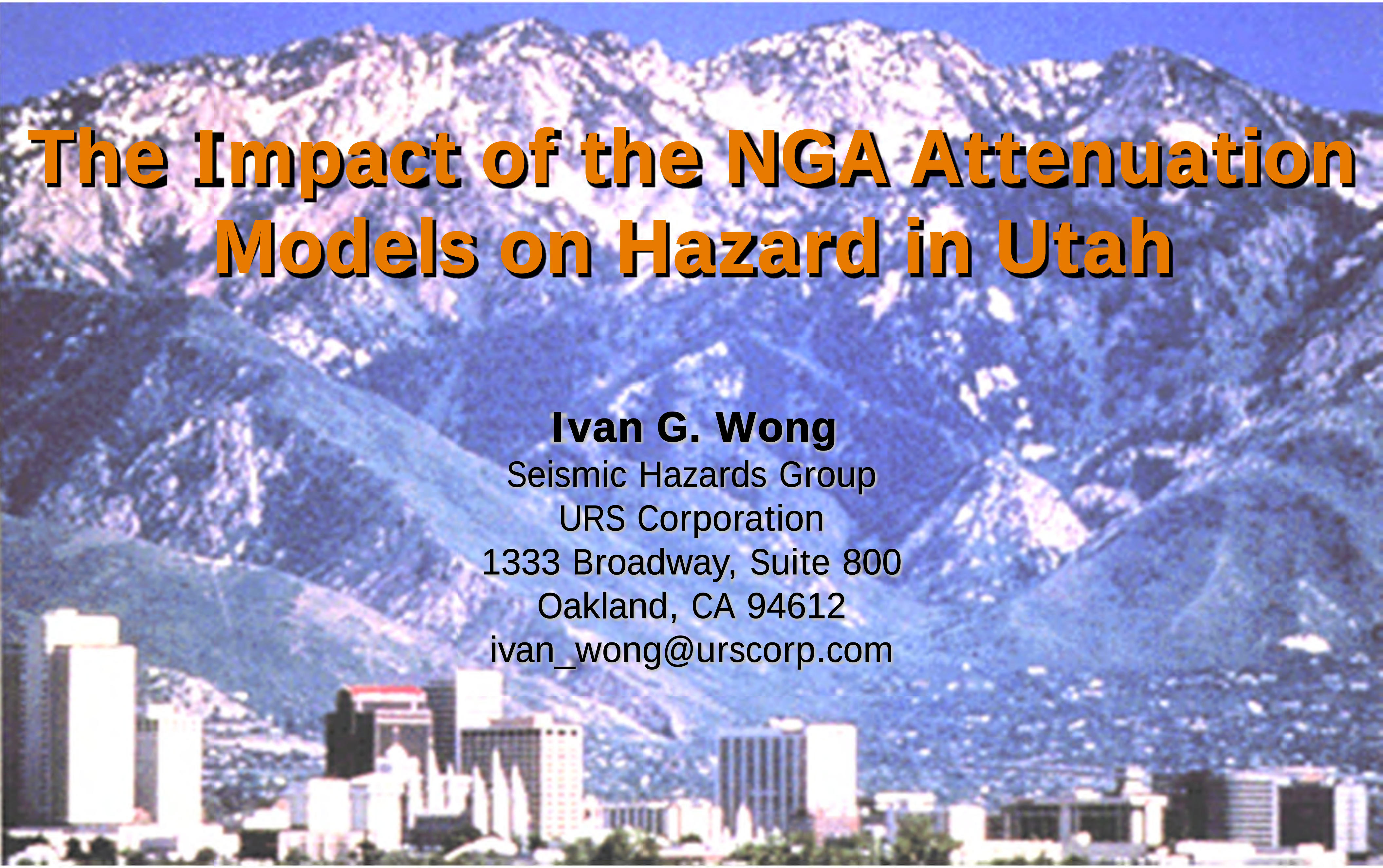
Well-characterized Salt Lake basin

Expanded Vs data outside SL basin

Indicate geologically-based units differ basin to basin

Allow for WF-wide characterization of individual basins

Individual units outside SLV not statistically robust



The Impact of the NGA Attenuation Models on Hazard in Utah

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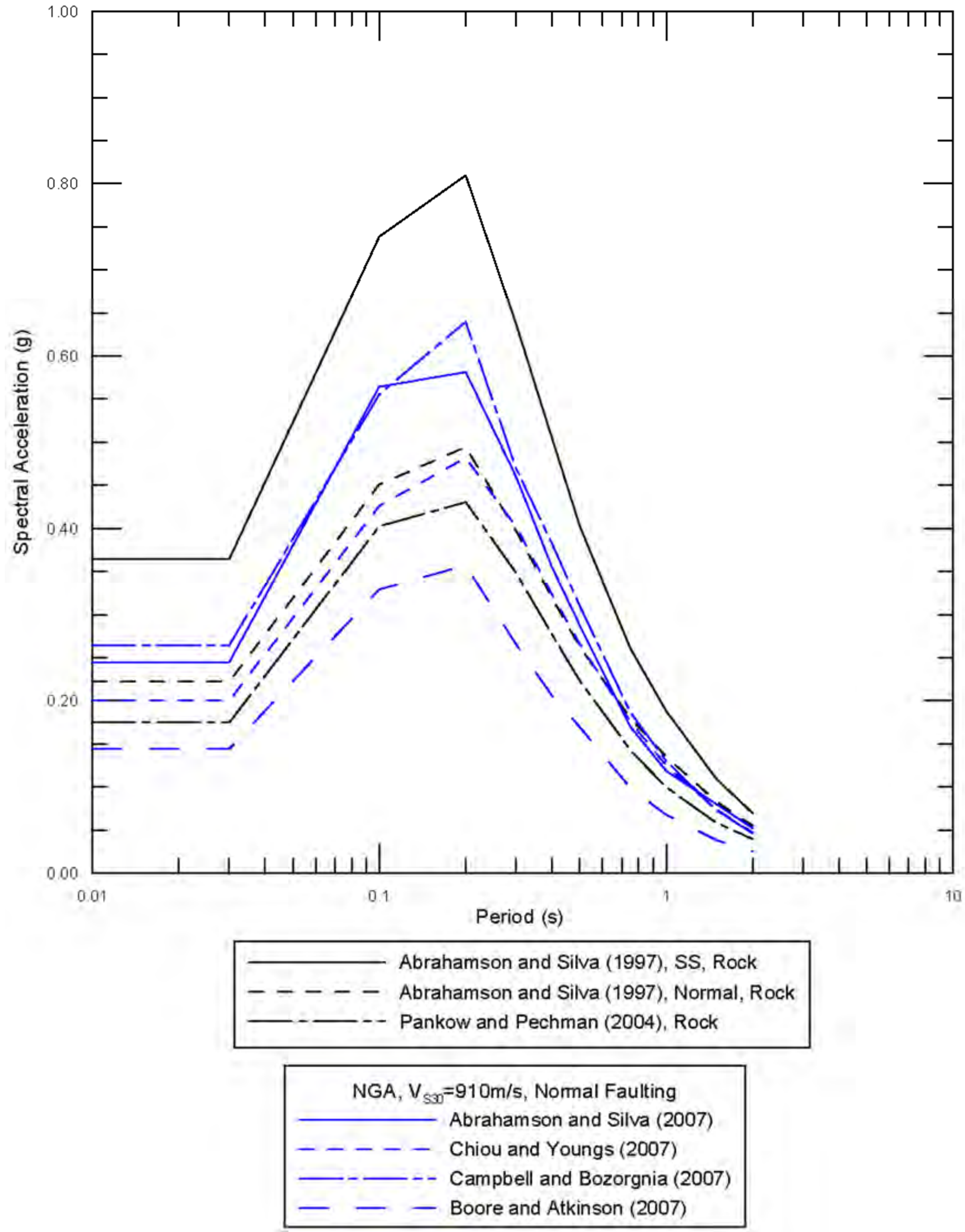
Oakland, CA 94612
ivan_wong@urscorp.com

Utah Ground Shaking Working Group Meeting #4

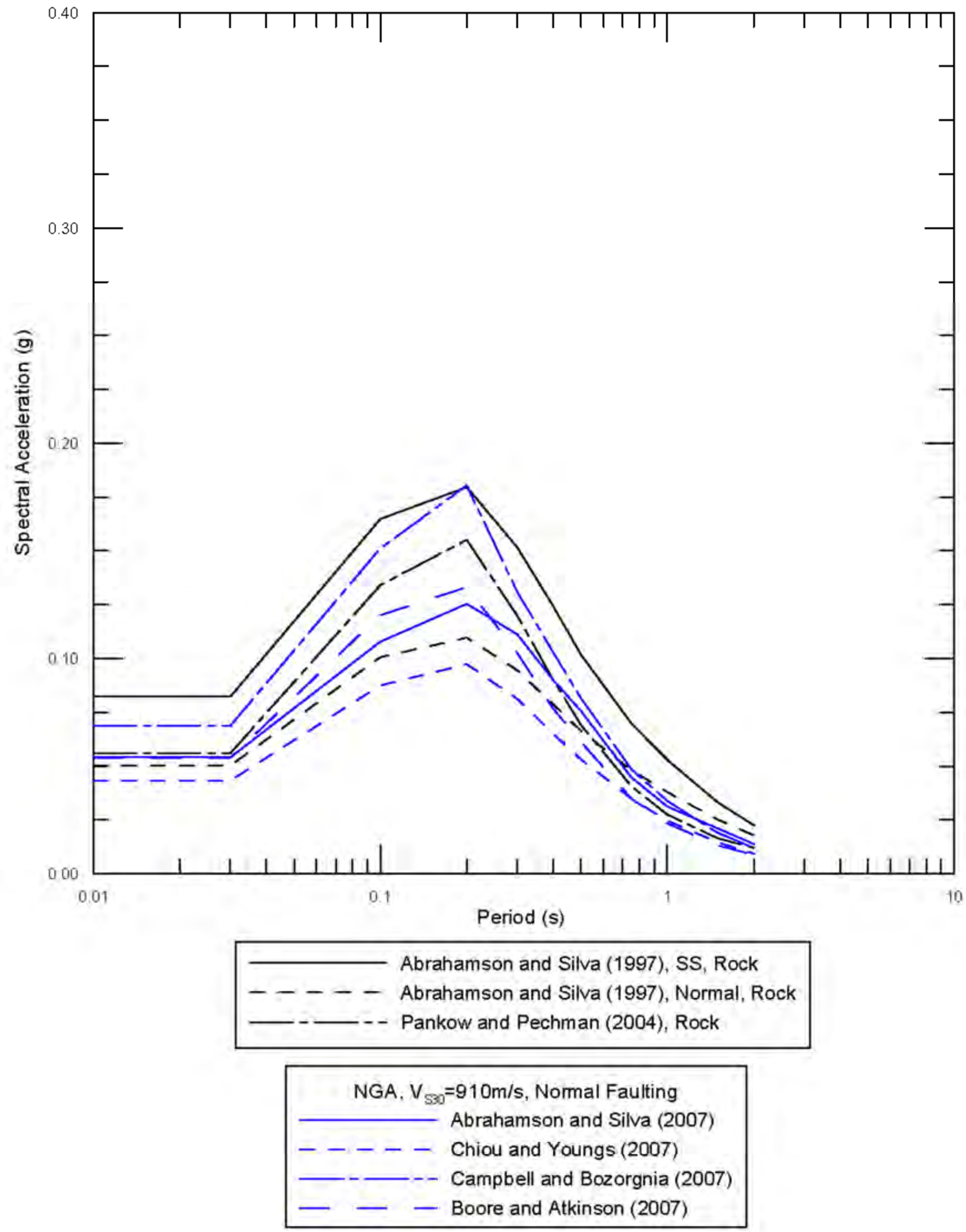
27 February 2007

Median Response Spectra for Normal Faulting and Rock Site Conditions for M 6.0 at 5 km (V_S = 910 m/sec)

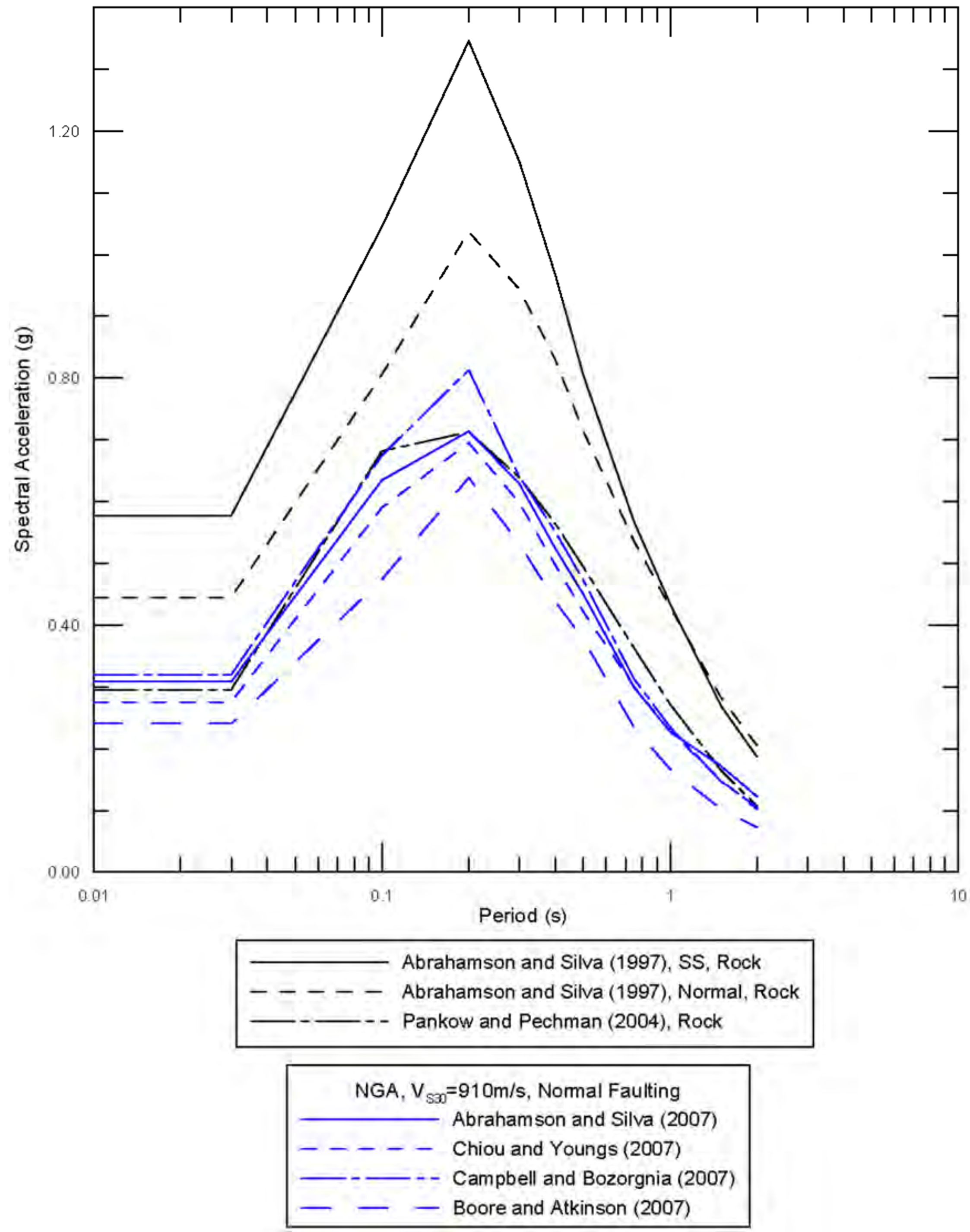


Median Response Spectra for Normal Faulting and Rock Site Conditions for **M** 6.0 at 25 km

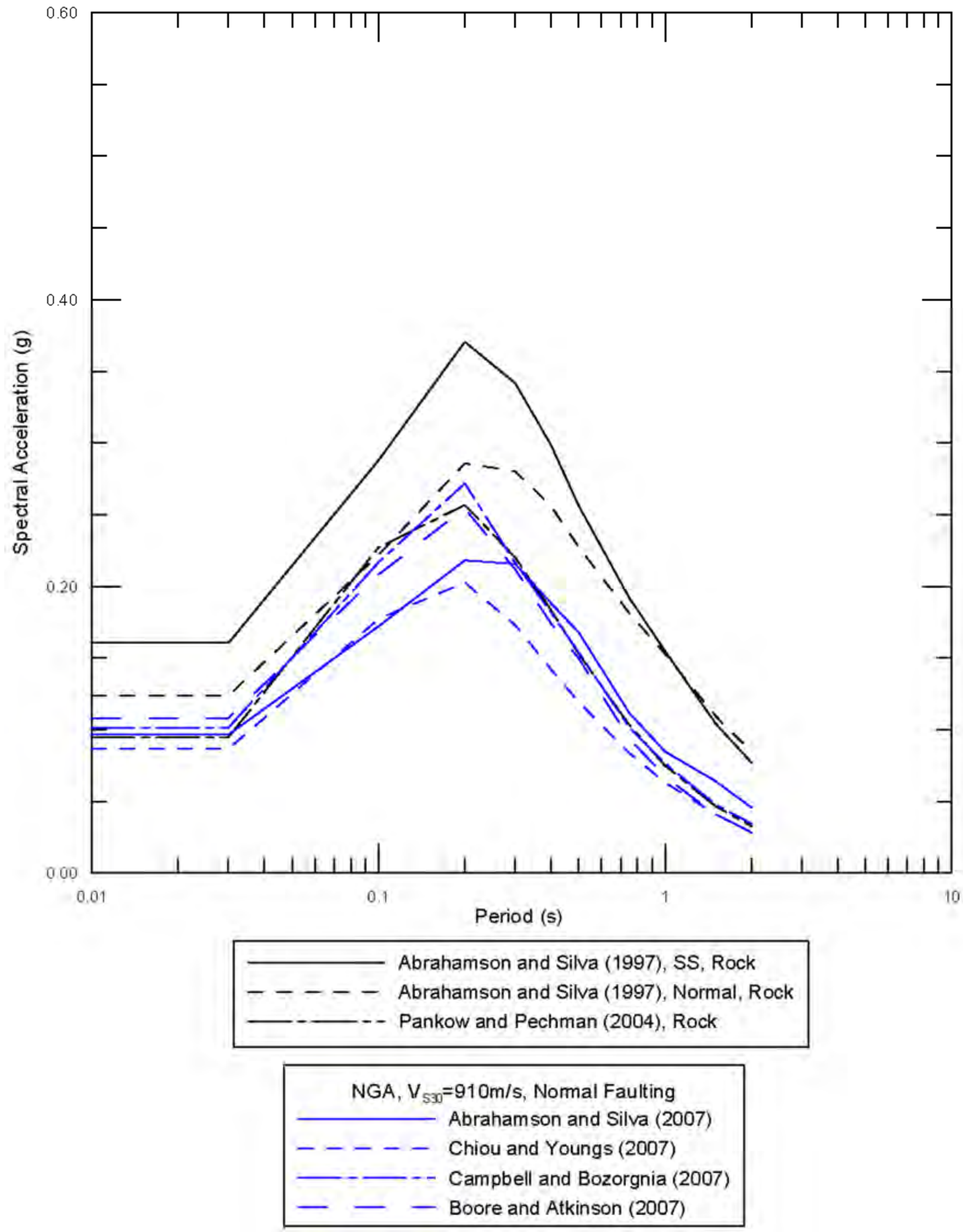
(V_S30 = 910 m/sec)



Median Response Spectra for Normal Faulting and Rock Site Conditions for M 7.0 at 5 km (V_S = 910 m/sec)



Median Response Spectra for Normal Faulting and Rock Site Conditions for **M** 7.0 at 25 km (V_S = 910 m/sec)



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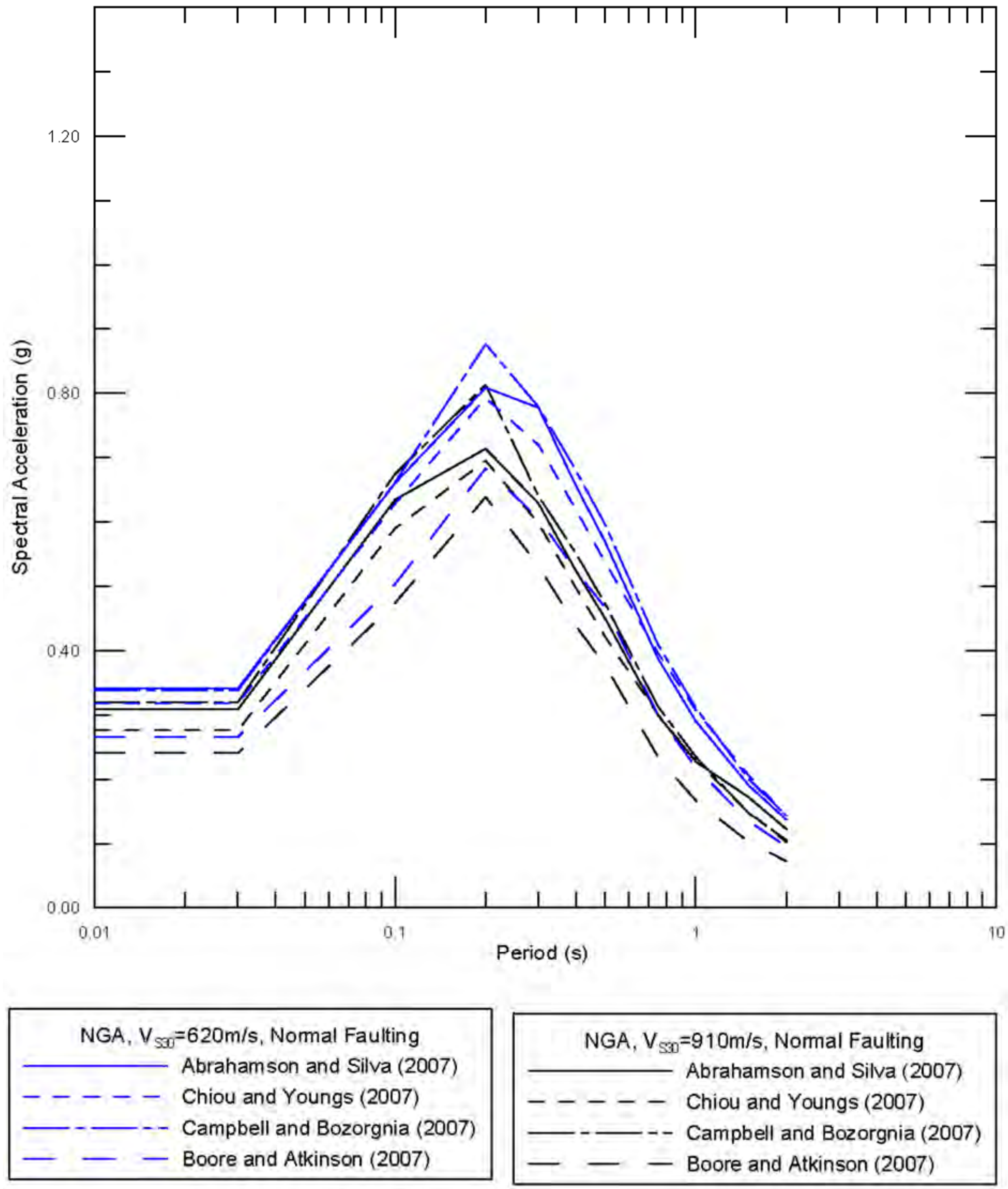
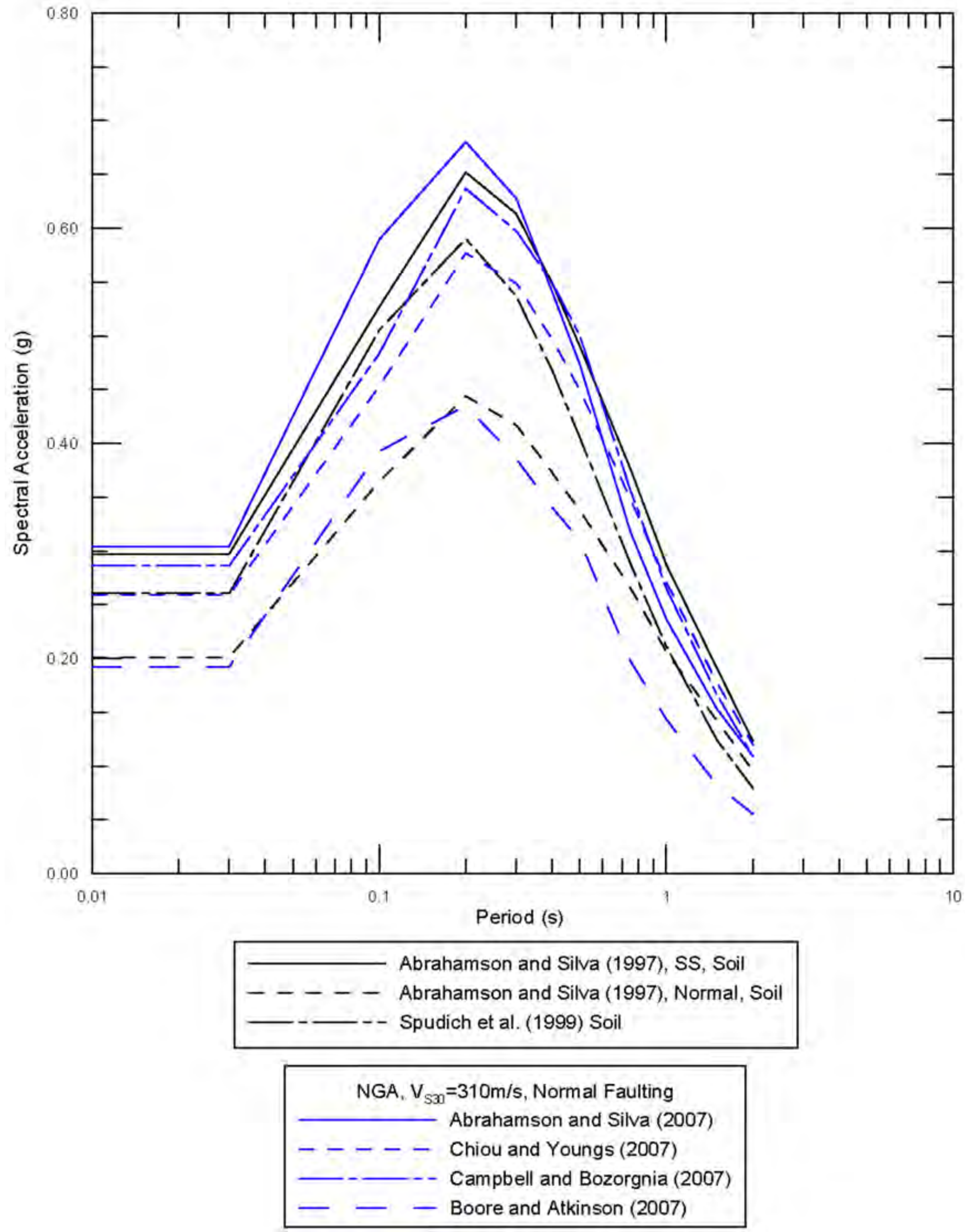
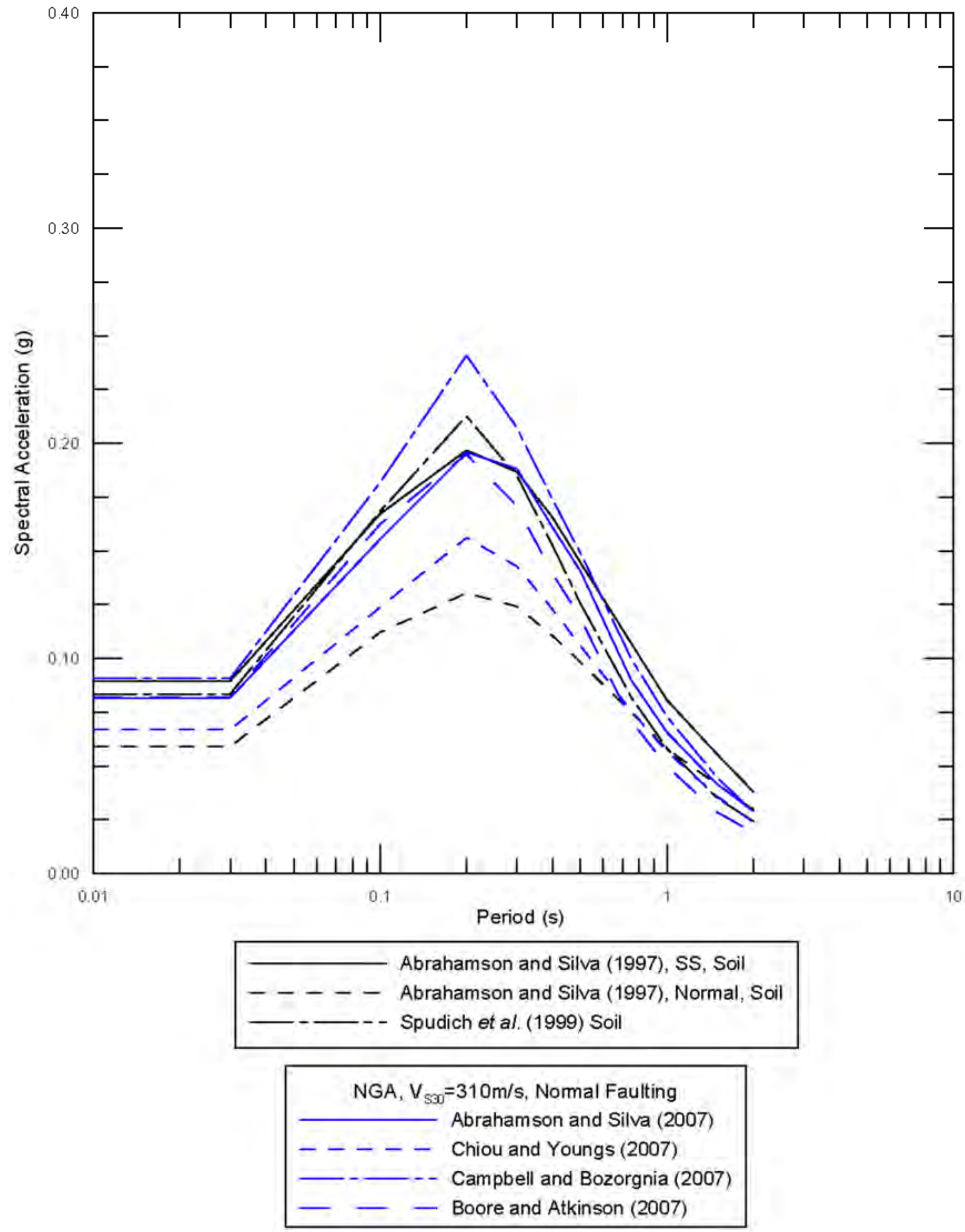
Median Response Spectra for Normal Faulting and Rock Site Conditions for **M** 7.0 at 5 km (V_S30 = 620 m/sec and 910 m/sec)



Median Response Spectra for Normal Faulting and Soil Site Conditions for **M** 6.0 at 5 km (V_S30 = 310 m/sec)

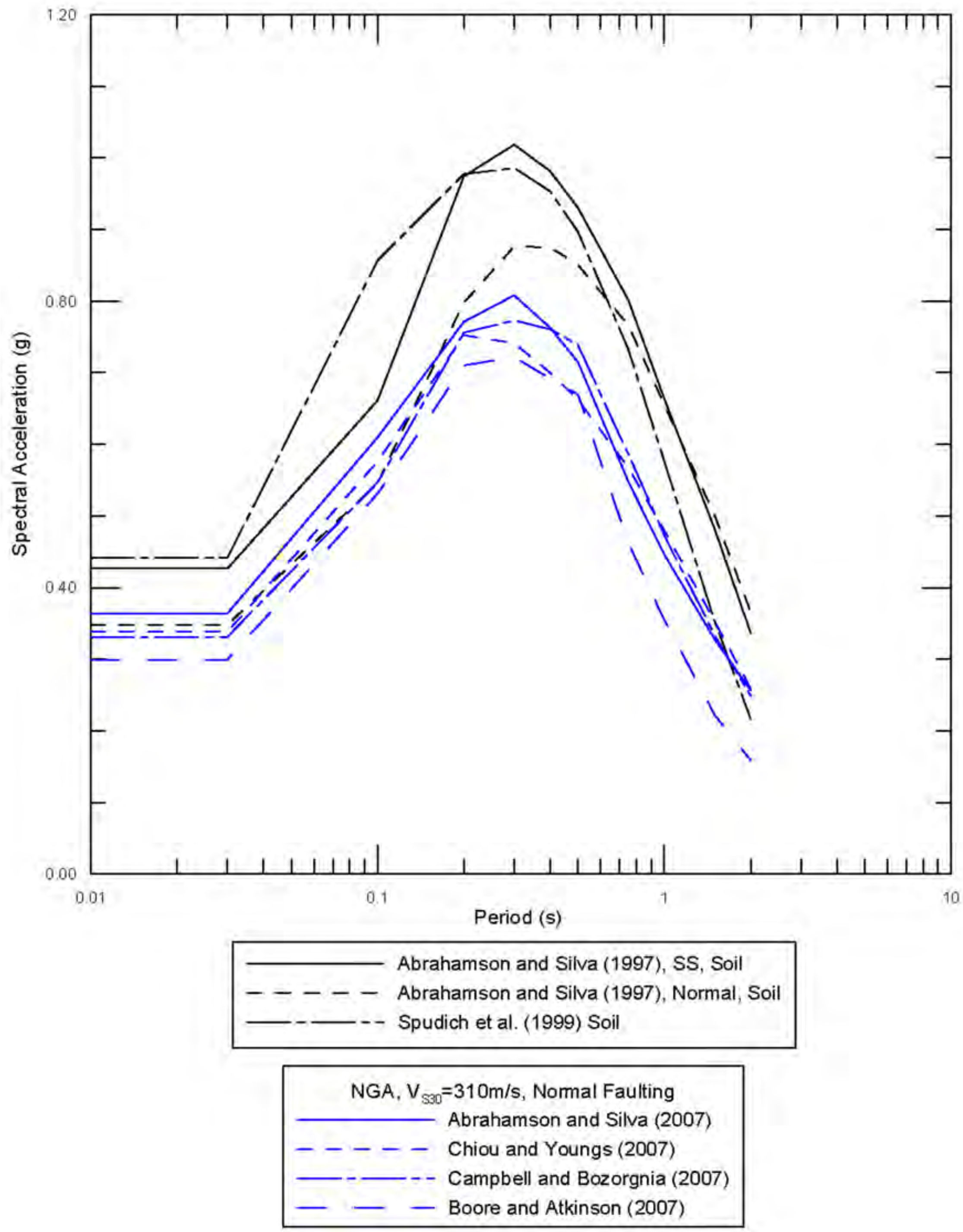


Median Response Spectra for Normal Faulting and Soil Site Conditions for **M** 6.0 at 25 km (V_S30 = 310 m/sec)

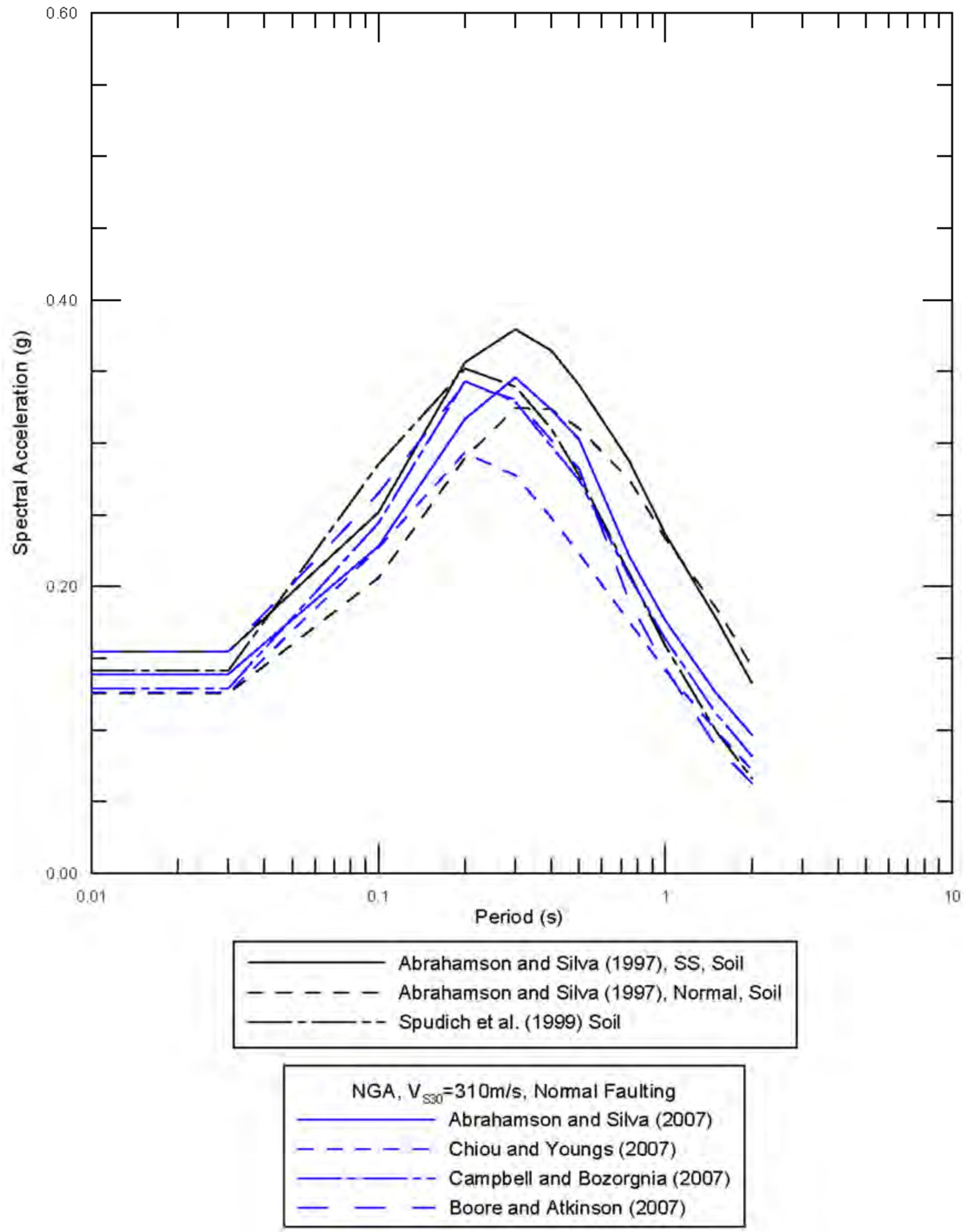


URS
SEISMIC HAZARDS

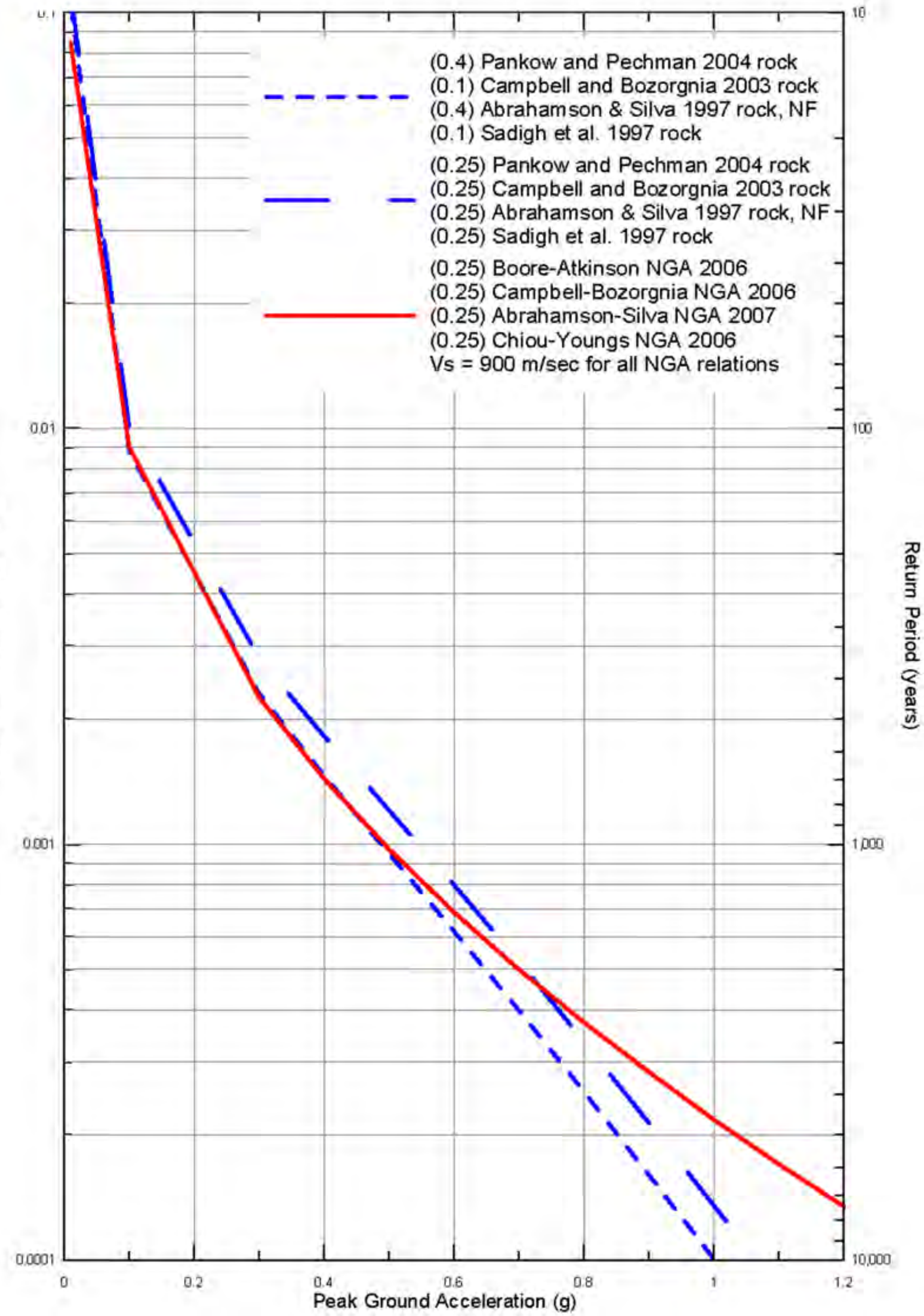
Median Response Spectra for Normal Faulting and Soil Site Conditions for **M** 7.0 at 5 km (V_S30 = 310 m/sec)



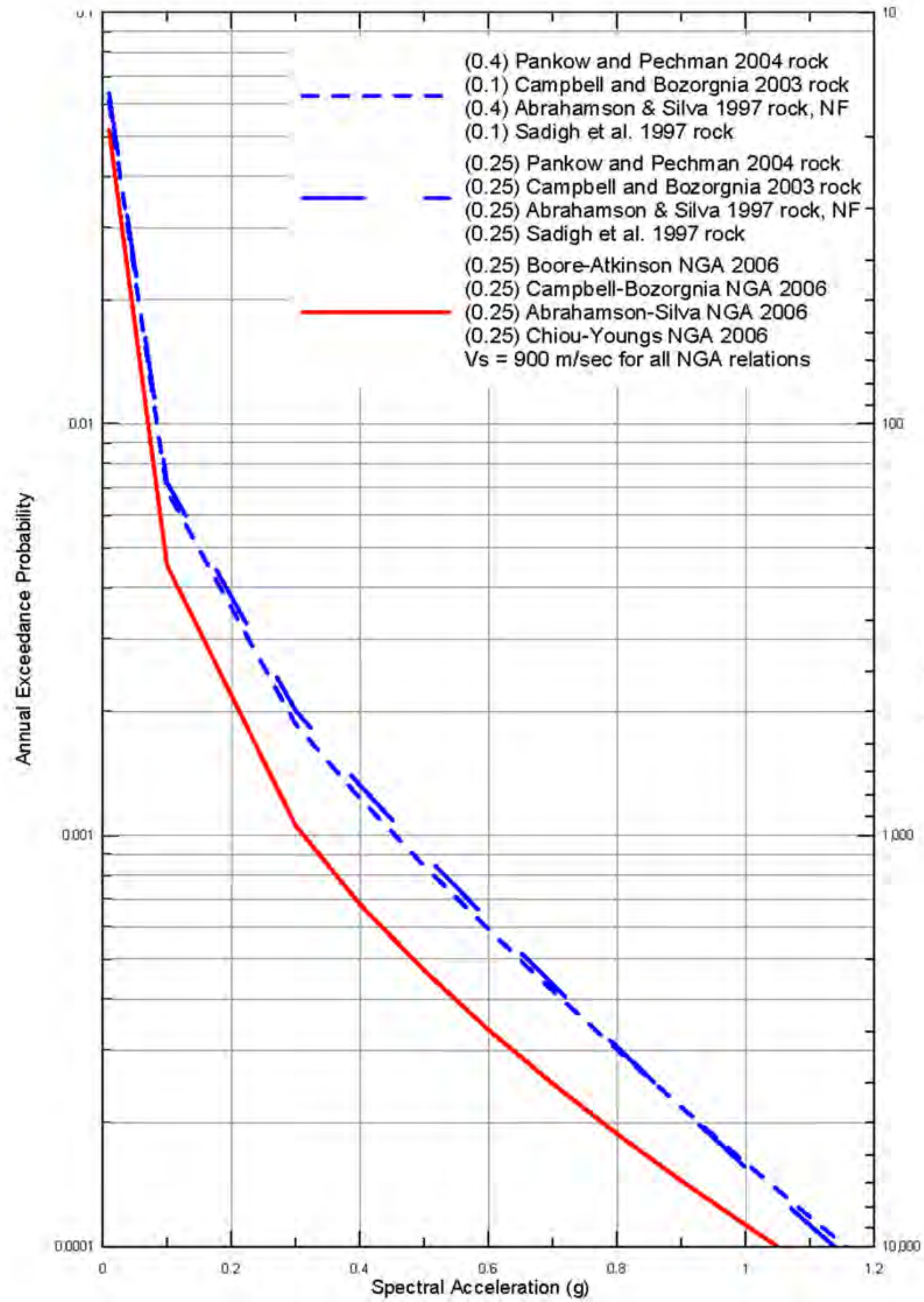
Median Response Spectra for Normal Faulting and Soil Site Conditions for **M** 7.0 at 25 km (V_S30 = 910 m/sec)



Mean Peak Horizontal Acceleration Hazard for Salt Lake City Rock Site (V_S = 900 m/sec)

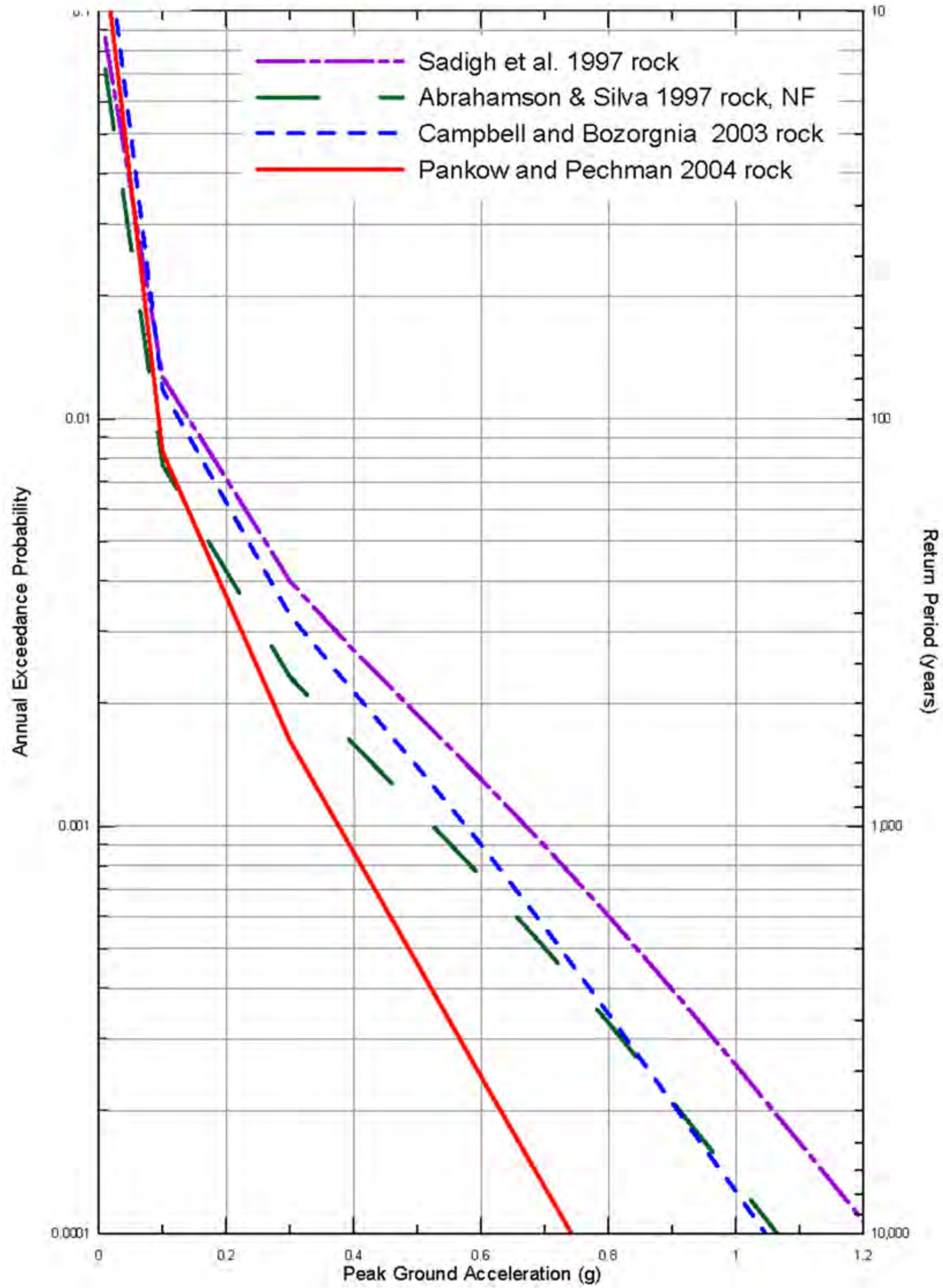


Mean Horizontal Spectral Acceleration Hazard at 1.0 Sec for Salt Lake City Rock Site (V_S = 900 m/sec)

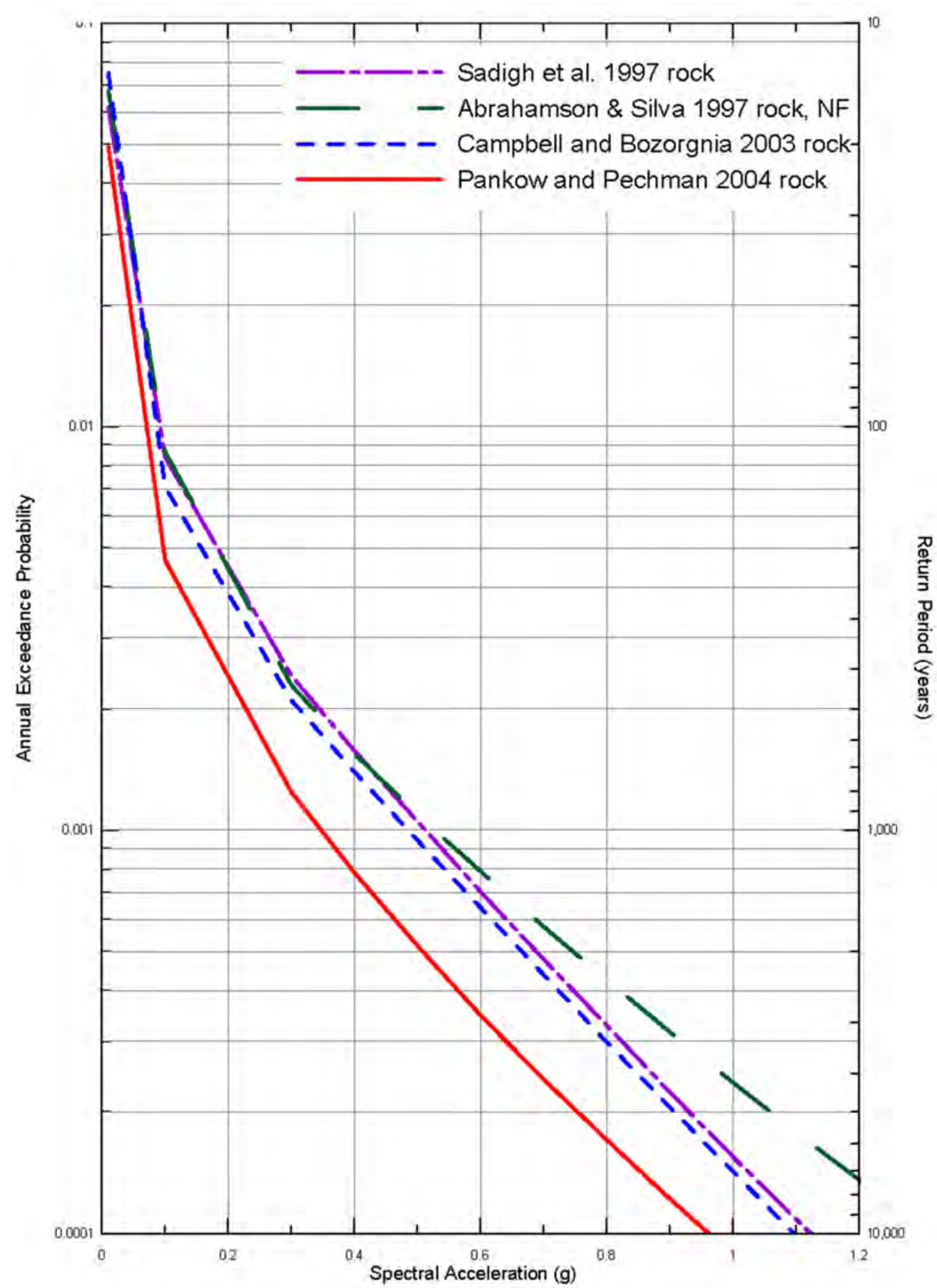


URS
SEISMIC HAZARDS

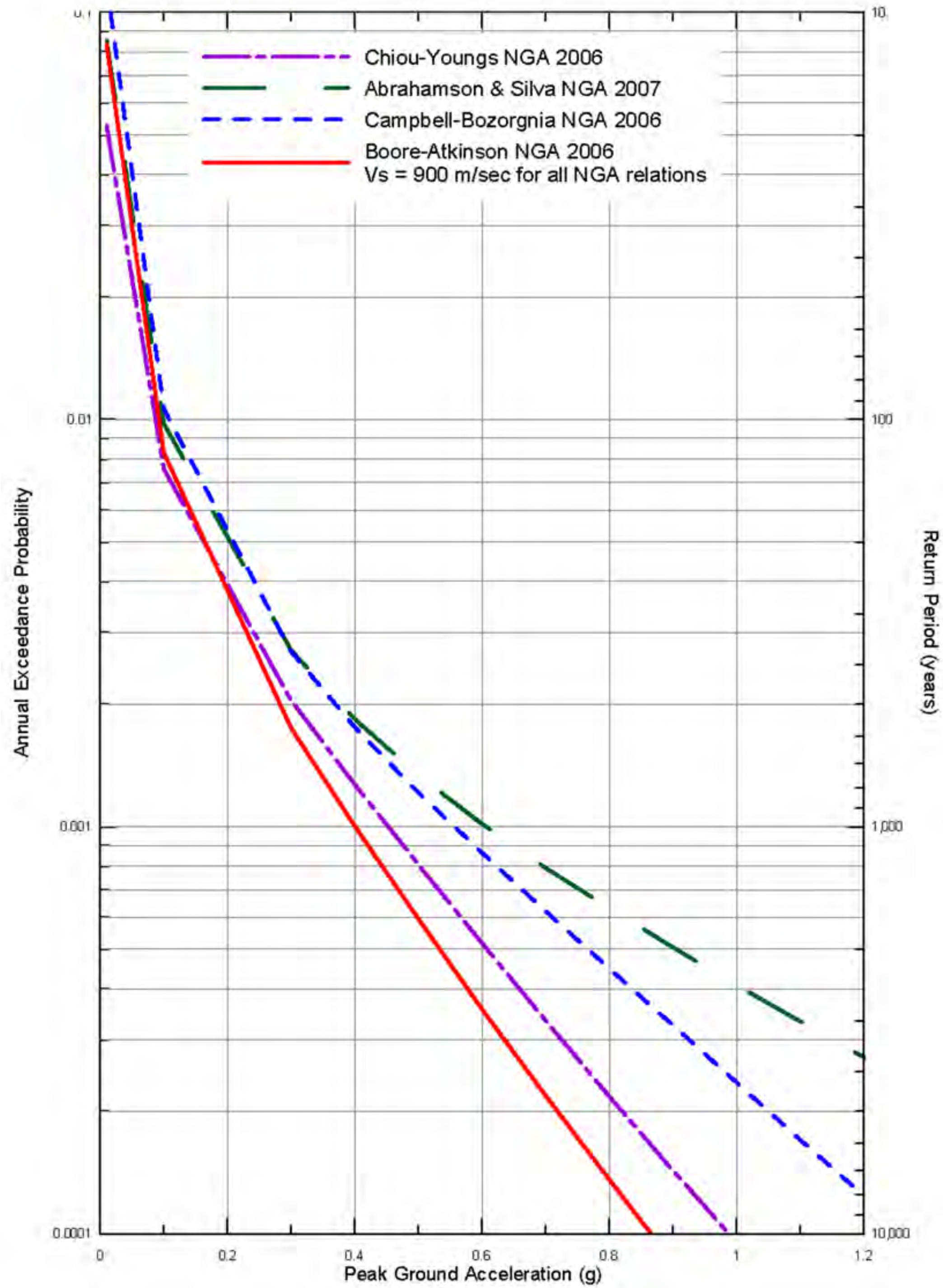
Sensitivity of Mean Peak Horizontal Acceleration Hazard to Attenuation Relations for Salt Lake City Rock Site



Sensitivity of Mean Horizontal Spectral Acceleration Hazard at 1.0 Sec to Attenuation Relations for Salt Lake City Rock Site (V_S = 900 m/sec)

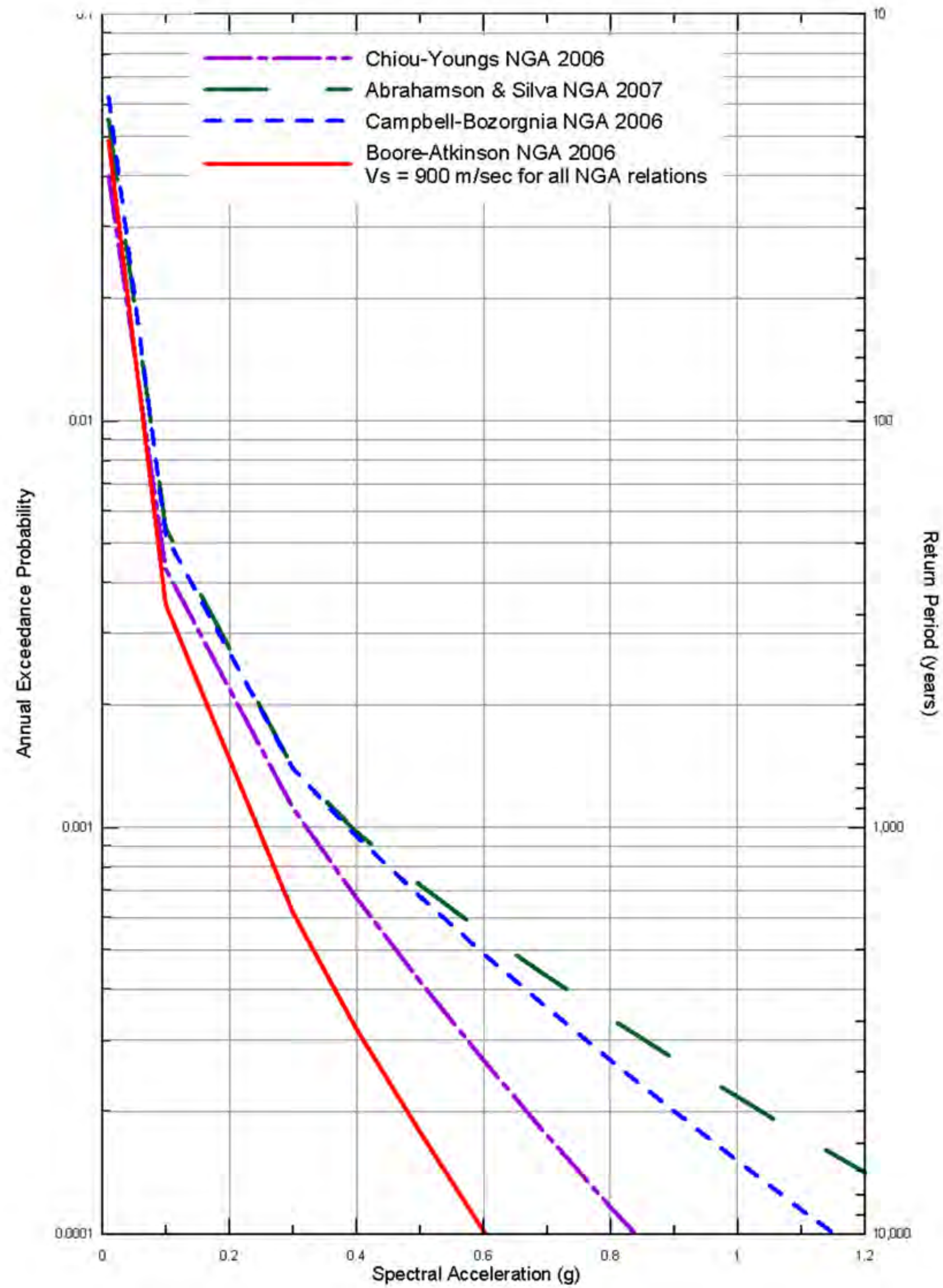


Sensitivity of Mean Peak Horizontal Acceleration Hazard to NGA Attenuation Relations for Salt Lake City Rock Site (V_S = 900 m/sec)

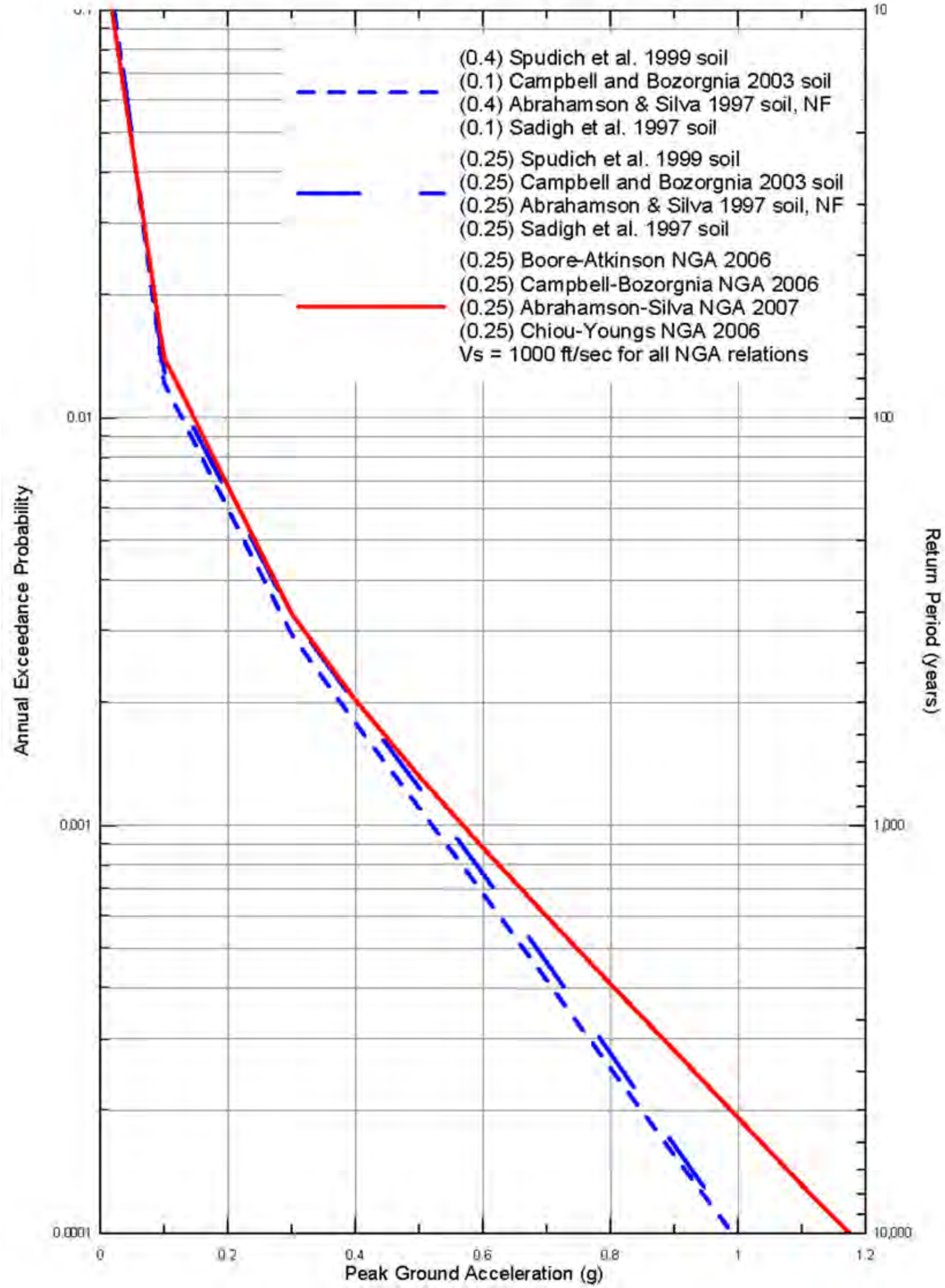


URS
SEISMIC HAZARDS

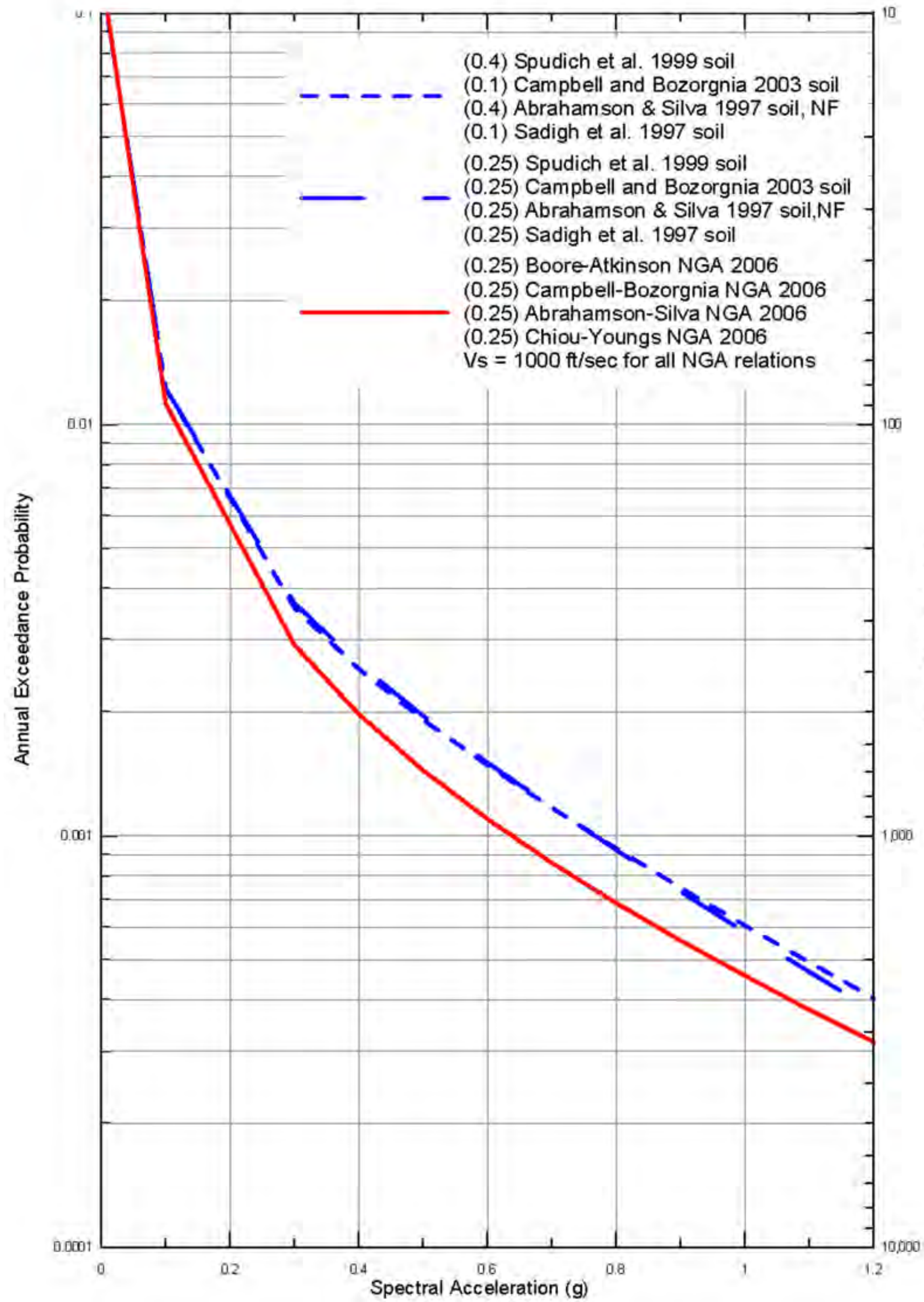
Sensitivity of Mean Horizontal Spectral Acceleration Hazard at 1.0 Sec to NGA Attenuation Relations for Salt Lake City Rock Site (V_S = 900 m/sec)



Mean Peak Horizontal Acceleration Hazard for Salt Lake City Soil Site (V_S = 1000 ft/sec)

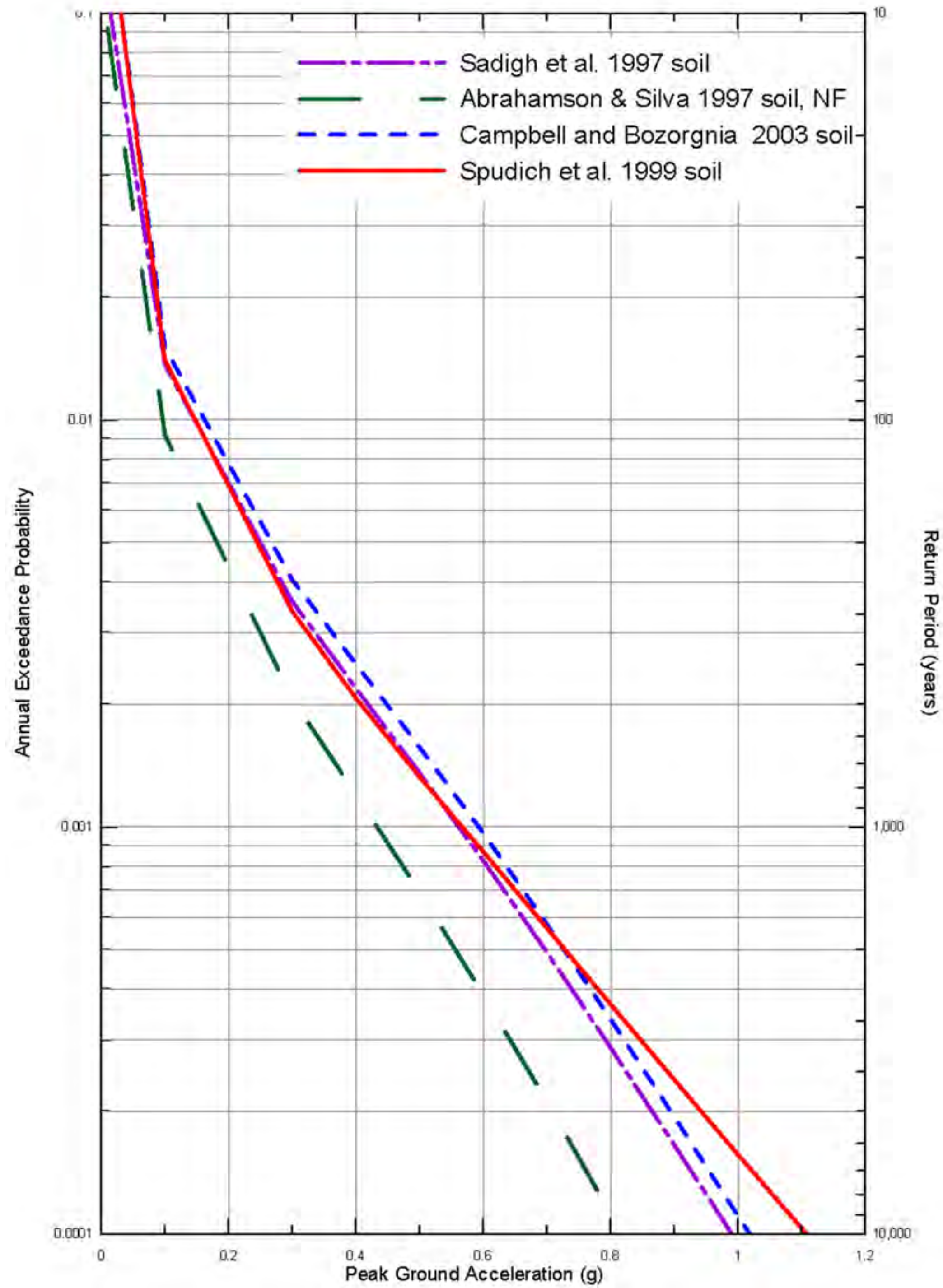


Mean Horizontal Spectral Acceleration Hazard at 1.0 Sec for Salt Lake City Soil Site (V_S = 1000 ft/sec)

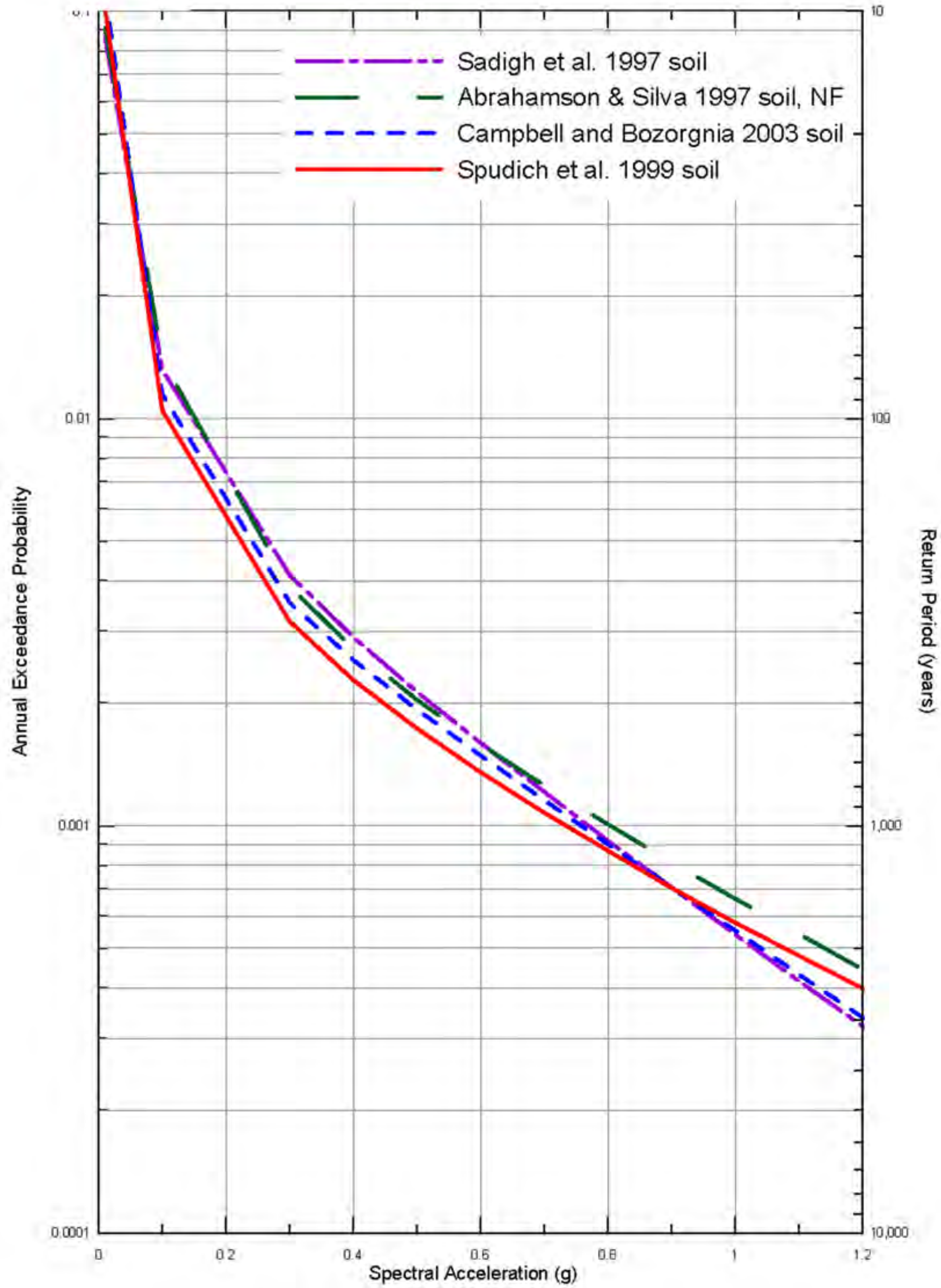


URS
SEISMIC HAZARDS

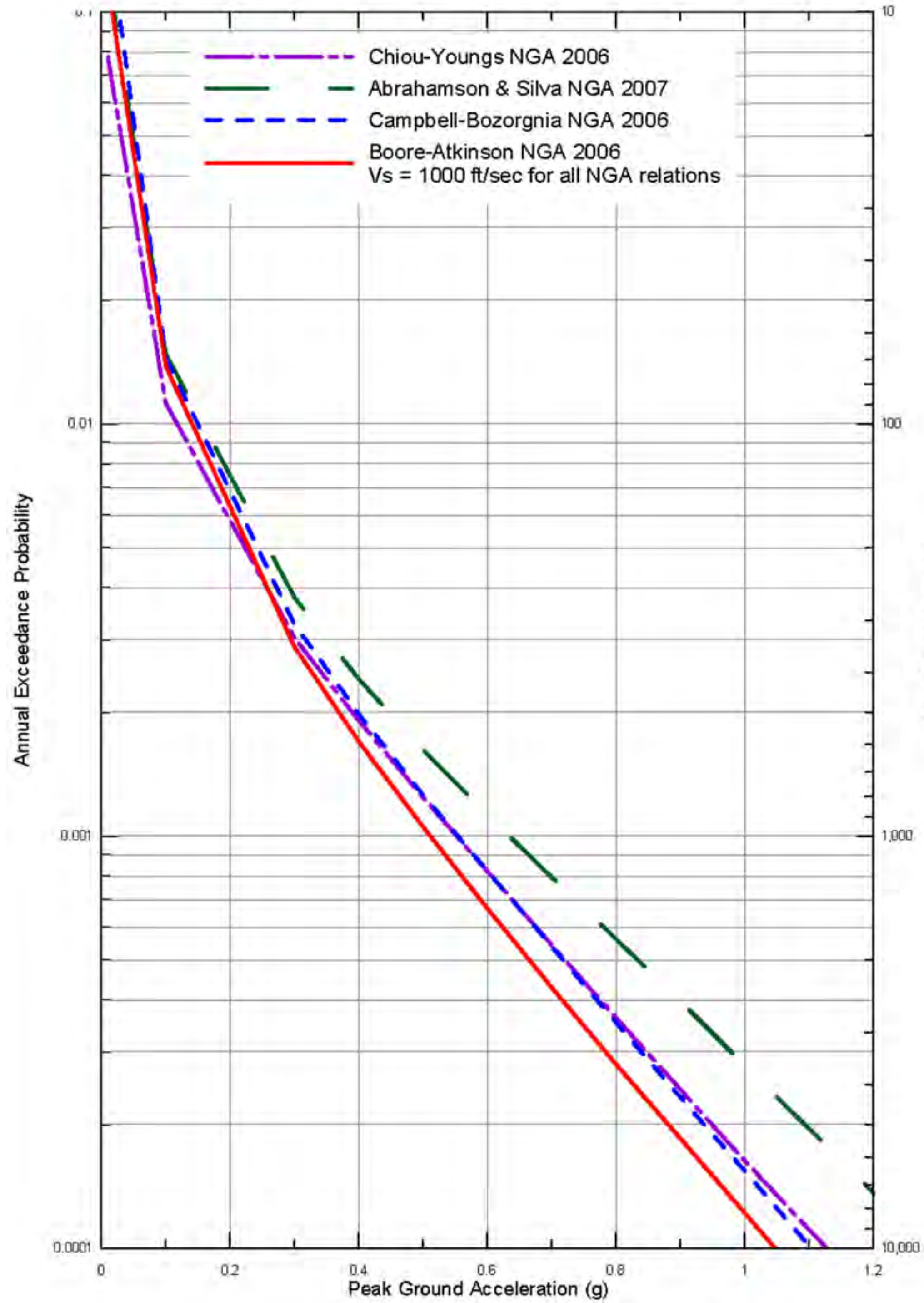
Sensitivity of Mean Peak Horizontal Acceleration Hazard to Attenuation Relations for Salt Lake City Soil Site (V_S = 1000 ft/sec)



Sensitivity of Mean Horizontal Spectral Acceleration Hazard at 1.0 Sec to Attenuation Relations for Salt Lake City Soil Site (V_S = 1000 ft/sec)

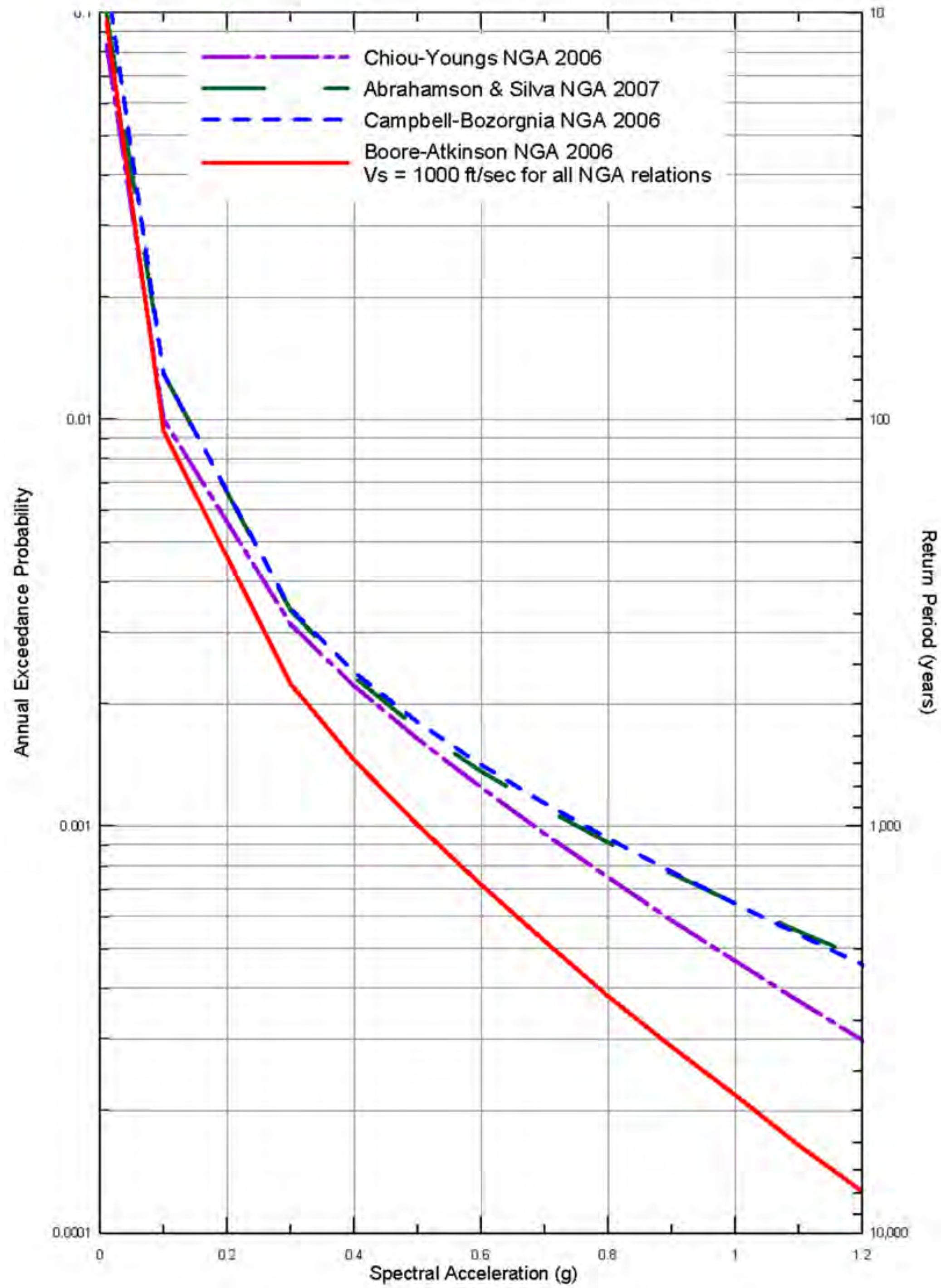


Sensitivity of Mean Peak Horizontal Acceleration Hazard to NGA Attenuation Relations for Salt Lake City Soil Site (V_S = 1000 ft/sec)

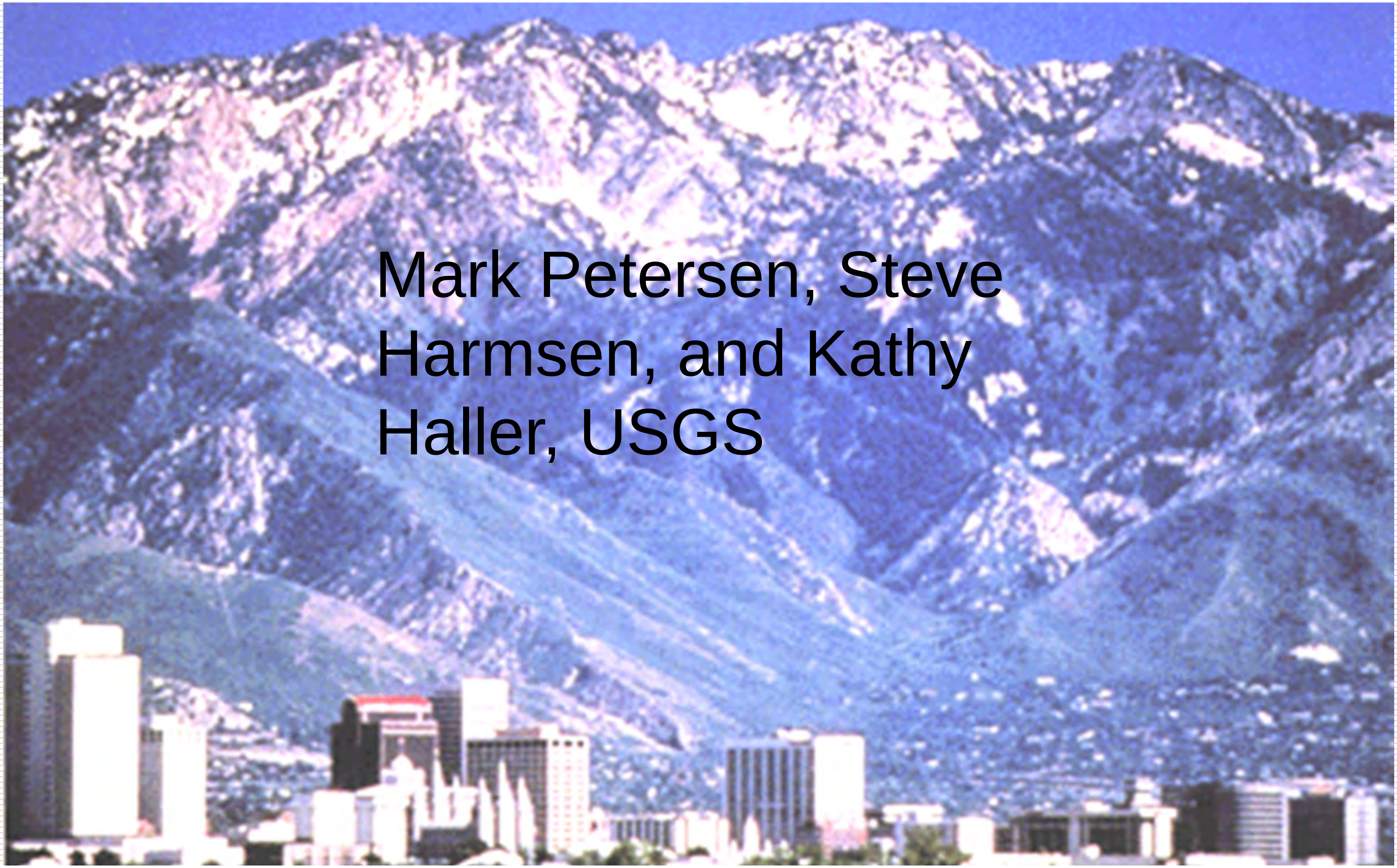


URS
SEISMIC HAZARDS

Sensitivity of Mean Horizontal Spectral Acceleration Hazard at 1.0 Sec to NGA Attenuation Relations for Salt Lake City Soil Site (V_S = 1000 ft/sec)



2007 National Seismic Hazard Maps for Utah



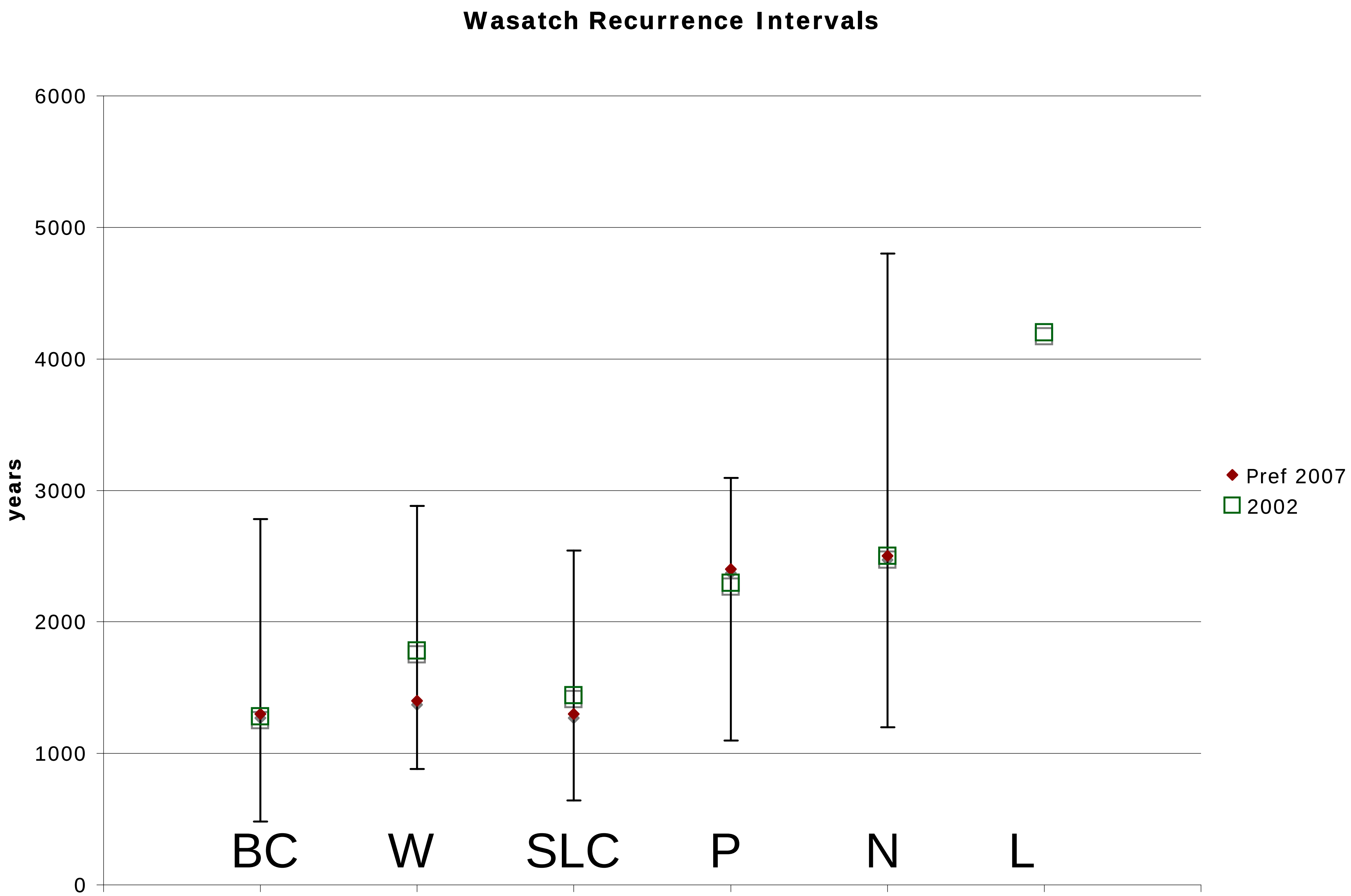
Mark Petersen, Steve Harmsen, and Kathy Haller, USGS

Changes for 2007 maps

- Wasatch fault (added floating M 7.4 earthquake, adjusted rates – based on WSSPC recommendations)
- Other faults (recurrence, slip rates, additions, deletions – based on UQFPWG recommendations)
- Fault dip (60 to 50 degrees – based on WSSPC recommendations) – raises hazard
- Attenuation relations (new NGA equations – based on WSSPC recommendations?)
  - Hanging wall effect (CY, CB)
  - Normal fault
  - Depth to top to rupture – GR M < 7 either 0 km, 2 km, 4 km
  - Additional epistemic uncertainty (20-50% symmetric)
- Geodetic data (doesn't affect Utah -applied to shear zones in CA/NV – based on WSSPC recommendations)

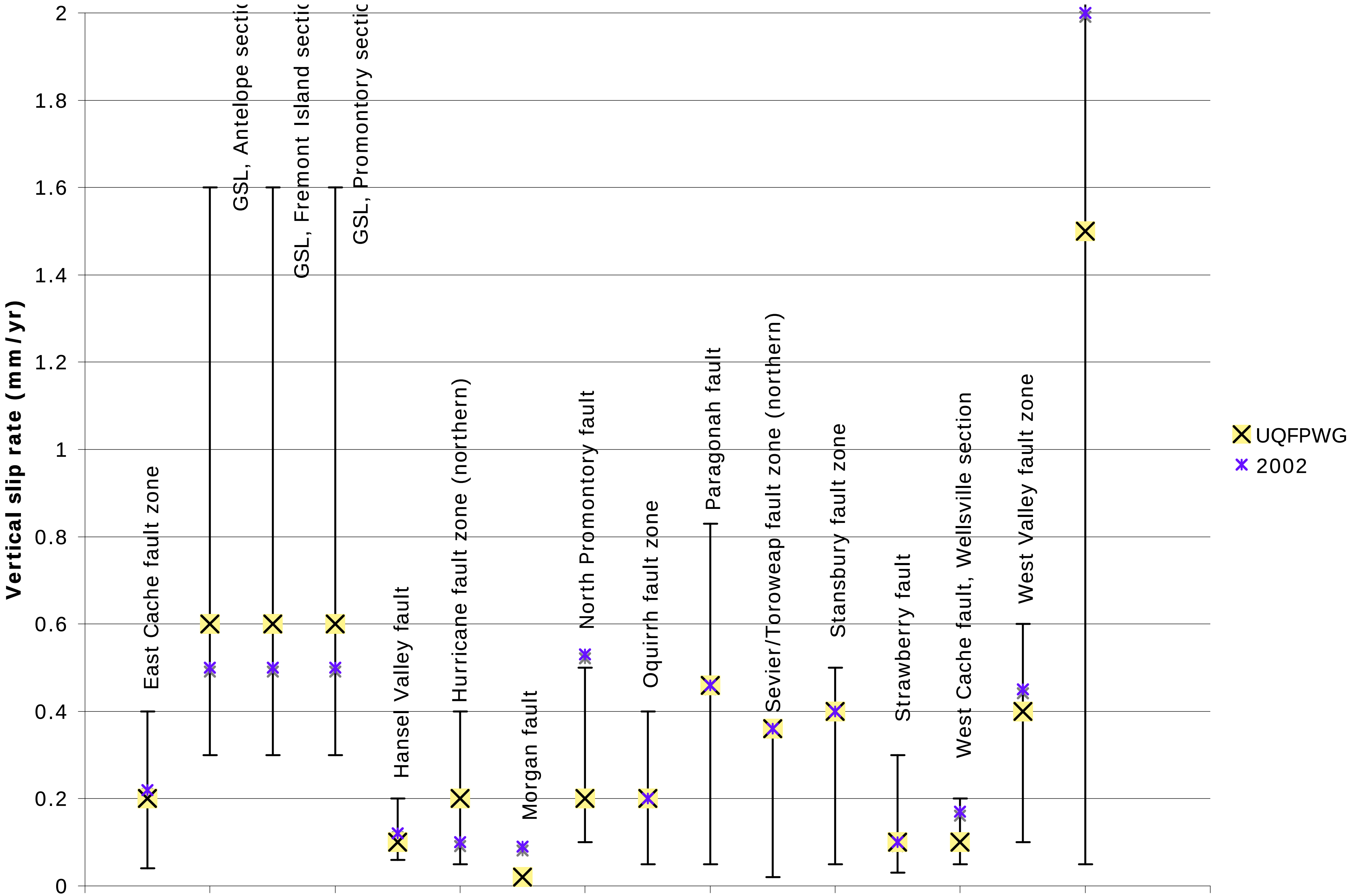
Wasatch Recurrence Intervals

	Min	2007 PREF	Max	2002
Brigham City	500	1300	2800	1282
Weber	500	1400	2500	1782
Salt Lake City	500	1300	2400	1441
Provo	1200	2400	3200	2297
Nephi	1200	2500	4800	2500
Levan				4200


Wasatch Recurrence Intervals
years
6000
5000
4000
3000
2000
1000
0
BC
W
SLC
P
N
L
Pref 2007
2002

UQFPWG recommendations

	Min	Max	2007 Pref	2002	Effective Change
East Cache fault zone	0.04	0.4	0.2	0.22	0.91
GSL fault zone, Antelope section	0.3	1.6	0.6	0.5	1.20
GSL, Fremont Island section	0.3	1.6	0.6	0.5	1.20
GSL, Promontory section	0.3	1.6	0.6	0.5	1.20
Hansel Valley fault	0.06	0.2	0.1	0.12	0.83
Hurricane fault zone (northern)	0.05	0.4	0.2	0.1	2.00
Morgan fault	0.01	0.04	0.02	0.09	0.22
North Promontory fault	0.1	0.5	0.2	0.53	0.38
Oquirrh fault zone	0.05	0.4	0.2	0.2	1.00
Paragonah fault	0.05	0.83	0.46	0.46	1.00
Sevier/Toroweap fault zone (northern)	0.02	0.36	0.36	0.36	1.00
Stansbury fault zone	0.05	0.5	0.4	0.4	1.00
Strawberry fault	0.03	0.3	0.1	0.1	1.00
West Cache fault, Wellsville section	0.05	0.2	0.1	0.17	0.59
West Valley fault zone	0.1	0.6	0.4	0.45	0.89
Bear River fault zone	0.05	2.5	1.5	2	0.75



Vertical slip rate (mm/yr)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
East Cache fault zone
GSL, Antelope sectio
GSL, Fremont Island sectio
GSL, Promontory sectio
Hansel Valley fault
Hurricane fault zone (northern)
Morgan fault
North Promontory fault
Oquirrh fault zone
Paragonah fault
Sevier/Toroweap fault zone (northern)
Stansbury fault zone
Strawberry fault
West Cache fault, Wellsville section
West Valley fault zone
UQFPWG
2002

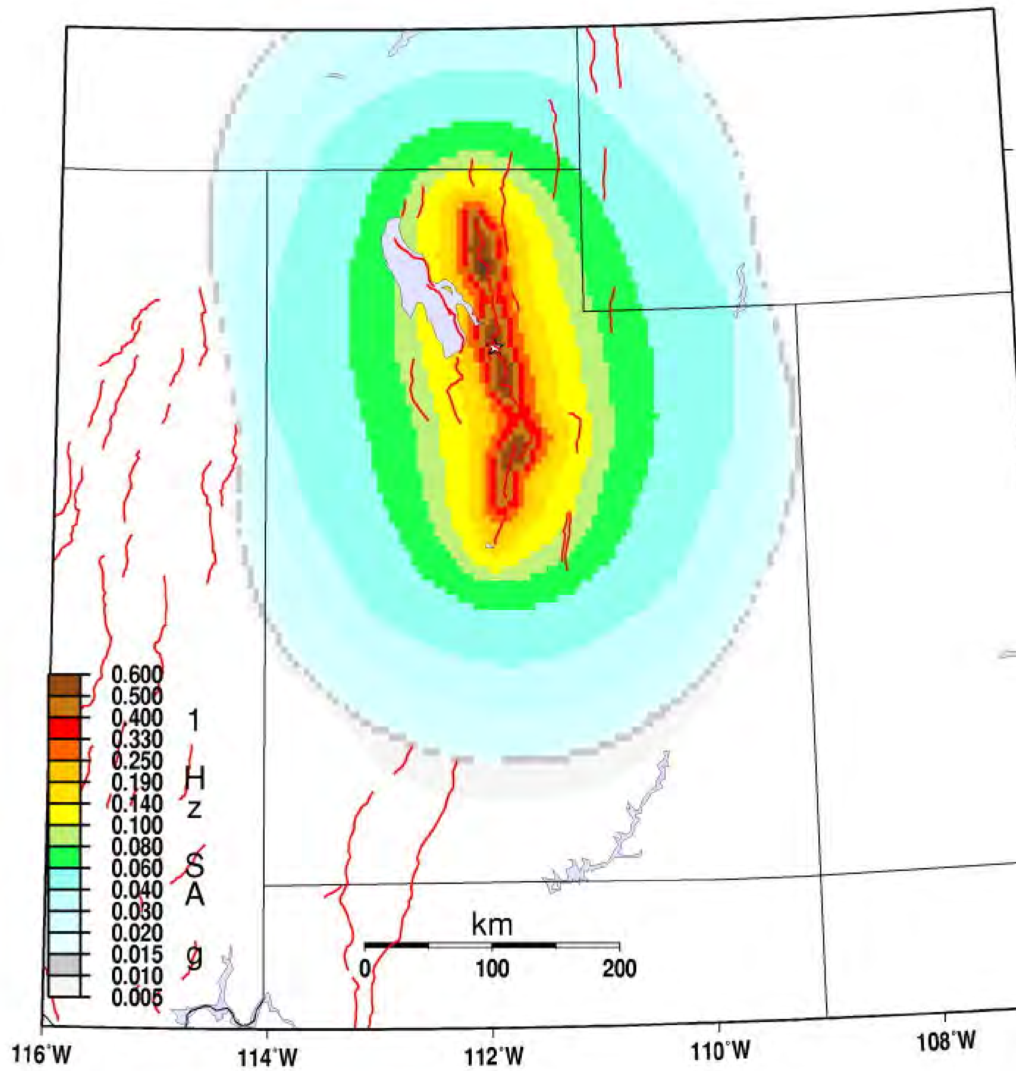
Additions

- West Cache fault zone, Clarkston fault
- Southern Oquirrh Mountains fault zone
- Utah Lake faults

Deletions

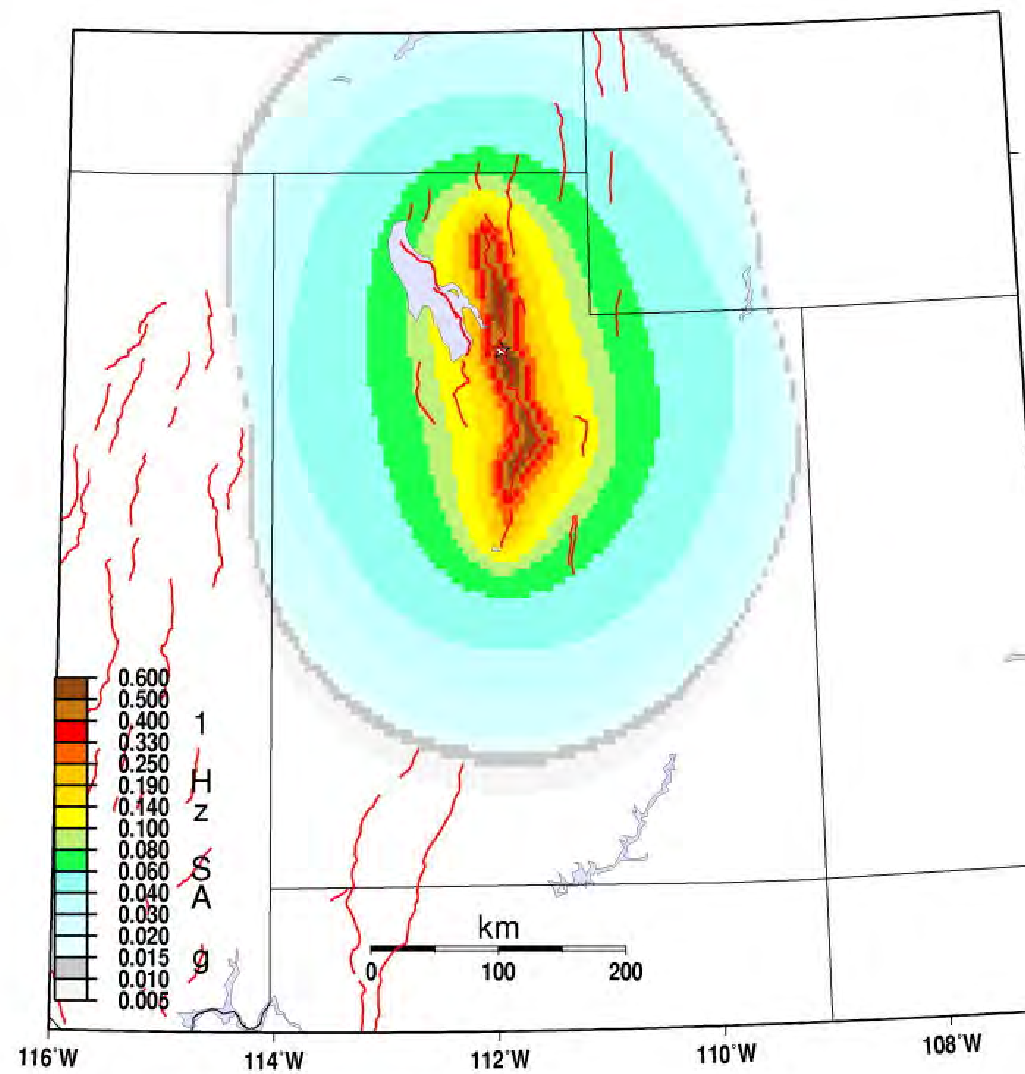
- Two Joes Valley fault sources combined into one

Wasatch-Characteristc only 2007 1-Hz SA w/2%PE50YR

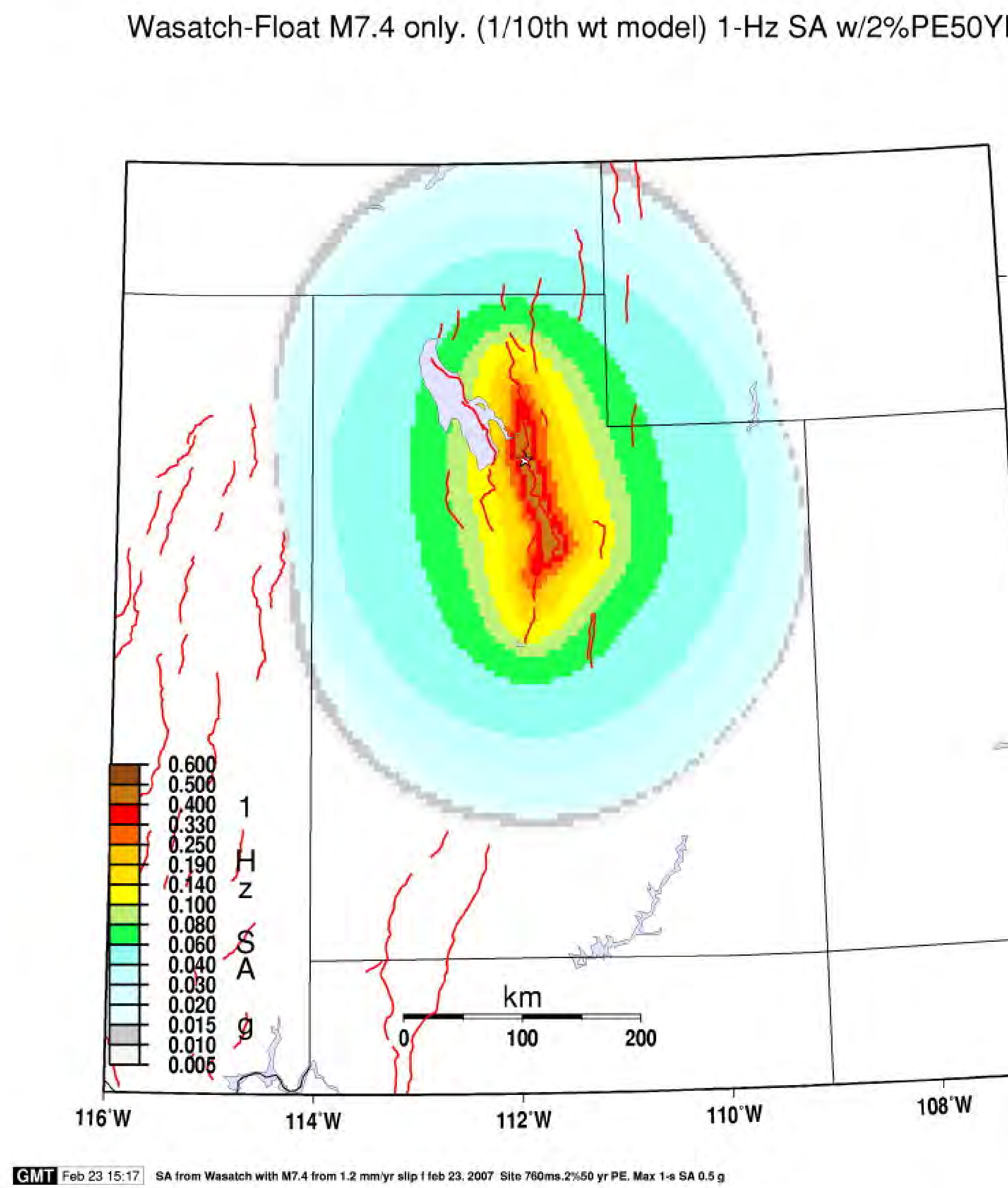


GMT Feb 23 15:25 SA from Wasatch with characteristic fault failure feb 23. 2007 Site 760ms.2%50 yr PE. Max 1-s SA 0.82 g

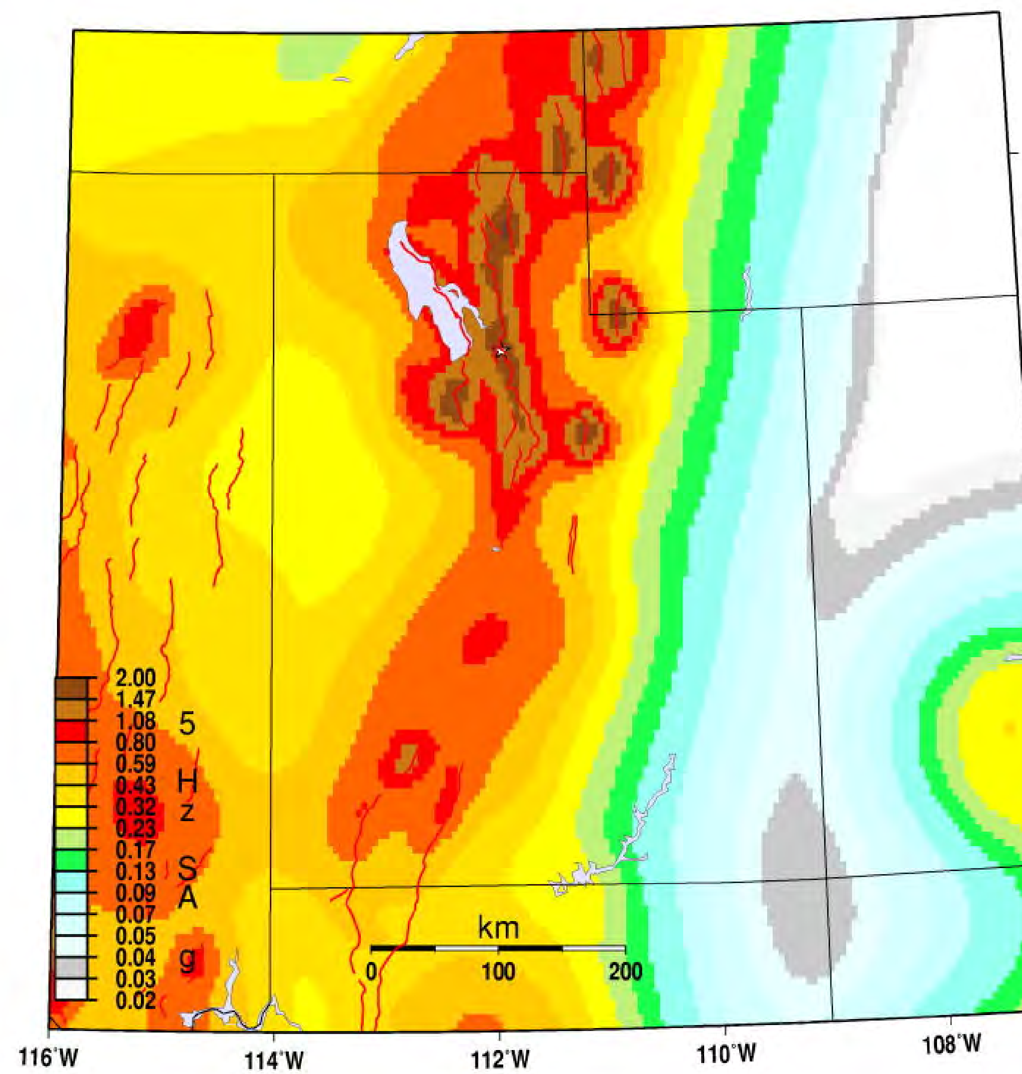
Wasatch-GR only 2007 1-Hz SA w/2%PE50YR



GMT Feb 23 15:06 SA from Wasatch with GR fault failure feb 23. 2007 Site 760ms.2%50 yr PE. Max 1-s SA 0.75 g

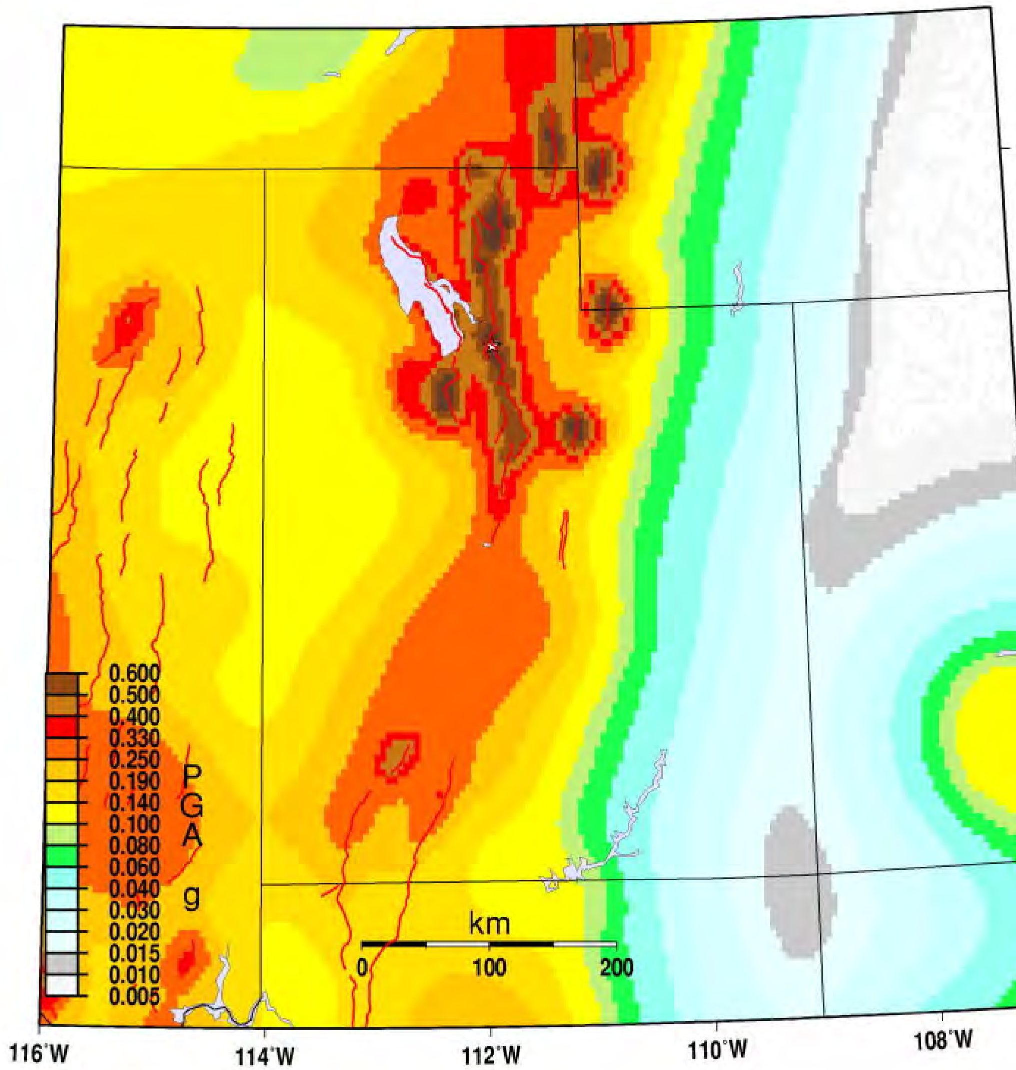

Wasatch-Float M7.4 only. (1/10th wt model) 1-Hz SA w/2%PE50YR
0.600
0.500
0.400
0.330
0.250
0.190
0.140
0.100
0.080
0.060
0.040
0.030
0.020
0.015
0.010
0.005
1 Hz SA g
km
0
100
200
116°W
114°W
112°W
110°W
108°W
GMT Feb 23 15:17
SA from Wasatch with M7.4 from 1.2 mm/yr slip f feb 23, 2007 Site 760ms.2%50 yr PE. Max 1-s SA 0.5 g

Utah 2007 5-Hz SA w/2%PE50YR

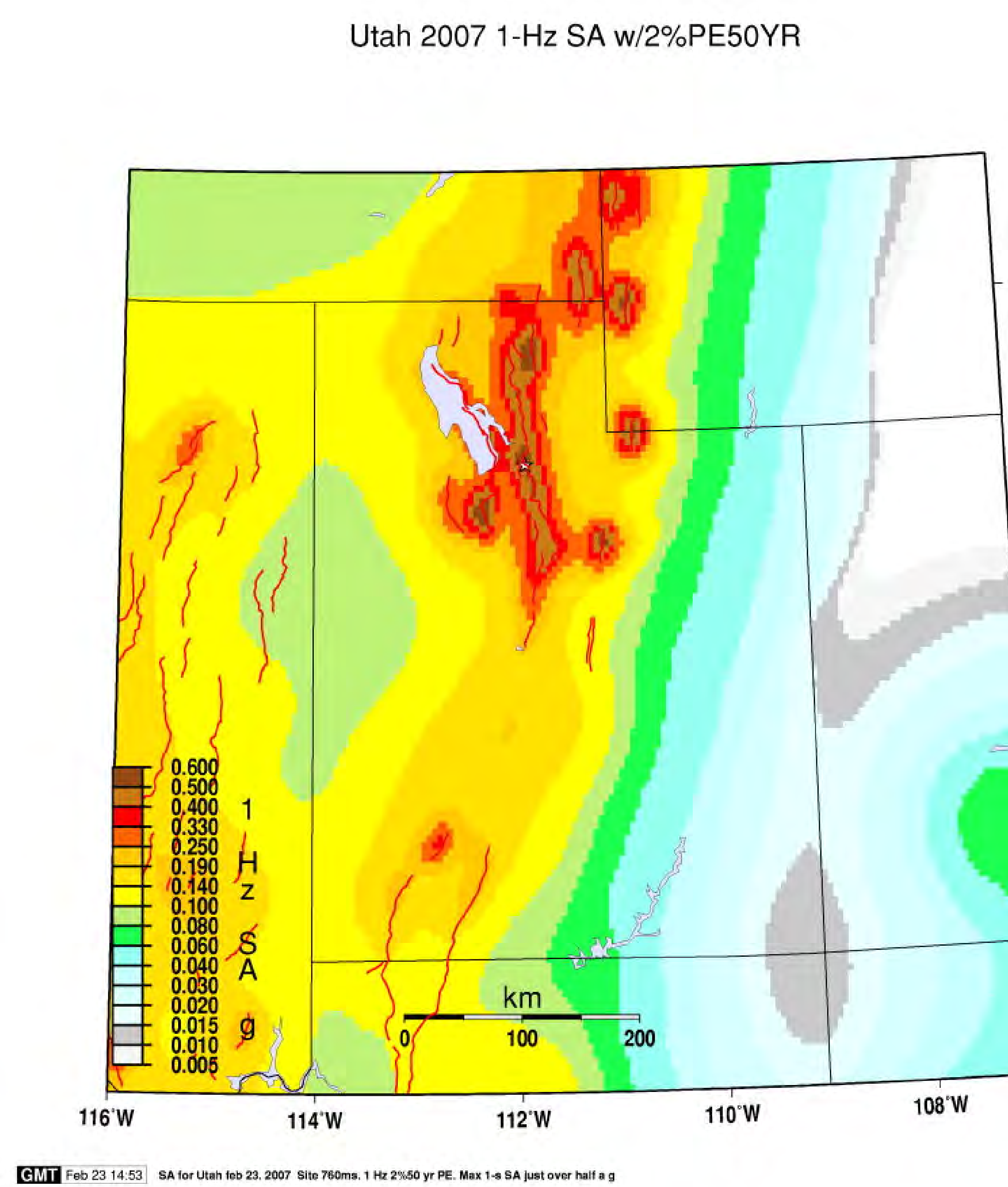


GMT Feb 23 14:52 SA for Utah feb 23, 2007 Site 760ms. 5 Hz 2%50 yr PE. Max 0.2-s SA just over 2g

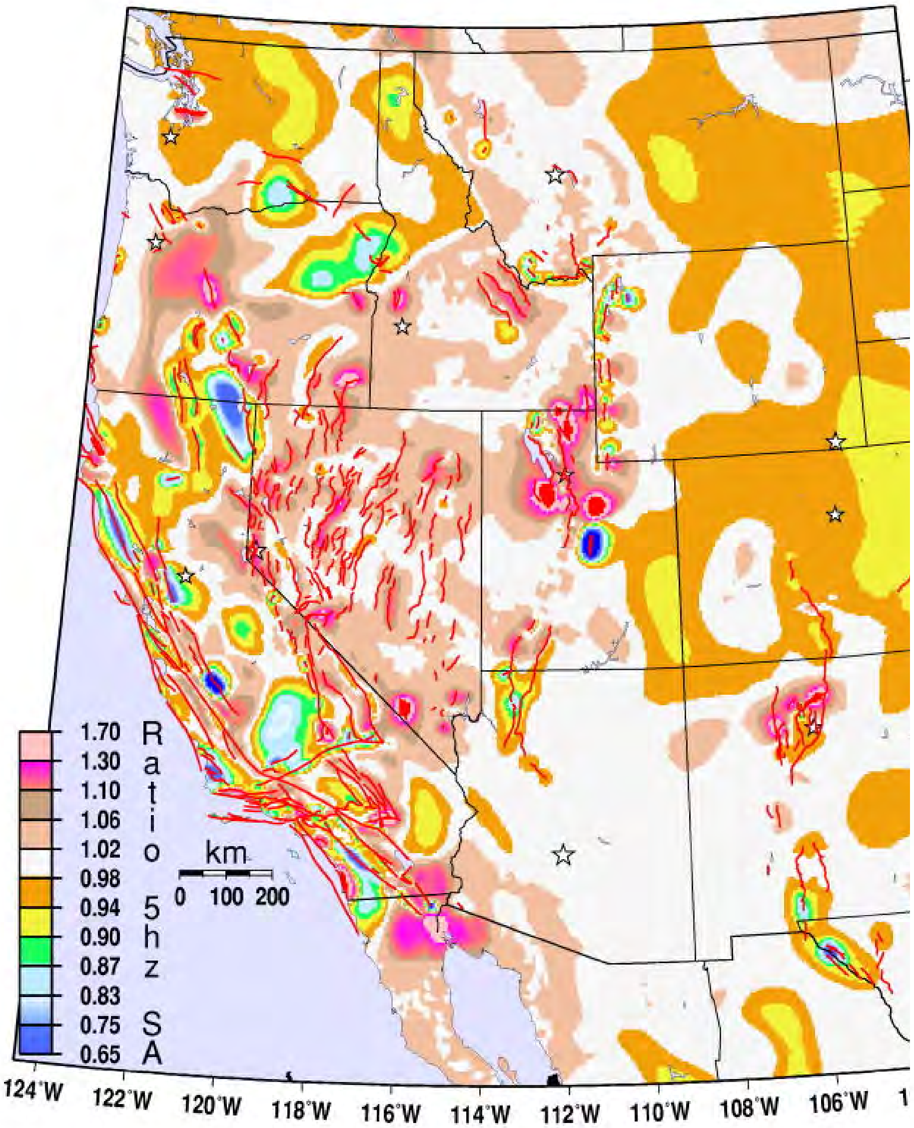
Utah 2007 PGA w/2%PE50YR



GMT Feb 23 15:00 PGA for Utah feb 23. 2007 Site 760ms. 2%50 yr PE. Max PGA just over 0.6 g

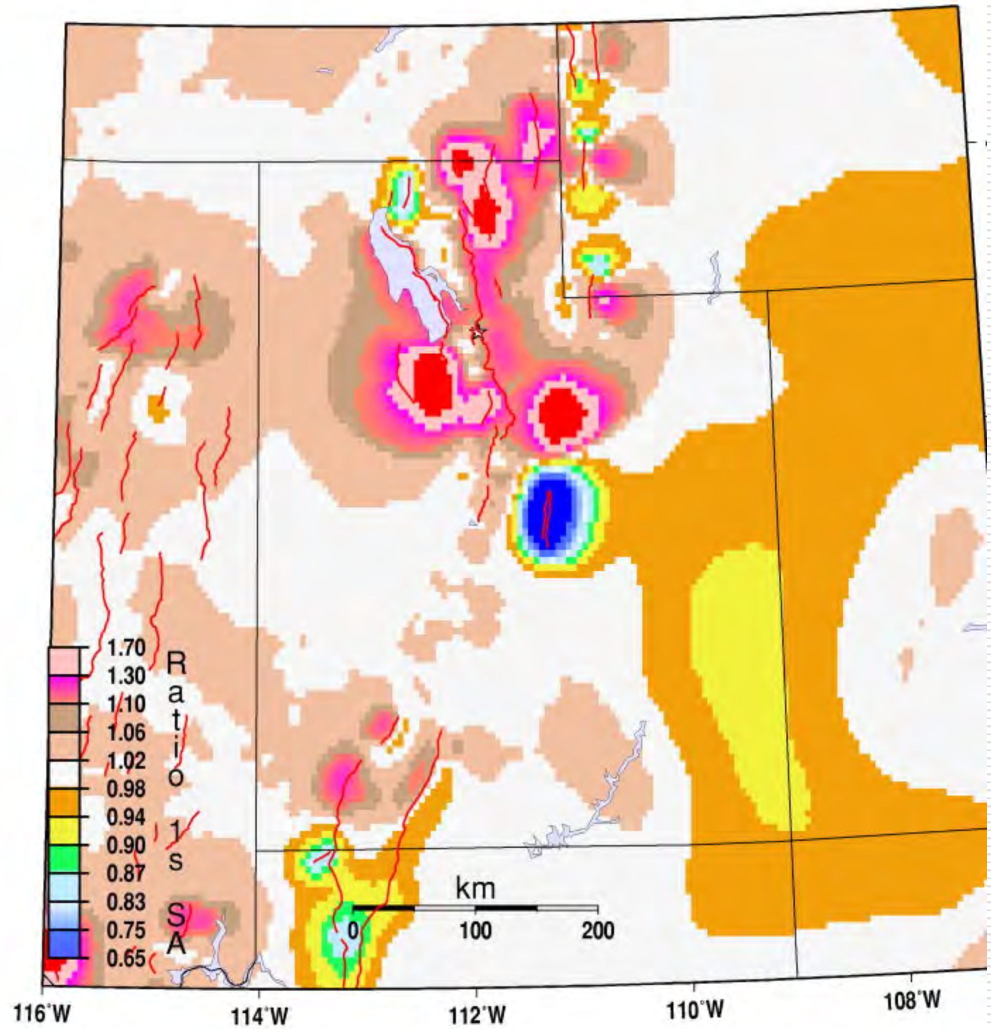

Utah 2007 1-Hz SA w/2%PE50YR
0.600
0.500
0.400
0.330
0.250
0.190
0.140
0.100
0.080
0.060
0.040
0.030
0.020
0.015
0.010
0.005
1 Hz SA g
km
0
100
200
116°W
114°W
112°W
110°W
108°W
GMT Feb 23 14:53
SA for Utah feb 23, 2007 Site 760ms. 1 Hz 2%50 yr PE. Max 1-s SA just over half a g

All-src WUS new/old ratio 5-Hz SA w/2%PE50YR



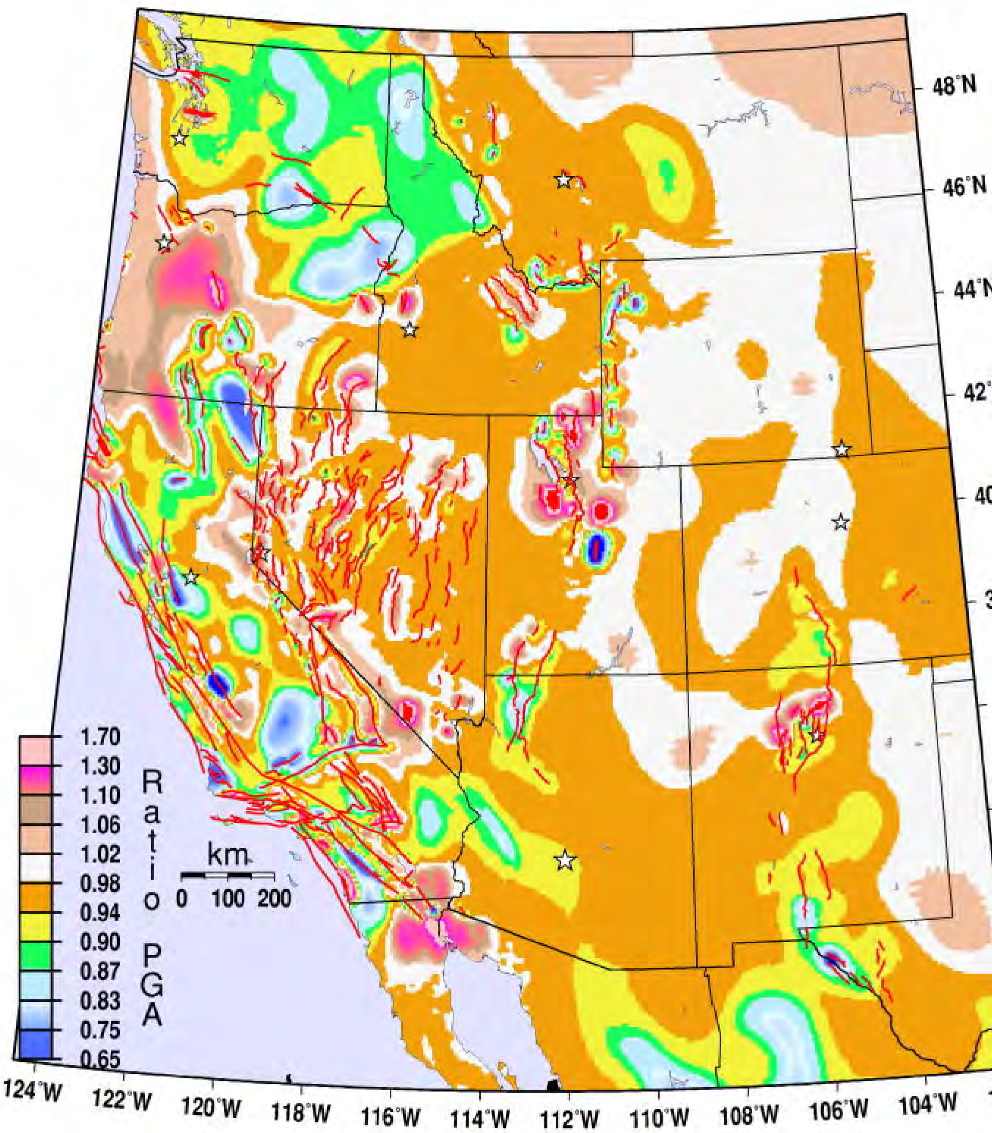
GMT Feb 23 13:31 Feb 15 2007 model over 2002 model. Site 760ms. 5 Hz 2%50 yr PE. denom is 2002 official 5hz sa

Utah 2007/2002 ratio 5-Hz SA w/2%PE50YR



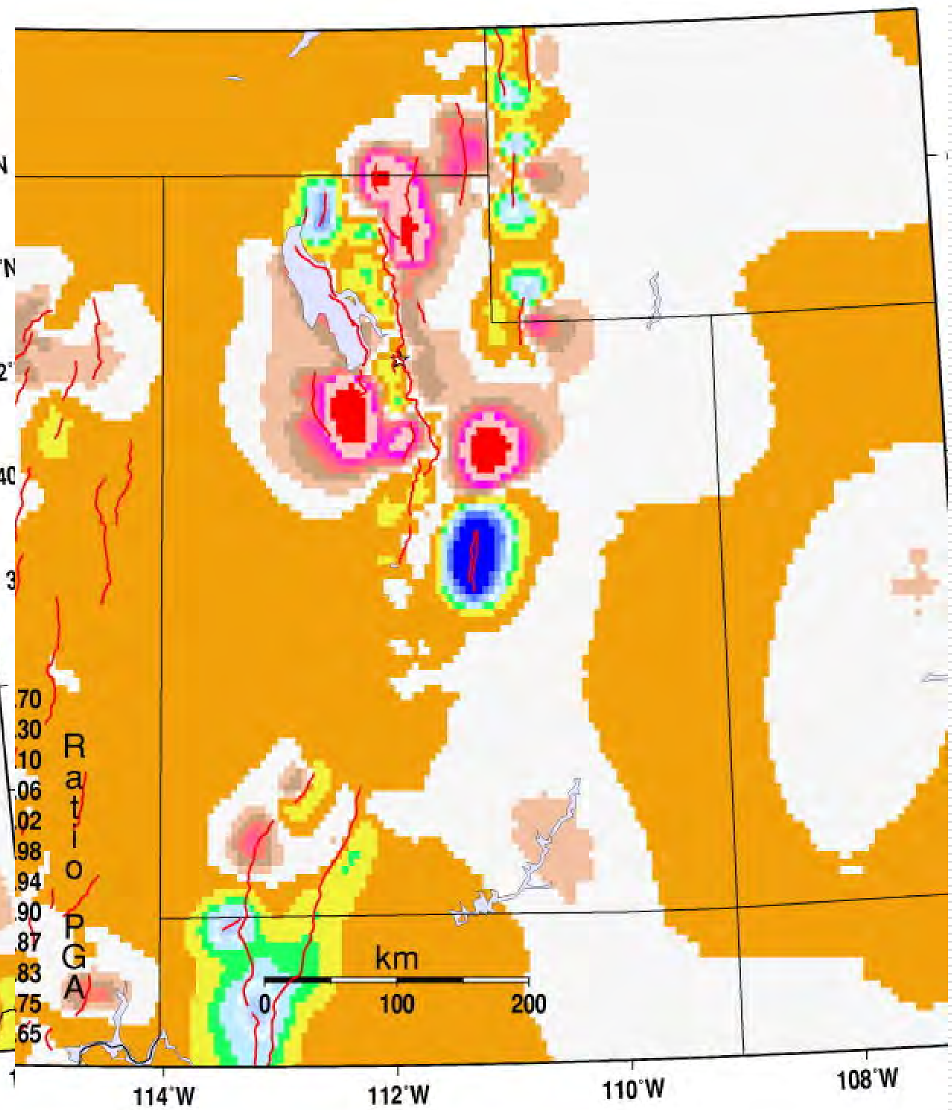
GMT Feb 23 14:26 SA ratio for Utah feb 23. 2007 over 2002. Site 760ms. 5 Hz 2%50 yr PE. denom is 2002. Dark blue means decrease more than 35%

WUS 2007/2002 ratio PGA w/2%PE50YR



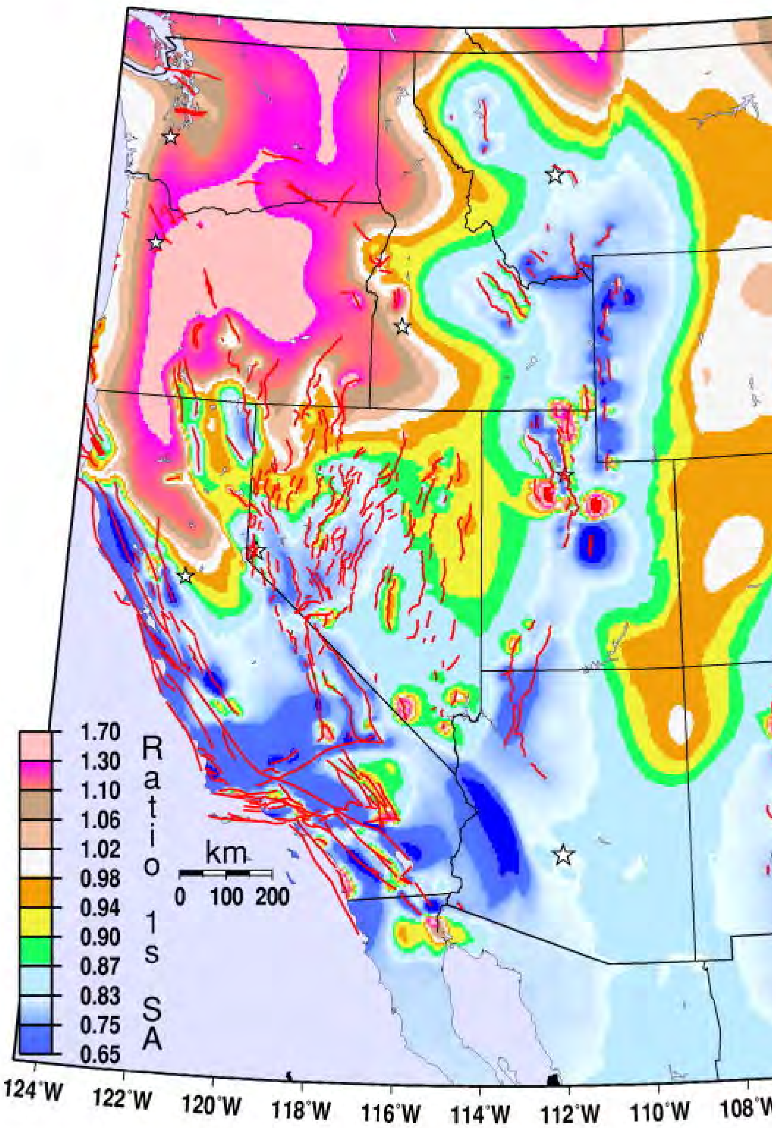
GMT Feb 23 13:42 Feb 15 2007 model over 2002. Site 760ms. PGA 2%50 yr PE. denom is 2002 official pga

Utah 2007/2002 ratio PGA w/2%PE50YR



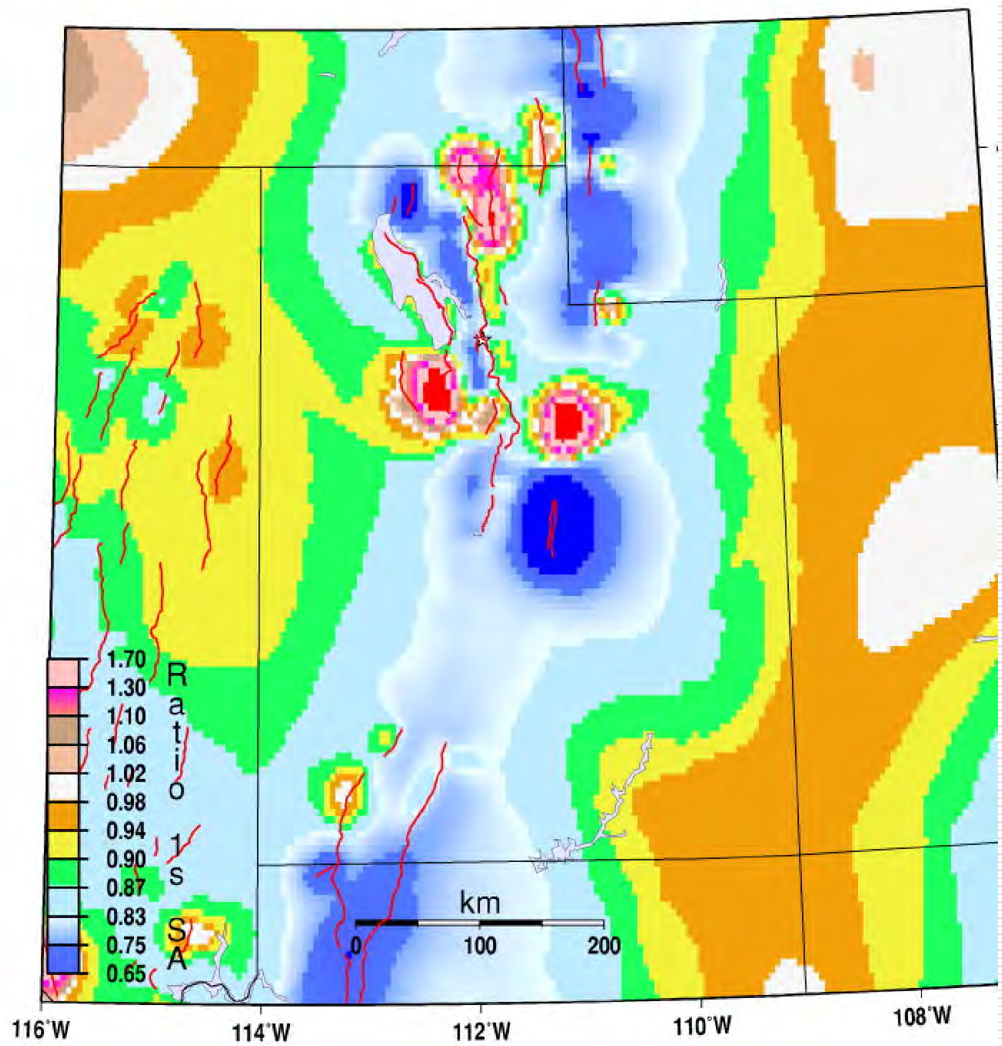
ratio for Utah feb 23. 2007 over 2002. Site 760ms. 2%50 yr PE. denom is 2002 . Bright red means increase more than 70%.

PSHA WUS 2007/2002 ratio 1-Hz SA w/2%P



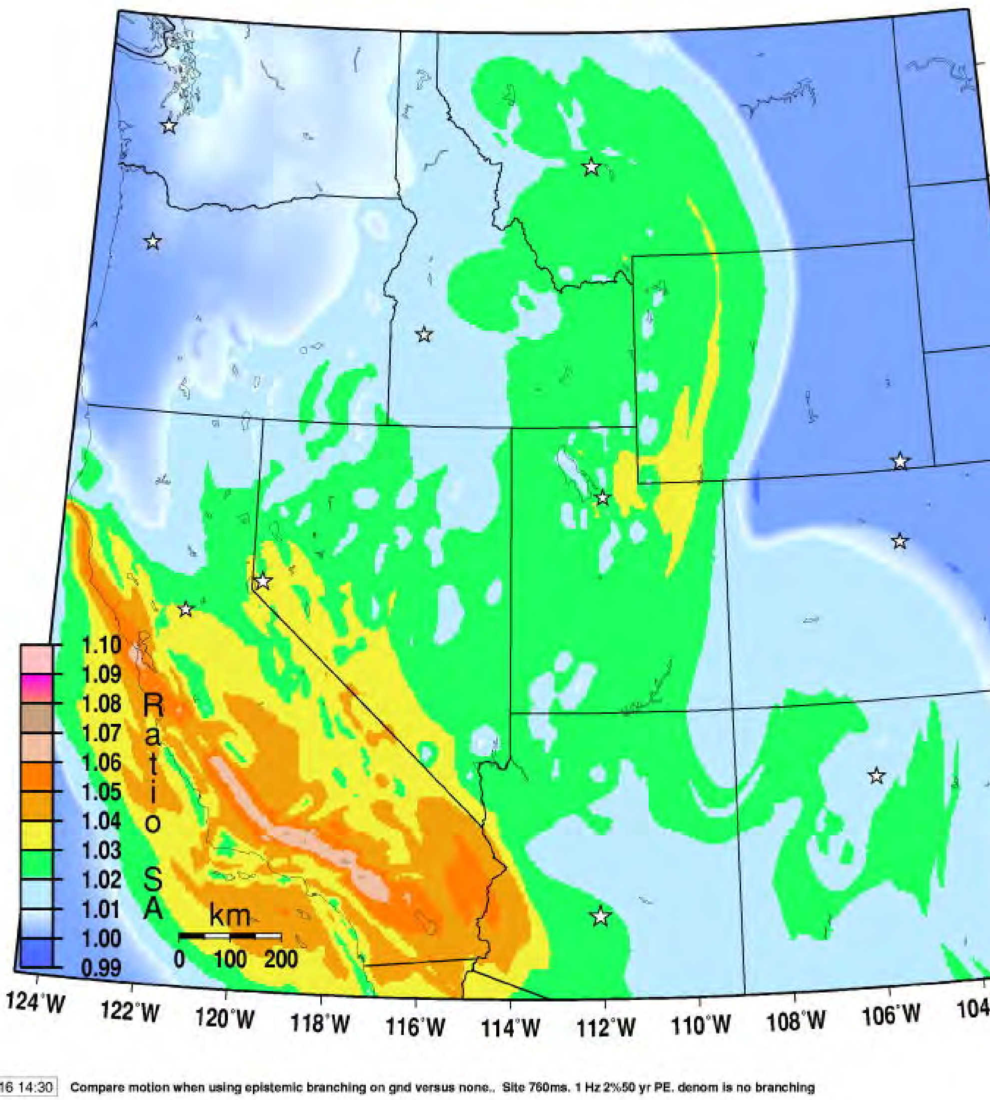
GMT Feb 23 13:47 Revised ratios for WUS feb 23. 2007 over 2002. Site 760ms. 1 Hz 2%50 yr PE. denom is 2002 official

Utah 2007/2002 ratio 1-Hz SA w/2%PE50YR



GMT Feb 23 14:22 SA ratio for Utah feb 23. 2007 over 2002. Site 760ms. 1 Hz 2%50 yr PE. denom is 2002 . Dark blue decrease more than 35%

gnd with epistemic/without epistemic 1-Hz SA w/2%PE50YR



Construction and Verification of a Wasatch Front Community Velocity Model

Harold Magistrale and Kim Olsen SDSU
Jim Pechmann UUSS

Utah GSWG 2/27/07

Wasatch Front Model Elements

-R1, R2, R3 in Salt Lake Valley

-R1, basement in other basins
gravity, wells, seismics

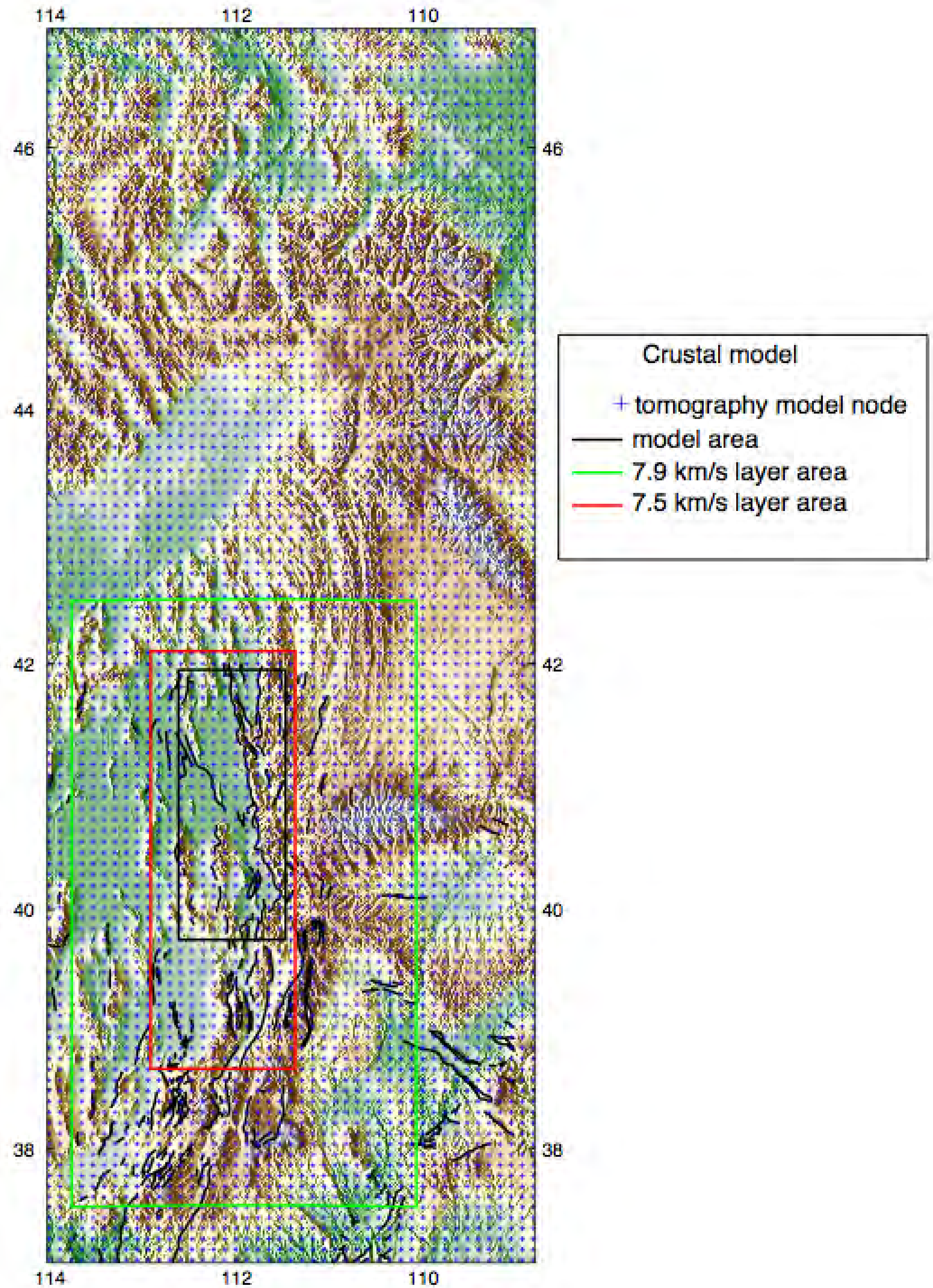
-Soil classes

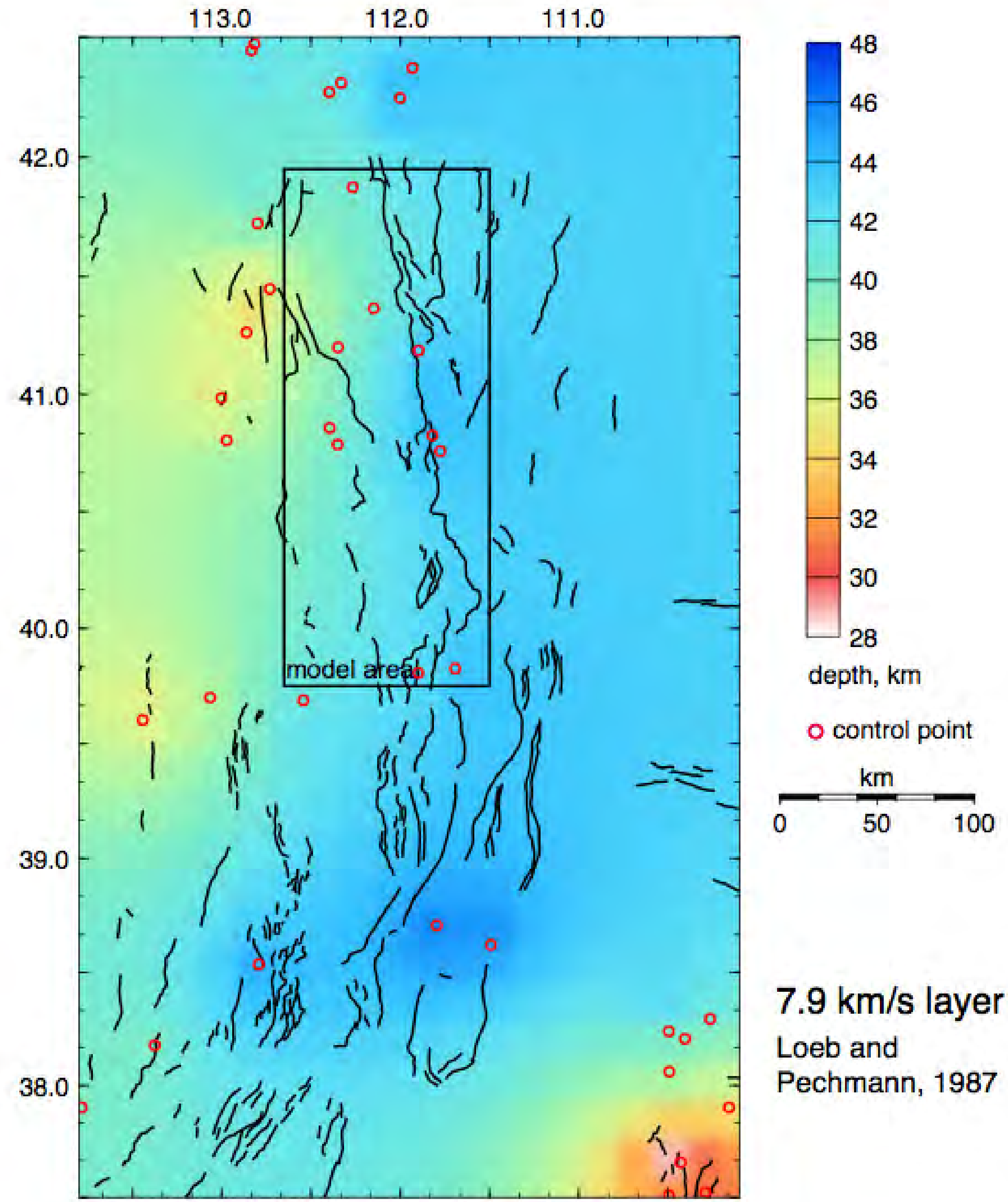
-Geotechnical boreholes

-Deep boreholes - seismic velocities

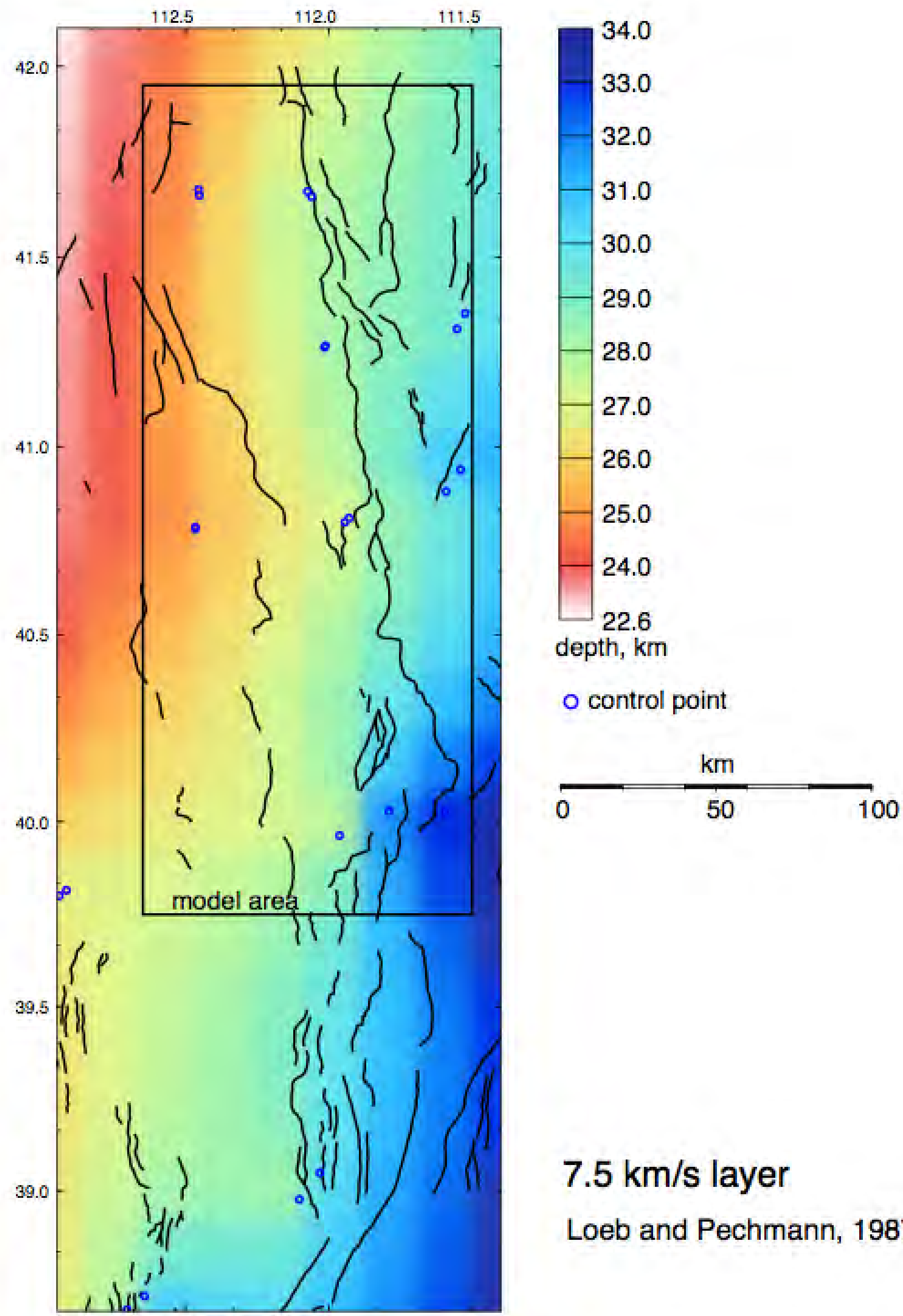
-Crustal tomography

-Moho


114
112
110
46
44
42
40
38
Crustal model
tomography model node
model area
7.9 km/s layer area
7.5 km/s layer area



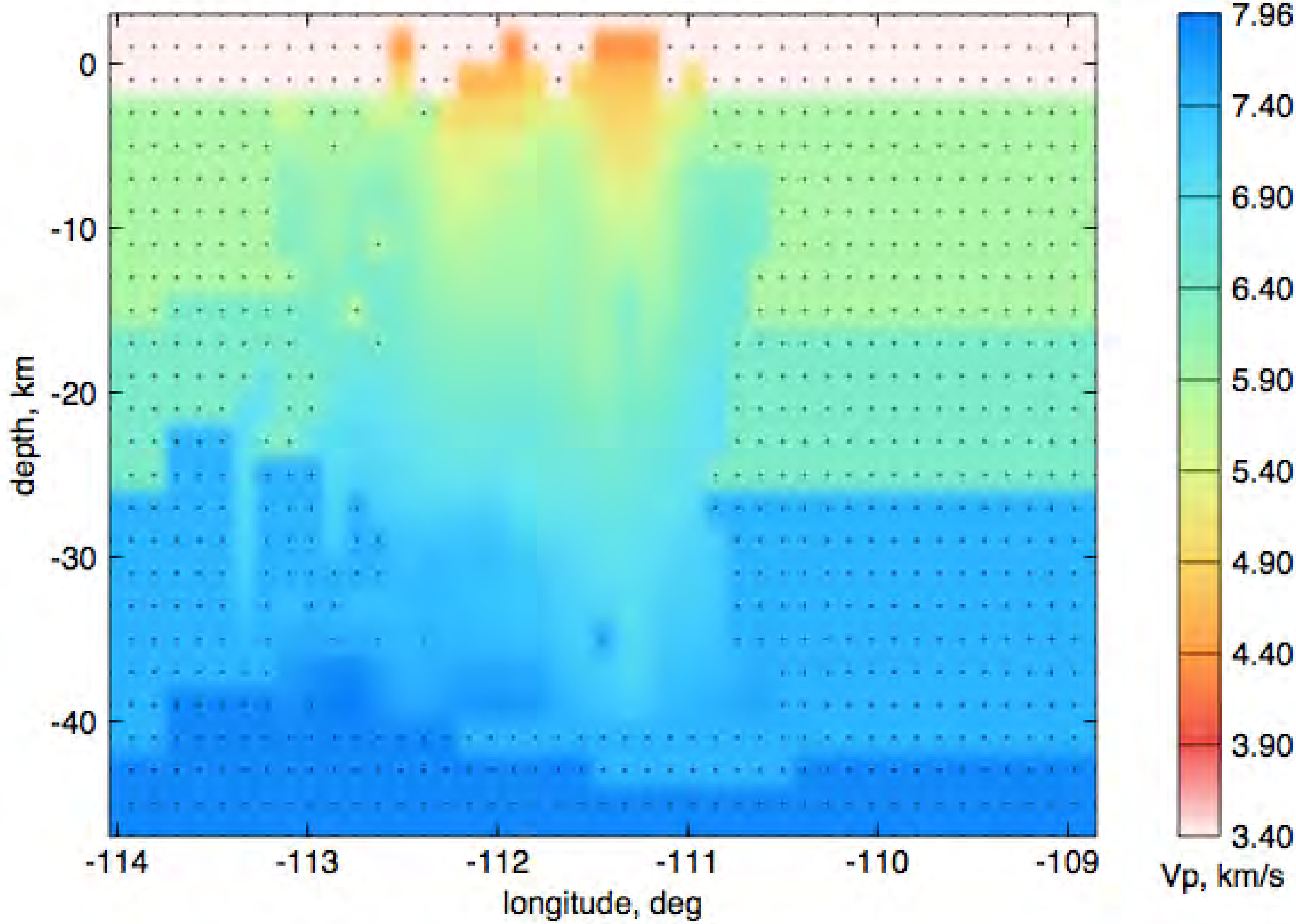
113.0
112.0
111.0
42.0
41.0
40.0
39.0
38.0
model area
48
46
44
42
40
38
36
34
32
30
28
depth, km
control point
km
0
50
100
7.9 km/s layer
Loeb and
Pechmann, 1987



7.5 km/s layer

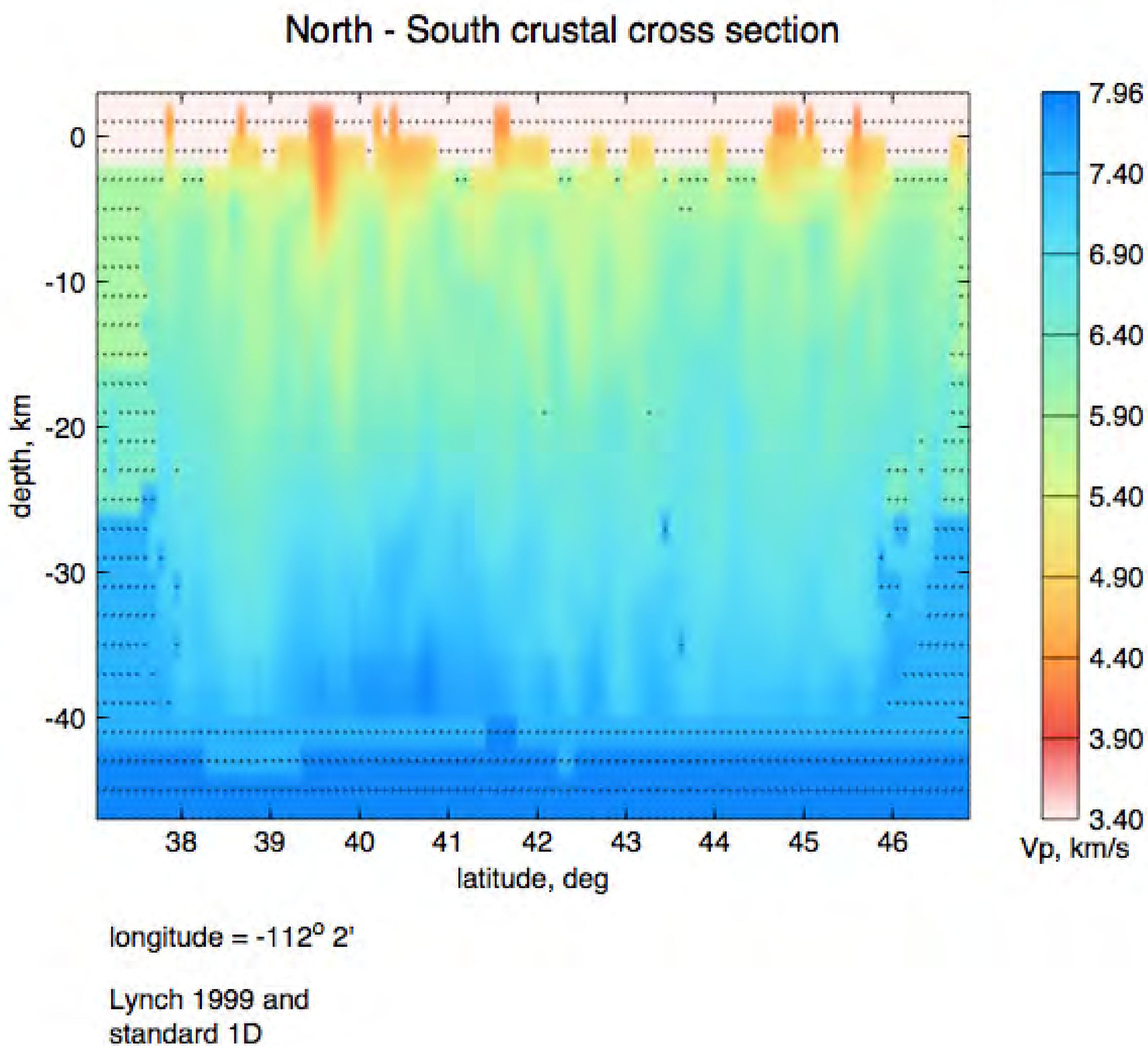
Loeb and Pechmann, 1987

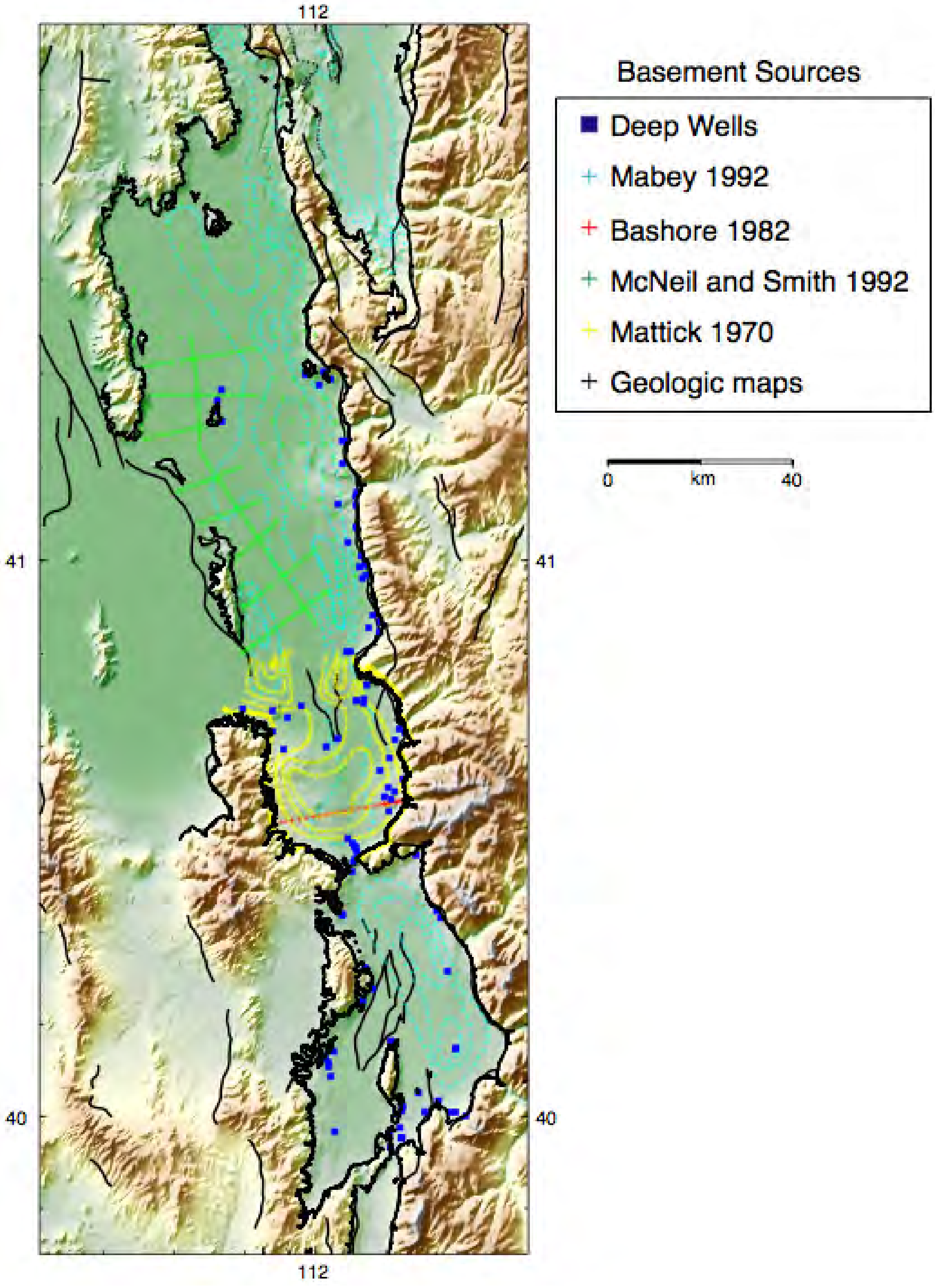
East - West crustal cross section

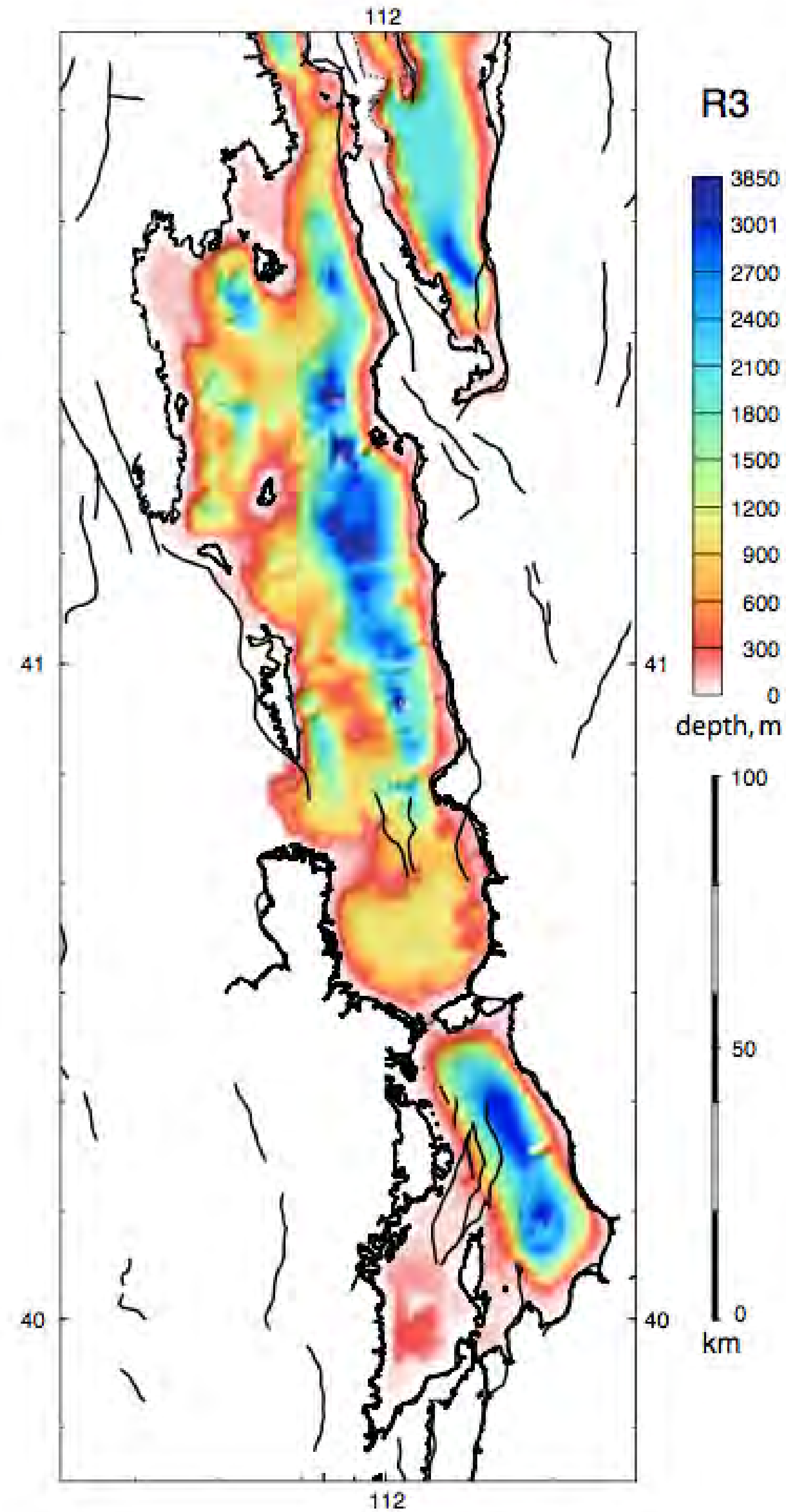


latitude = 40° 28'

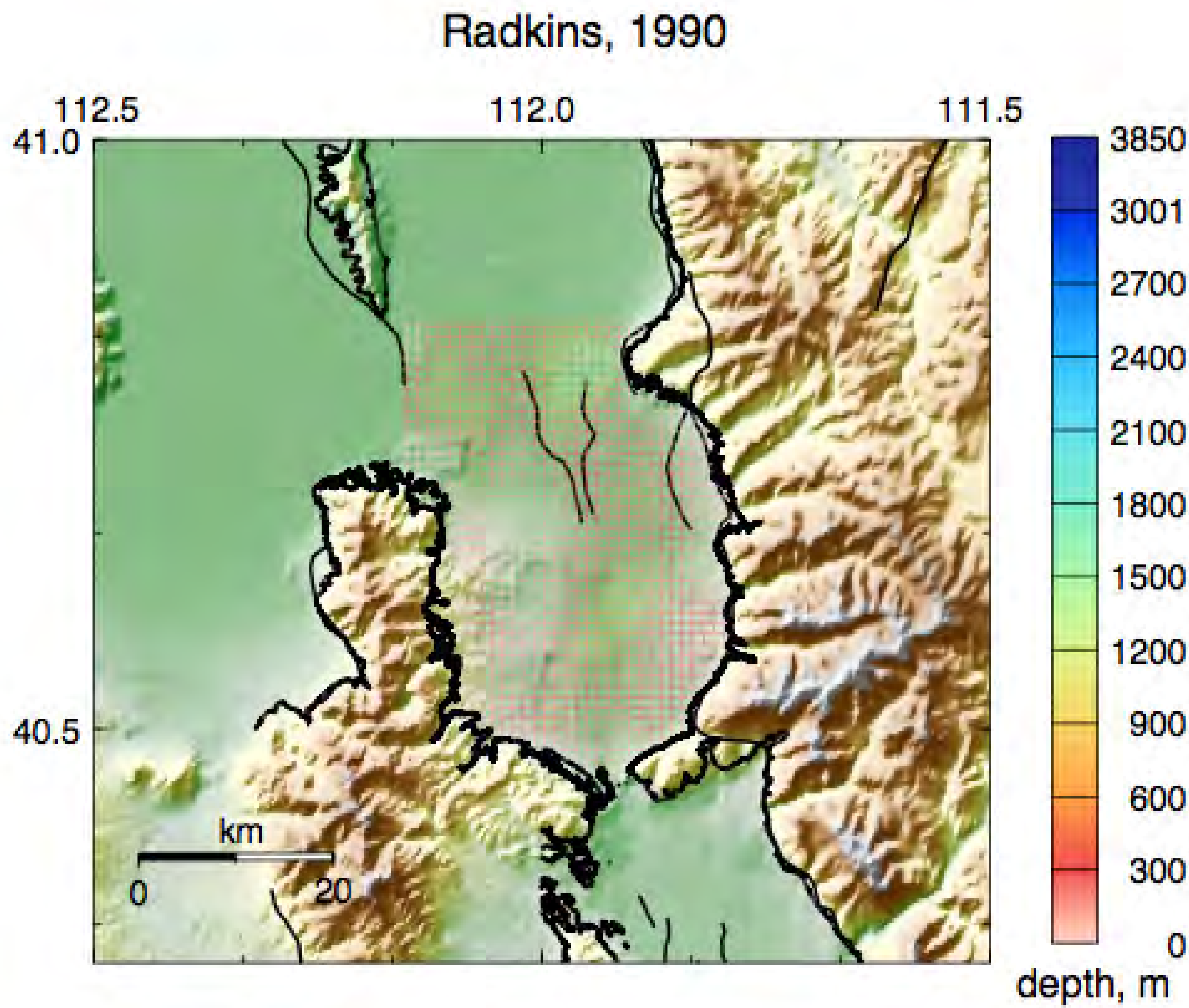
Lynch 1999 and
standard 1D

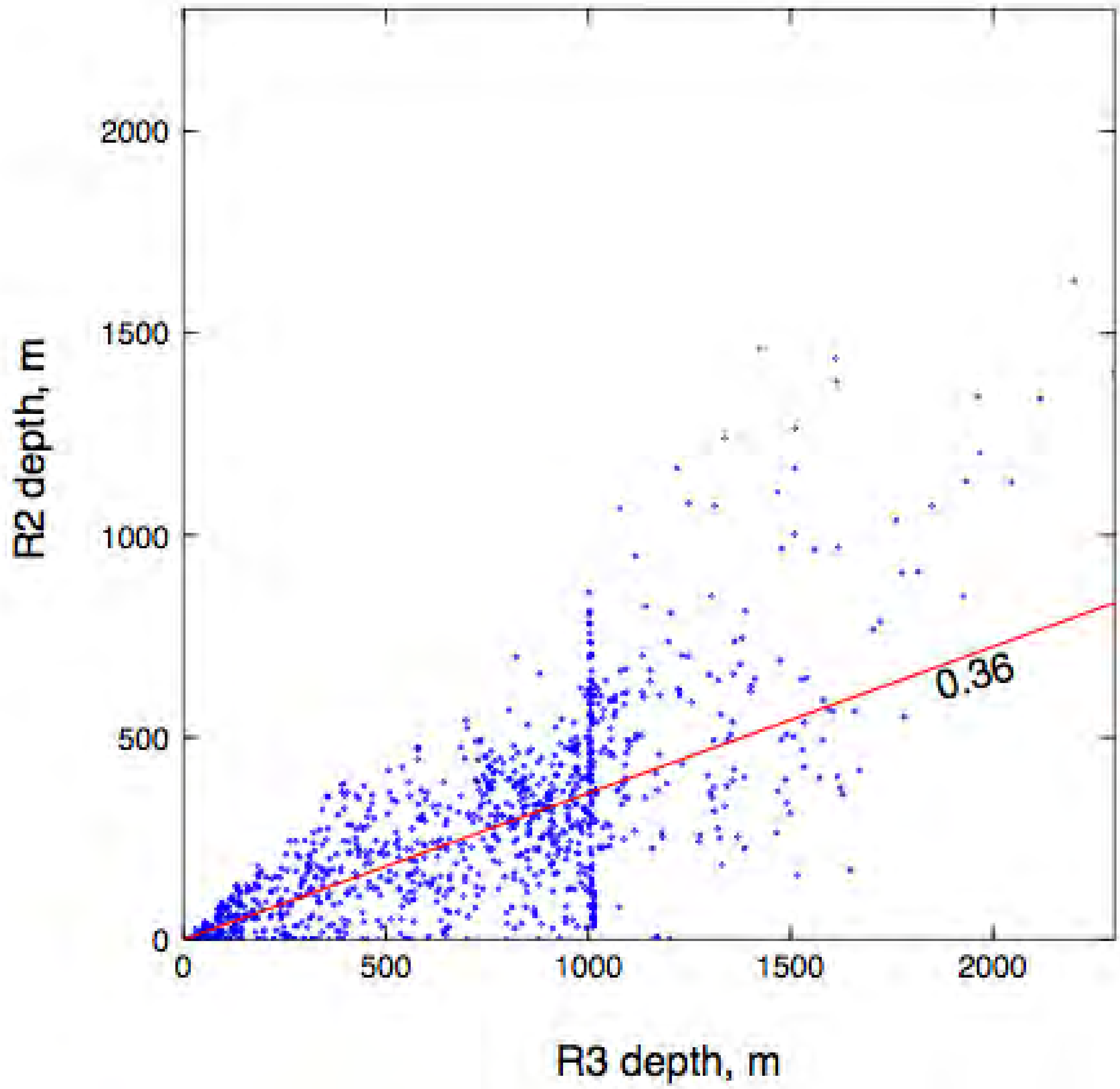

North - South crustal cross section
0
-10
-20
-30
-40
depth, km
38
39
40
41
42
43
44
45
46
latitude, deg
7.96
7.40
6.90
6.40
5.90
5.40
4.90
4.40
3.90
3.40
Vp, km/s
longitude = -112° 2'
Lynch 1999 and
standard 1D

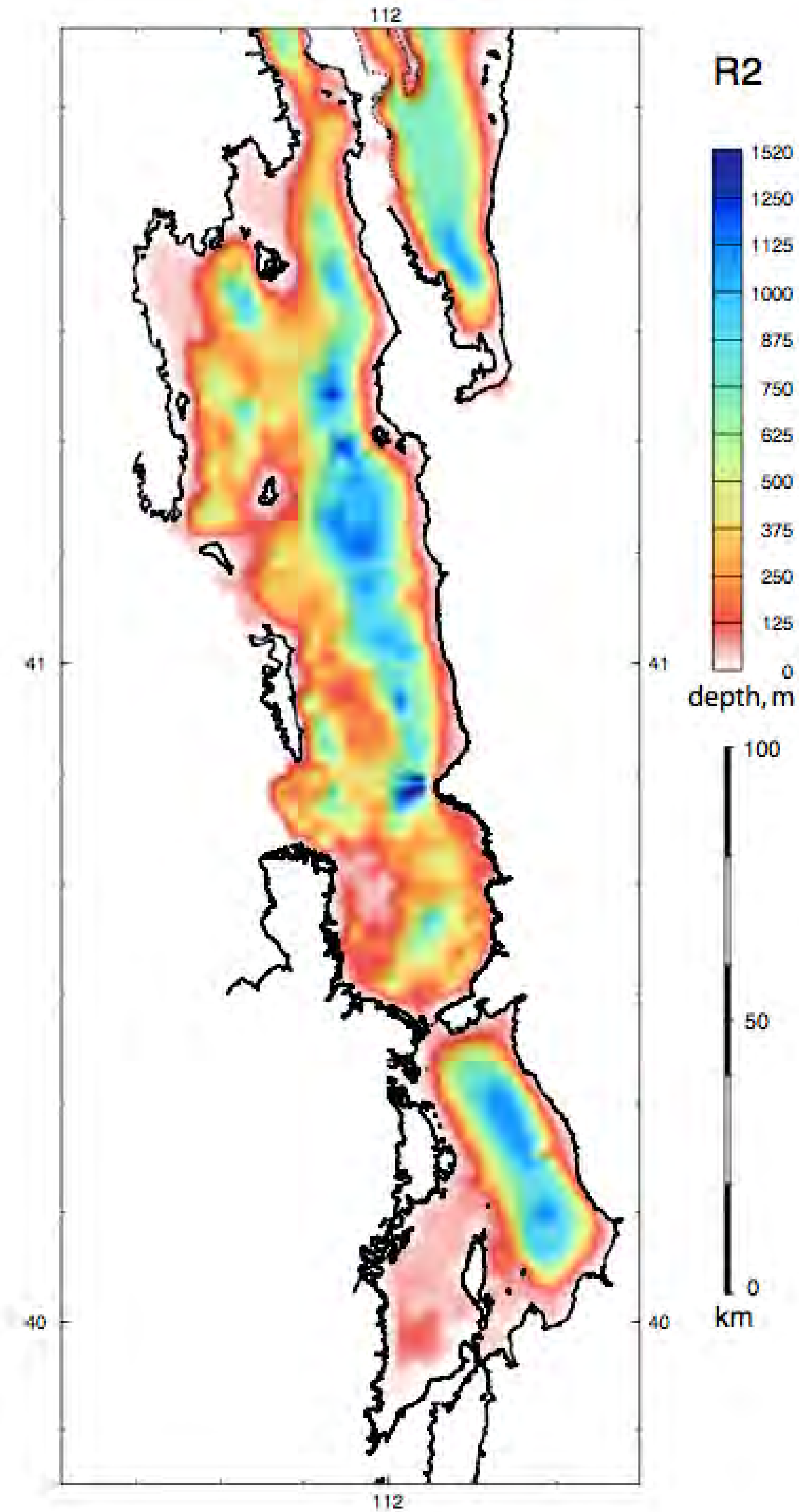

112
41
40
Basement Sources
Deep Wells
Mabey 1992
Bashore 1982
McNeil and Smith 1992
Mattick 1970
Geologic maps
0
km
40



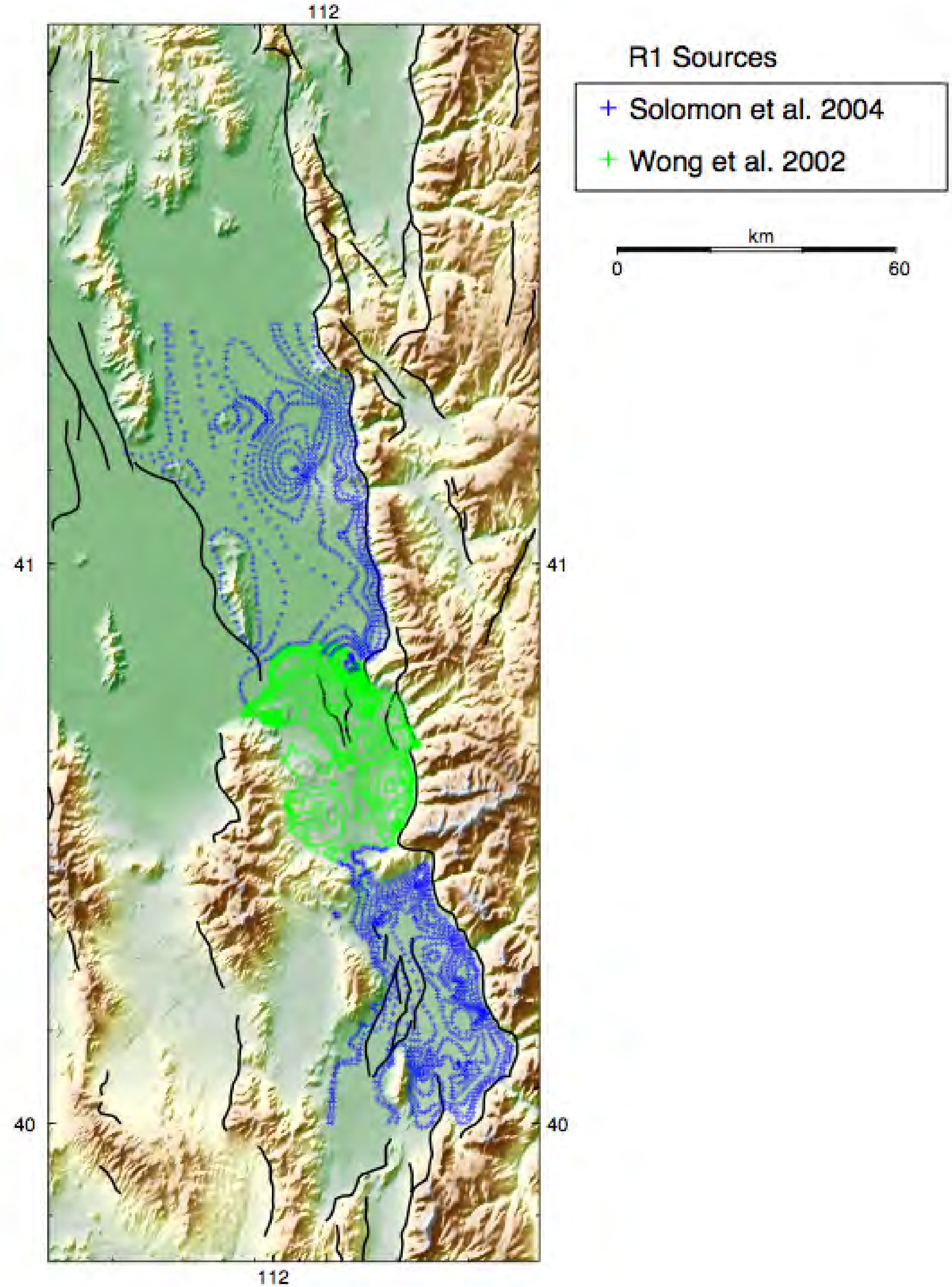
112
R3
3850
3001
2700
2400
2100
1800
1500
1200
900
600
300
0
depth, m
41
41
100
50
0
40
40
km
112


Radkins, 1990
112.5
112.0
111.5
41.0
40.5
km
0
20
3850
3001
2700
2400
2100
1800
1500
1200
900
600
300
0
depth, m

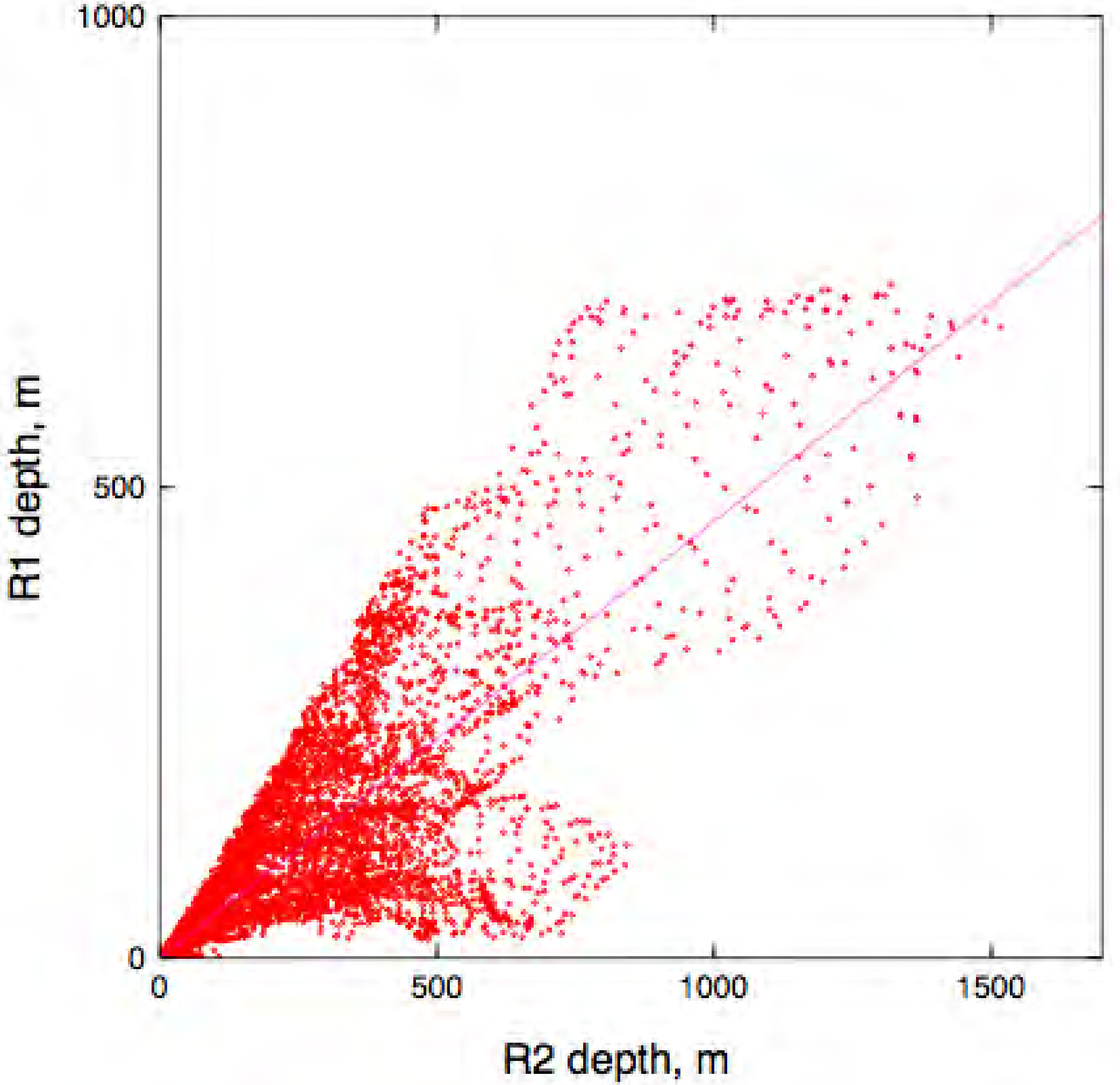

R2 depth, m
2000
1500
1000
500
0
0
500
1000
1500
2000
0.36
R3 depth, m



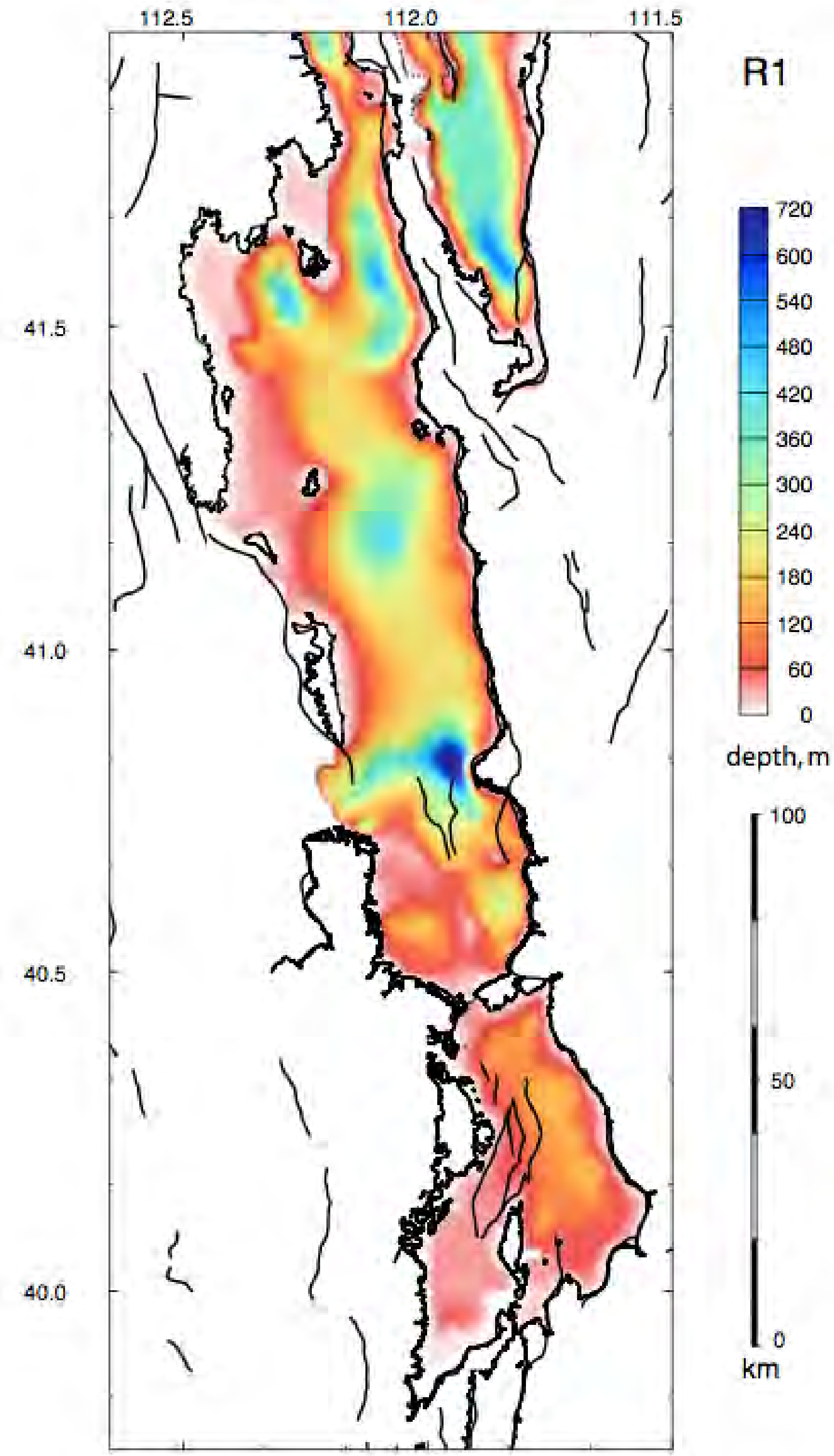
112
R2
1520
1250
1125
1000
875
750
625
500
375
250
125
0
depth, m
100
50
0
km
41
41
40
40
112



112
41
40
R1 Sources
Solomon et al. 2004
Wong et al. 2002
km
0
60

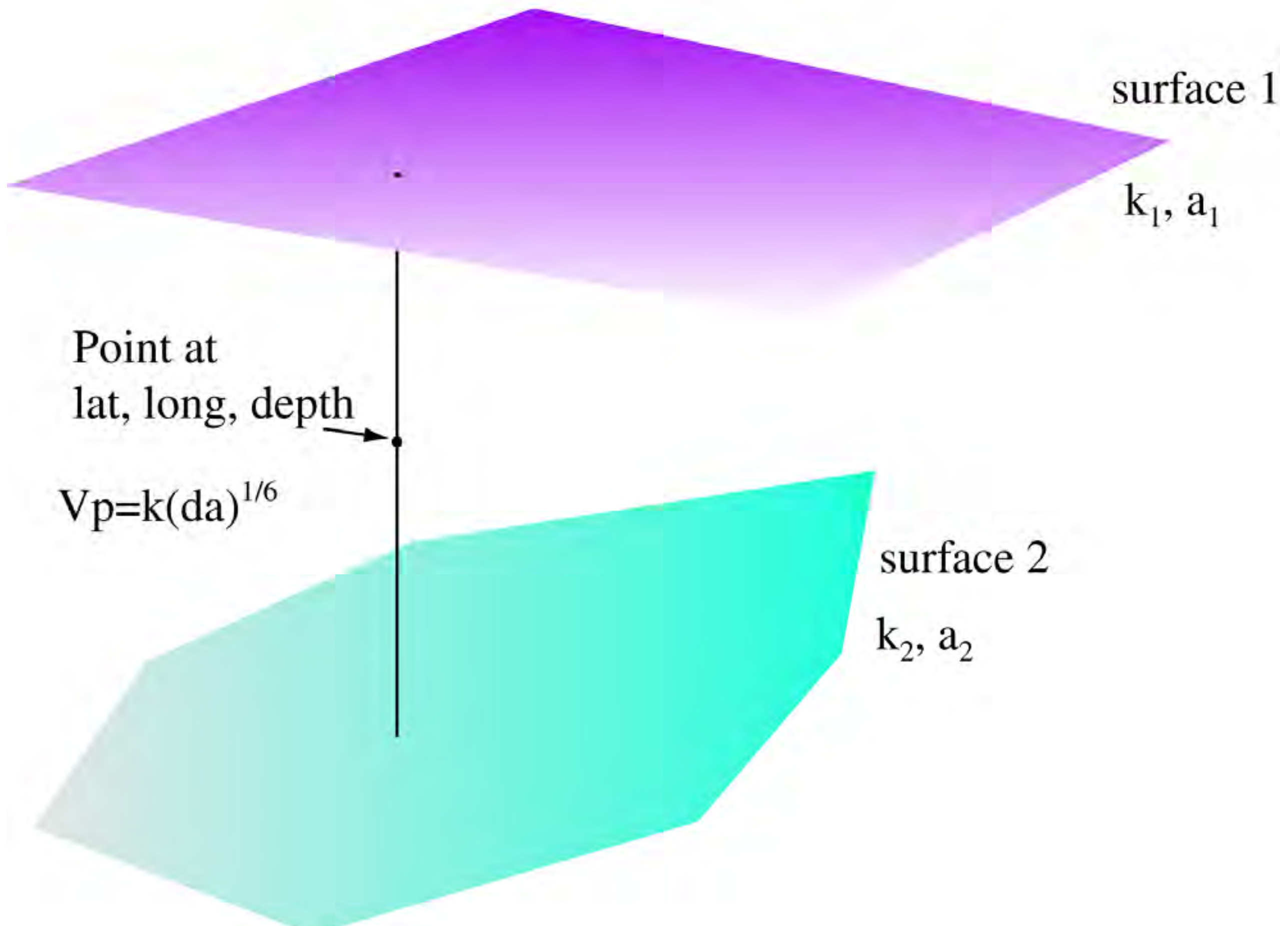


1000
500
0
0
500
1000
1500
R1 depth, m
R2 depth, m

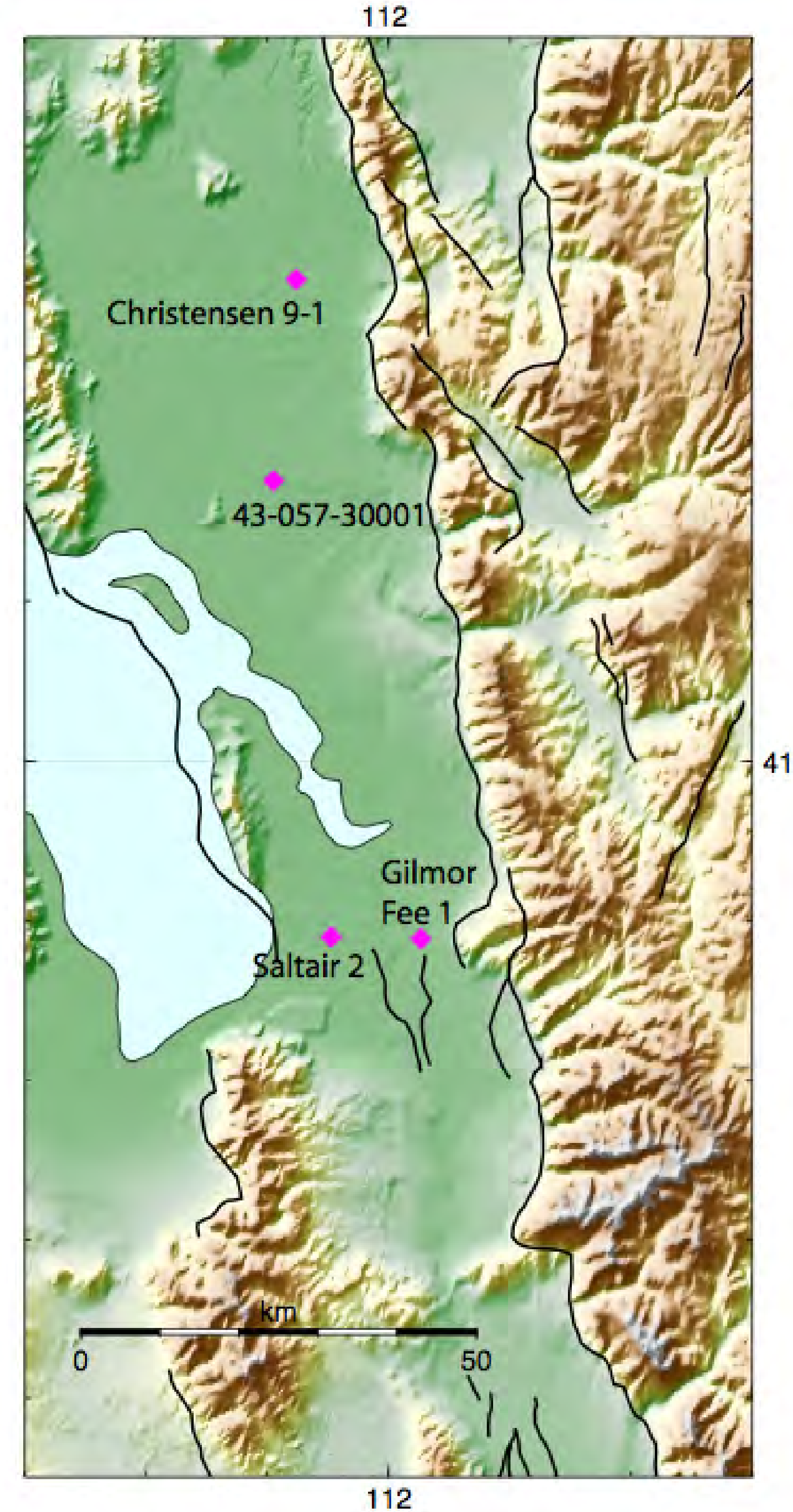


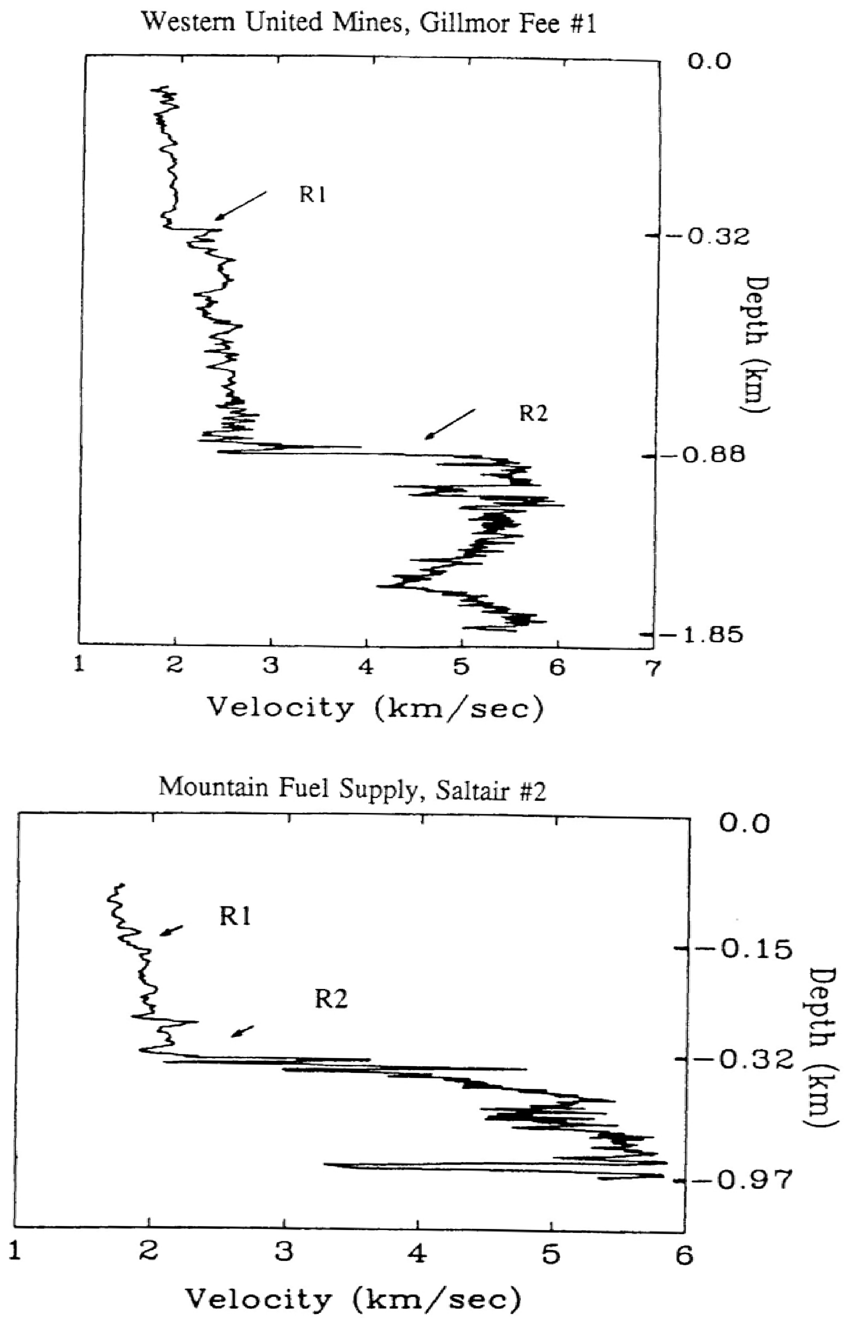
112.5
112.0
111.5
41.5
41.0
40.5
40.0
R1
720
600
540
480
420
360
300
240
180
120
60
0
depth, m
100
50
0
km

Model Parameterization

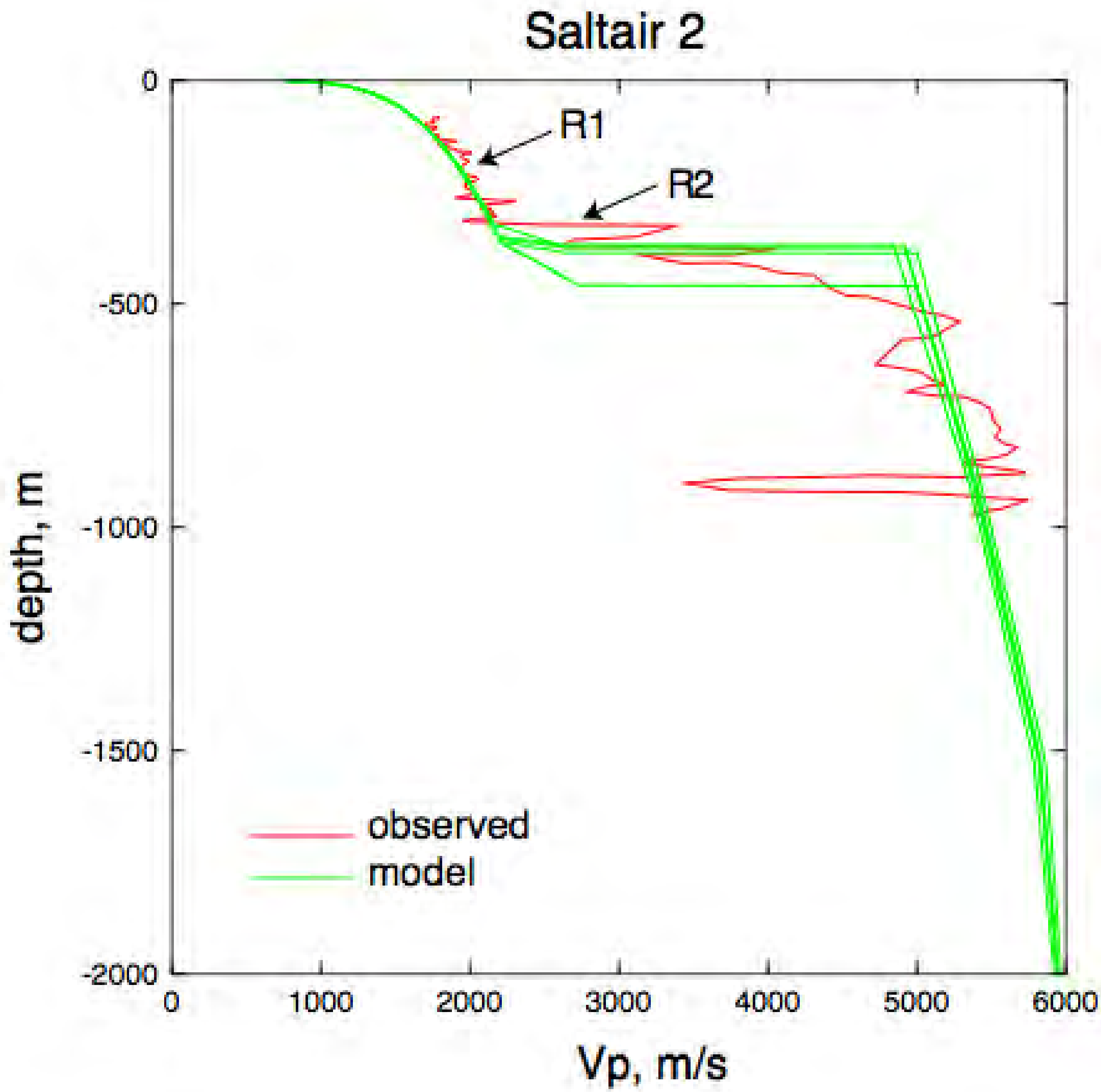


Faust's rule: $Vp=k(da)^{1/6}$

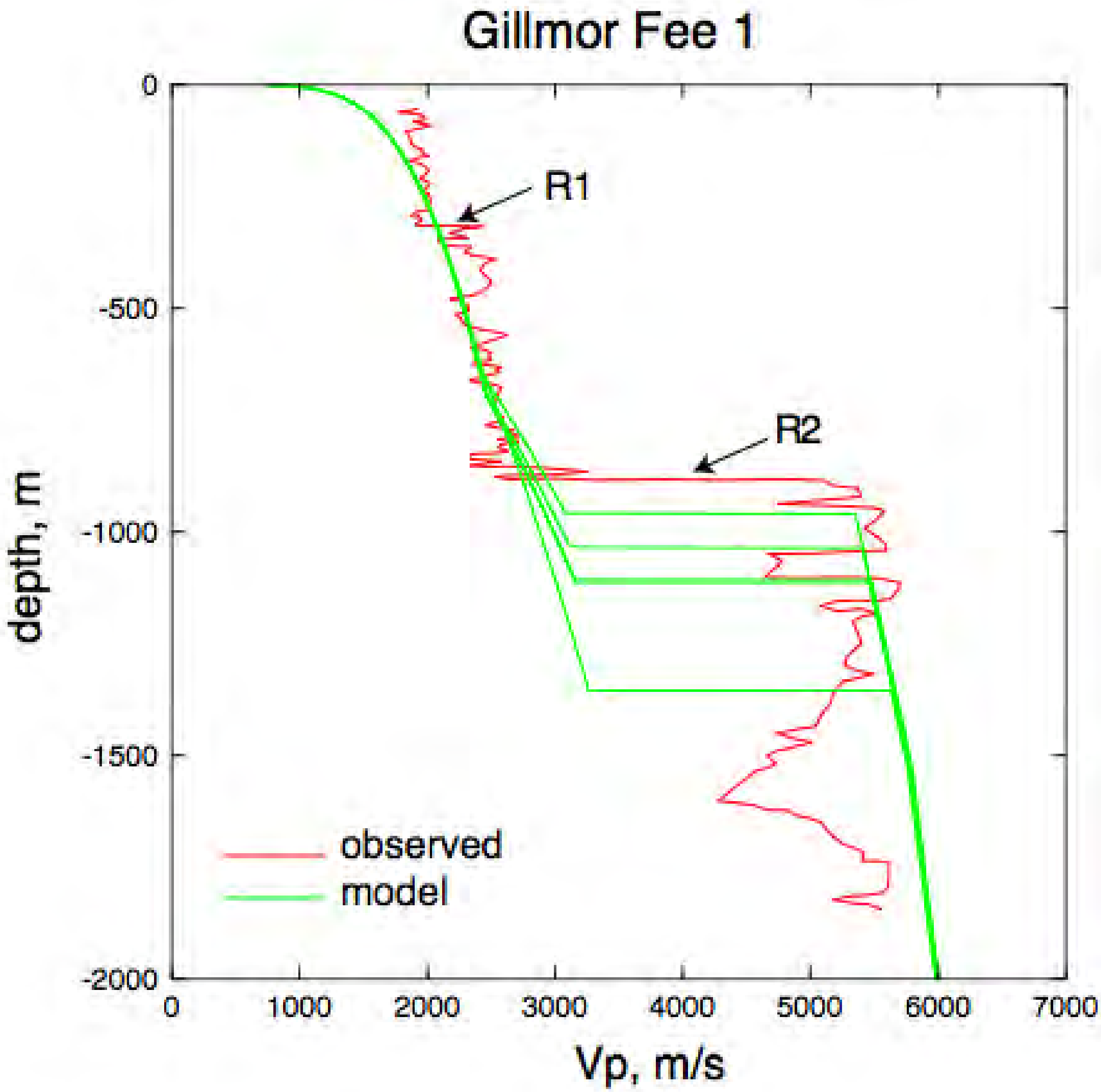

112
Christensen 9-1
43-057-30001
41
Gilmor
Fee 1
Saltair 2
km
0
50
112



Radkins et al. 1989

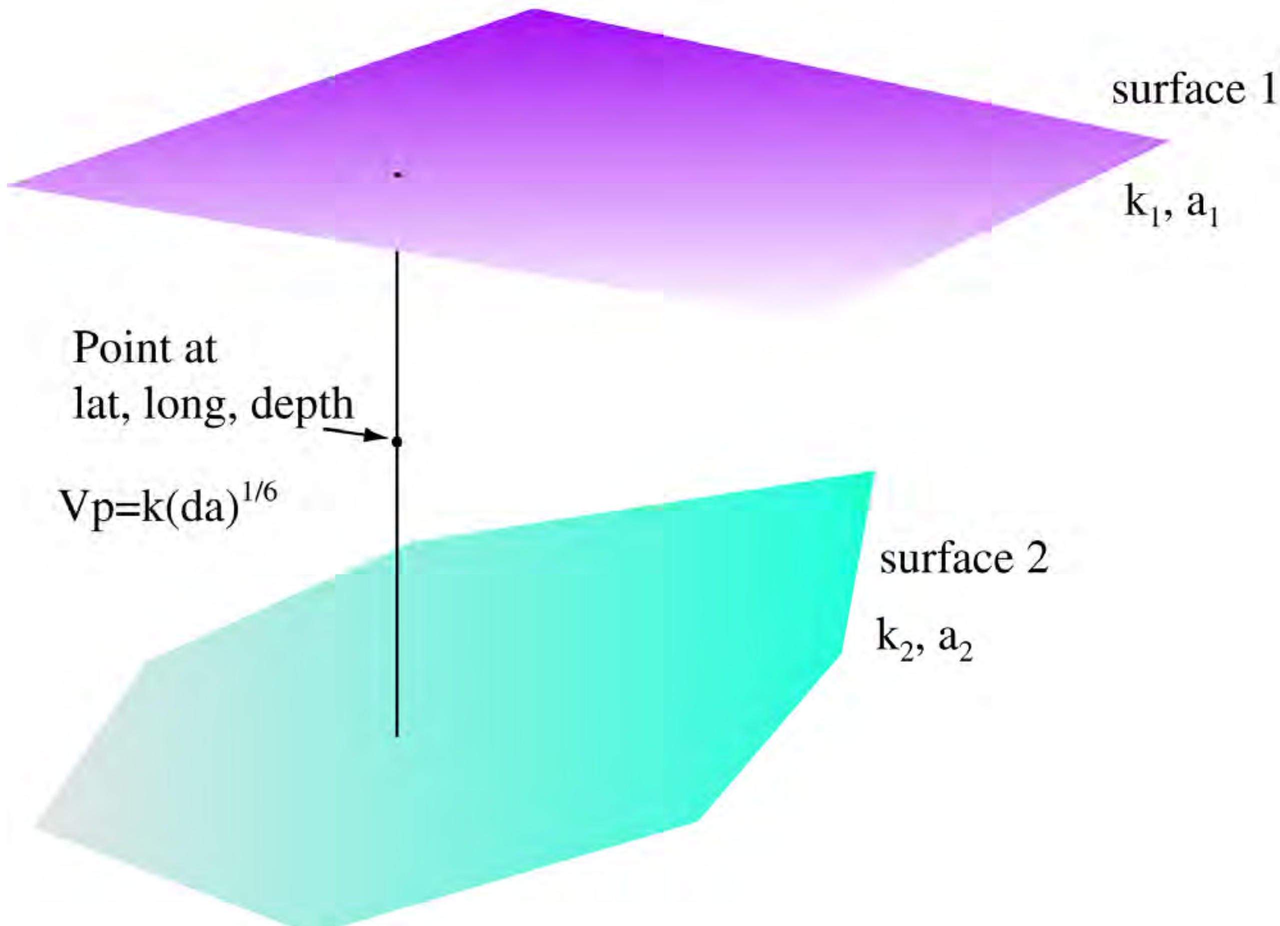


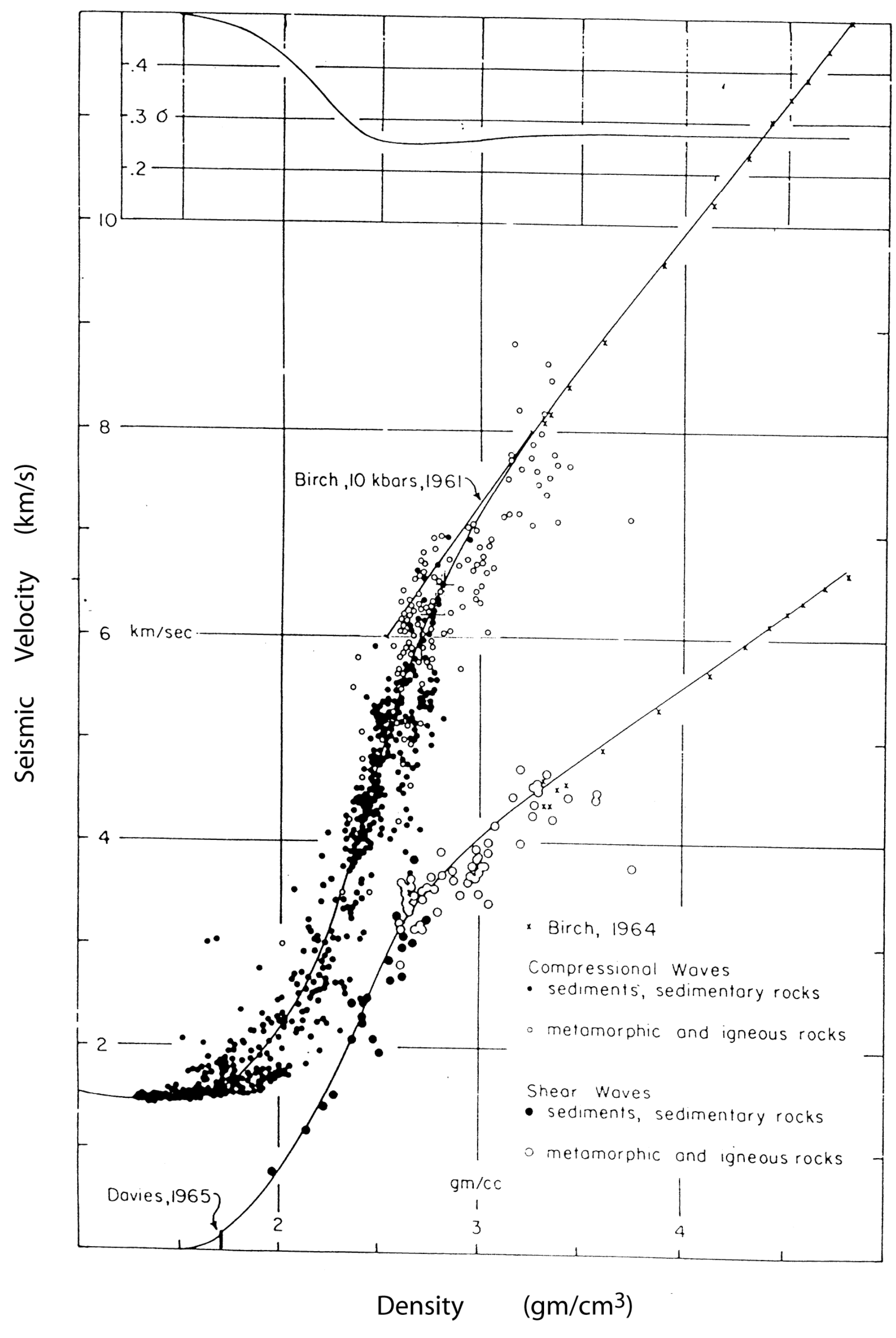
from Radkins et al. 1989

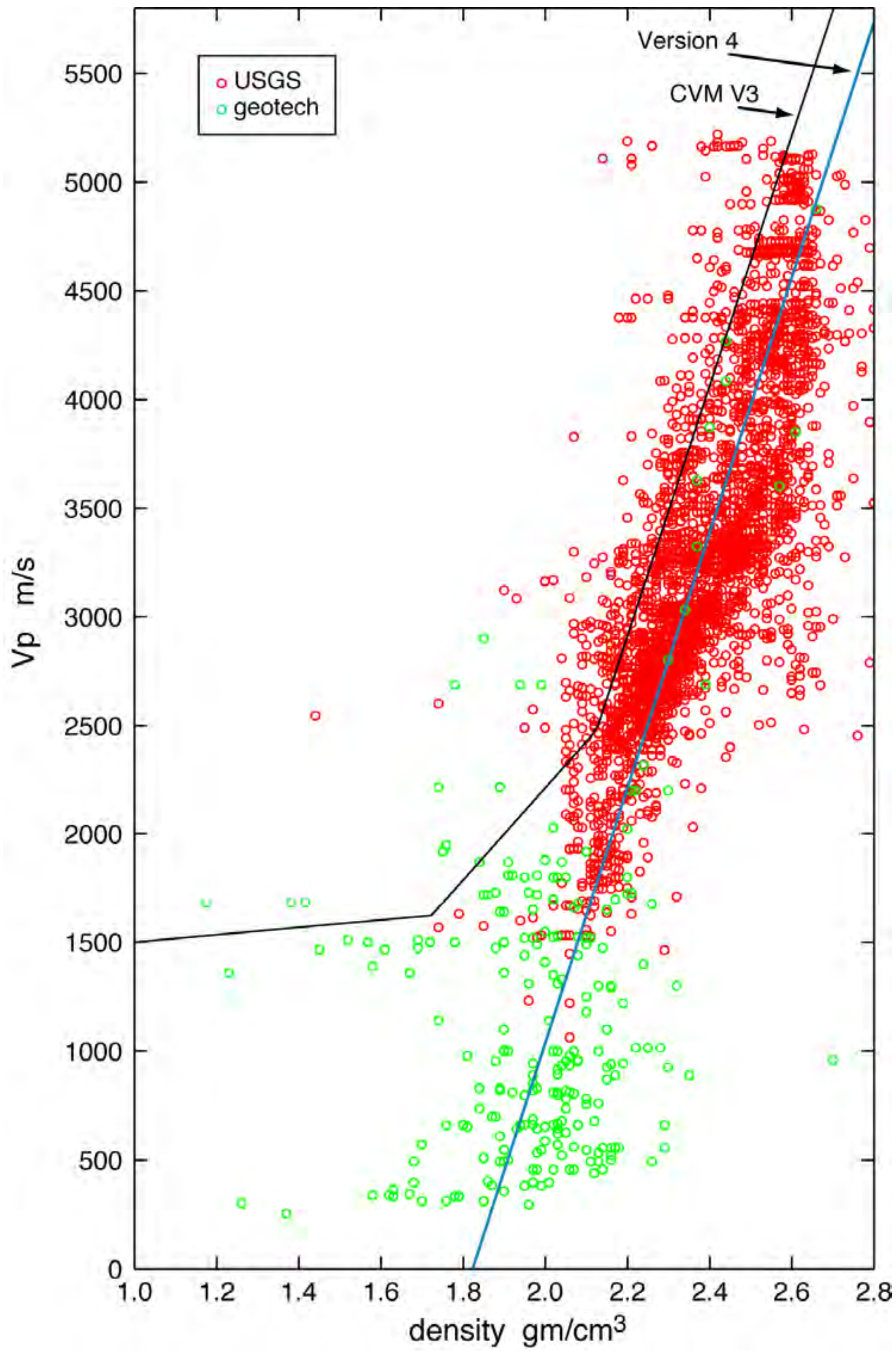


from Radkins et al. 1989

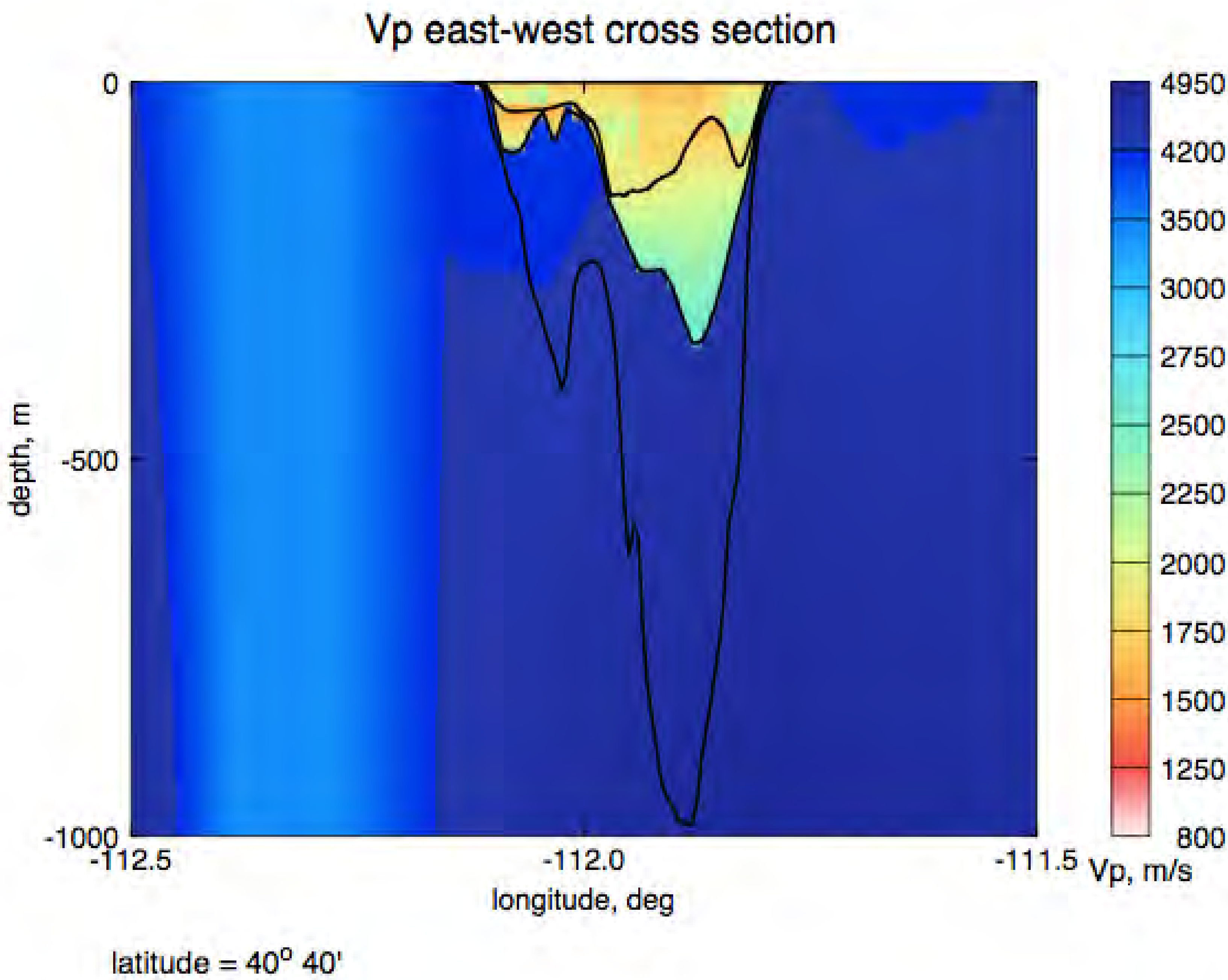
Model Parameterization

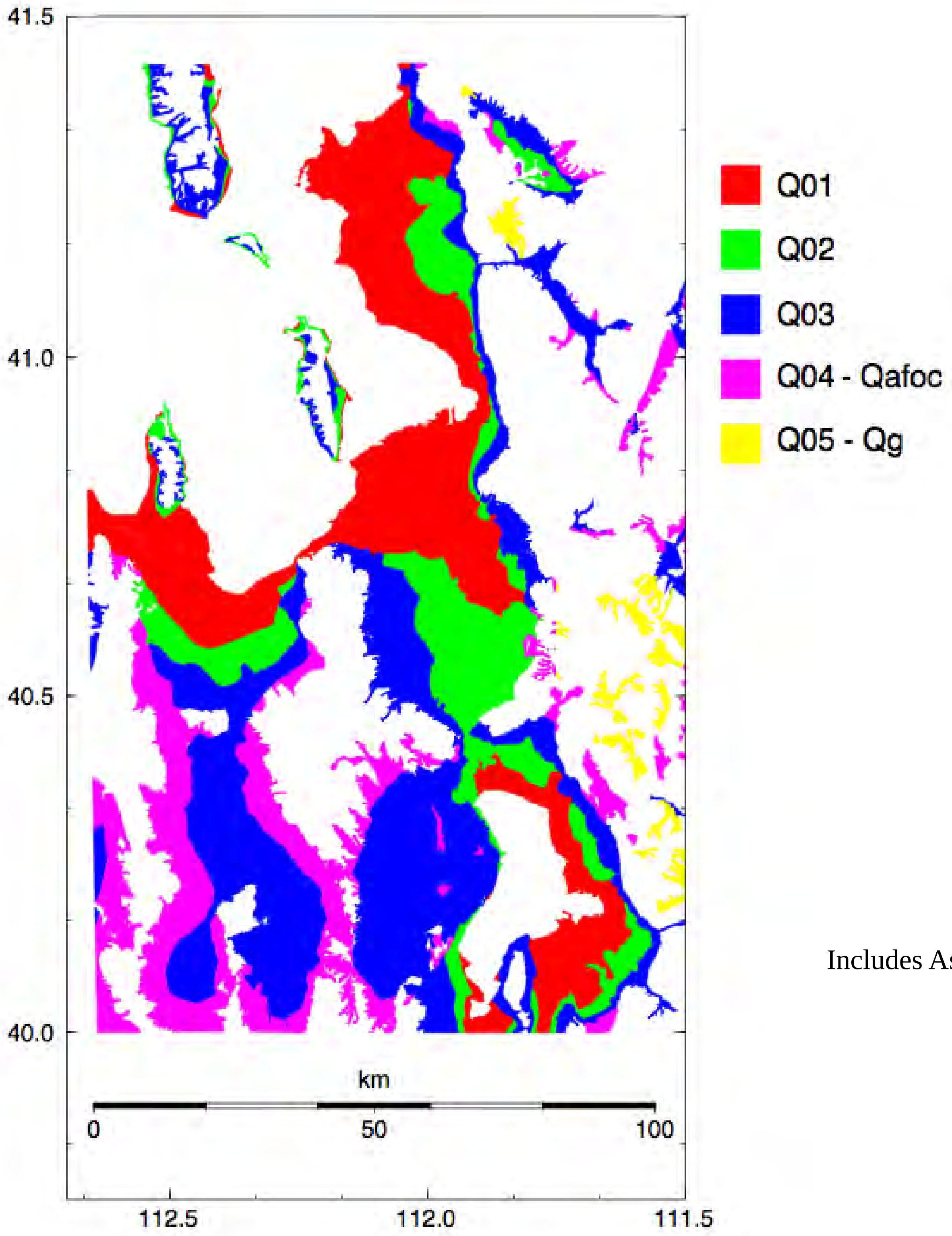



.4
.3 σ
.2
10
8
6 km/sec
4
2
Birch, 10 kbars, 1961
Davies, 1965
gm/cc
2
3
4
x Birch, 1964
Compressional Waves
• sediments, sedimentary rocks
◦ metamorphic and igneous rocks
Shear Waves
● sediments, sedimentary rocks
○ metamorphic and igneous rocks
Seismic Velocity (km/s)
Density (gm/cm3)

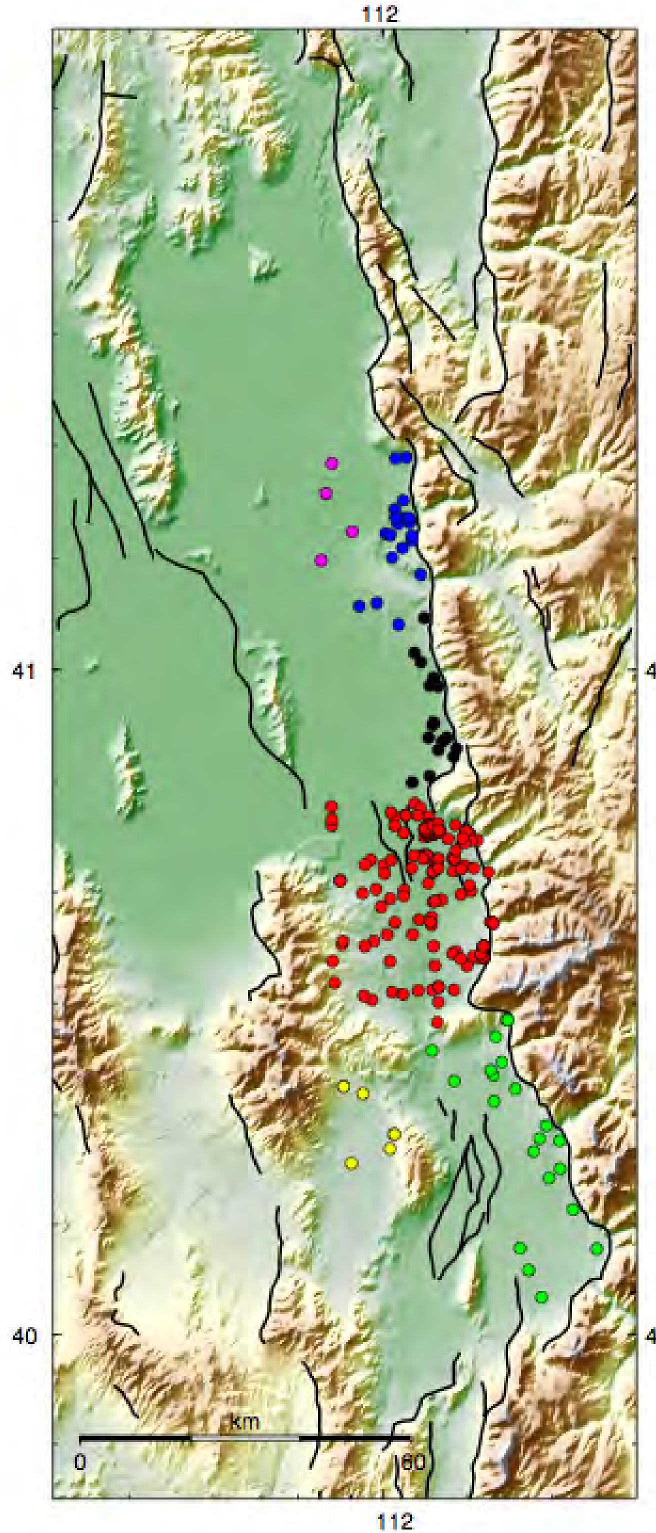


Version 4
CVM V3
USGS
geotech
Vp m/s
density gm/cm3
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8

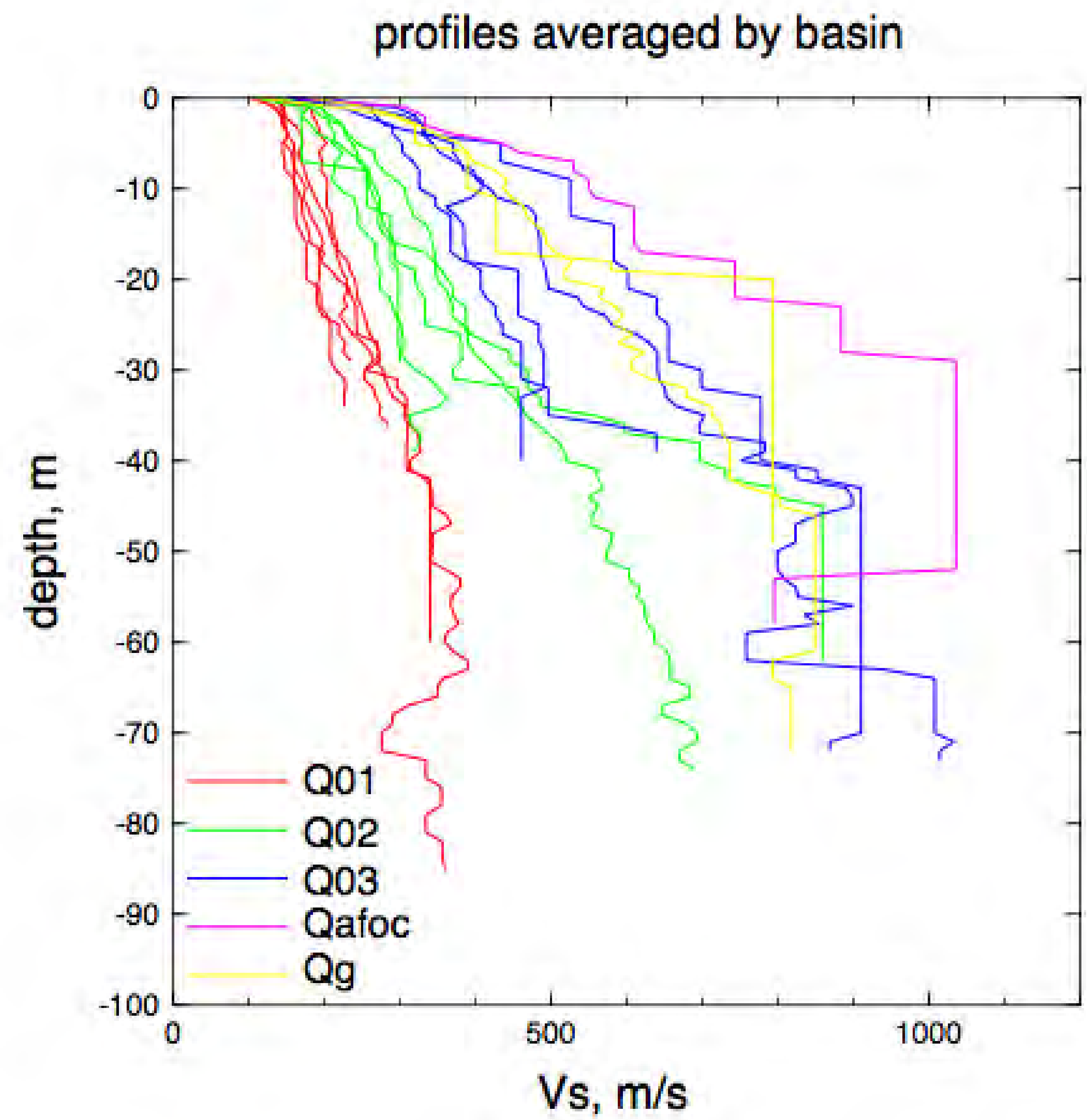

Vp east-west cross section
0
-500
-1000
depth, m
-112.5
-112.0
-111.5
longitude, deg
4950
4200
3500
3000
2750
2500
2250
2000
1750
1500
1250
800
Vp, m/s
latitude = 40° 40'



Includes Ashland 2001, 2004



McDonald Oct 2006



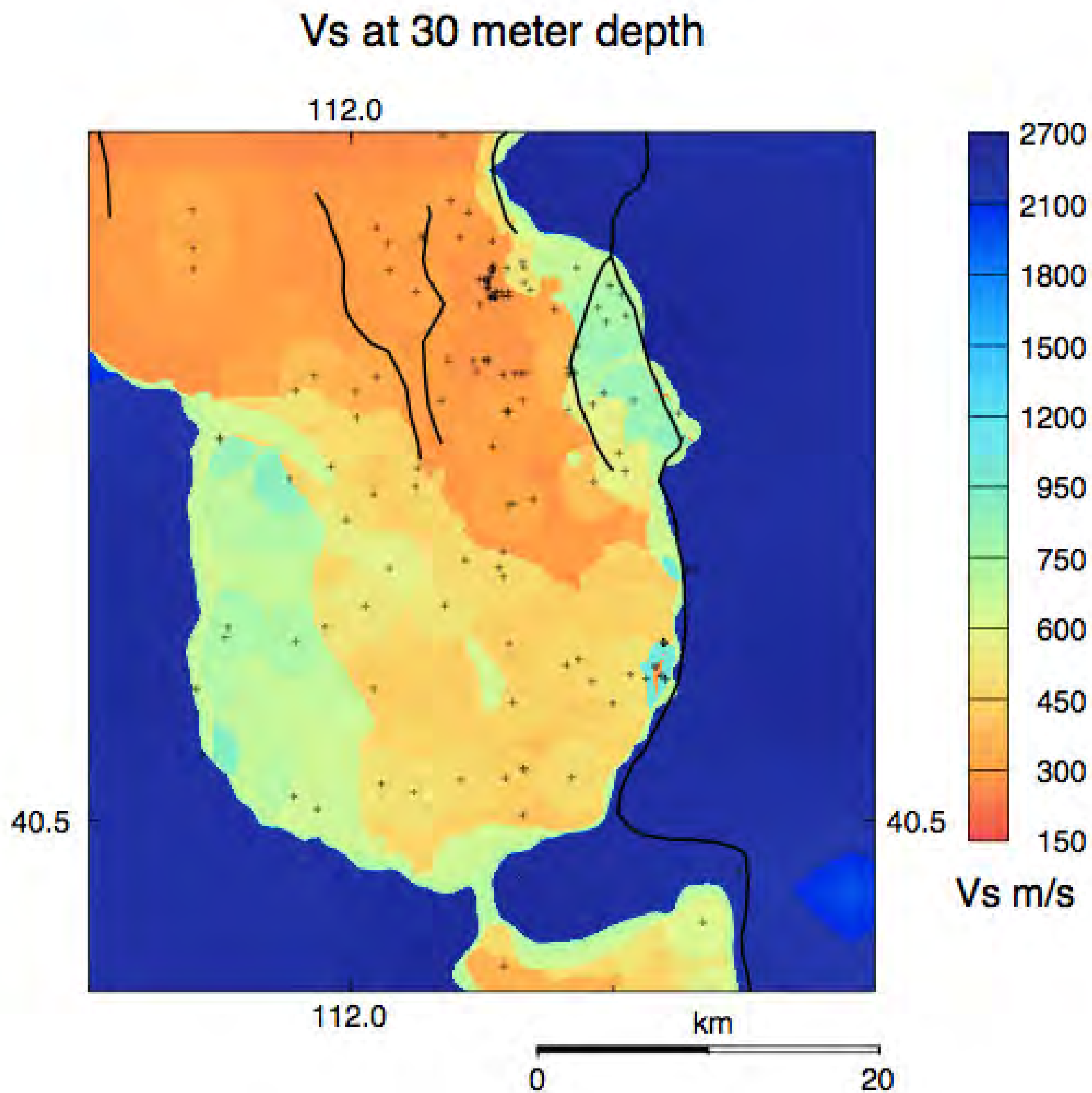
profiles averaged by basin
depth, m
Vs, m/s
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
500
1000
Q01
Q02
Q03
Qafoc
Qg

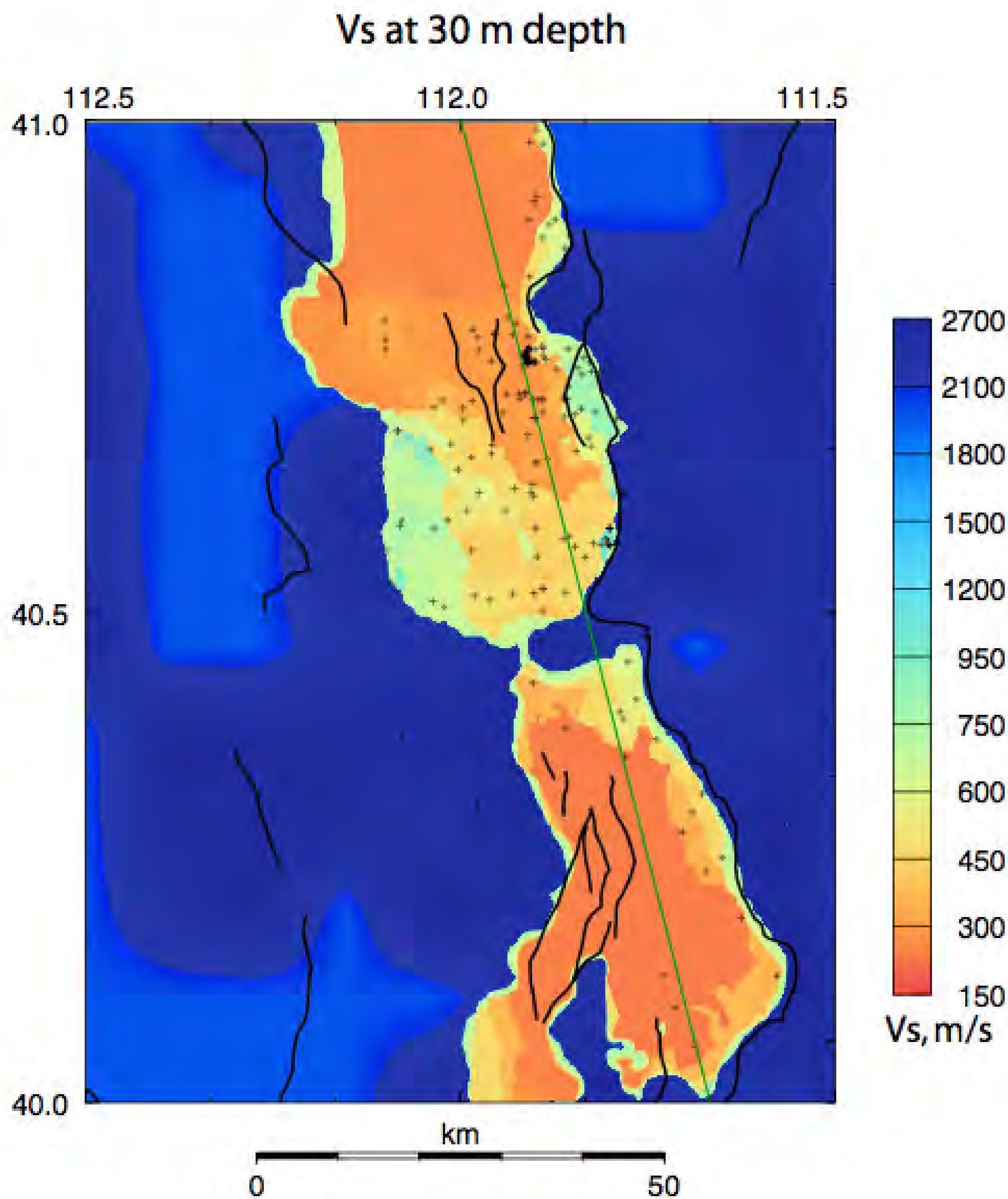
Castagna et al. (1985):

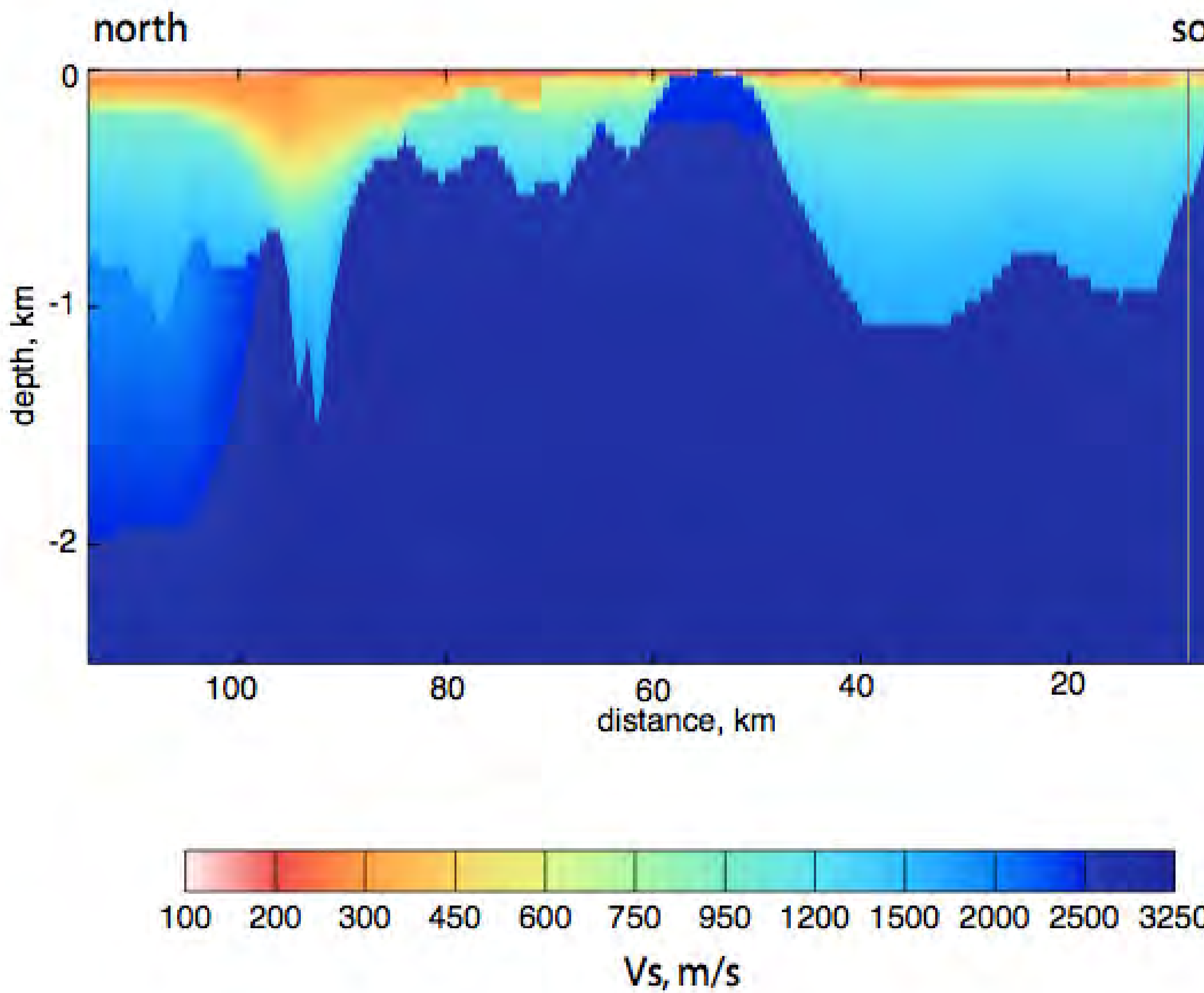
$$Vp\ (km/s) = 1.16Vs + 1.36$$

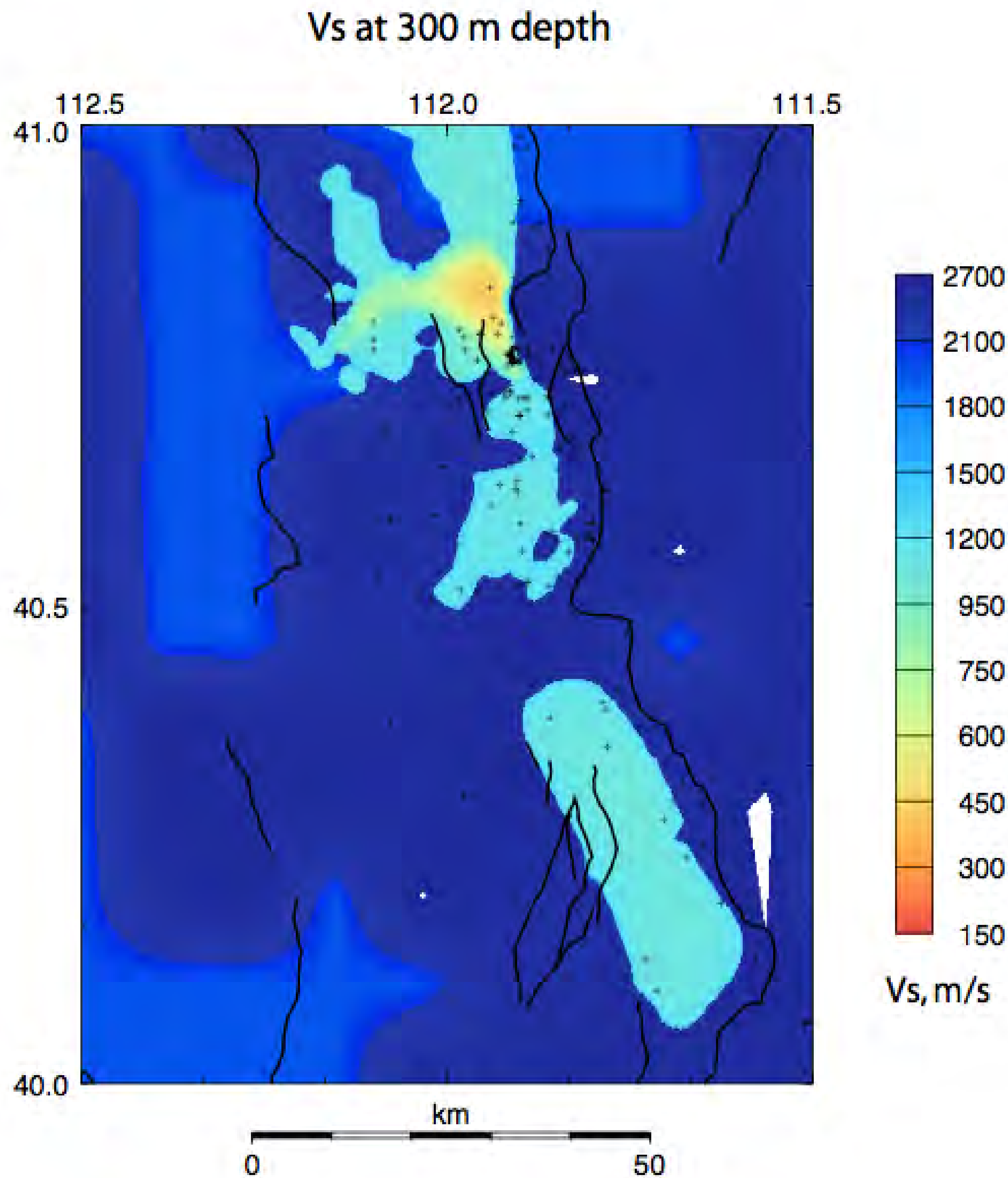
$$1.5 < Vp < 4.5\ km/s$$

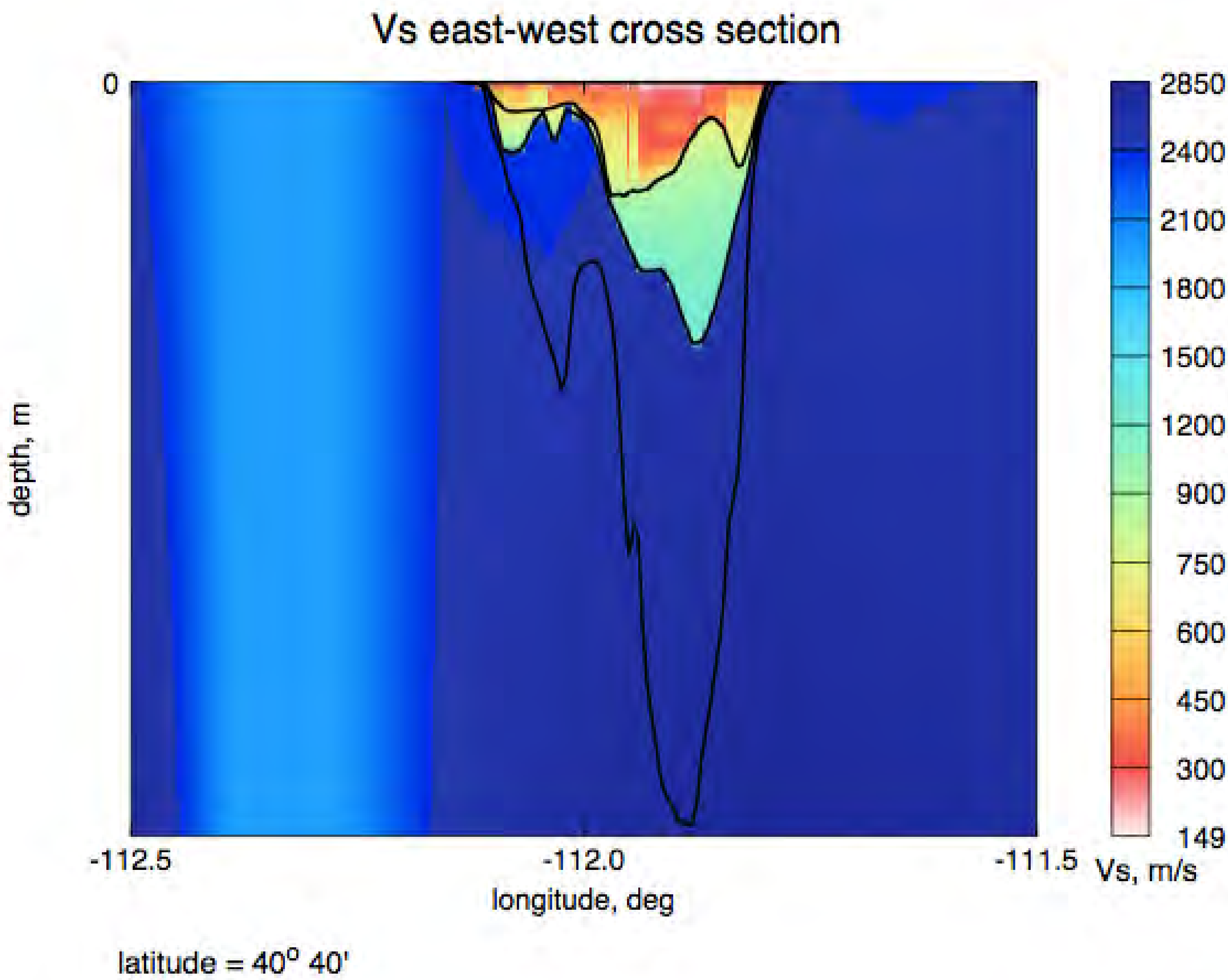
(in Brocher 2005)


Vs at 30 meter depth
112.0
40.5
40.5
112.0
km
0
20
2700
2100
1800
1500
1200
950
750
600
450
300
150
Vs m/s


Vs at 30 m depth
112.5
112.0
111.5
41.0
40.5
40.0
km
0
50
2700
2100
1800
1500
1200
950
750
600
450
300
150
Vs, m/s

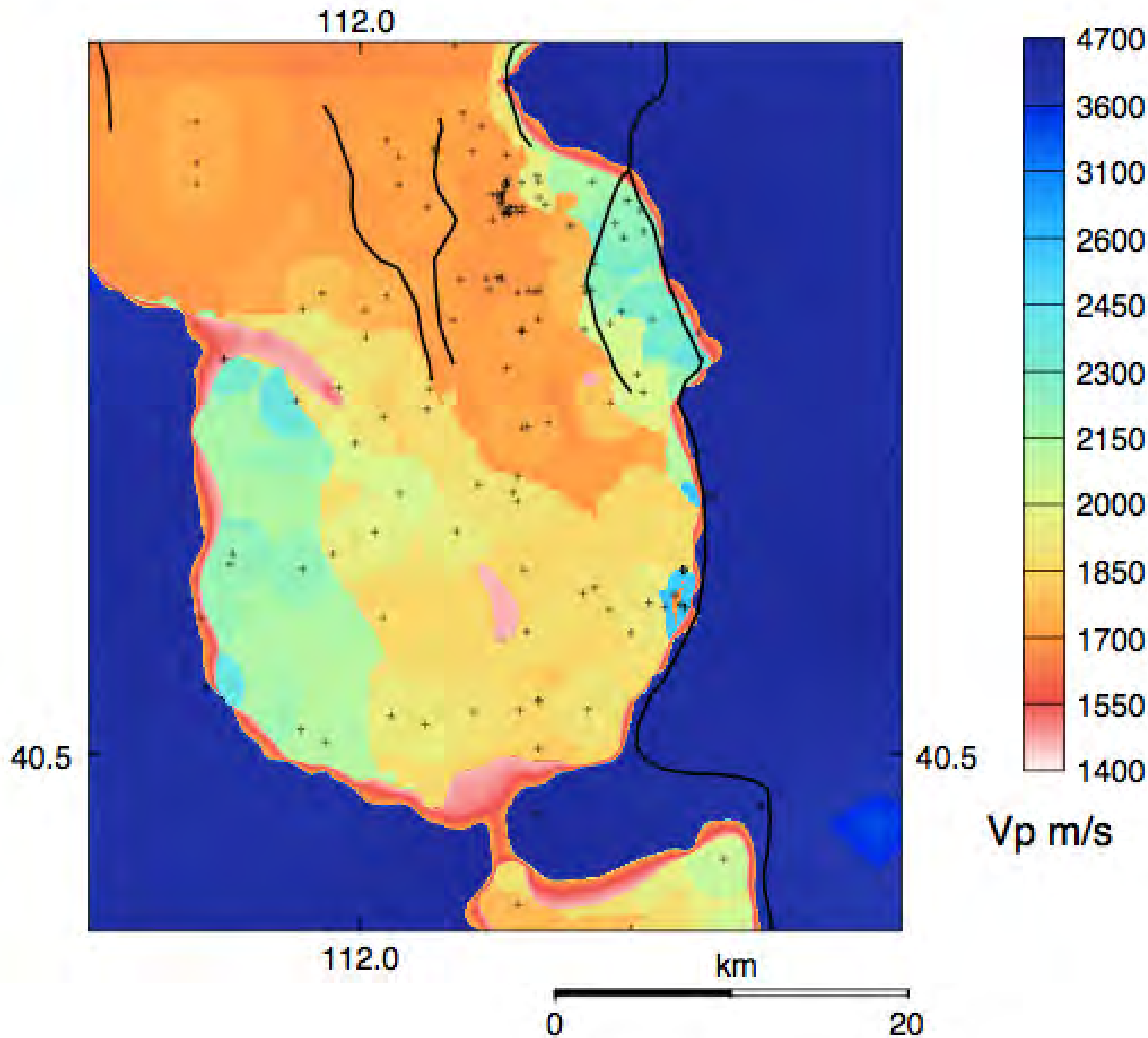

north
south
0
-1
-2
depth, km
100
80
60
40
20
0
distance, km
100
200
300
450
600
750
950
1200
1500
2000
2500
3250
Vs, m/s


Vs at 300 m depth
112.5
112.0
111.5
41.0
40.5
40.0
km
0
50
2700
2100
1800
1500
1200
950
750
600
450
300
150
Vs, m/s



Vs east-west cross section
0
depth, m
-112.5
-112.0
-111.5
longitude, deg
2850
2400
2100
1800
1500
1200
900
750
600
450
300
149
Vs, m/s
latitude = 40° 40'

Vp at 30 meter depth



Rule Based Seismic Velocity Model

-Compile geologic and geophysical information.

examples: stratigraphy
oil well sonic logs
tomography results

-Define reference surfaces (or other objects).

examples: lithologic contacts (isoage surface)
isovelocity surface
tomography model nodes

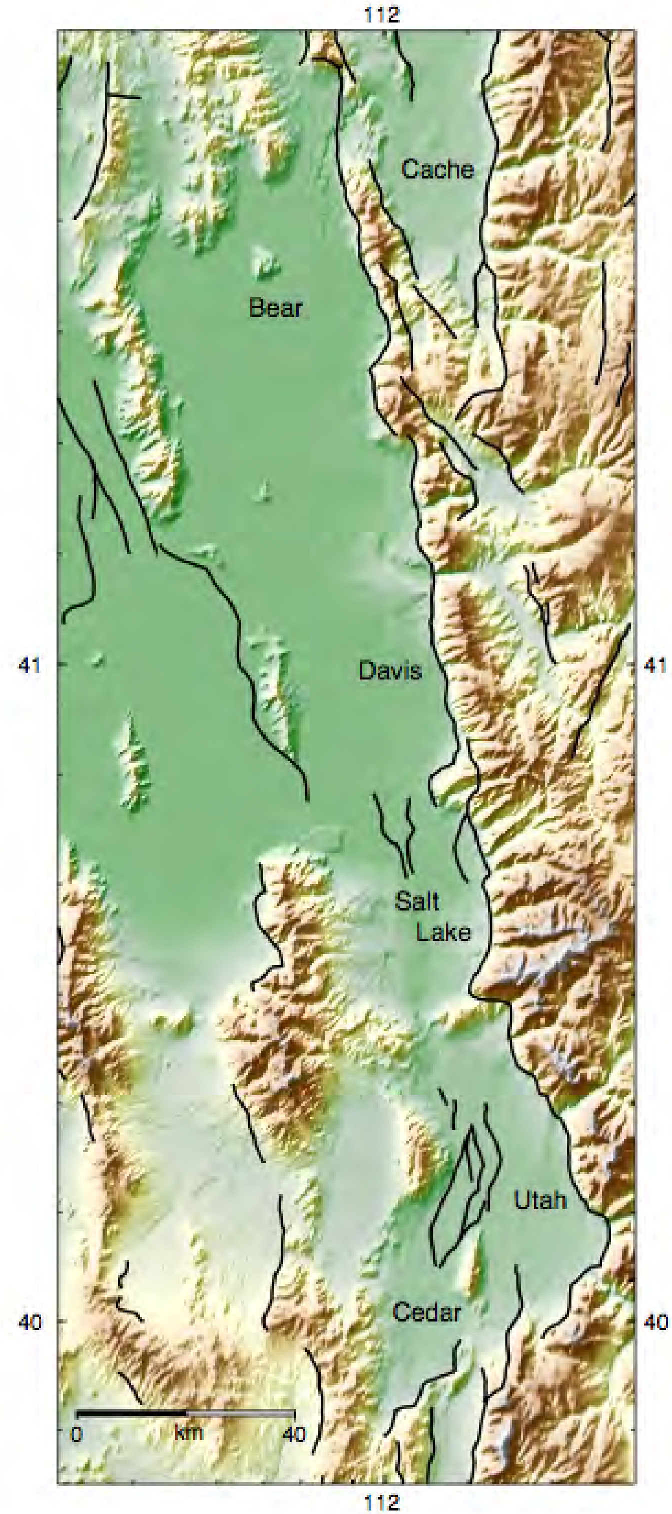
-Compare point of interest to objects and interpolate properties.

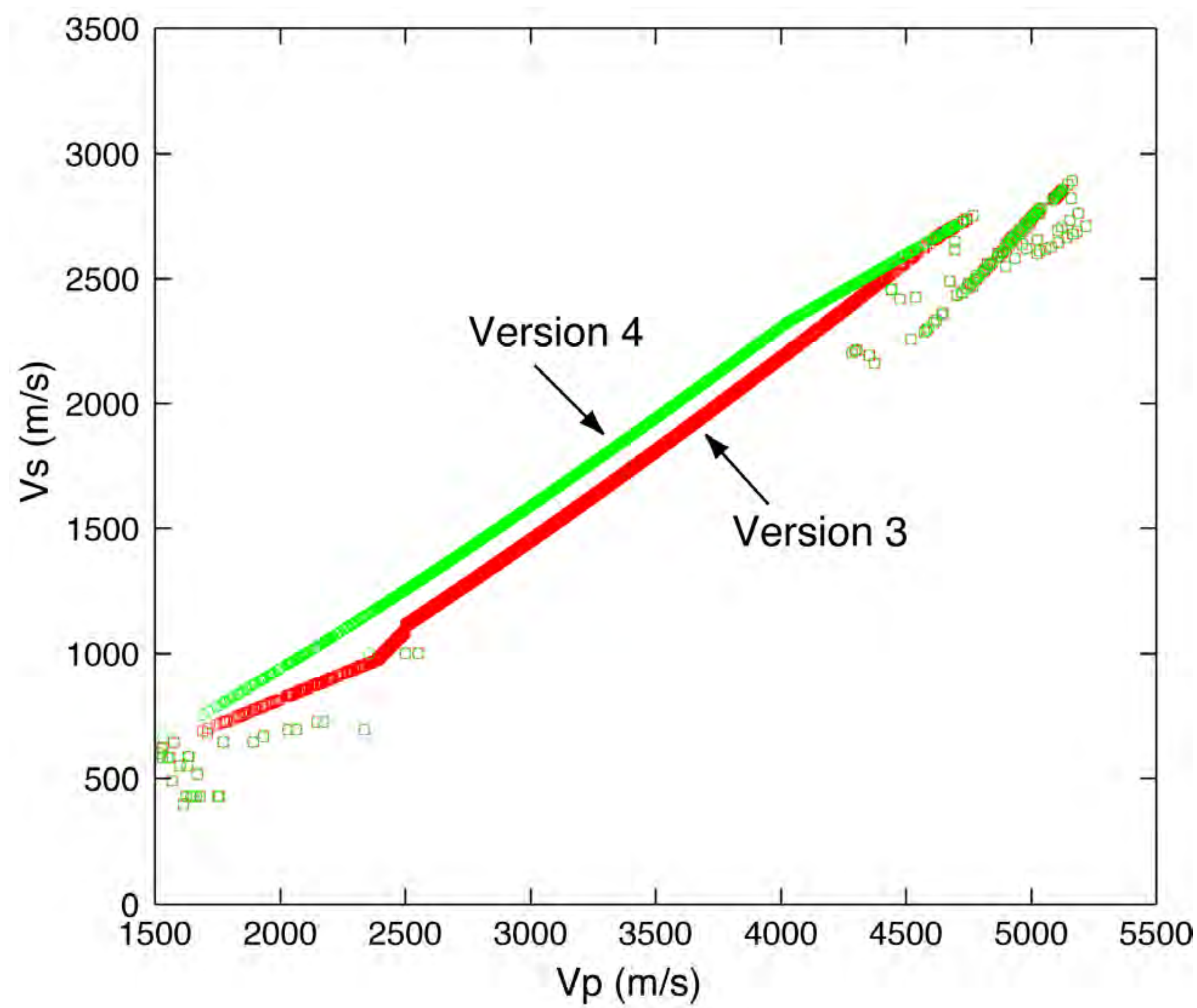
examples: interpolation of age between surfaces
interpolation of velocity between tomography nodes

-Apply rule to get velocity (or other property) at point of interest.

examples: linear gradient between isovelocity surfaces
Faust’s rule (velocity-age-depth relation)

$$Vp=k(da)^{1/6}$$


112
Cache
Bear
Davis
Salt
Lake
Utah
Cedar
41
41
40
40
0
km
40
112

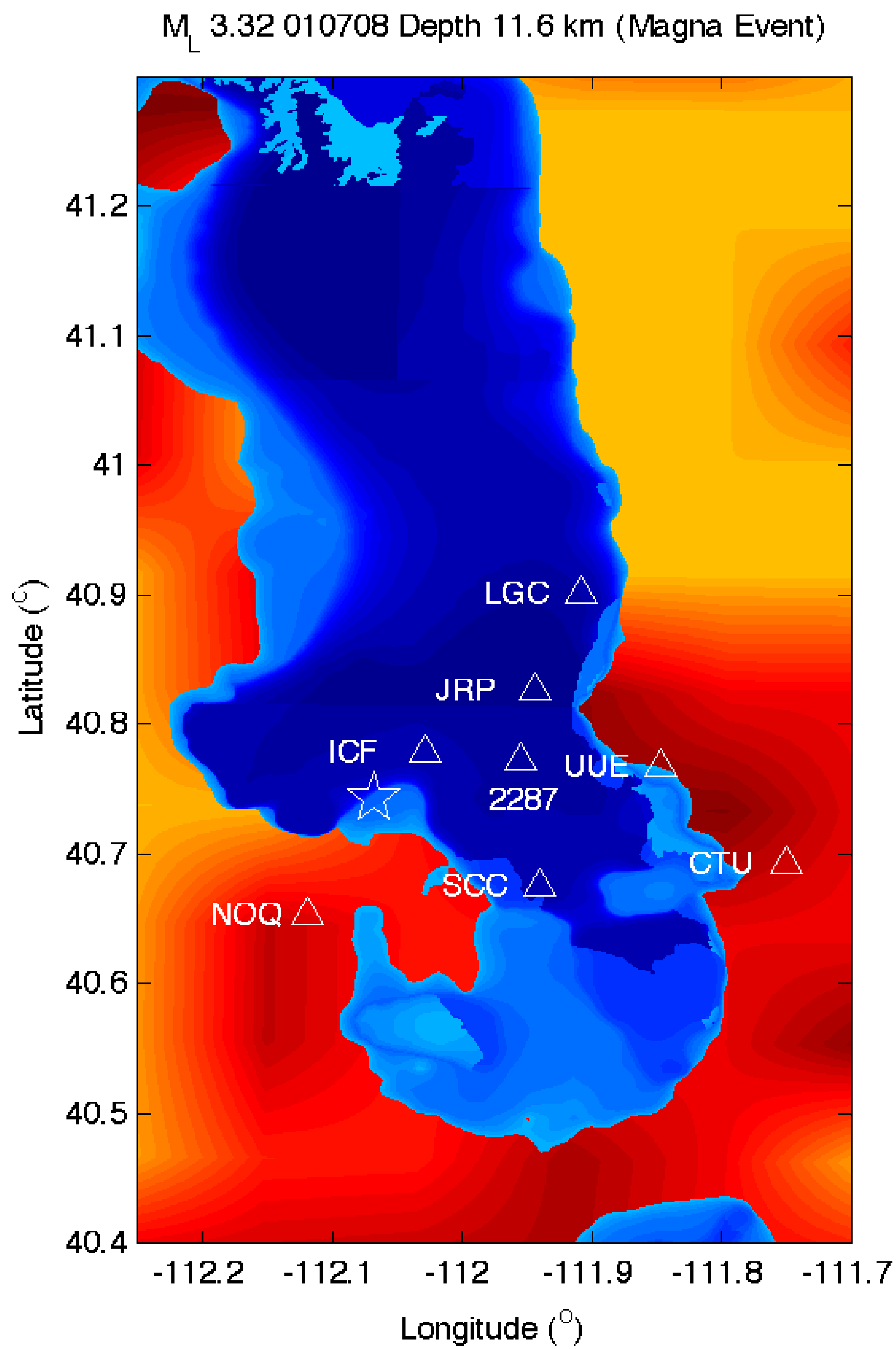

Version 4
Version 3
Vs (m/s)
Vp (m/s)
3500
3000
2500
2000
1500
1000
500
0
1500
2000
2500
3000
3500
4000
4500
5000
5500

Validation of the Wasatch Front Community Velocity Model - Preliminary Waveform Fits

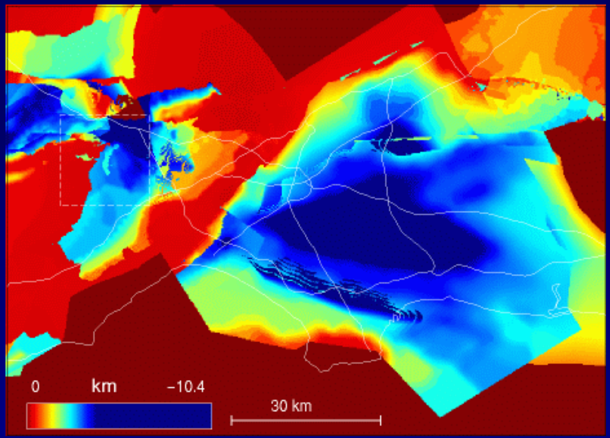
(or The Good the Bad, and the Ugly)

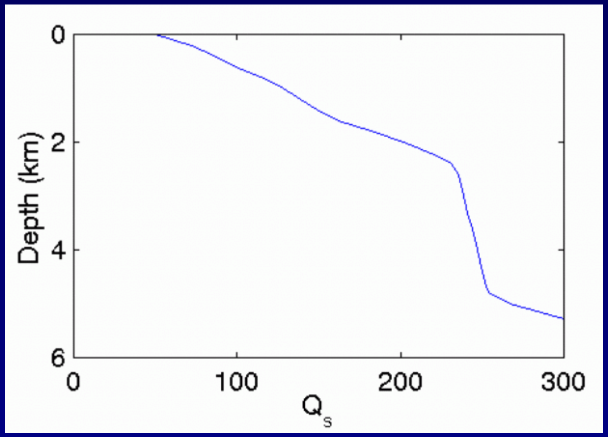
Kim Olsen
San Diego State University

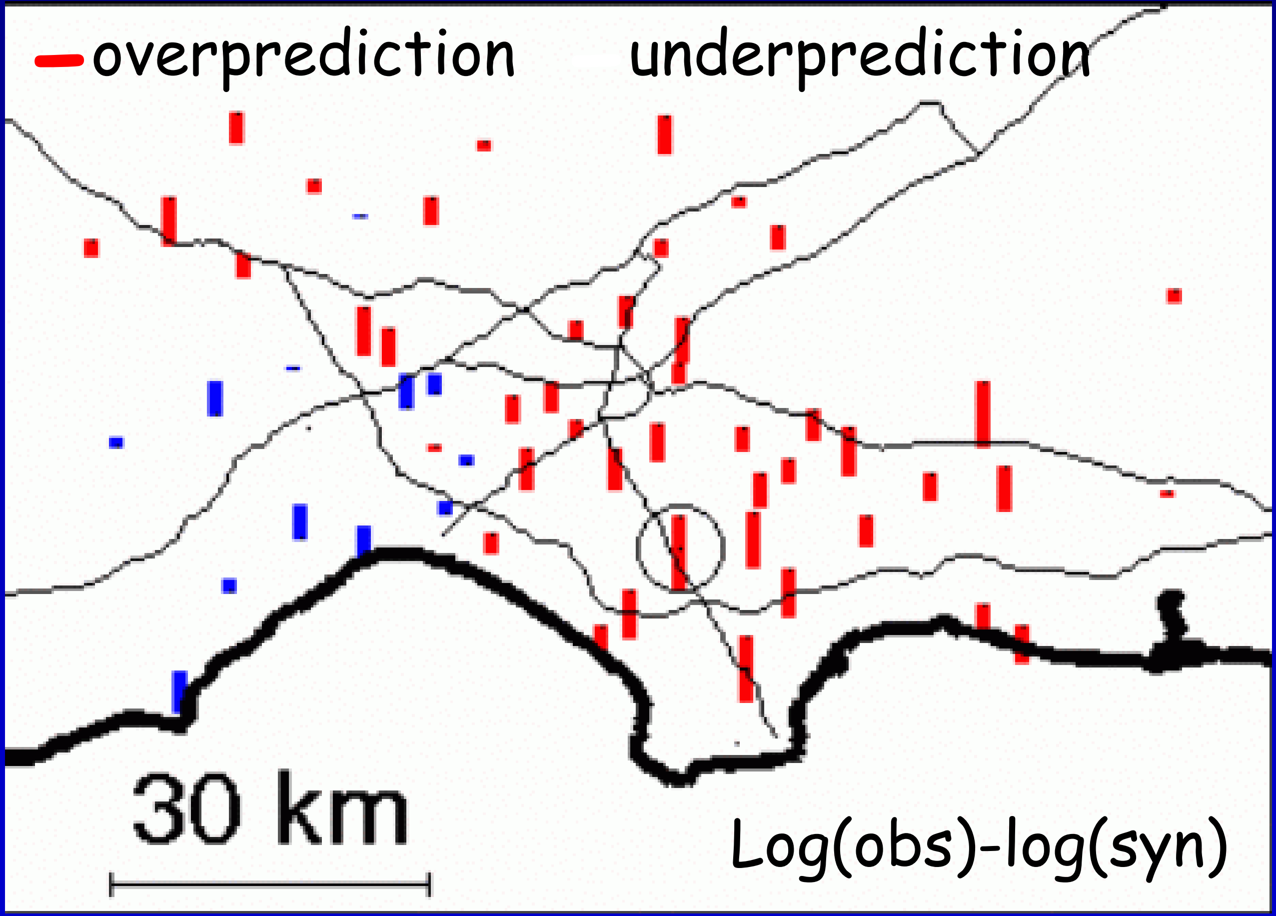
UGS, Feb 17 2007

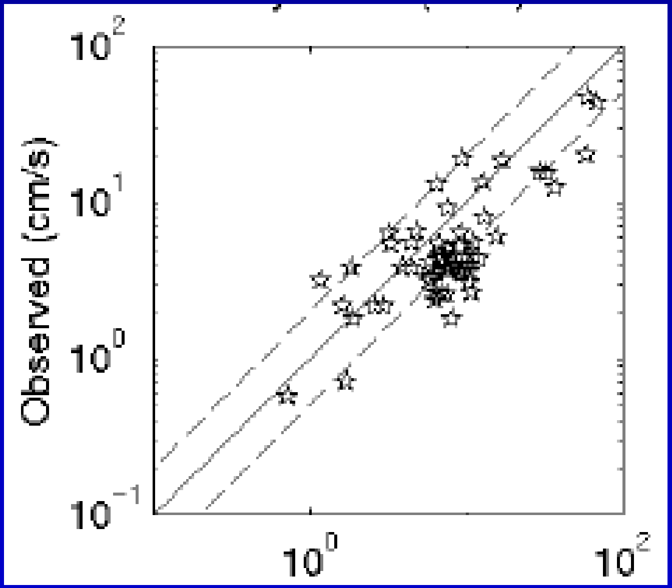

M_L 3.32 010708 Depth 11.6 km (Magna Event)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
Latitude (°)
-112.2
-112.1
-112
-111.9
-111.8
-111.7
Longitude (°)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ

$Q_s=0.1V_s$
$(V_s^{min}=0.5km/s)$



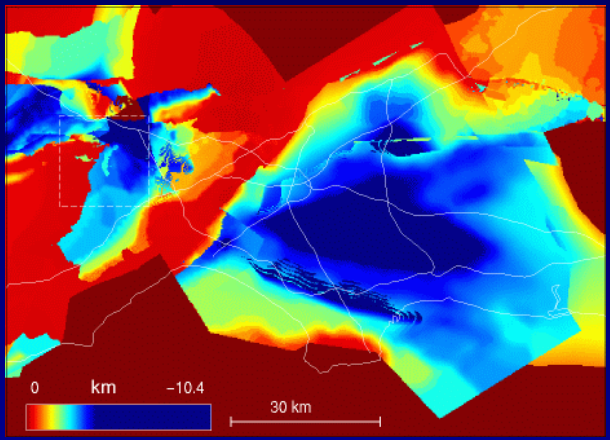


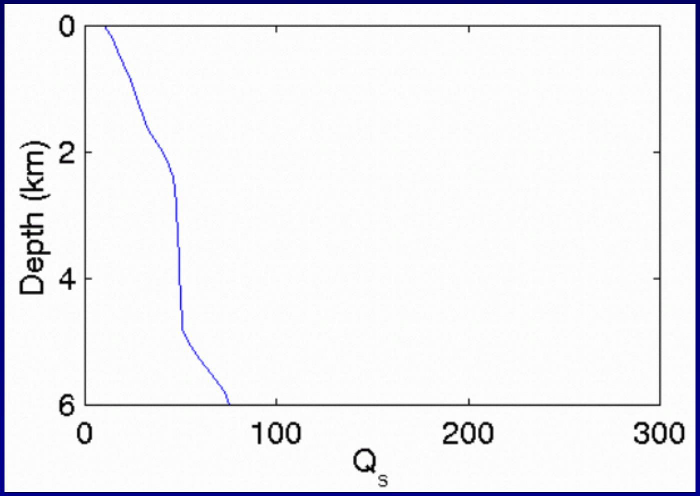


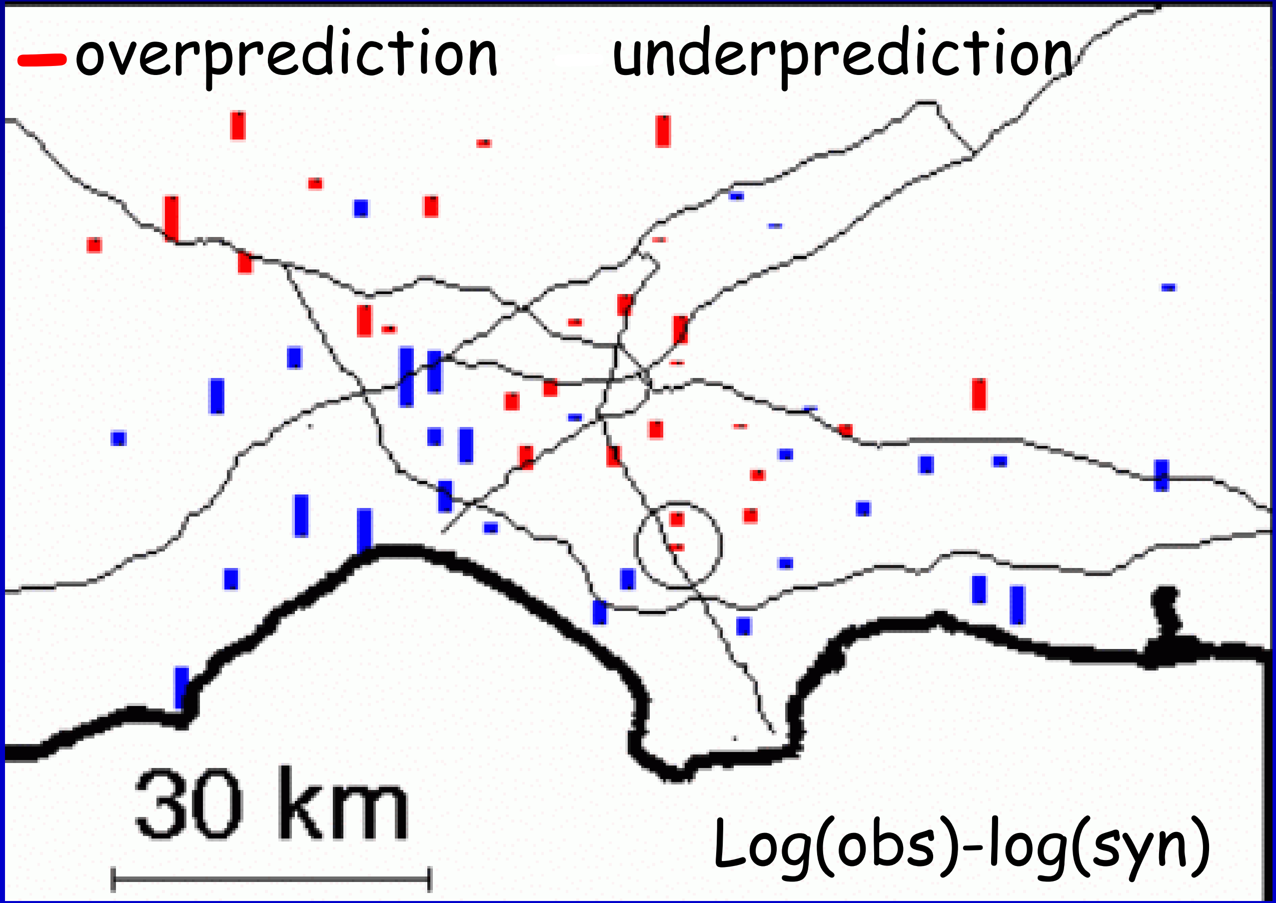


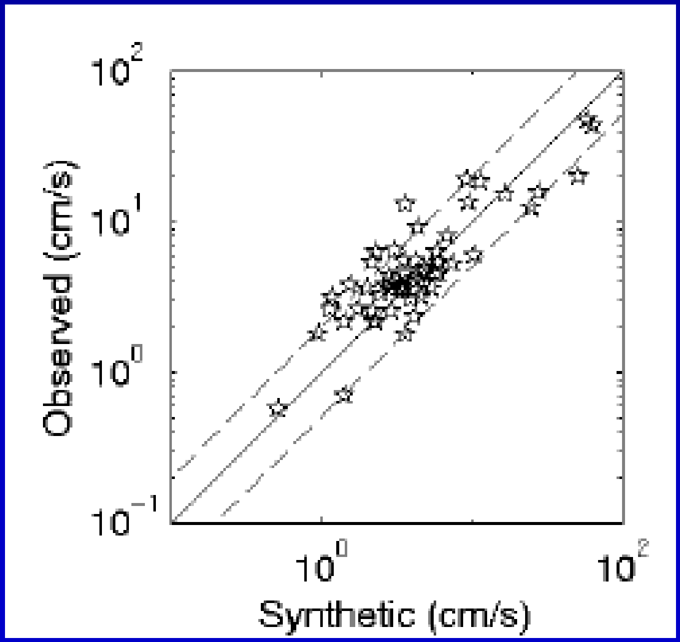
$Q_s = 0.02 V_s$

$(V_s^{min} = 0.5 km/s)$

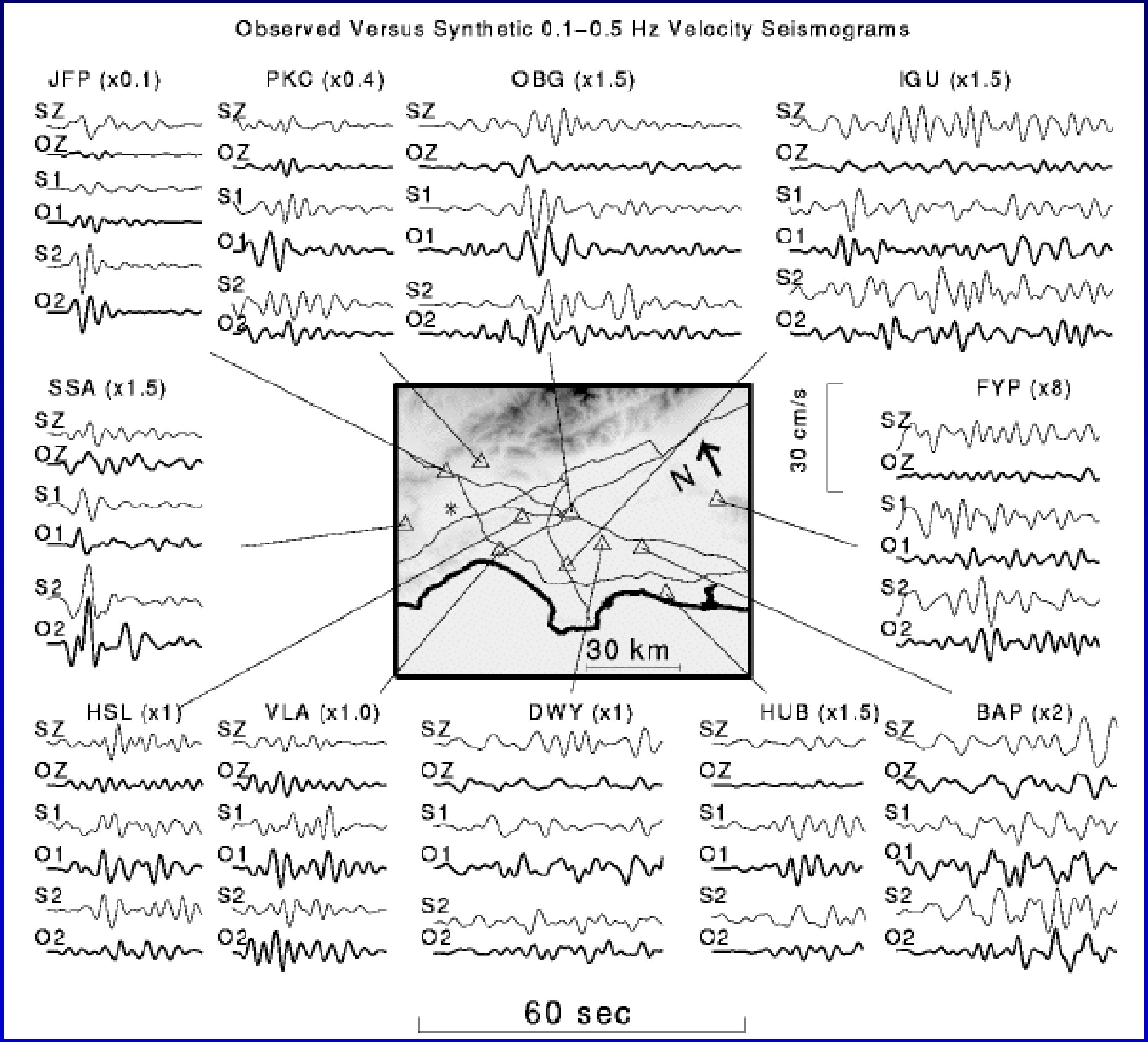


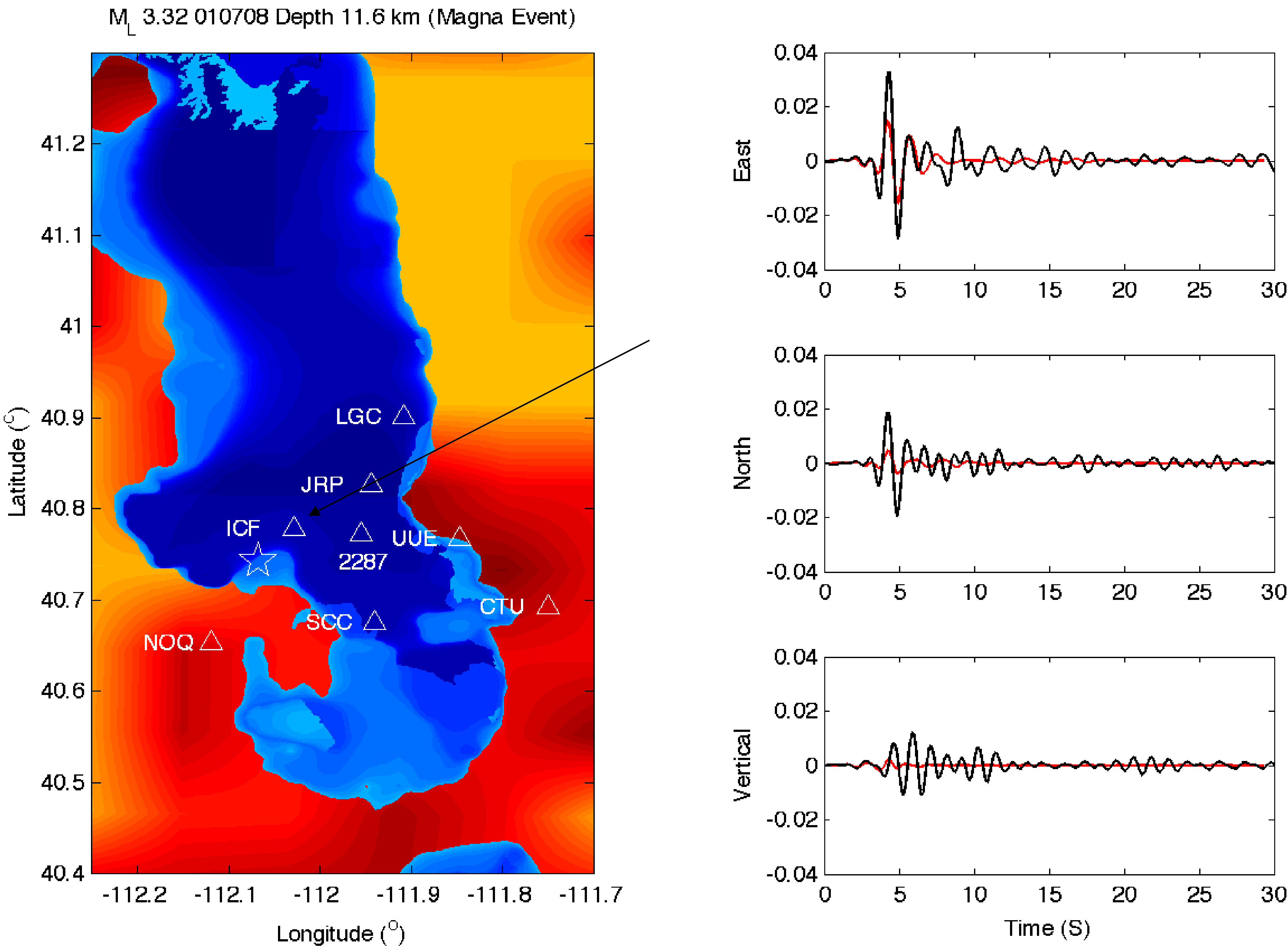


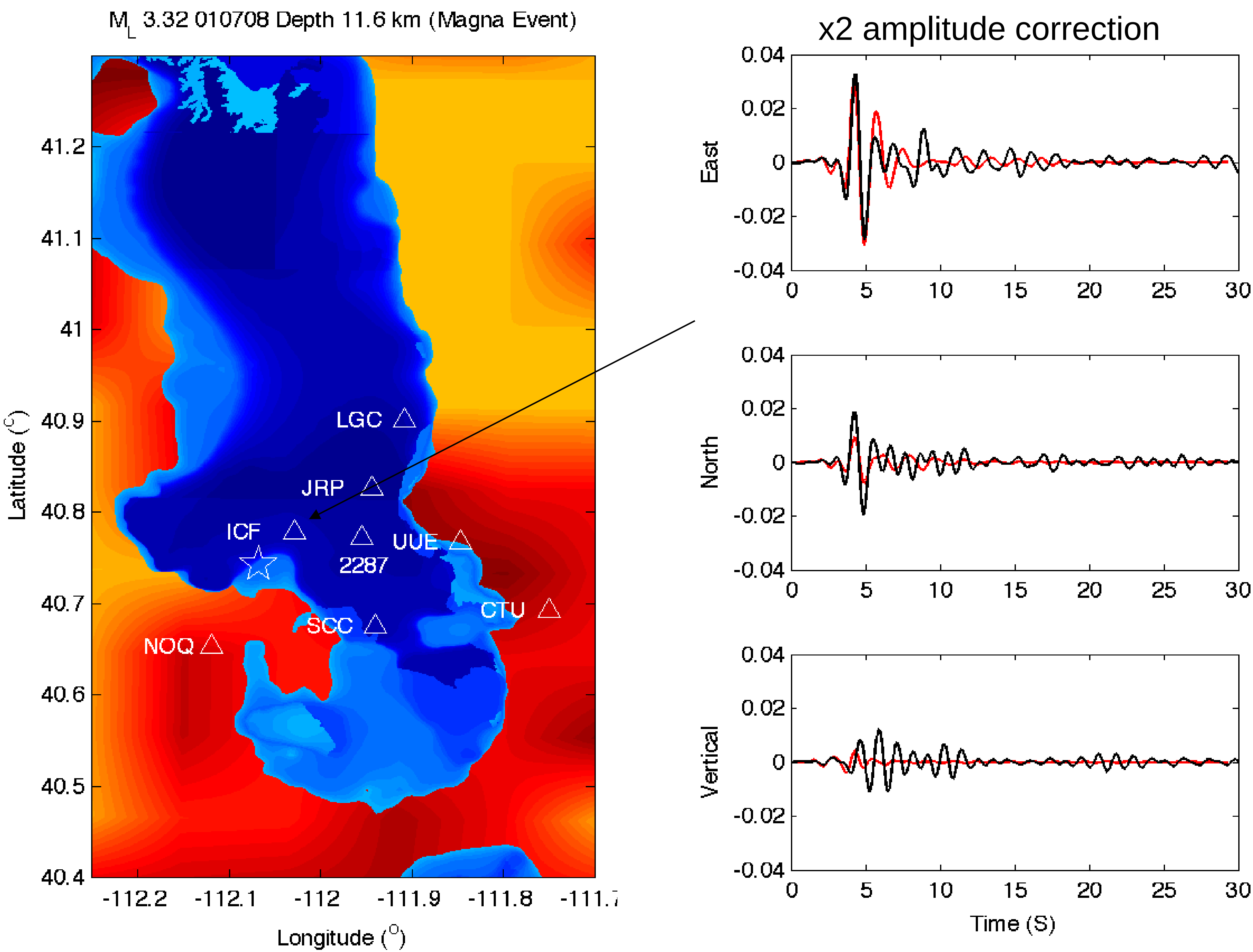




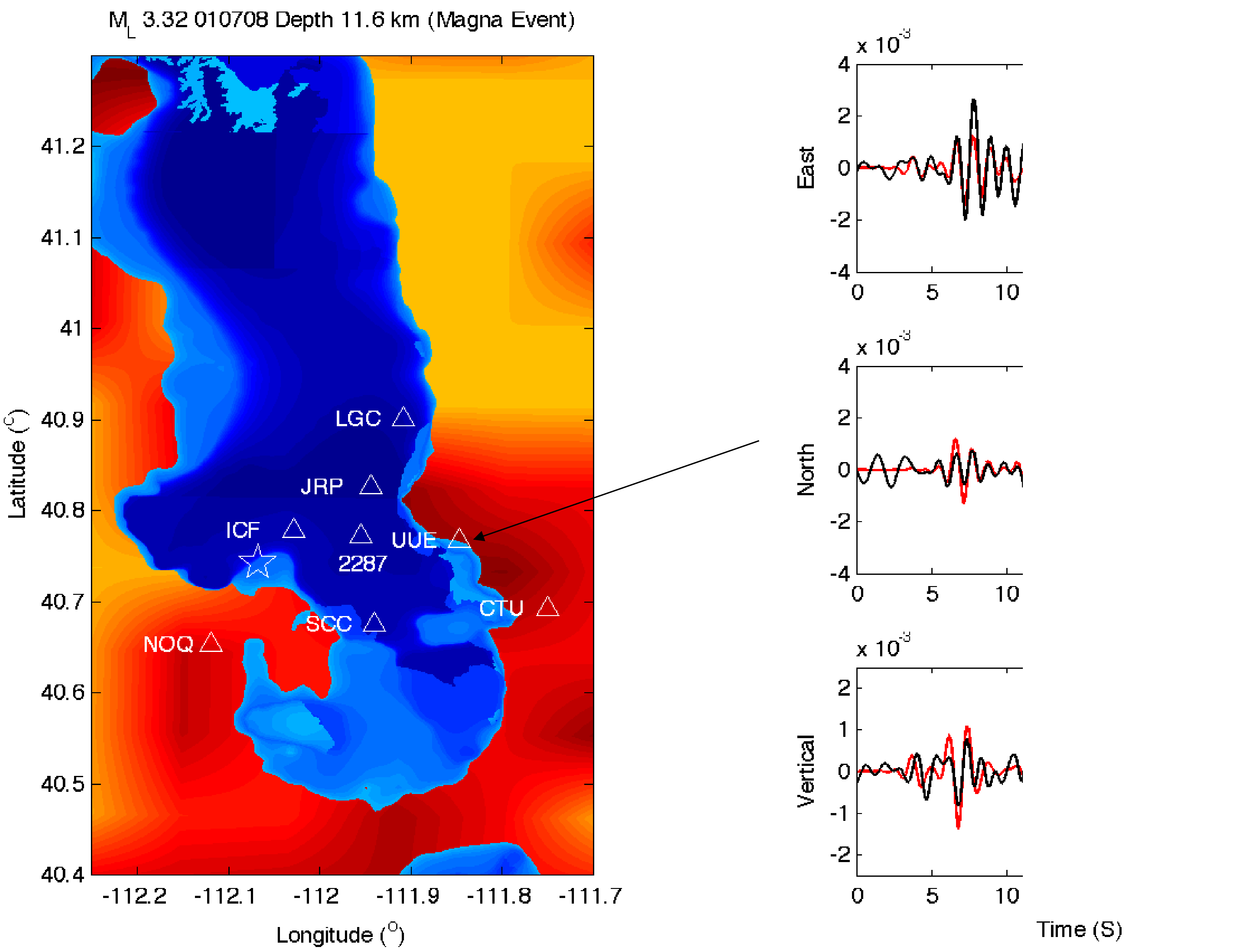
Validation: 1994 Northridge



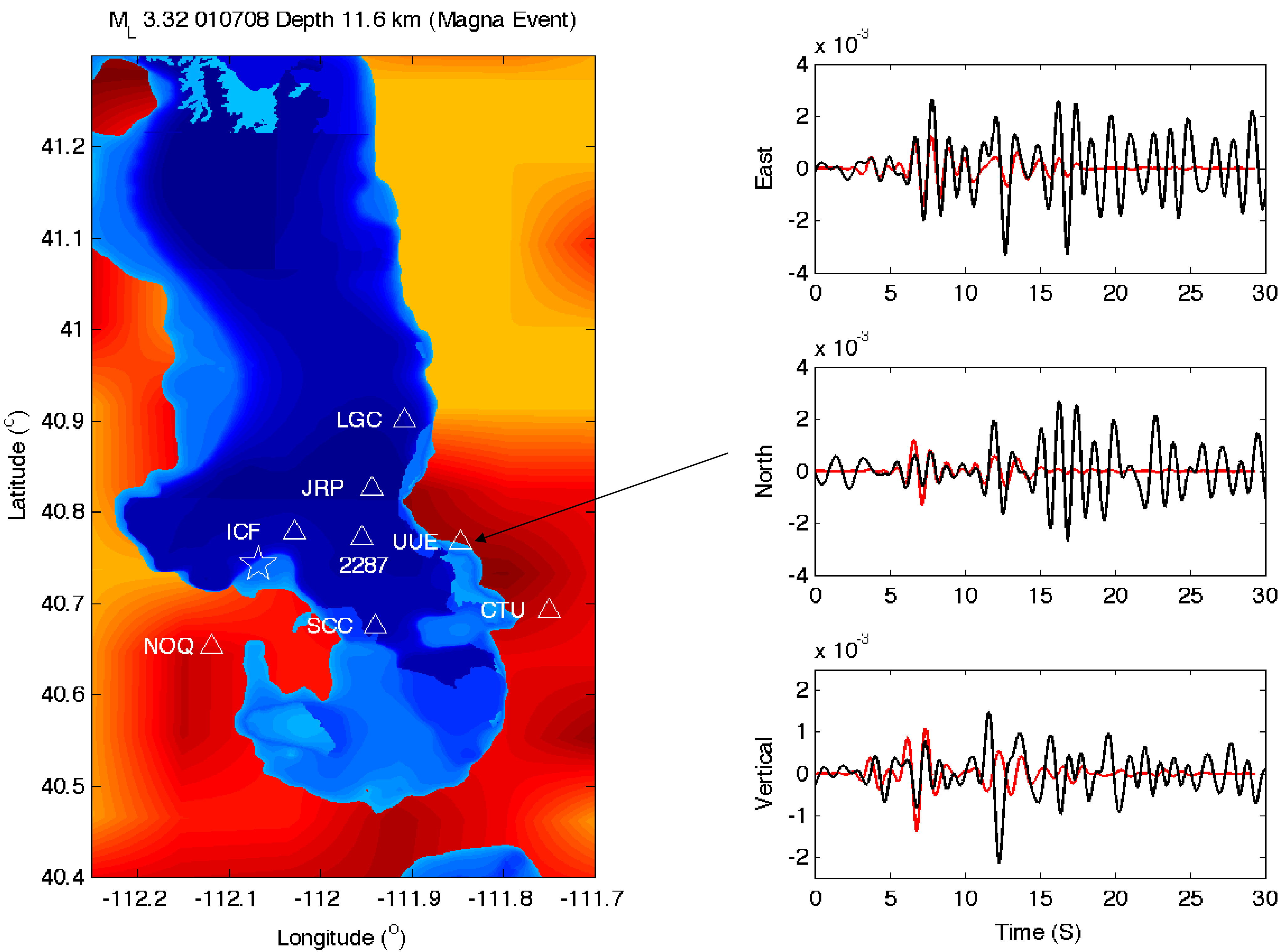

M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
East
North
Vertical
Time (S)
0.04
0.02
0
-0.02
-0.04
0
5
10
15
20
25
30



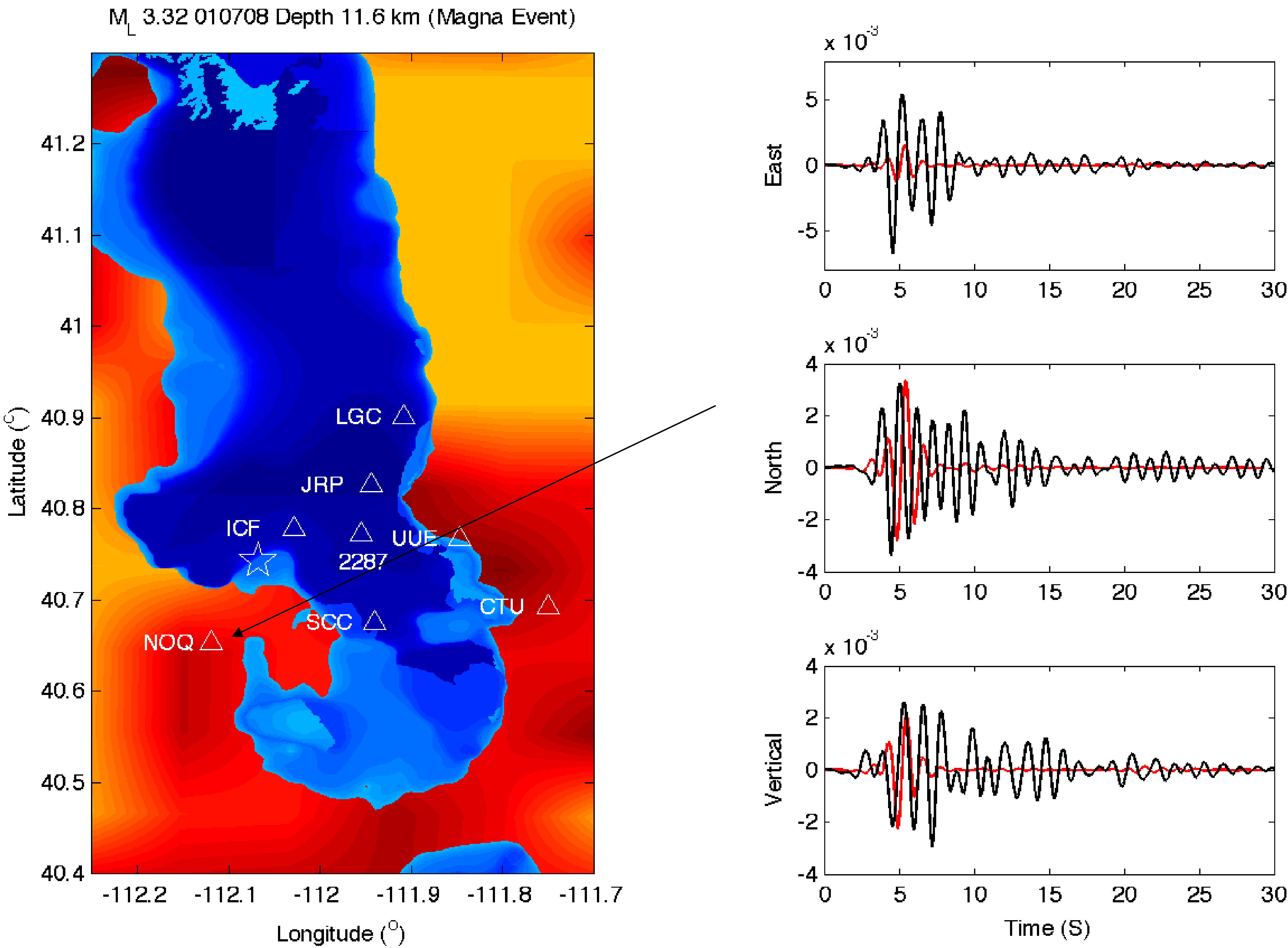
M_L 3.32 010708 Depth 11.6 km (Magna Event)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
x2 amplitude correction
East
North
Vertical
0.04
0.02
0
-0.02
-0.04
0
5
10
15
20
25
30
Time (S)



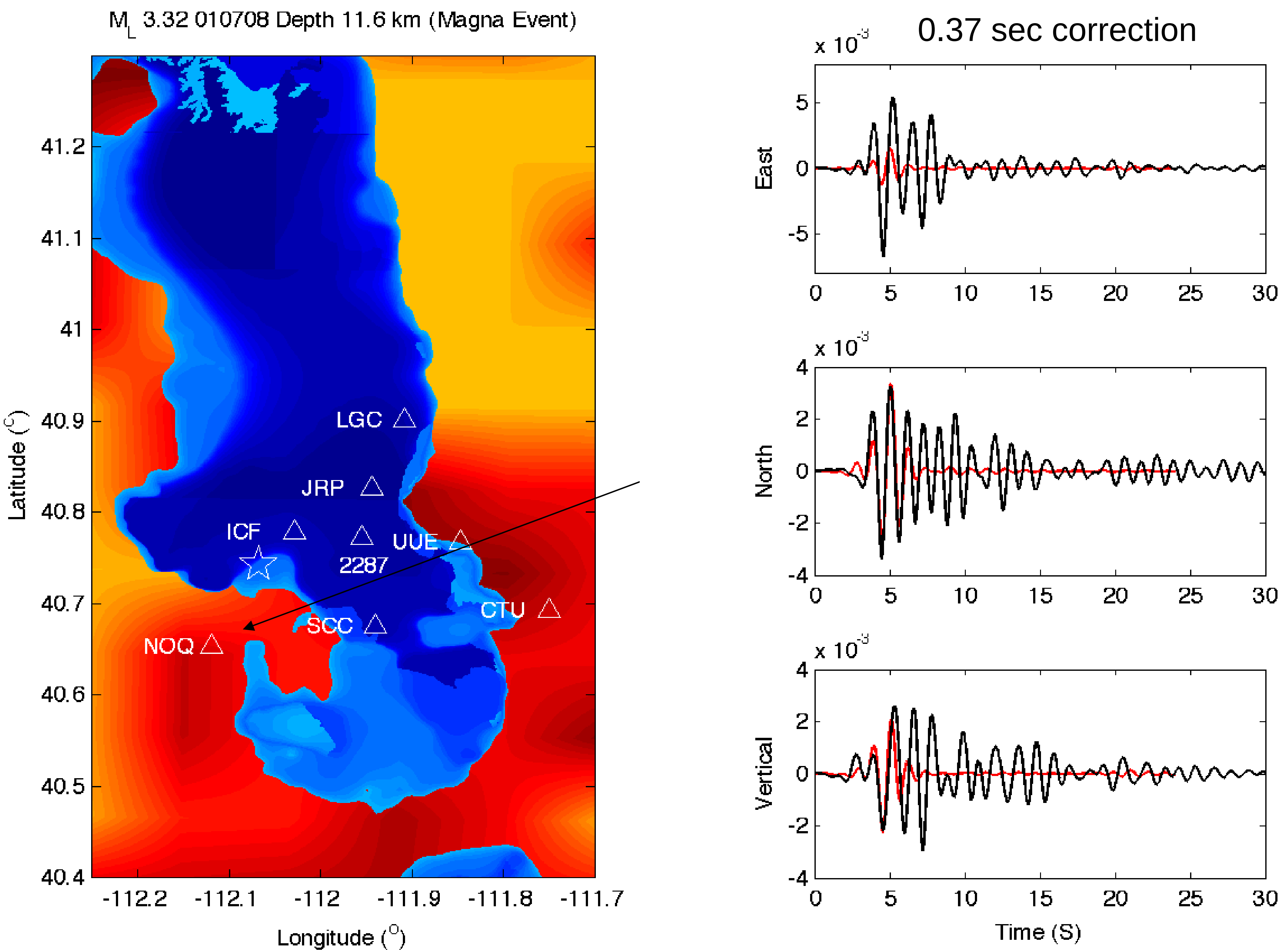
M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
x 10^{-3}
East
North
Vertical
Time (S)



M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
x 10^-3
East
North
Vertical
Time (S)

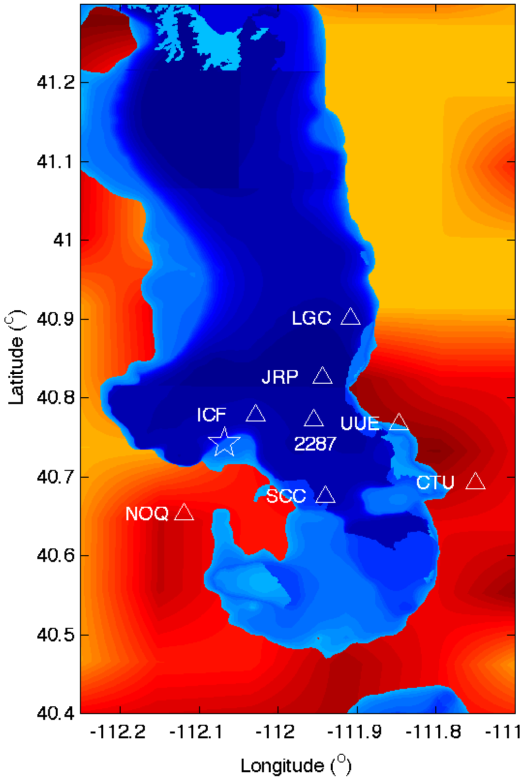


M$_L$ 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
x 10^{-3}
East
North
Vertical
Time (S)
0
5
10
15
20
25
30
-5
4
2
-2
-4

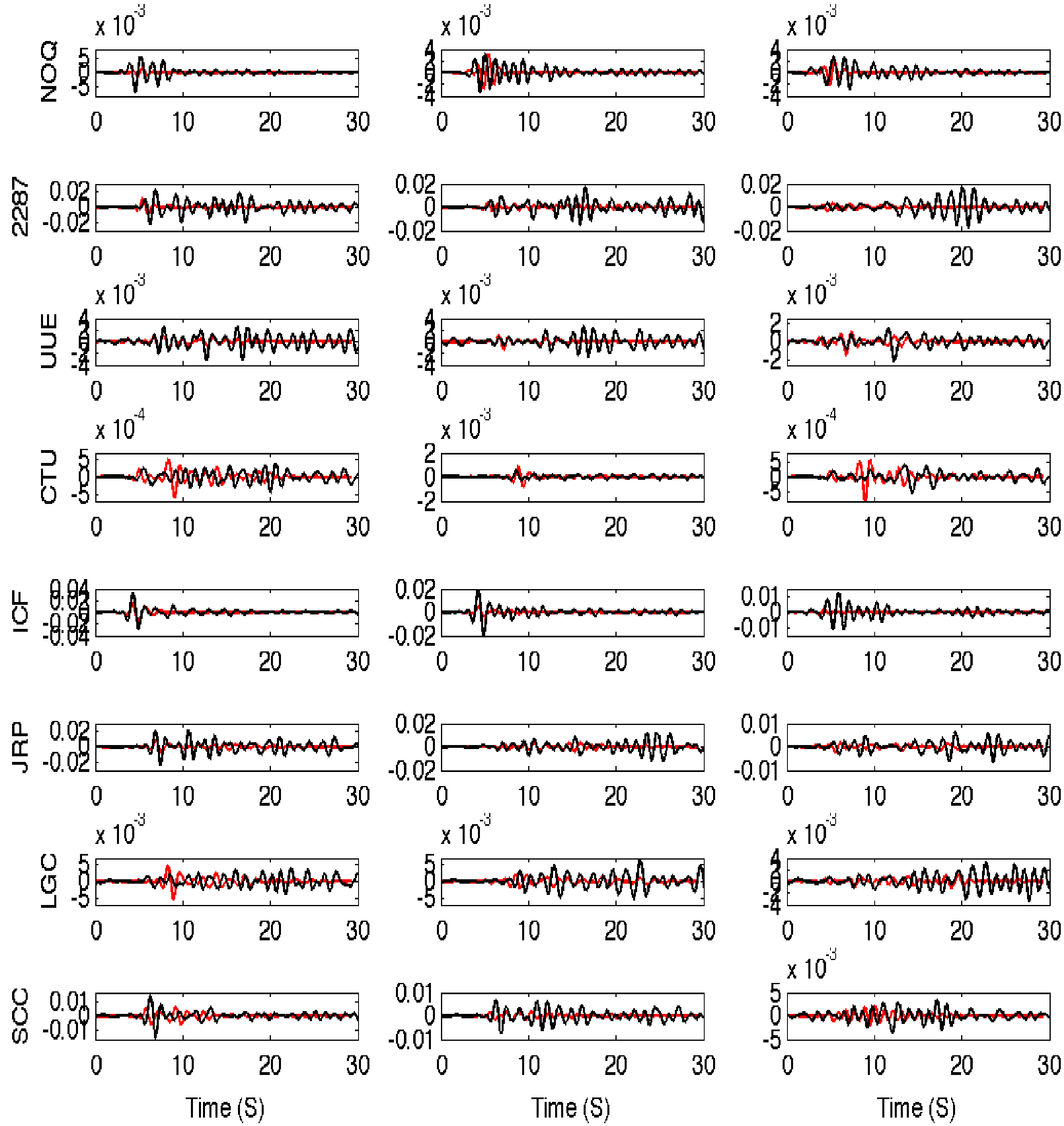


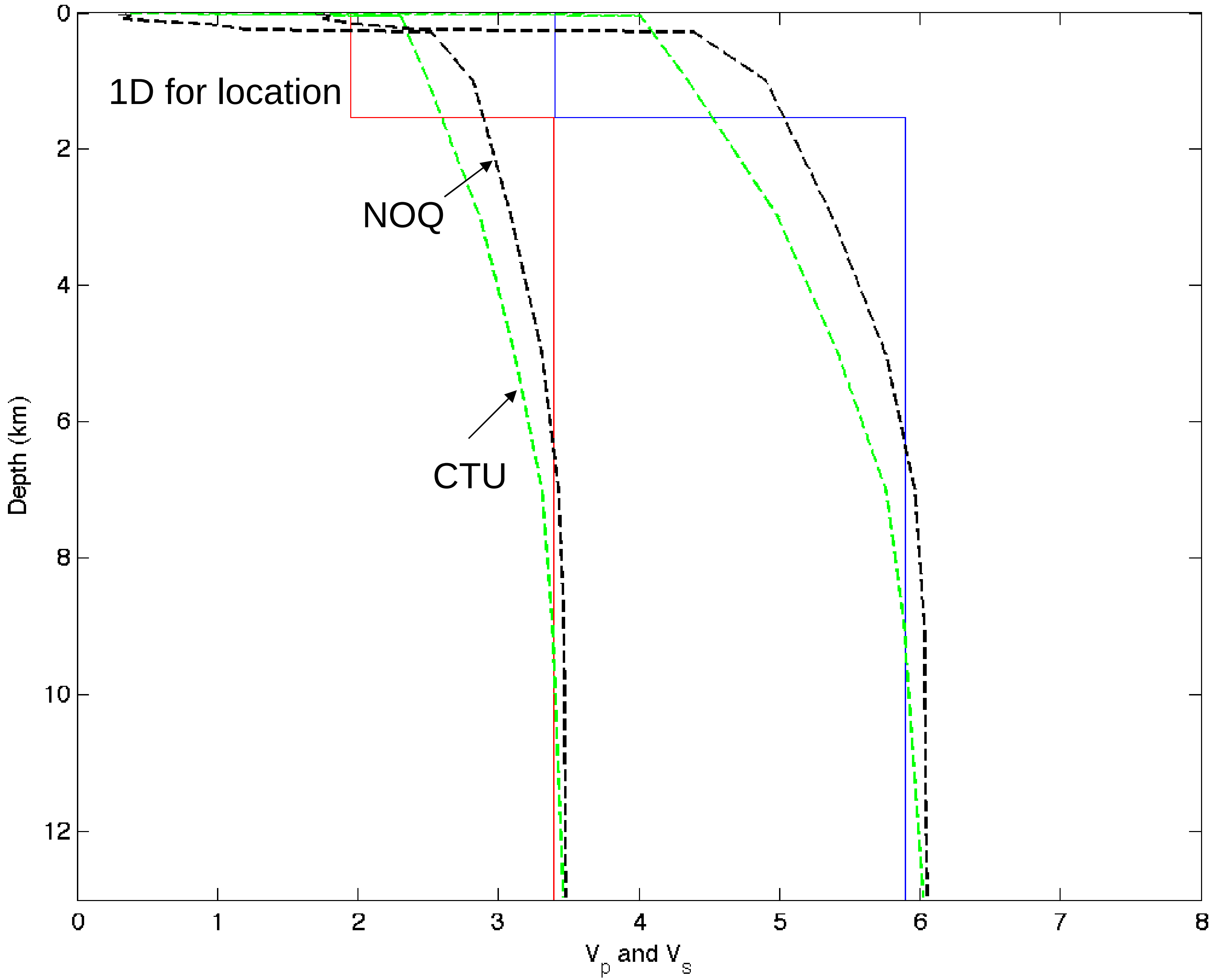
M L 3.32 010708 Depth 11.6 km (Magna Event)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
0.37 sec correction
x 10^-3
East
North
Vertical
Time (S)

M$_L$ 3.32 010708 Depth 11.6 km (Magna Event)

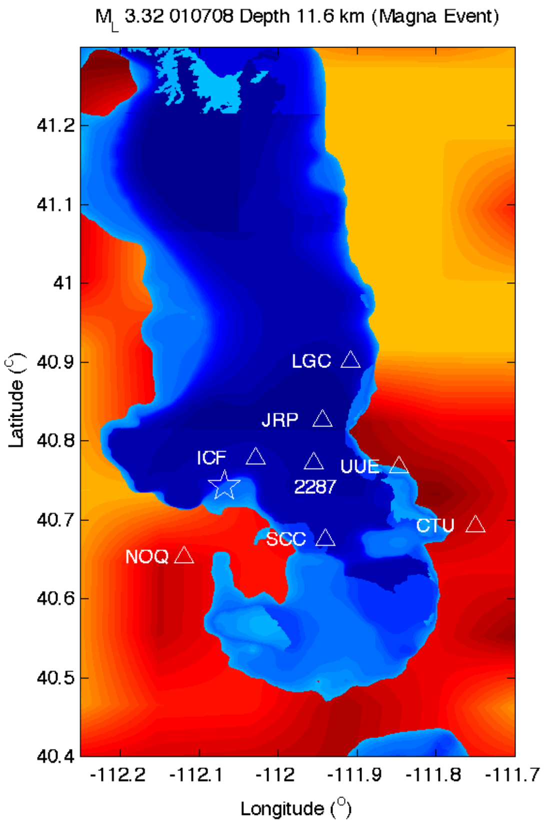


Qs=0.02*Vs

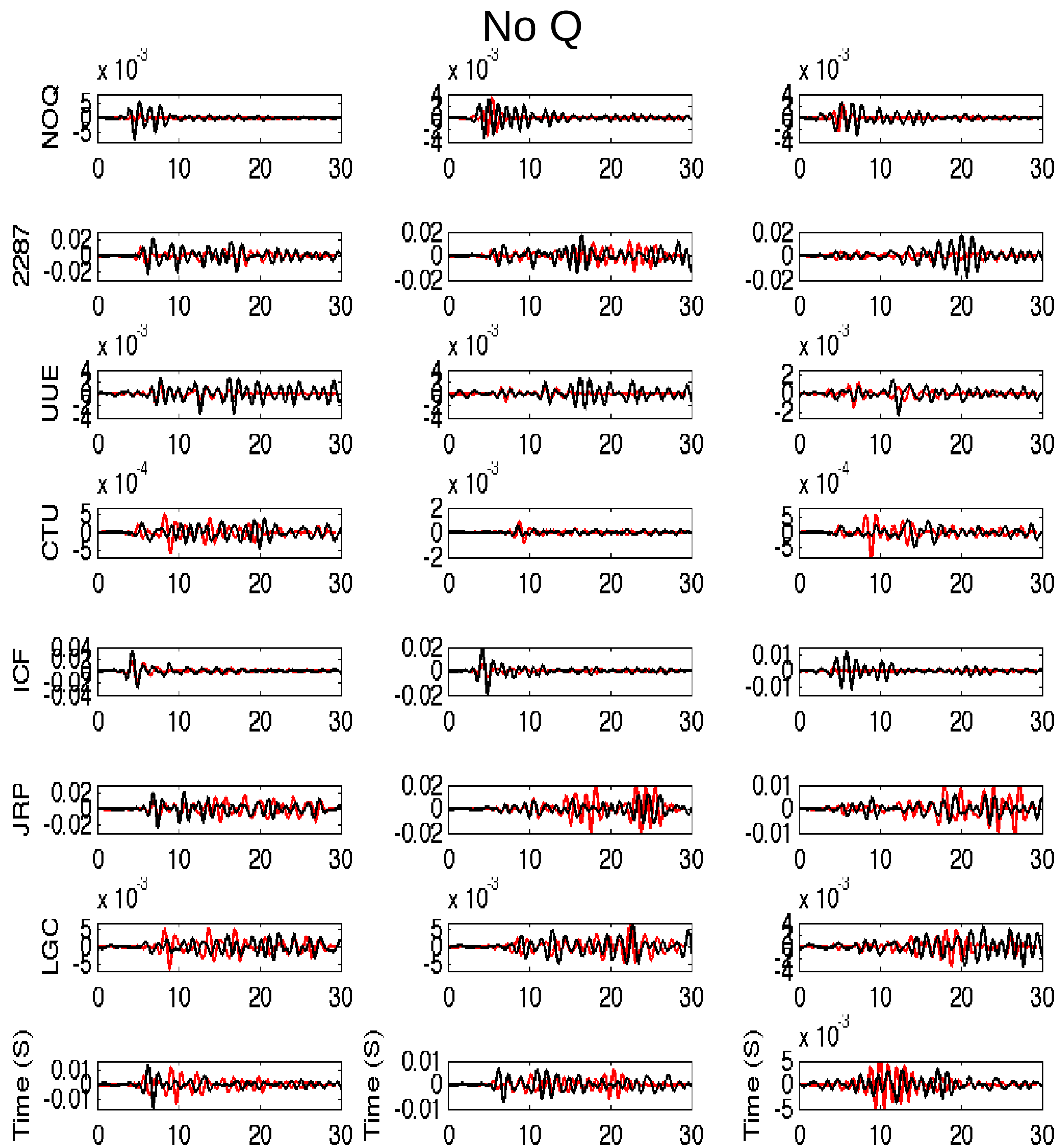




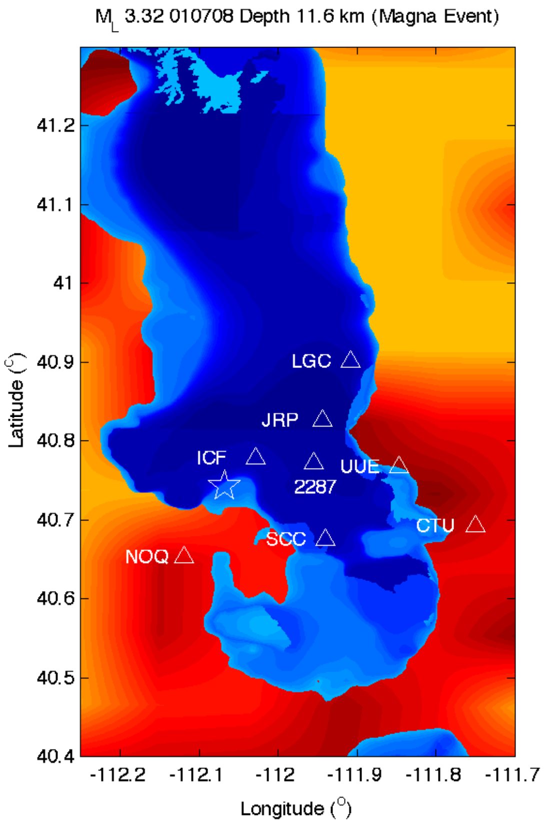
1D for location
NOQ
CTU
Depth (km)
0
2
4
6
8
10
12
0
1
2
3
4
5
6
7
8
V_p and V_s



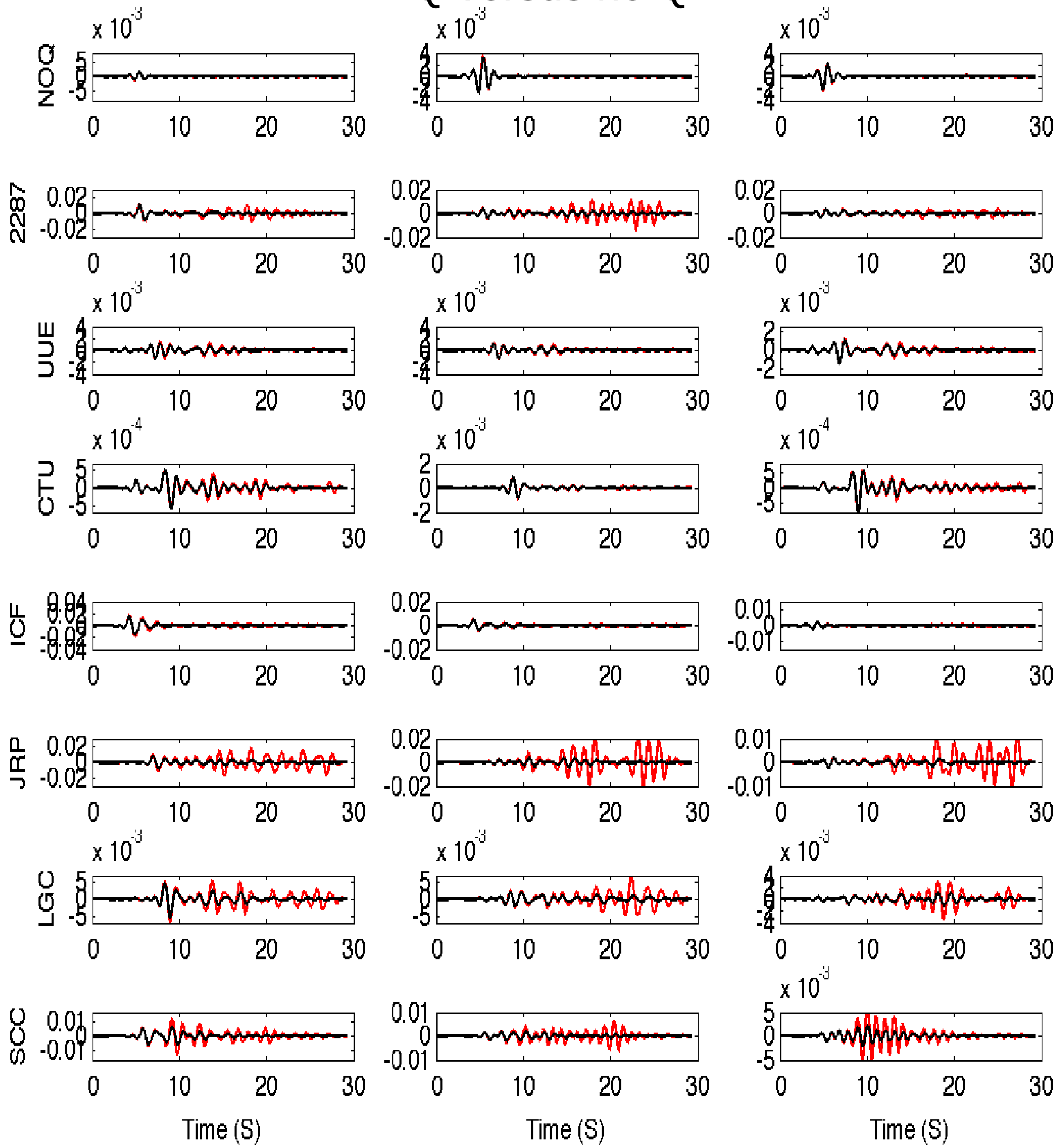
M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ

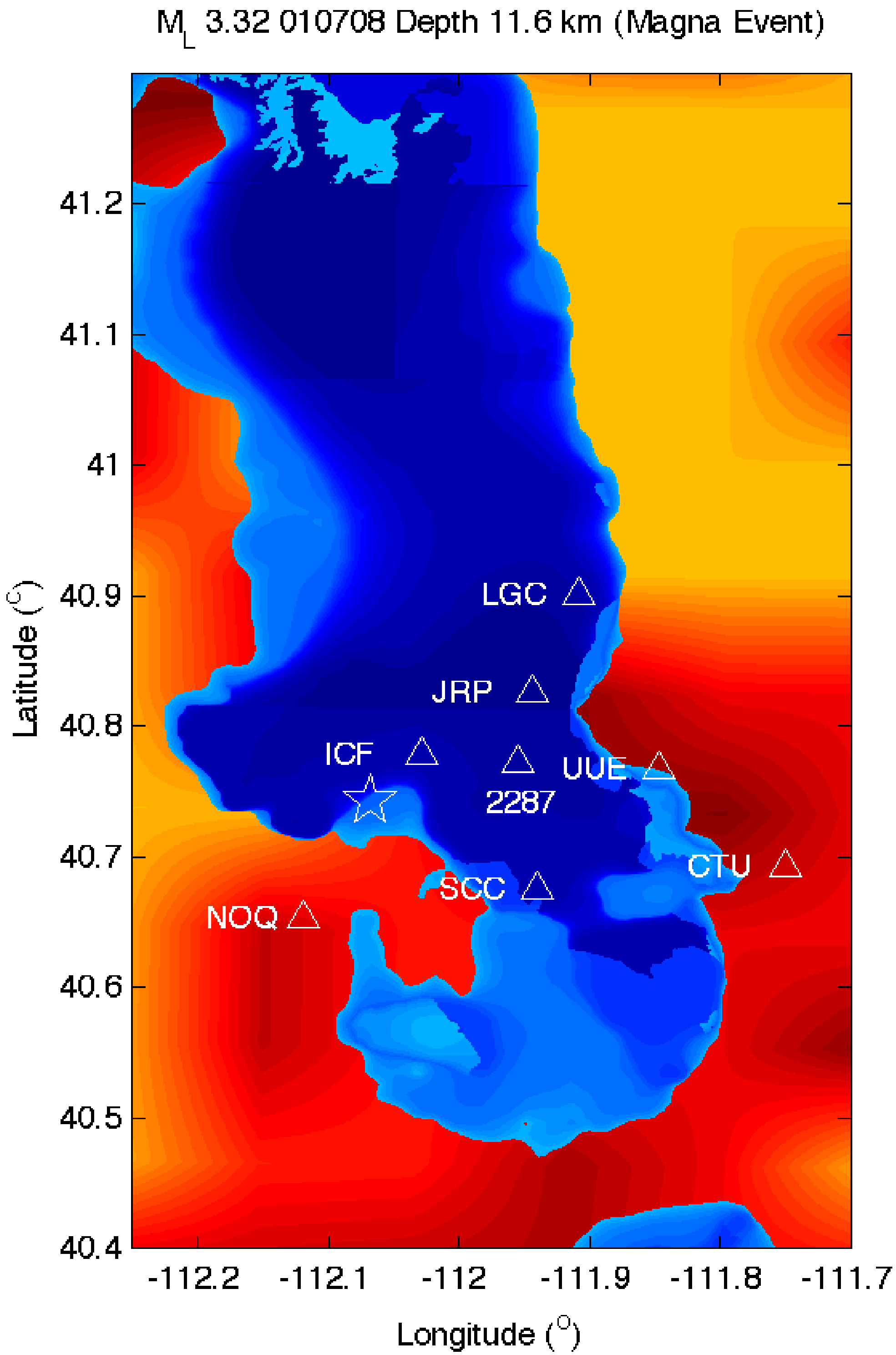


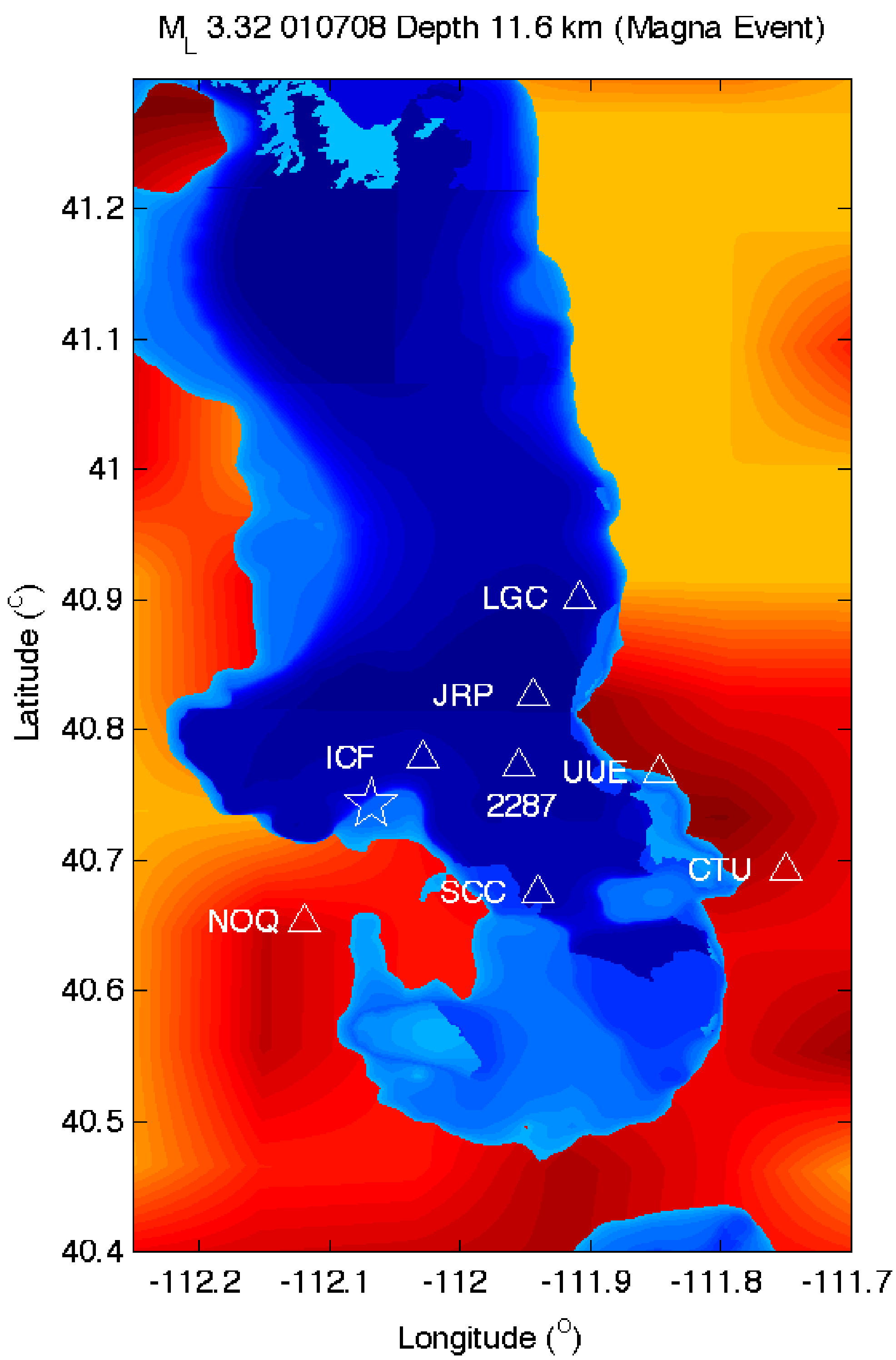
No Q
NOQ
2287
UUE
CTU
ICF
JRP
LGC
Time (S)
x 10^-3
x 10^-4
0
10
20
30


M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ

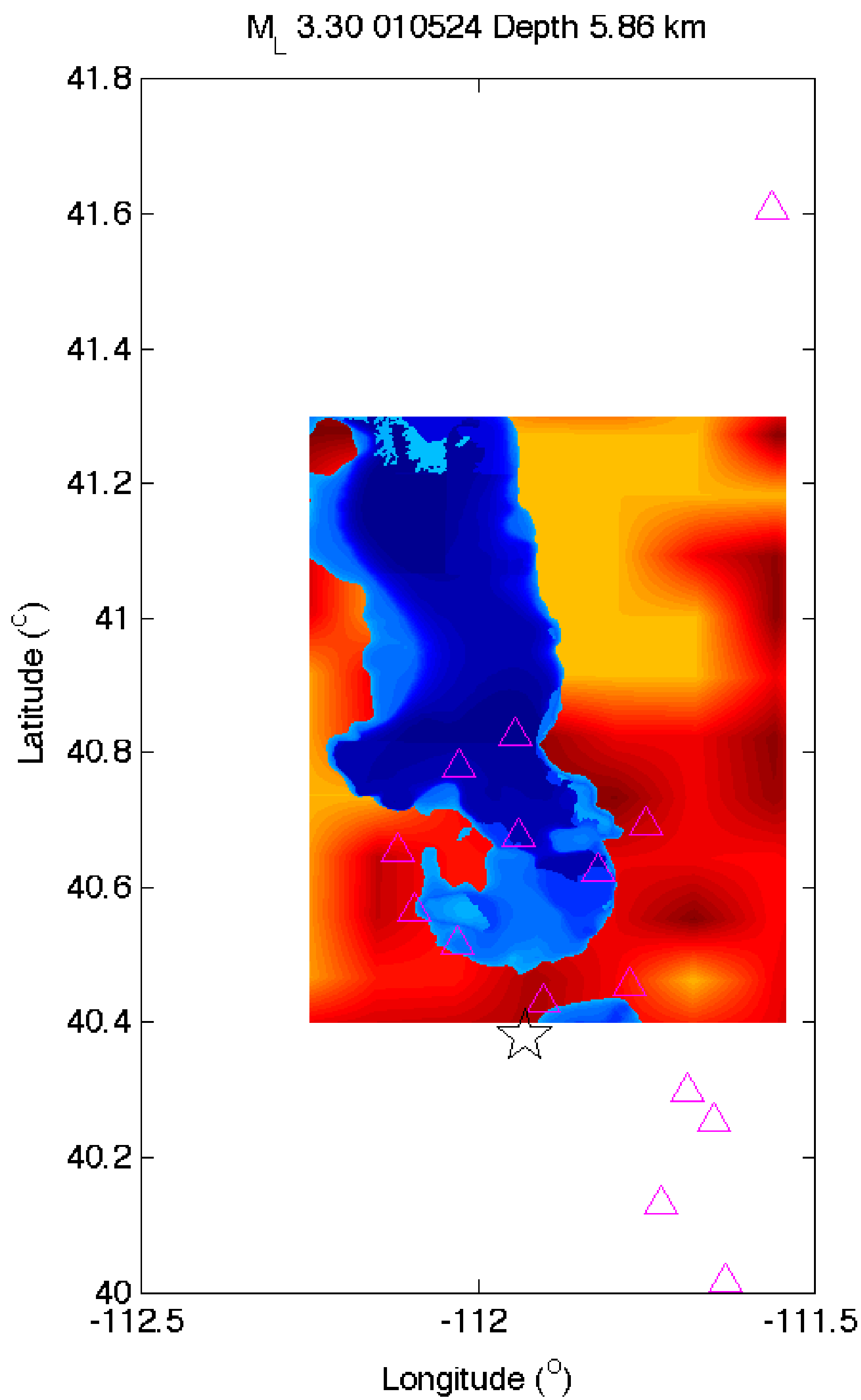
Q versus no Q


NOQ
2287
UUE
CTU
ICF
JRP
LGC
SCC
Time (S)
Time (S)
Time (S)

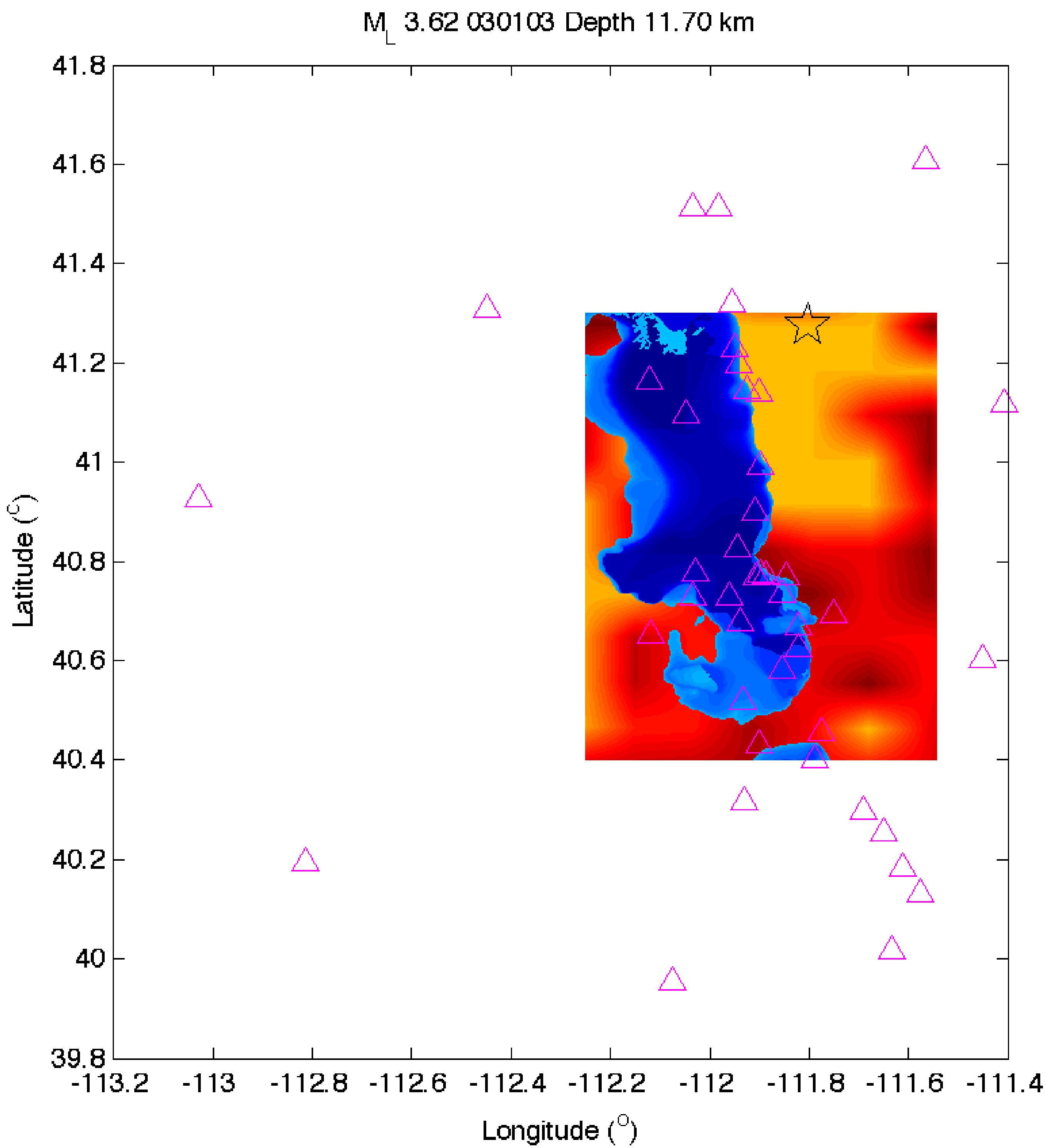

M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
LGC
JRP
ICF
UUE
2287
CTU
SCC
NOQ



M_L 3.32 010708 Depth 11.6 km (Magna Event)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
Latitude (°)
-112.2
-112.1
-112
-111.9
-111.8
-111.7
Longitude (°)
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ



M_L 3.30 010524 Depth 5.86 km
Latitude (°)
41.8
41.6
41.4
41.2
41
40.8
40.6
40.4
40.2
40
-112.5
-112
-111.5
Longitude (°)

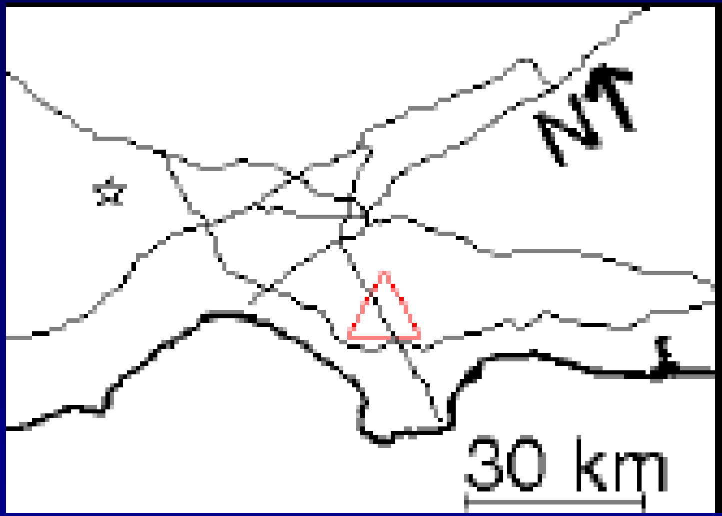


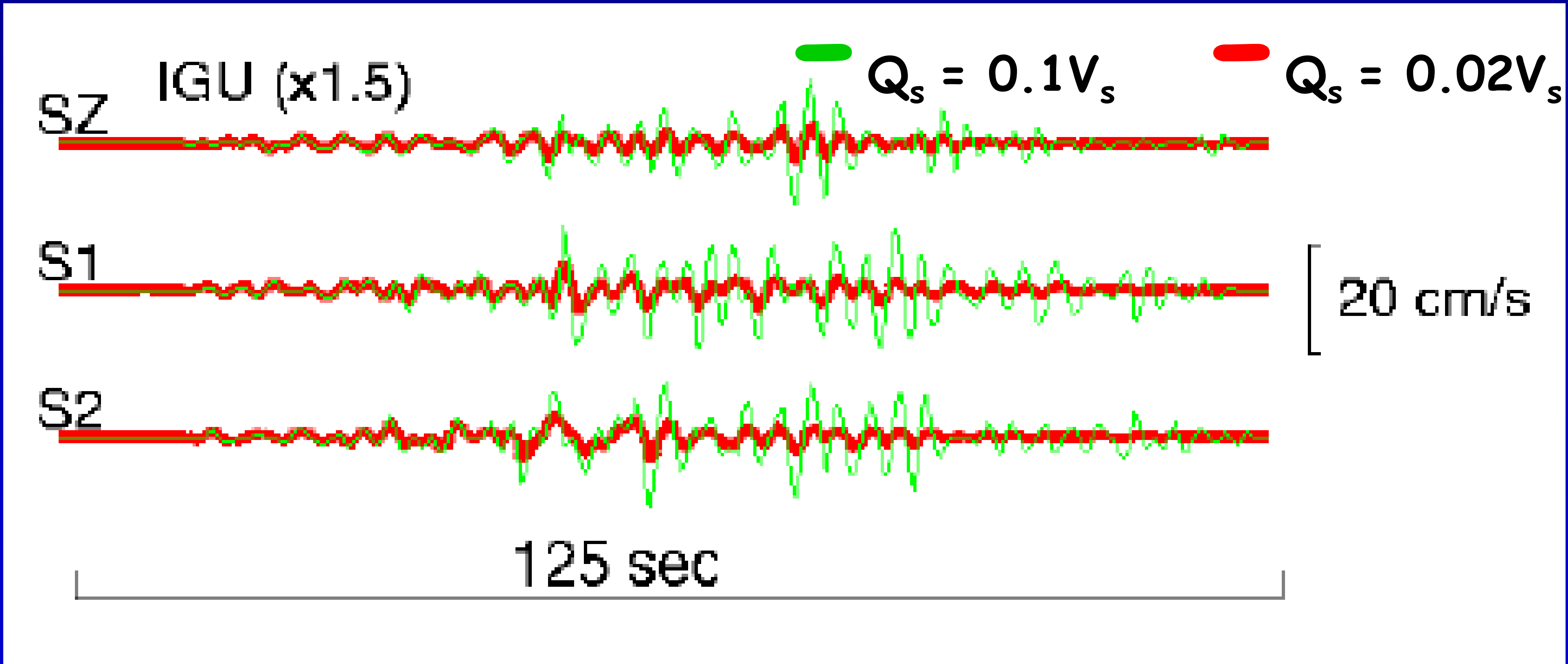
M_L 3.62 030103 Depth 11.70 km
41.8
41.6
41.4
41.2
41
40.8
40.6
40.4
40.2
40
39.8
Latitude (°)
-113.2
-113
-112.8
-112.6
-112.4
-112.2
-112
-111.8
-111.6
-111.4
Longitude (°)

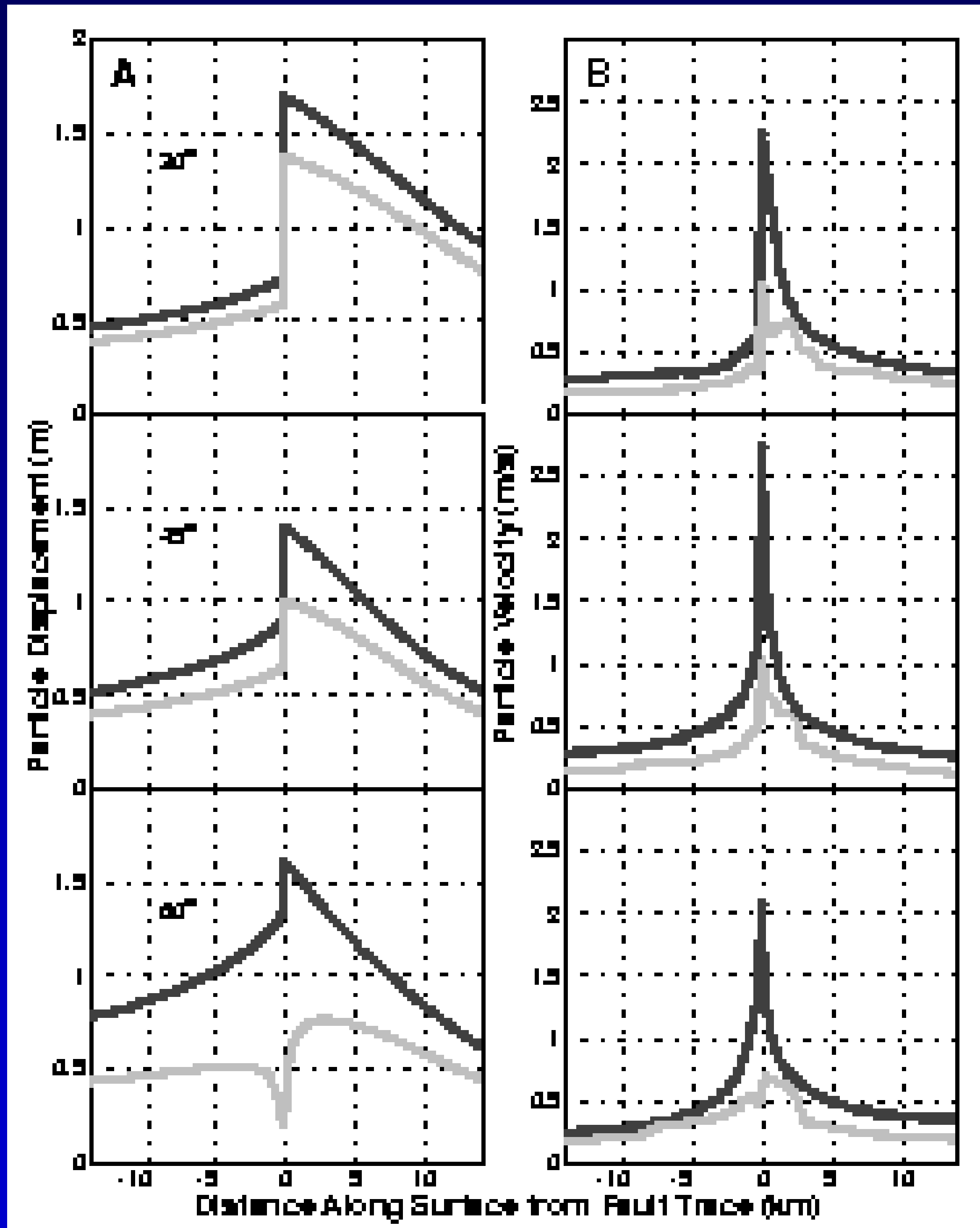
Summary of preliminary CVM validation

- Overall good fit for 0.25-1Hz peak velocities
- Durations under-predicted at (deep) soil sites
- Some timing discrepancies (~<0.4 s)
- Validation events sensitive to Q
- Q model different from So Cal(?)
- Location in 1D model versus modeling in 3D model

IGU






A
B
Particle Displacement (m)
Particle Velocity (m/s)
Distance Along Surface from Fault Trace (km)

PROPAGATING THRUST FAULT

LAYER OVER HALFSPACE

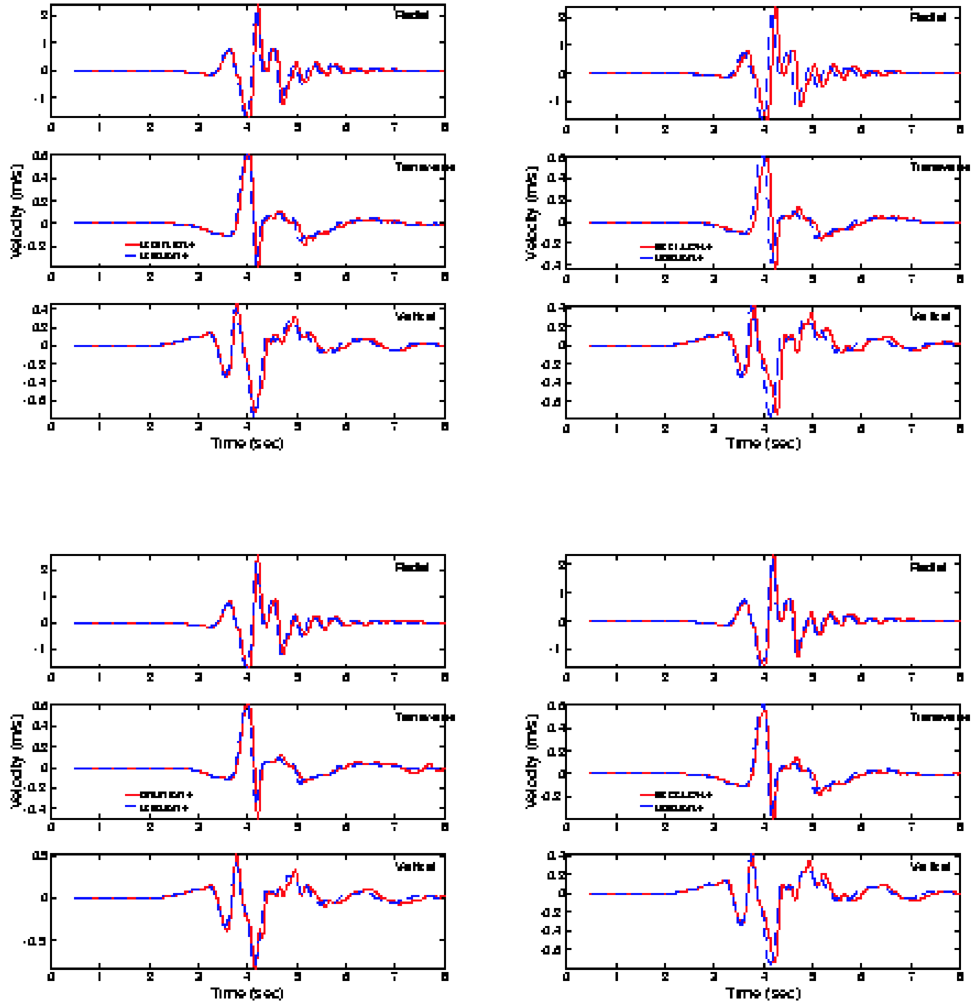


Figure 4: Comparison between solutions for five modeling groups, with the UCSB solution (to be used in this proposal) common to each plot, for a buried, 6 by 6 km fault, with strike, dip and rake (Aki and Richards, 1980, convention) of 115°, 40°, and 70°, respectively. The rupture propagates radially from the hypocenter located at the center bottom of the fault at a depth of 6 km with homogeneous slip and a velocity of 3 km/s. The model is a 1-km-thick layer (V_s=2 km/s, V_p=4 km/s, ρ=2.6 g/cm^3) over a halfspace (V_s=3.464 km/s, V_p=6 km/s, ρ=2.7 g/cm^3), with Q_p and Q_s infinite everywhere. The comparison is made at a station 10 km from the epicenter at an azimuth of 53.13°. The simulation used a Gaussian source time function with spread 0.05 sec, which accommodates frequencies between 0 and 5 Hz in the synthetic seismograms.