# UTAH GROUND SHAKING WORKING GROUP

## Annual Meeting #6: Introduction

12 February 2008

# 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 2007 MEETING: PRIORITIES FOR 2008 RESEARCH

- Collect additional shallow Vs30 data for Weber/Davis/Utah Counties.

- Collect intermediate and deep Vs data in Weber/Davis/Utah Counties, and additional data in Salt Lake County if sites are available.

# RESULTS OF 2007 MEETING: PRIORITIES FOR 2008 (cont.)

- Form a working group to develop a near-surface site-amplification model(s).

- Use CVM to perform deep-basin model simulations and evaluate its validity; evaluate R1 and R2 surfaces with respect to Vs data and define their velocities.

# GOALS OF THE 2008 MEETING

- Present results of 2006-2007 research
- Discuss issues related to 2007 update of NSHMs
- Give updates on on-going projects summarized in previous meetings
- Perform technical review of completed CVM (development and verification) and assess adequacy of data for urban hazard maps

# GOALS OF THE 2008 MEETING (cont.)

- Finalize plan to prepare Wasatch Front urban seismic hazard maps
  - Characterize earthquake sources
  - Develop site-amplification and basin models
  - Prepare maps
- Identify 2009 research priorities

# 2007 SCHEDULE FOR PREPARING MAPS

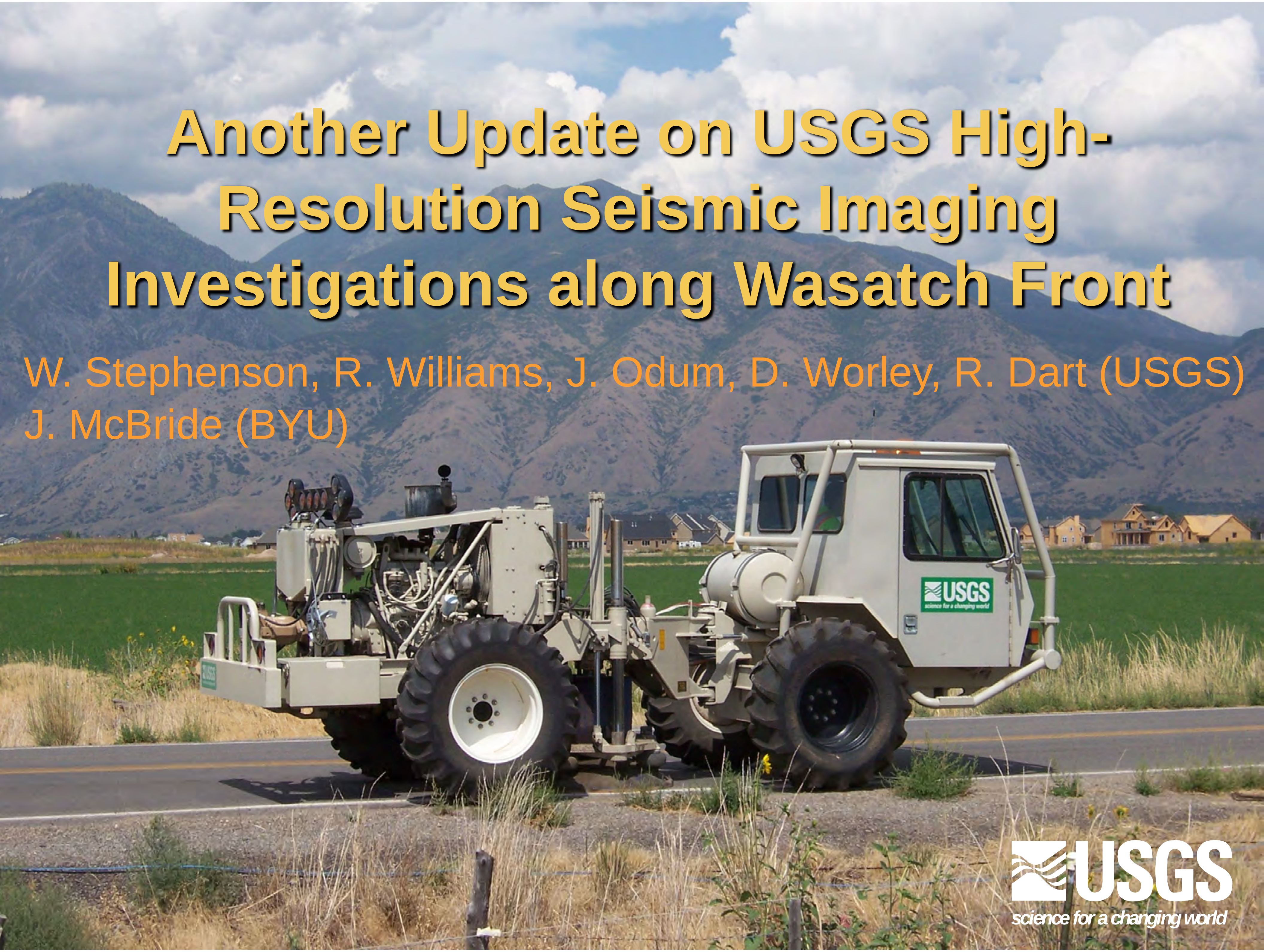
- Complete and validate the CVM by 12/07 (Magistrale, Olsen, Pechmann).
- Propose site-amplification modeling for 2008 NEHRP (Wong, others). If funded, results available by 12/08-6/09.
- Perform basin modeling by 12/08 (Pechmann, Olsen).
- Begin urban hazard map development in 2009.

# OTHER ISSUES

- UGS/USGS co-op agreement that funds Working Group meetings ends Dec. 2009.
- EERI Annual Meeting in SLC Feb. 2009

# Another 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)



USGS
science for a changing world

# *Overview of Presentation*

– Update on P-wave minivib seismic reflection in Utah Valley between Spanish Fork and Mapleton

– Preliminary results of SPAC microtremor data analysis for Salt Lake and Utah Valleys

USGS
Science for a changing world

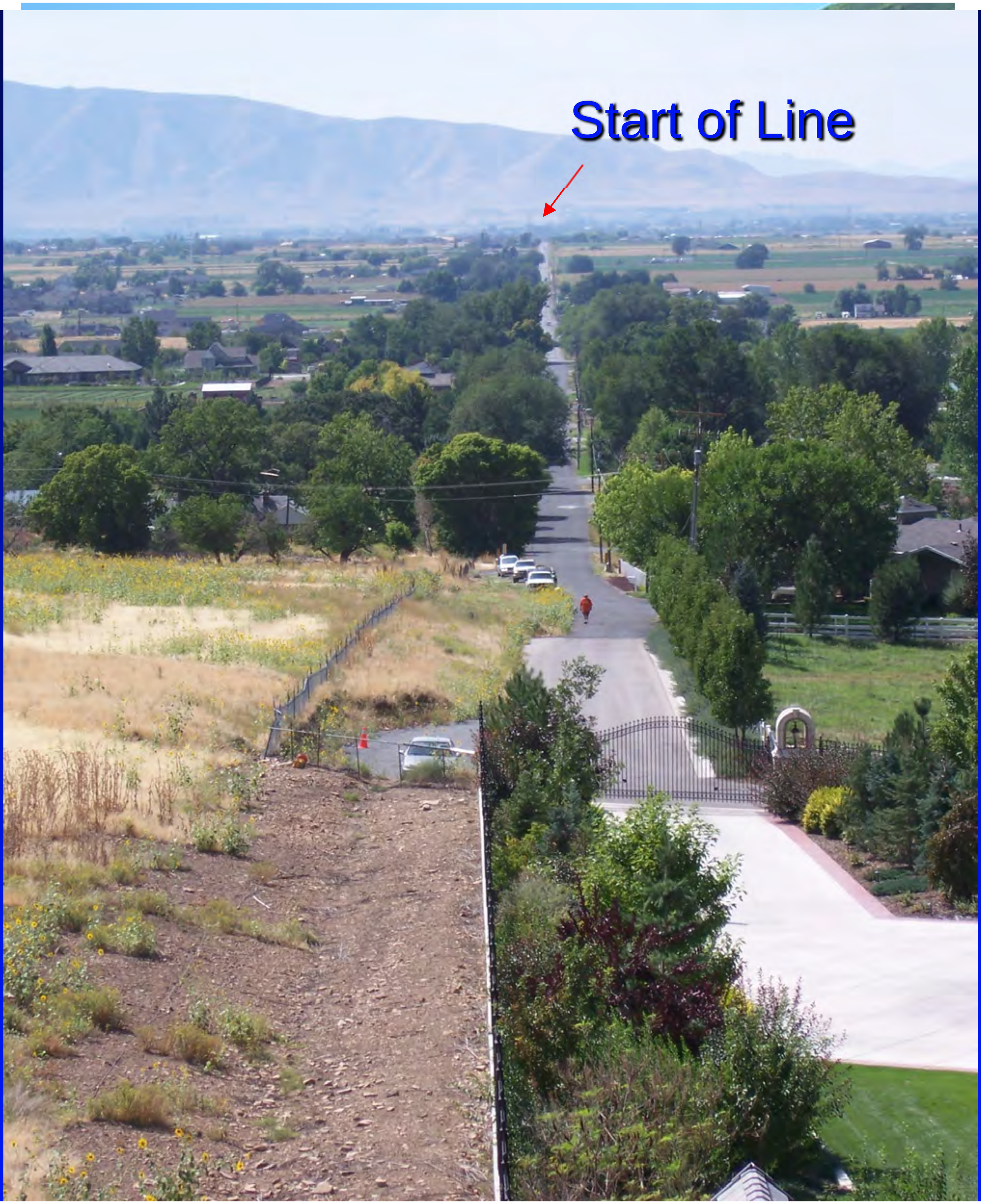
# *P-wave Seismic Reflection Imaging*

Spanish Fork to Mapleton


– ~5.6 km

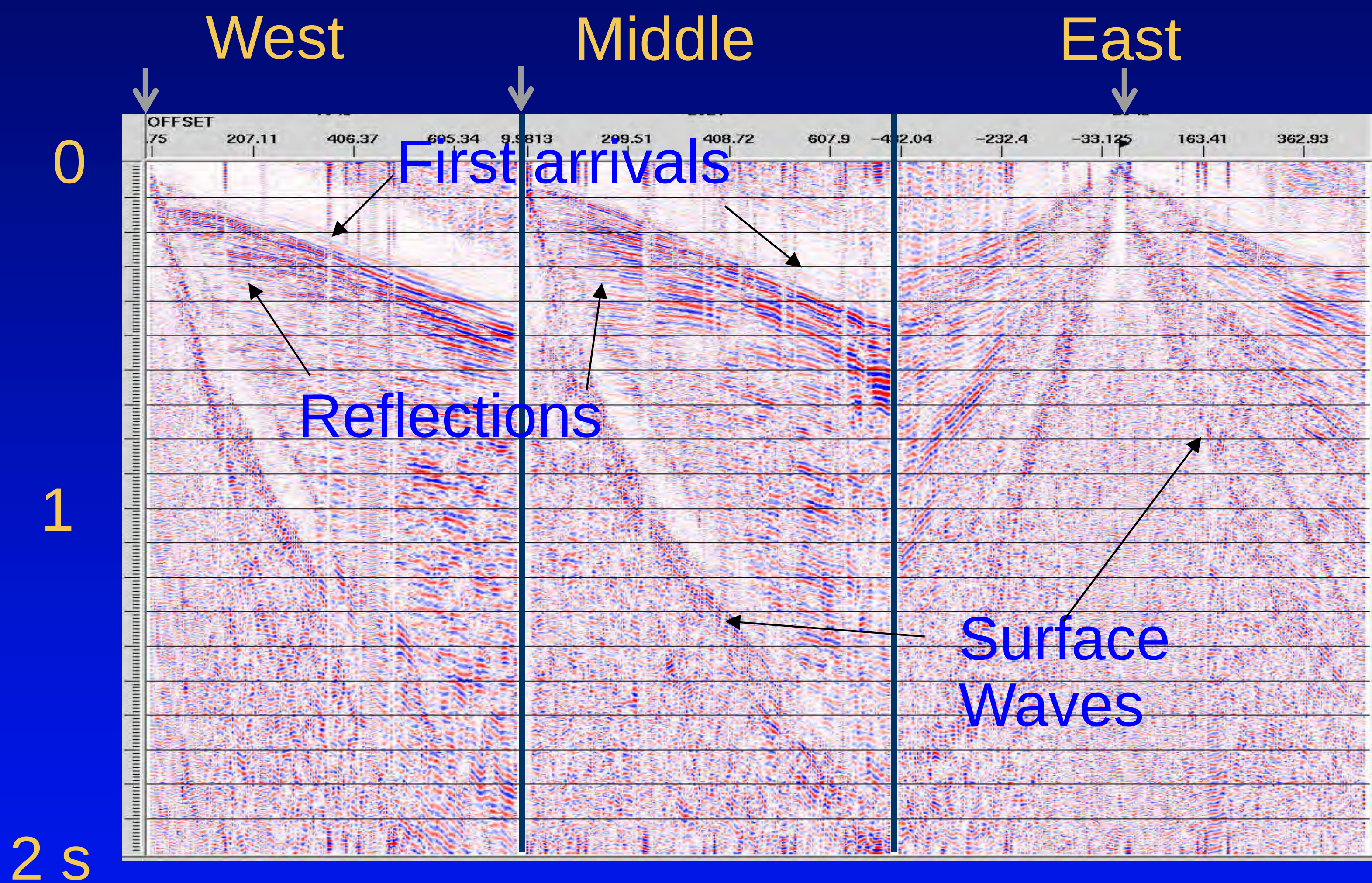
– 5 m source / receiver spacing

USGS
Science for a changing world


Start of Line

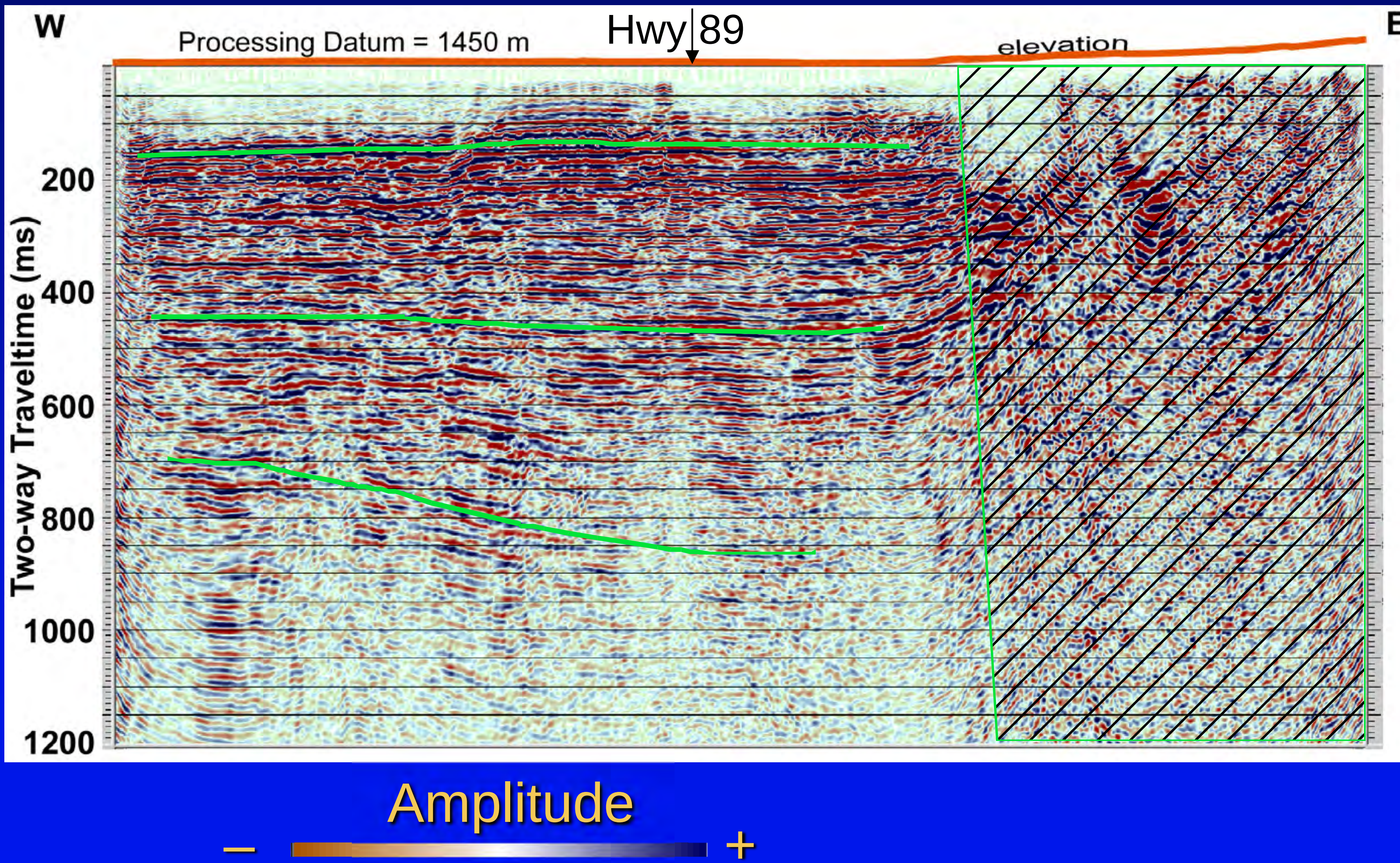

USGS

# Spanish Fork-Mapleton P-wave Field Records

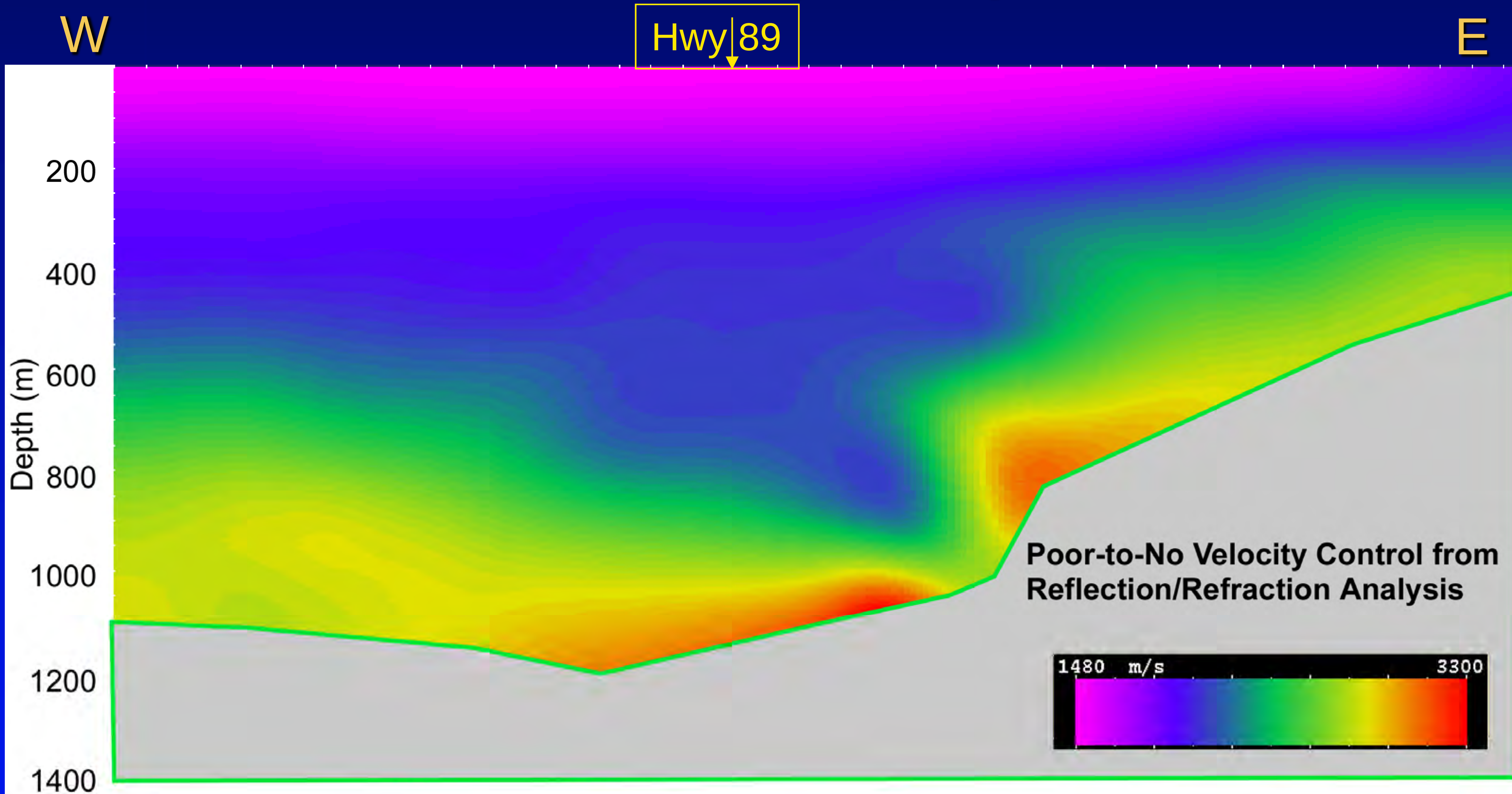



- Records displayed with AGC and bandpass.

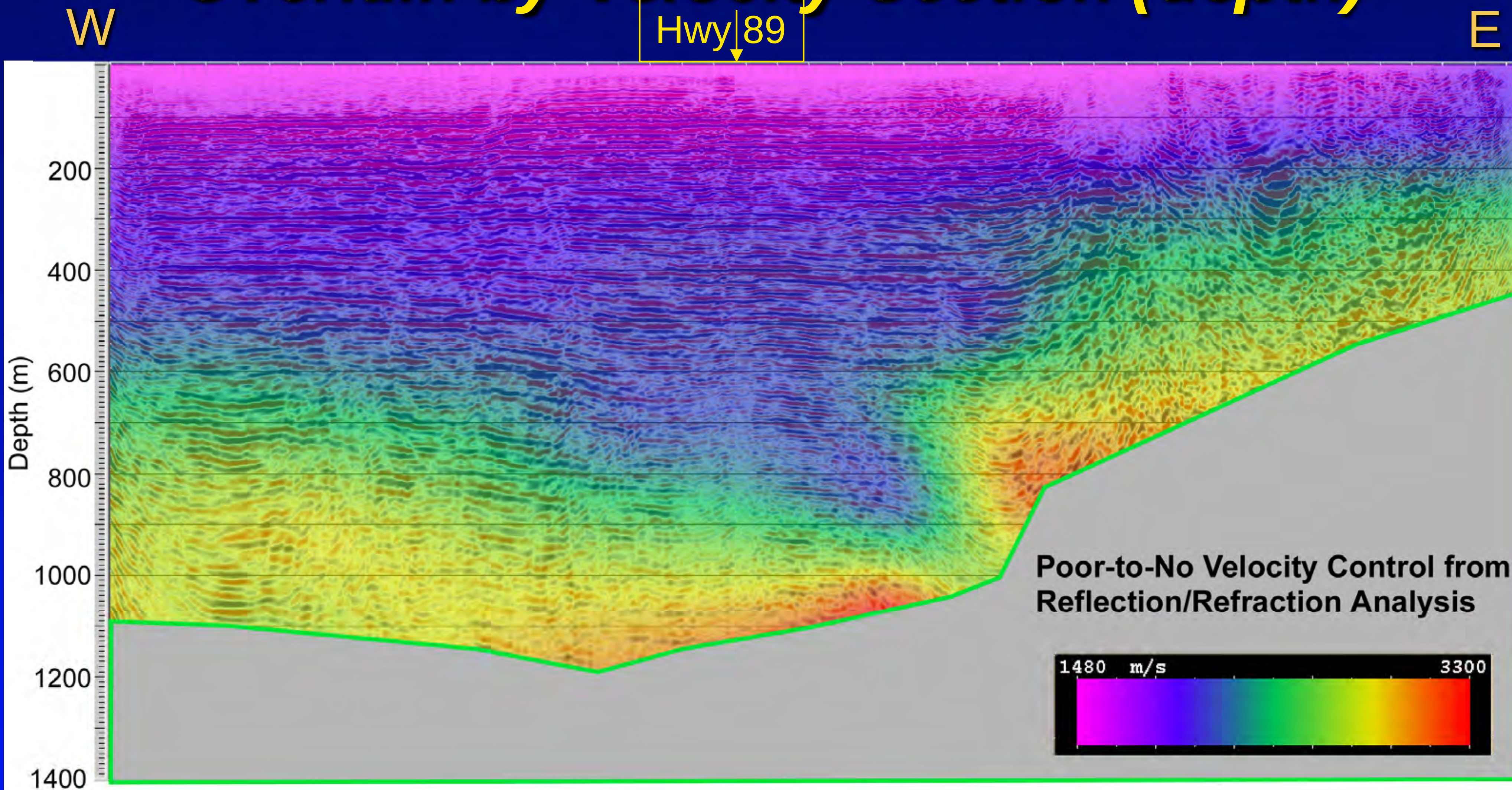
# Spanish Fork-Mapleton Preliminary Stacked Seismic Profile (time)



# Spanish Fork-Mapleton P-wave Velocity Section (depth)



# Spanish Fork-Mapleton P-wave Seismic Overlain by Velocity Section (depth)

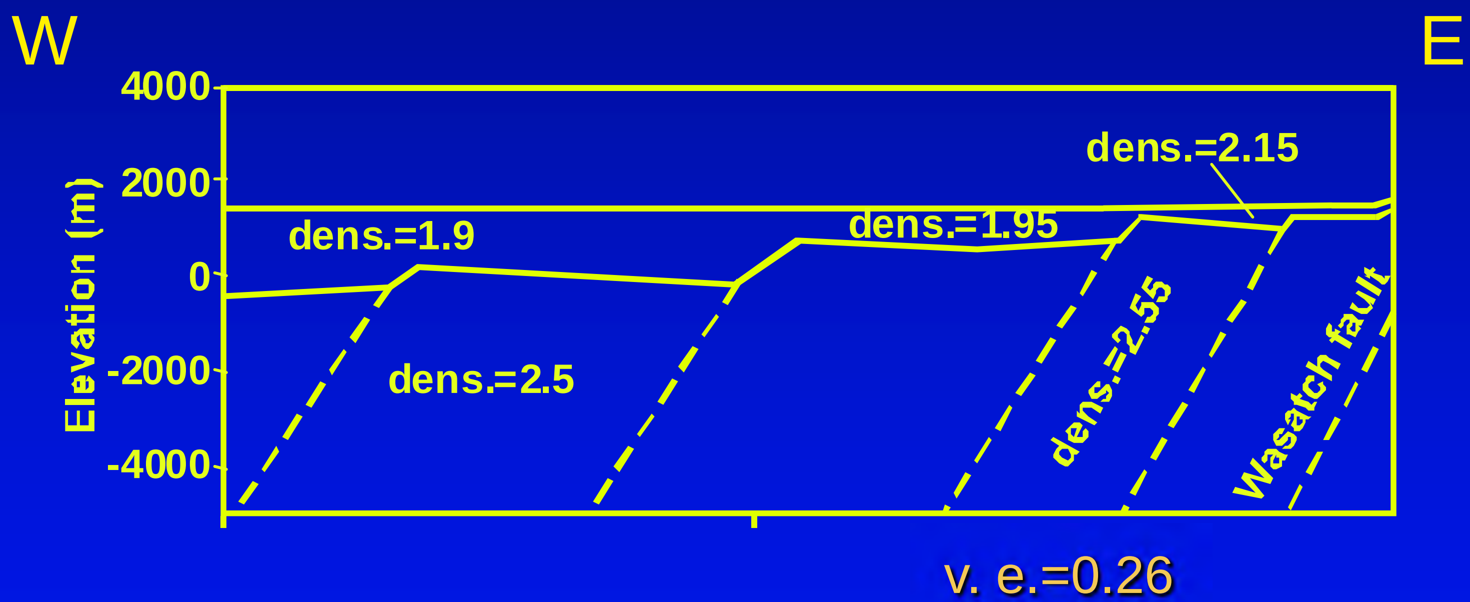



USGS
Science for a changing world

# Other Information in area of Spanish Fork-Mapleton Profile

Gravity Modeling

(Benson and Hash, Engr. Geology, 1998)

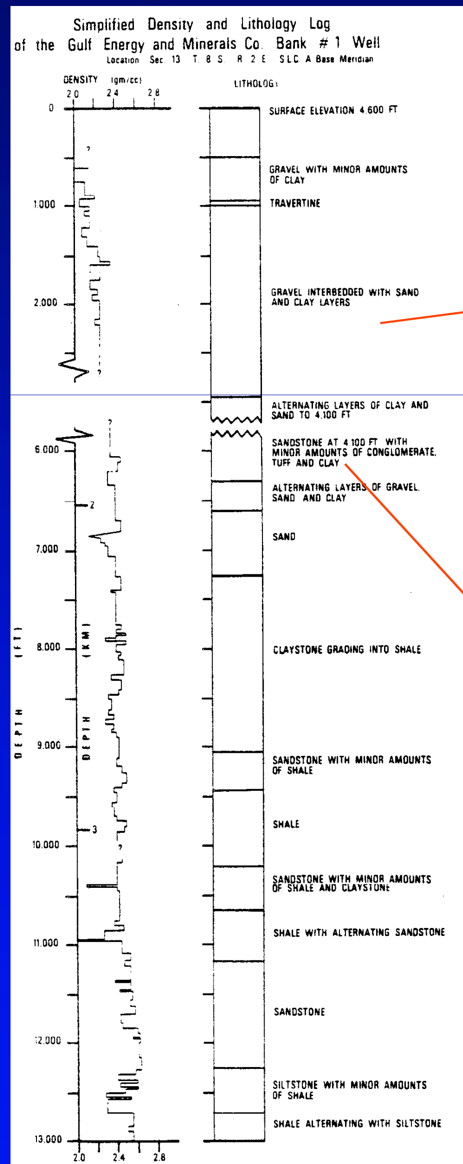



2D model ~ 2km north of profile

# *Other Information in area of Spanish Fork-Mapleton Profile*

Well Logs
(UGS database, 2005)

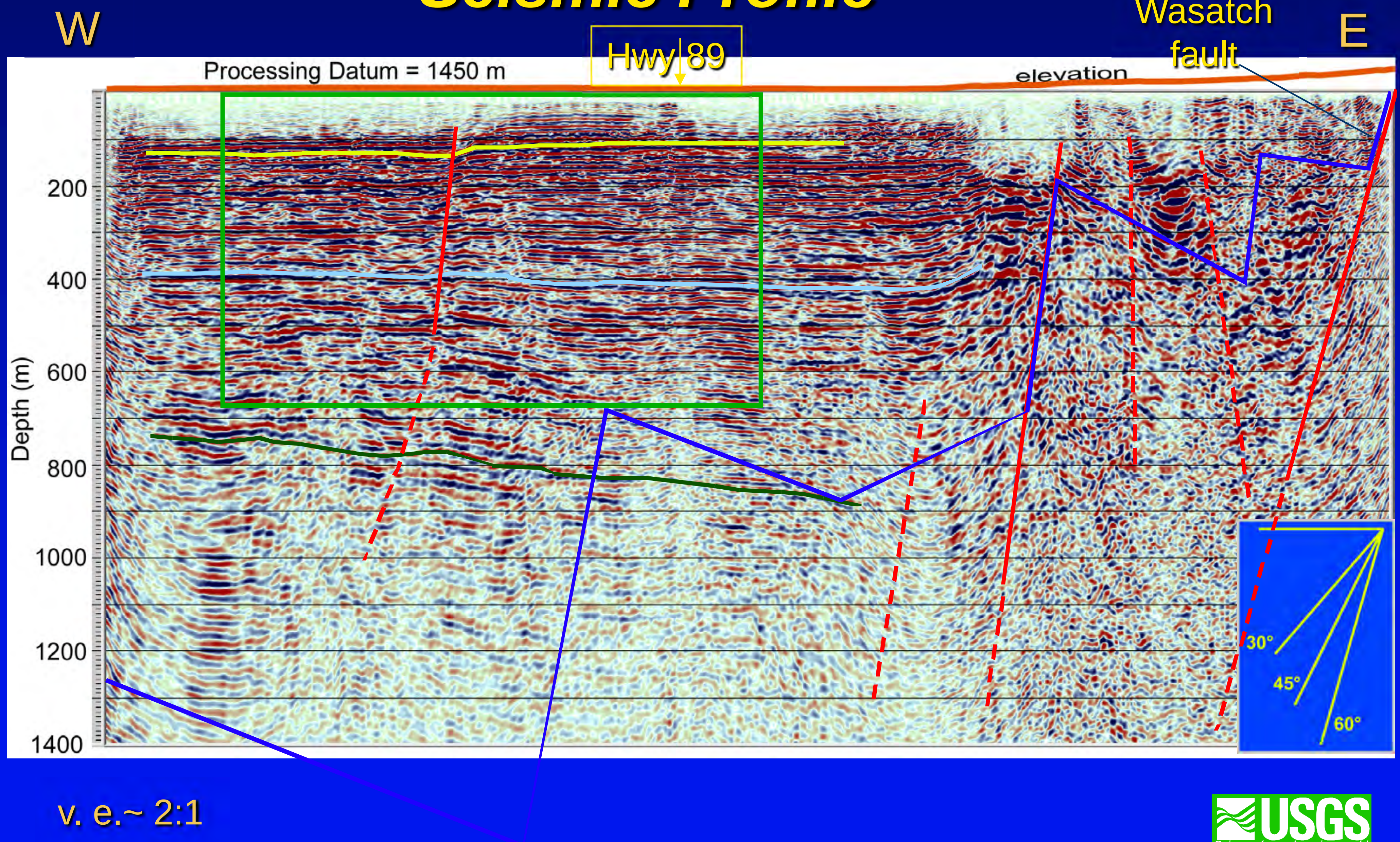
Gulf No. 1 ~3km NW of end of seismic profile




interbedded gravel, sand, clay

"sandstone" at ~ 1.25 km depth

# Interpretation of Spanish Fork-Mapleton Seismic Profile

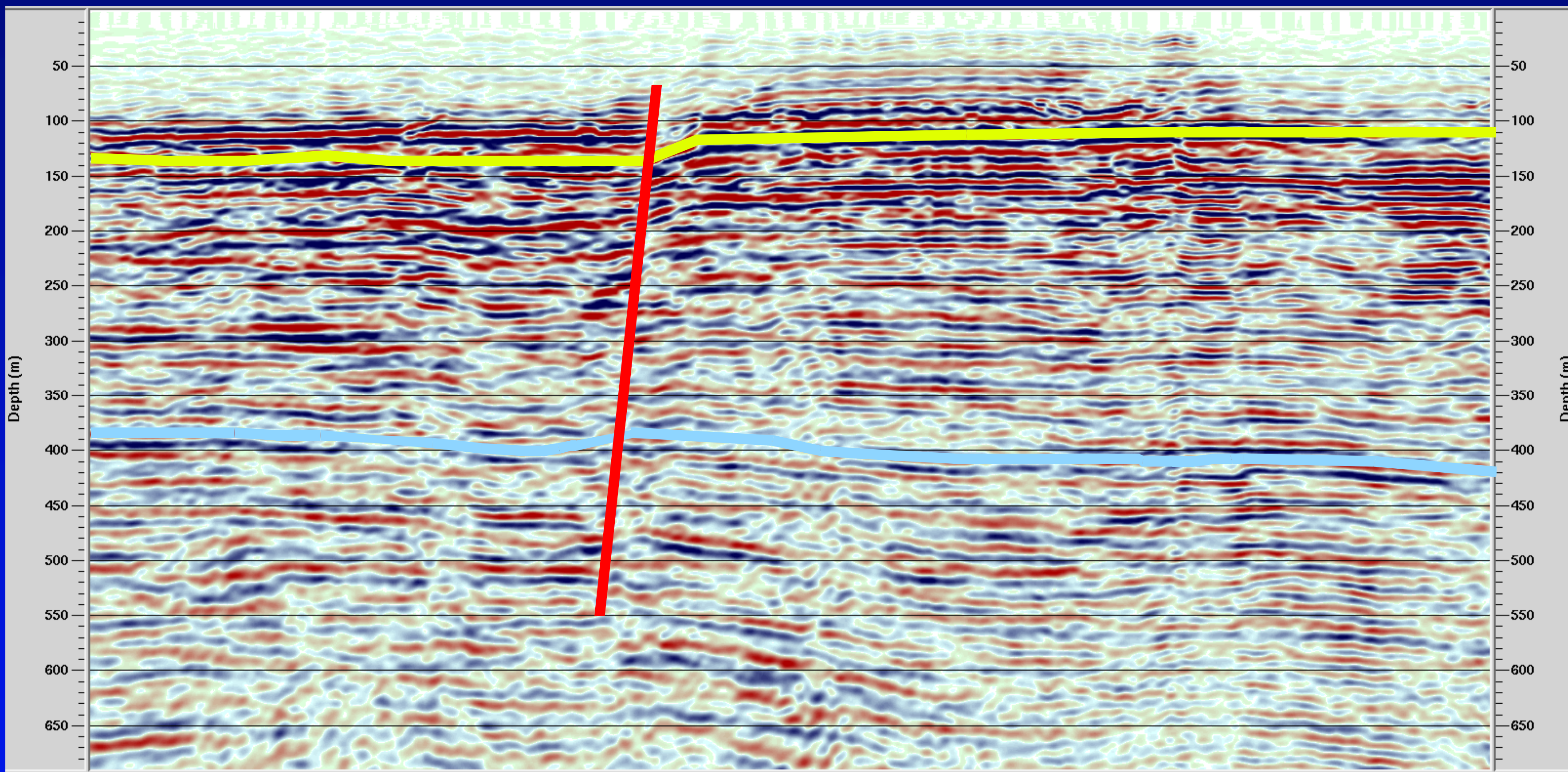



v. e.~ 2:1

USGS
Science for a changing world

# *Spanish Fork-Mapleton Westernmost Interpreted Fault*

W




E

v.e. ~2:1

USGS
Science for a changing world

# *Surface Methods for S-wave Velocity Determination*

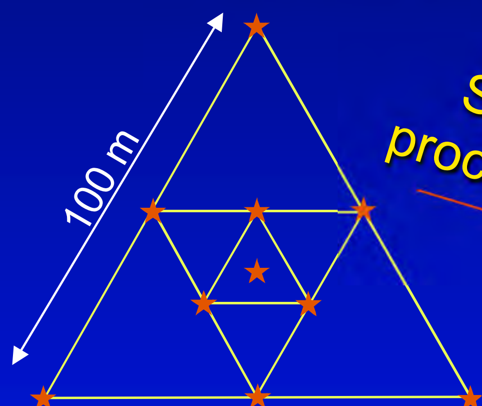
| ***Active*** | ***Passive*** |
| --- | --- |
| SASW | ReMi |
| CXW | FK |
| MASW | SPAC |
| Reflection/Refraction | H/V (Nakamura) |

USGS
Science for a changing world

# *SPAC Methodology*

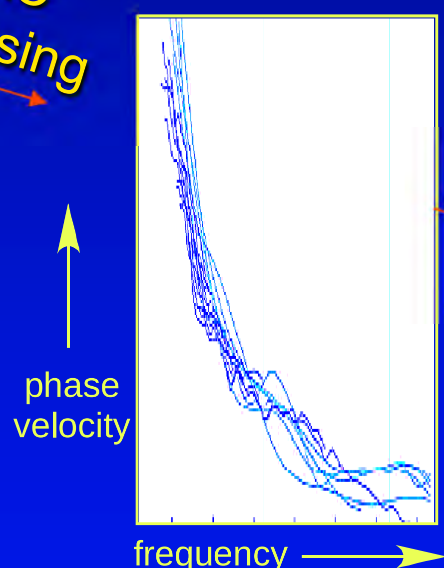
SPAC = SPatial AutoCorrelation (Aki, 1957)

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



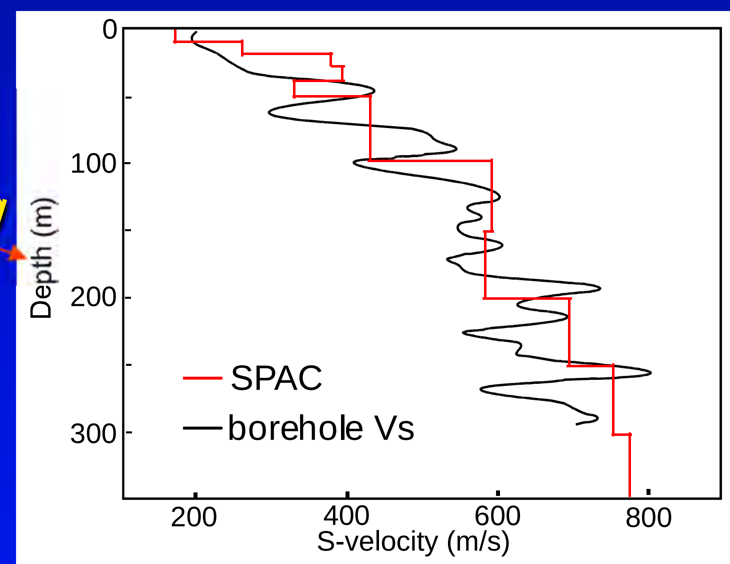

array w/ sensors at stars

SPAC processing




dispersion curve

modeling

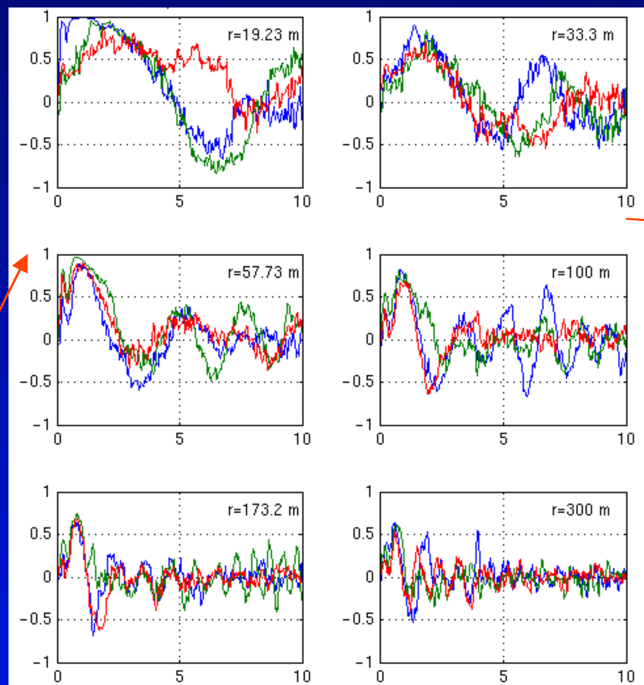



From Hartzell et al., 2005

USGS
Science for a changing world

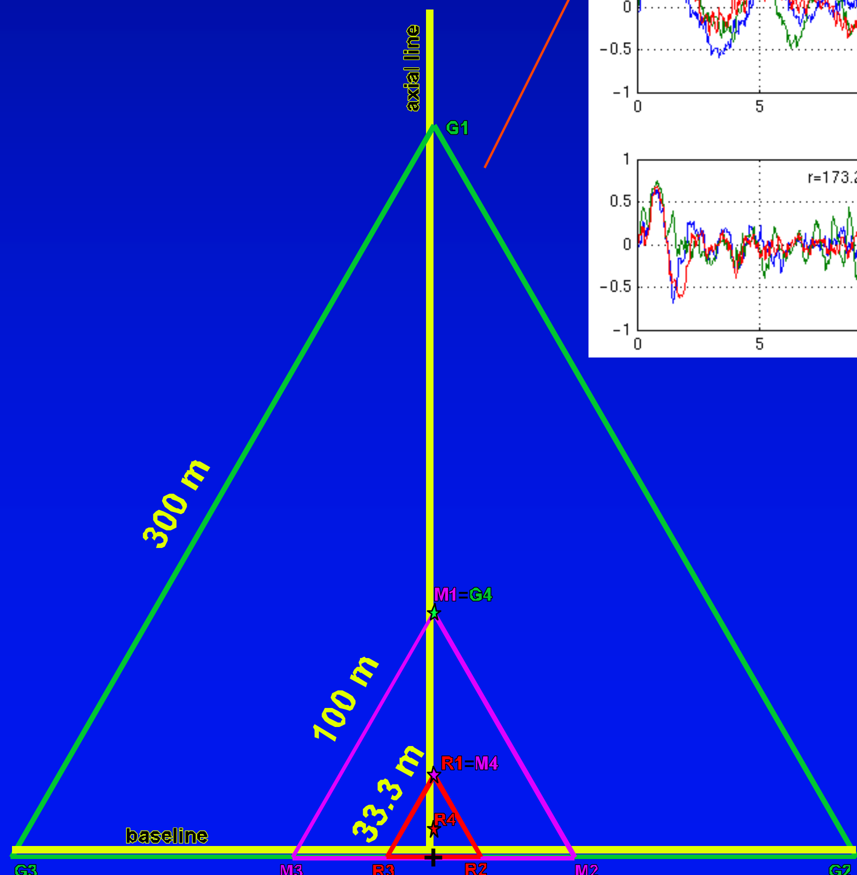
# SPAC Acquisition in S.L./UT Valleys

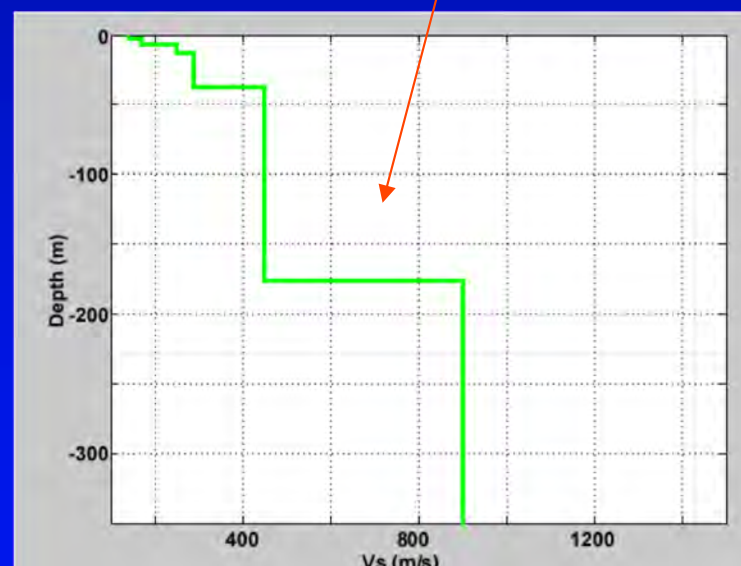
Focus: Derive Vs to depths greater than 30 m




SPAC processing to get dispersion

forward and/or inverse modeling




Science for a changing world

# *SPAC Sites in Salt Lake-Provo Area*


~100 km

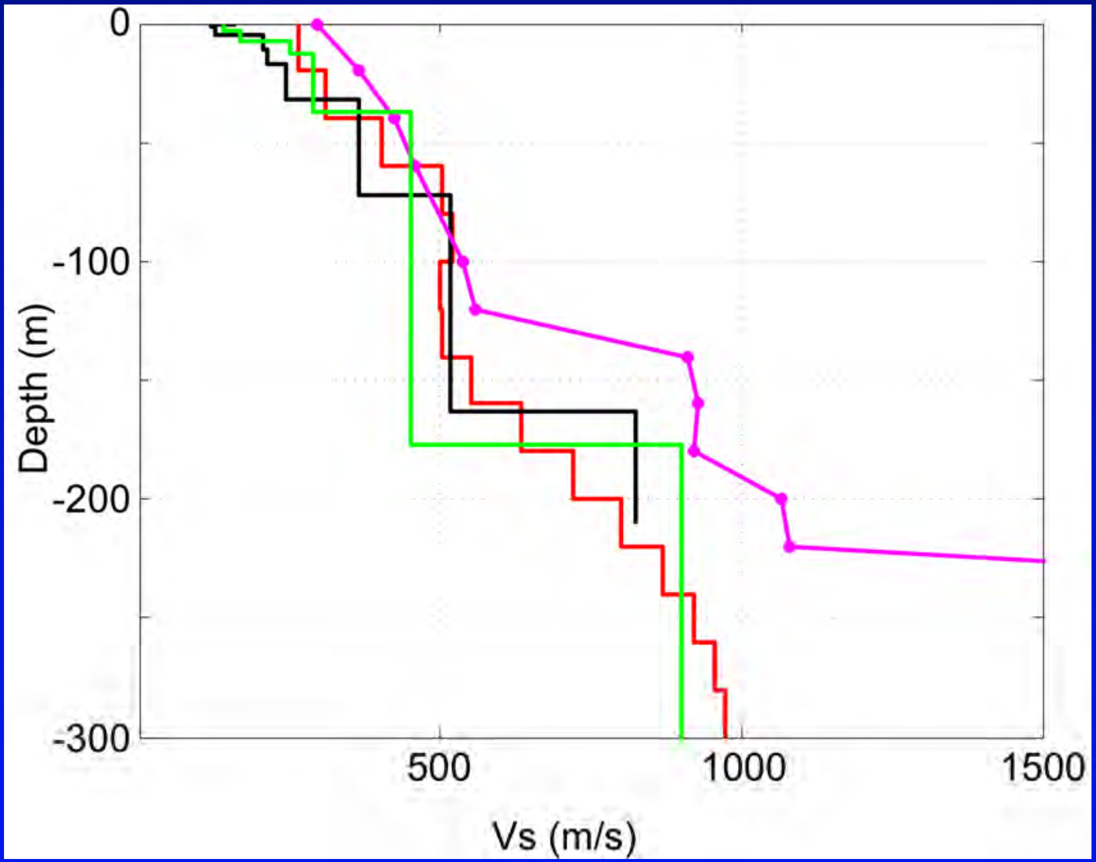
14 in Salt Lake Valley
4 in Utah Valley

Site selection Criteria:
1) accessible w/ arrays
2) near other Vs data
  -borehole
  - minivib/liquidator
3) near ANSS station
4) 2D transects

USGS
Science for a changing world

# SPAC, Liquidator S-Velocity Comparison

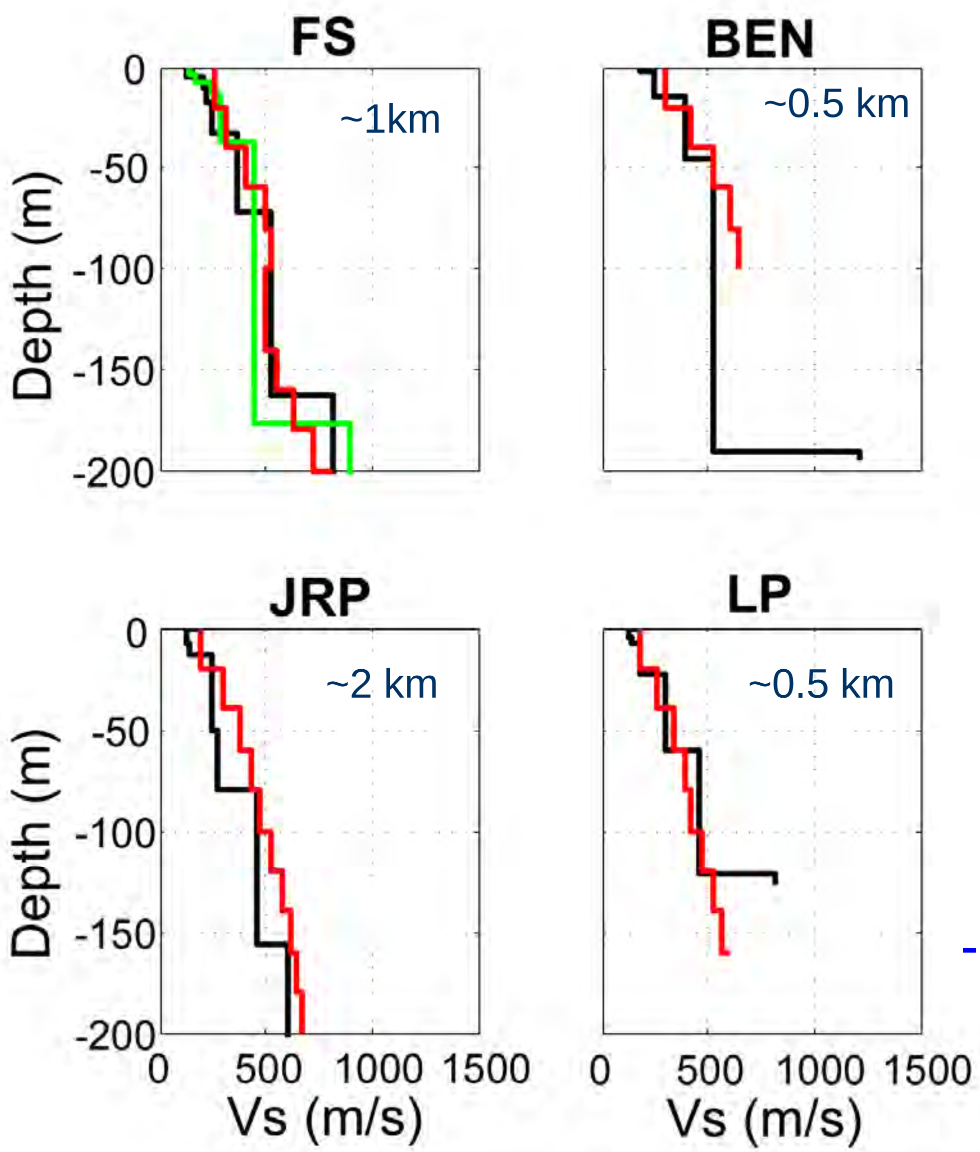
## Salt Lake Valley, near 5600 S




green=spac forward mdl
red=spac inversion
black=liquidator
magenta= Wasatch CVM

<u>Vs100</u>
spac forward mdl ~342 m/s
spac inversion ~373 m/s
liquidator ~312 m/s
CVM ~398 m/s

# SPAC, Liquidator S-Velocity Comparison

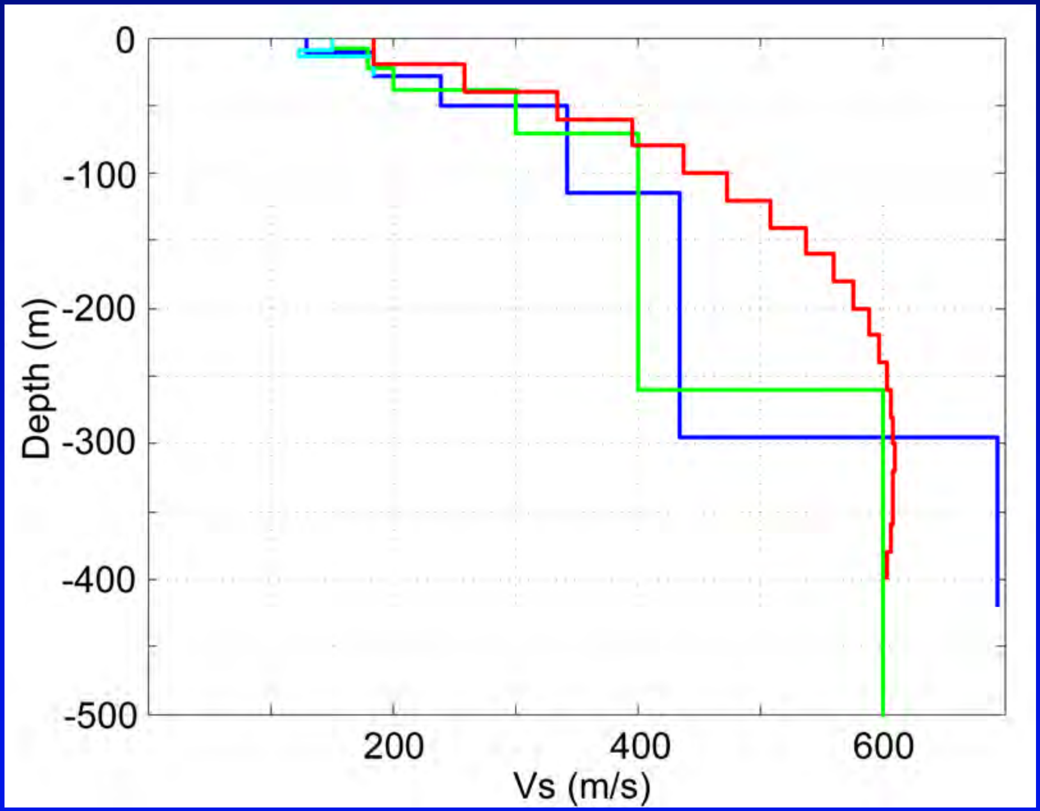



-Good qualitative Match

-SPAC does not always “see” deeper

# Borehole, SPAC, Minivib Vs Comparison

## Provo Airport

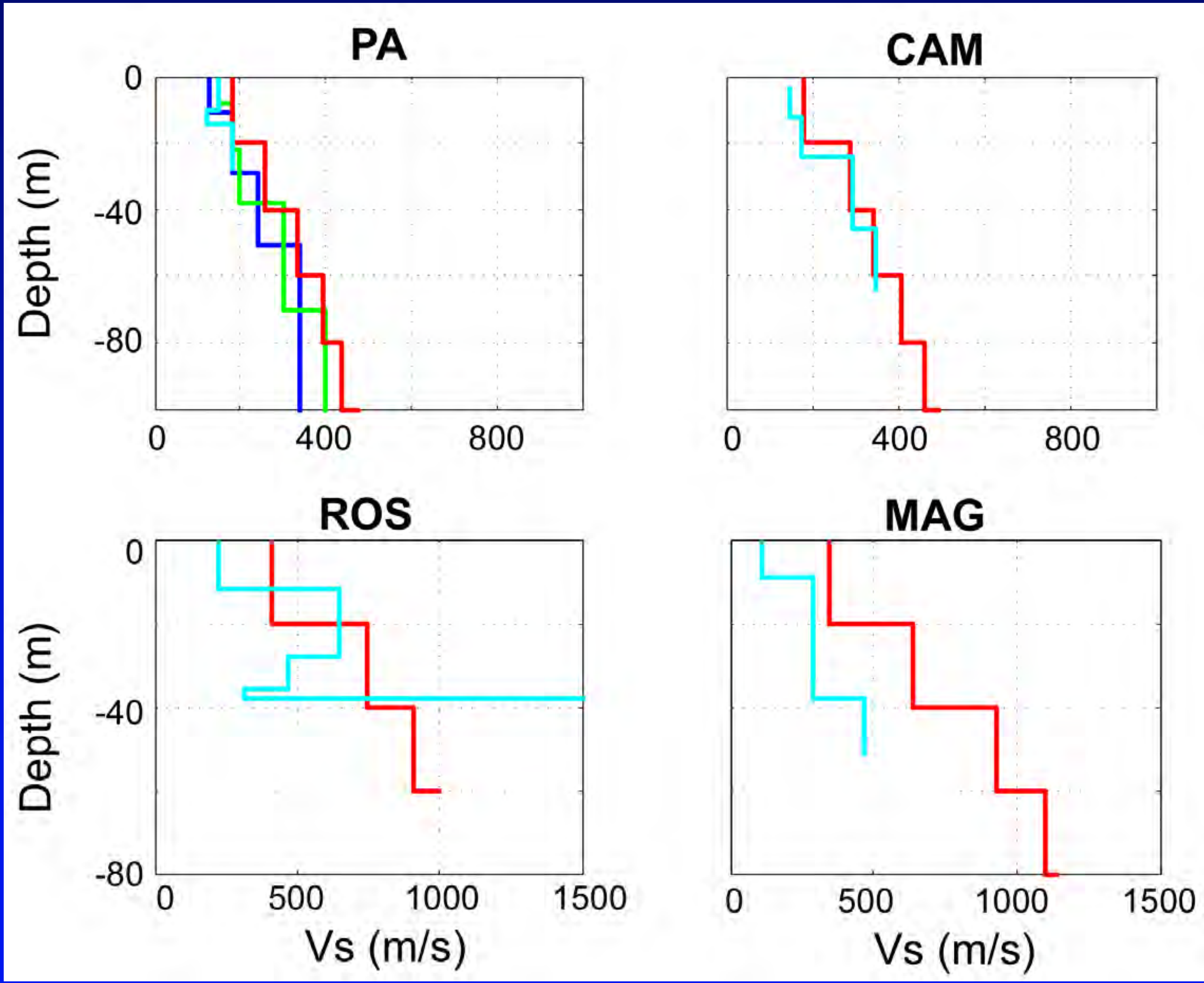



green=spac forward mdl
red=spac inversion
blue=minivib (refl./refr.)
Cyan=downhole

Vs100
spac forward mdl ~255 m/s
spac inversion ~292 m/s
minivib ~235 m/s

Vs30
dh ~160 m/s
mv ~161 m/s
spac fwd ~175 m/s
spac inv ~203 m/s

# SPAC, Borehole S-Velocity Comparison




green=spac fwd. mdl
red=spac inversion
blue=minivib
cyan=downhole


The End
USGS

# National Seismic Hazard Mapping Project

- Oliver Boyd (Memphis)
- Arthur Frankel
- Kathleen Haller
- Stephen Harmsen
- Nicolas Luco
- Charles Mueller
- David Perkins
- Mark Petersen
- Russell Wheeler
- Yuehua Zeng

<u>Emeritus:</u>

Chuck Bufe

E.V. Leyendecker

Robert Wesson

H

# Time-table for NSHMP products

- Dec 2007 Delivered NSHMP to BSSC
- Jan 2008 Delivered Design maps to BSSC
- March 2008 Plan to roll-out the National Seismic Hazard Maps (maps, documentation, press-release, fact sheets)
- FY08: work with BSSC on soil maps/amplification factors, develop new ARC-IMS web products, put all input and output files on website, update deaggregations and design webtools, begin discussions on Hawaii update, continue work on American Samoa and Guam hazard maps, update Q-fault database, participate in NGA-East, participate in CEUS Mmax workshop, research (discussed below)

# Central and Eastern U.S. Sources

- Arkansas/Tennessee: lower building code (Memphis), confusion about 2500 year ground motions and design maps
- Kentucky: disagree with methodology and maps
- Geodetic data: Low strain-rate over New Madrid (0-1 mm/yr strain rate)
- Geologic data: liquefaction data, sedimentation rate studies along New Madrid
- Geophysics data: reflection data

# Central and Eastern U.S. Sources

- Charleston, SC sources – future workshop
- Maximum magnitude: global analogs, other?, NRC – Workshop this year
- Catalogs (mblg vs Mw, uncertainties)

# Intermountain West

- WSSPC recommendations (e.g., slip rate uncertainty – UT and NV)
- Geodetic data differs from geologic and seismic data (How do we quantify aseismic slip)
- Magnitude-frequency distribution – too many M 6.5 – 7 events
- Fault and community velocity model working groups – UT and NV

Zeng and Shen 2006

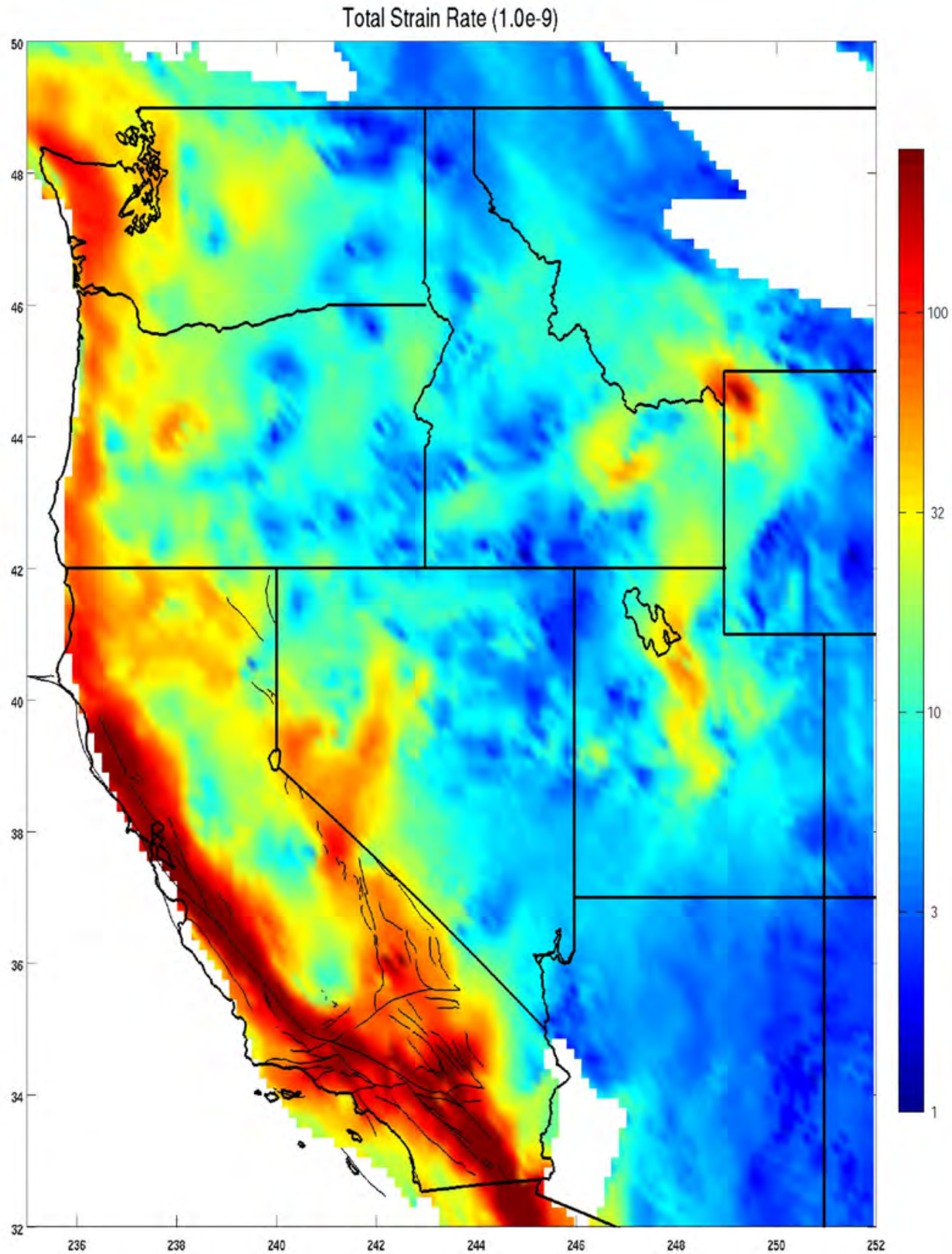



Figure 14: GPS strain data for the western U.S.

# Pacific NW

- Cascadia subduction zone (Relative number of M 9’s vs M 8’s – Does this differ between northern and southern sections?)
- Sources not well defined (LIDAR)

# California- WGCEP

- Developed new models for A-faults, B-faults, shear zones – fault interactions, multisegment ruptures
- Reduced slip rate to account for aftershocks and small earthquakes by 10%, some thought that we should reduce by 30-40%
- New earthquake catalog- considered magnitude uncertainty
- Tried to match Magnitude-frequency distributions from the model and historic catalog

# Ground motions

- WUS: Applied NGA with additional epistemic uncertainty
- CEUS: Applied new Atkinson and Boore with two stress drops (140 and 200 bar), NGA-East (NRC)
- Subduction interface: Replaced new Zhao et al. equation for the Sadigh equation

# Maps

- Changes about +/- 30% in WUS for 1 s SA
- Changes about +/- 10% in WUS for 5 hz SA
- Changes about +/- 15% in CEUS for 1 s and 5 hz SA

# Future work

- Resolve remaining issues in 2008 version
- Time-dependent hazard (Alaska, Cascadia, CA, UT, New Madrid)
- Temporal/Spatial cluster models for earthquake recurrence
- Uncertainty and sensitivity analysis
- Develop earthquake ground motion scenarios or without site response
- Produce urban hazard maps (Seattle, Wasatch front, Reno-Carson City corridor, Las Vegas)
- Risk analysis
- Web tools to help homeowners assess risk
- Cost-benefit analysis (especially for New Madrid)

# Challenges

- Project is small (less than 10 FTE) - difficult to find experts in seismic hazard analysis
- Coordination with Menlo Park
- Balance OFA work with National Seismic Hazard Map research (NRC, USAID, GEM)

# National Seismic Hazard Maps

Delivered to BSSC January, 2008

Planned release end of March, 2008

Mark Petersen, USGS

# Intermountain West

- WSSPC recommendations (e.g., consider slip rate uncertainty – UT and NV, model multi-segment rupture on Wasatch, promote M 6.5 earthquakes, modify magnitude-freq on faults, use 50 degree dip with uncertainty)
- Geodetic data differs from geologic and seismic data (How do we quantify aseismic slip)
- Magnitude-frequency distribution – too many M 6.5 – 7 events
- Convened fault and community velocity model working groups – UT and NV
- Included new NGA ground motion equations


Figure 11: Faults in the western U.S. showing style of faulting

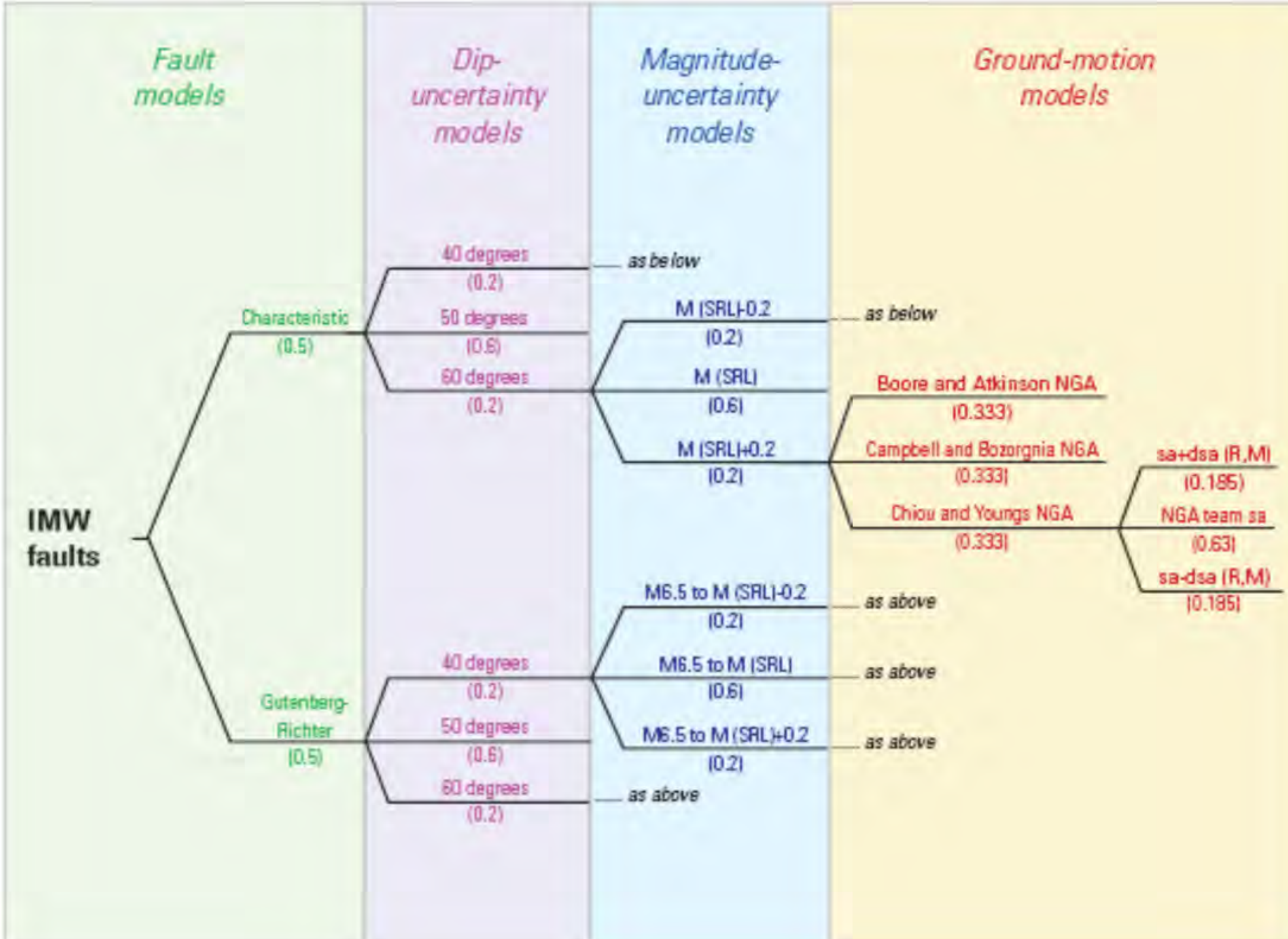



Figure 17. Logic tree for fault sources in the Intermounrtain West. Parameters in this table include some aleatory variability as well as depicted epistemic uncertainty. Additional aleatory variability may be associated with all models depicted. We treat aleatory variability in ground motion in the hazard code. Most faults in the Intermountain West have assigned characteristic magnitudes (see first panel) based on surface rupture length except where histroical earthquakes serve as analogs and where the characteristic magnitude is constrained to M7.5 (shown in table G-3). Short faults (<17 km) in the region with characteristic magnitude less than 6.5 are treated like the upper branch but with full weight.

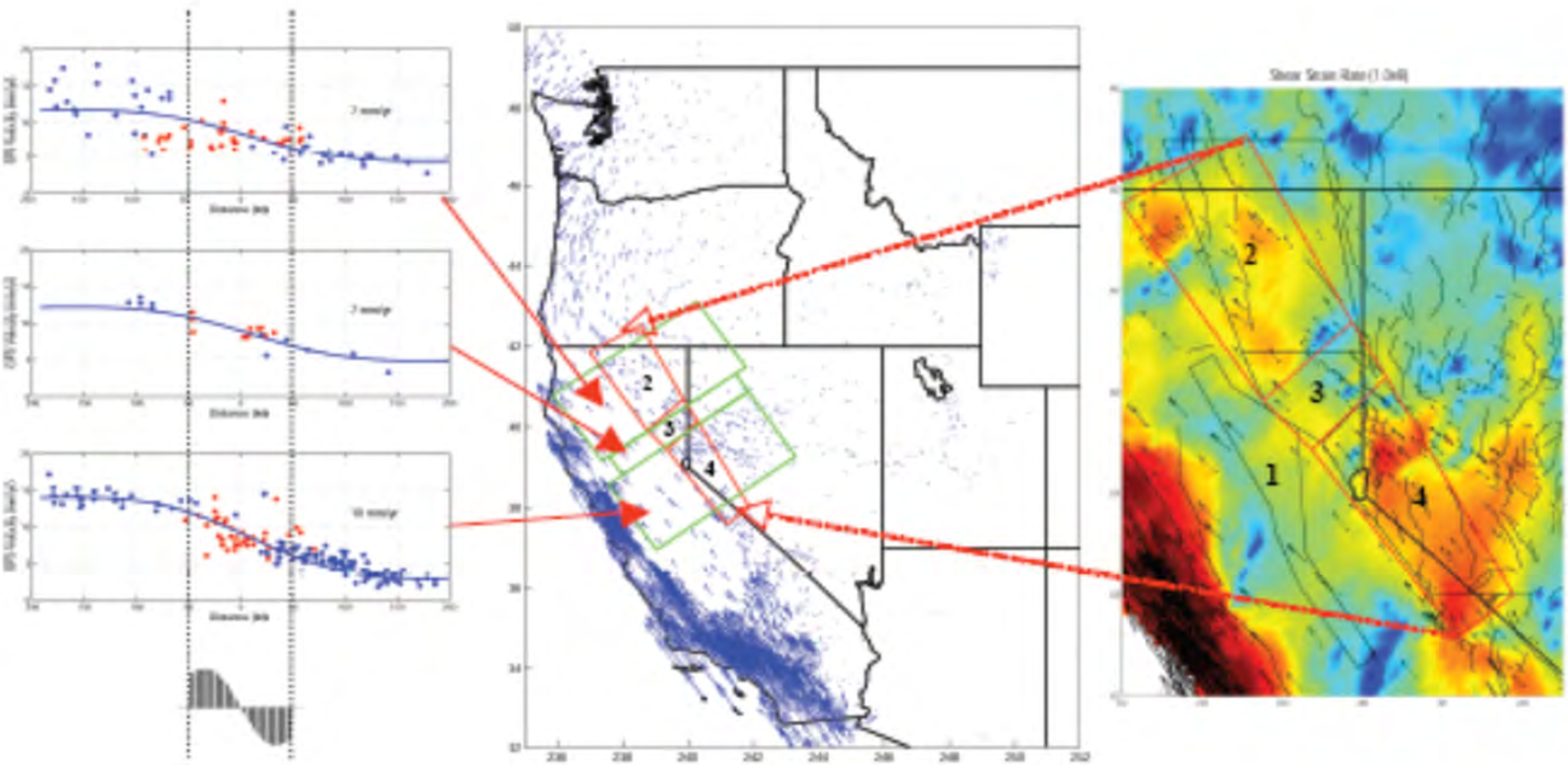
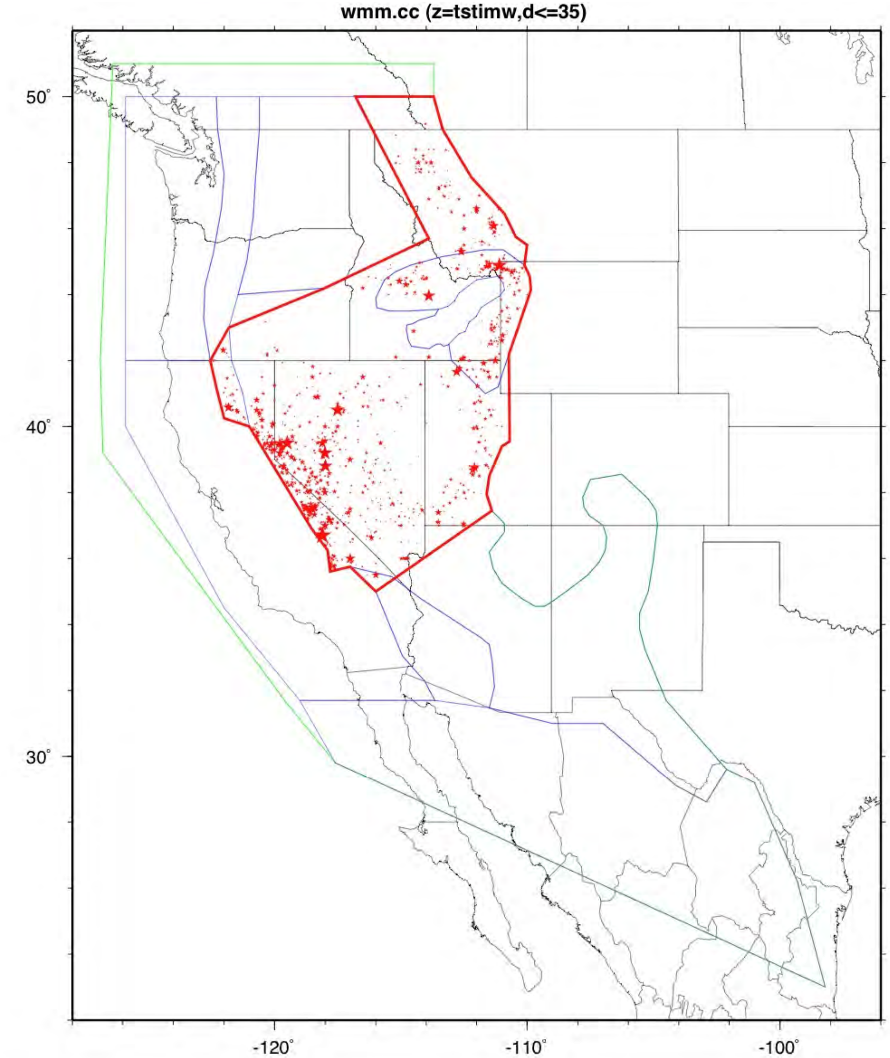
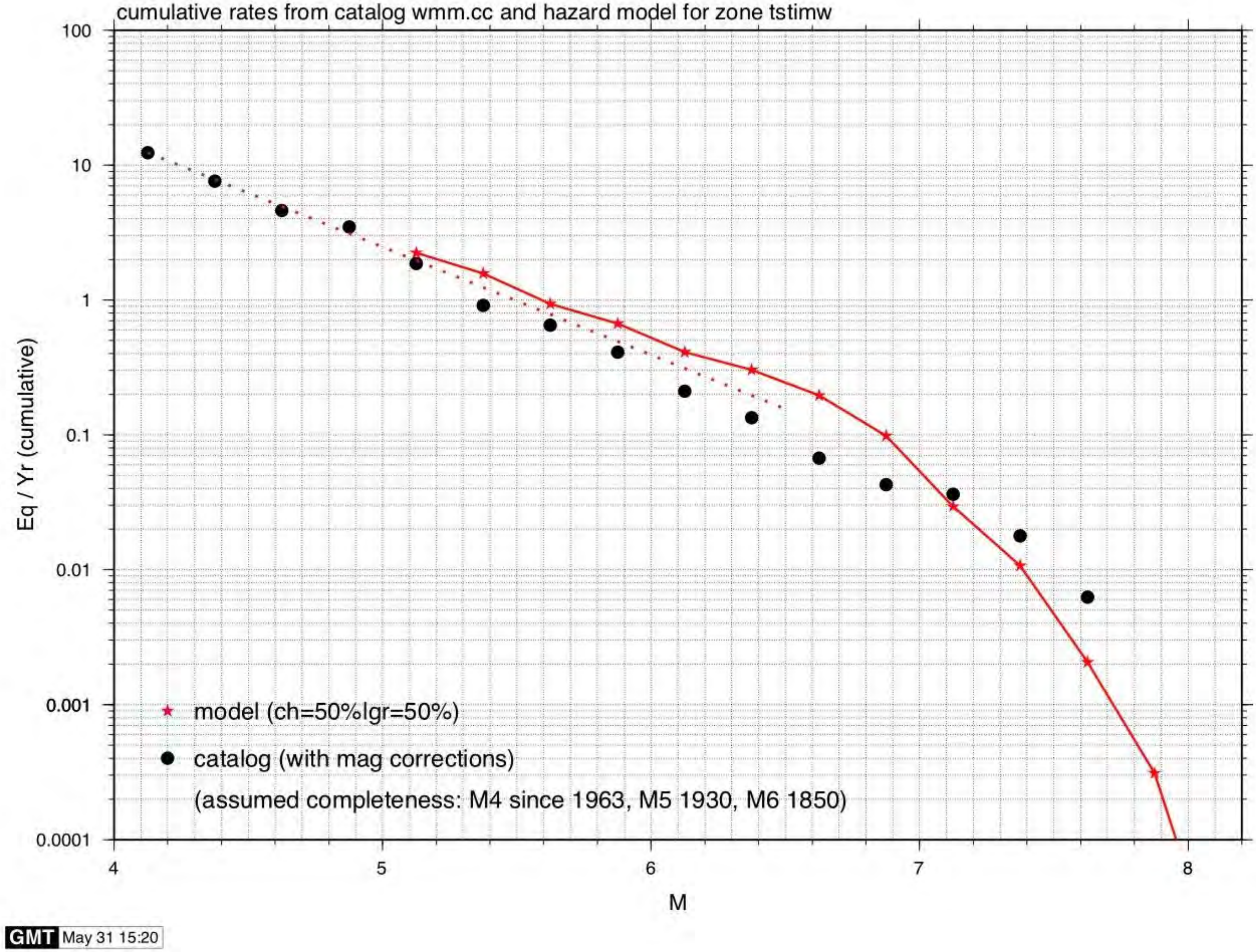


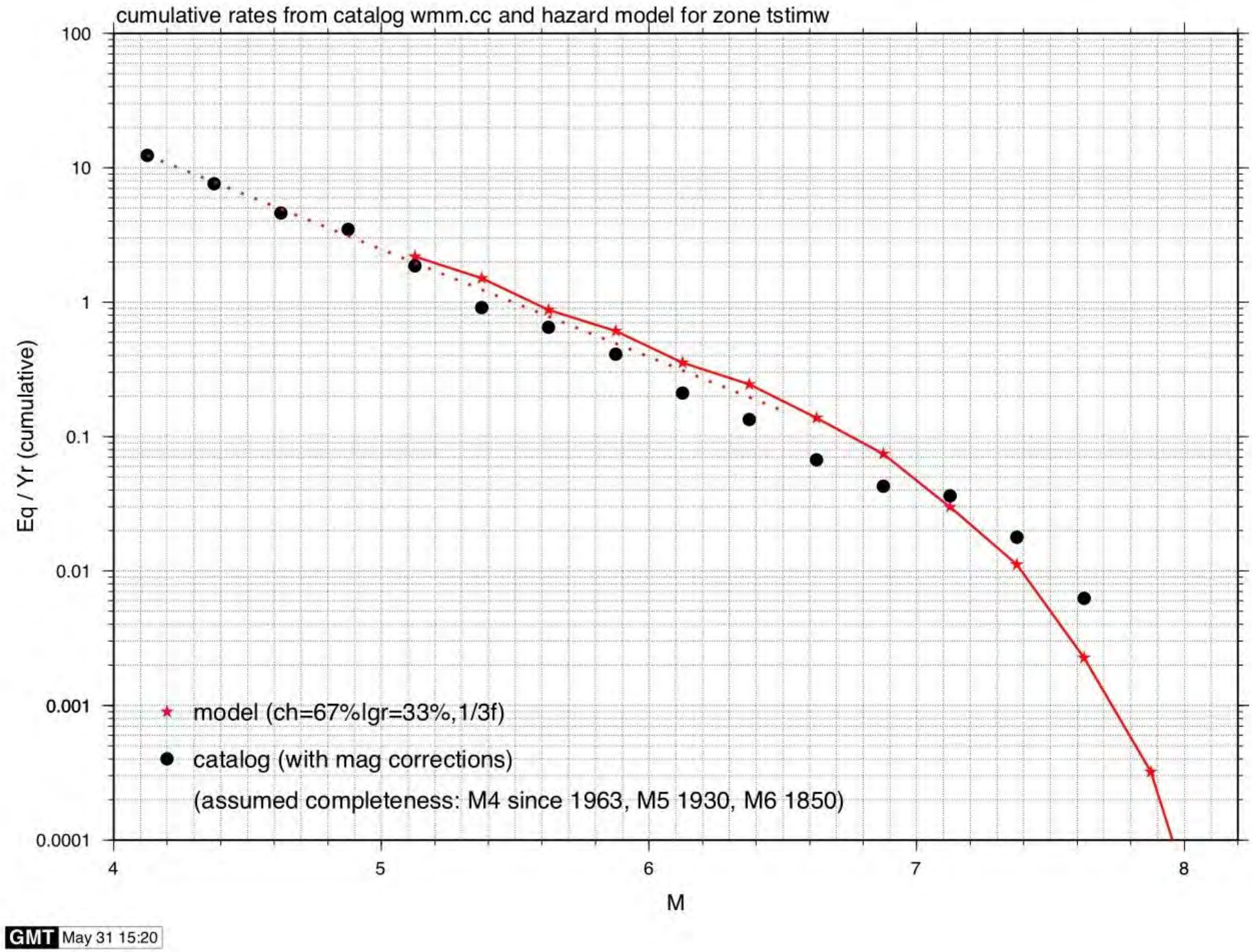
Figure 16. Moment estimated from Global Positioning System (GPS) data.

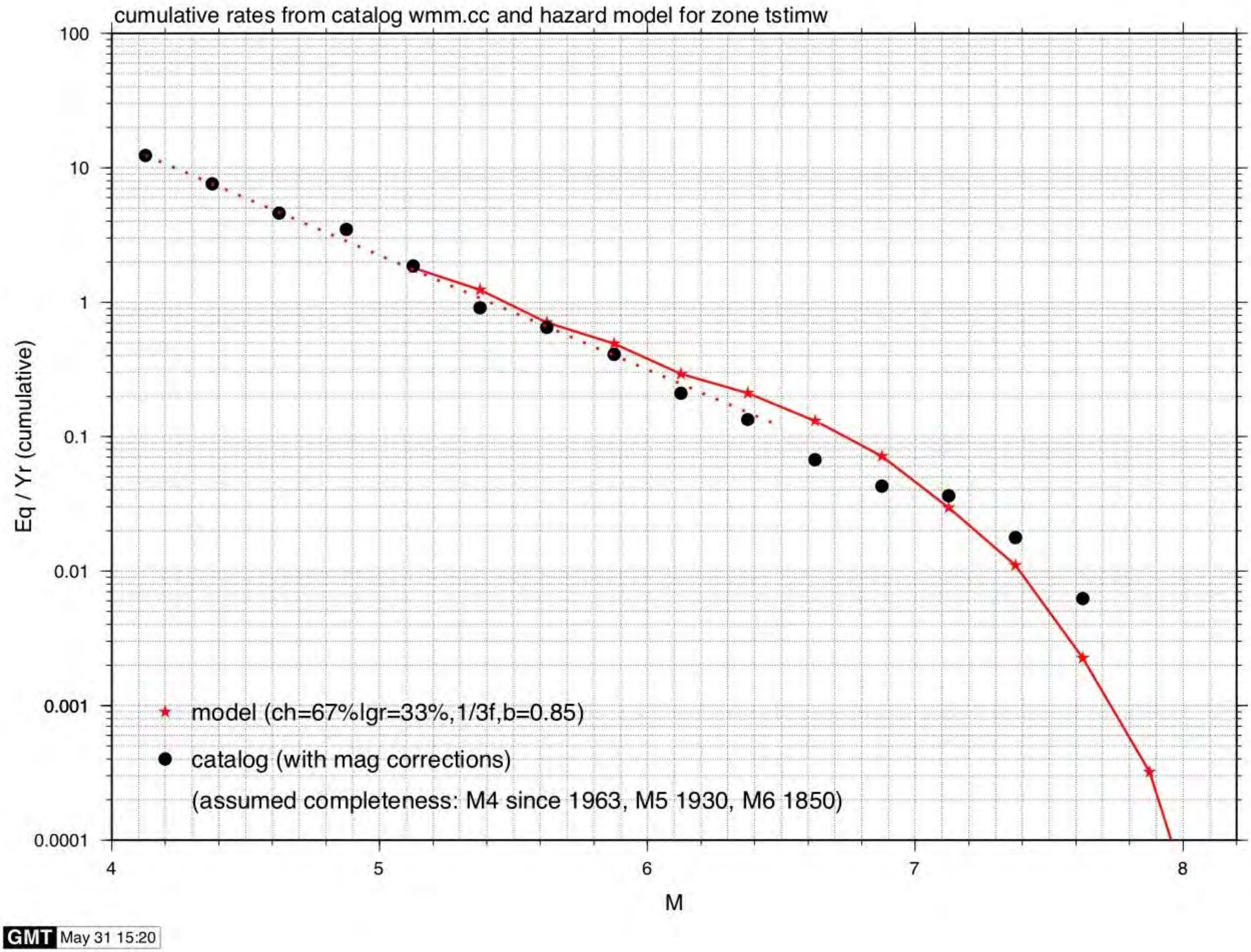
wmm.cc (z=tstimw,d<=35)




GMT May 15 15:28


cumulative rates from catalog wmm.cc and hazard model for zone tstimw
100
10
1
0.1
0.01
0.001
0.0001
Eq / Yr (cumulative)
4
5
6
7
8
M
model (ch=50%lgr=50%)
catalog (with mag corrections)
(assumed completeness: M4 since 1963, M5 1930, M6 1850)
GMT May 31 15:20


cumulative rates from catalog wmm.cc and hazard model for zone tstimw
Eq / Yr (cumulative)
100
10
1
0.1
0.01
0.001
0.0001
4
5
6
7
8
M
model (ch=67%Igr=33%,1/3f)
catalog (with mag corrections)
(assumed completeness: M4 since 1963, M5 1930, M6 1850)
GMT May 31 15:20



cumulative rates from catalog wmm.cc and hazard model for zone tstimw
100
10
1
0.1
0.01
0.001
0.0001
Eq / Yr (cumulative)
4
5
6
7
8
M
model (ch=67%lgr=33%,1/3f,b=0.85)
catalog (with mag corrections)
(assumed completeness: M4 since 1963, M5 1930, M6 1850)
GMT May 31 15:20

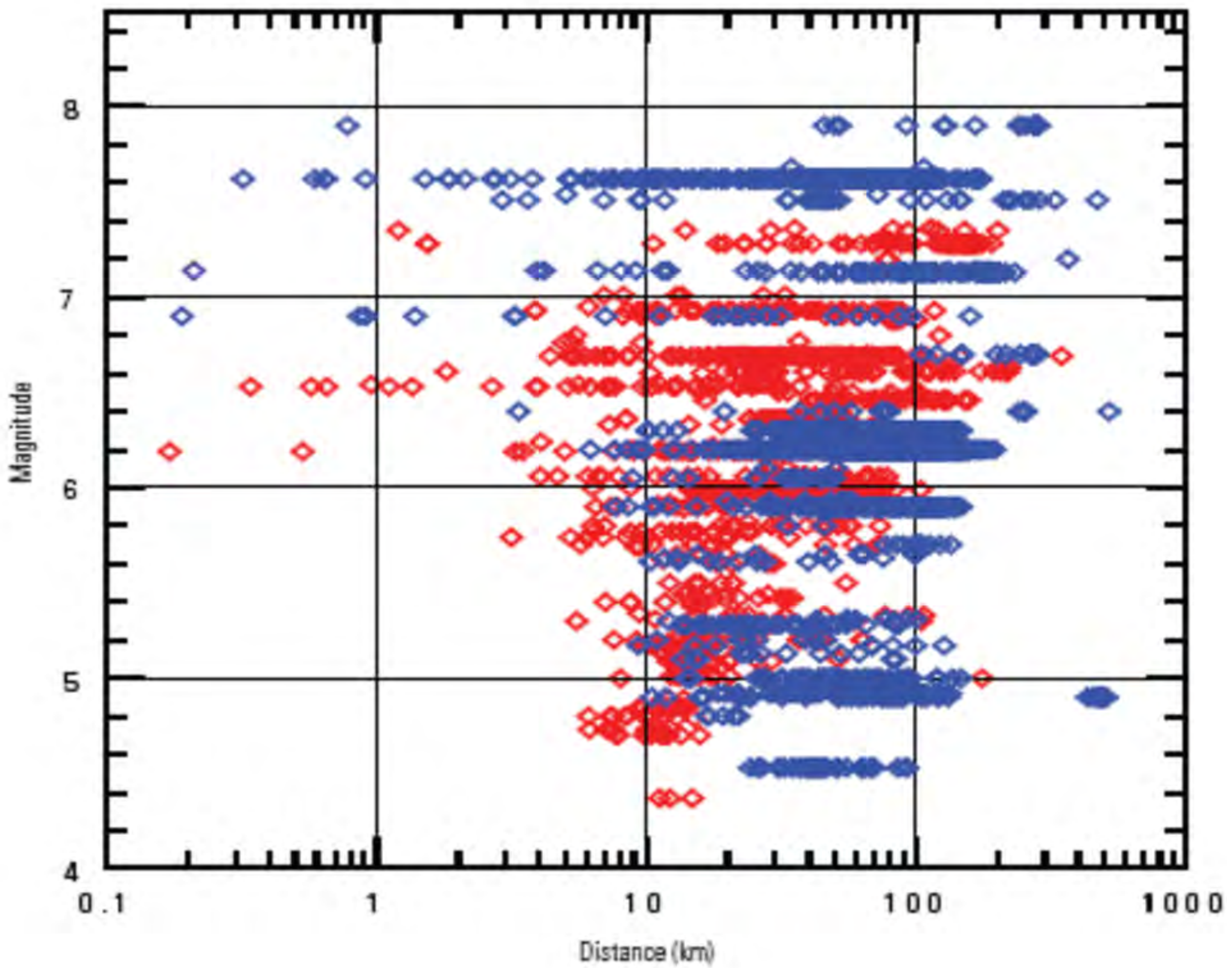



Figure 23. Peer earthquake database. Red diamonds represent the previous data set and the blue diamonds represent the new data set. Illustration provided by Y. Bozorgnia and K. Campbell.

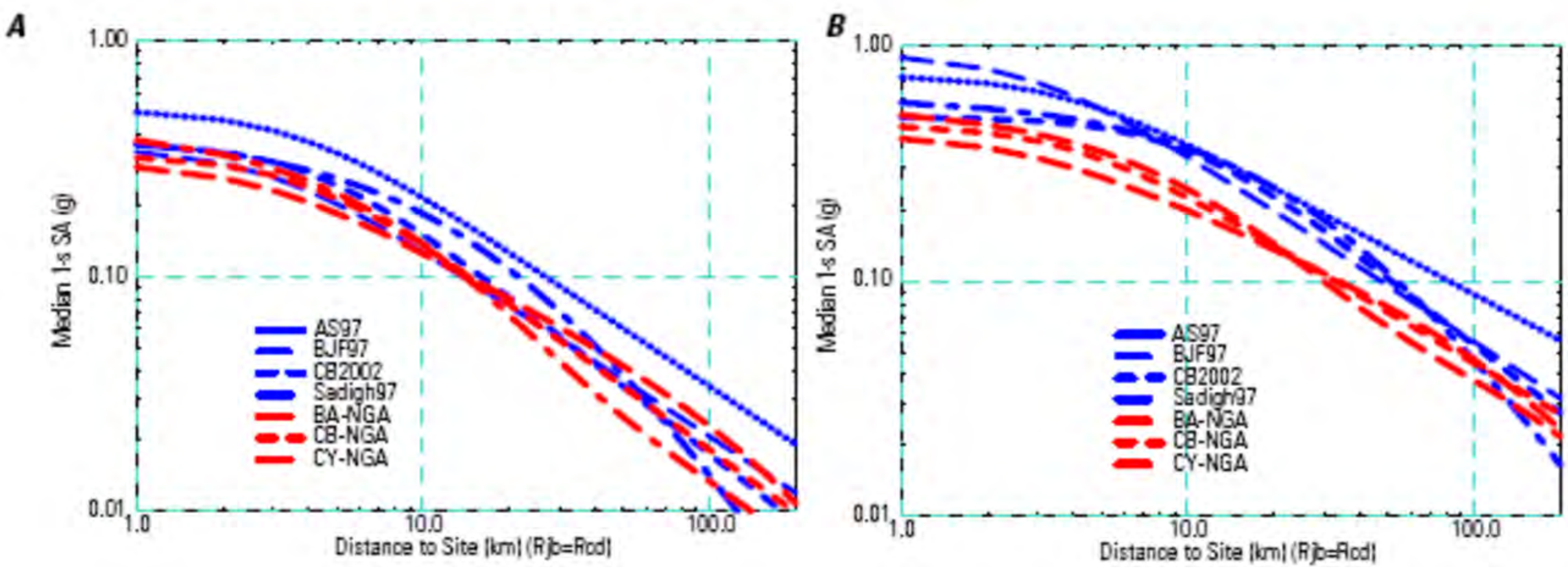



Figure 25. WUS ground motion (1-s SA) for (***A***) M6.5 earthquakes and (***B***) M7.5 earthquakes from strike-slip source at firm rock site.

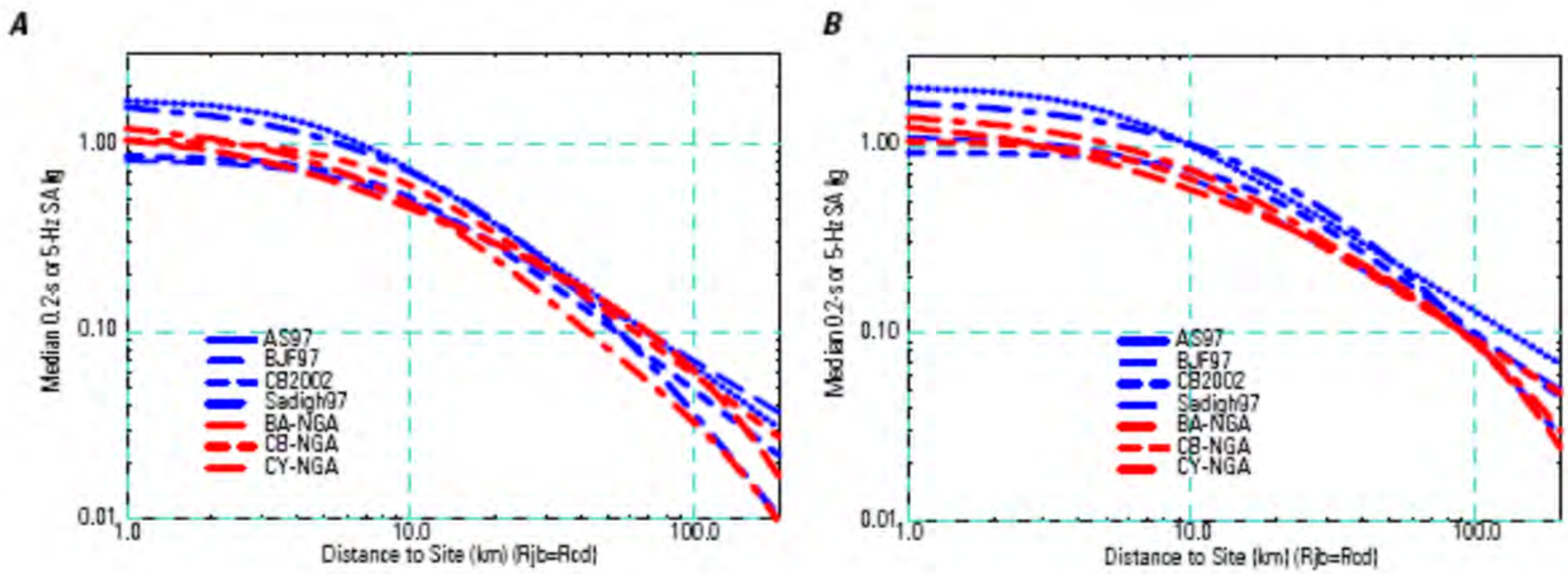
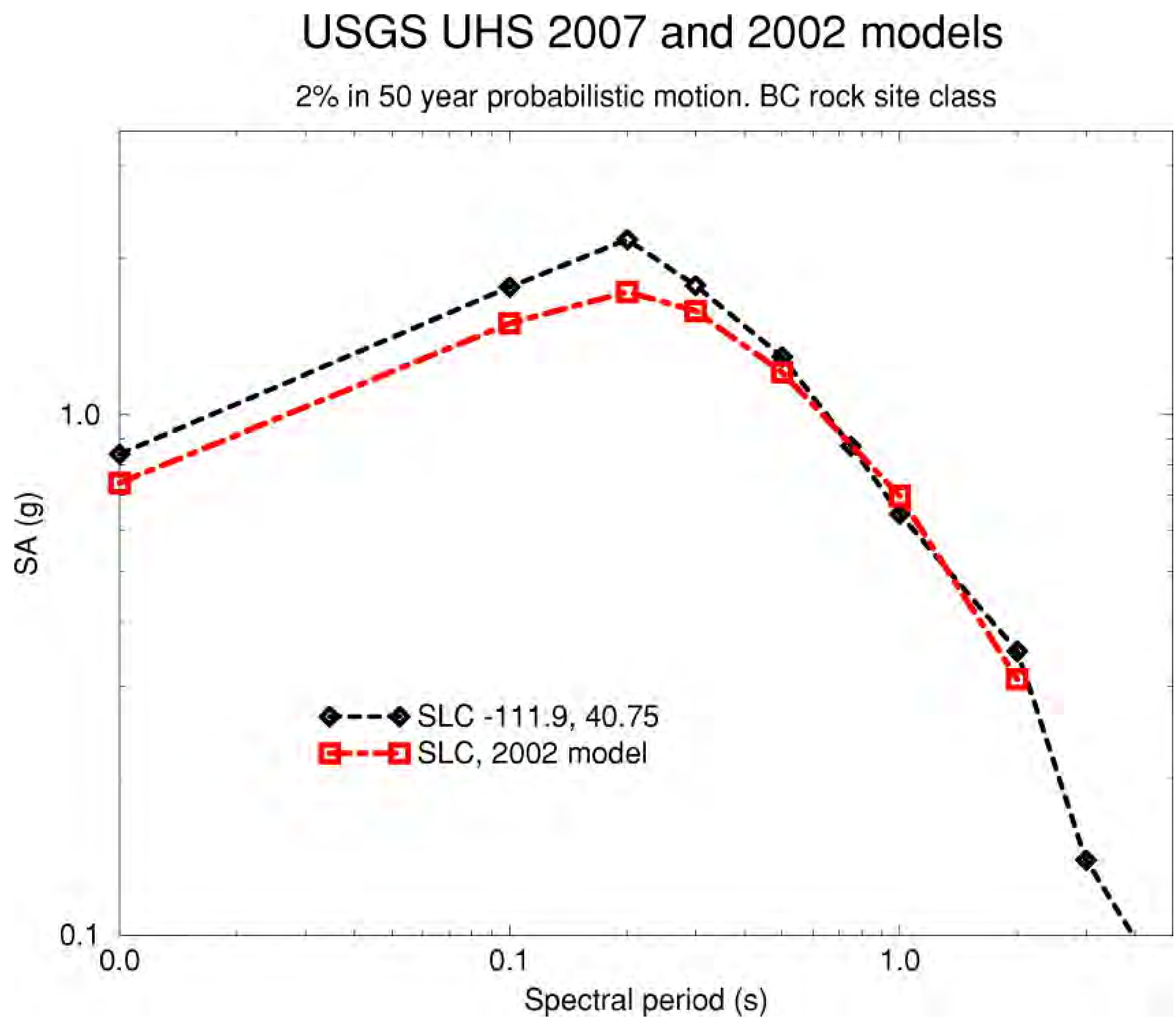
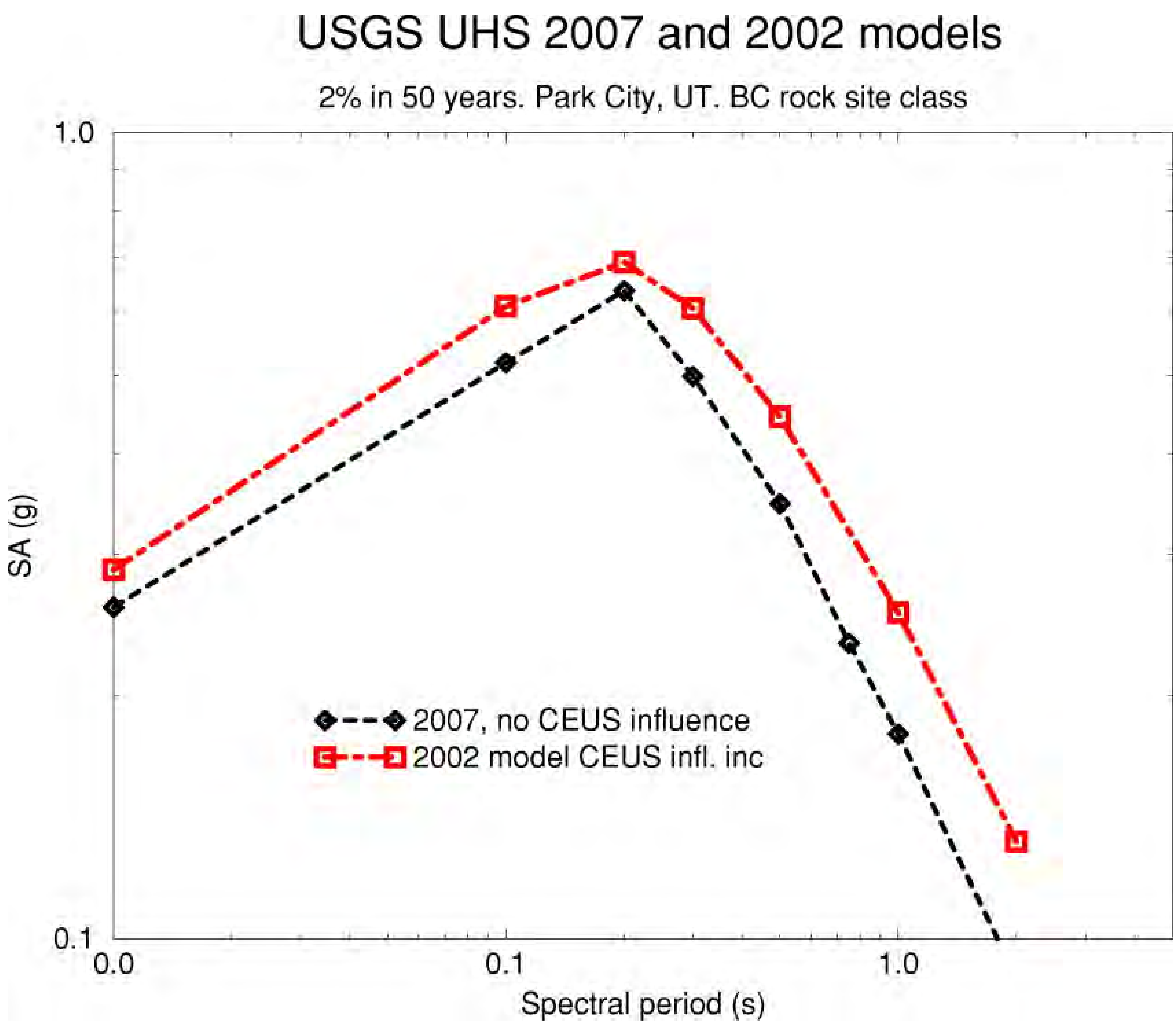
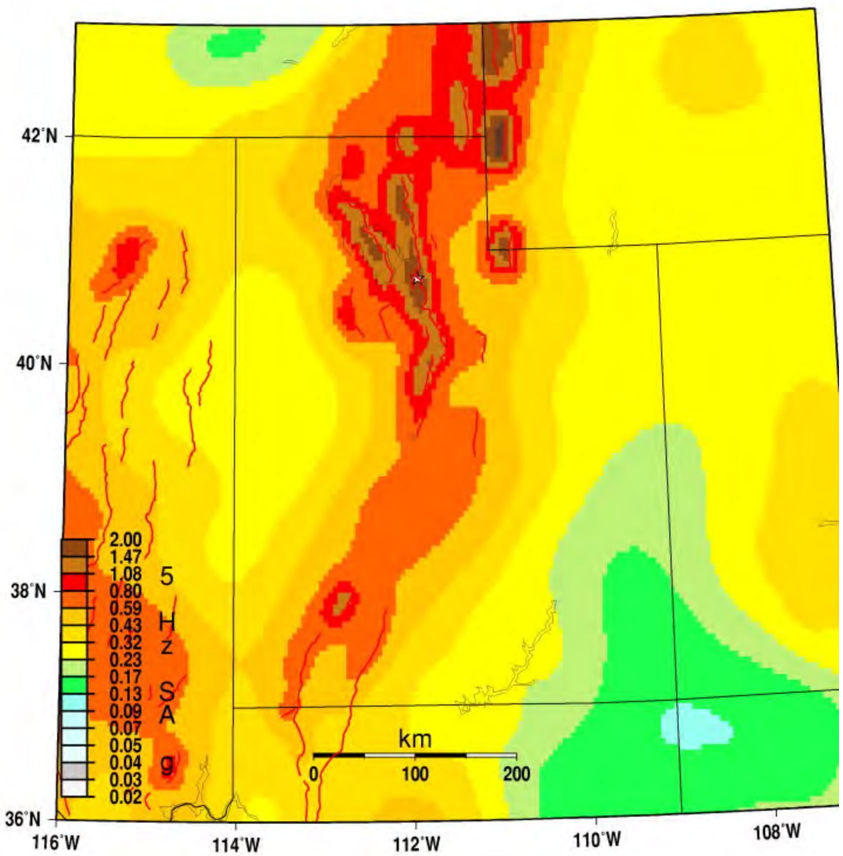



Figure 24. WUS ground motion (1-s SA) for (***A***) M6.5 earthqukes and (***B***) M7.5 earthquakes from strike-slip source at firm rock site.


USGS UHS 2007 and 2002 models
2% in 50 year probabilistic motion. BC rock site class
SA (g)
1.0
0.1
0.0
0.1
1.0
Spectral period (s)
SLC -111.9, 40.75
SLC, 2002 model

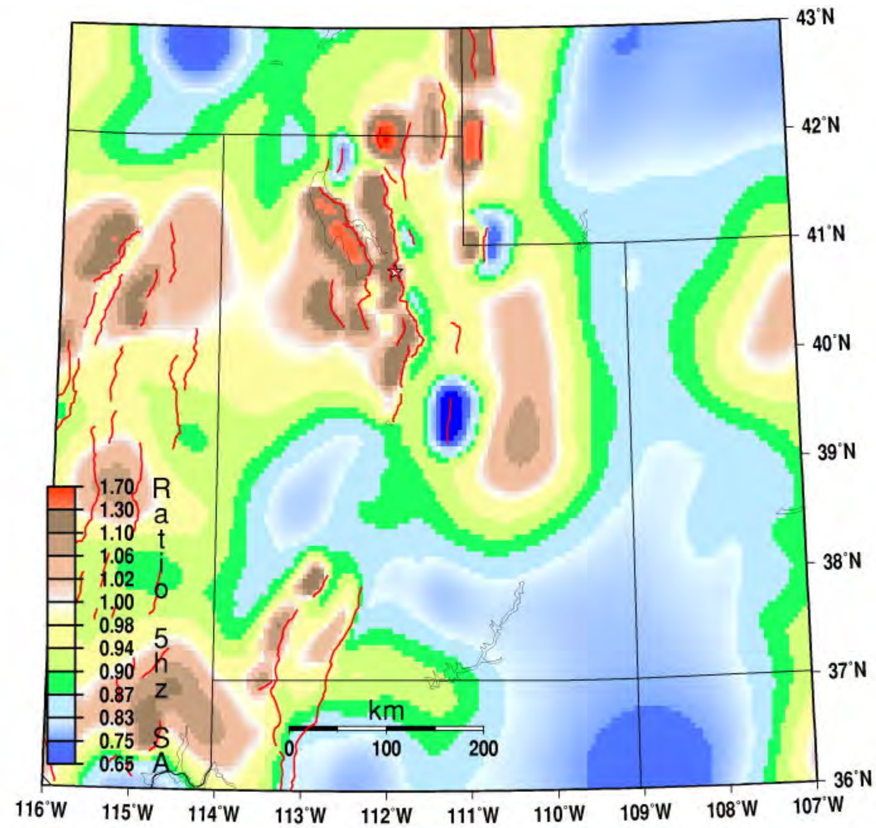

USGS UHS 2007 and 2002 models
2% in 50 years. Park City, UT. BC rock site class
1.0
0.1
SA (g)
0.0
0.1
1.0
Spectral period (s)
2007, no CEUS influence
2002 model CEUS infl. inc

Utah 2007 5-Hz SA w/2%PE50YR



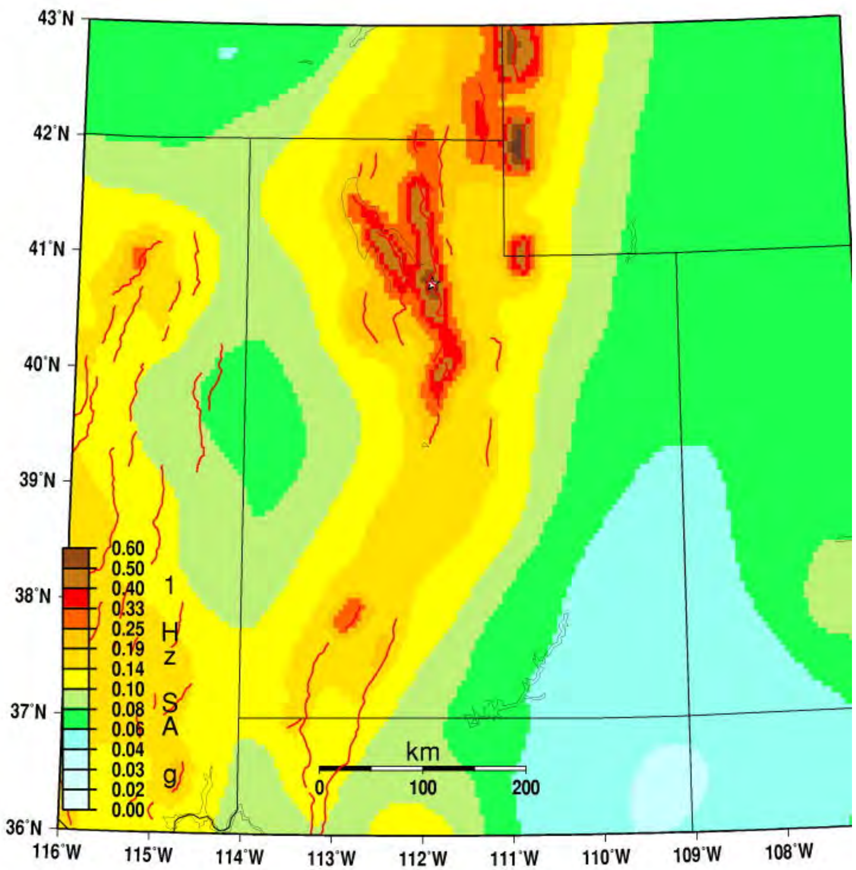

GMT Jan 7 09:42 SA for Utah 2007.. Site Vs30 760ms. 5 Hz 2%50 yr PE.

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



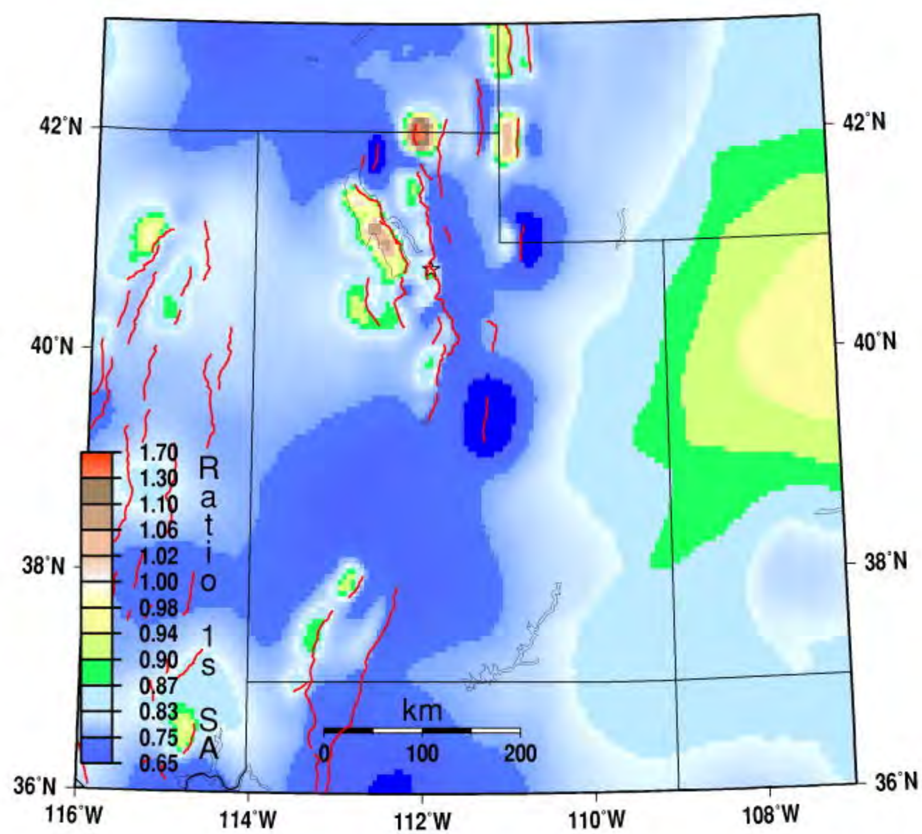

GMT Jan 7 09:43 SA ratio , 2007 over 2002. Site Vs30 760 m/s. 5 Hz 2%50 yr PE. Red lines Qfaults. Dark blue means decrease more than 35%

Utah 2007 1-Hz SA w/2%PE50yr




GMT Jan 7 09:25 SA for Utah Dec 2007 Site 760ms. 1 Hz 2%50 yr PE. Qfaults are red lines.

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




GMT Jan 7 09:15 SA ratio for Utah. 2007 over 2002. Site 760ms. 1 Hz 2%50 yr PE. denom is 2002 . Dark blue decrease more than 35%

# Plans for Urban Hazard Maps

- Construct community velocity model
- Validate model using small earthquakes
- Determine where new data is needed
- Compute 3-d ground motions (several teams)
- Compute shallow ground motions from Wasatch earthquakes (several teams)
- Compare relative ground motions from different teams with NGA equations
- Develop hazard map by modifying NGA equations for site effects

# External Grants Budget

- $6.4 million
- Presidents budget request for FY09 has reduction of $3 million targeted to external research support

# SOURCE CHARACTERIZATION

- Use the same faults used in the NSHM (including additions for the 2007 update); less active, poorly understood faults that don’t meet NSHM fault criteria will not be included.
- The UQFPWG and UGS will work with the USGS to define fault parameters for faults in the urban hazard maps.

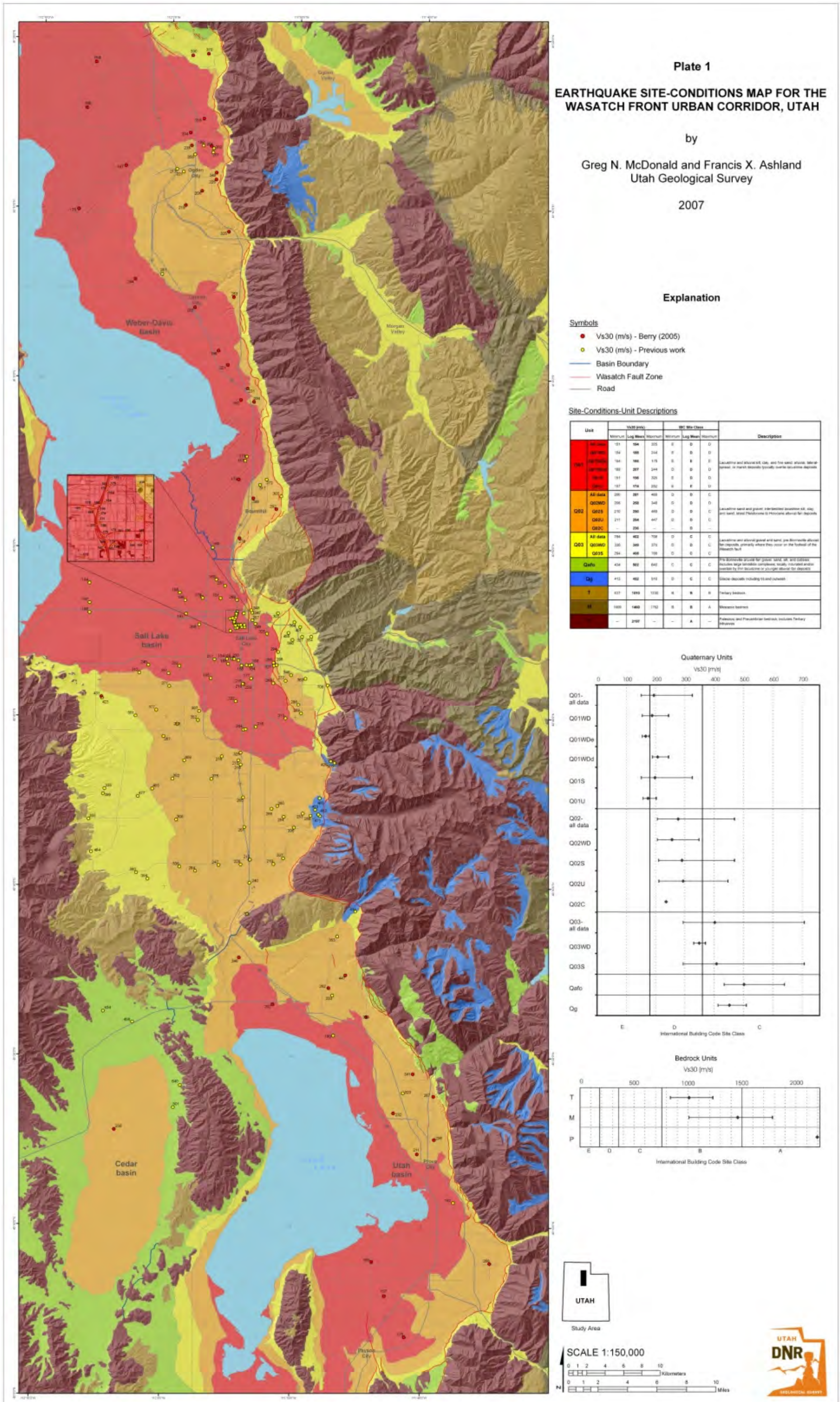
# SOURCE CHARACTERIZATION (cont.)

- The USGS performs full logic-tree analysis for uncertainties in fault parameters, even though this is not done for the NSHMs.

- USGS has incorporated most BRPEWG source-characterization recommendations, including 2/3 max. magnitude/1/3 exponential magnitude-frequency relationship for B&R faults.

# SOURCE CHARACTERIZATION (cont.)

- Rupture directivity will be addressed in 3D simulations.
- Gridded/regional background seismicity
- Geodetic rates




# Earthquake Site-Conditions Map for the Wasatch Front Urban Corridor

**Ref: McDonald and Ashland, 2007, UGS Special Study 125**

**map/shape files available upon request**

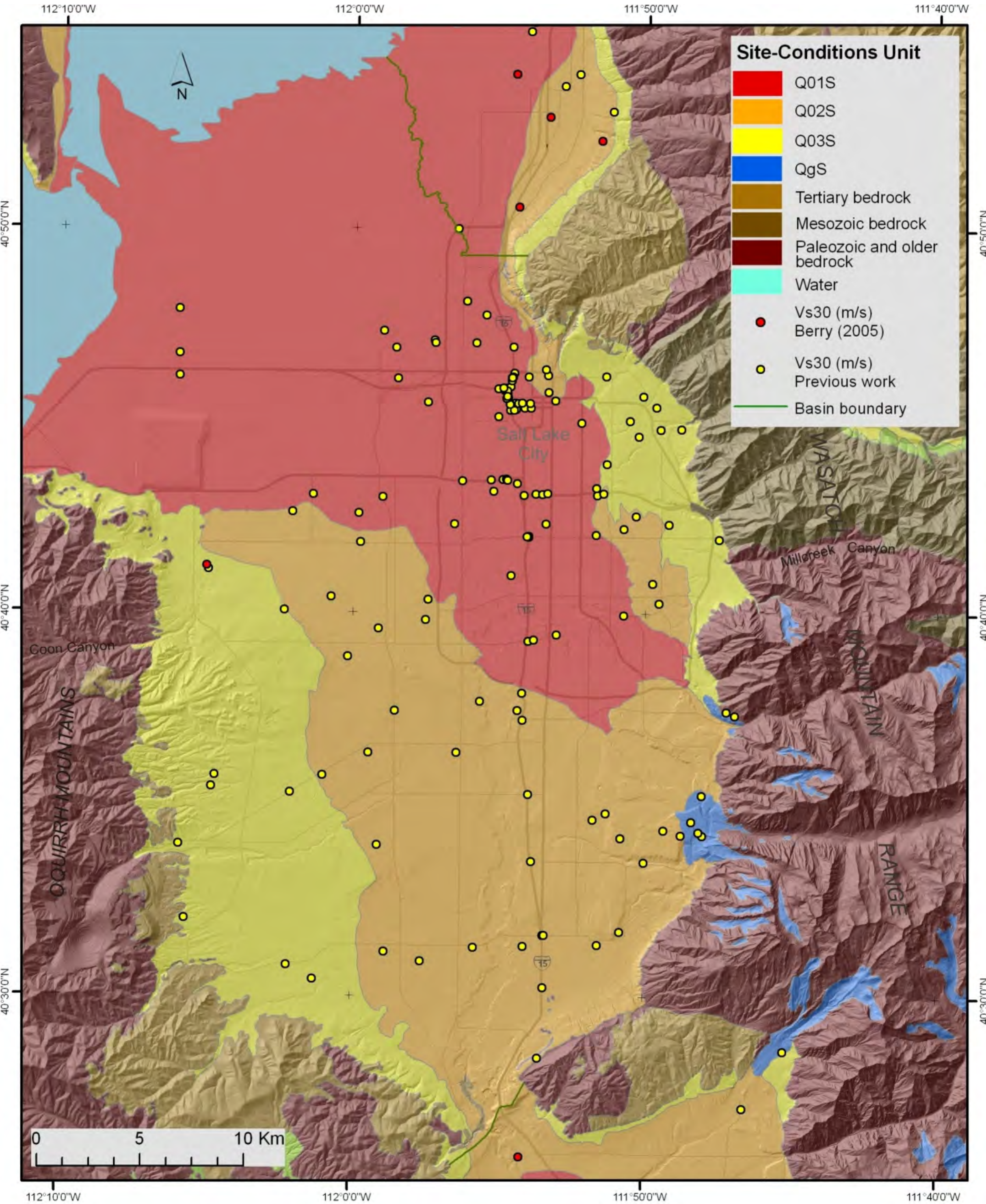



Figure 2. Salt Lake basin site-conditions map from Ashland and others (2005).
See plate 1 for detailed unit descriptions and Vs30 values.

# Salt Lake basin

139 Vs30 profiles
(68% of WF total)

Q01S – 198 m/s

Q02S – 290 m/s

Q03S – 408 m/s

Qg – 453 m/s

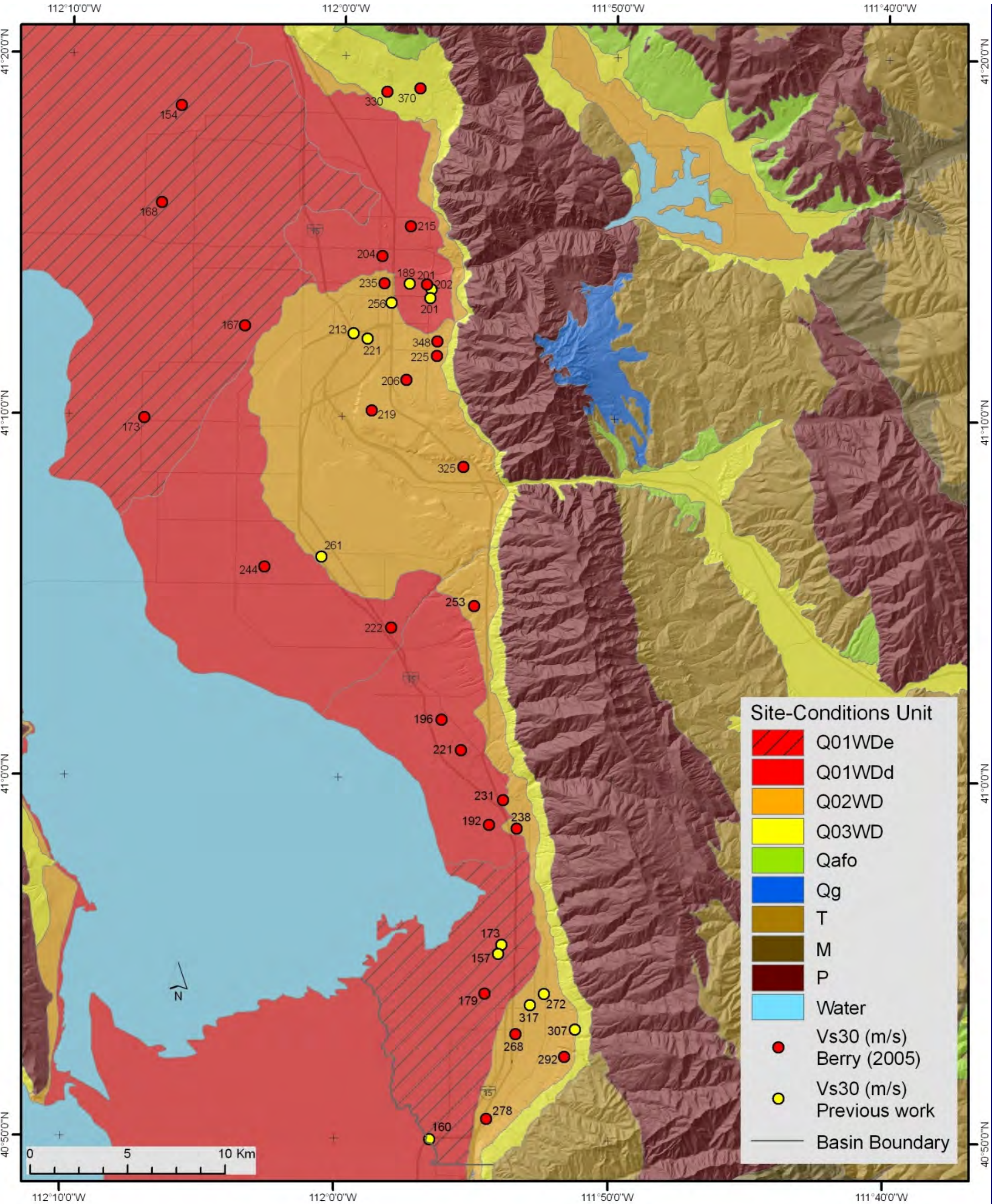



Figure 24. Weber-Davis composite basin site-conditions units (see plate 1 for unit descriptions).

# Weber-Davis basin

## 24 Vs30 profiles

Q01WDe – 166 m/s

Q01WDd – 207 m/s

Q02WD – 256 m/s

Q03WD – 349 m/s

Qafo – 502 m/s

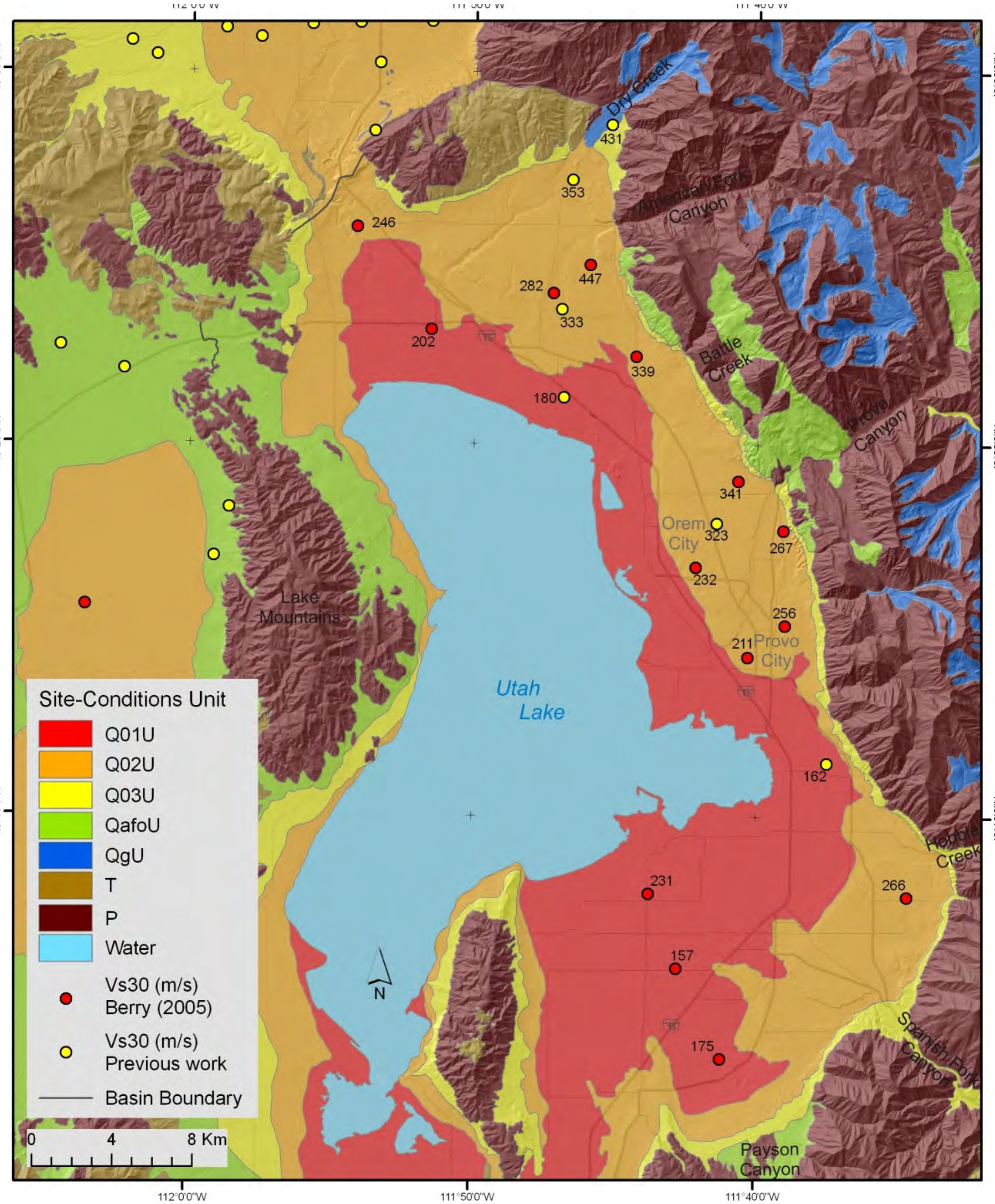



Figure 16. Utah basin site-conditions units (see Plate 1 for unit descriptions)

# Utah basin

20 Vs30 profiles

Q01U – 174 m/s

Q02U – 267 m/s

Q03U – 363 m/s

Qafo - 502

Qg – 453 m/s

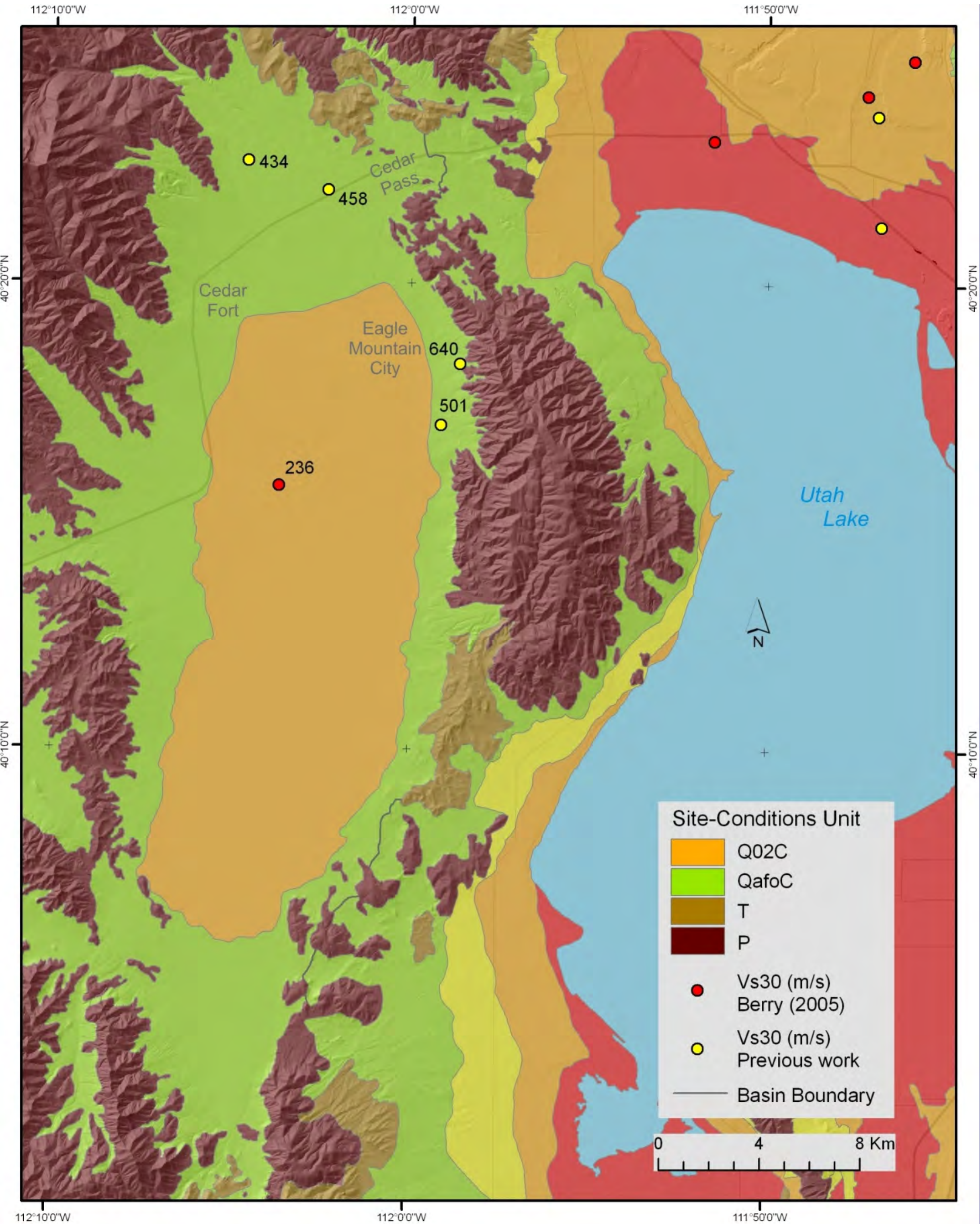



Figure 19. Cedar basin site-conditions units (see plate 1 for unit descriptions).

# Cedar basin

5 Vs30 profiles

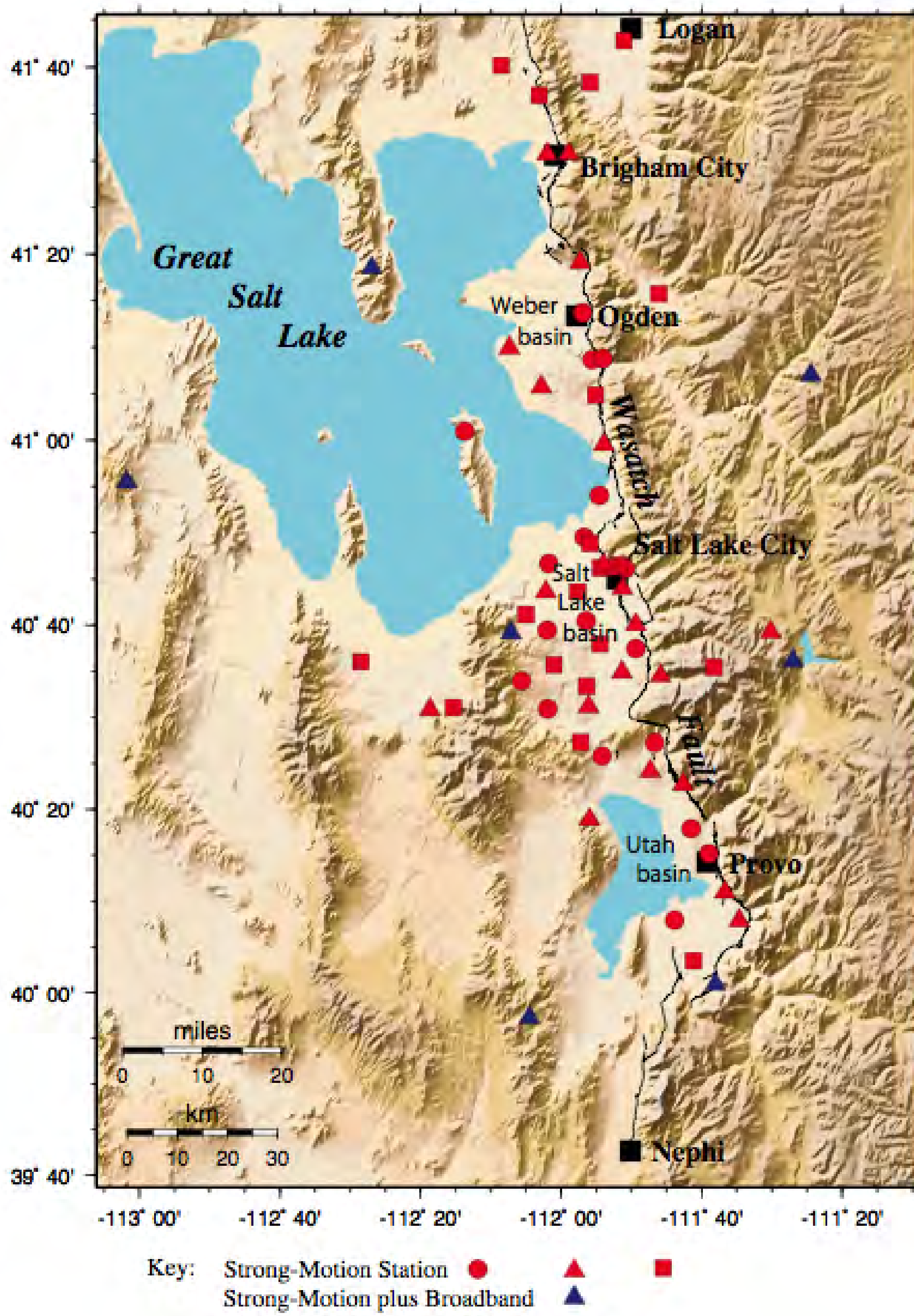
Q02C – 236 m/s

Qafo – 502 m/s

# The Wasatch Front Community Velocity Model

Harold Magistrale SDSU
Jim Pechmann UUSS
Kim Olsen SDSU

Utah GSWG Meeting 2/12/08


Logan
Brigham City
Great
Salt
Lake
Weber
basin
Ogden
Wasatch
Salt Lake City
Salt
Lake
basin
Fault
Utah
basin
Provo
Nephi
miles
0
10
20
km
0
10
20
30
41° 40'
41° 20'
41° 00'
40° 40'
40° 20'
40° 00'
39° 40'
-113° 00'
-112° 40'
-112° 20'
-112° 00'
-111° 40'
-111° 20'
Key: Strong-Motion Station
Strong-Motion plus Broadband

# Wasatch Front Model Elements

-Soil classes

-Geotechnical boreholes/shear wave profiles

-Basin sediment interfaces:

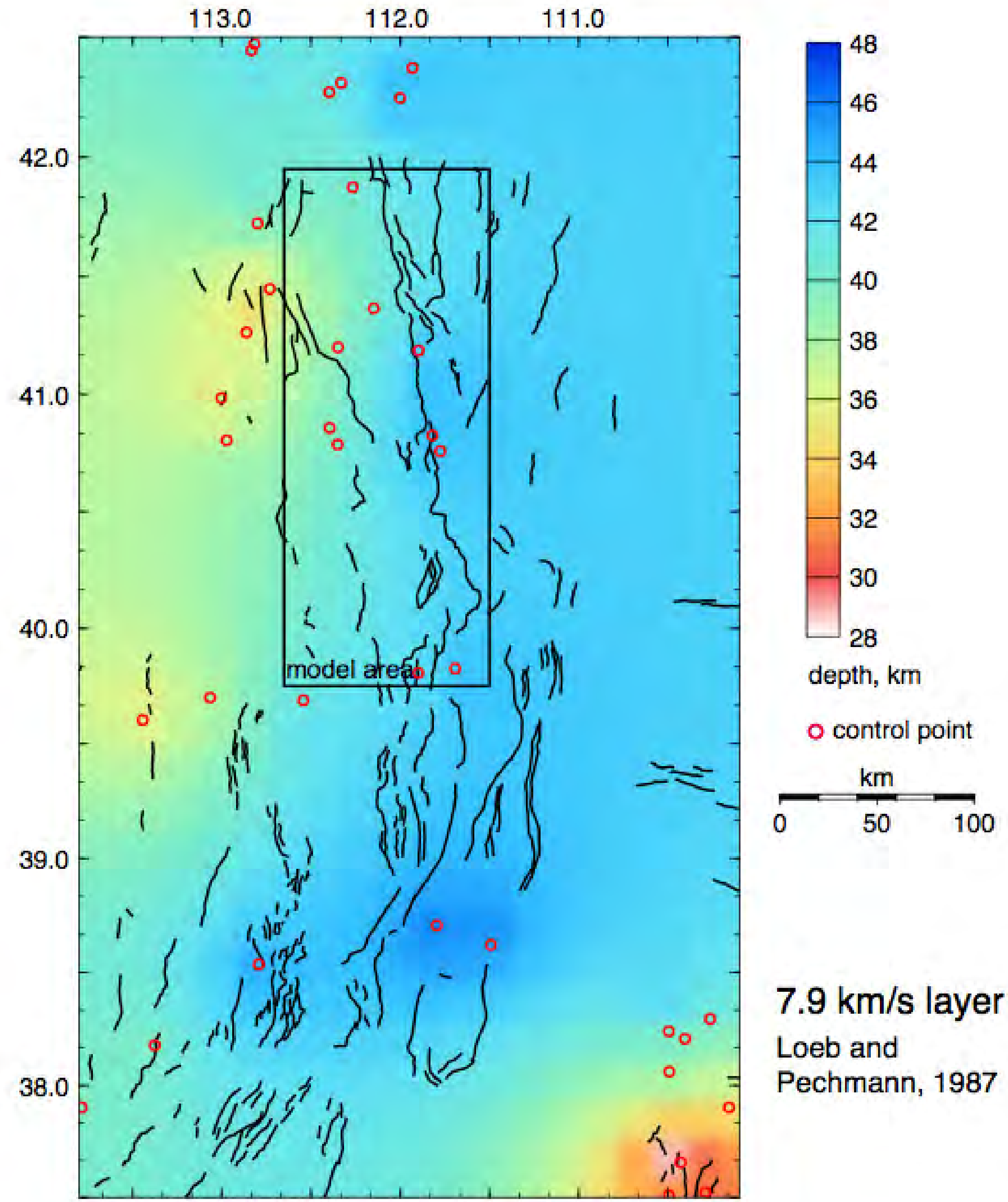
    -R1, R2, R3 in Salt Lake Valley

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

-Deep boreholes (seismic velocities)

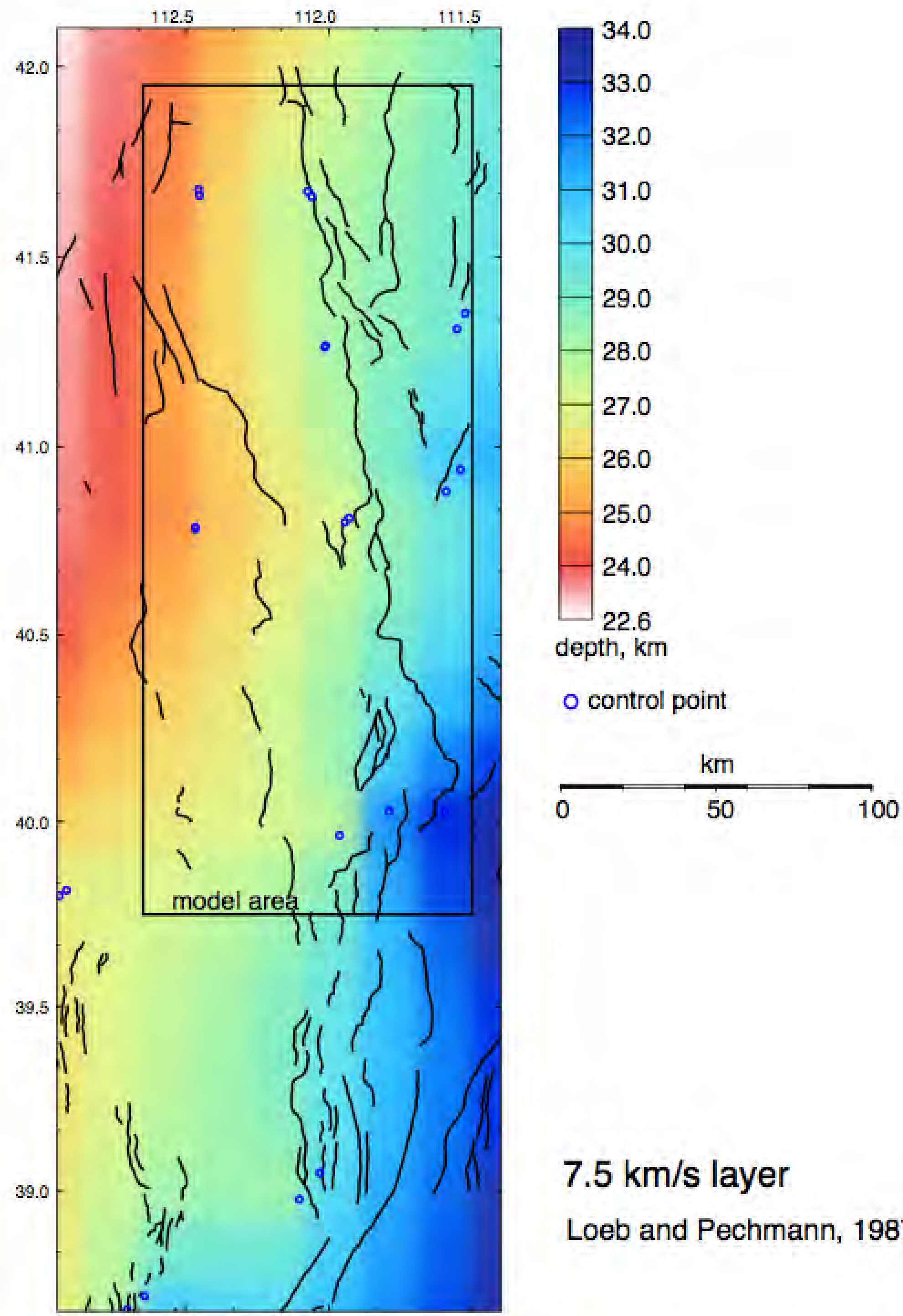
-Crustal tomography

-Moho (upper mantle Vp)



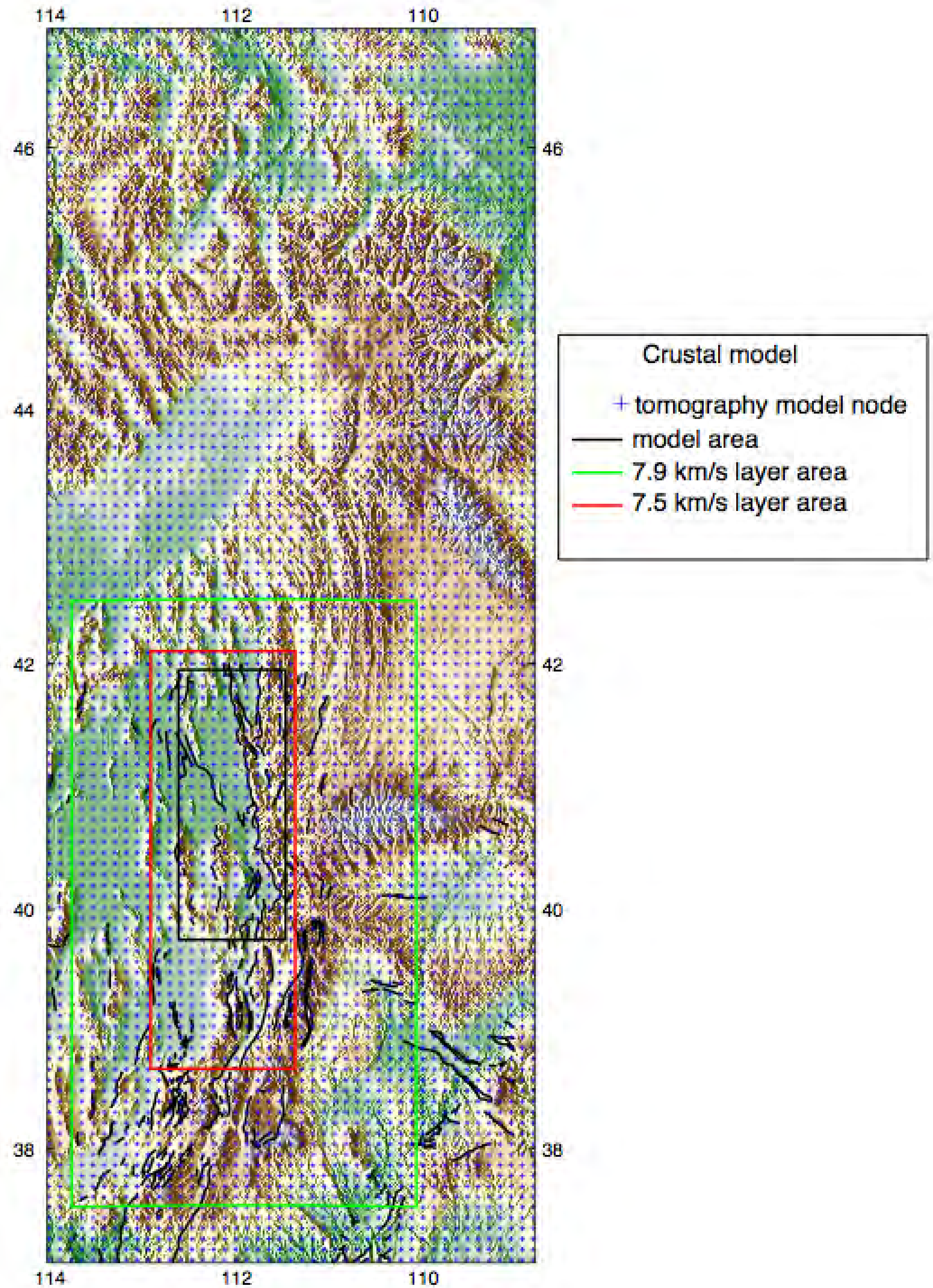

7.9 km/s layer

Loeb and Pechmann, 1987

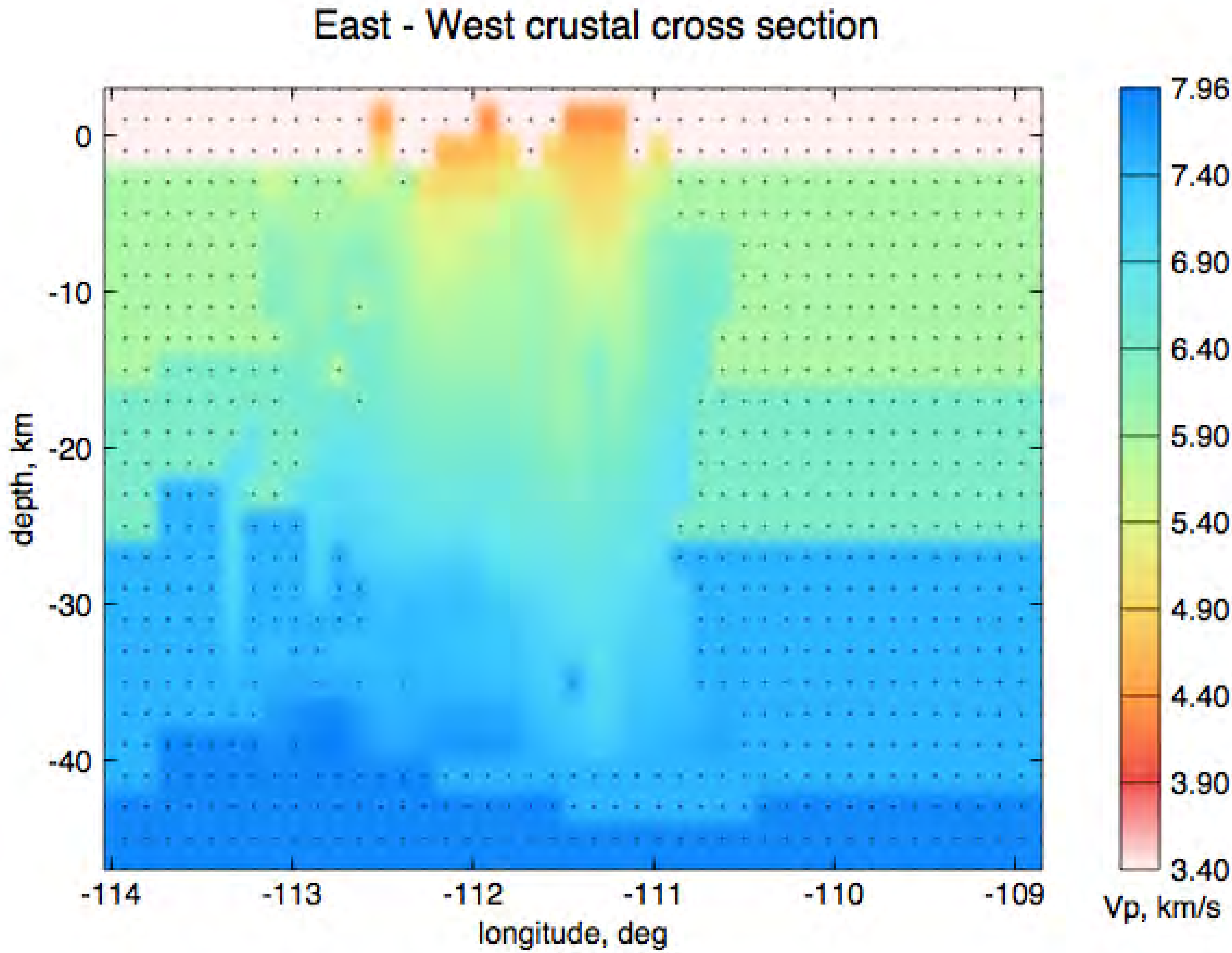



7.5 km/s layer

Loeb and Pechmann, 1987



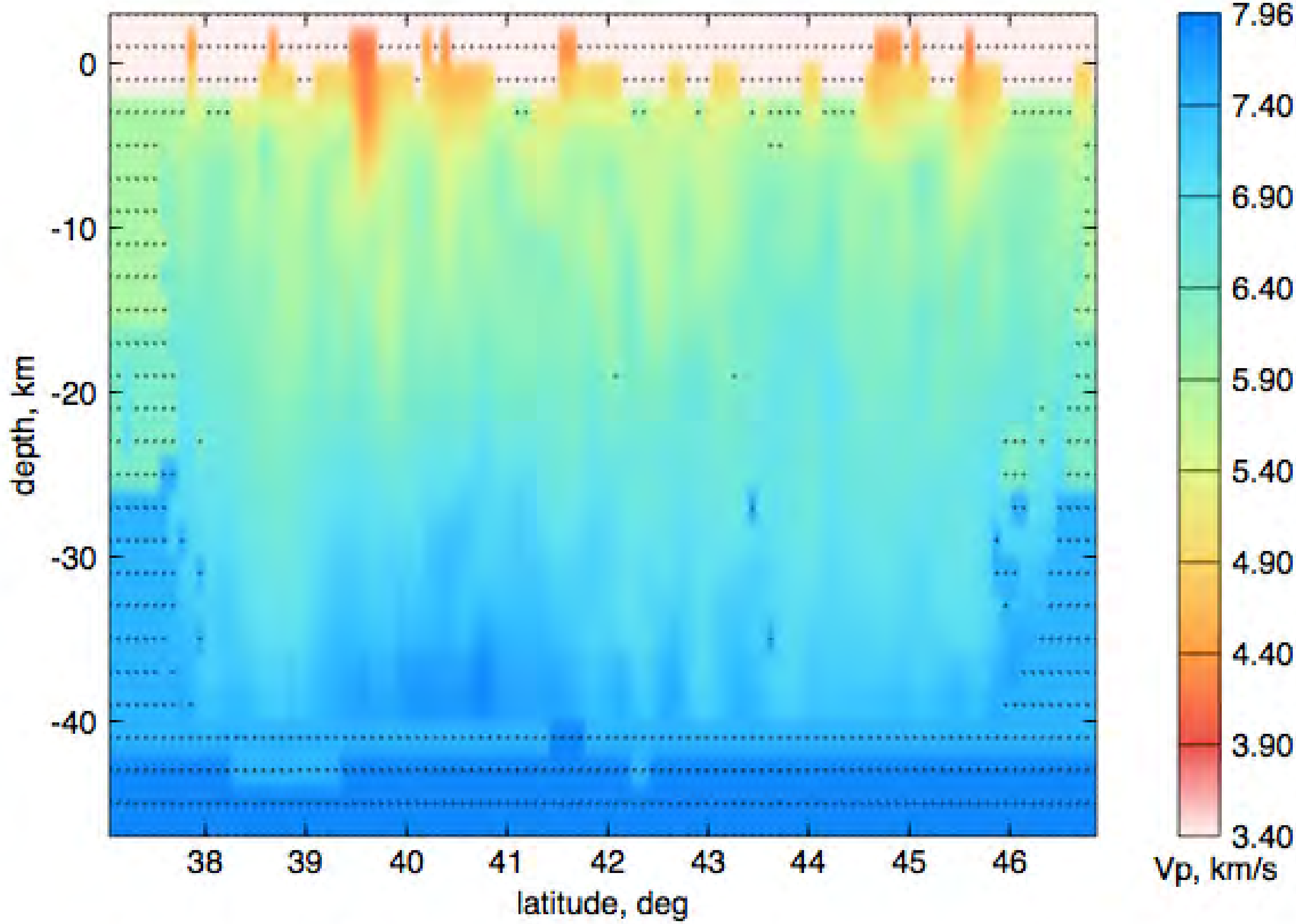
114
112
110
46
44
42
40
38
Crustal model
tomography model node
model area
7.9 km/s layer area
7.5 km/s layer area




latitude = 40° 28'

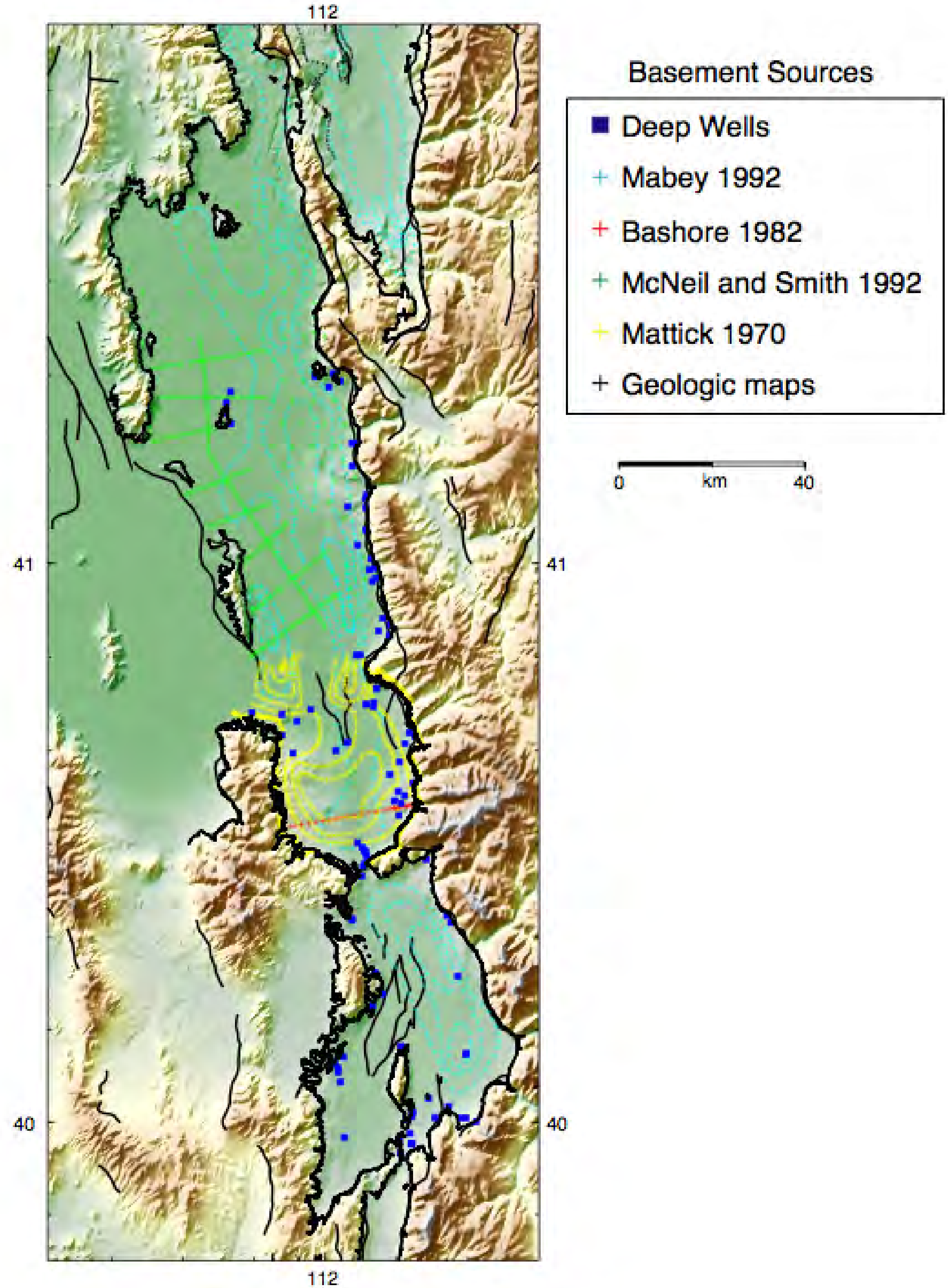
Lynch 1999 and
standard 1D

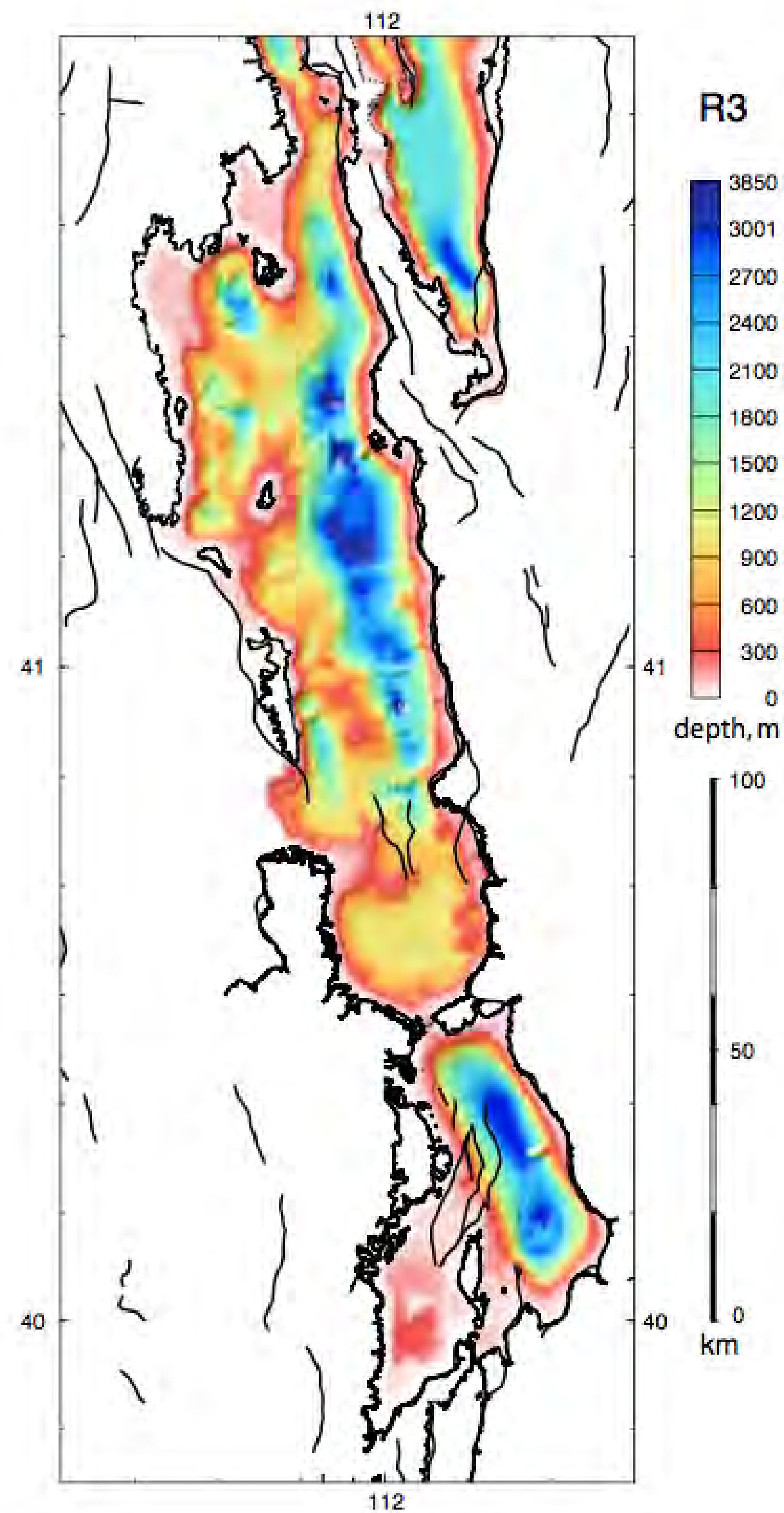
# North - South crustal cross section



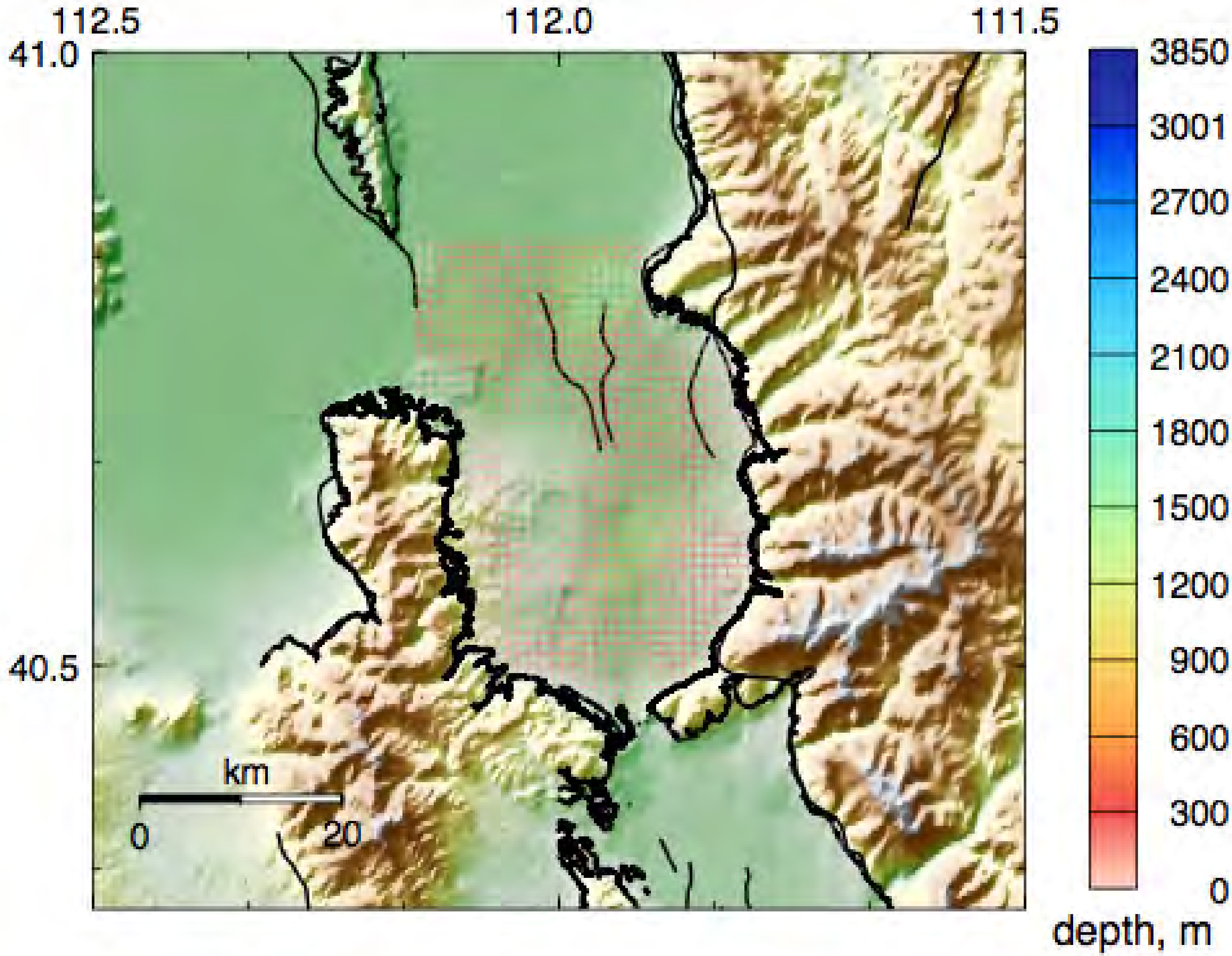

longitude = -112° 2'

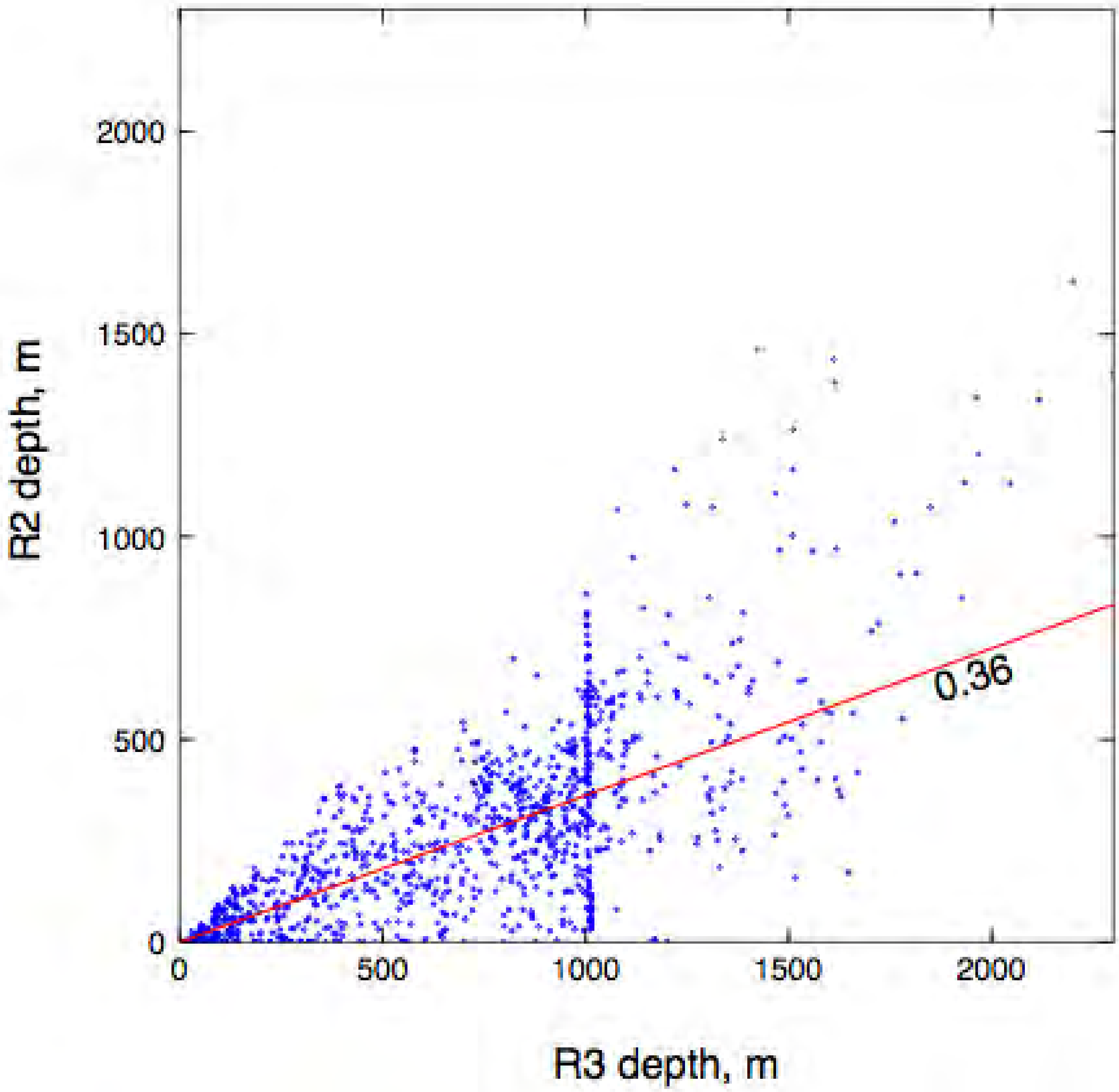
Lynch 1999 and
standard 1D


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

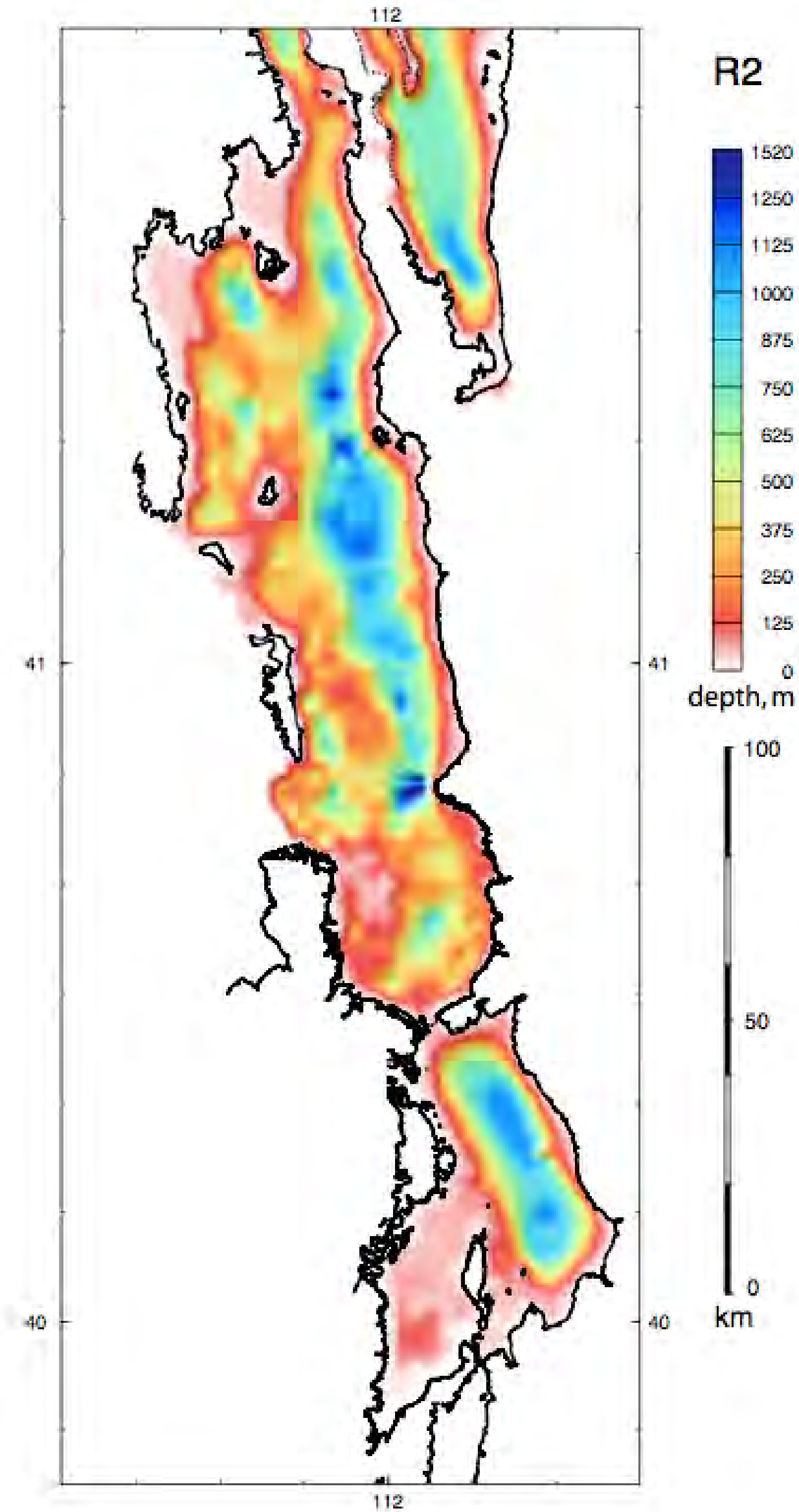

R3
3850
3001
2700
2400
2100
1800
1500
1200
900
600
300
0
depth, m
100
50
0
km
112
41
40

# Radkins, 1990

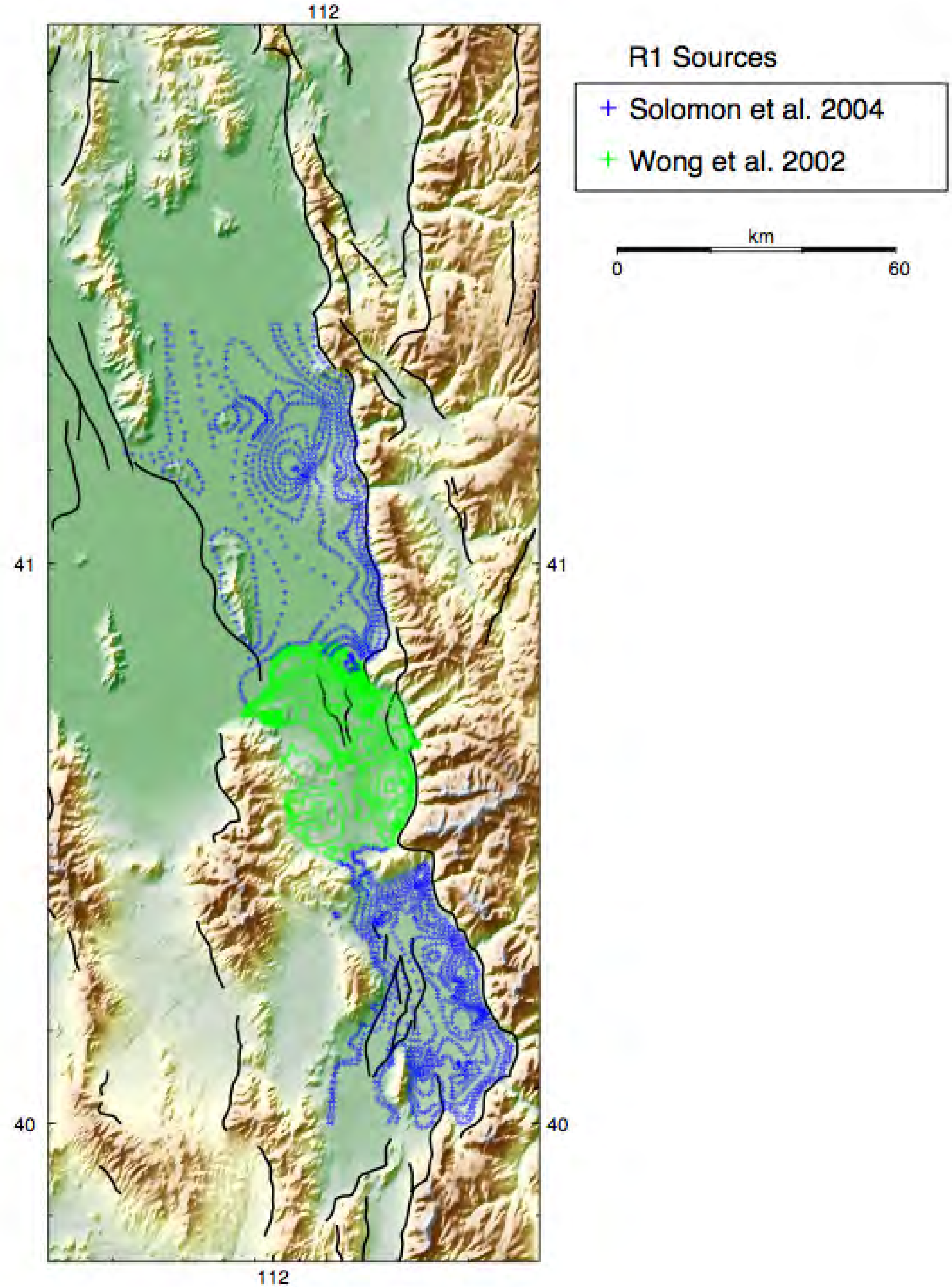




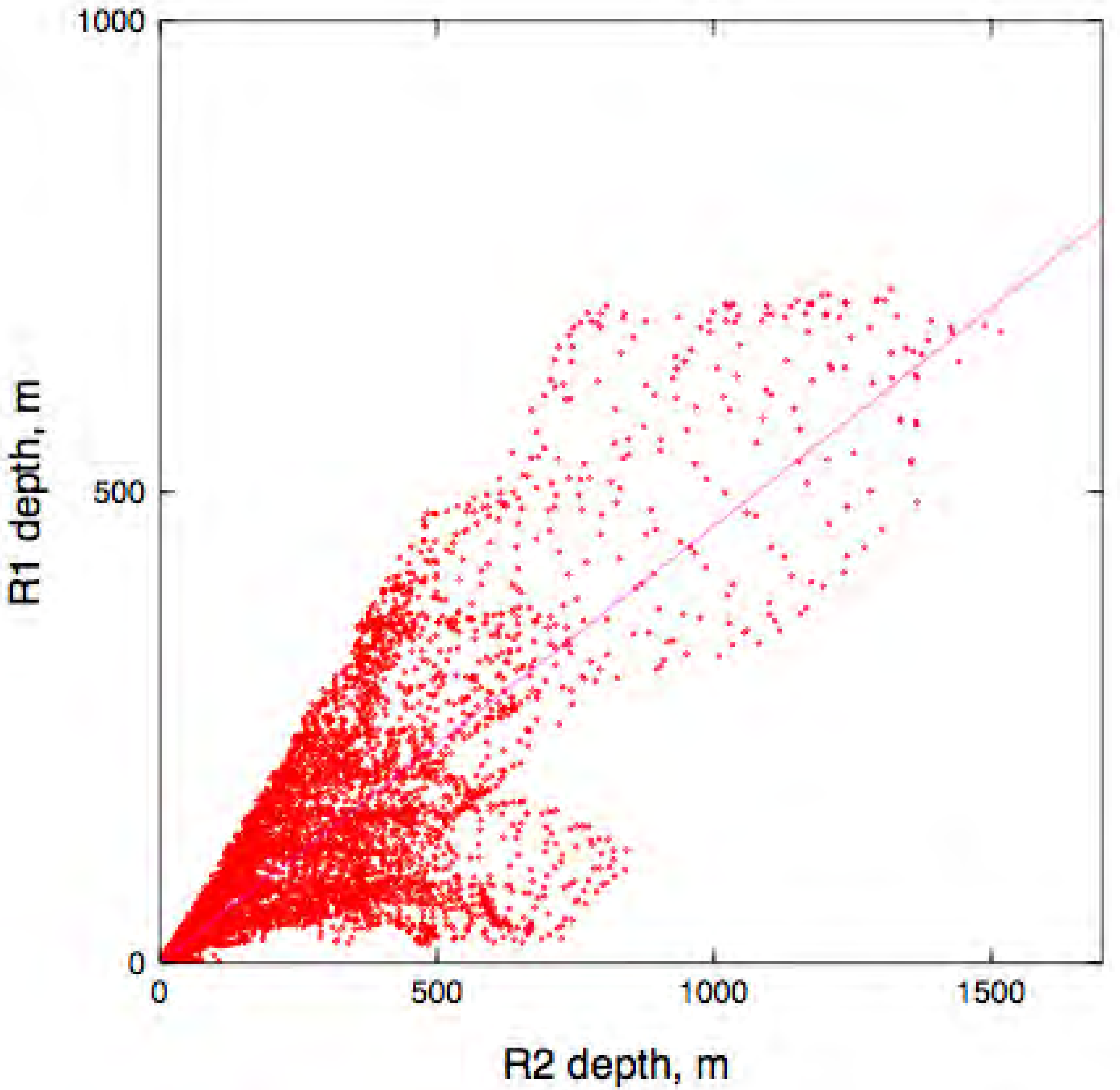
2000
1500
1000
500
0
R2 depth, m
0
500
1000
1500
2000
R3 depth, m
0.36

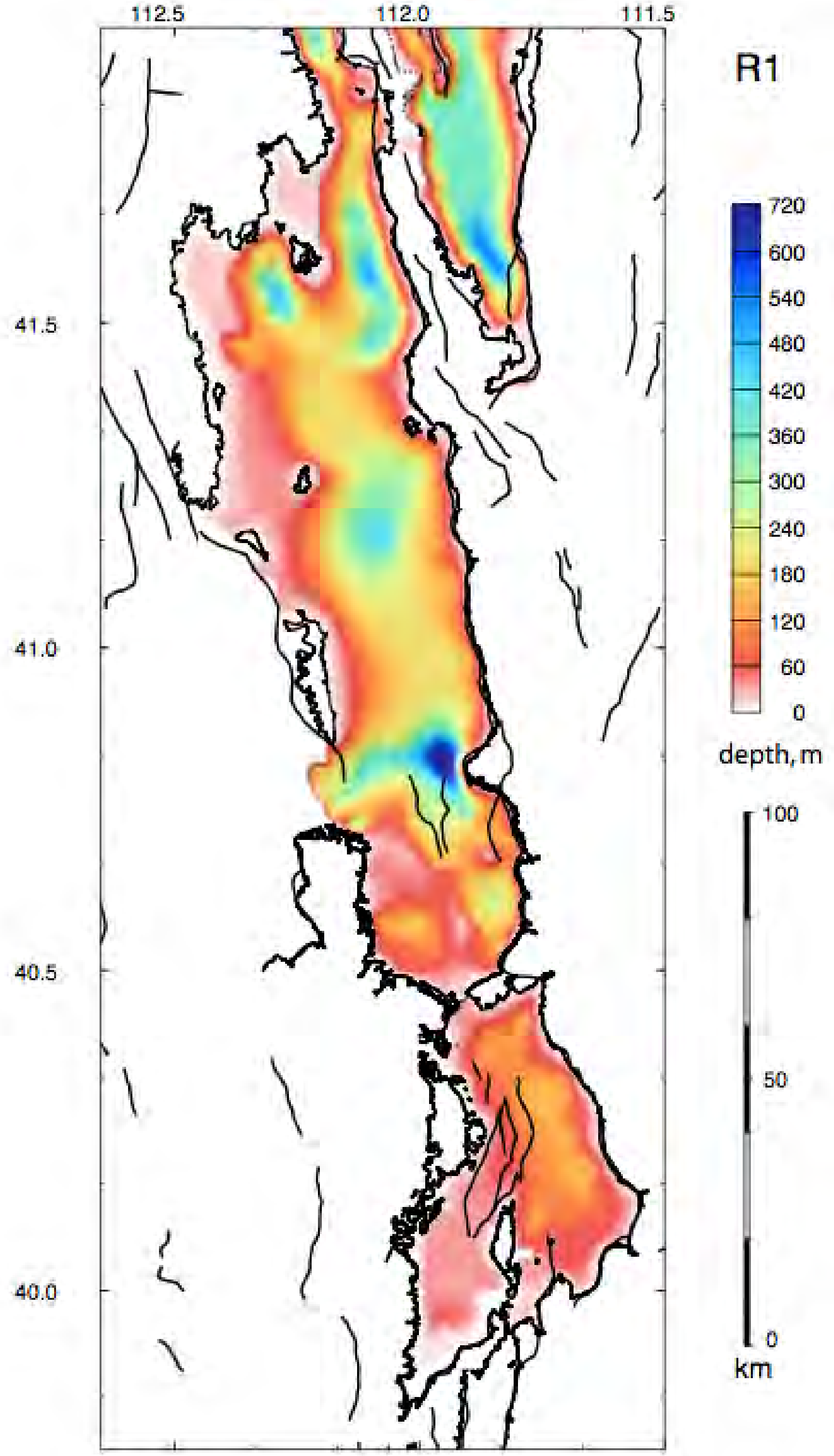


112
R2
1520
1250
1125
1000
875
750
625
500
375
250
125
0
depth, m
100
50
0
km
41
41
40
40
112



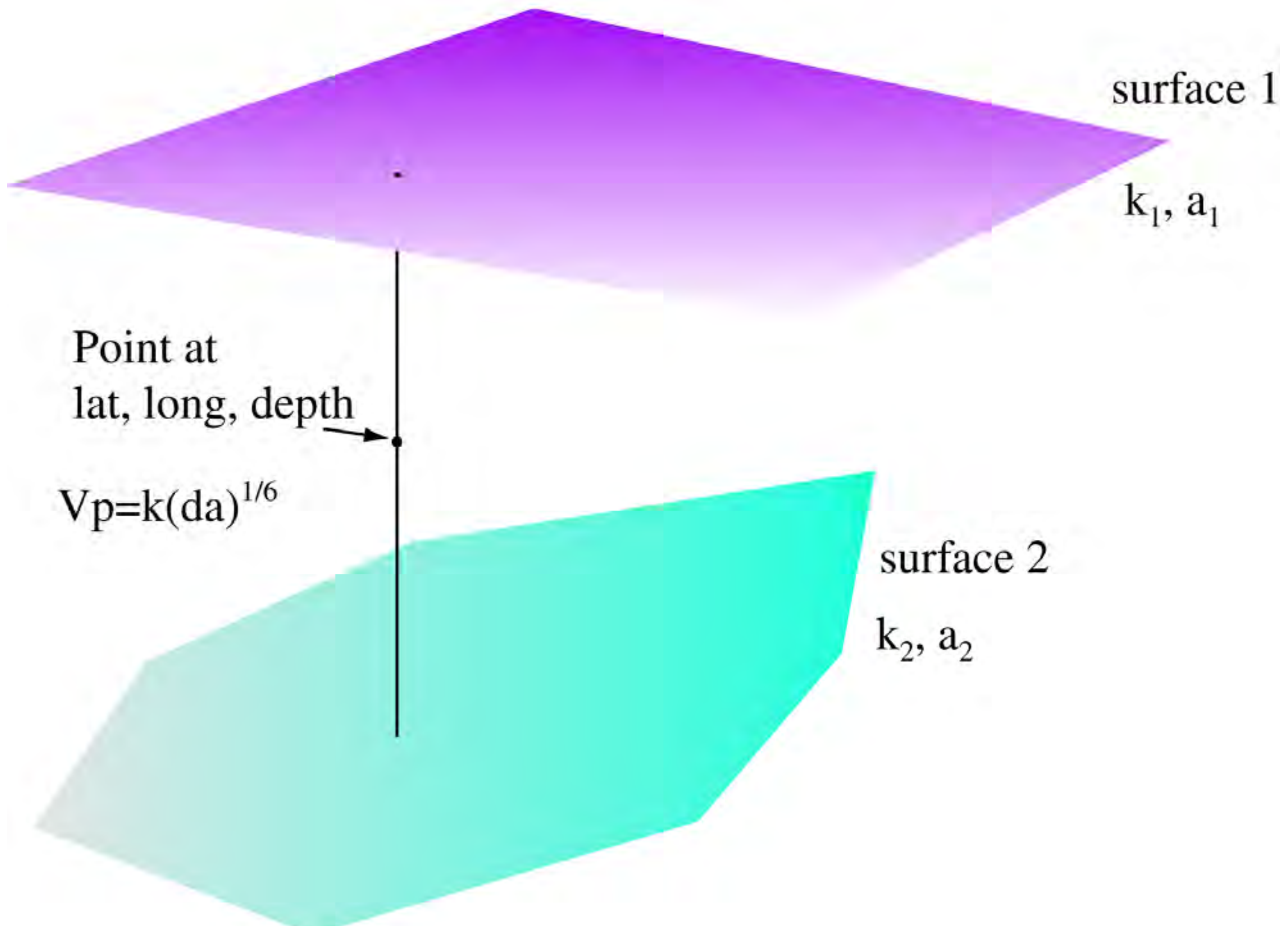
112
41
41
40
40
112
R1 Sources
Solomon et al. 2004
Wong et al. 2002
km
0
60


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

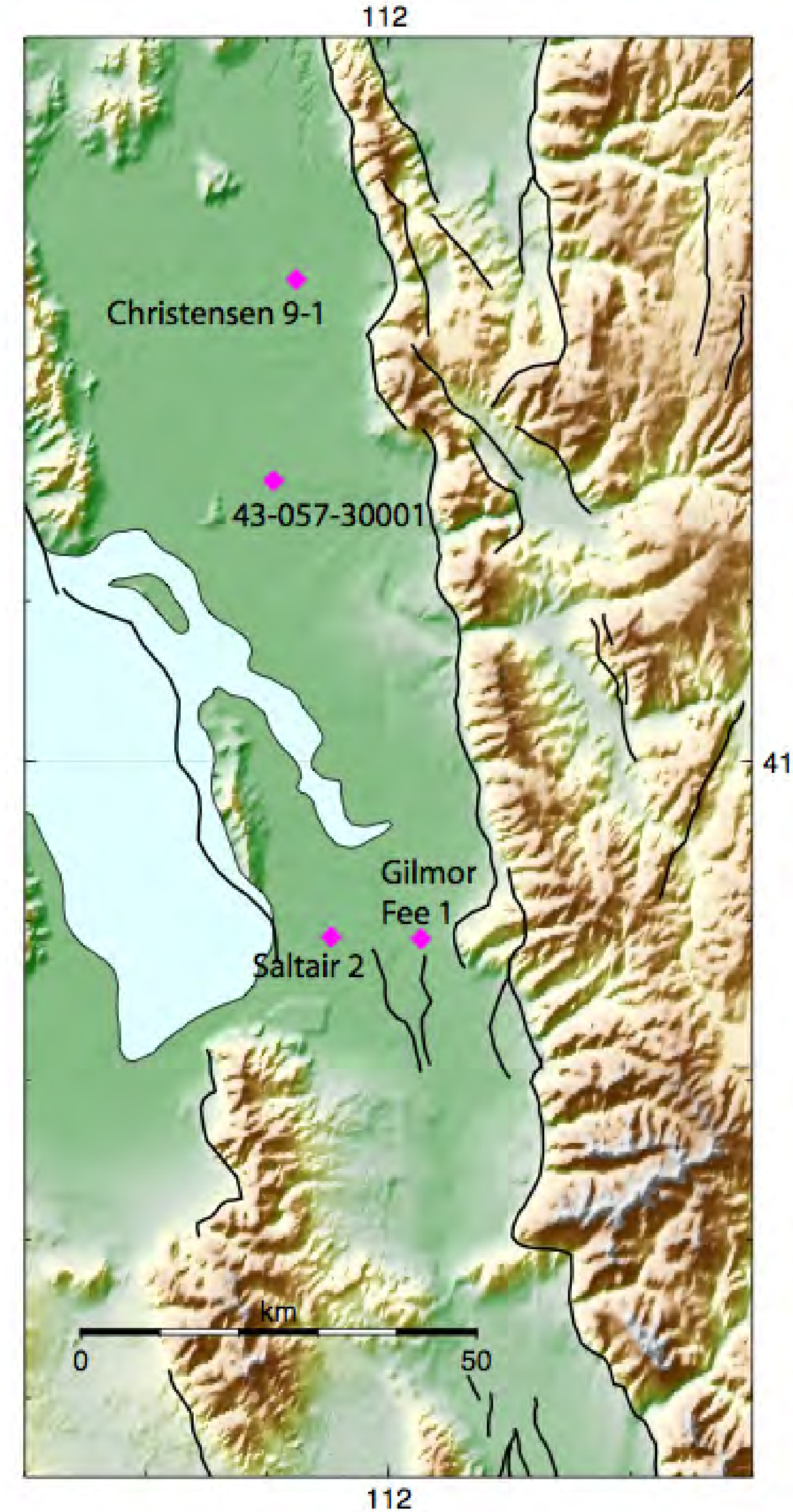


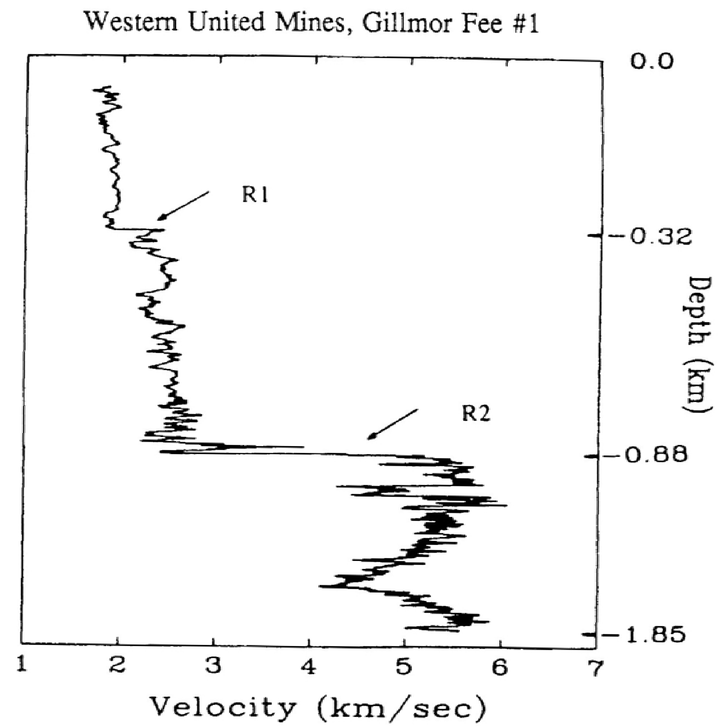
112.5
112.0
111.5
41.5
41.0
40.5
40.0
R1
720
600
540
480
420
360
300
240
180
120
60
0
depth, m
100
50
0
km

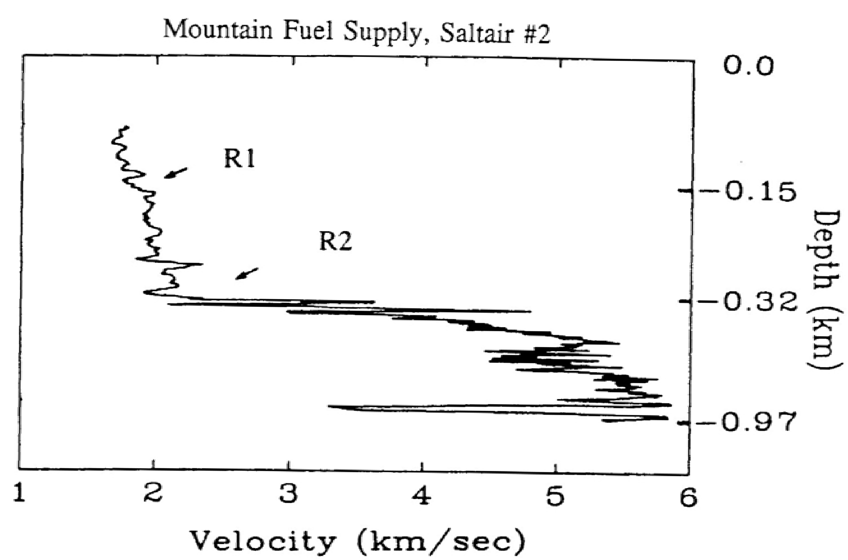
# Model Parameterization



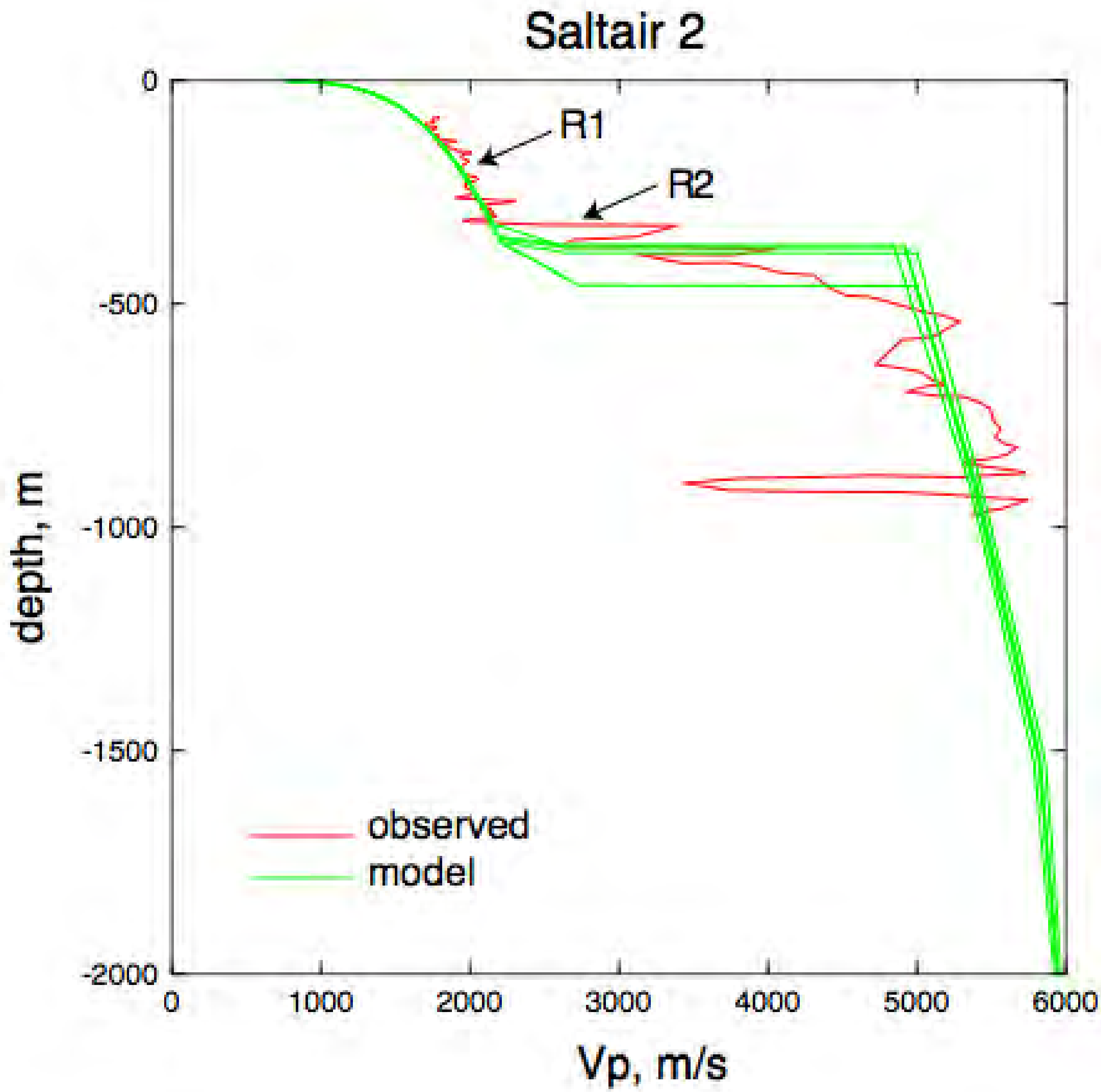

Faust's rule: $V_p = k(da)^{1/6}$


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

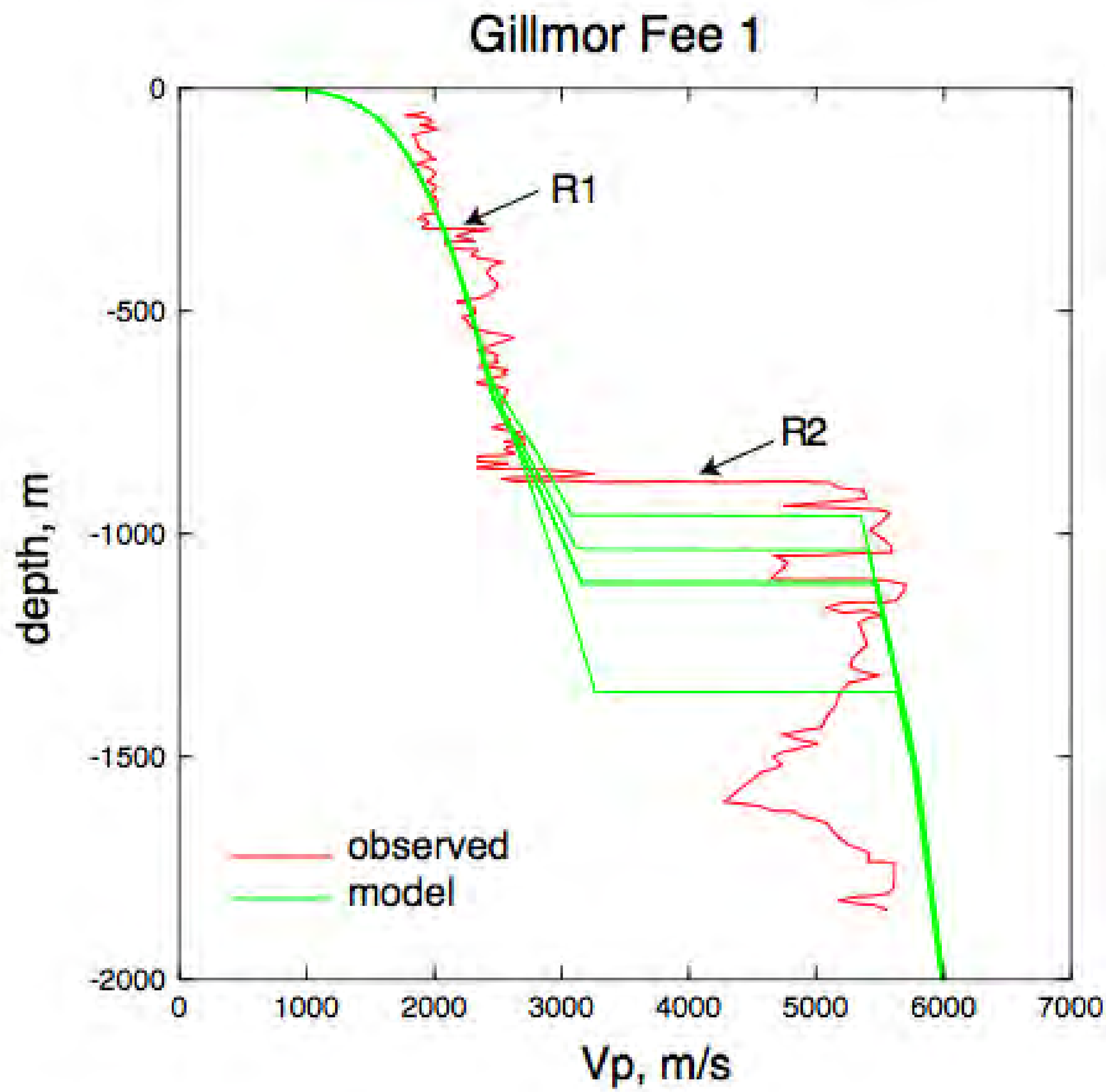


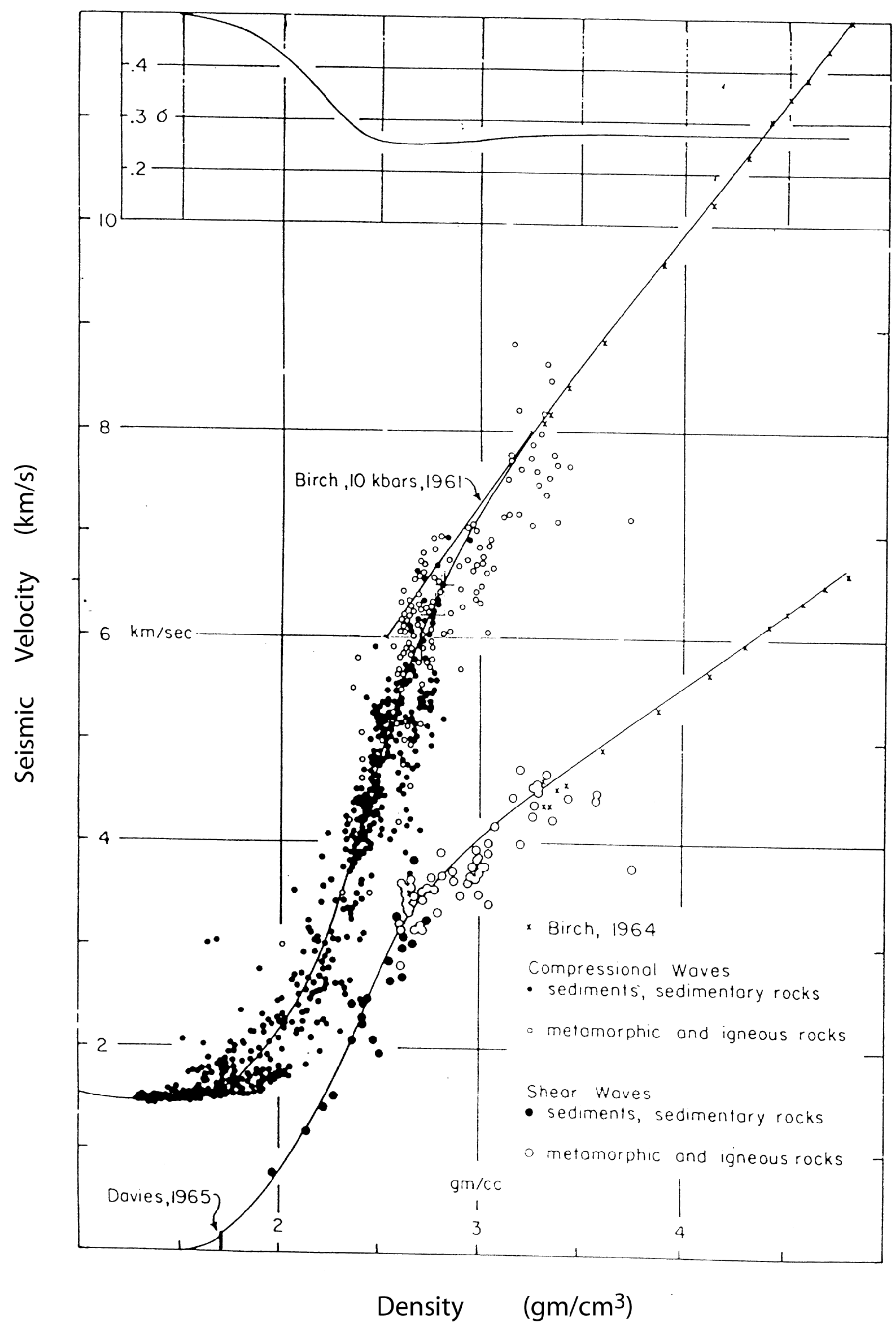

Radkins et al. 1989

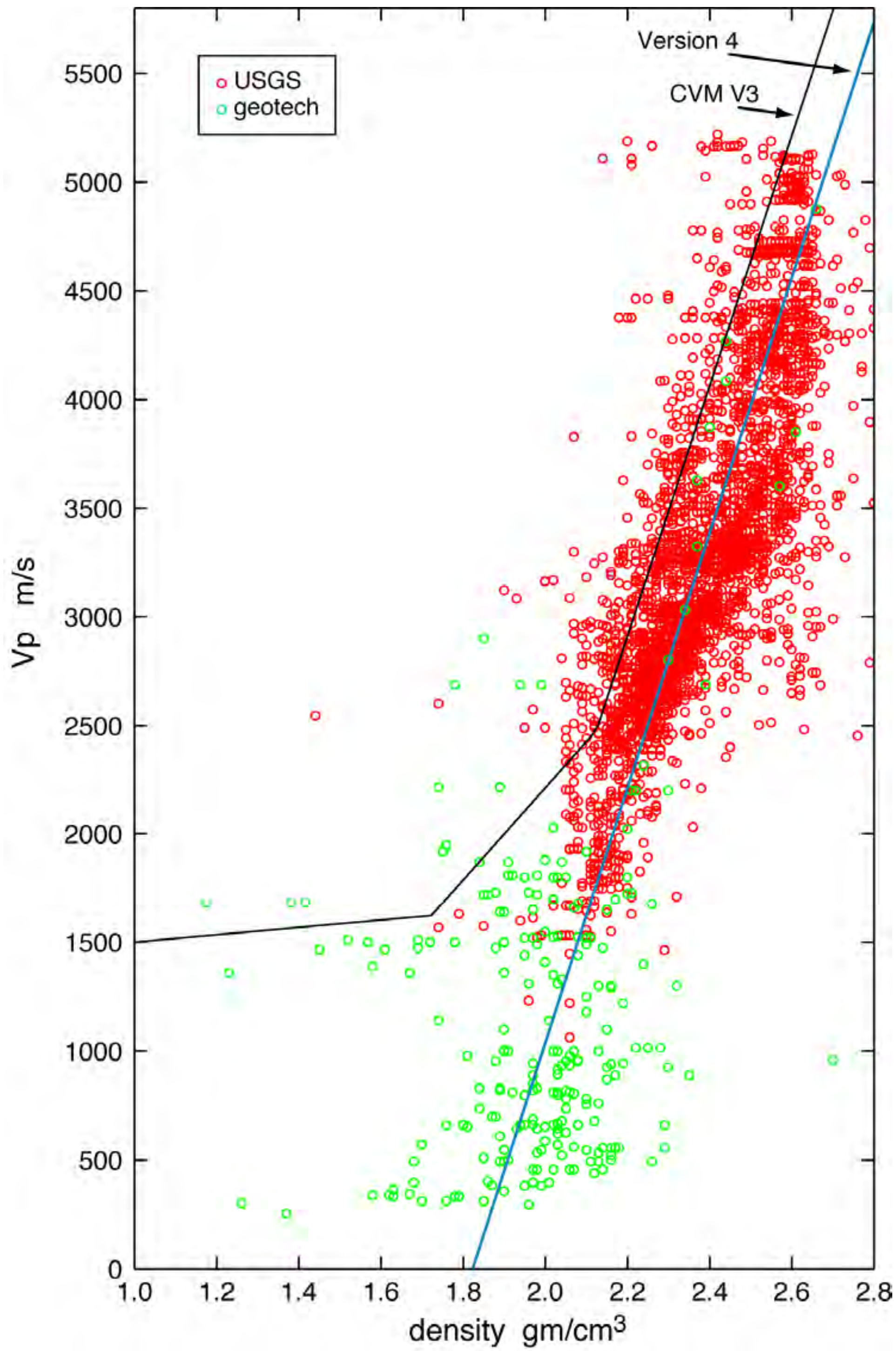



from Radkins et al. 1989

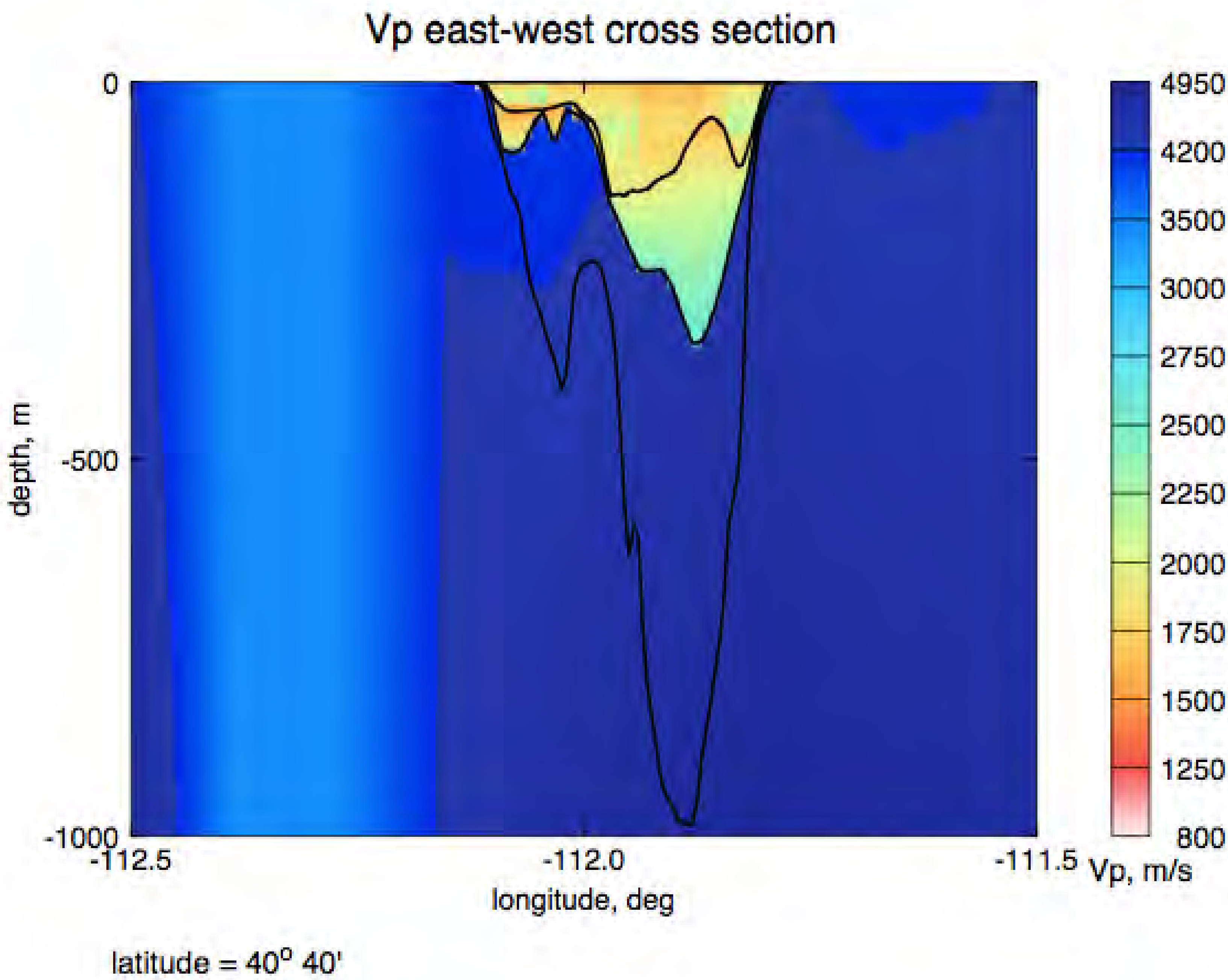



from Radkins et al. 1989

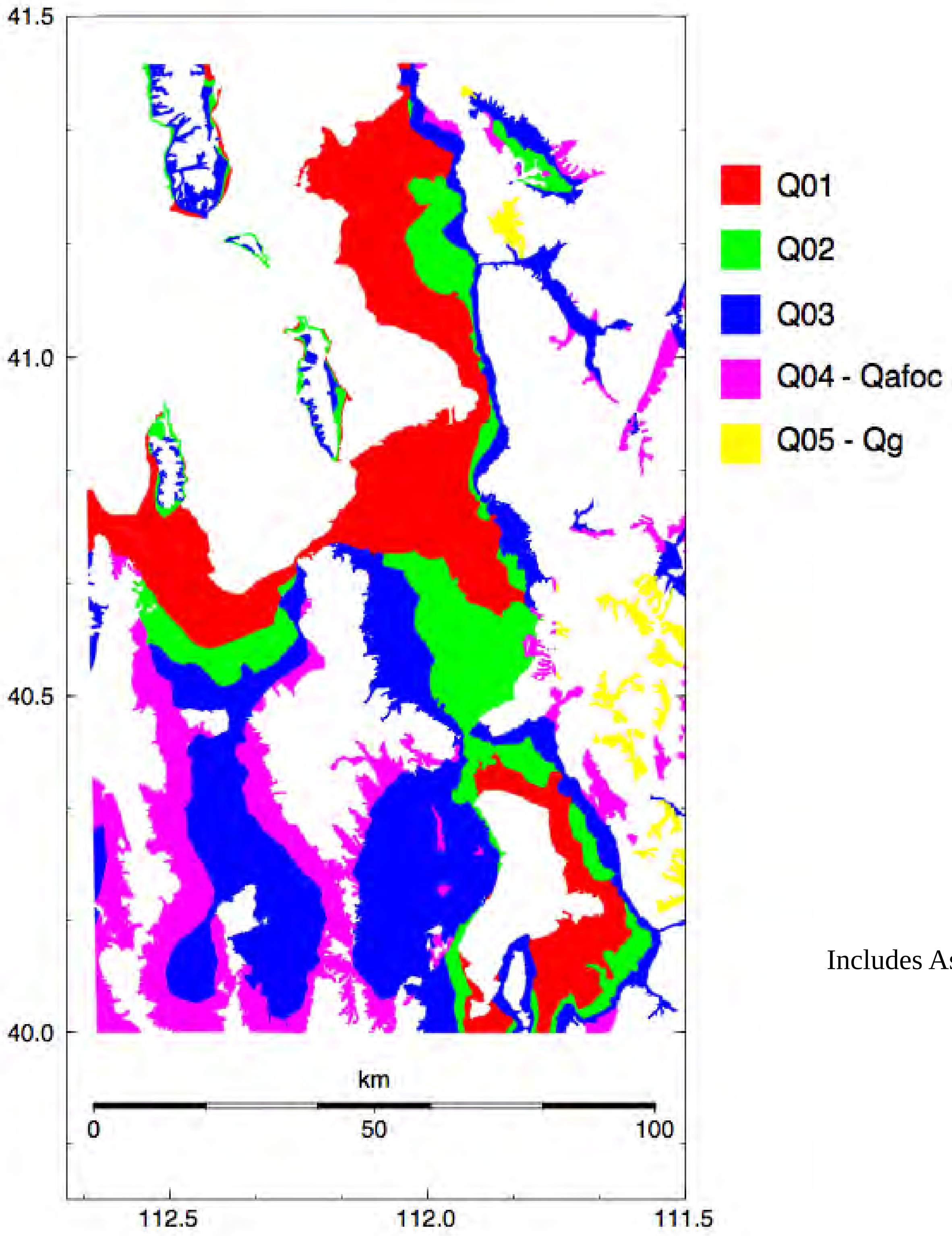

.4
.3 σ
.2
10
8
6 km/sec
4
2
Seismic Velocity (km/s)
Birch, 10 kbars, 1961
Davies, 1965
2
3
4
gm/cc
x Birch, 1964
Compressional Waves
• sediments, sedimentary rocks
◦ metamorphic and igneous rocks
Shear Waves
● sediments, sedimentary rocks
○ metamorphic and igneous rocks
Density (gm/cm3)



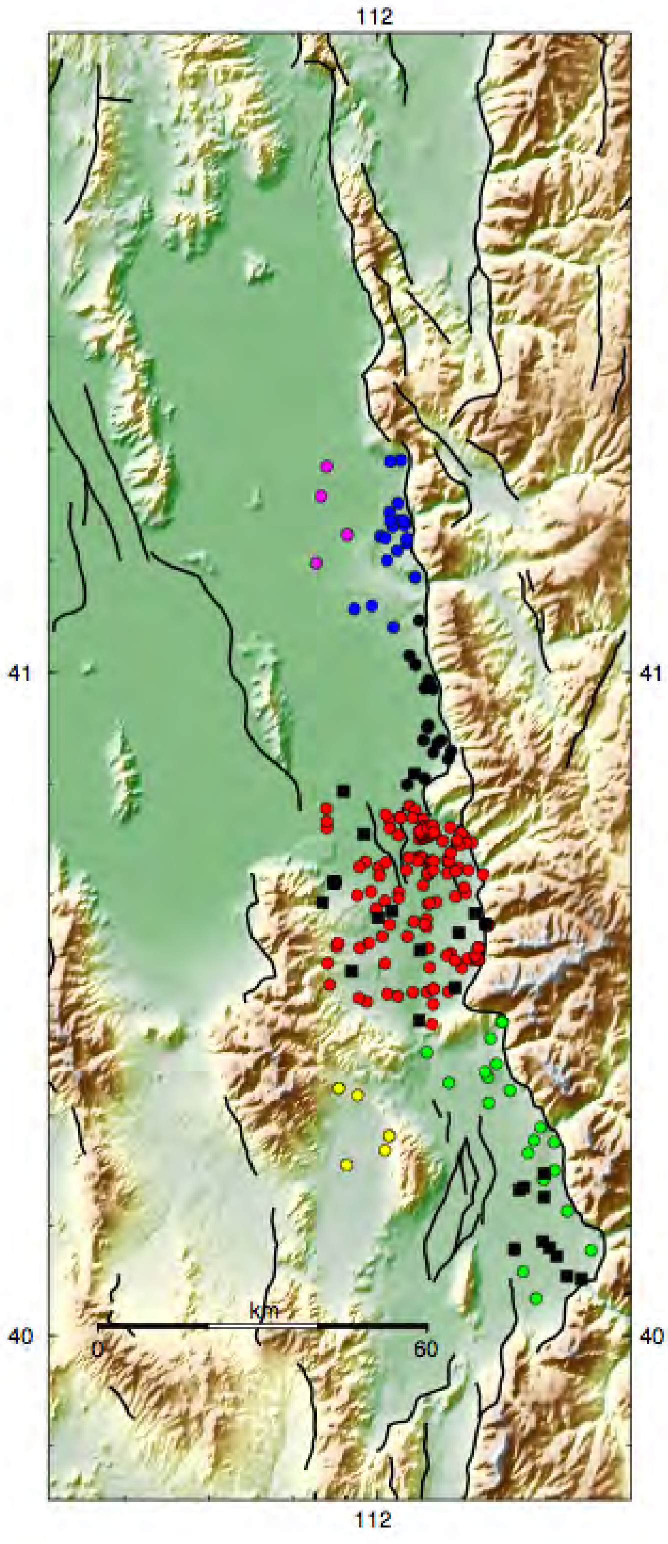
USGS
geotech
Version 4
CVM V3
Vp m/s
density gm/cm3
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8



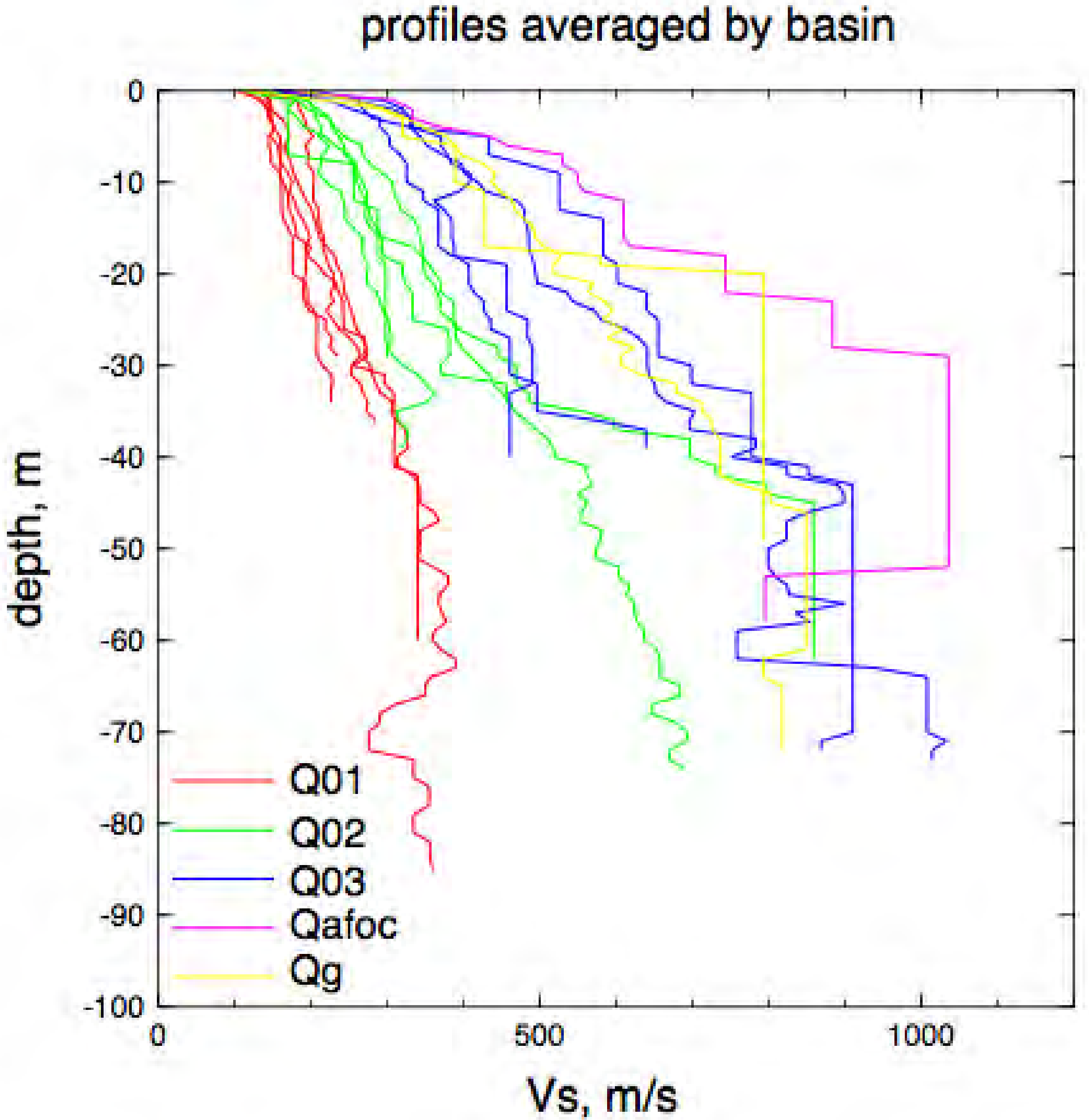
Vp east-west cross section
0
-500
-1000
depth, m
-112.5
-112.0
-111.5
longitude, deg
4950
4200
3500
3000
2750
2500
2250
2000
1750
1500
1250
800
Vp, m/s
latitude = 40° 40'




Includes Ashland 2001, 2004




McDonald October 2006
UT, USGS



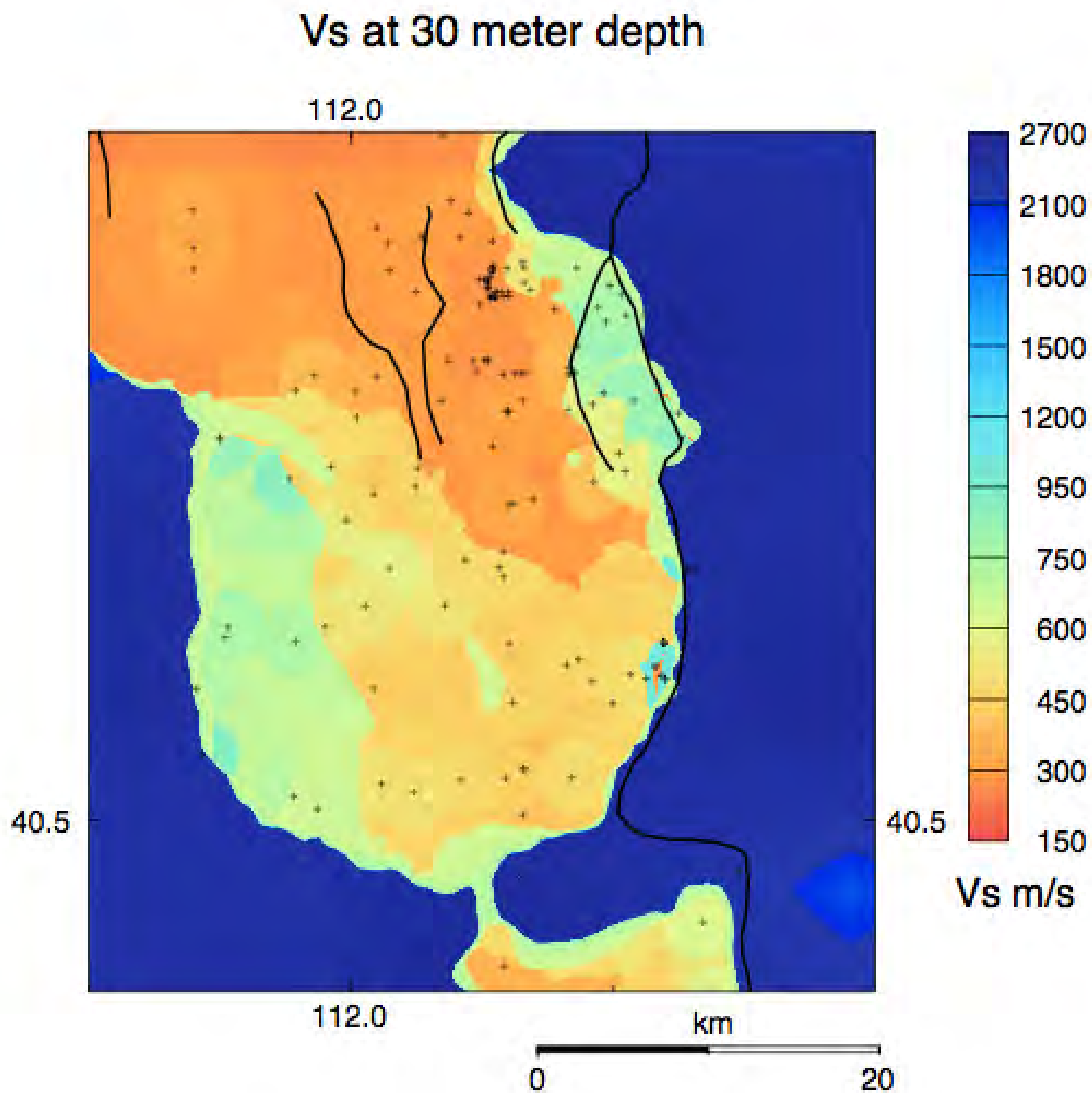
profiles averaged by basin
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
depth, m
0
500
1000
Vs, m/s
Q01
Q02
Q03
Qafoc
Qg

Castagna et al. (1985):

$$V_p\ (\text{km/s}) = 1.16 V_s + 1.36$$

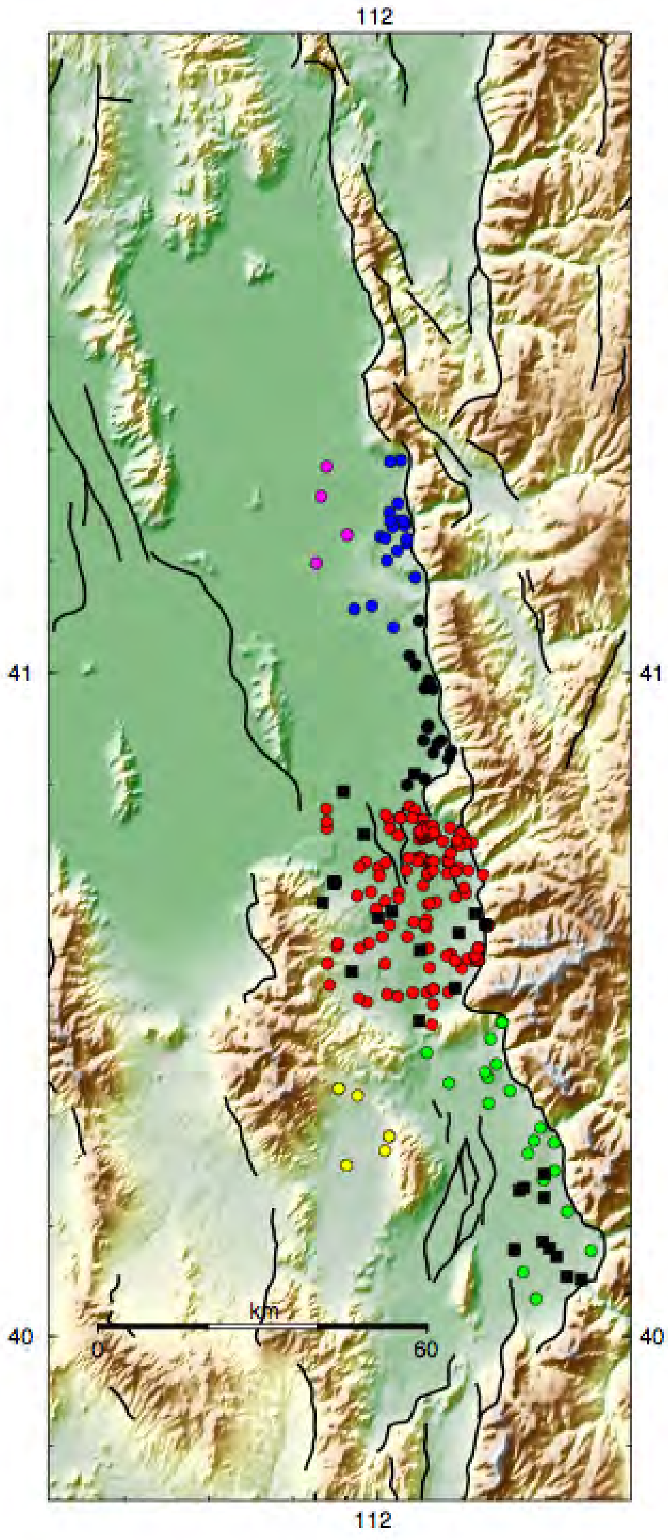
$$1.5 < V_p < 4.5\ \text{km/s}$$

(in Brocher 2005)

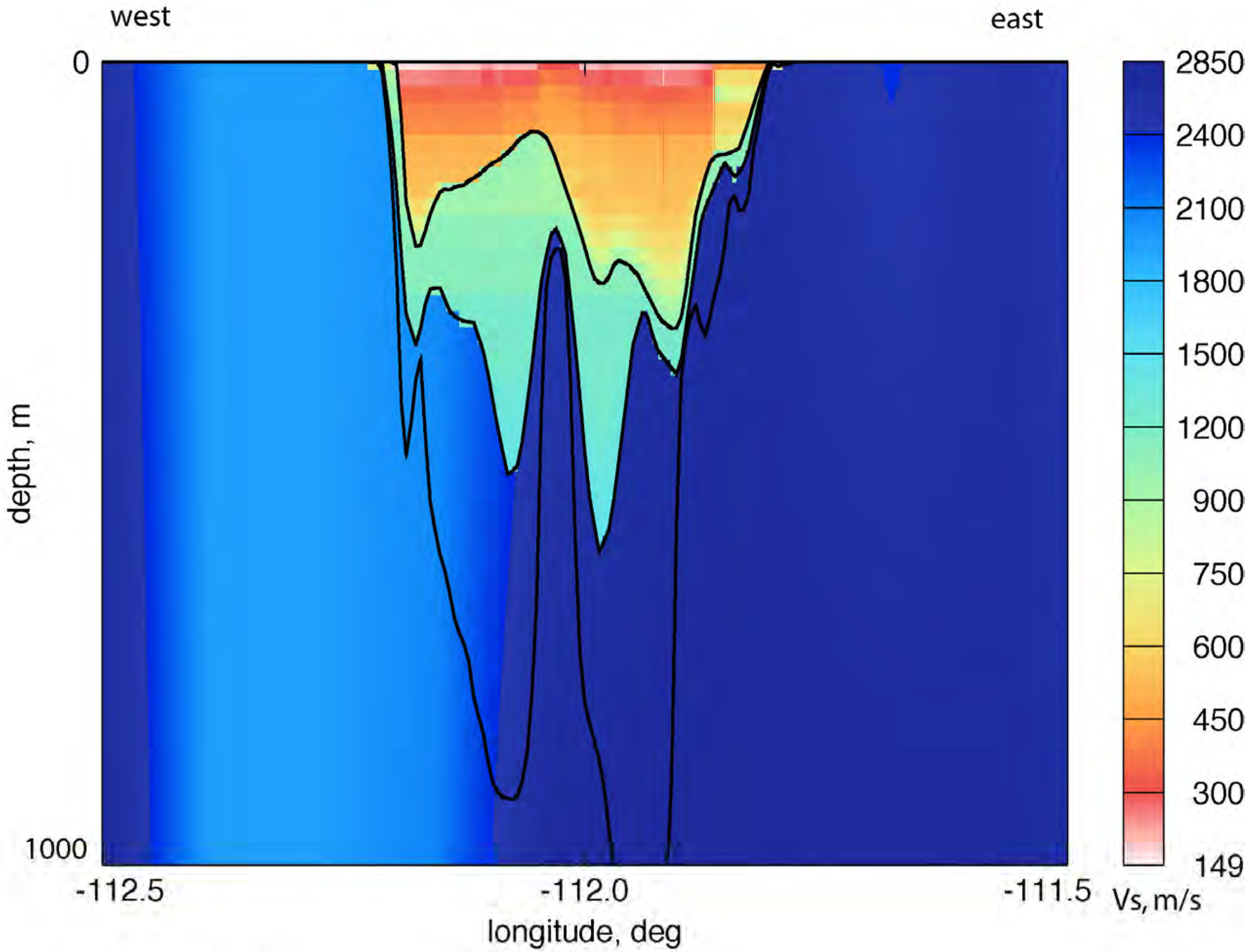


Vs at 30 meter depth
112.0
112.0
40.5
40.5
2700
2100
1800
1500
1200
950
750
600
450
300
150
Vs m/s
km
0
20

| | version 1 | version 2a | version 2b | version 2c |
|---|---|---|---|---|
| R1 | r1t4.xyz | Ò | Ò | Ò |
| R2 | r2t3.xyz | Ò | Ò | r2t4 |
| R3 | bas3.xyz | Ò | Ò | bas4 |
| crust/Moho | reg_mod | Ò | Ò | Ò |
| SRU | soil2.pgm | Ò | Ò | Ò |
| shallow Vs profiles | boreholes | boreholes2 | Ò | Ò |
| generic Vs profiles | soil_generic | soil_generic2 | soil_generic2_lo | Ò |
| k | uniform | Utah Valley | Ò | Ò |
| comments | initial model | added USGS and UT profiles | divided generic profiles to get contrast at R1 | modified east side of basins to reflect WF fault control |




McDonald October 2006
UT, USGS




latitude 40.75
version 2b

Bruhn et al. 1992
USGS Pro Pap 1500H

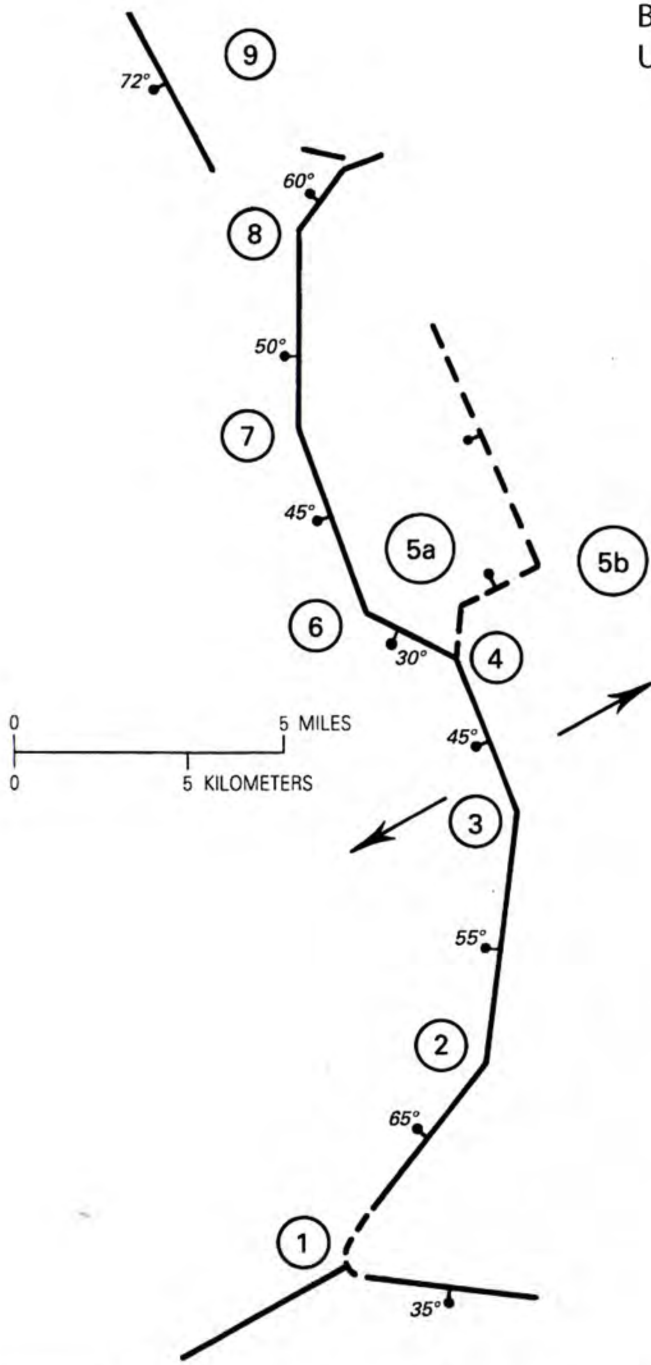
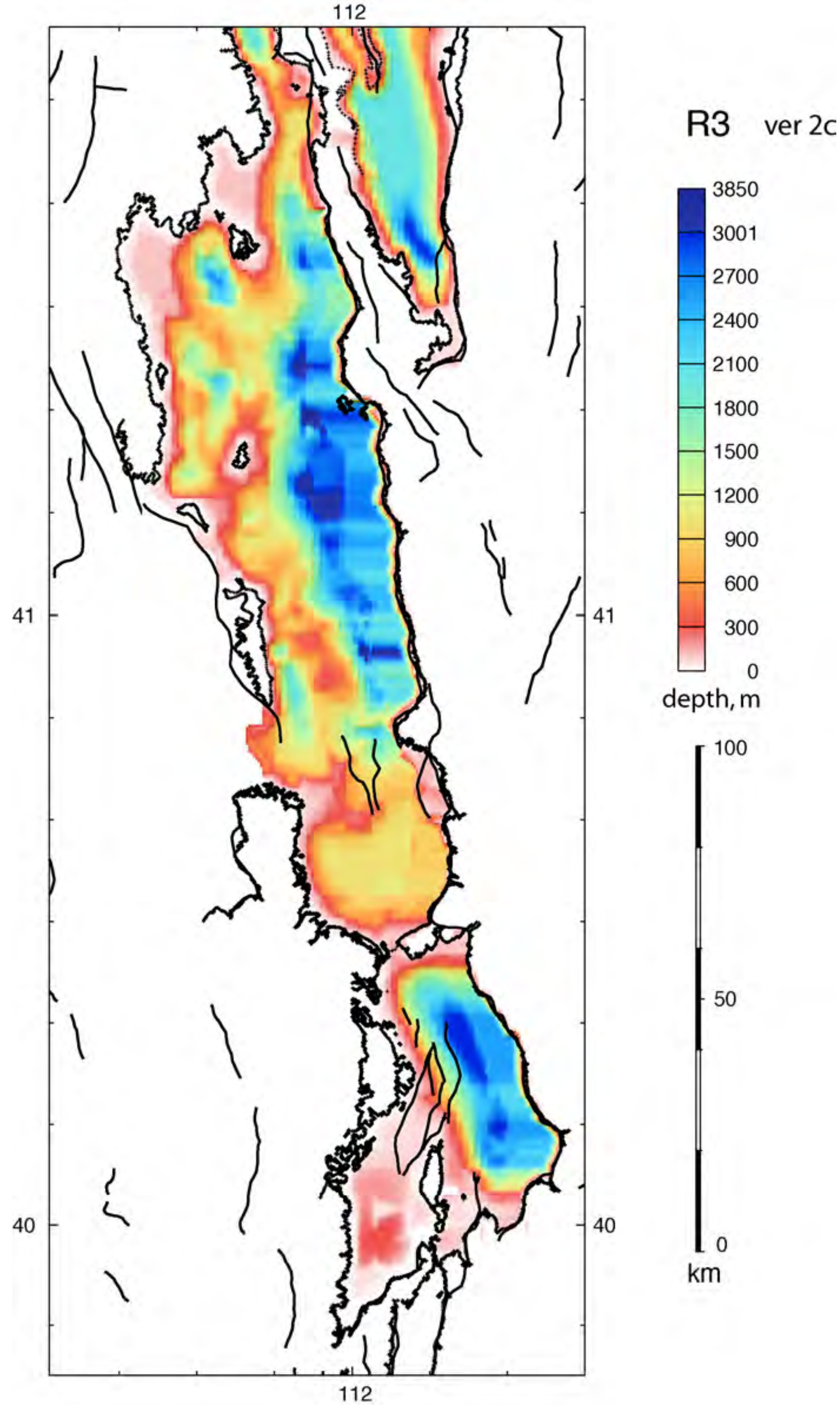
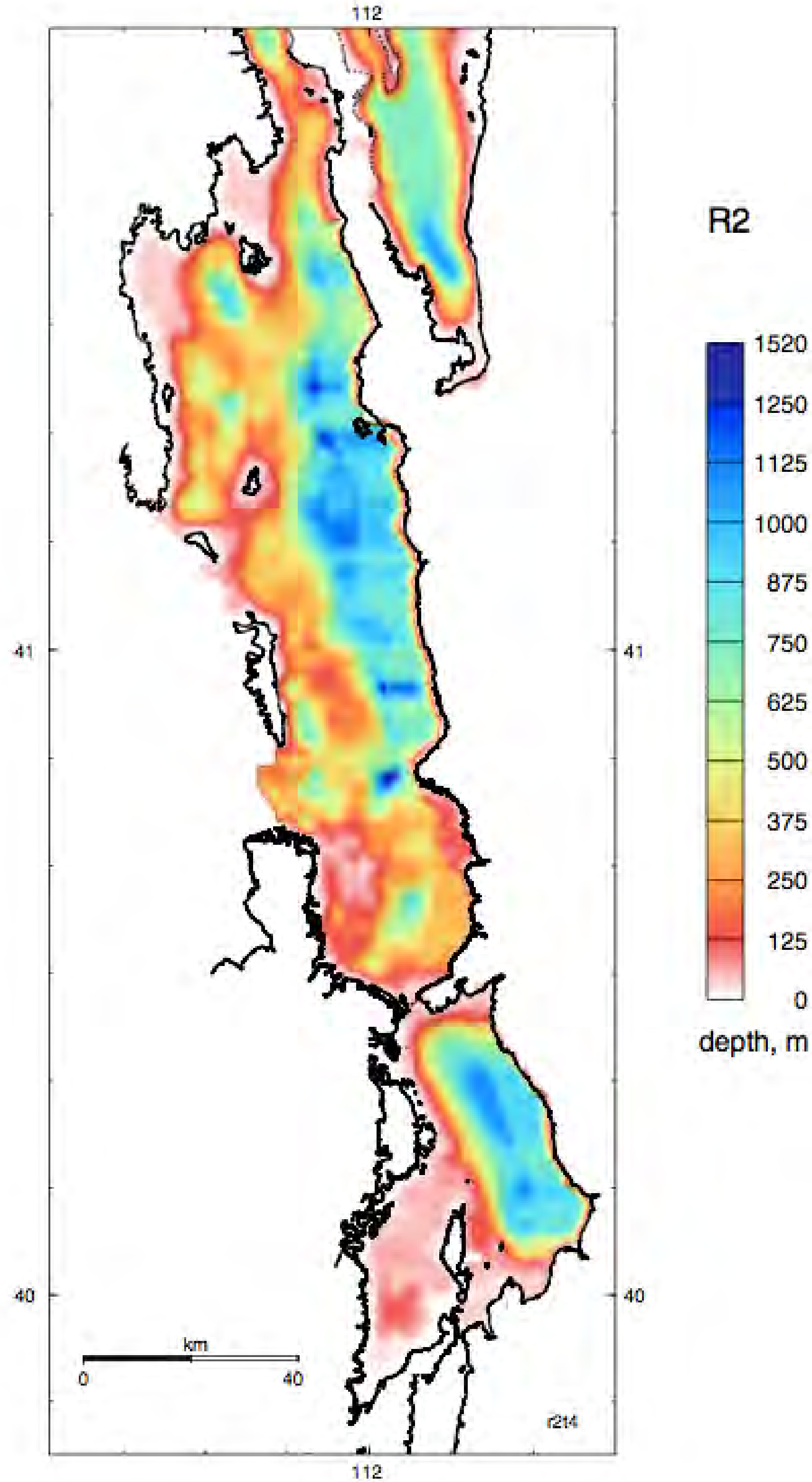
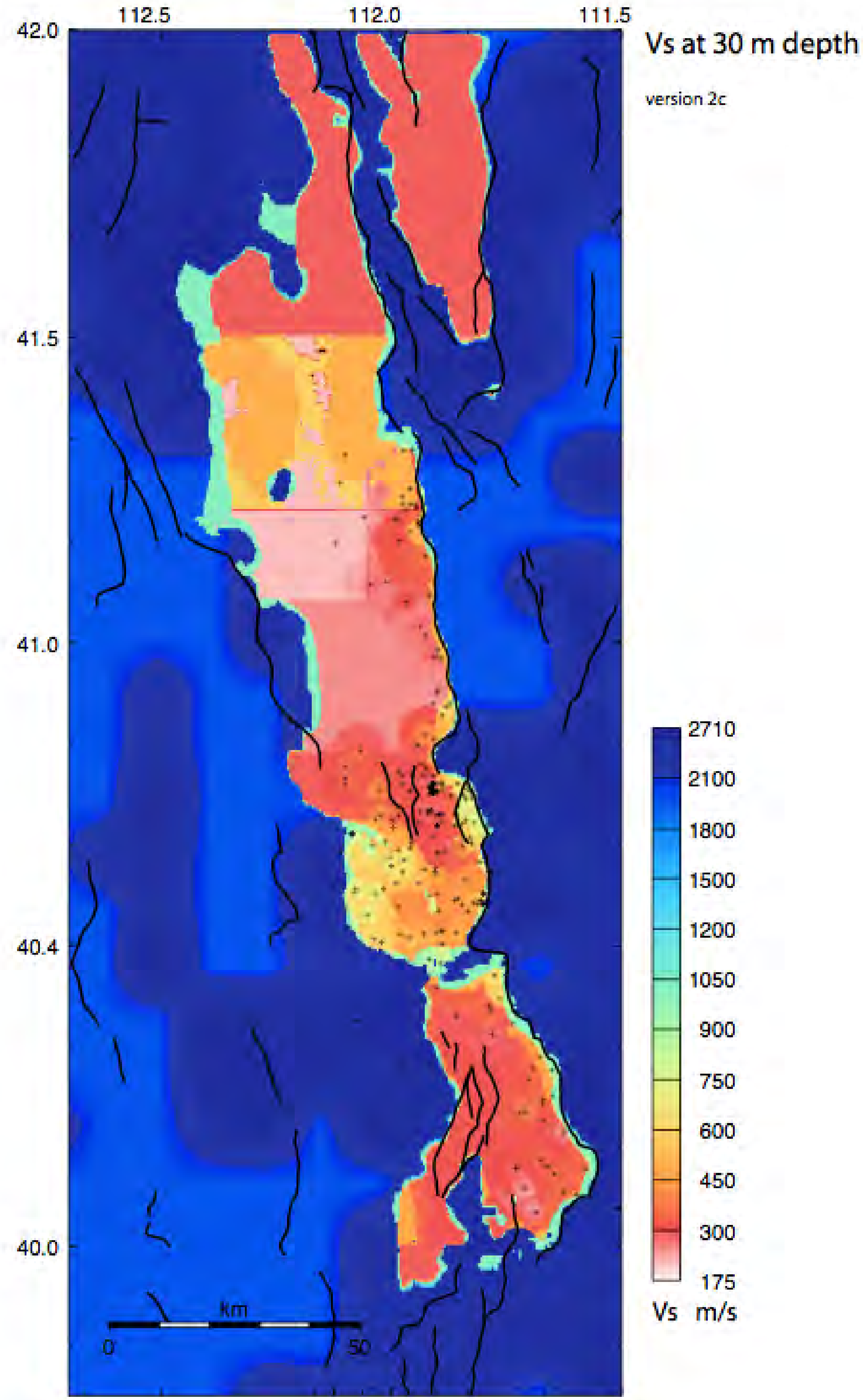


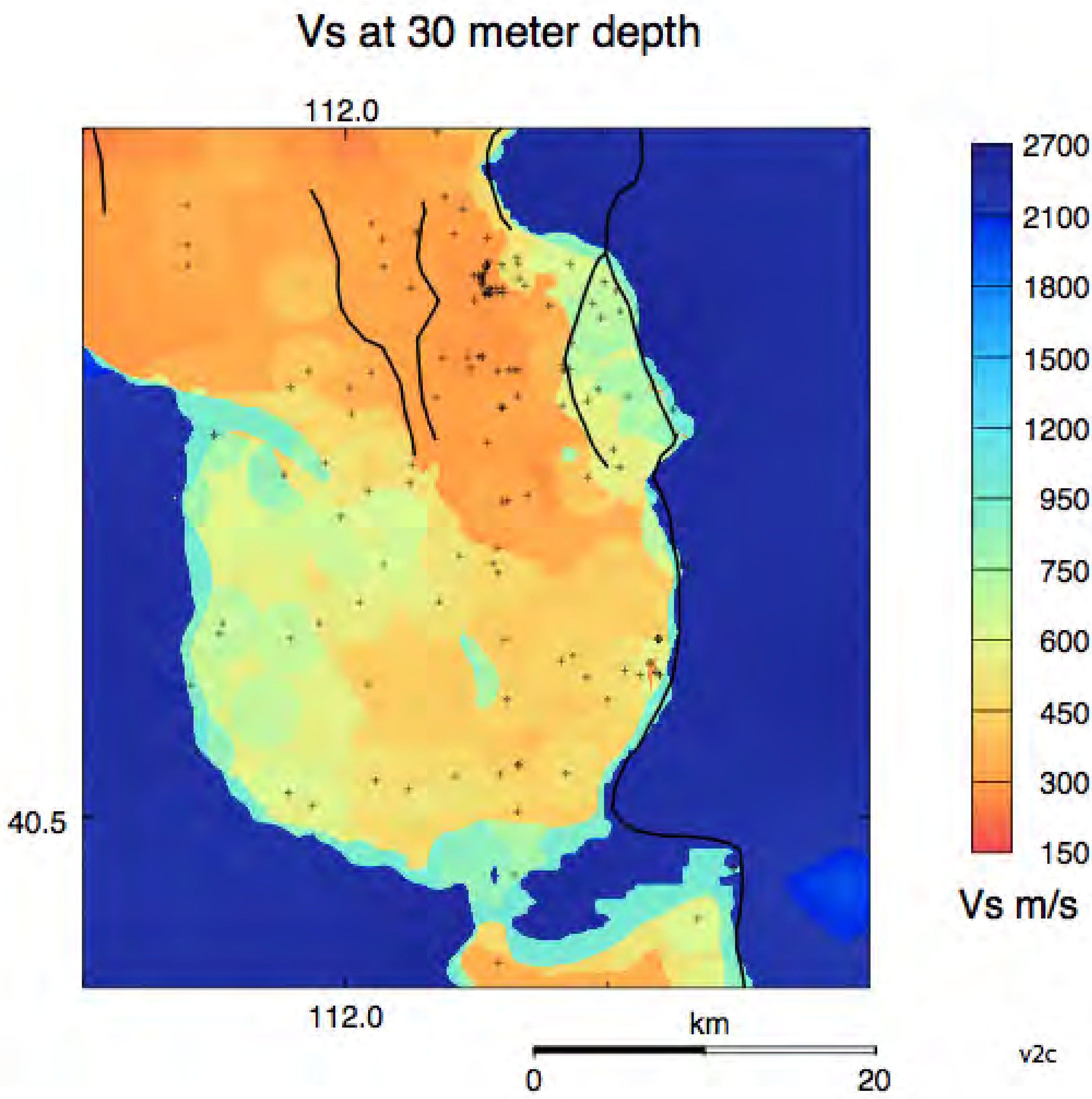

FIGURE 8.—Surface fault traces in the Salt Lake segment and preferred dip angles based on geometric modeling. Numbers of barriers are the same as those in figure 2 and table 1. Solid lines indicate normal faults (ball and bar on hanging wall, dashed where inferred or buried). Large arrows indicate inferred directions of extension. See text for discussion.

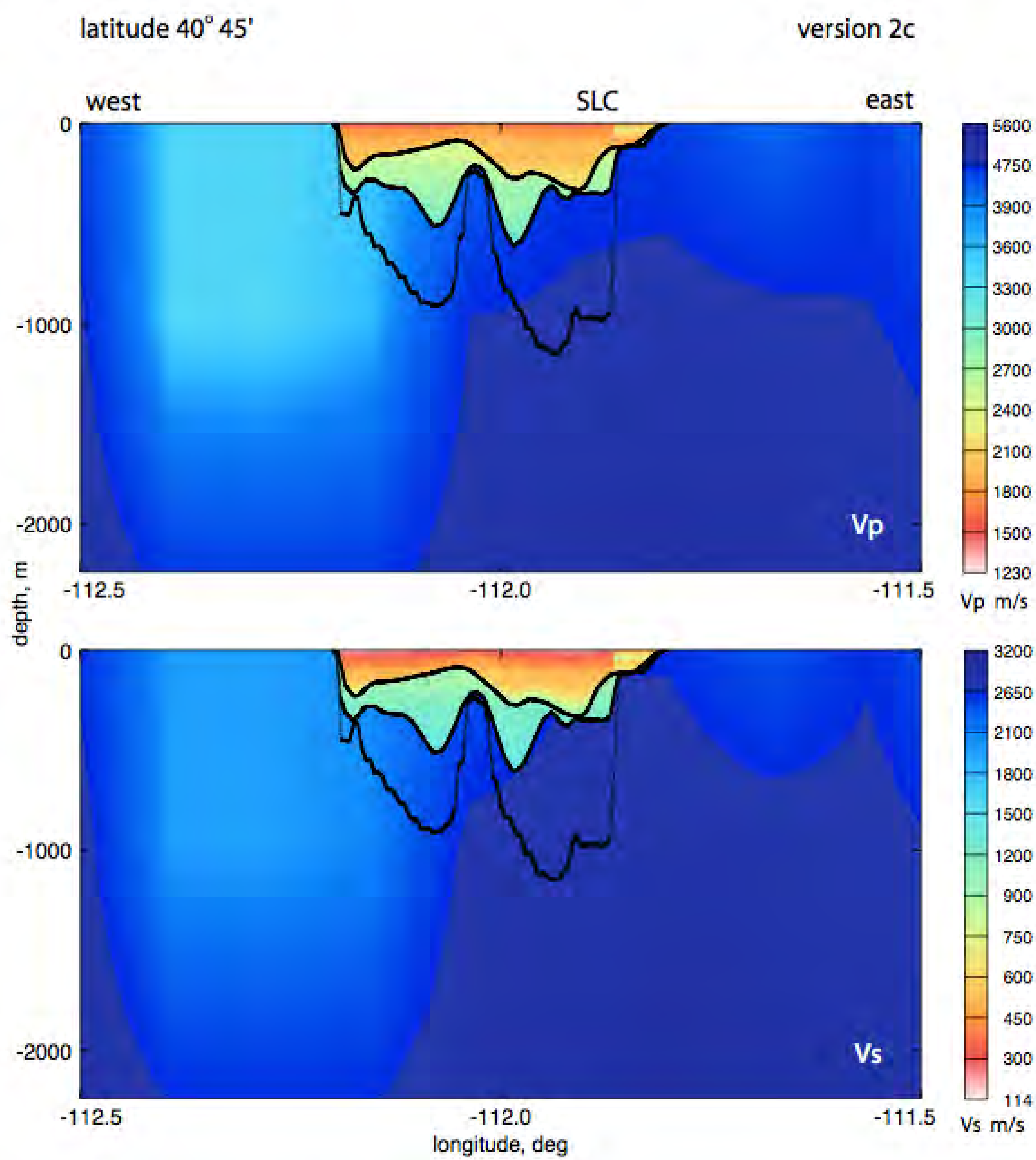

112
R3 ver 2c
3850
3001
2700
2400
2100
1800
1500
1200
900
600
300
0
depth, m
100
50
0
km
41
41
40
40
112


112
R2
1520
1250
1125
1000
875
750
625
500
375
250
125
0
depth, m
41
41
40
40
km
0
40
r214
112

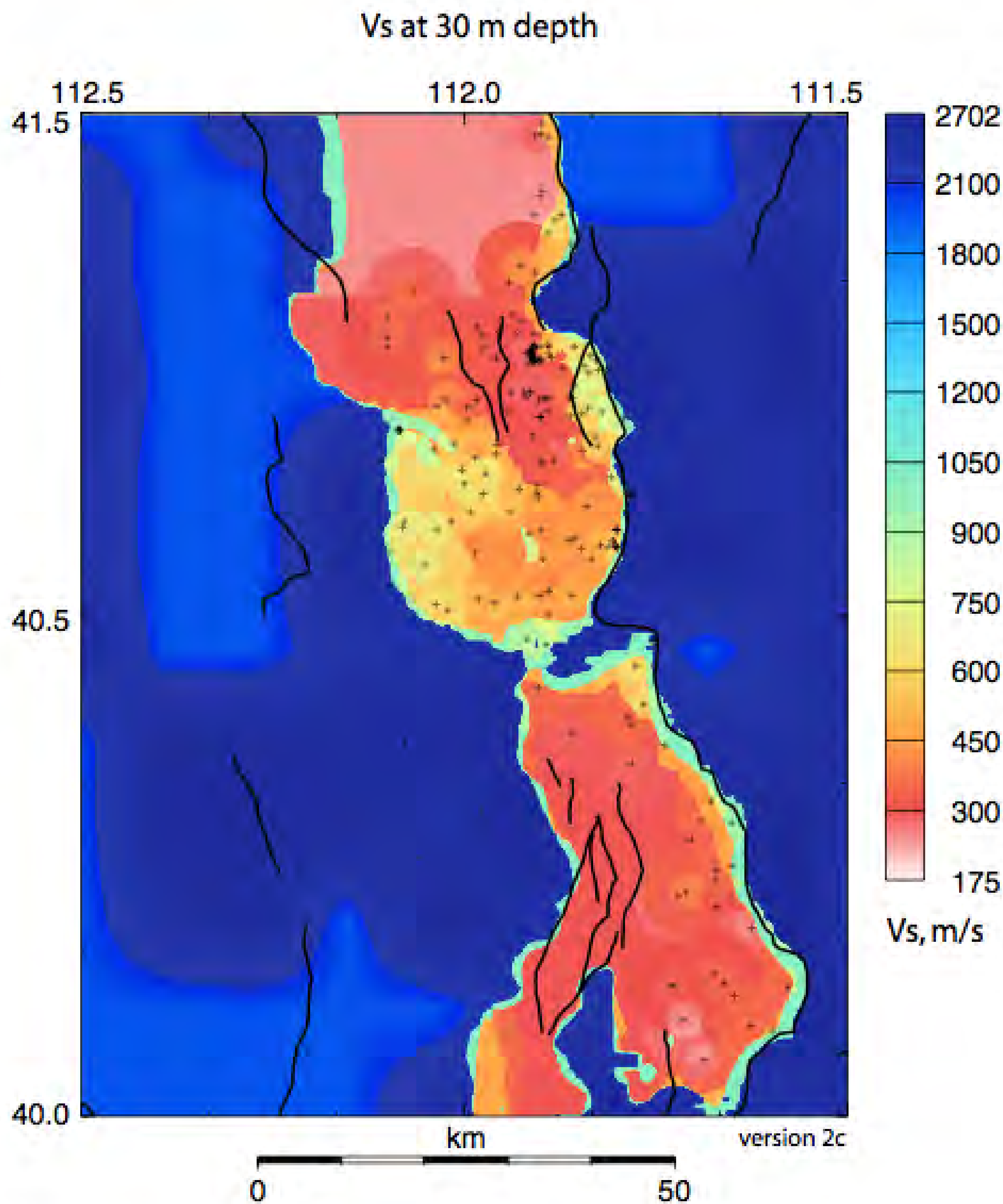


Vs at 30 m depth
version 2c
112.5
112.0
111.5
42.0
41.5
41.0
40.4
40.0
km
0
50
2710
2100
1800
1500
1200
1050
900
750
600
450
300
175
Vs m/s

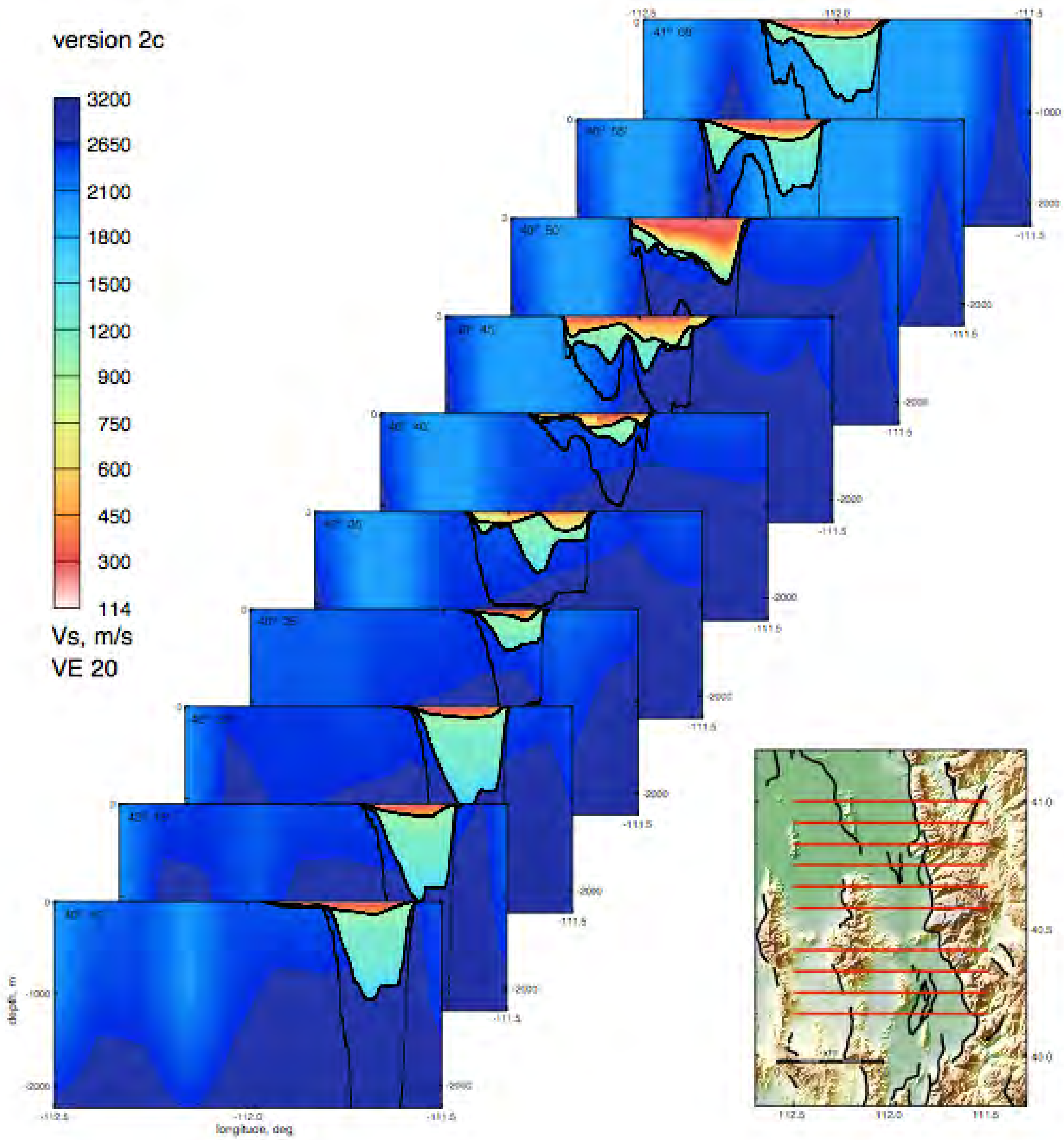

Vs at 30 meter depth
112.0
40.5
112.0
2700
2100
1800
1500
1200
950
750
600
450
300
150
Vs m/s
km
0
20
v2c



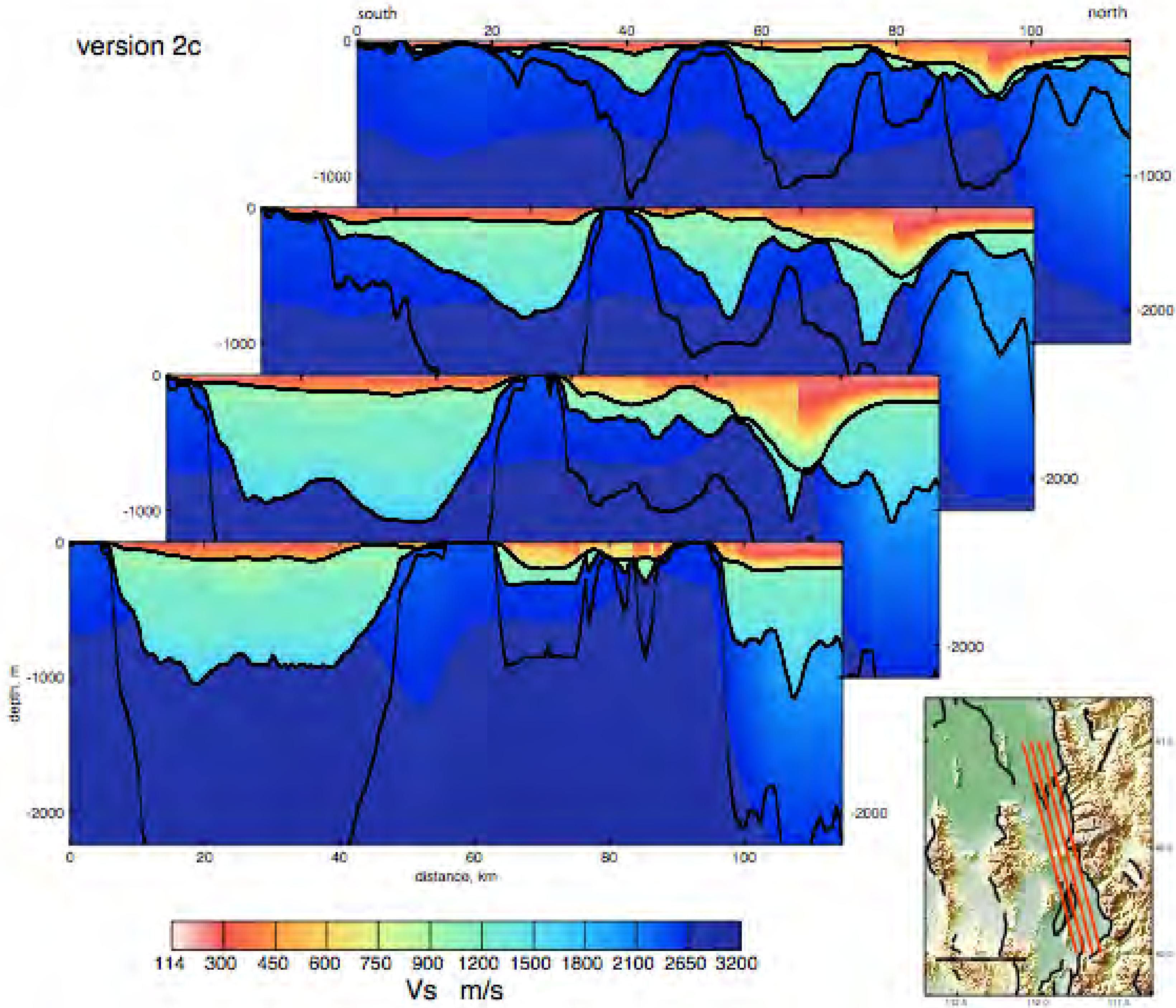
latitude 40° 45'
version 2c
west
SLC
east
0
-1000
-2000
depth, m
-112.5
-112.0
-111.5
Vp
5600
4750
3900
3600
3300
3000
2700
2400
2100
1800
1500
1230
Vp m/s
0
-1000
-2000
-112.5
-112.0
-111.5
longitude, deg
Vs
3200
2650
2100
1800
1500
1200
900
750
600
450
300
114
Vs m/s



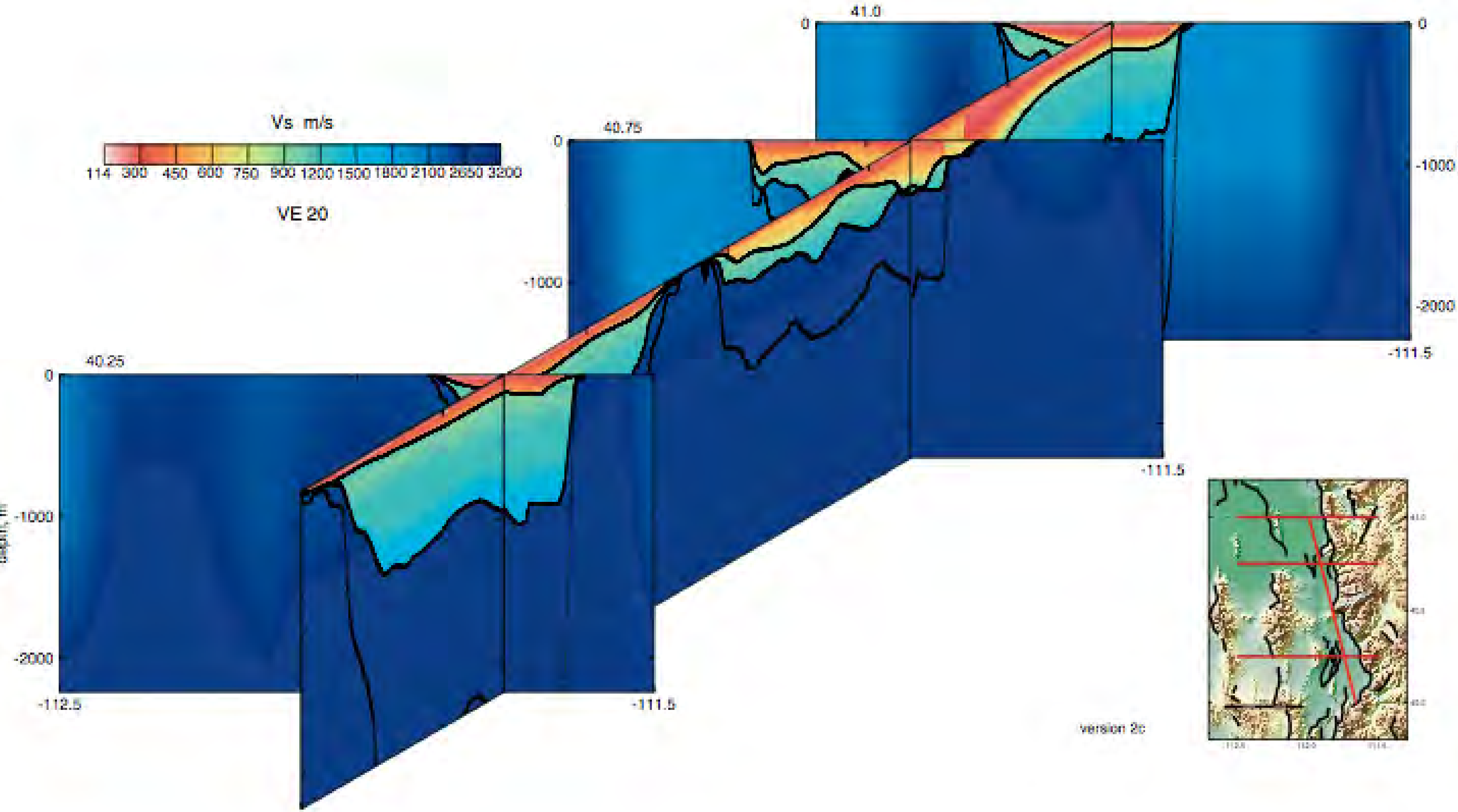
Vs at 30 m depth
112.5
112.0
111.5
41.5
40.5
40.0
2702
2100
1800
1500
1200
1050
900
750
600
450
300
175
Vs, m/s
km
0
50
version 2c



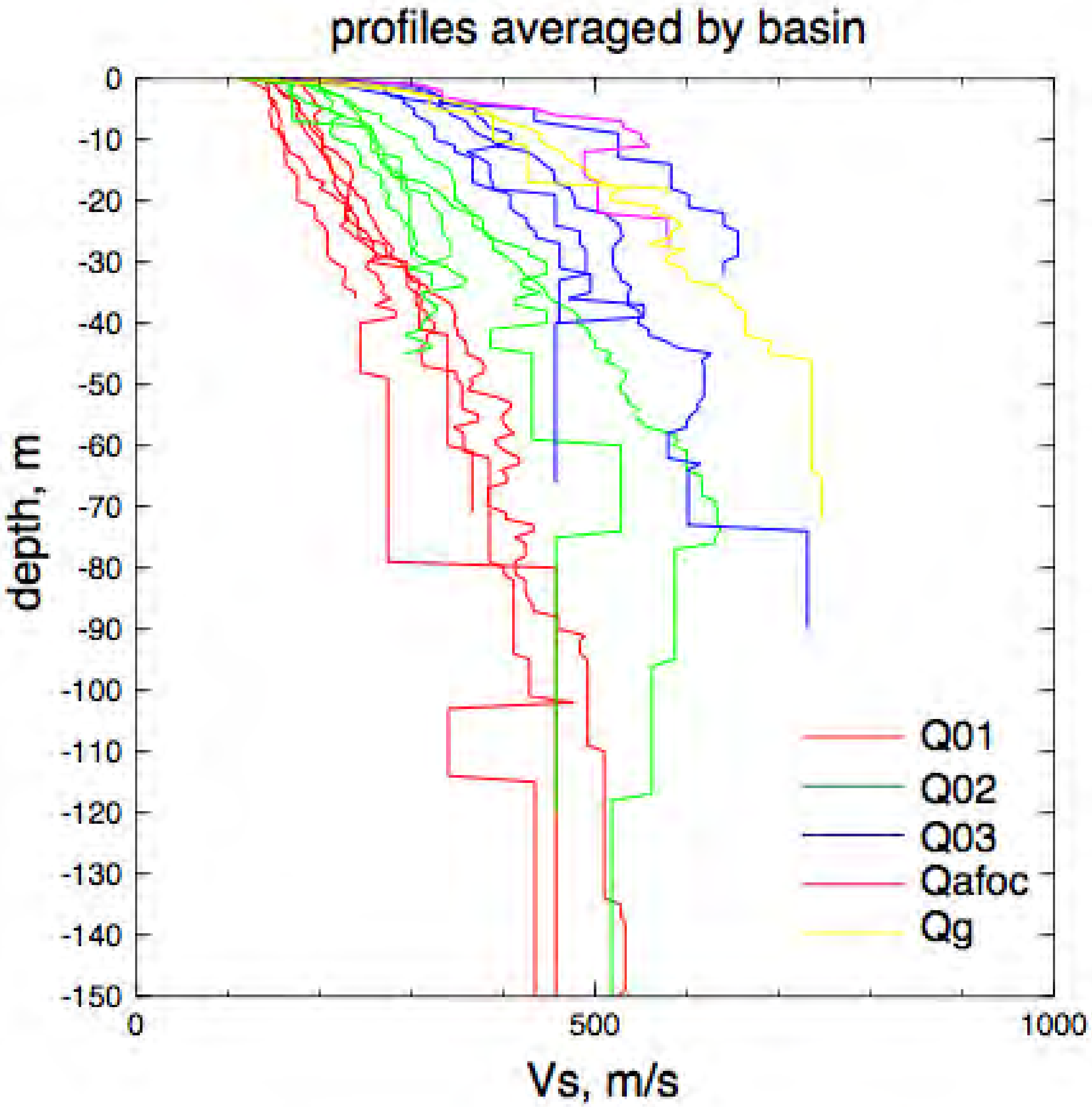
version 2c
3200
2650
2100
1800
1500
1200
900
750
600
450
300
114
Vs, m/s
VE 20
depth, m
longitude, deg

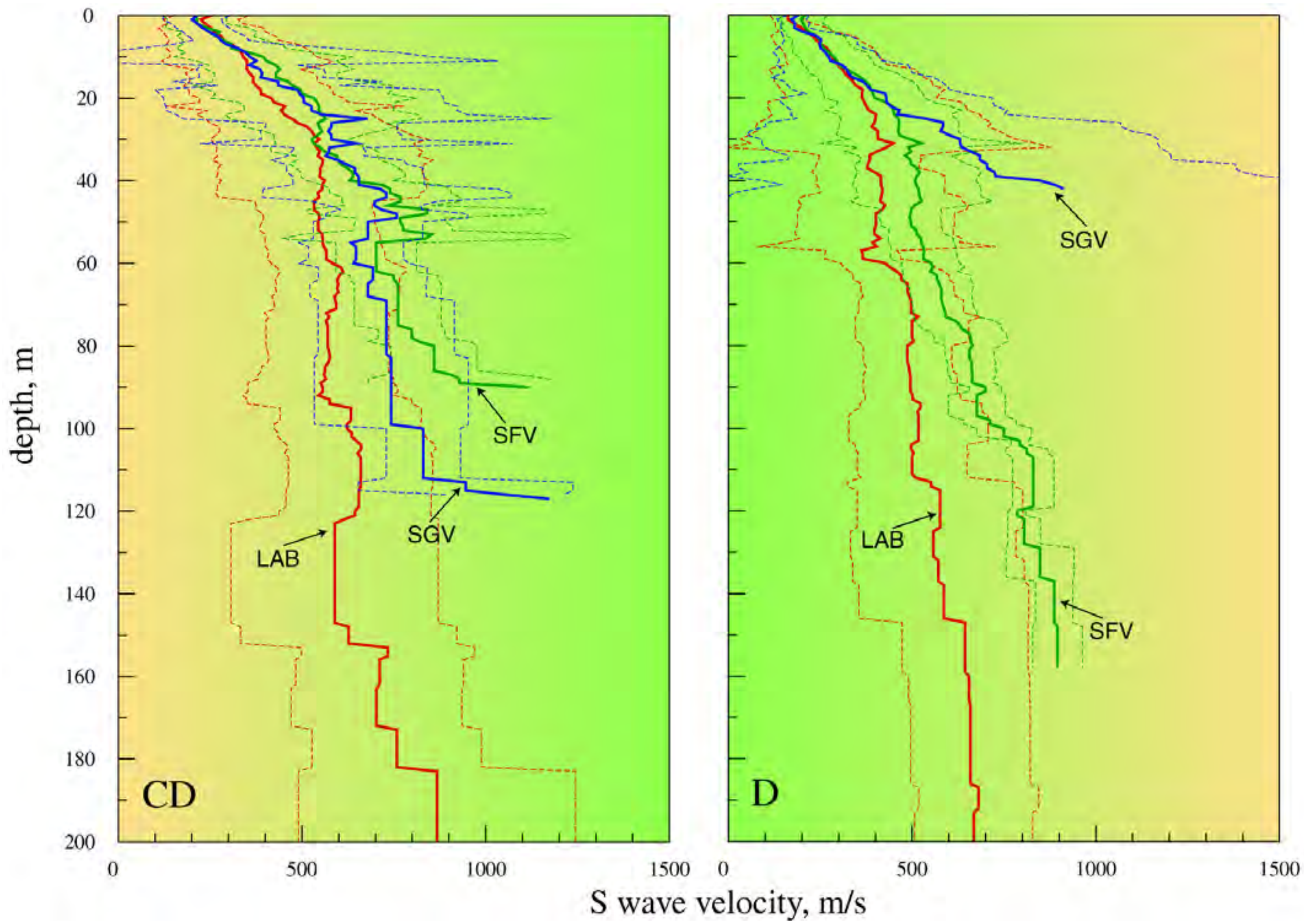


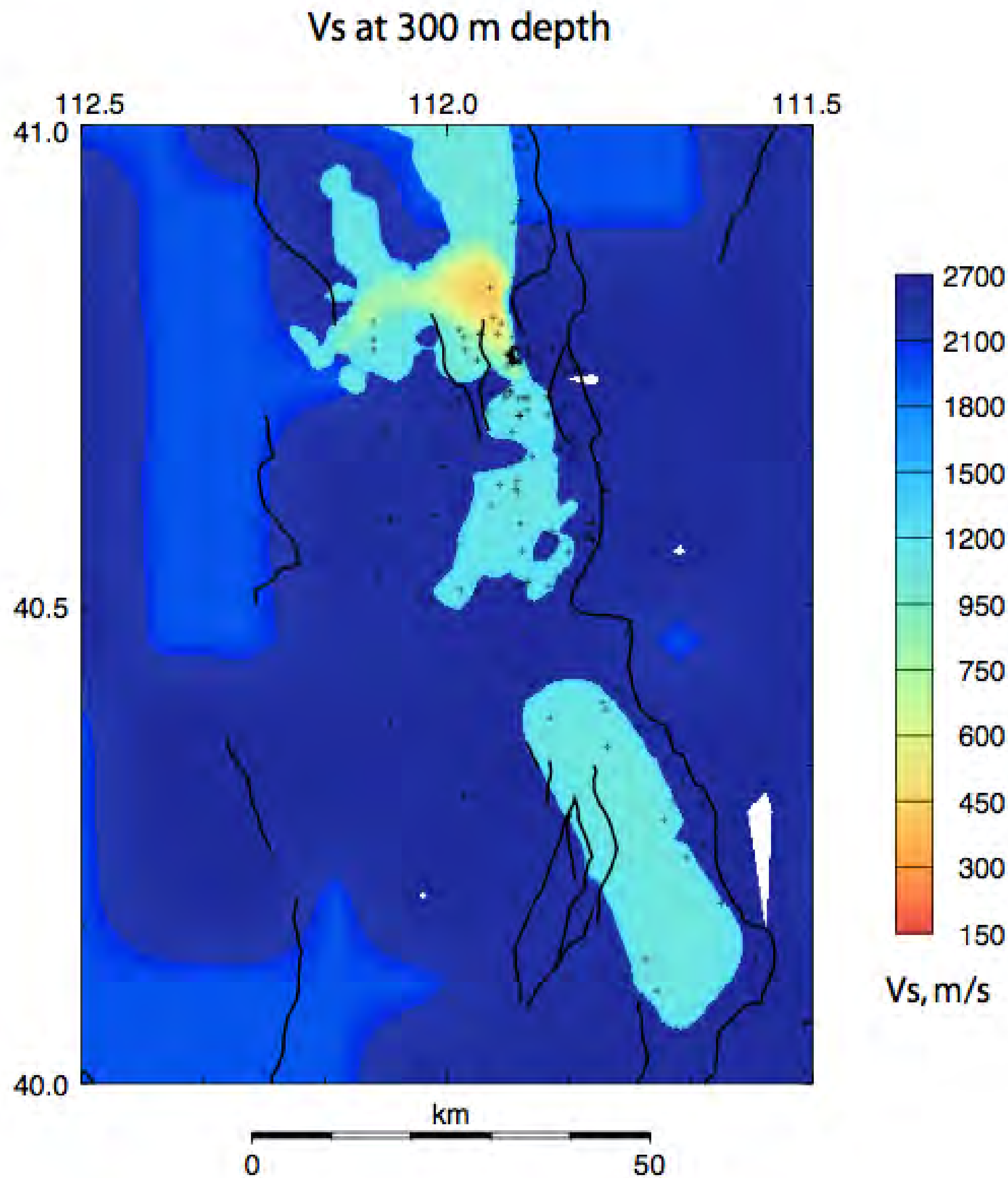
version 2c
south
north
0
20
40
60
80
100
-1000
-2000
depth, m
distance, km
114
300
450
600
750
900
1200
1500
1800
2100
2650
3200
Vs m/s

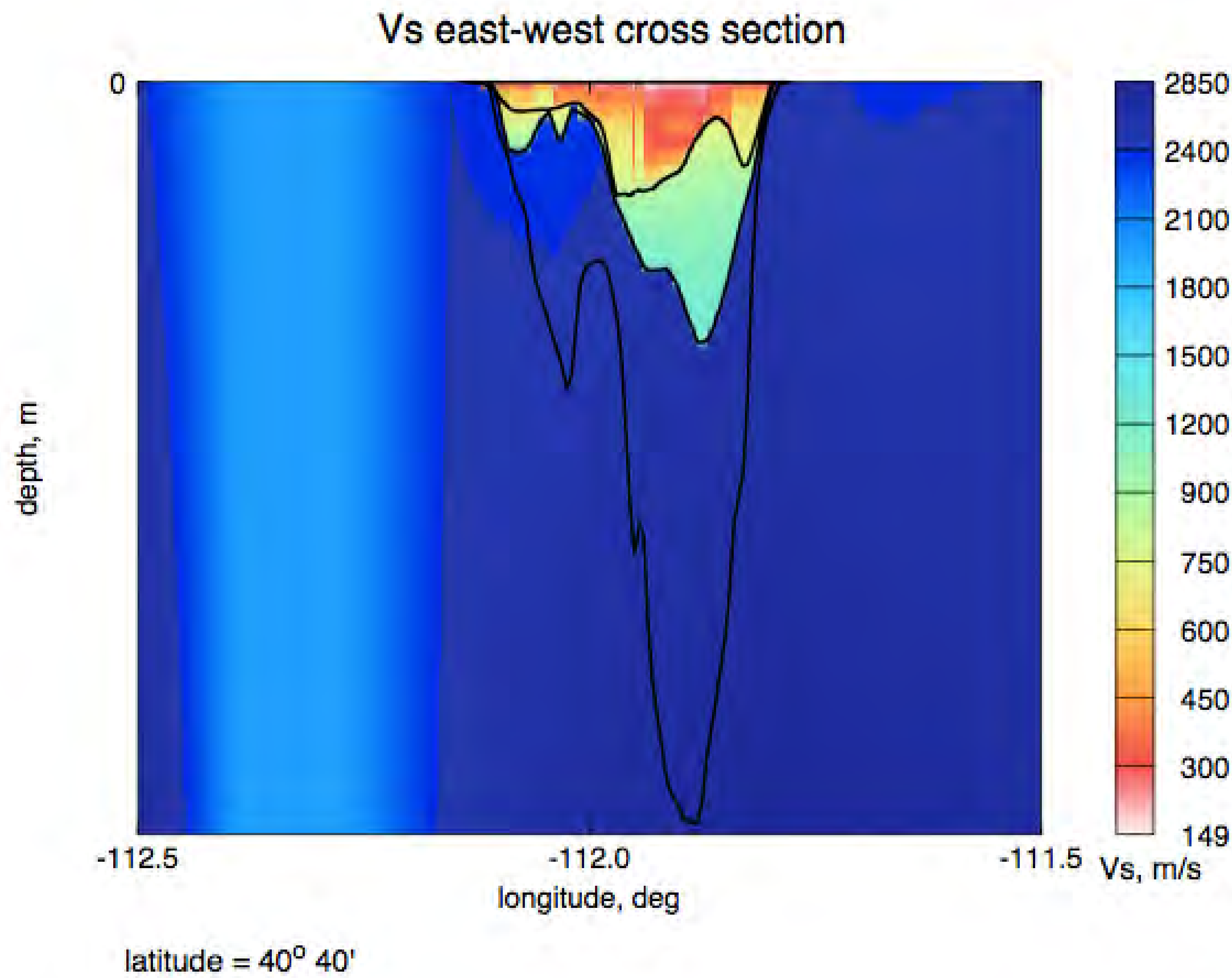


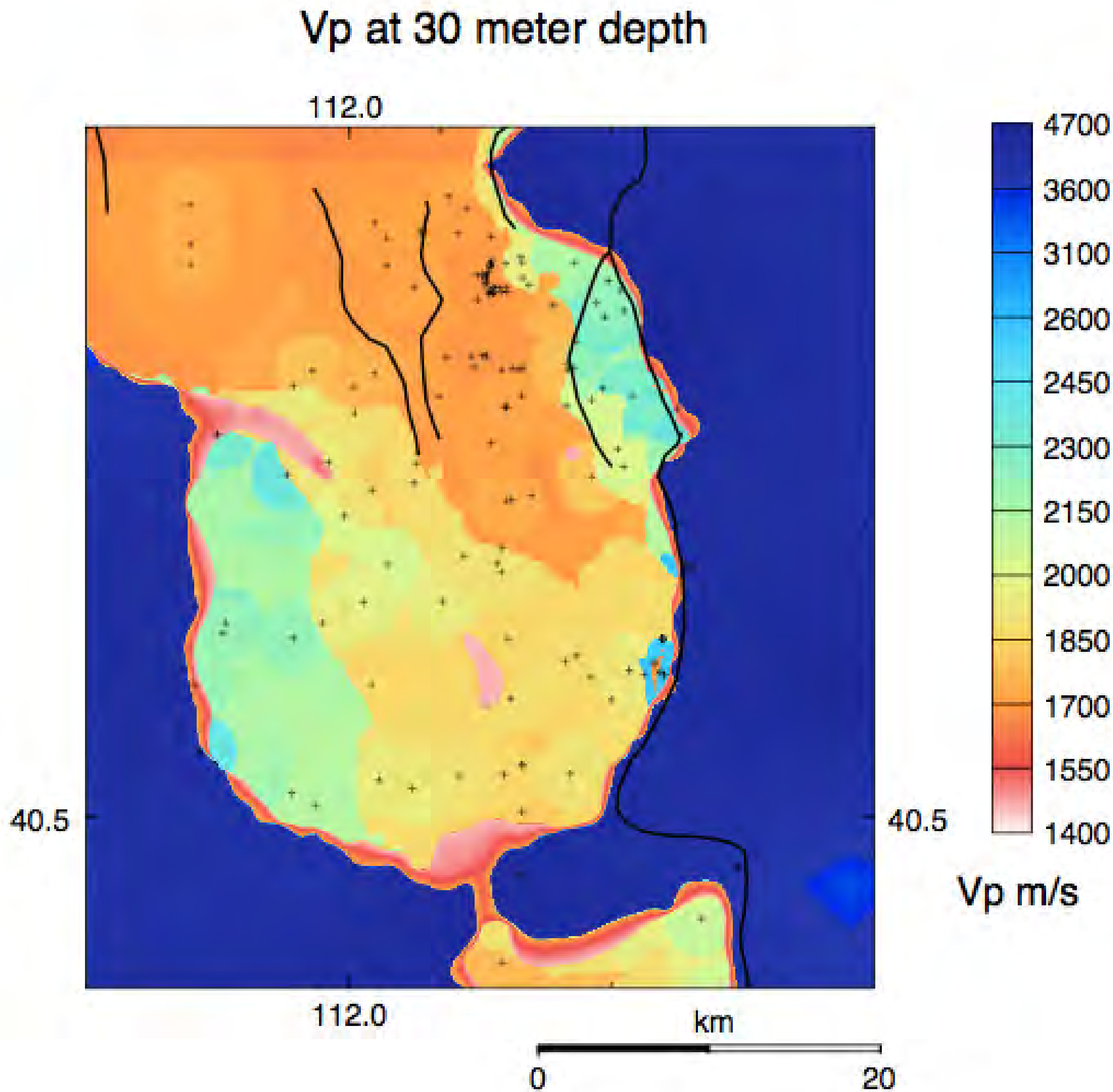
Vs m/s
114 300 450 600 750 900 1200 1500 1800 2100 2650 3200
VE 20
41.0
40.75
40.25
0
-1000
-2000
-112.5
-111.5
depth, m
version 2c


profiles averaged by basin
depth, m
Vs, m/s
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
0
500
1000
Q01
Q02
Q03
Qafoc
Qg


depth, m
S wave velocity, m/s
CD
D
LAB
SGV
SFV
LAB
SGV
SFV
0
20
40
60
80
100
120
140
160
180
200
0
500
1000
1500
0
500
1000
1500


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


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
112.0
112.0
40.5
40.5
4700
3600
3100
2600
2450
2300
2150
2000
1850
1700
1550
1400
Vp m/s
km
0
20

# 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

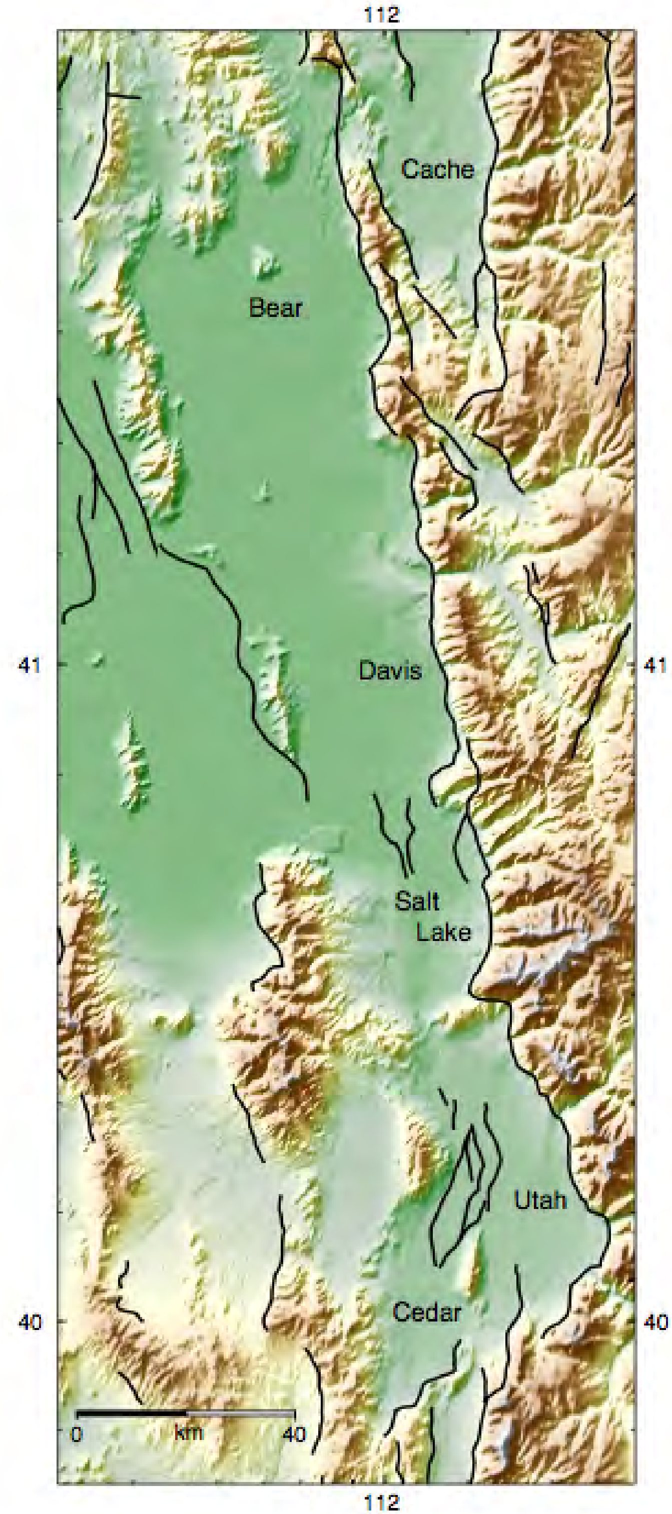
-Compare point of interest to objects and interpolate properties.

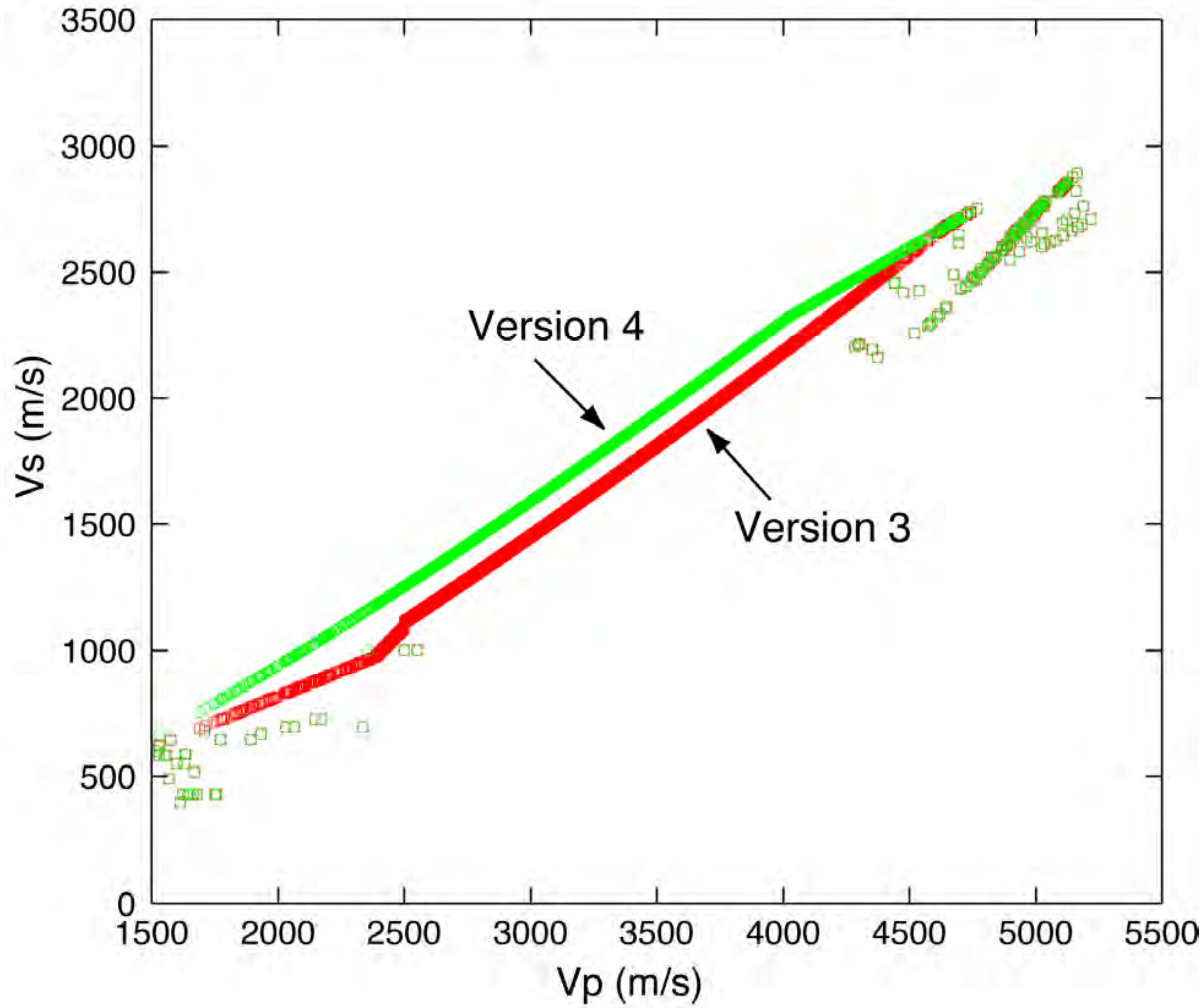
examples: interpolation of age between surfaces
interpolation of velocity between tomography nodes

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

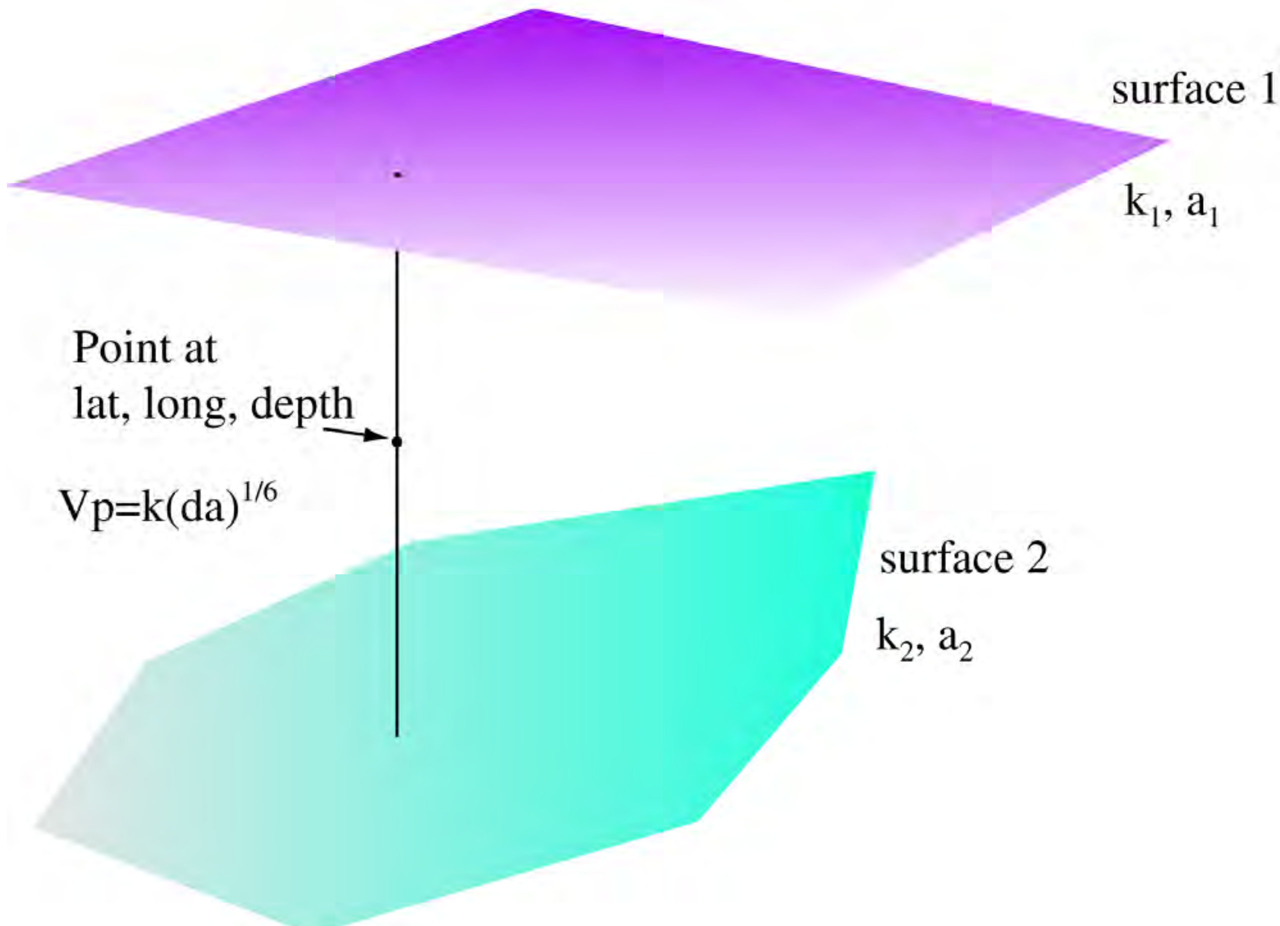
examples: linear gradient between isovelocity surfaces
Faust's rule (velocity-age-depth relation)

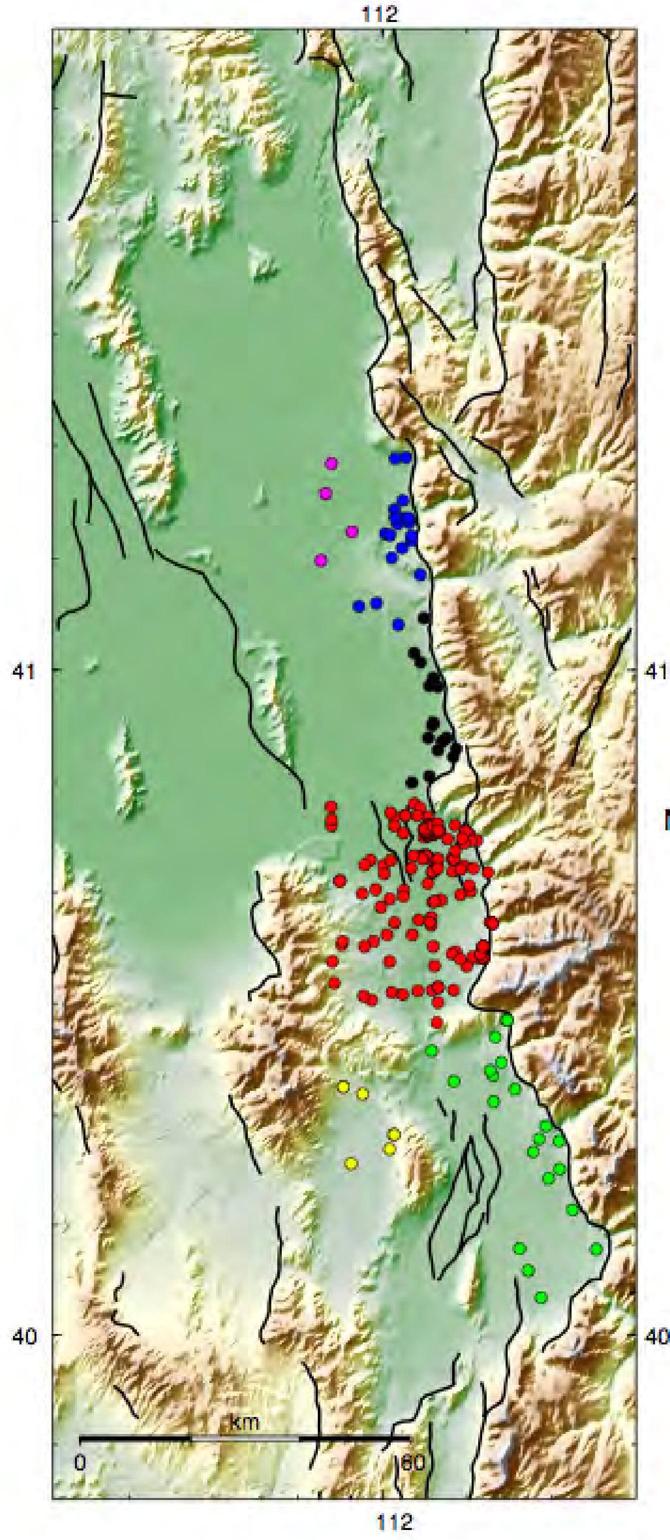
$$Vp=k(da)^{1/6}$$


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

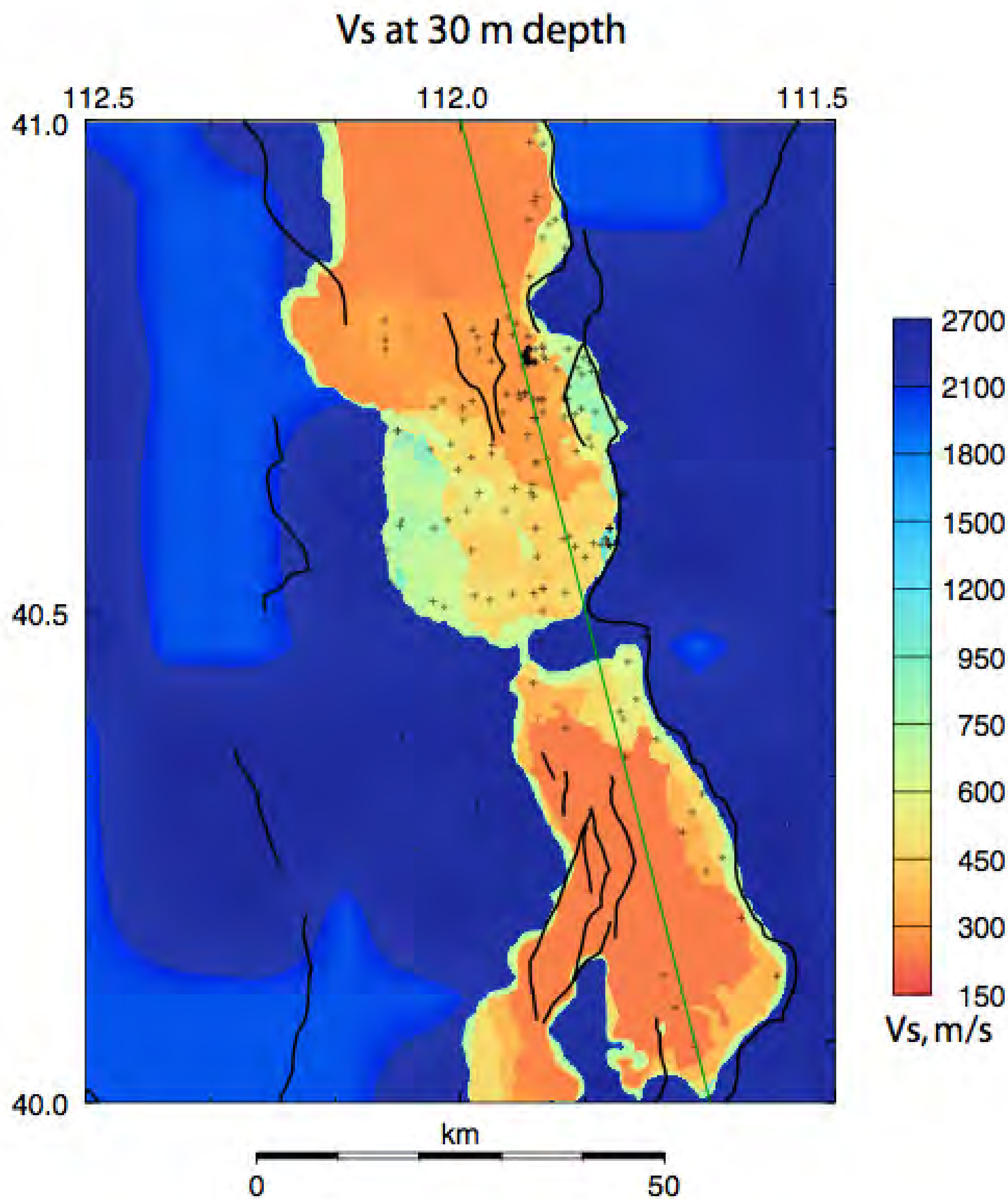

Version 4
Version 3
Vs (m/s)
Vp (m/s)
0
500
1000
1500
2000
2500
3000
3500
1500
2000
2500
3000
3500
4000
4500
5000
5500

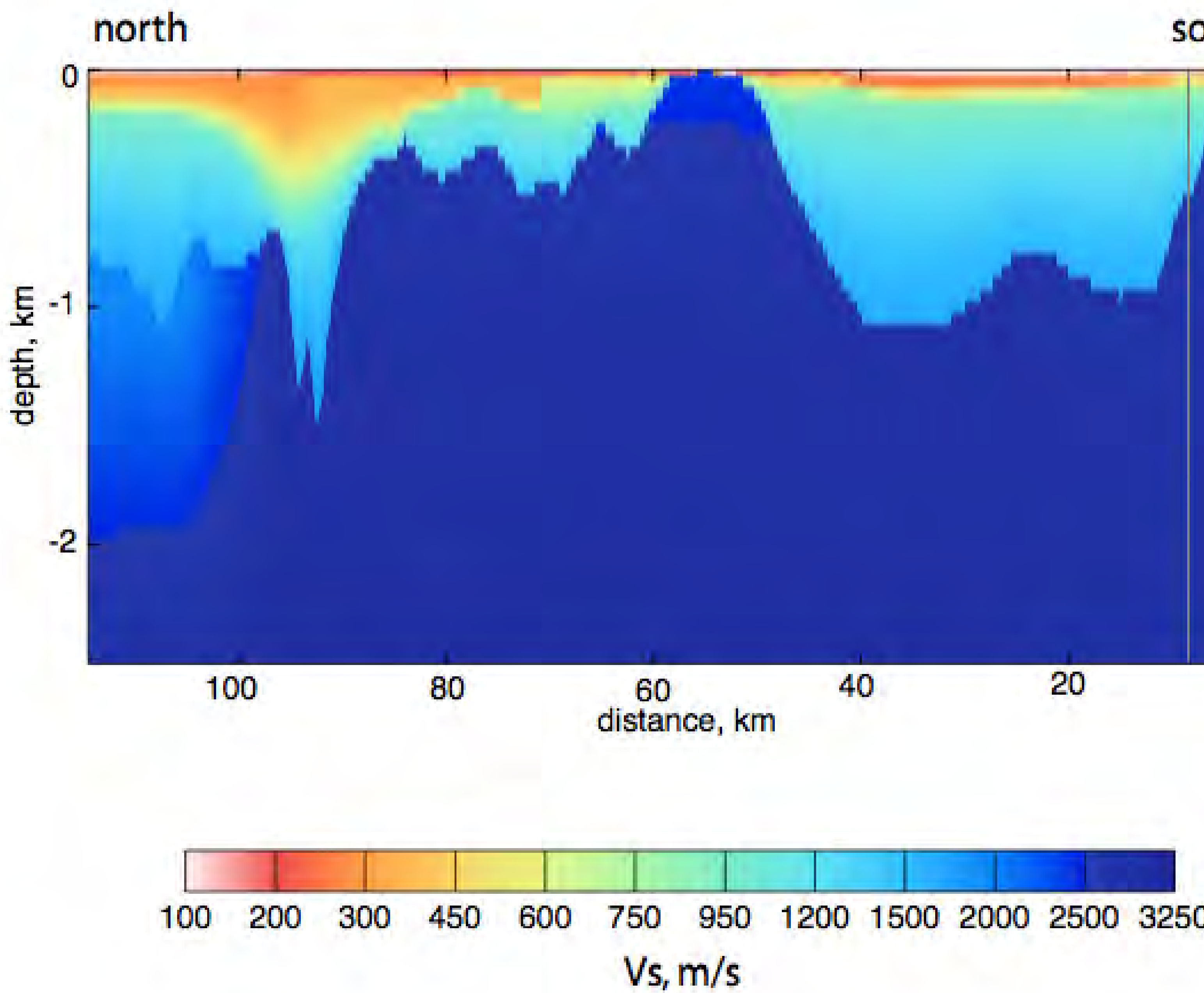
## Model Parameterization

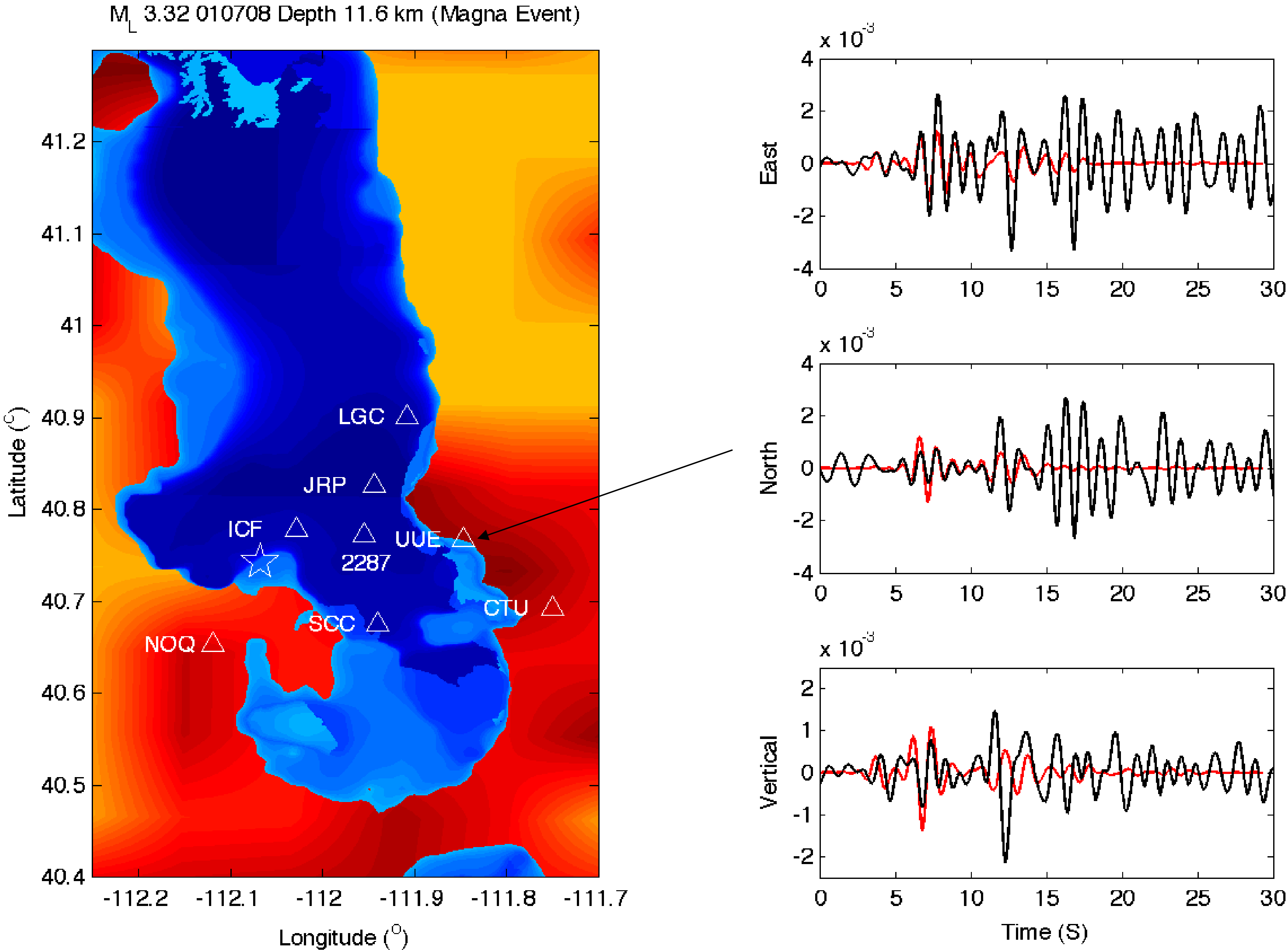




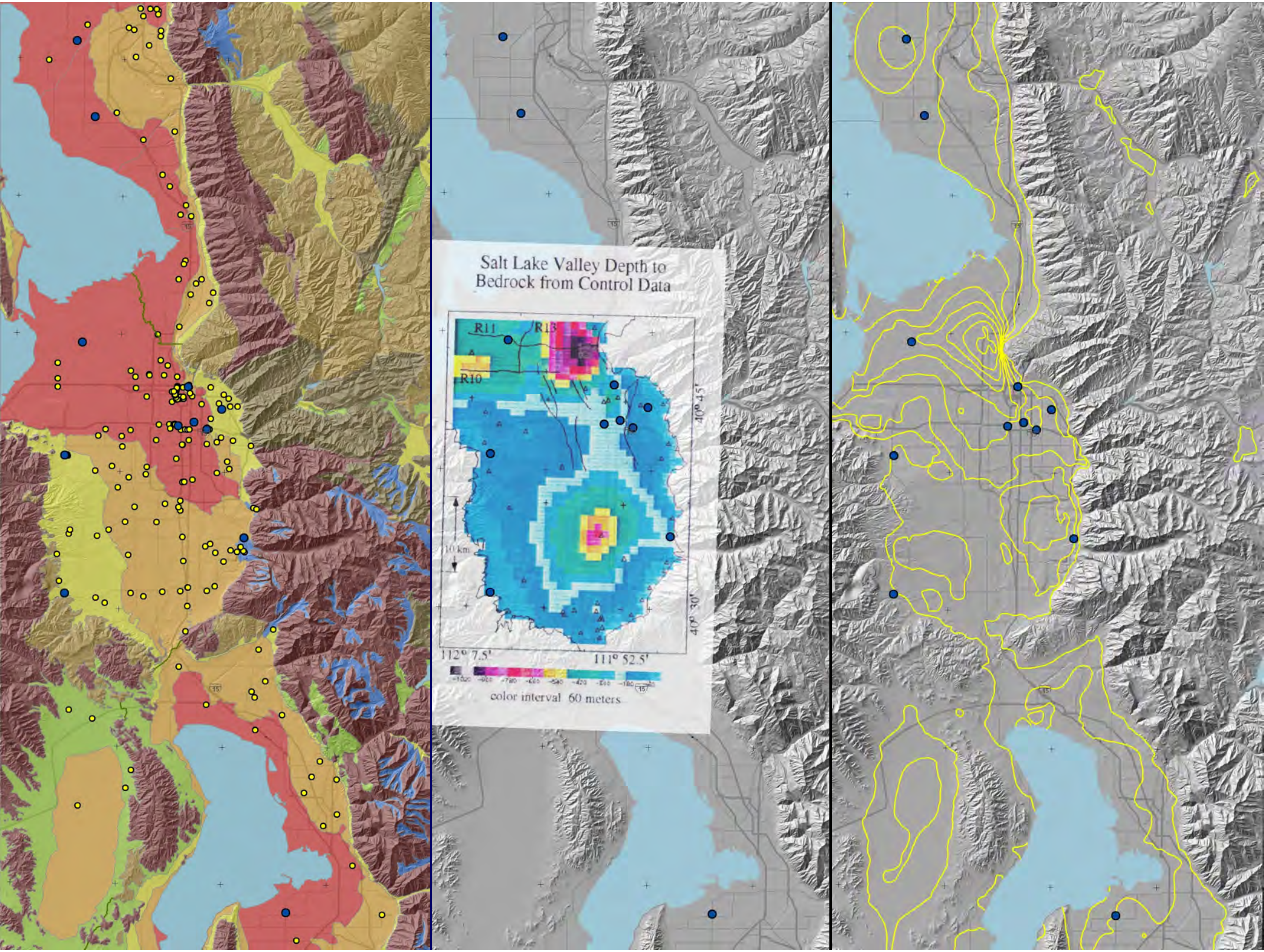

McDonald Oct 2006


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

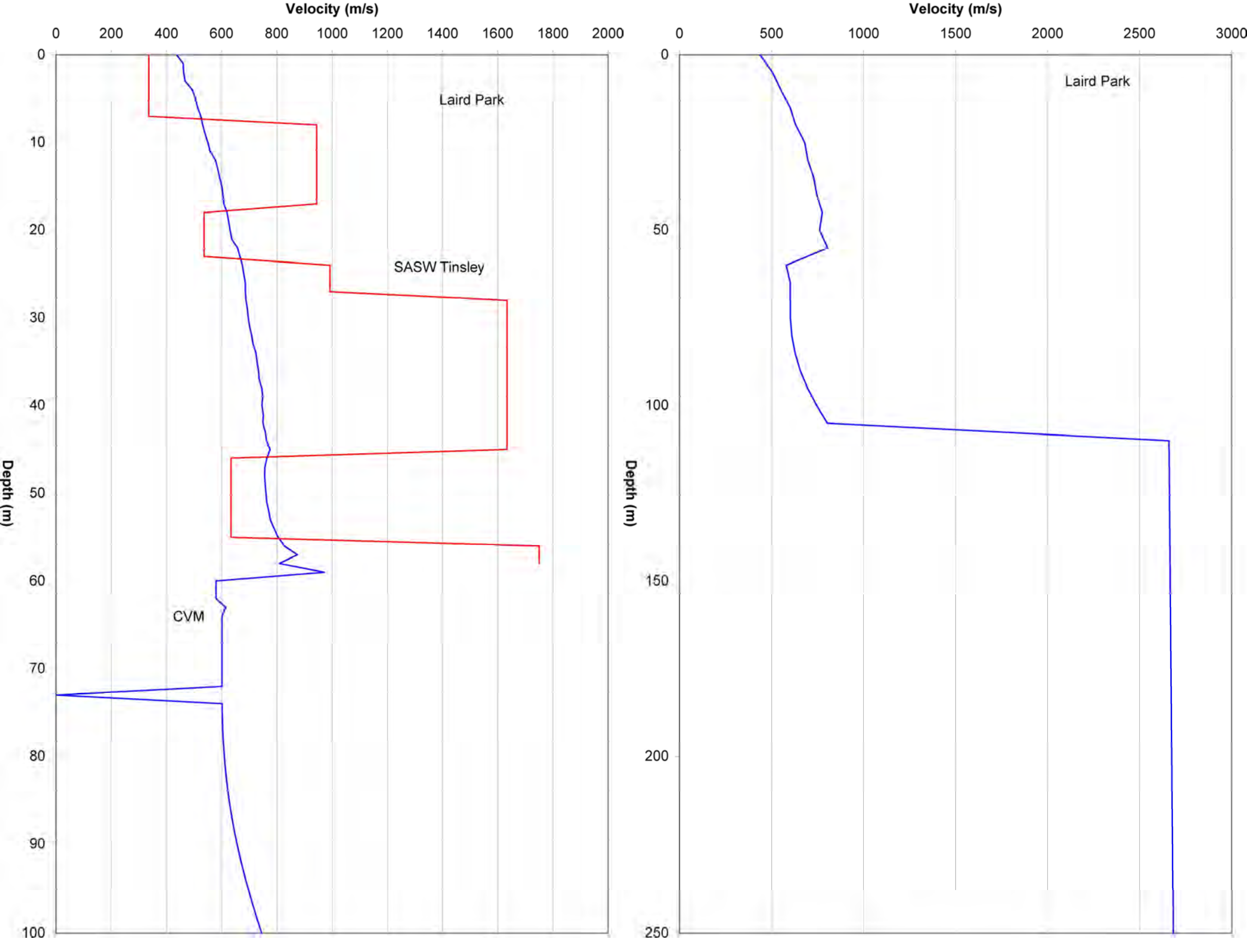

north
south
0
-1
-2
depth, km
100
80
60
40
20
0
distance, km
100
200
300
450
600
750
950
1200
1500
2000
2500
3250
Vs, m/s

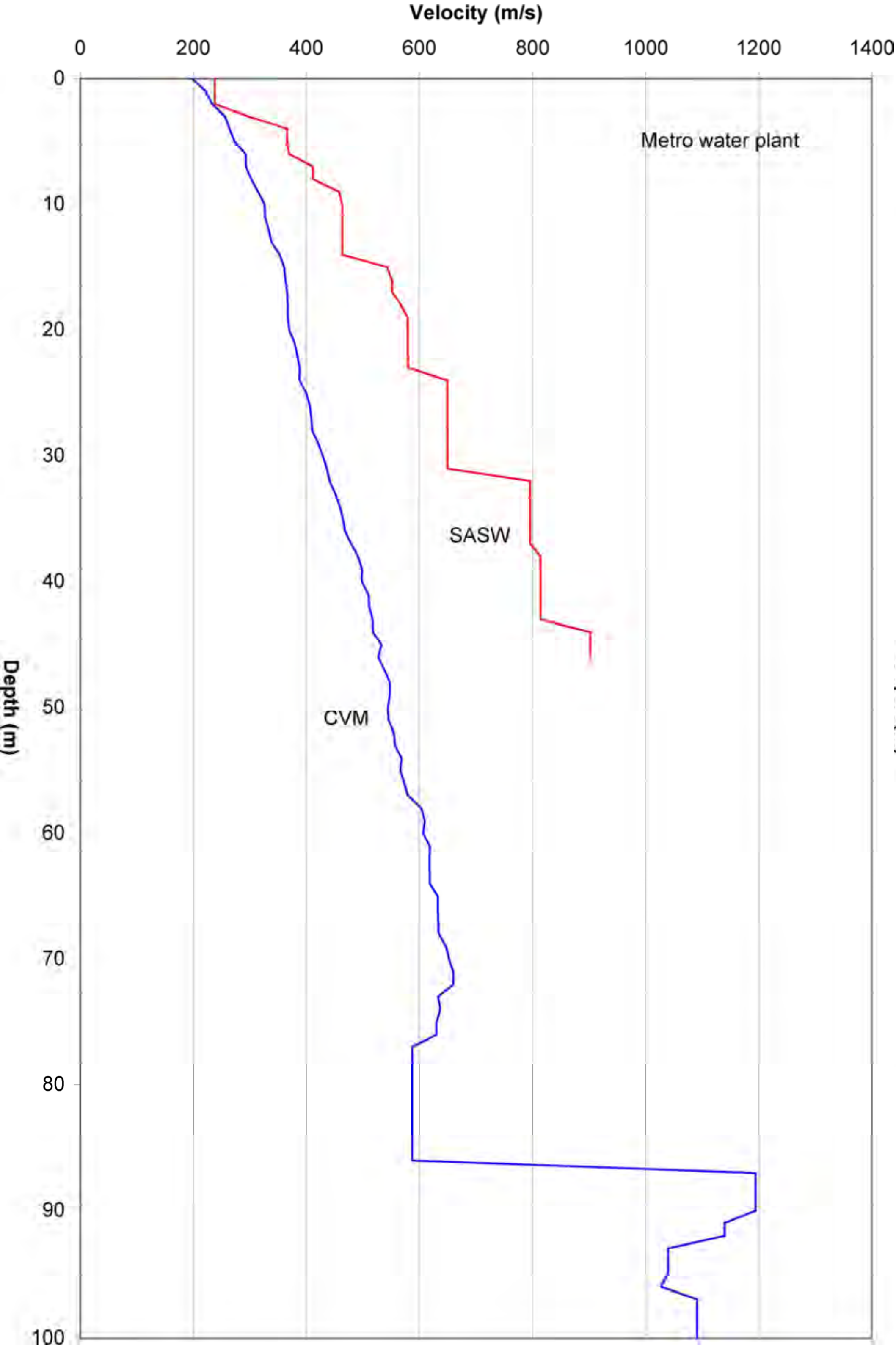


M_L 3.32 010708 Depth 11.6 km (Magna Event)
Latitude (°)
Longitude (°)
41.2
41.1
41
40.9
40.8
40.7
40.6
40.5
40.4
-112.2
-112.1
-112
-111.9
-111.8
-111.7
LGC
JRP
ICF
2287
UUE
CTU
SCC
NOQ
x 10^-3
East
North
Vertical
Time (S)

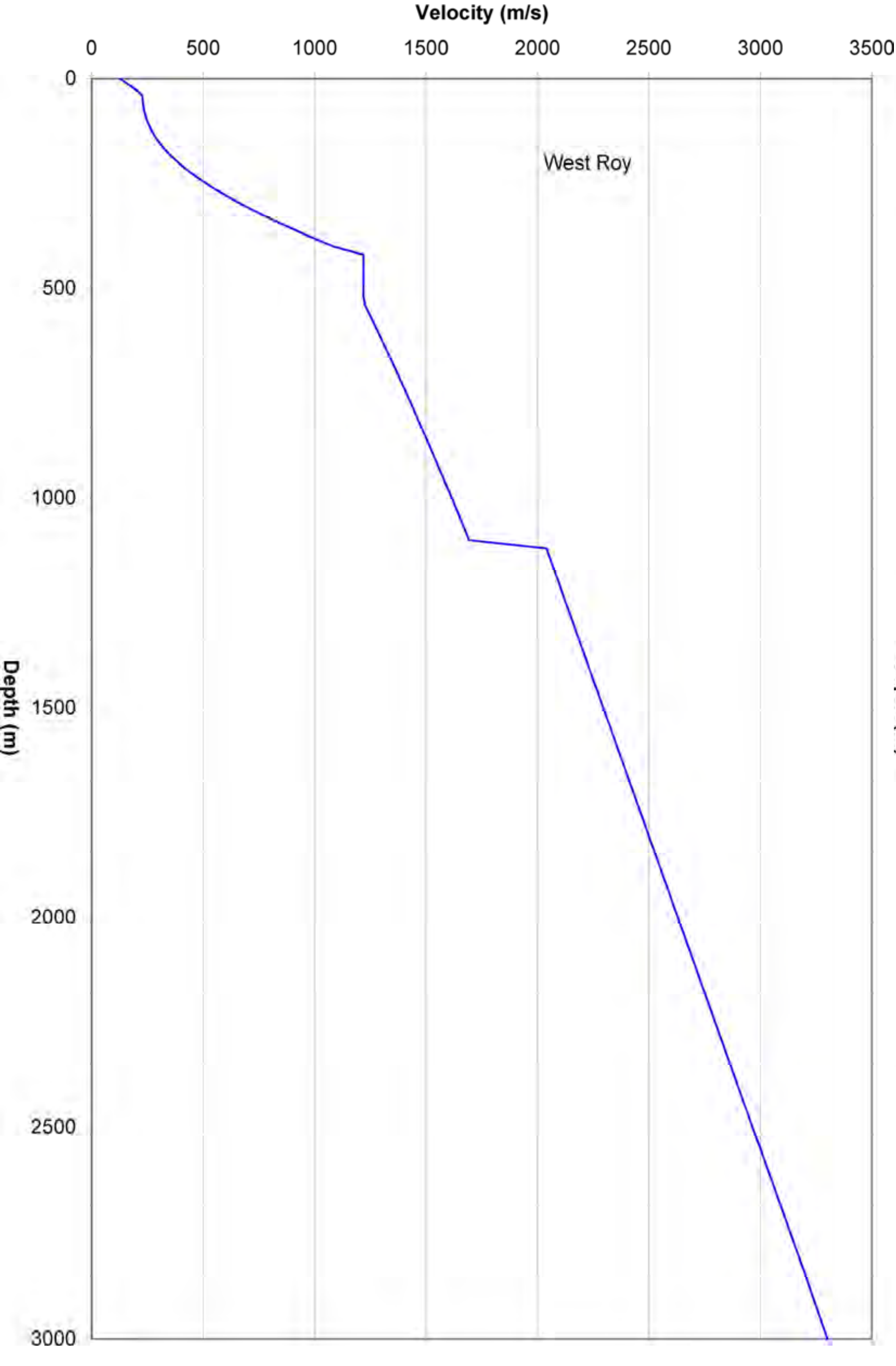


Salt Lake Valley Depth to Bedrock from Control Data
R11
R13
R10
10 km
40° 45'
40° 30'
112° 7.5'
111° 52.5'
-1020
-900
-780
-660
-540
-420
-300
-180
color interval 60 meters
15

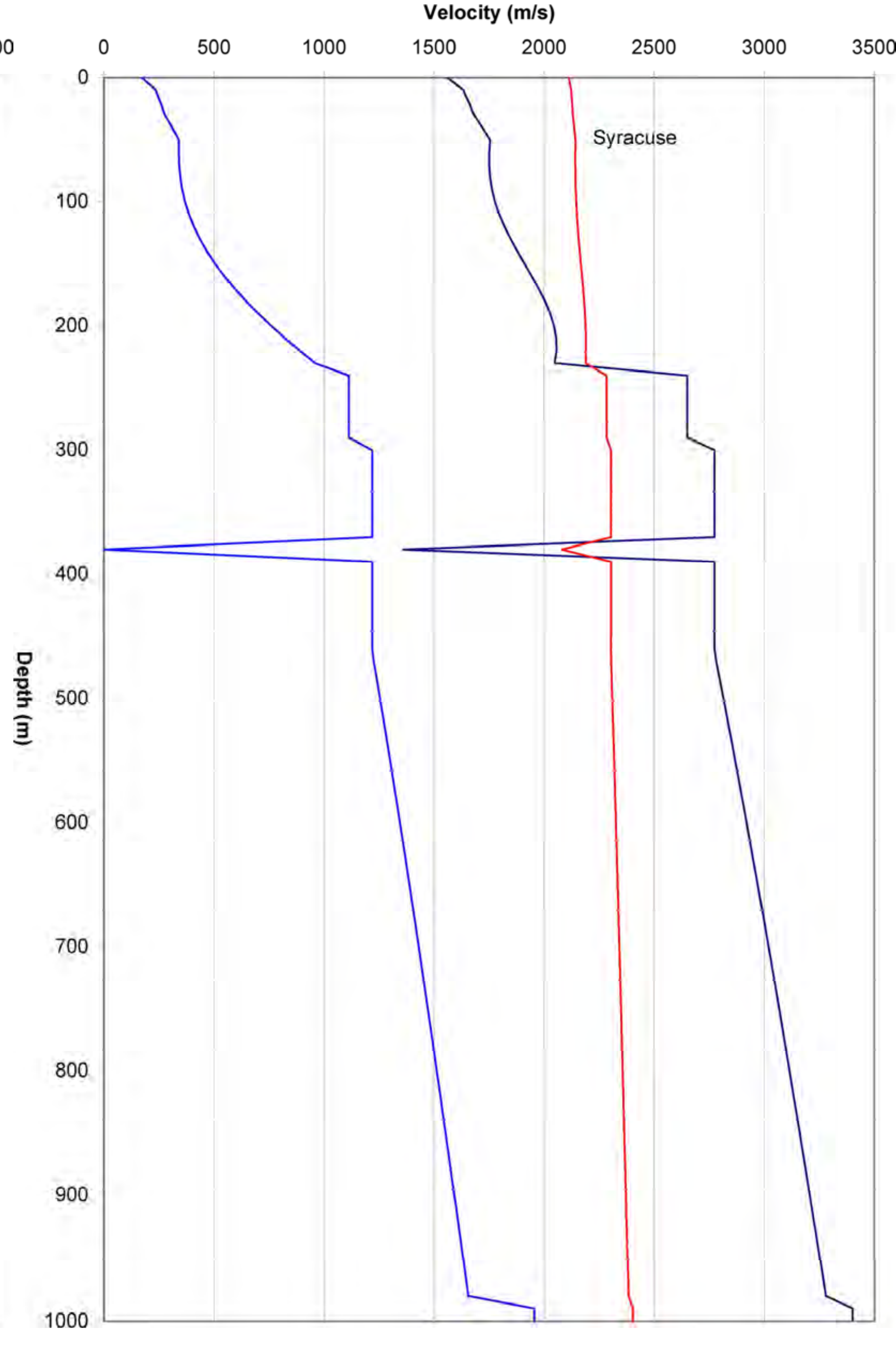

Velocity (m/s)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Laird Park
SASW Tinsley
CVM
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
Depth (m)
0
50
100
150
200
250
Laird Park


Velocity (m/s)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90
100
Depth (m)
Metro water plant
SASW
CVM

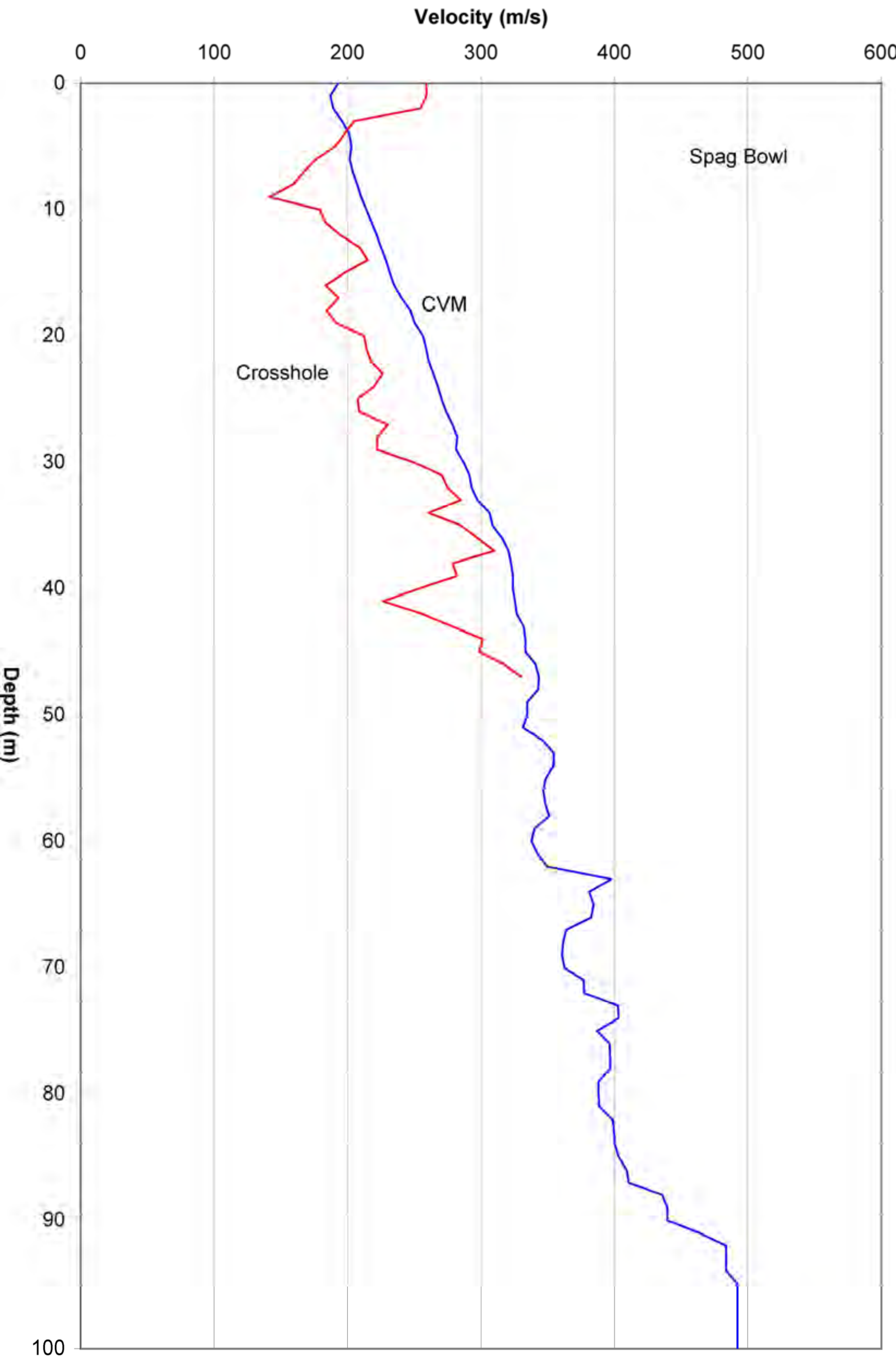

Velocity (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
100
200
300
400
500
600
700
800
900
1000
Depth (m)
Metro water plant

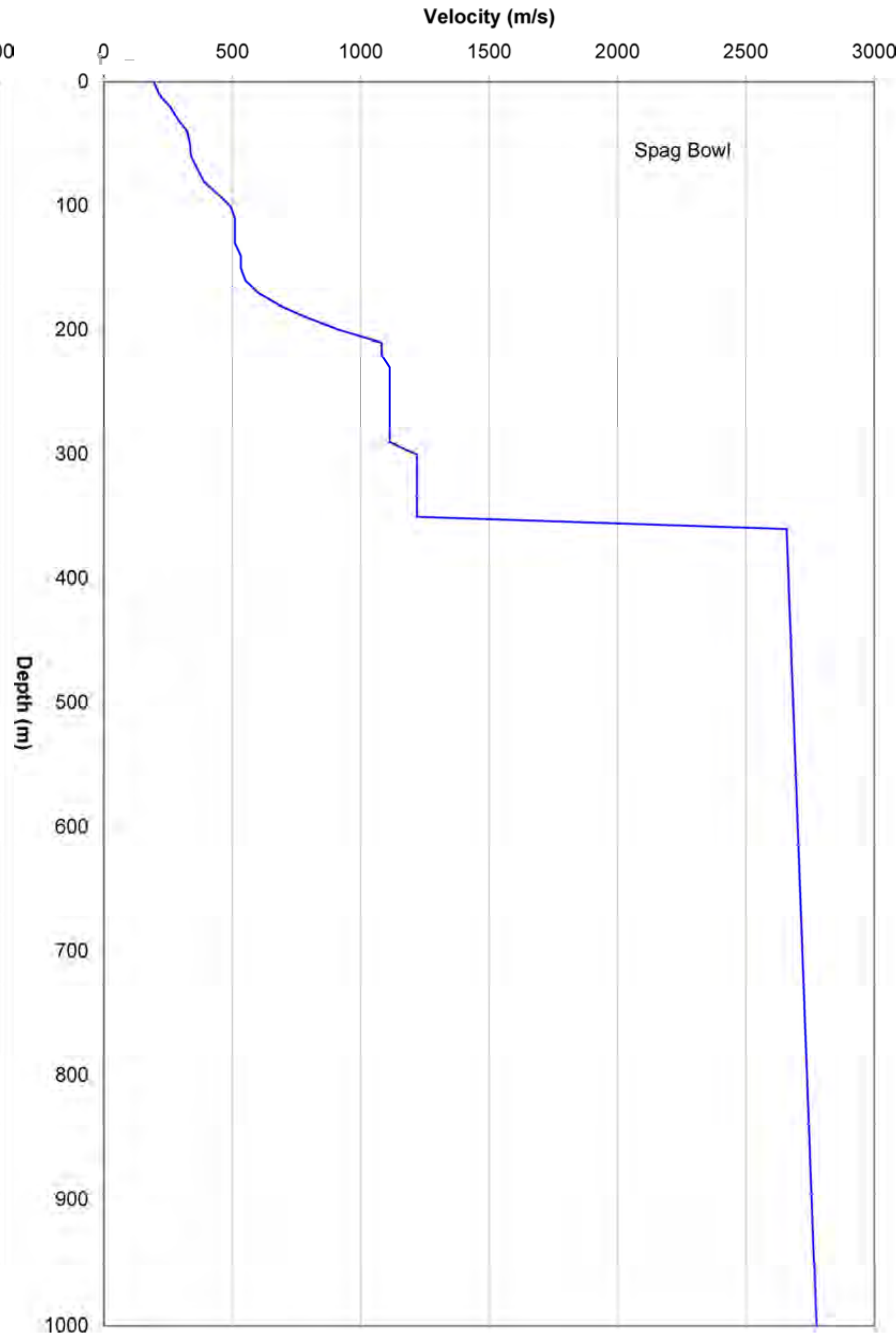


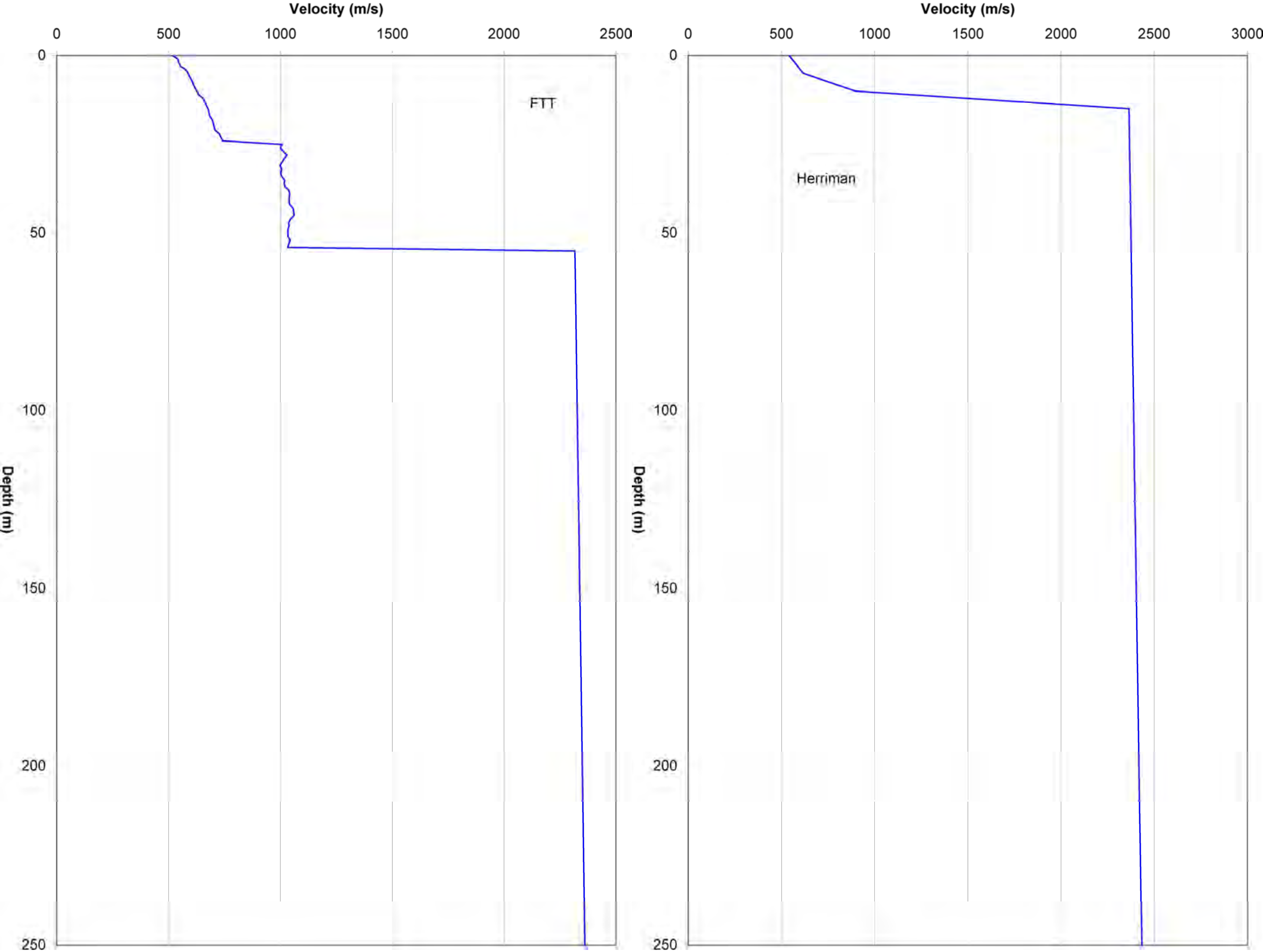
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
3500
West Roy
Depth (m)
0
500
1000
1500
2000
2500
3000

Velocity (m/s)
0
500
1000
1500
2000
2500
3000
3500
Syracuse
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000

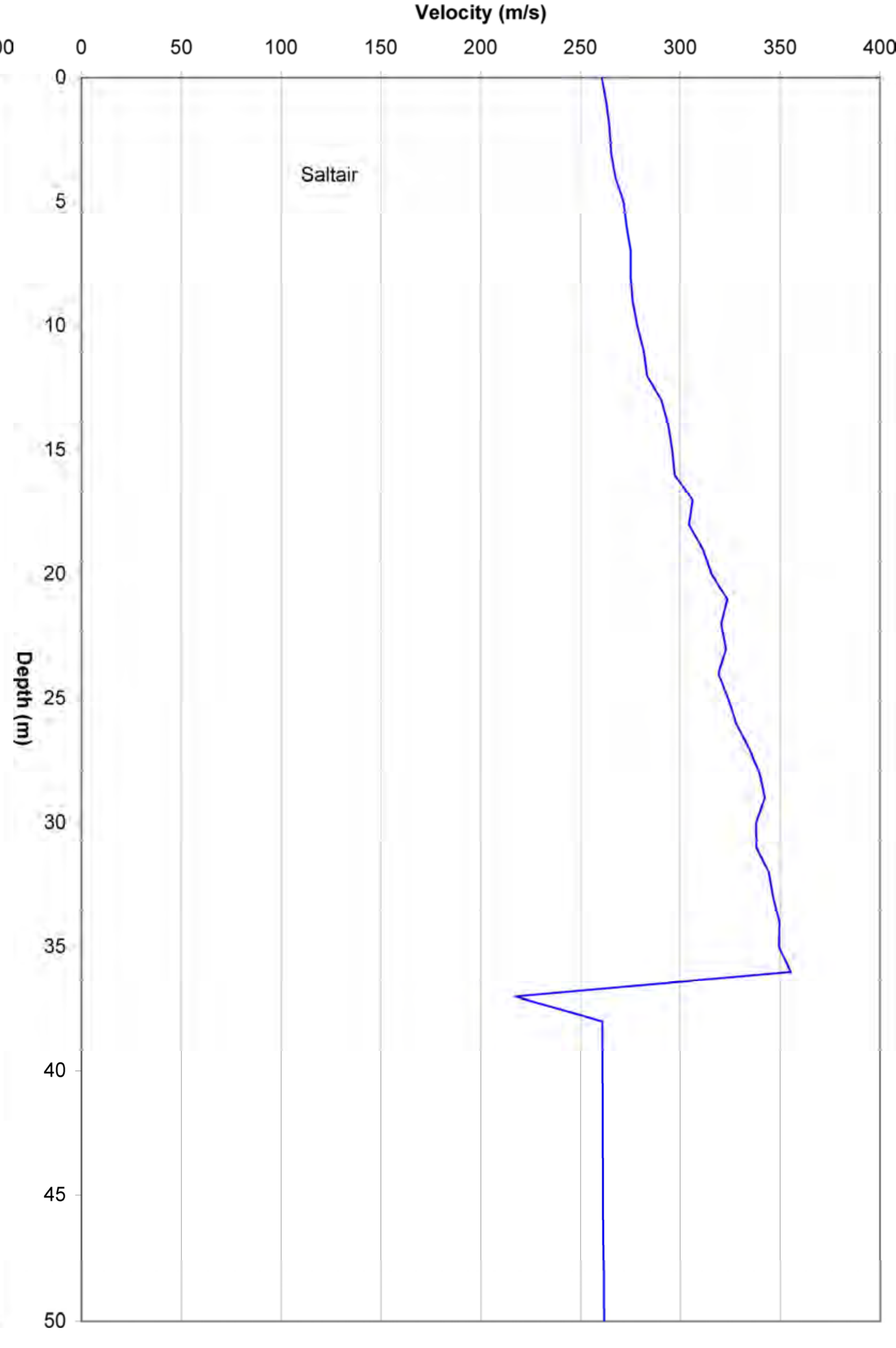

Velocity (m/s)
0
100
200
300
400
500
600
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Spag Bowl
CVM
Crosshole


Velocity (m/s)
0
500
1000
1500
2000
2500
3000
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
Spag Bowl

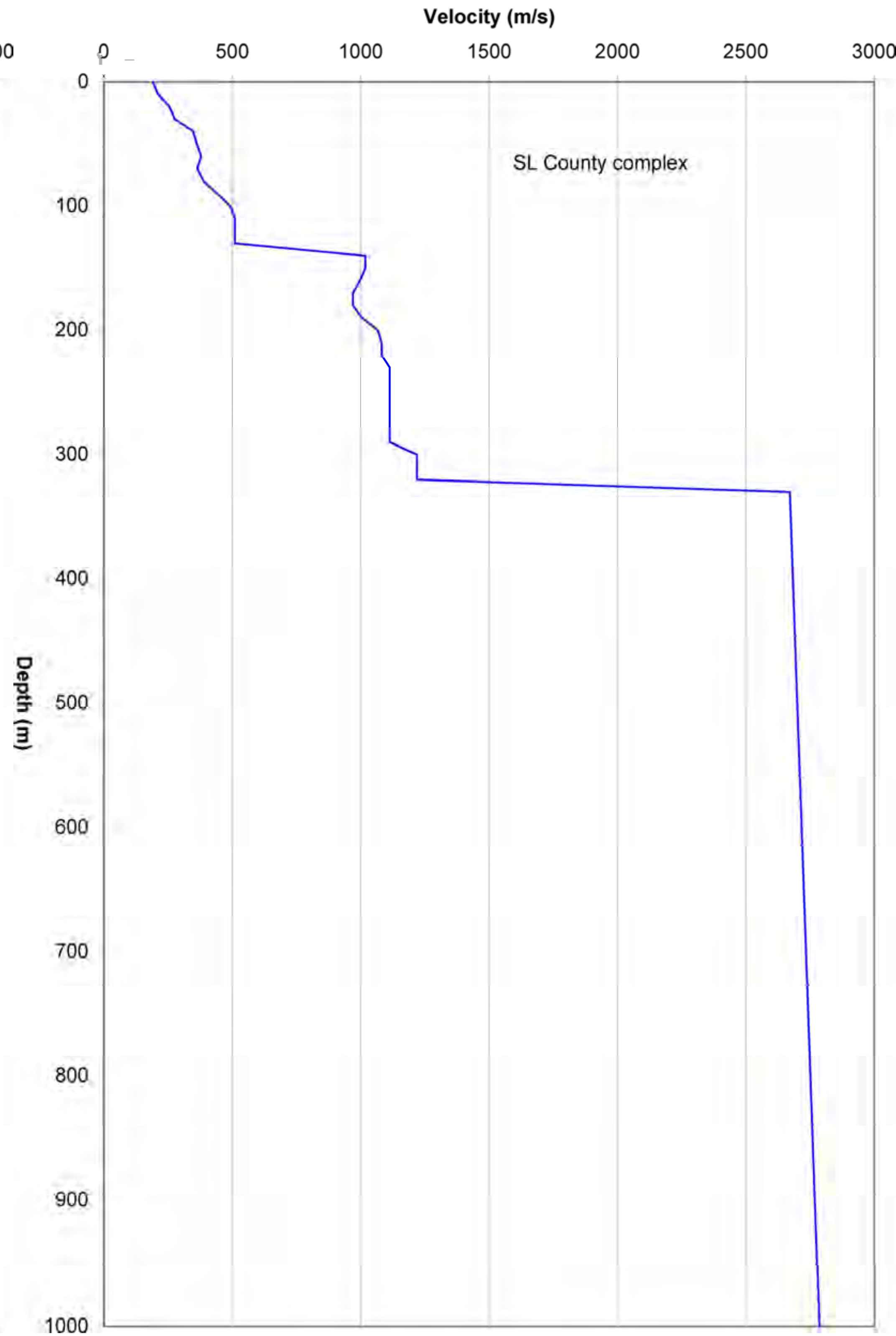


Velocity (m/s)
0
500
1000
1500
2000
2500
0
50
100
150
200
250
Depth (m)
FTT
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
0
50
100
150
200
250
Depth (m)
Herriman


Velocity (m/s)
0
500
1000
1500
2000
2500
3000
Saltair
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000

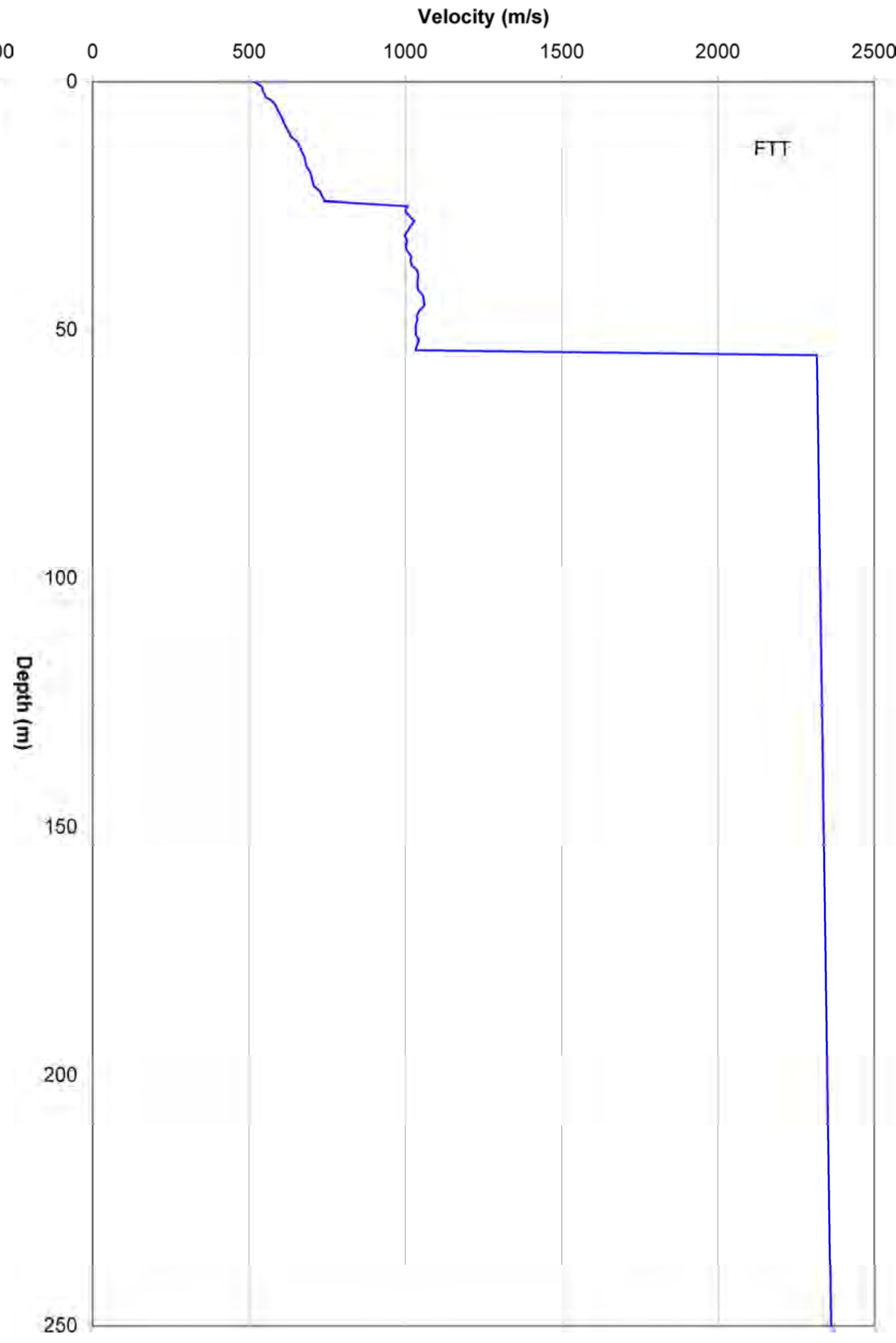

Velocity (m/s)
0
50
100
150
200
250
300
350
400
Saltair
Depth (m)
0
5
10
15
20
25
30
35
40
45
50

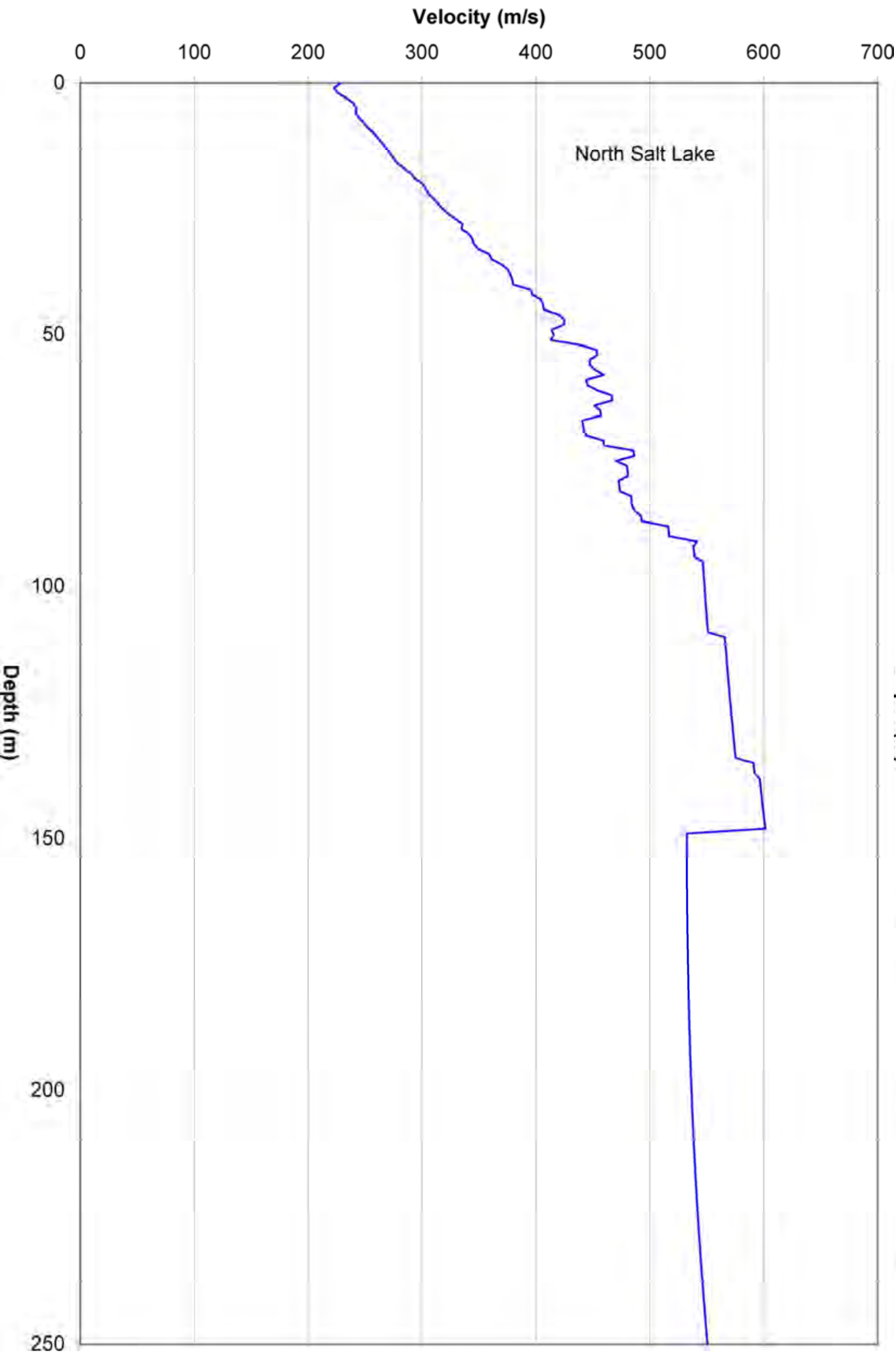
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
Forest Dale
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000

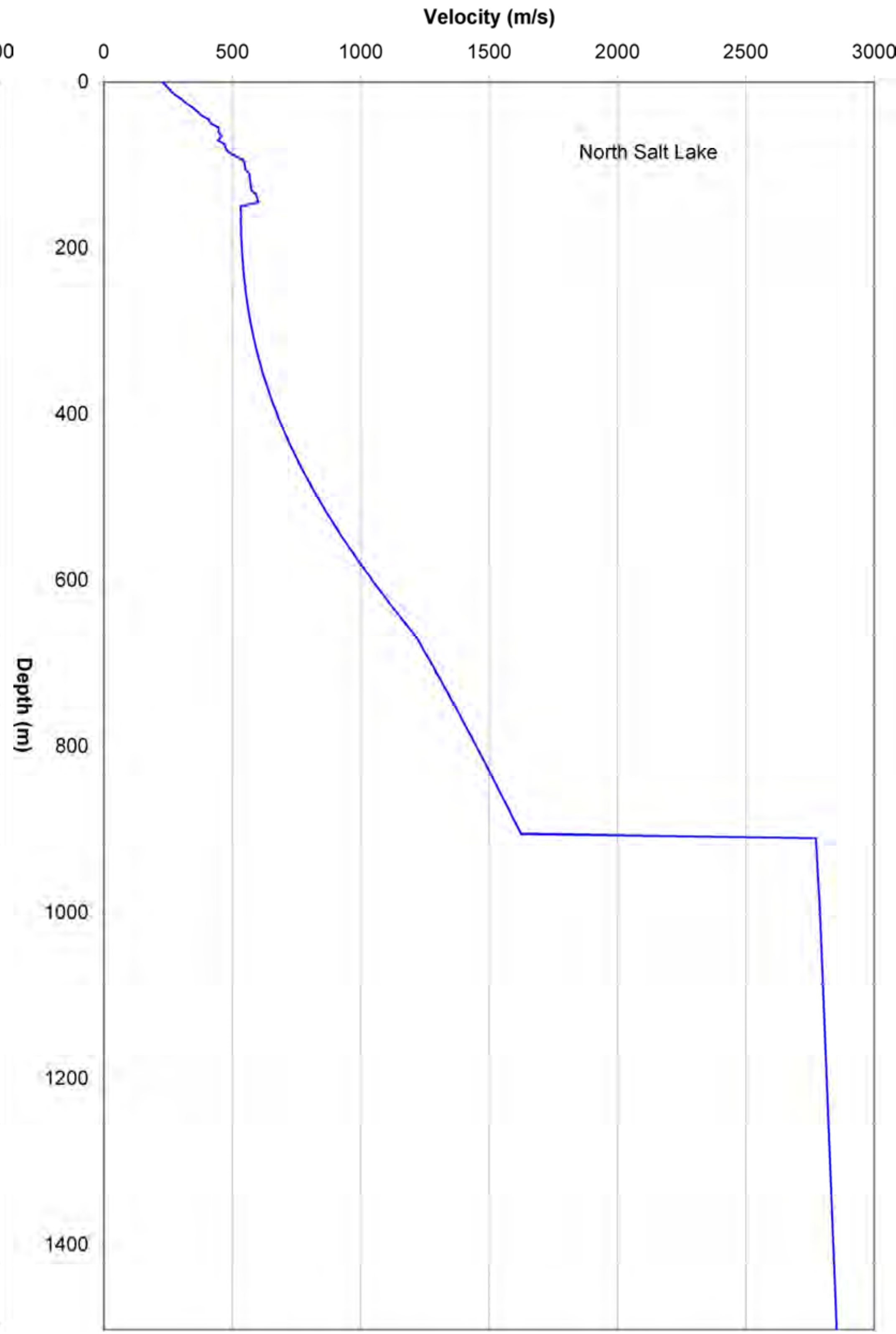
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
SL County complex
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000


Velocity (m/s)
0
500
1000
1500
2000
2500
3000
Depth (m)
0
50
100
150
200
250
Temple Square

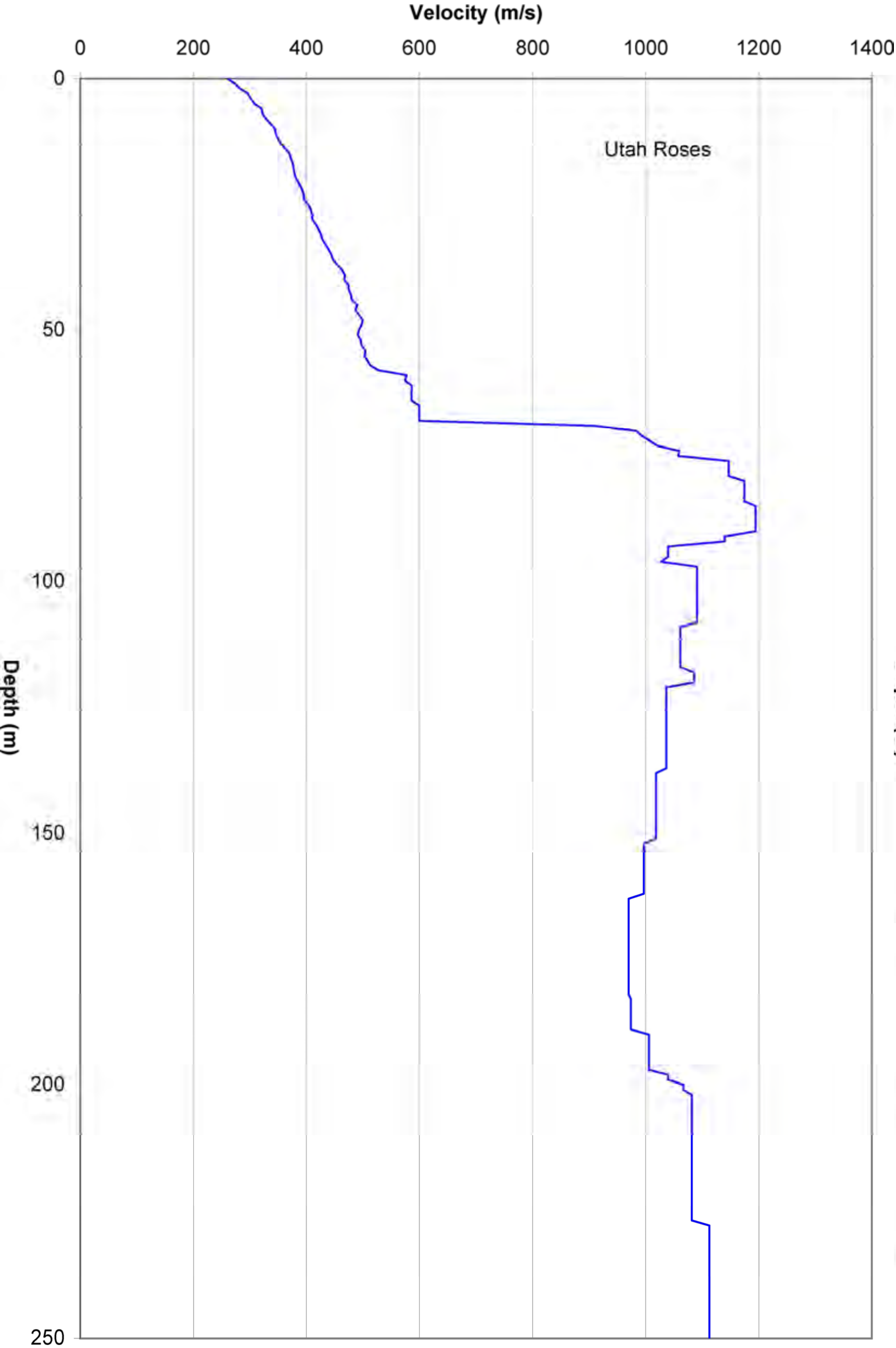

Velocity (m/s)
0
500
1000
1500
2000
2500
Depth (m)
0
50
100
150
200
250
FTT

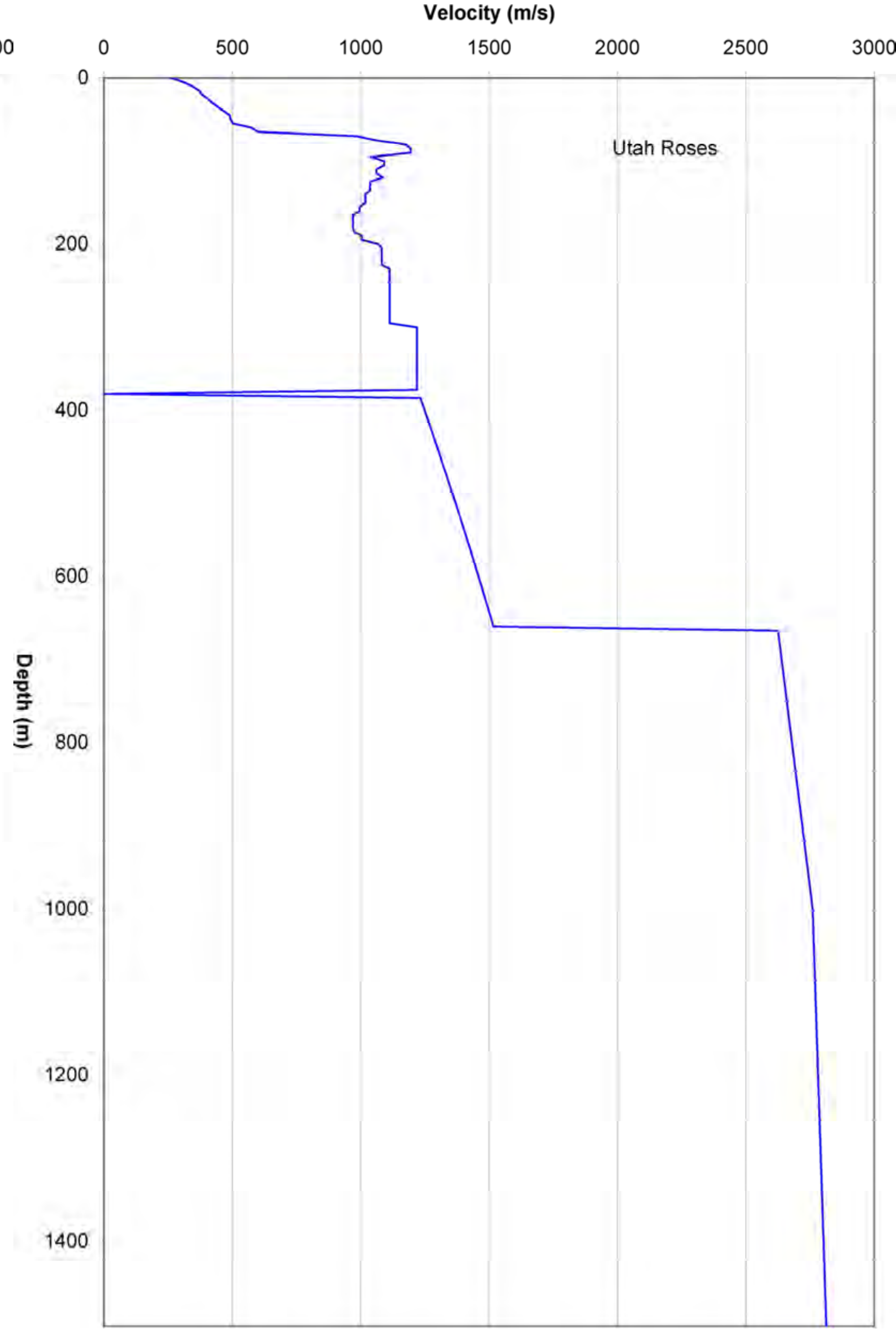


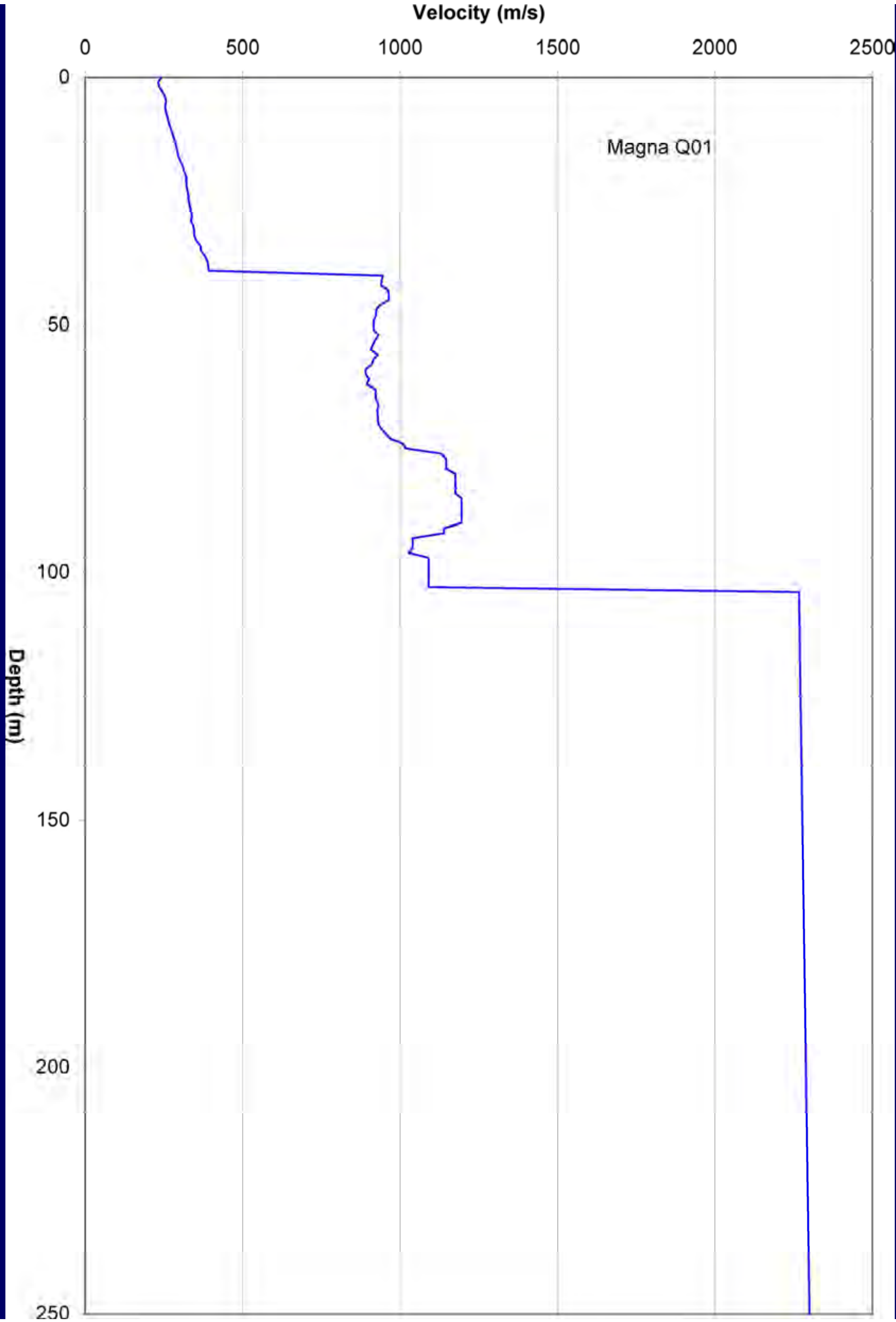
Velocity (m/s)
0
100
200
300
400
500
600
700
North Salt Lake
Depth (m)
0
50
100
150
200
250

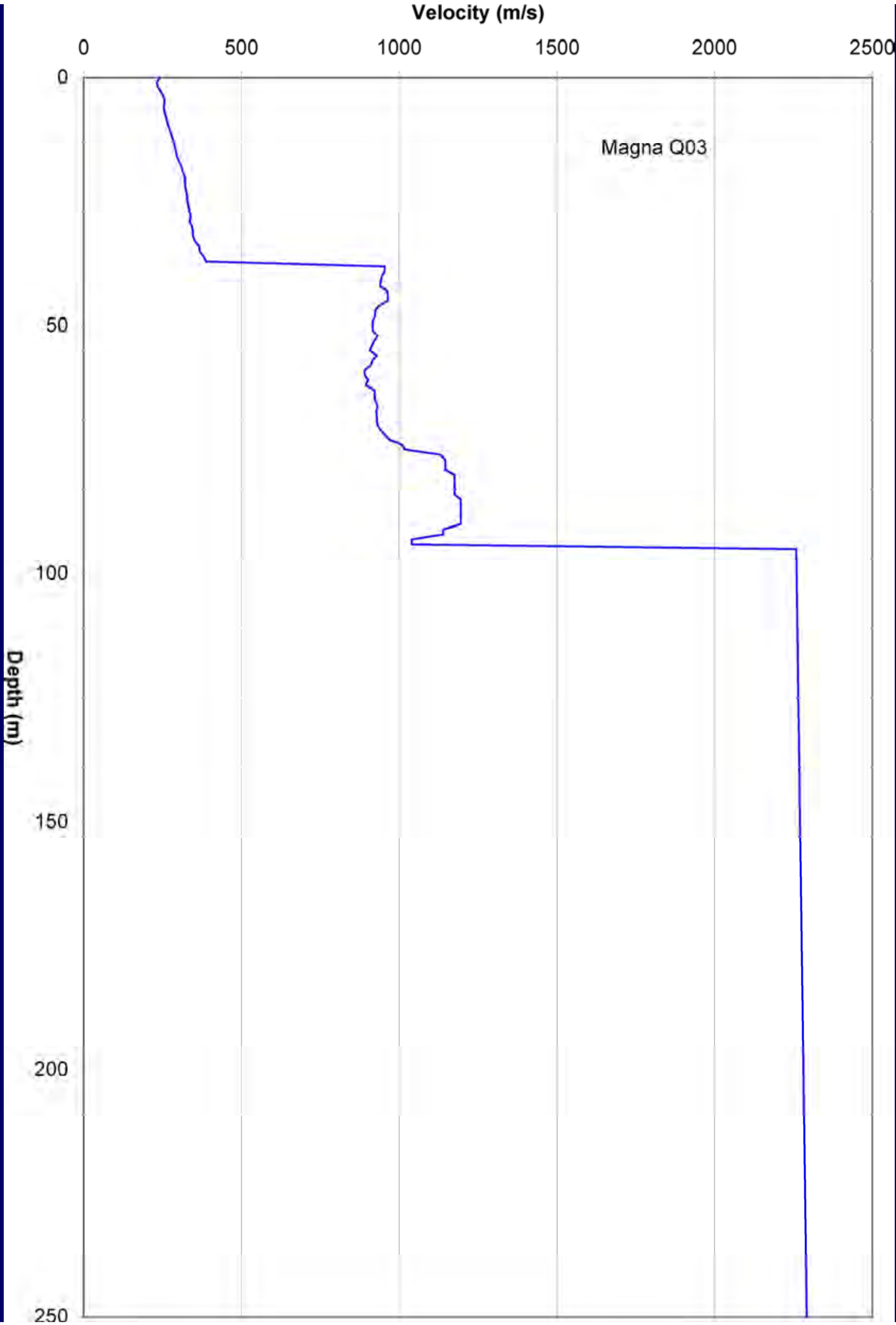



Velocity (m/s)
0
500
1000
1500
2000
2500
3000
North Salt Lake
Depth (m)
0
200
400
600
800
1000
1200
1400


Velocity (m/s)
0
200
400
600
800
1000
1200
1400
Utah Roses
Depth (m)
0
50
100
150
200
250


Velocity (m/s)
0
500
1000
1500
2000
2500
3000
Utah Roses
Depth (m)
0
200
400
600
800
1000
1200
1400


Velocity (m/s)
0
500
1000
1500
2000
2500
0
50
100
150
200
250
Depth (m)
Magna Q01



Velocity (m/s)
0
500
1000
1500
2000
2500
Magna Q03
Depth (m)
0
50
100
150
200
250