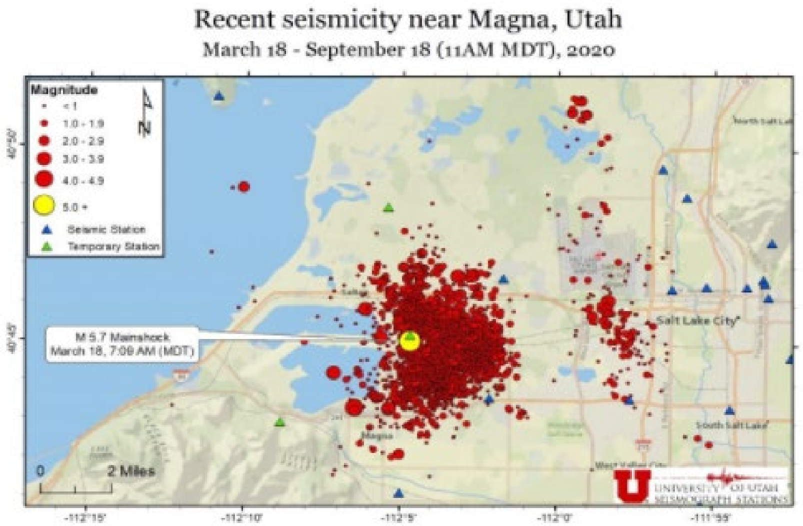
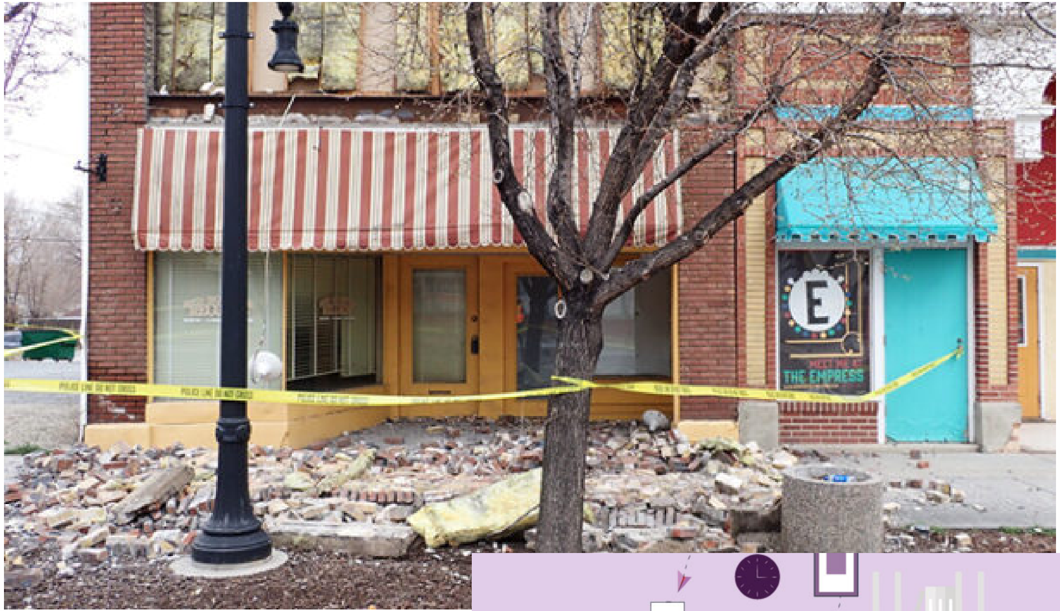
Welcome to the 2021 Virtual Quaternary Fault Parameters Working Group Meeting

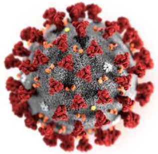
Tuesday, February 2, 2021

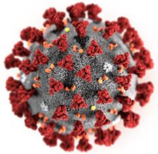
Geologic Hazards Program - Utah Geological Survey

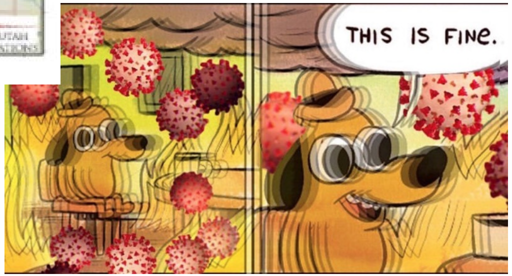
It’s been a year…

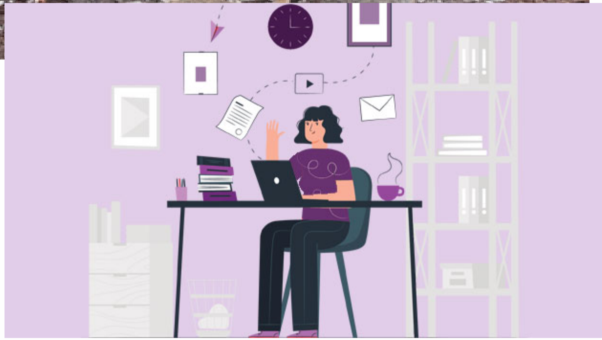












Utah Quaternary Fault Parameters Working Group

Serves as a standing committees to help set and coordinate Utah’s earthquake hazard research agenda.

Reviews ongoing paleoseismic research in Utah and updates the Utah consensus slip-rate and recurrence-interval database as necessary.

Provides advice/insight regarding technical issues related to fault behavior in Utah.

Identifies and prioritizes future Utah Quaternary fault paleoseismic investigation https://geology.utah.gov/hazards/info/workshops/working-groups/q-faults/

GEOLOGIC HAZARDS

UTAH QUATERNARY FAULT PARAMETERS

The main goal of the Utah Quaternary Fault Parameters Working Group (UQFPWG) is to characterize active fault sources in Utah.

The working group began by developing consensus slip-rate and recurrence-interval data for all Utah trenched faults (Lund, 2005) in 2003 and 2004. The working group also developed an initial priority list of faults requiring additional study and, based on each year's paleoseismic investigations, has updated the list annually.

As new paleoseismic data became available, the working group modified its consensus slip-rate and recurrence-interval values as necessary. The UQFPWG started annual meetings in 2005.

The next meeting of the Utah Quaternary Fault Parameters Working Group is on February 2nd, 2021.
Sign up to attend the virtual meeting.
Download Agenda

2020 UQFPWG Summary Table

Please review before final discussion

Table 2. Status of proposed and published paleoseismic-related investigations based on priorities developed by the UQFPWG since 2005. If there are any missing publications, please send the reference to ekleber@utah.gov.

Study Type	Utah Fault or Fault Segment	UQFPWG Priorities 2005	UQFPWG Priorities Additions	Investigation Status (as of 3/2020)
Earthquake Timing	Nephi segment, Wasatch fault zone	1	2012 2017	UGS FTR Report, 05HQGR0098 (2005) USGS SI Map 2966 (2007) UGS Special Study 124 (2008) UGS FTR Report, G12AP20076 (2014) UGS Special Study 151 (2014) UGS Special Study 159 (2017) UGS FTR, G17AP00001 (2018)
	West Valley fault zone	2		
	Granger fault		2017	UGS Special Study 149 (2014)
	Taylorsville fault		2011 2017	UGS FTR, G15AP00117 (2017)
	Weber segment, Wasatch fault zone – most recent event and multiple events	3 4	2012 2017	UGS Miscellaneous Publication 05-8 (2006) UGS FTR, 07HQGR0093 (2007) UGS Special Study 130 (2009)
	Utah Lake faults and folds	5		
	Acquire earthquake timing information to investigate the relation of earthquakes to large earthquakes on the Provo segment.		2015 2017	UUGG FTR Report, G08AP0016 (2014)
	Great Salt Lake fault zone	6		
	Rozelle section, East Great Salt Lake fault Carrington fault, Great Salt Lake fault zone		2007	UUGG FTR Report, G08AP0016 (2014) Janecke and Evans (2017)
	Collinston and Clarkston Mountain segments, Wasatch fault zone	7	--	UGS Special Study 121 (2007) UGS Open-File Report 638 (2015)
	Sevier and Toroweap faults	8	2016	UGS Special Study 122 (2008)
	Washington fault zone (includes Dutchman Draw fault)	9	--	UGS Open-File Report 583 (2011) UGS Miscellaneous Publication 15-6 (2015)
	Cedar City-Parowan monocline (removed 2016) and Paragonah fault	10	--	UGS Map 270 (2015) 2016 presentation file Paragonah fault, no activity
	Enoch graben	11	--	UGS Open-File Report 628 (2014)
	East Cache fault zone	12	2013	USU FTR Report, 07HQGR0079 (2012)
	Clarkston fault	13	--	UGS Special Study 98 (2000) UGS Special Study 121 (2007) UGS Open-File Report 638 (2015) UGS FTR, G17AP00001 (2018)

Utah Quaternary Fault Parameters Working Group 2020 presentations

- Update on Quaternary Fault Mapping in Utah: Adam Hiscock, Utah Geological Survey
- Paleoseismic Investigation of the Levan and Fayette Segments of the Wasatch Fault Zone, Utah: Greg McDonald, Utah Geological Survey
- East Cedar Valley Fault Zone— New Fault Strands and Younger Events: Adam McKean, Utah Geological Survey
- A Field Test of Portable OSL— Using 345 Samples from the Deep Creek Colluvial Wedge Exposure to Explore Earthquake-Timing Uncertainty: Chris DuRoss, U.S. Geological Survey
- Topliff Hill Paleoseismic Site— Six Events Since 69.3 ka on the Topliff Hills Fault: Nathan Toké, Utah Valley University

2021 Priorities

Acquire new paleoseismic information for areas with ongoing lidar fault mapping projects:

- Cache Valley faults (ECFZ, WCFZ), 5 central segments of the Wasatch fault zone, West Valley fault zone, Oquirrh fault zone, Sevier fault

"Salvage paleoseismology" (i.e., earthquake timing investigations as rapid development is encroaching on un-modified paleoseismic trenching sites):

- Faults in Cache Valley, West Valley fault zone

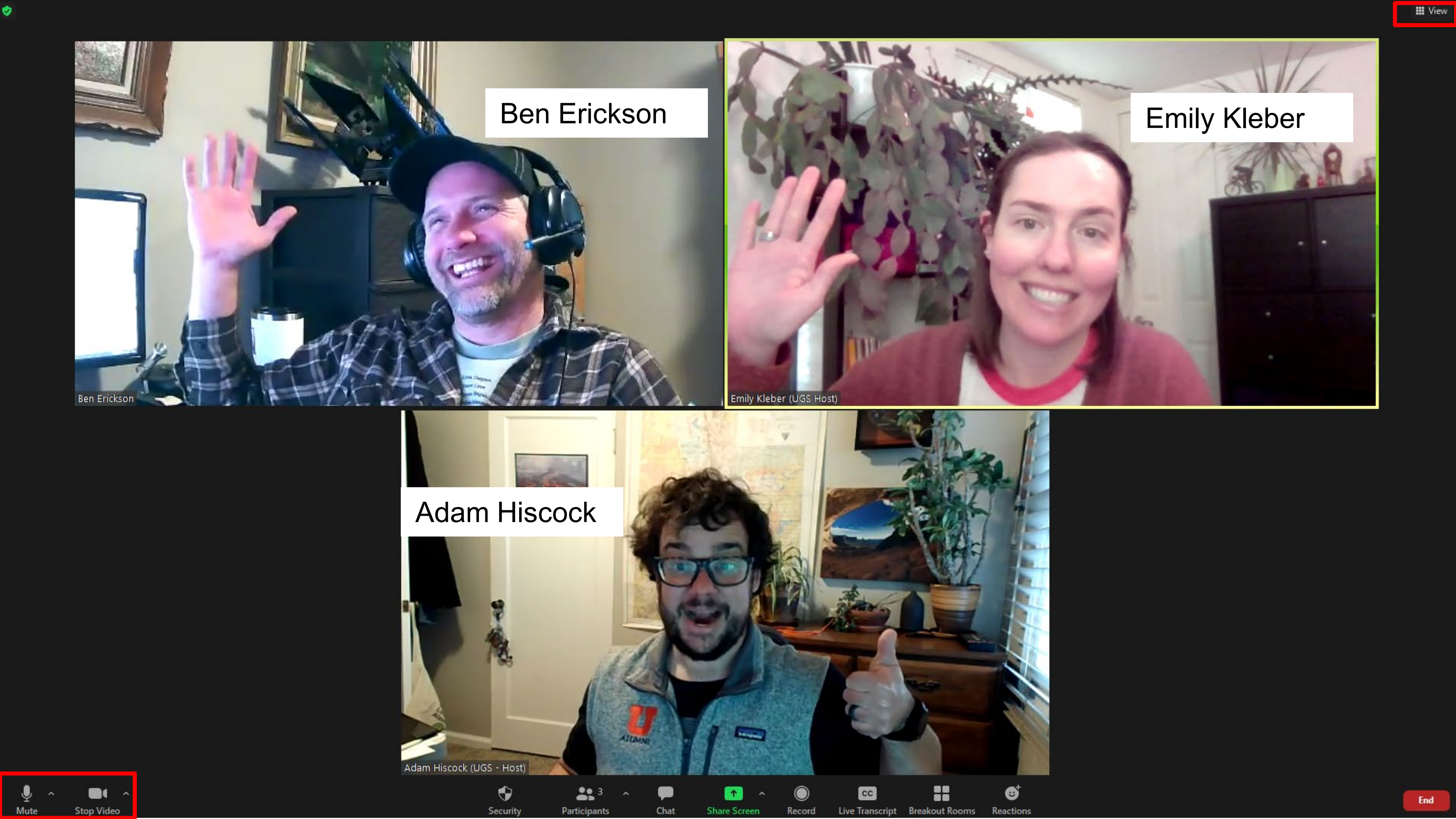
Use recently acquired lidar data to more accurately map the traces of the:

- Scipio Valley faults, Beaver Basin faults (partial coverage), Hansel Valley, Mineral Mountains West-side faults, Stansbury fault zone

This does not include other priorities that have carried over from previous years.

Zoom Review - General

- You are welcome to come and go to the meeting. We will be starting sessions at their scheduled times.
- You will be muted upon entering the meeting.
- To save bandwidth for all attendees, please leave your camera off unless you are speaking.
- The hosts reserve the right to mute participants who have left their microphones on, or who are being disruptive to the meeting.
- If you are having technical issues, **PRIVATELY** message Ben Erickson, Adam Hiscock, or Emily Kleber. Should be labeled as “Host”



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Emily Kleber
Ben Erickson
Emily Kleber (UGS Host)
Adam Hiscock
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Breakout Rooms
Reactions
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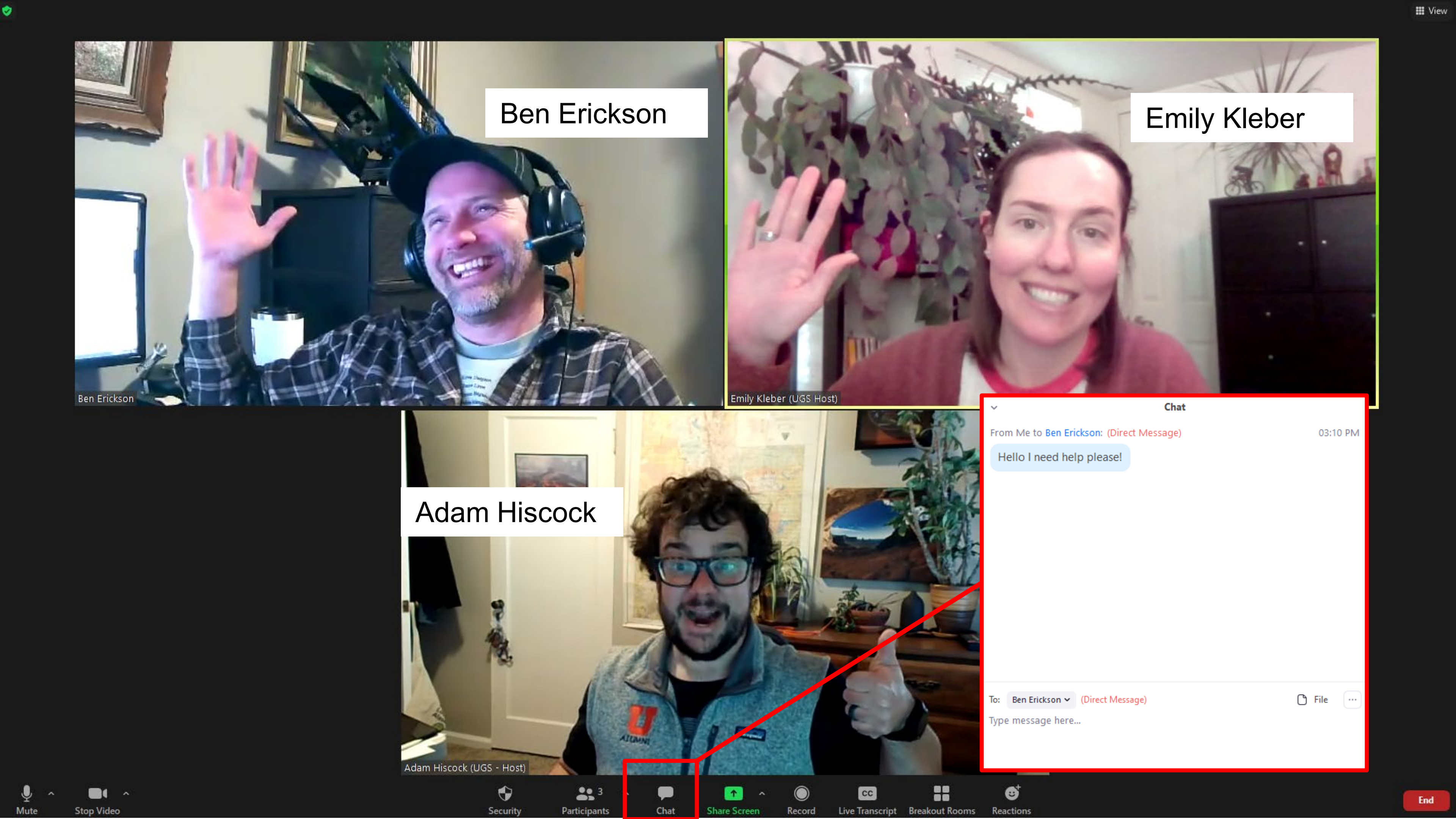

Ben Erickson
Emily Kleber
Adam Hiscock
Ben Erickson
Emily Kleber (UGS Host)
Adam Hiscock (UGS - Host)
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From Me to Ben Erickson: (Direct Message)
03:10 PM
Hello I need help please!
To: Ben Erickson (Direct Message)
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Breakout Rooms
Reactions
End

Zoom Review - Presentations

- We (Zoom hosts) have presenters' slides and will be sharing our screens.
- Presenters have 15 minutes. We will use visual cues to indicate remaining time in upper righthand corner
- 5 Minutes 1 Minute

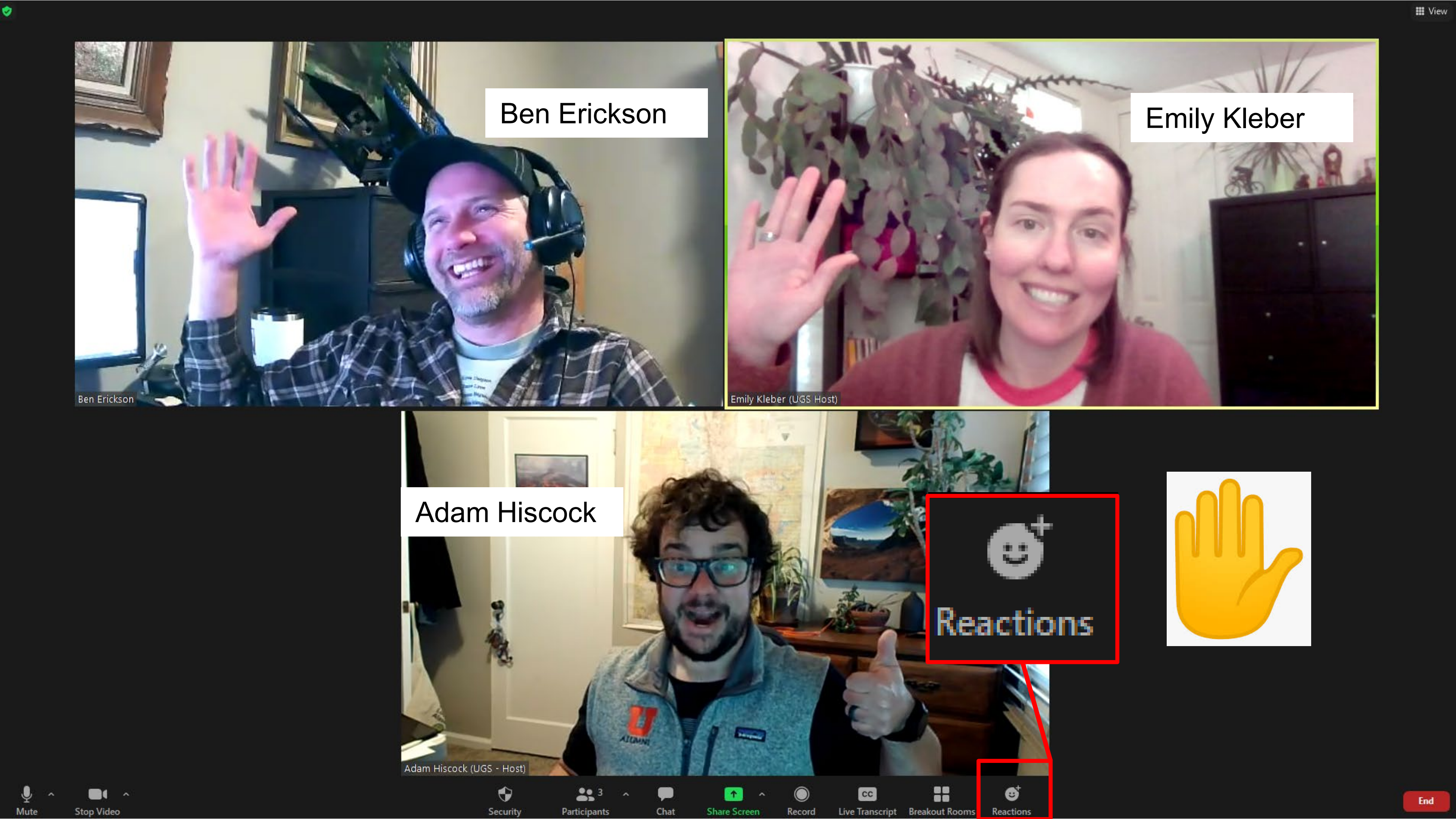
UTAH DNR GEOLOGICAL SURVEY

Zoom Review - Presentations

- If you have questions during a presentation for the speaker, please type your question into the chat box.
- The hosts will read out the questions for the speaker, who will then answer.
- If additional follow up or discussion is required, please “raise your hand” via ZOOM.
- We have scheduled time for discussion, so if you question is not answered, please make note.

Zoom Review - Discussions

- Questions or comments can be typed into the chat box OR you can raise your hand via Zoom. You will be called on by a UGS Host.
- Pauses and awkward silences are OK!
- Accidentally talking over each other is OK!
- Please be respectful and patient.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End

Schedule (Mountain Standard Time)

- 8:00 am to 10:00 am - Recent Studies in Utah
- 10:30 am to 11:30 am - Buried Urban Faults and Special Study Zones
- 1:00 pm to 3:00 pm - Magna Earthquake
- 3:30 pm to 4:00 pm - Wrap Up

Thank you and let's get going!

USGS Earthquake Geology Intermountain West (IMW)

Christopher DuRoss, USGS Intermountain West Regional Coordinator

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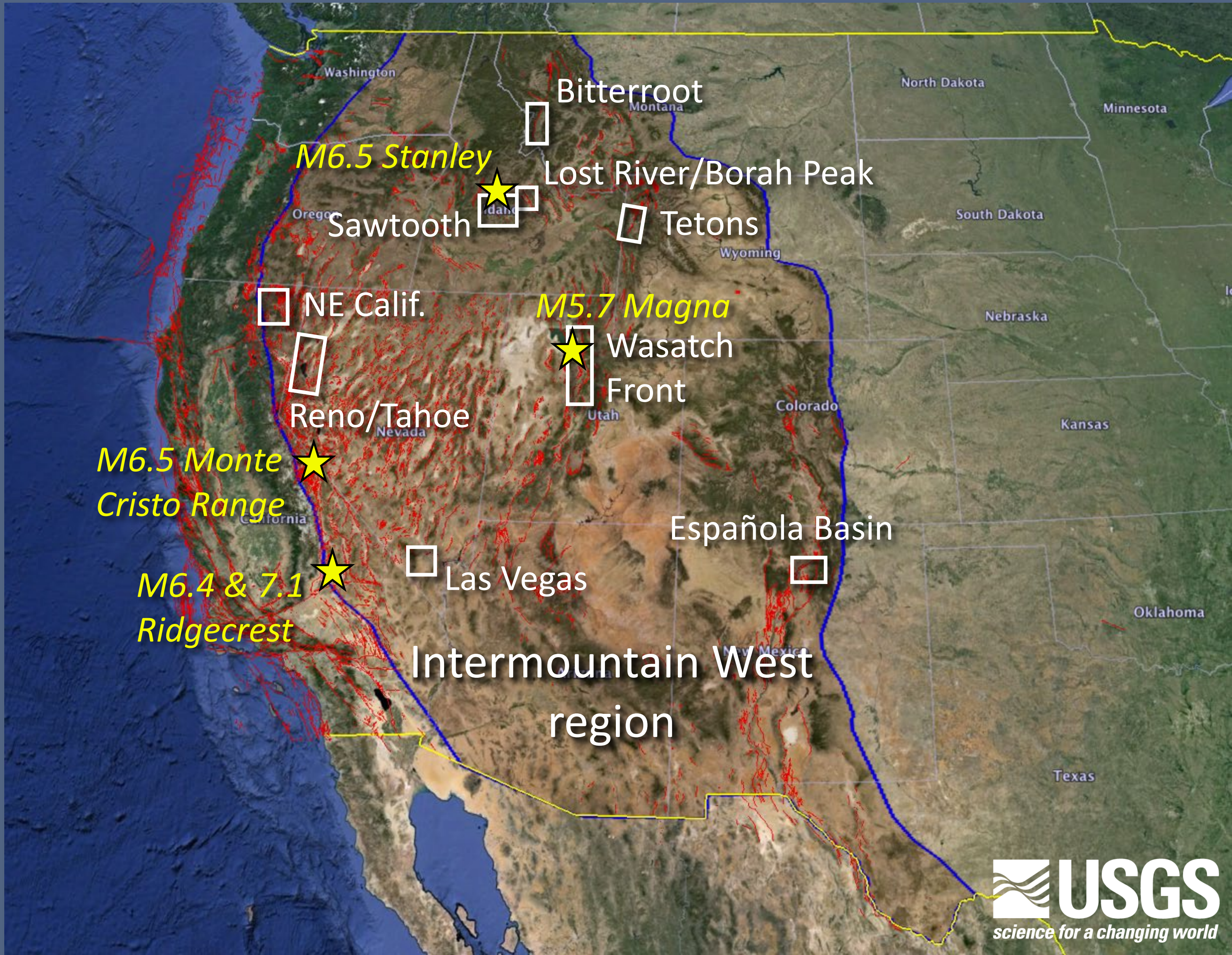
USGS science for a changing world

Ongoing Research and Collaboration in the IMW

- **Earthquake response & research** *(UUSS, UNR, UGS, IGS, CGS…and others)*
- **Wasatch Front** *(UGS, UVU)*
- **Teton fault** *(WGS, Univ. of ID, BGC, BoR, USFS)*
- **Lost River fault zone/Borah Peak earthquake** *(IGS, UGS, UVU)*
- **Sawtooth fault** *(IGS, Univ. of ID, BGC)*
- **Bitterroot fault** *(MBMG, BoR)*
- **Española Basin** *(BoR)*
- **Walker Lane** *(NBMG, UNR)*
- **NE California** *(PG&E, Univ. of Oregon)*
- **Las Vegas** *(NBMG, UNR, UNLV)*



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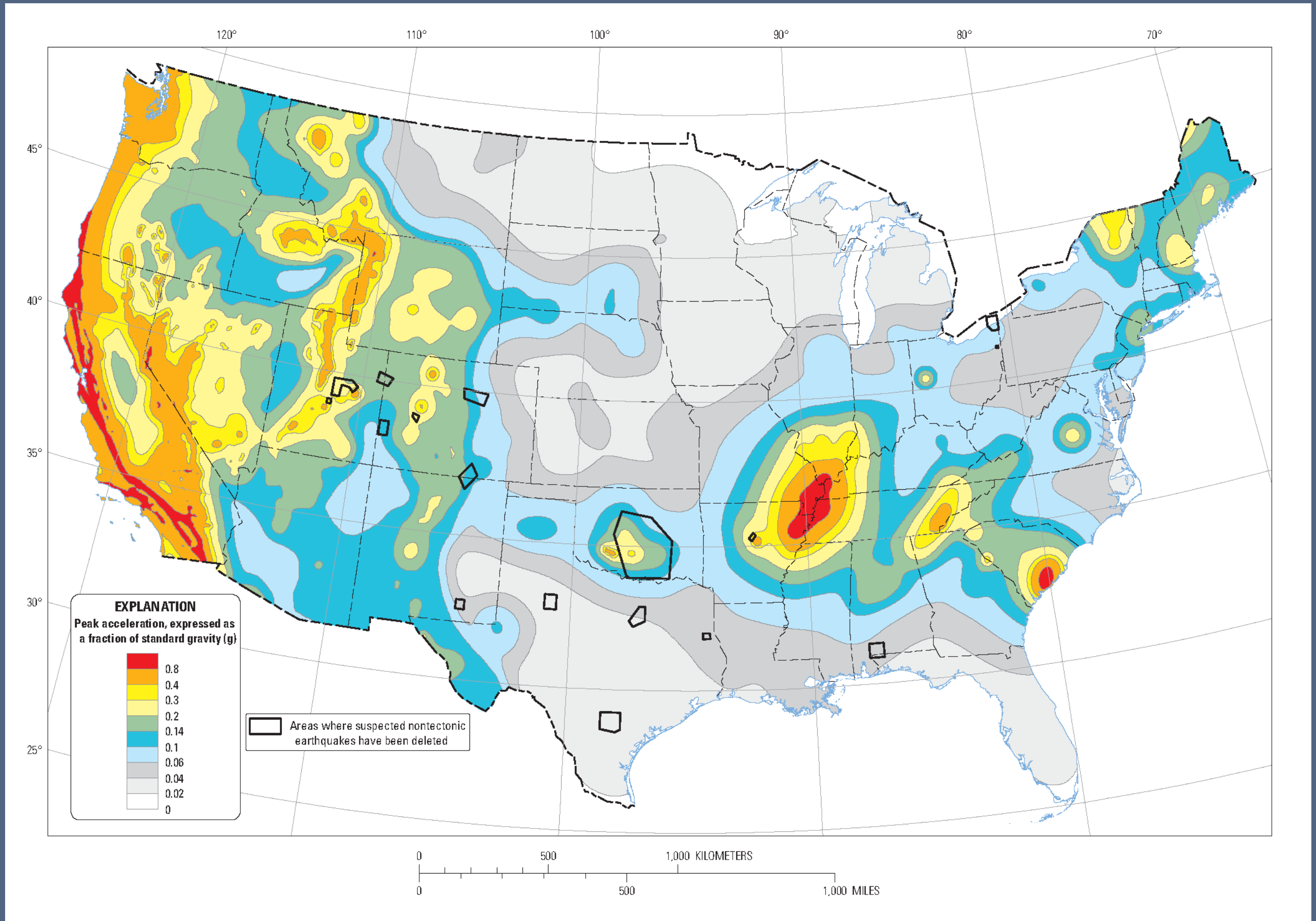
USGS National Seismic Hazard Model



Two-percent probability of exceedance in 50 years map of peak ground acceleration

2018 long-term hazard model (Petersen et al., 2019).

- Uses best-available science to calculate ground-shaking probabilities across the U.S.
- Lasting impact on seismic design in building codes, insurance rates, public policy, and emergency planning.
- Last updated in 2018 (source faults updated in 2014).
- ***2023 update process underway***. Current focus (2020-2021) on source fault model. More details from Alex Hatem.

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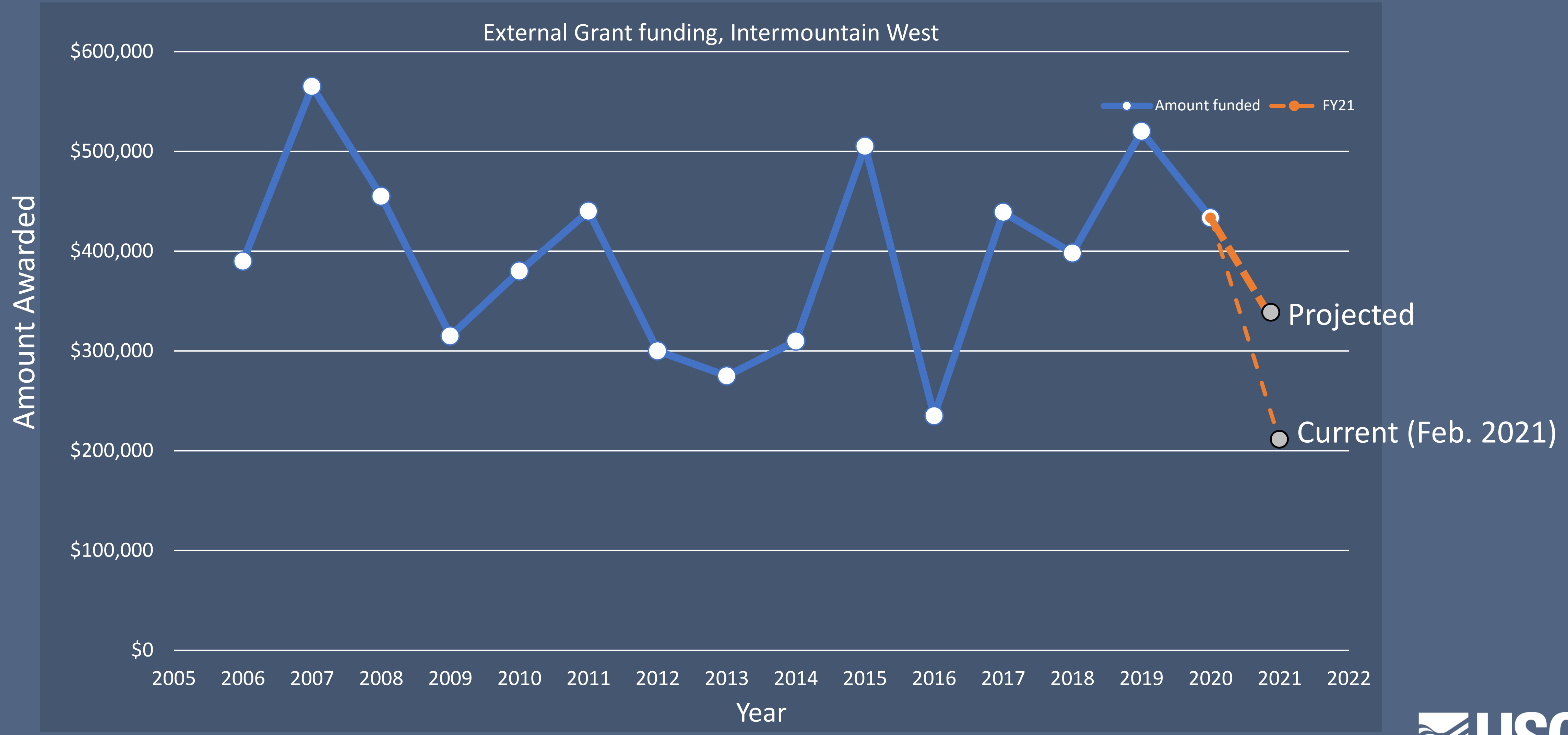
USGS External Grants Program, FY2020 (last year)

- $4.6M in competitive research grants funded.
- IMW funded 10 proposals ($433k).

Regional/Topical Area	FY20 Funded Amount	%	FY20 # of new grants funded
CEUS	$597,493.00	13%	10
EP	$609,174.00	13%	8
ESI	$516,821.00	11%	7
IMW	$433,448.00	9%	10
NAT	$544,262.00	12%	9
NC	$615,614.00	13%	8
PNA	$553,947.00	12%	9
SC	$512,084.00	11%	7
EEW	$267,588.00	6%	4
Totals	**$4,650,431.00**	**100%**	**72**

Intermountain West External Grants funding



IMW External Grants 2021 (in progress)

- ***FY2021 IMW proposals:***
  - 22 submitted (compared to 17 in FY20).
  - Total request of $1.22M.
  - Average proposal in fund or "fund if possible" category: $46.6k (FY21), compared to ~$43.3k (FY20).

- ***Current status** (Feb. 2021):*
  - Three proposals funded (~$200k).
  - Likely that ~$300-$370k will be funded.
  - FY21 Federal budget passed (Dec. 2020). Increased congressional direction on how funds must be spent (may negatively impact External Grants Program).
  - Final award letters anticipated March 2021.

Funding by state

- NV: 2 grants funded; 1 in "hold" status
- UT: 1 grant funded; 1 in "hold" status
- ID: 3 grants in "hold" status
- CO: 1 grant in "hold" status
- E Calif: 1 grant in "hold" status

Majority of proposals funded focused on 2020 IMW earthquakes (Magna, Utah; Stanley, Idaho; Monte Cristo, Nevada).

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External Grants – guidance going forward (FY22)

- Look for program announcement in March 2021.
- Proposal dues in May 2021.
- IMW panel meets in August 2021.

  Please email cduross@usgs.gov if you'd be interested in serving and won't have conflict of interest (e.g., submitting a proposal this year or from an institution submitting proposals).
- USGS letters of commitment.

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Earthquake Geology Input Data for the U.S. National Seismic Hazard Model 2023

Hatem, A.E., Collett, C.M., Gold, R.D., Briggs, R.W., Angster, S.A., Field, E.H., Anderson, M., Ben-Horin, J.Y., Dawson, T., DeLong, S., DuRoss, C., Thompson Jobe, J., Kleber, E., Knudsen, K.L., Koehler, R., Koning, D., Lifton, Z., Madin, I., Mauch, J., Morgan, M., Pearthree, P., Petersen, M., Pollitz, F., Scharer, K., Powers, P., Sherrod, B., Stickney, M., Wittke, S., and Zachariasen, J.

USGS author; State partner author

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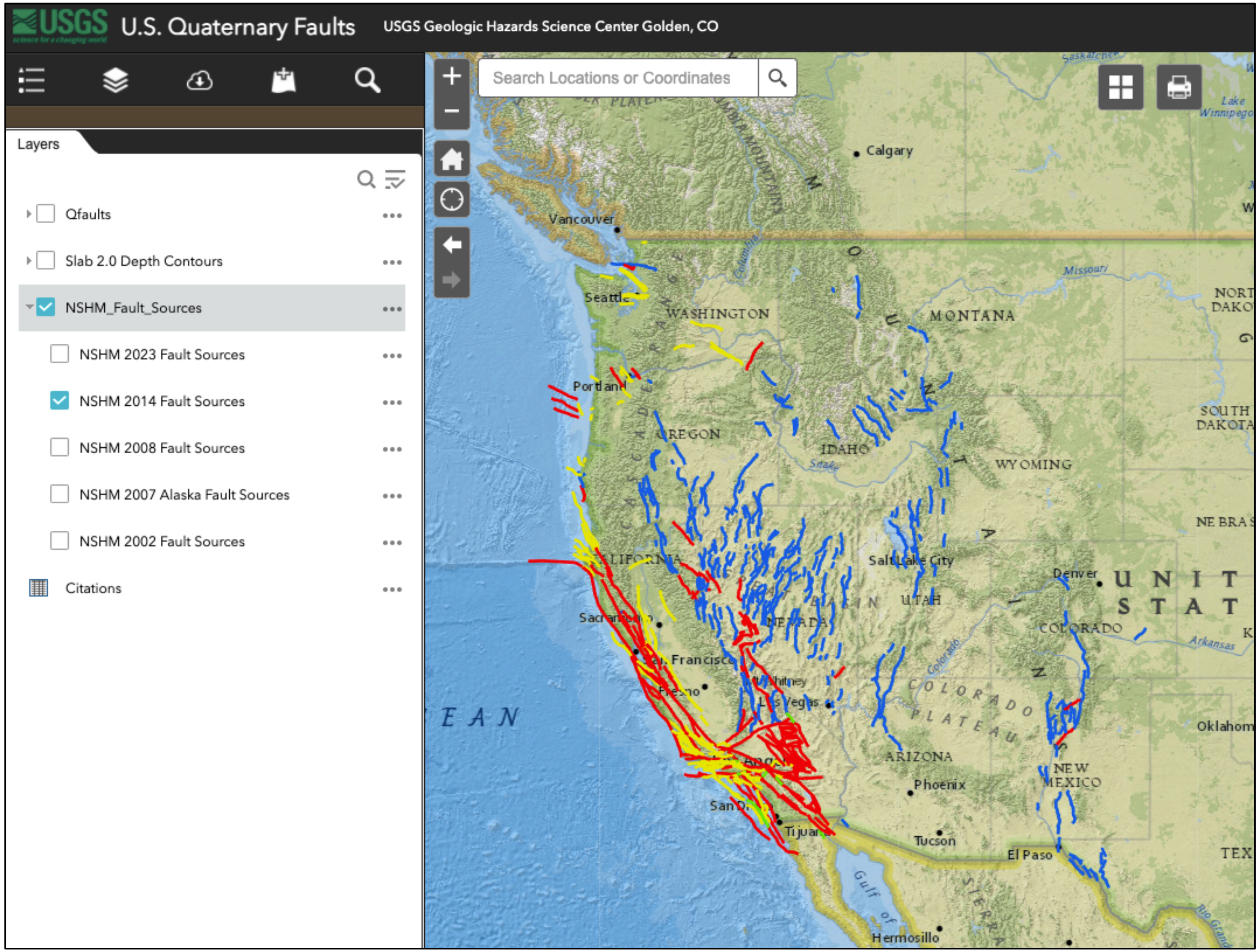
Background: National Seismic Hazard Map 2023 Update

A 50-state update of the National Seismic Hazard Model (NSHM) is planned for 2023 release.

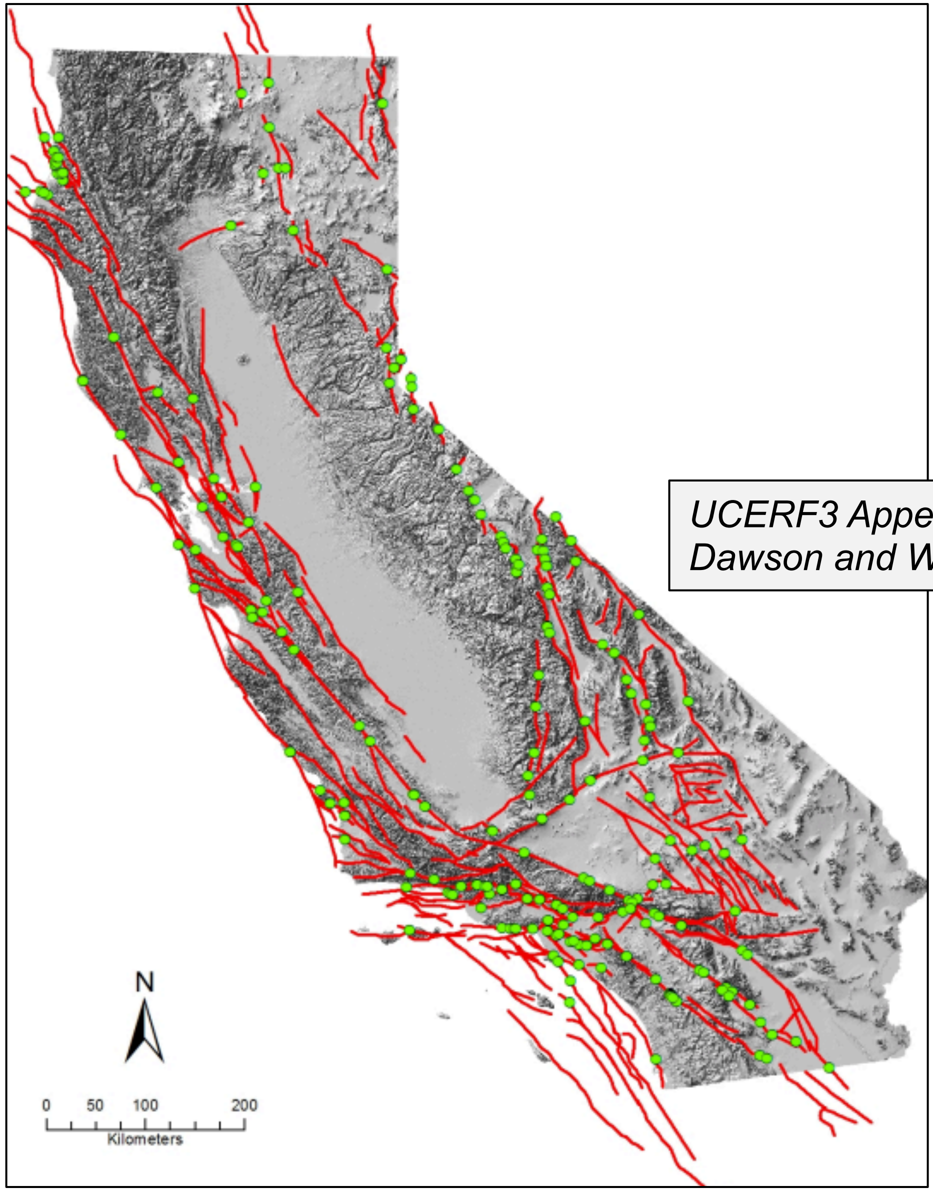
- The last release of conterminous U.S. NSHM was in 2018; the last update of fault geometries and slip rate information occurred in 2014.



Background: National Seismic Hazard Map 2023 Update

In past NHSM's, only faults with site-specific slip rates were included as NSHM fault sections. This excludes many known, Quaternary active faults.

- In Uniform California Earthquake Rupture Forecast, v3 (UCERF3), faults without measured slip rates were included with nominal, categorical slip rates.



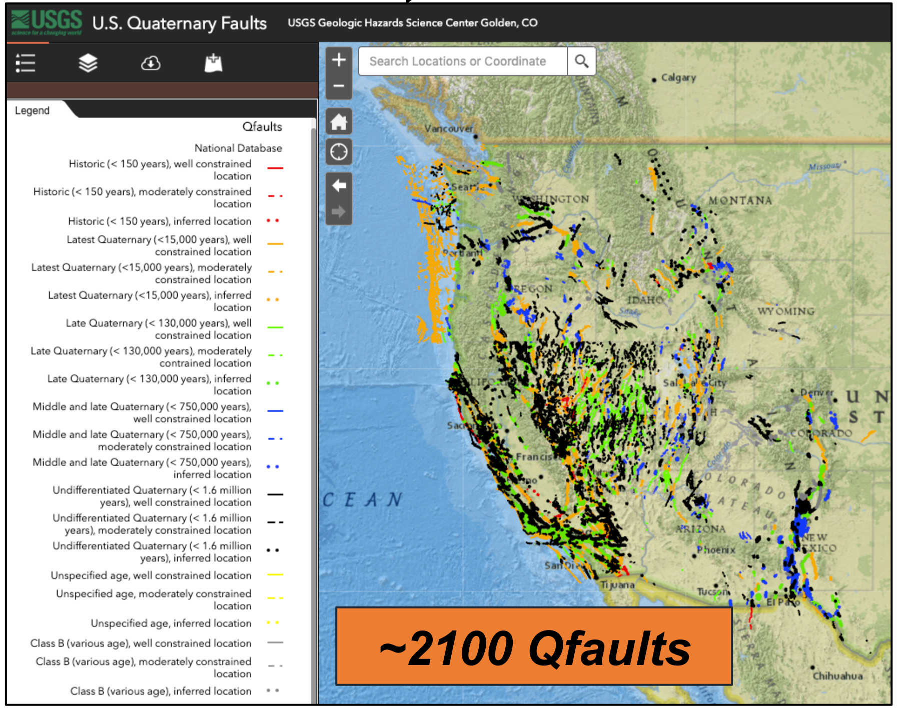
UCERF3 Appendix B
Dawson and Weldon, 2014

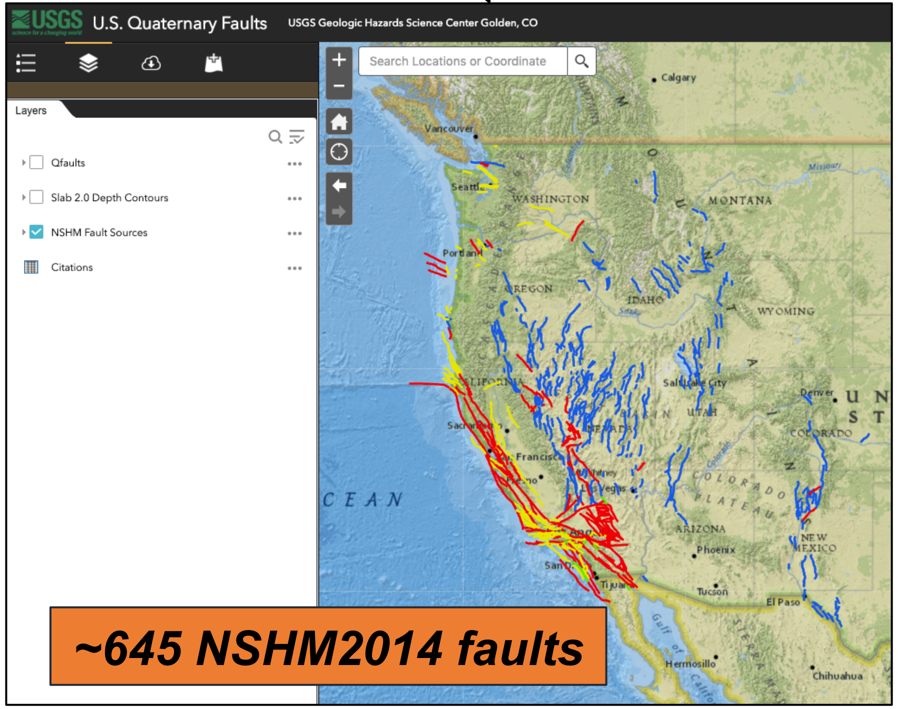
Background: National Seismic Hazard Map 2023 Update

NSHM 2014/2018 fault sections under-represent the number of known Quaternary active faults.

- NSHM14/18 contained ~645 faults; USGS Quaternary Fault and Fold Database (QFFD) has >2,100 faults.

Mismatch between different datasets



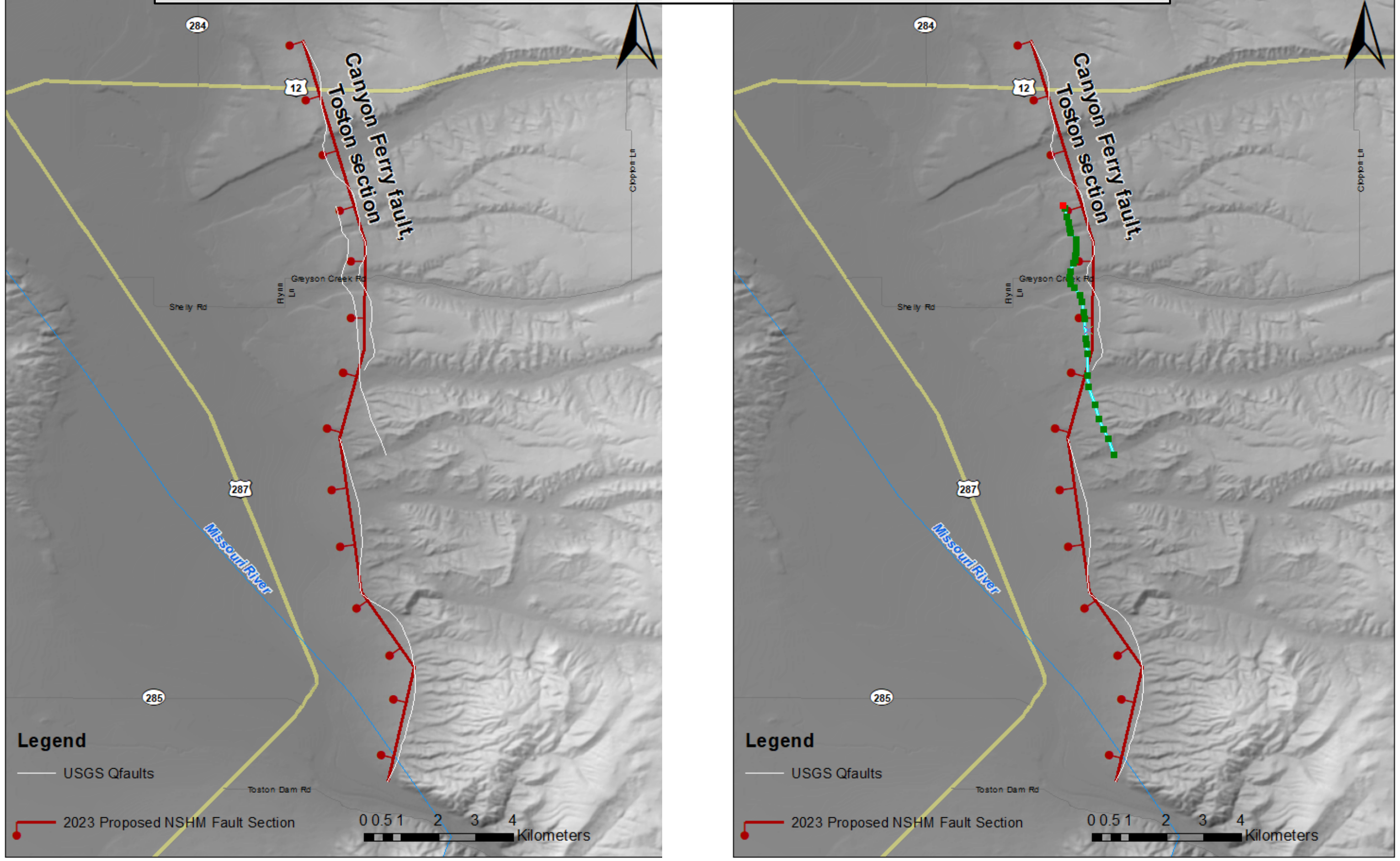


Goals: Earthquake Geology Updates ahead of National Seismic Hazard Map 2023

Generate an updated fault sections repository to more accurately represent more potential earthquake sources in NSHM2023.

- Evaluate Quaternary Fault and Fold Database (QFFD) as a starting place for including additional fault sections.
- Simplify high-resolution geometries from geologic field studies numerically suitable for seismic hazard modeling.
    - Minimize node spacing.
    - Approximate fault structure at depth.

Example from Canyon Ferry (Totson section) near Helena, Montana

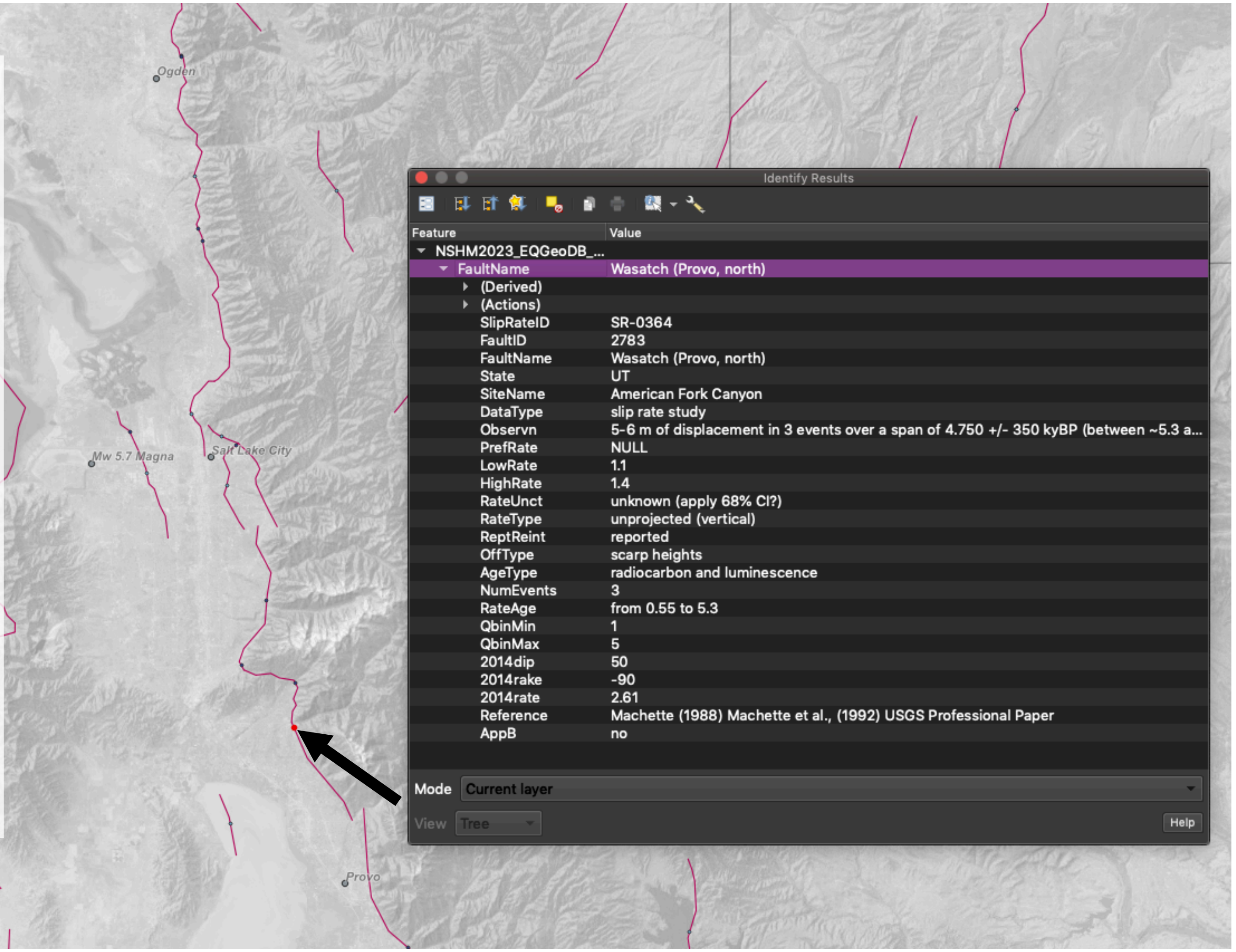


Figures courtesy of Camille Collett

Goals: Earthquake Geology Updates ahead of National Seismic Hazard Map 2023

Develop a western US database of geologic slip rates.

- Point-based measurements of slip rate with metadata and uncertainty estimates.
- Apply a categorical slip rate where slip rate has not yet been directly investigated.
  - Preferred slip rates will be assigned during upcoming geologic deformation modeling.



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Earthquake Rupture Forecast construction

Fault Models

Specifies the spatial geometry of larger, more active faults.

→

Deformation Models

Provides fault slip rates used to calculate seismic moment release.

→

Earthquake-Rate Models

Gives the long-term rate of all possible damaging earthquakes throughout a region.

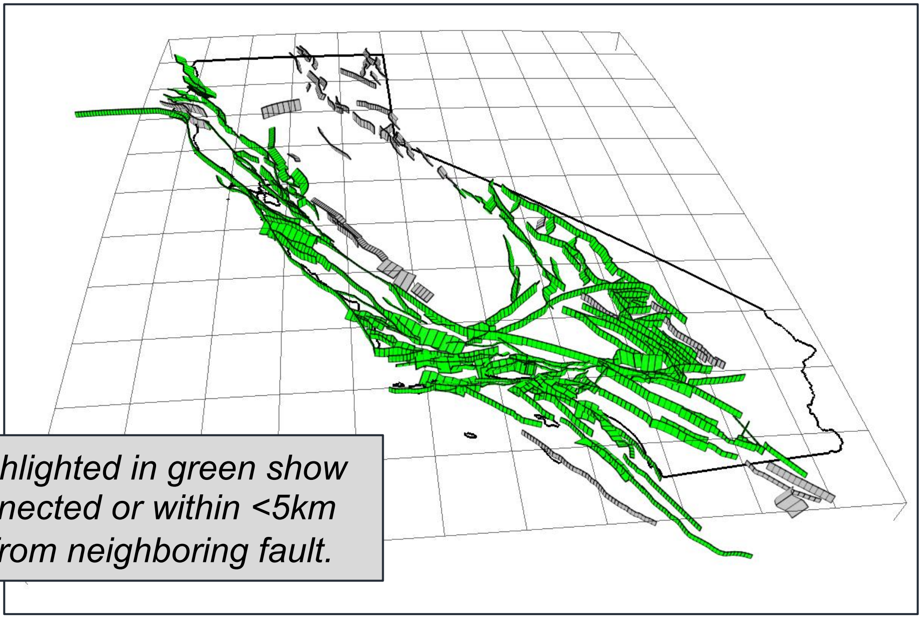
→

Probability Models

Gives the probability that each earthquake in the given Earthquake Rate Model will occur during a specified time span.

Physics-Based-Simulator Models

Produces synthetic catalogs of events using physics-based approaches that track the state of stress and frictional properties on faults over time.



Faults highlighted in green show faults connected or within <5km distance from neighboring fault.

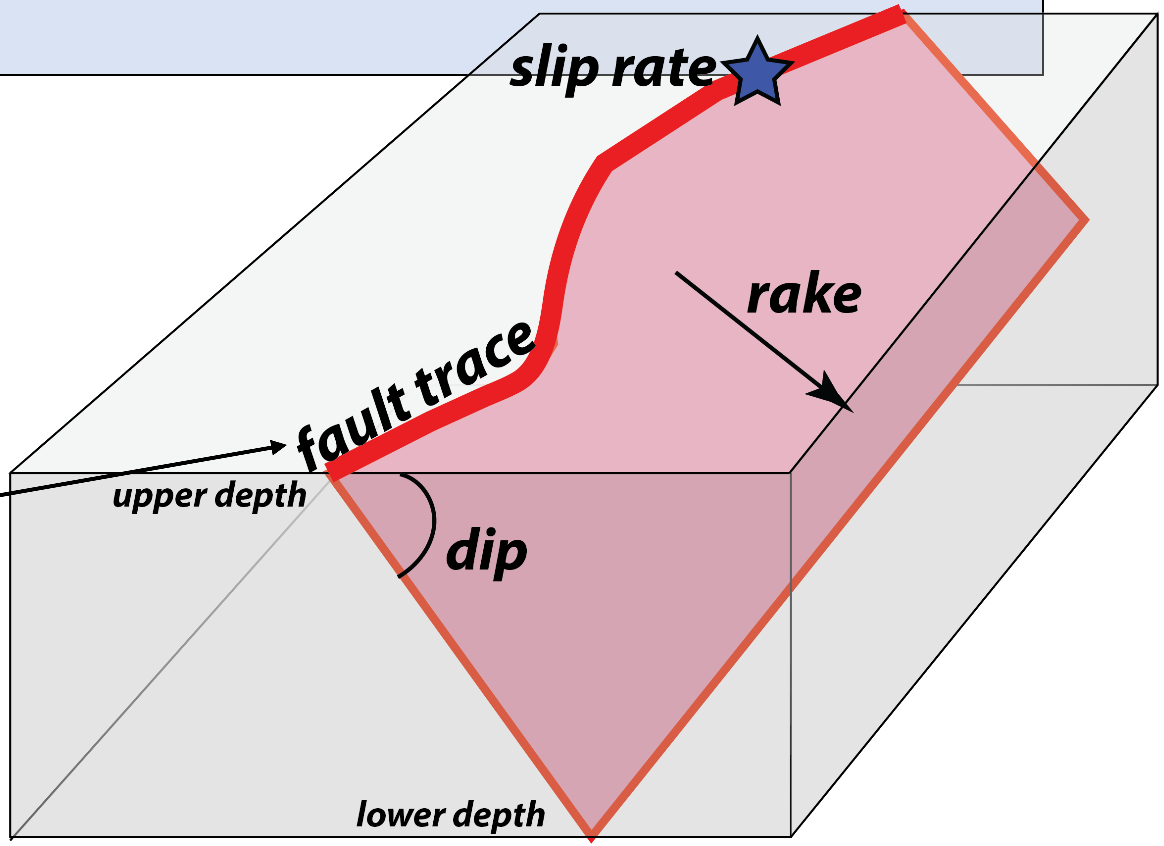
Courtesy of Ned Field

Database construction

Separate fault section geometries from the parameters that govern their activity (ex: geologic slip rates).

EQGeoDB:
- Unique fault section ID
- Unique site ID
- Lat, Lon of site location
- Observations
- Preferred, low and high slip rate (mm/yr)
- Rate uncertainty
- Rate, offset and age type
- Age range of slip rate
- Number of events
- Reference

Fault sections database:
- Unique fault section ID
- Fault trace geometry
- Dip (°)
- Dip direction
- Rake (°)
- Upper seismogenic depth (km)
- Lower seismogenic depth (km)



Criteria for inclusion into fault sections database

2014 NSHM fault sections

- Fault with a known geologic slip rate.
- No apparent restriction on Quaternary activity.
- No length requirement.

2023 NSHM proposed fault sections

- Quaternary active fault.
- Faults no longer excluded for lack of geologic slip rate.
- >7 km in length.

Preliminary Information-Subject to Revision.
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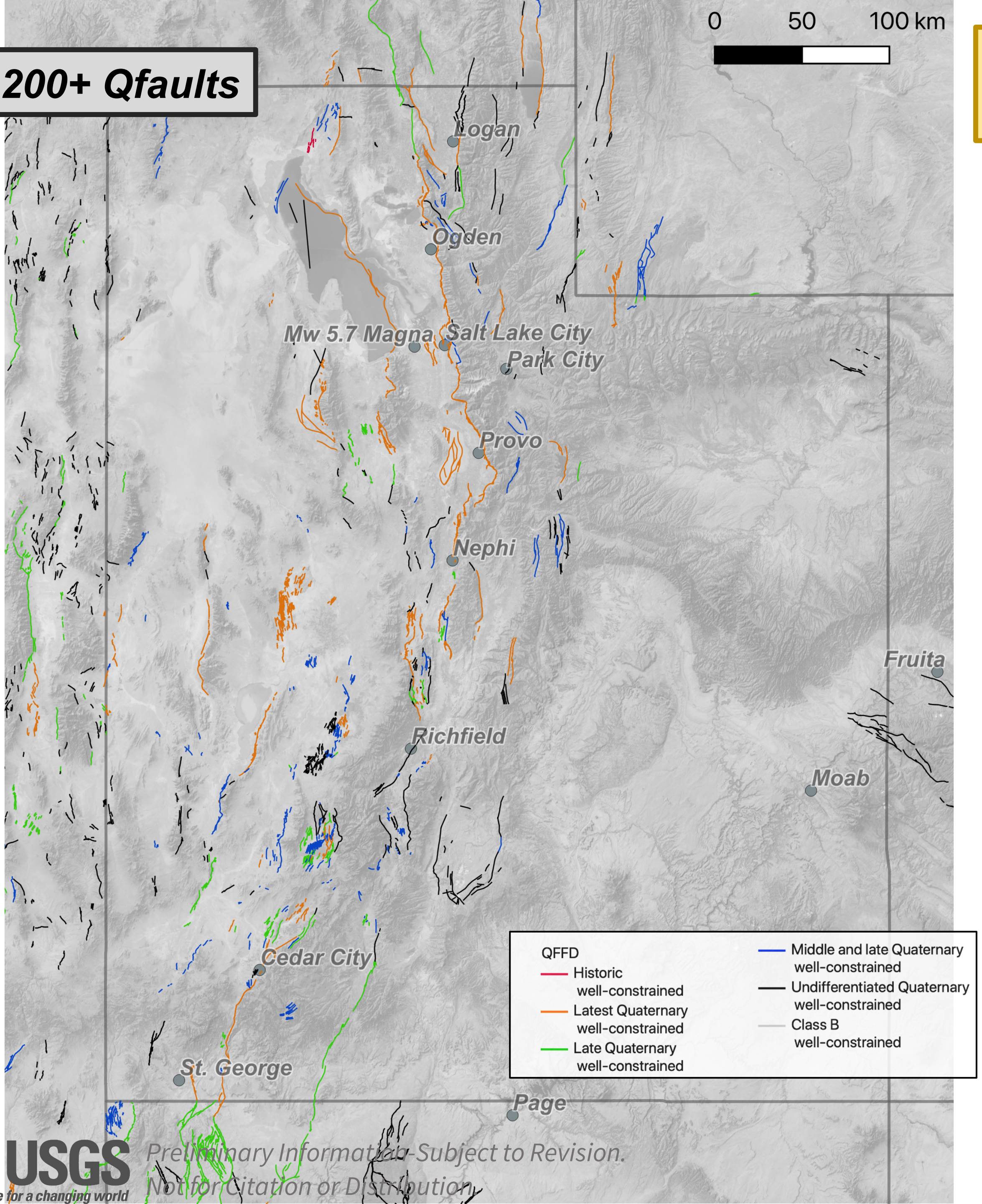

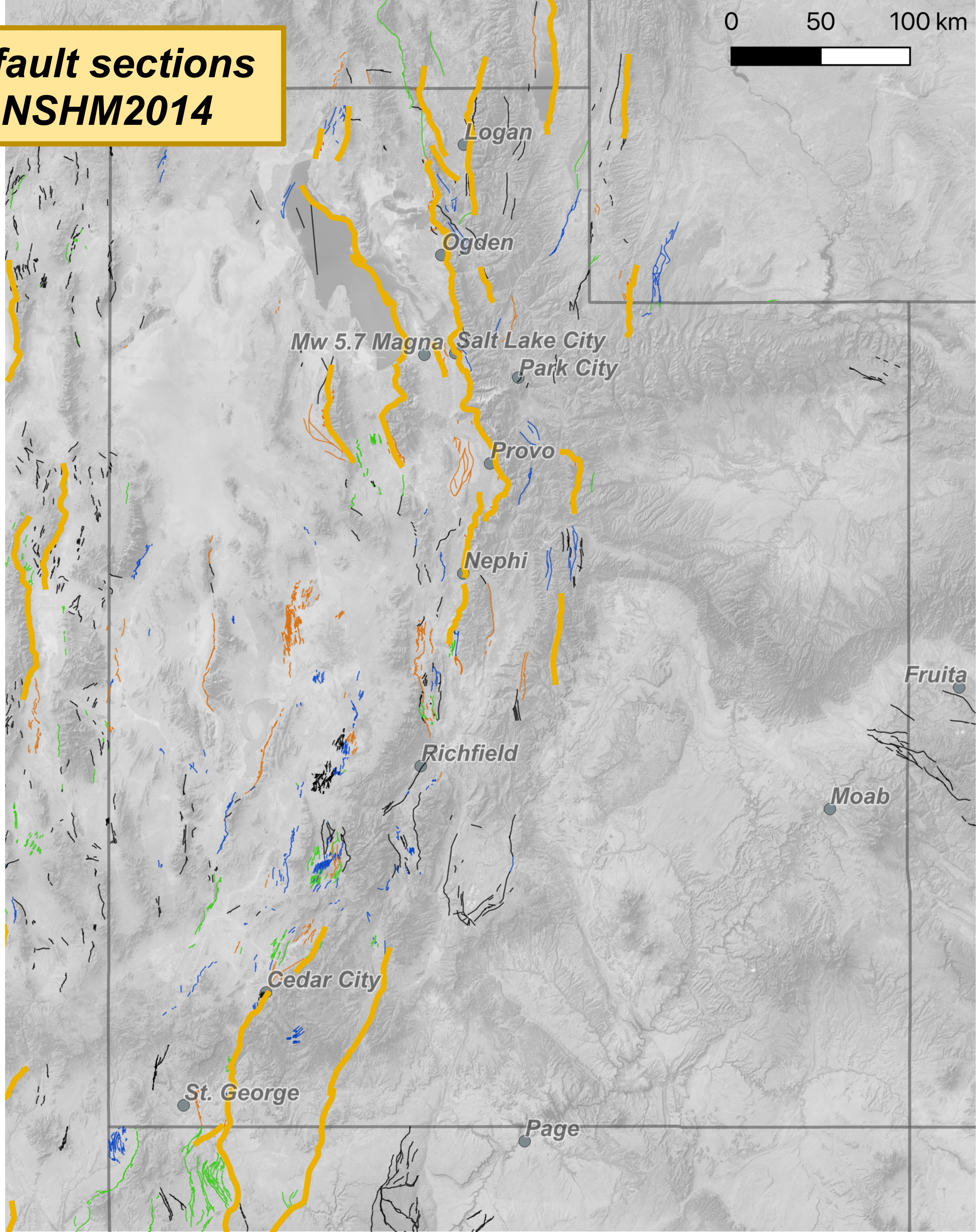

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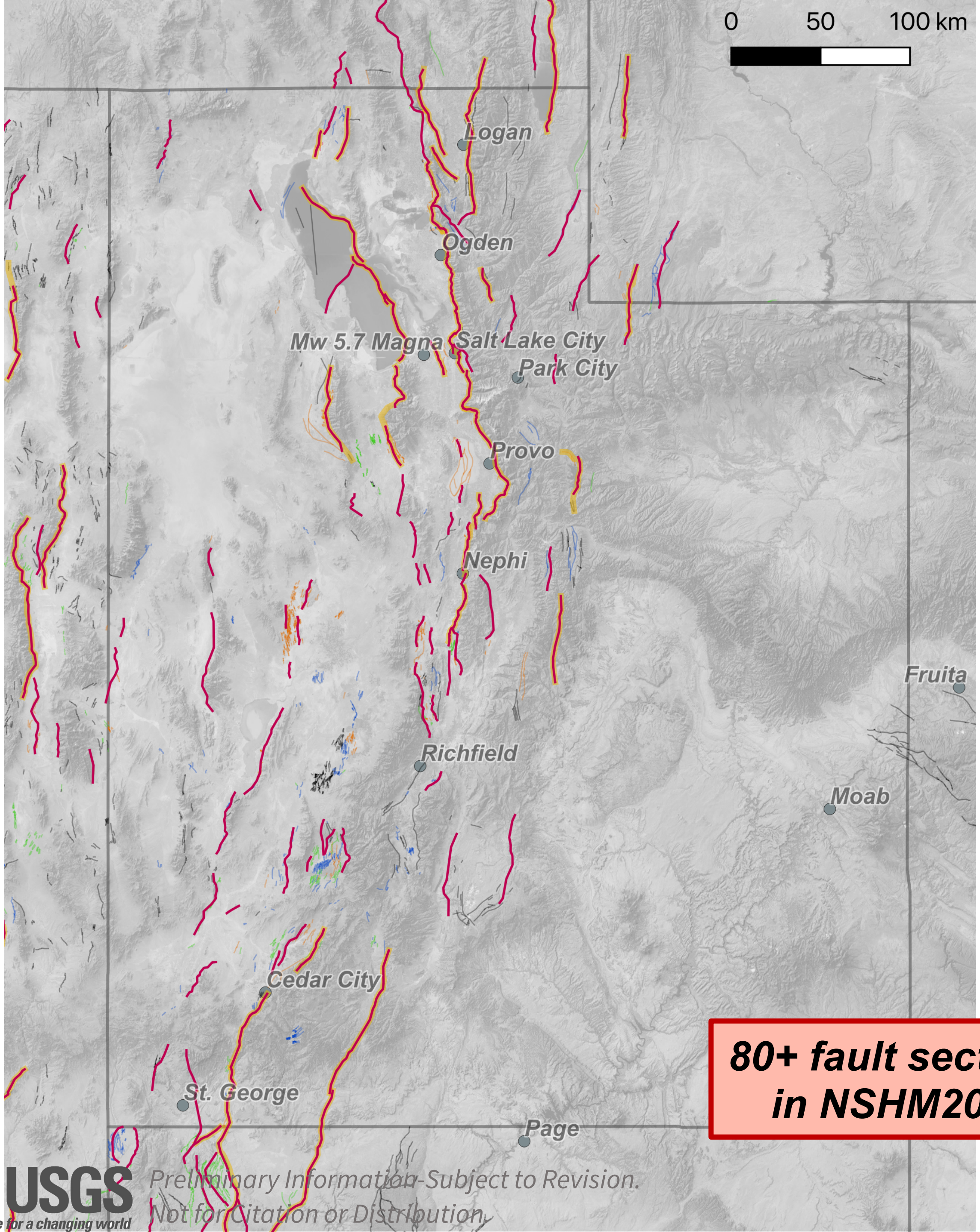

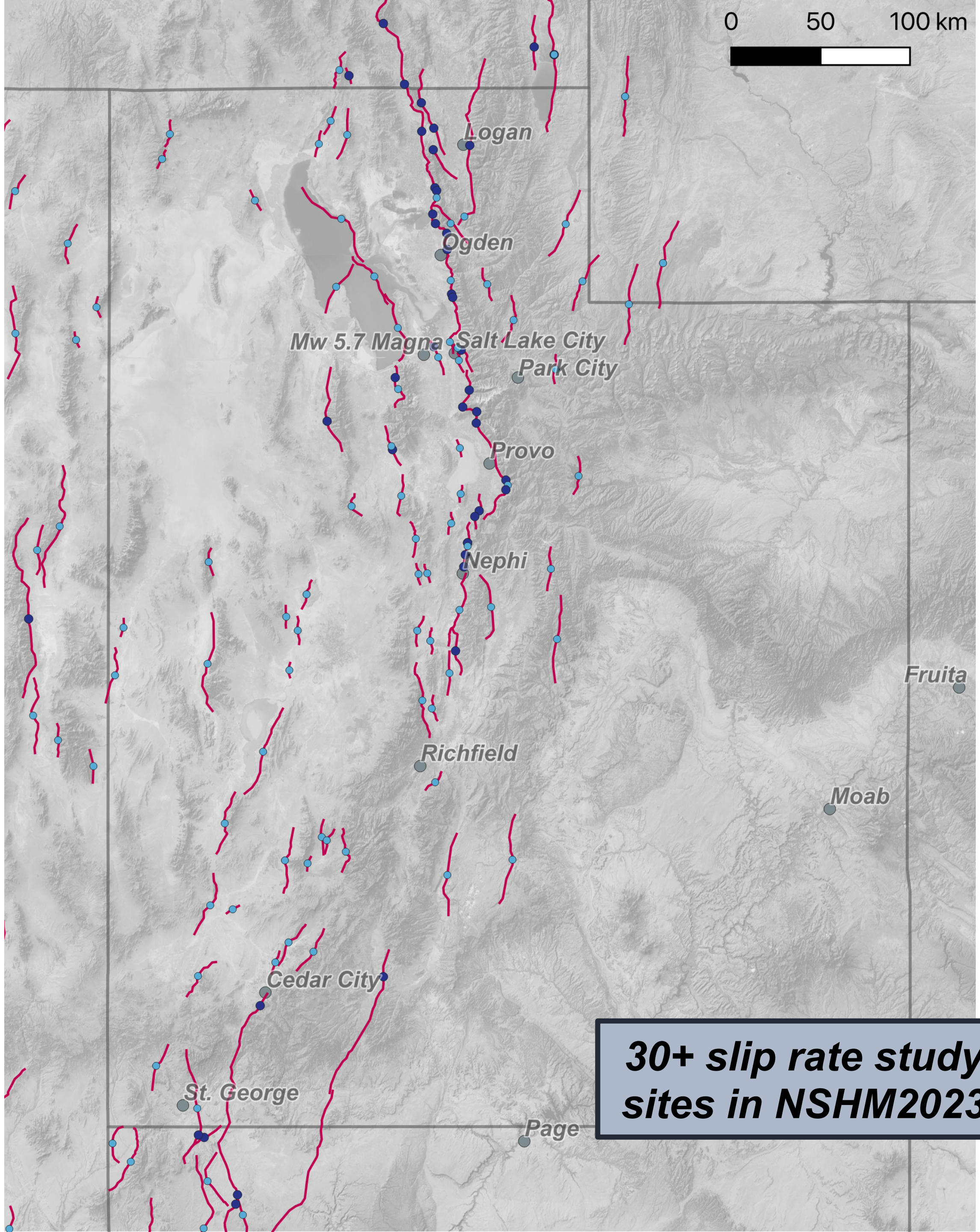

80+ fault sections in NSHM2023

30+ slip rate study sites in NSHM2023

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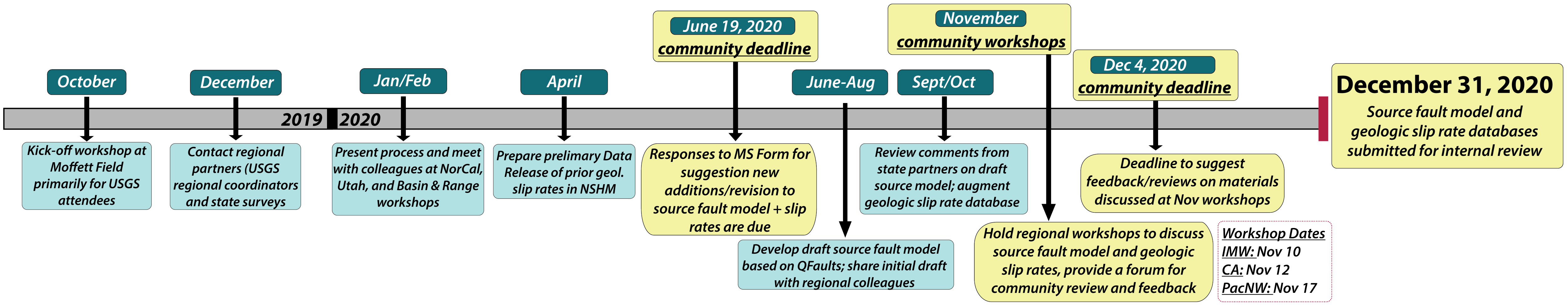
Utah faults (primary and border-crossing) newly added to NSHM2023 fault sections

1. Annabella graben
2. Antelope Range
3. Beaver Basin (east)
4. Beaver Basin (intrabasin, central)
5. Beaver Basin (intrabasin, east)
6. Beaver Basin (intrabasin, west)
7. Big Pass
8. Black Mountain
9. Broadmouth Canyon - James Peak
10. Carrington
11. Crater Bench
12. Crawford Mountains - Saleratus Creek
13. Cricket Mountains (west)
14. Dover Drum Mountains (east)
15. Drum Mountains (northwest)
16. Drum Mountains (south)
17. East Kamas
18. East Tintic Mountains (northwest)
19. East Tintic Mountains (southeast)
20. East Tintic Mountains (southwest)
21. Enoch Graben
22. Fish Springs
23. Gooseberry Graben
24. Goshen
25. Grouse Creek - Dove Creek Mountains (north)
26. Grouse Creek - Dove Creek Mountains (south)
27. Gunlock
28. Gunnison
29. Hansel Mountains (east side)
30. Hogsback
31. House Range
32. Little Valley (east)
33. Little Valley (west)
34. Main Canyon
35. Maple Grove
36. Mineral Mountains
37. North Genola
38. Ogden Valley North Fork
39. Paunsaugunt
40. Porcupine Mountains
41. Red Hills
42. San Francisco Mountains (west)
43. Scipio - Maple Grove - Pavant Range - Red Canyon
44. Sheeprock
45. Snake Valley (north)
46. Snake Valley (south)
47. Thousand Lake
48. Topliff Hill
49. Utah Lakes
50. Wah Wah Mountains (south)
51. Wasatch (Clarkston Mountain)
52. Wasatch (Collinston)
53. Wasatch (East Bench)
54. Wasatch (Fayette)
55. Wasatch (Foothills)
56. Wasatch (Virginia Street)
57. Washington (Fort Pearce)
58. Western Bear Lake

Utah geologic slip rate sites added to NSHM2023 EQGeoDB

1. East Cache; McCalpin (1994) UGS Special Study
2. Hurricane (Ash Creek, Cedar City); Lund et al (2006) UGS Special Study
3. Oquirrh; Olig et al., (1996) UGS Special Study
4. Sevier - Toroweap (north); Lund et al., (2008) UGS Special Study
5. Southern Oquirrh Mountains; Olig et al (2001) URS/WC report
6. Stansbury; Swan et al., (2005) BRPSHSII
7. Wasatch (Brigham City); Personius (1990) geologic map; Jewell and Bruhn (2013); Howe et al., (2019)
8. Wasatch (Brigham City); Howe et al., (2019) BSSA
9. Wasatch (Brigham City); DuRoss et al (2012) UGS Special Study
10. Wasatch (Brigham City); Personius (1991) UGS Special Study
11. Wasatch (Clarkston Mountain); WGUEP (2016; Hylland (2007)
12. Wasatch (Collinston); WGUEP (2016); Personius (1990); Hylland (2007)
13. Wasatch (Foothills); DuRoss et al (2014) within DuRoss and Hylland (2014) UGS Special Study
14. Wasatch (Fayette); WGUEP (2015); Hylland (2007); Hylland and Machette (2008)
15. Wasatch (Nephi, north); DuRoss et al., (2017) UGS Special Study
16. Wasatch (Nephi, north); DuRoss et al., (2008) reported in Crone et al., (2014) UGS Special Study
17. Wasatch (Nephi, south); Jackson (1991) UGS special study
18. Wasatch (Nephi, south); Harty et al., (1997) reported in Crone et al., (2014) UGS Special Study
19. Wasatch (Nephi, south); Crone et al., (2014) UGS Special Study
20. Wasatch (Nephi, south); DuRoss et al., (2017) UGS Special Study
21. Wasatch (Nephi, south); Harty et al.,(1997) reported in Crone et al., (2014) UGS Special Study
22. Wasatch (Nephi, south); Hanson et al., (1981; 1982); Crone et al., (2014) UGS Special Study Wasatch (Provo, north); Bennett et al., (2018) BSSA
23. Wasatch (Provo, north); Machette (1988) Machette et al., (1992) USGS Professional Paper
24. Wasatch (Provo, south); Swan et al., (1980)
25. Wasatch (Salt Lake City, south); DuRoss et al., (2018) BSSA
26. Wasatch (Salt Lake City, south); Swan et al (1981)
27. Wasatch (Weber); DuRoss et al., (2009) UGS Special Study
28. Wasatch (Weber); Nelson et al., (2006) UGS Special Study; Benson et al., (2011)
29. Wasatch (Weber); Nelson et al., (2006) UGS Special Study
30. Wasatch (Weber); Nelson et al., (2006) reports rate from McCalpin et al. (1994)
31. Wasatch (Weber); Swan et al., (1980) BSSA
32. Wasatch (Provo, south); Lund et al (1991) UGS Special Study
33. West Cache (Clarkston); Black et al., (2000) UGS Special Study; Lund (2005) UGS Bulletin
34. West Cache (Junction Hills); Black et al (2000) UGS Special Study; Lund (2005) UGS Bulletin
35. West Cache (Wellsville); Black et al., (2000) UGS Special Study
36. West Valley; Hylland et al (2014) in DuRoss and Hylland (2014) UGS Special Study

Earthquake Geology Databases Update Timeline



last updated Oct 8, 2020

USGS science for a changing world
Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

A community effort involving regional experts

ReadMe
References
Change Log

Geologic Slip Rates saved as:
SHP, CSV, KML, geoJSON

Fault Sections saved as:
SHP, CSV, KML, geoJSON

USGS science for a changing world

ScienceBase-Catalog   Communities   Help

Databases are now available on ScienceBase.gov!

ScienceBase Catalog → Earthquake geology inputs f... → Earthquake geology inputs f...

Earthquake geology inputs for the U.S. National Seismic Hazard Model (NSHM) 2023, version 1.0

Dates

Publication Date : 2021-01-21
Start Date : 1970
End Date : 2020

Citation

Hatem, A.E., Collett, C.M., Gold, R.D., Briggs, R.W., Angster, S.A., Field, E.H., Anderson, M., Ben-Horin, J.Y., Dawson, T., DeLong, S., DuRoss, C., Thompson Jobe, J., Kleber, E., Knudsen, K.L., Koehler, R., Koning, D., Lifton, Z., Madin, I., Mauch, J., Morgan, M., Pearthree, P., Petersen, M., Pollitz, F., Scharer, K., Powers, P., Sherrod, B., Stickney, M., Wittke, S., and Zachariasen, J., 2021, Earthquake geology inputs for the National Seismic Hazard Model (NSHM) 2023, version 1.0: U.S. Geological Survey data release, https://doi.org/10.5066/P918XCUU.

Summary

This Data Release contains preliminary versions of two related databases: 1) A fault sections database ("NSHM2023_FaultSections_v1"), which depicts the geometry of faults capable of hosting independent earthquakes, and 2) An earthquake geology site information database ("NSHM2023_EQGeoDB_v1"), which contains fault slip-rate constraints at points. These databases were prepared in anticipation of updates to the National Seismic Hazard Model (NSHM) 2023. Fault-specific geologic parameters for the NSHM have not been updated since the 2014 NSHM release. The datasets include the states of Washington, Oregon, California, Idaho, Nevada, Arizona, Montana, Wyoming, Colorado, New Mexico and Texas. Datasets containing fault information for Alaska and the Central and Eastern United States will be the subject of future efforts. These databases are provided as geospatial data (e.g., .SHP, .KML, .GeoJSON file formats) and tables (.CSV format).

Child Items (3)

- Documentation
- NSHM2023_EQGeoDB_v1
- NSHM2023_FaultSections_v1

Contacts

Map »

Spatial Services

ScienceBase WMS :
https://www.sciencebase.gc

Communities

- USGS Data Release Prod

Tags

Harvest Set : USGS Science D
Theme : hazards
Place : Arizona, California, Co
Montana, New Mexico, Ore
Washington, Wyoming
USGS Scientific Topic Keywor
Structural Geology

Provenance

Percent Increase of Fault Sections from 2014/18 to 2023 in Western US

Listed By State

State	NSHM14/18	NSHM2023	Percent increase
Arizona	7	55	686%
Colorado	5	11	120%
Idaho	9	21	133%
Montana	14	24	71%
New Mexico	30	82	173%
Nevada	126	256	103%
Texas	12	12	0%
Utah	24	85	254%
Wyoming	9	15	67%
Oregon	43	65	51%
Washington	18	36	100%
California	347	358	3%
TOTAL	644	1020	58%

Listed By Region

Region	NSHM14/18	NSHM2023	Percent increase
IMW	236	561	138%
PNW	61	101	66%
CA	347	358	3%
TOTAL	644	1020	58%

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

Next steps

Conduct geologic deformation modeling.

- Determine preferred geologic slip rates for categorical slip rates.
- Refine uncertainty estimates of existing, measured slip rates.
- Ensure moment balancing across transects given far-field GPS vectors.

Any questions, comments or concerns?
Please contact Alex Hatem at ahatem@usgs.gov

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

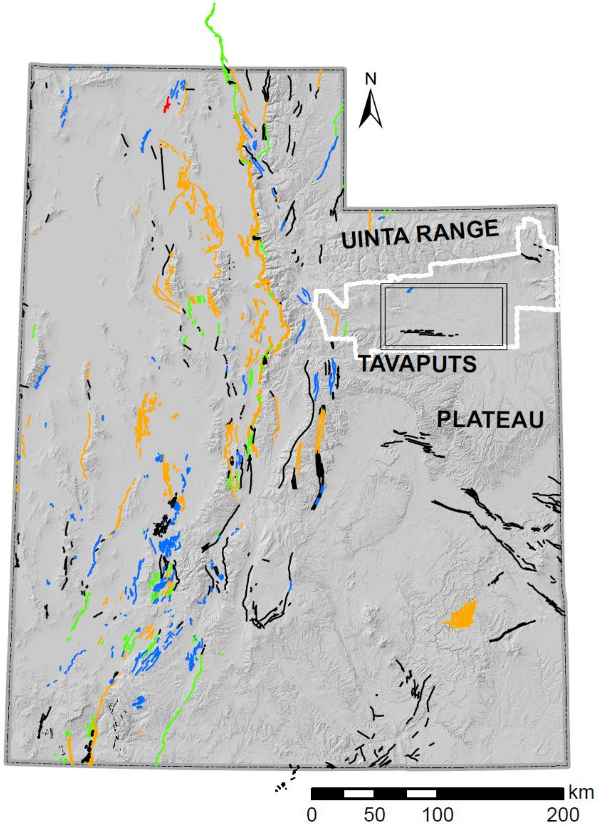
BUREAU OF RECLAMATION

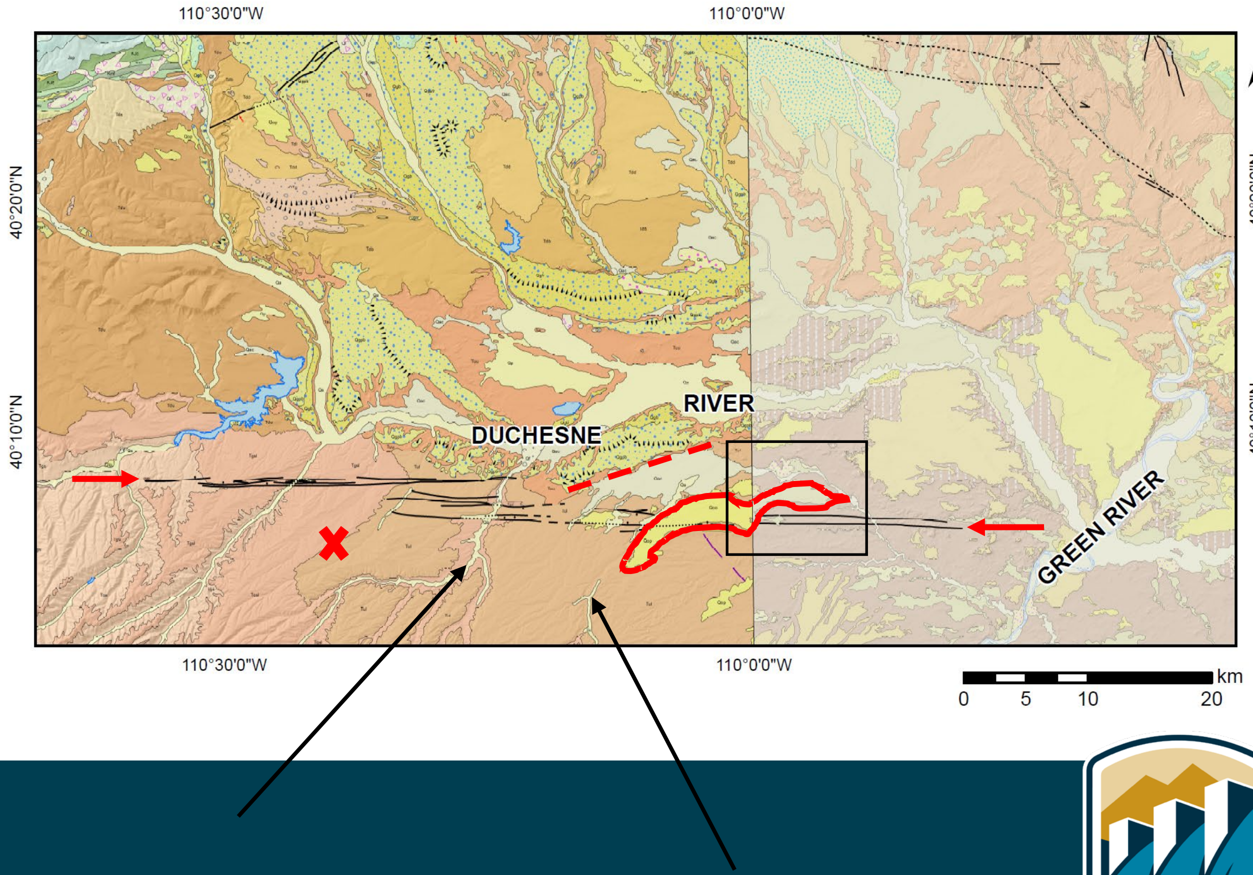
Preliminary Evaluation of Quaternary Activity on the Duchesne-Pleasant Valley Fault, Uinta Basin, Utah

Julia Howe

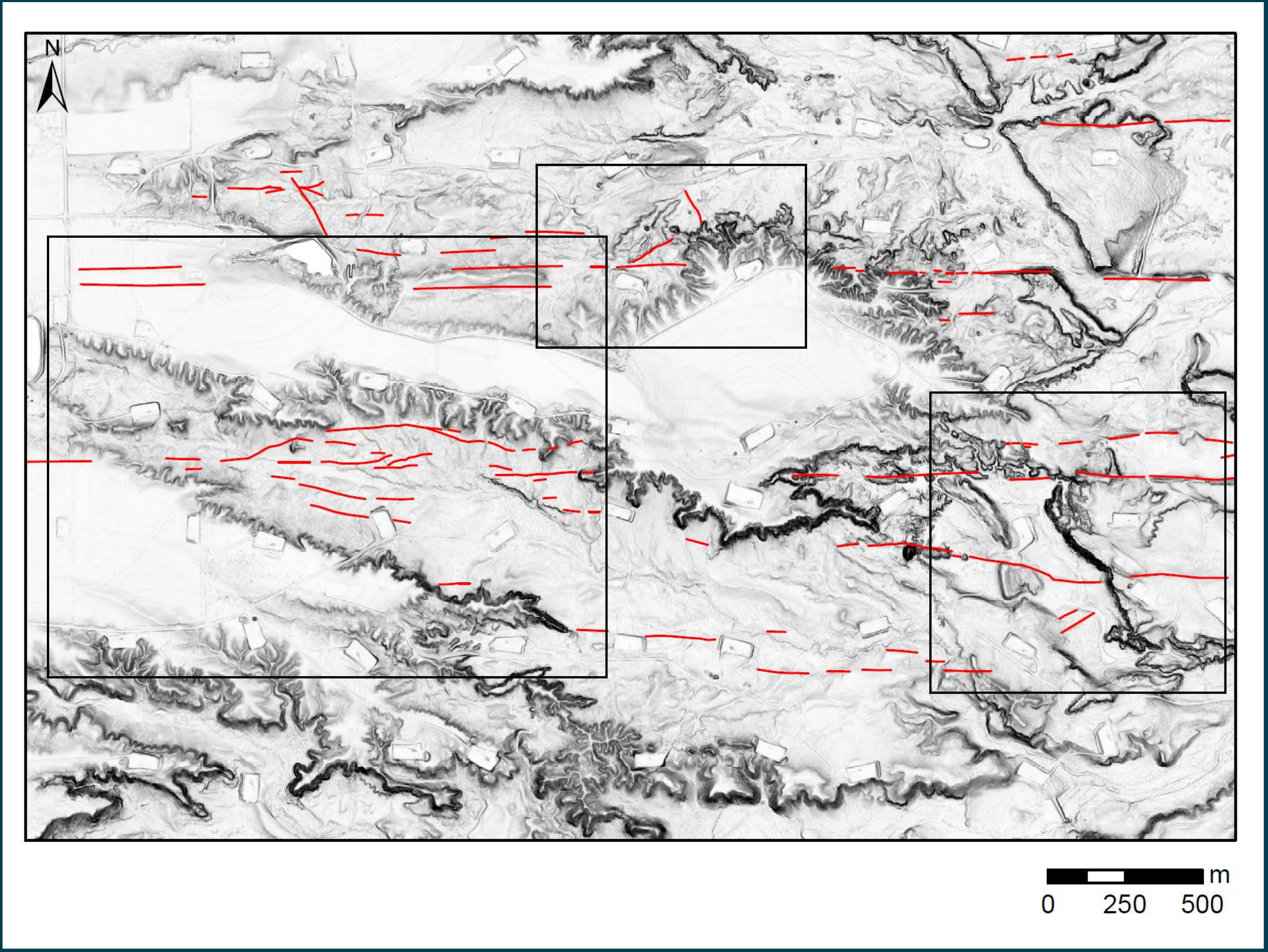
Ralph Klinger

Geologic Setting





This Study



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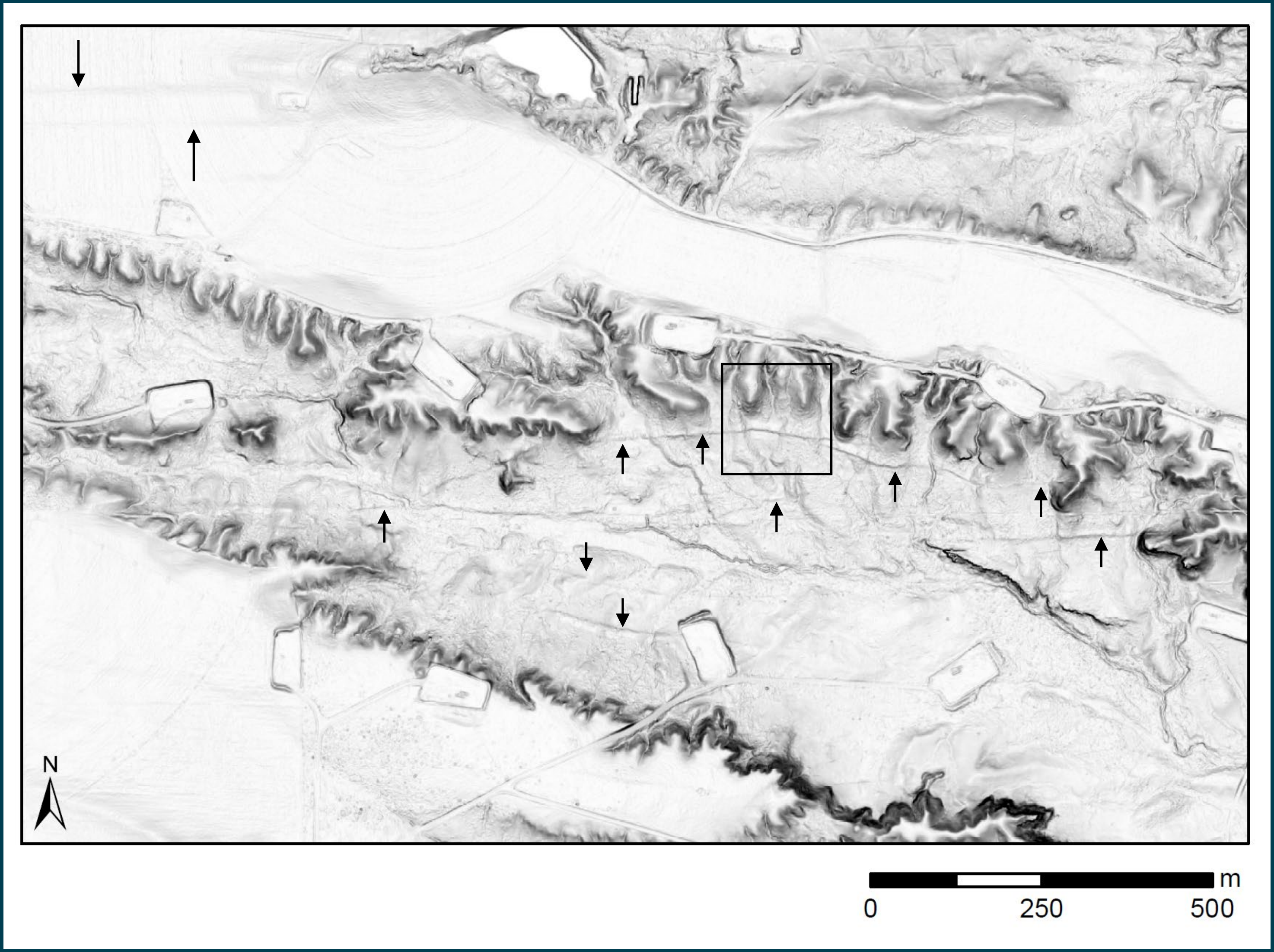
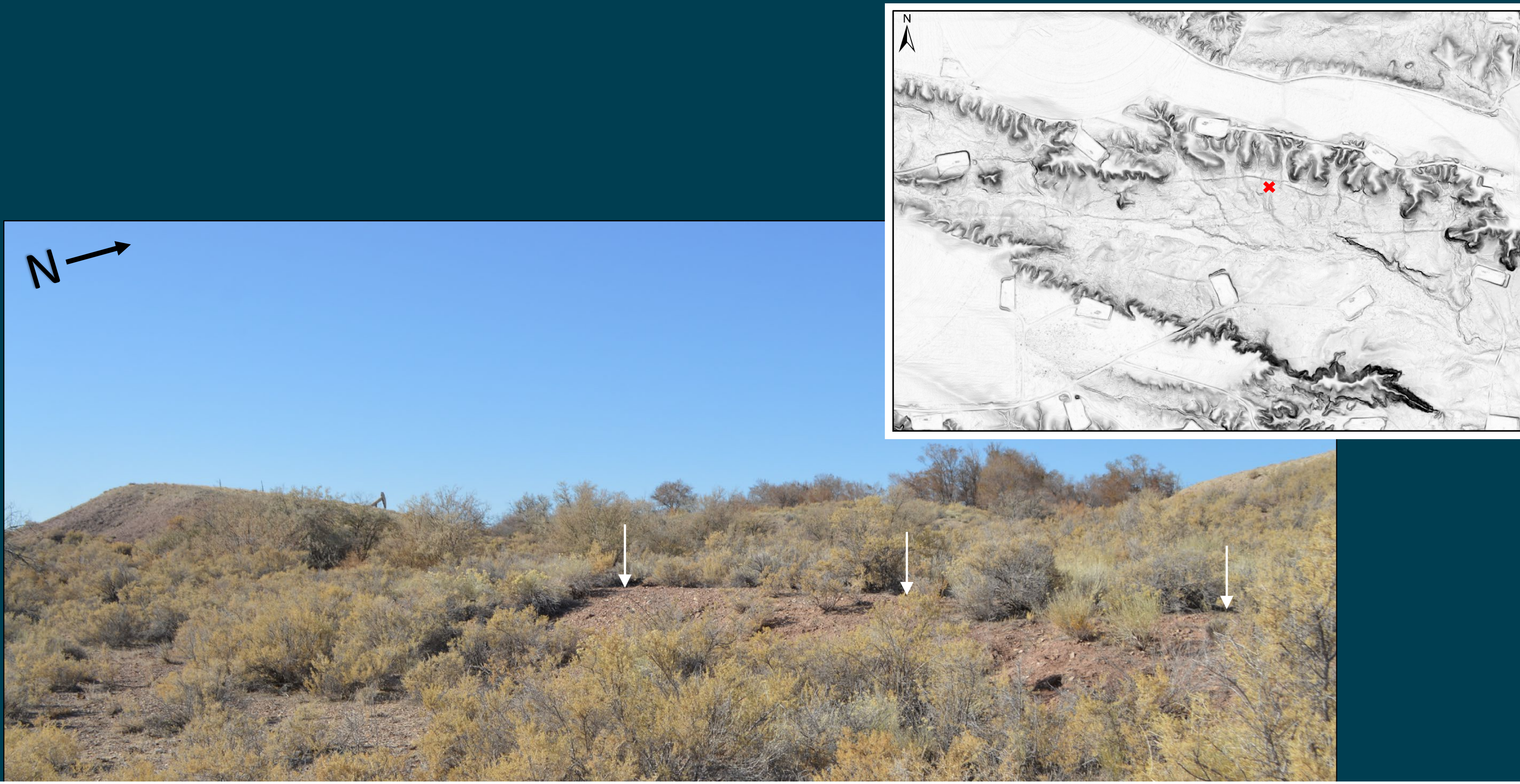
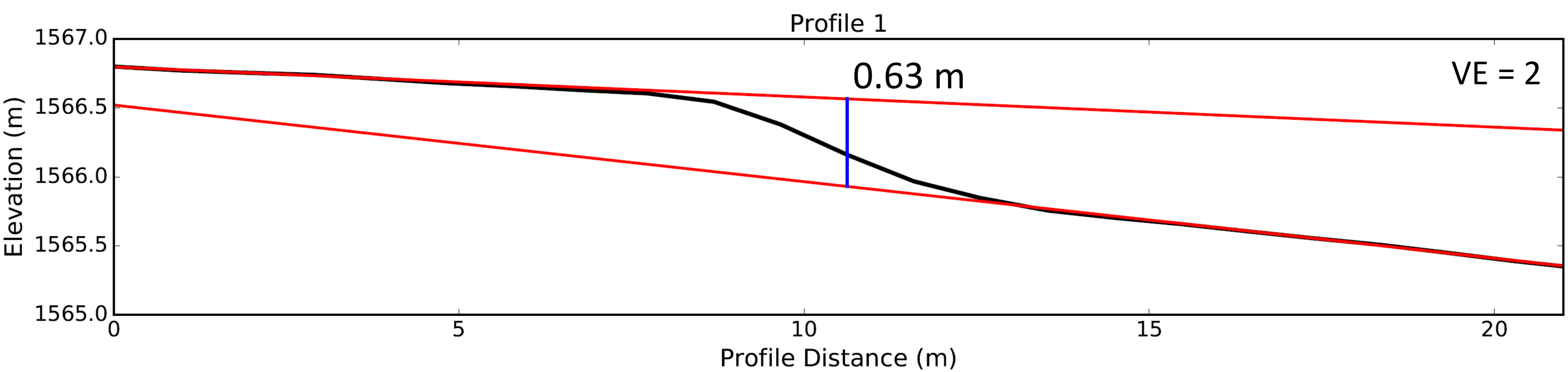
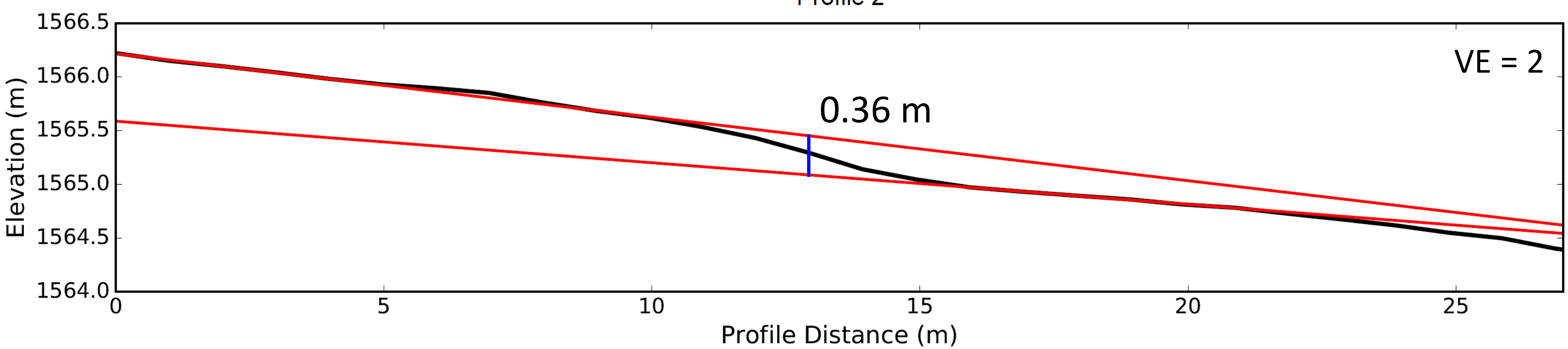



N
N

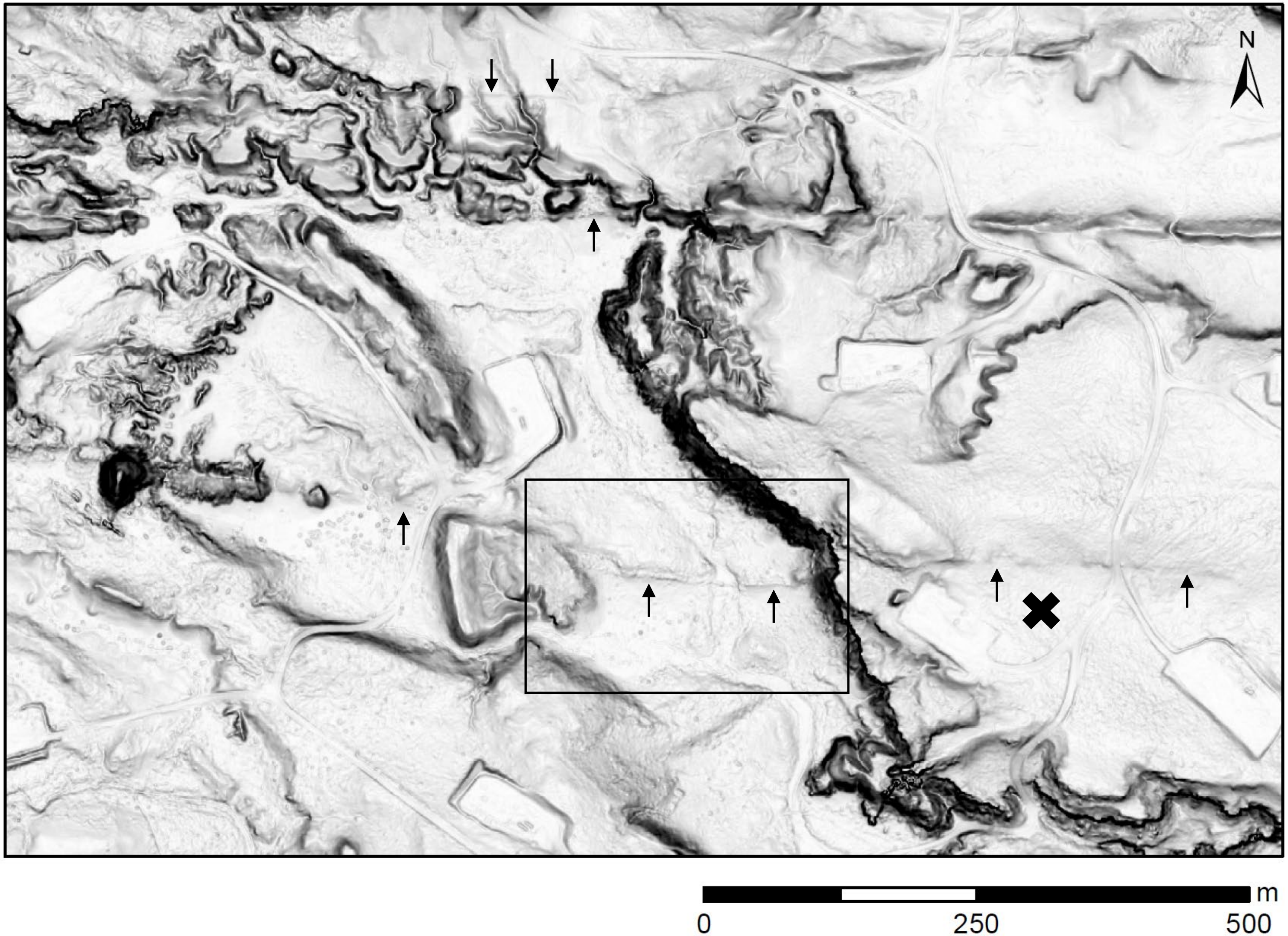

Profile 1
0.63 m
VE = 2
Elevation (m)
Profile Distance (m)
1567.0
1566.5
1566.0
1565.5
1565.0
0
5
10
15
20


N


N


Profile 2
VE = 2
0.36 m
Elevation (m)
1566.5
1566.0
1565.5
1565.0
1564.5
1564.0
Profile Distance (m)
0
5
10
15
20
25

Site 2



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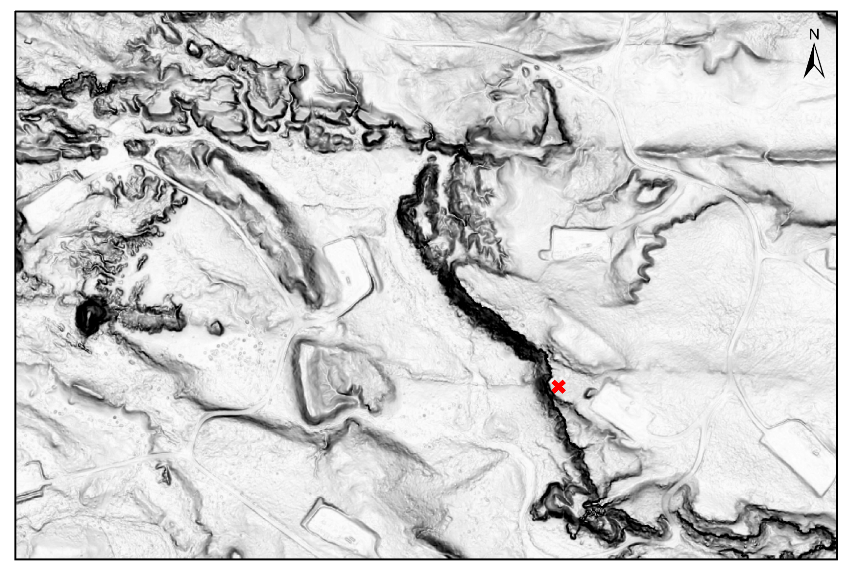
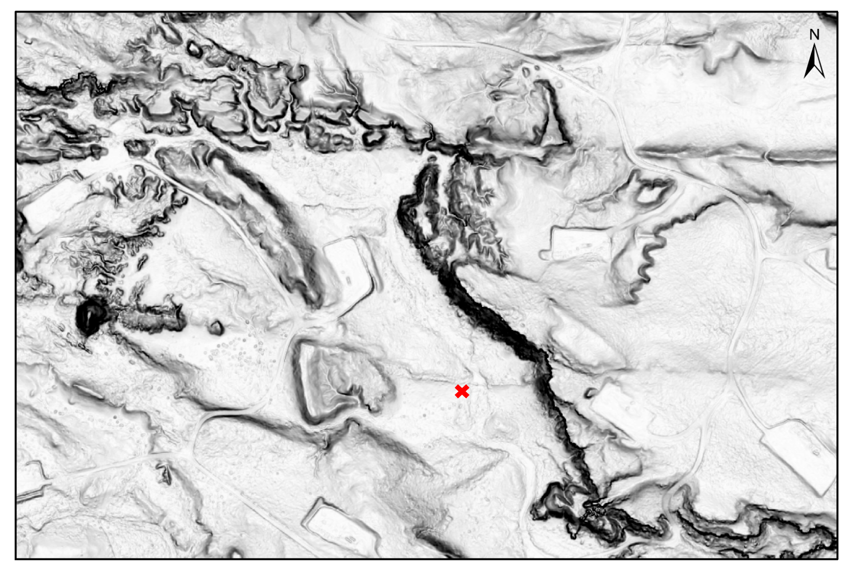


Site 2


N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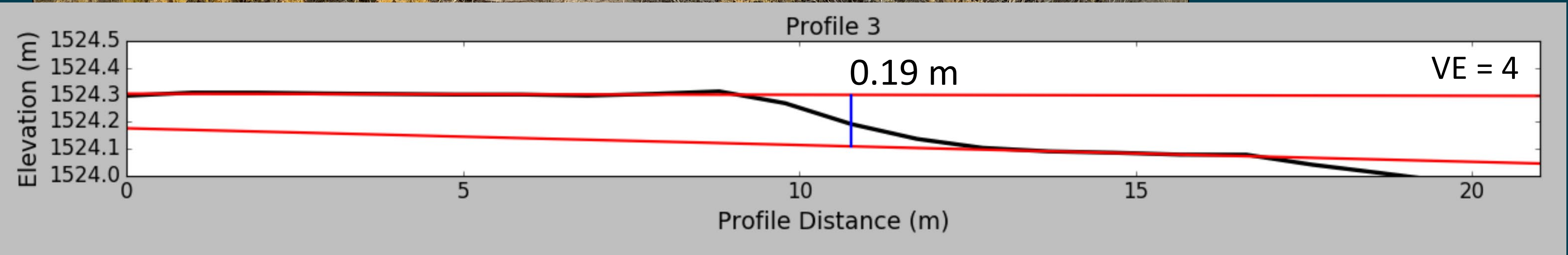
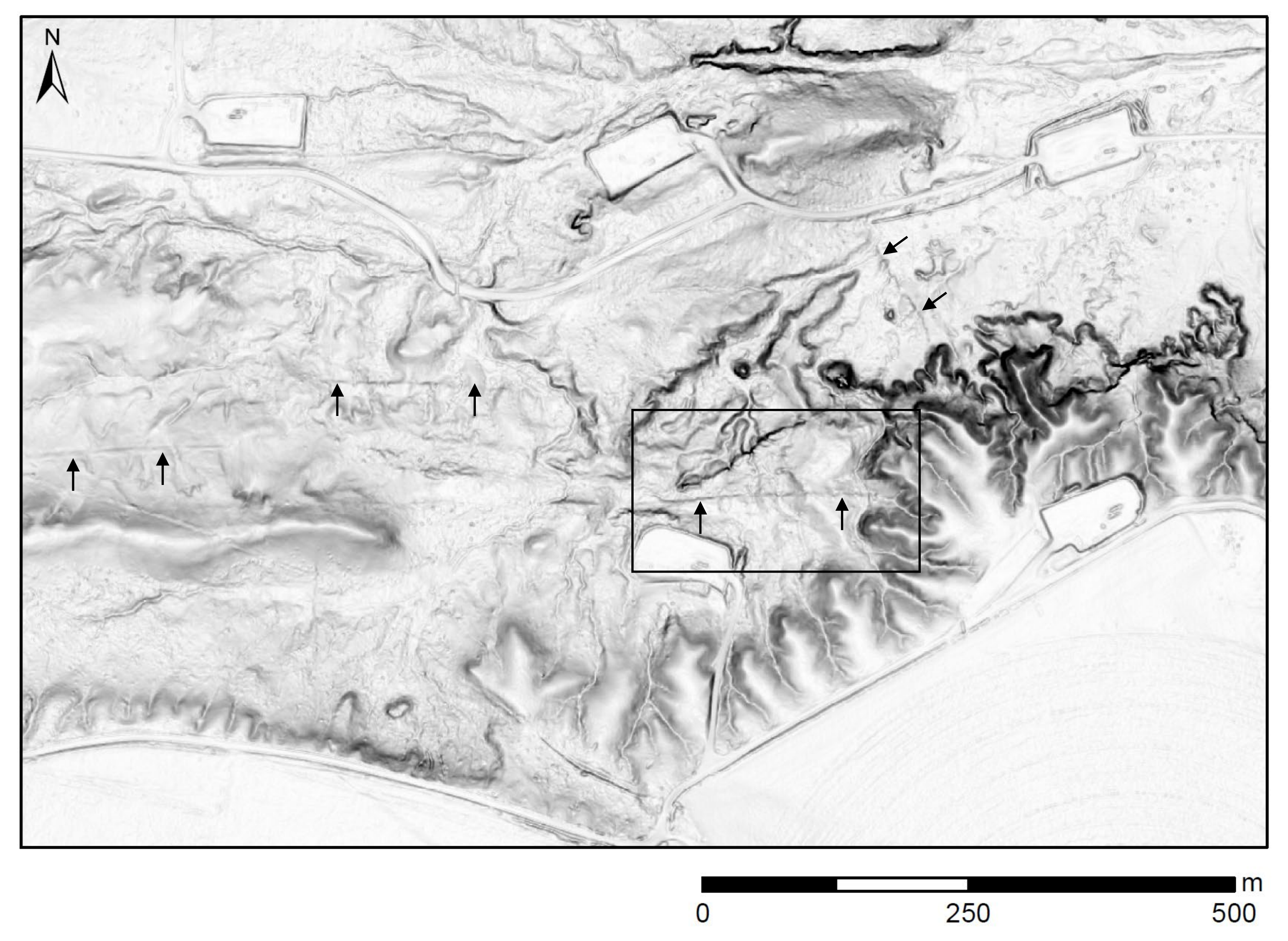
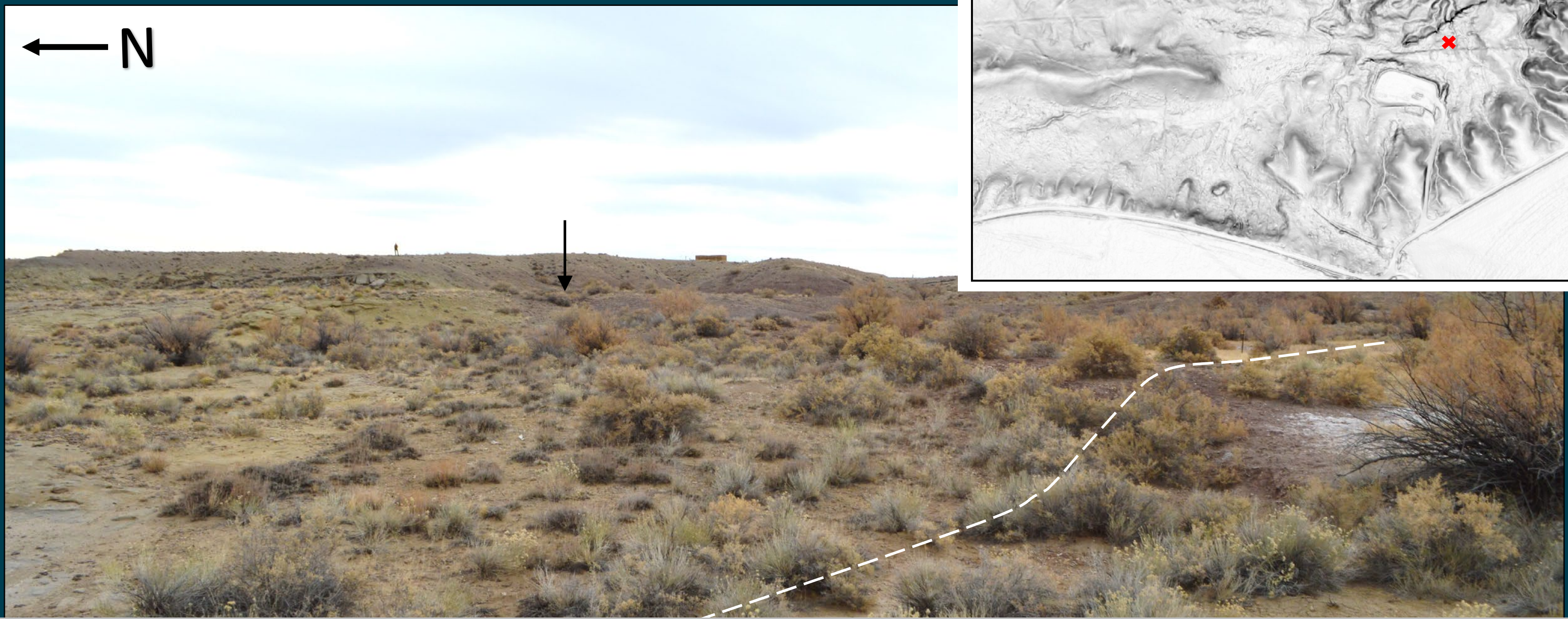

Profile 3
Elevation (m)
1524.5
1524.4
1524.3
1524.2
1524.1
1524.0
0.19 m
VE = 4
0
5
10
15
20
Profile Distance (m)

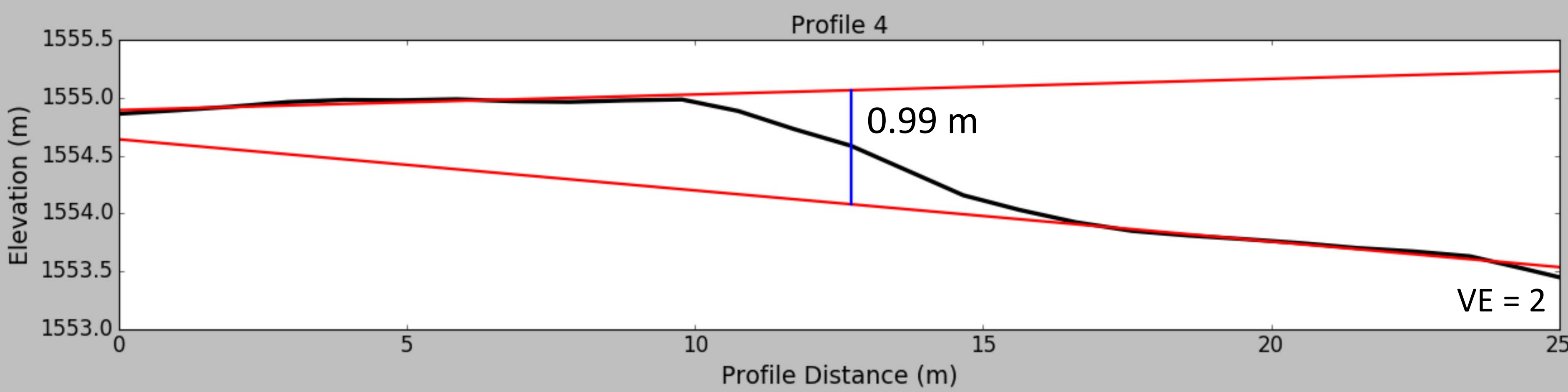
Site 3



Site 3


N


N

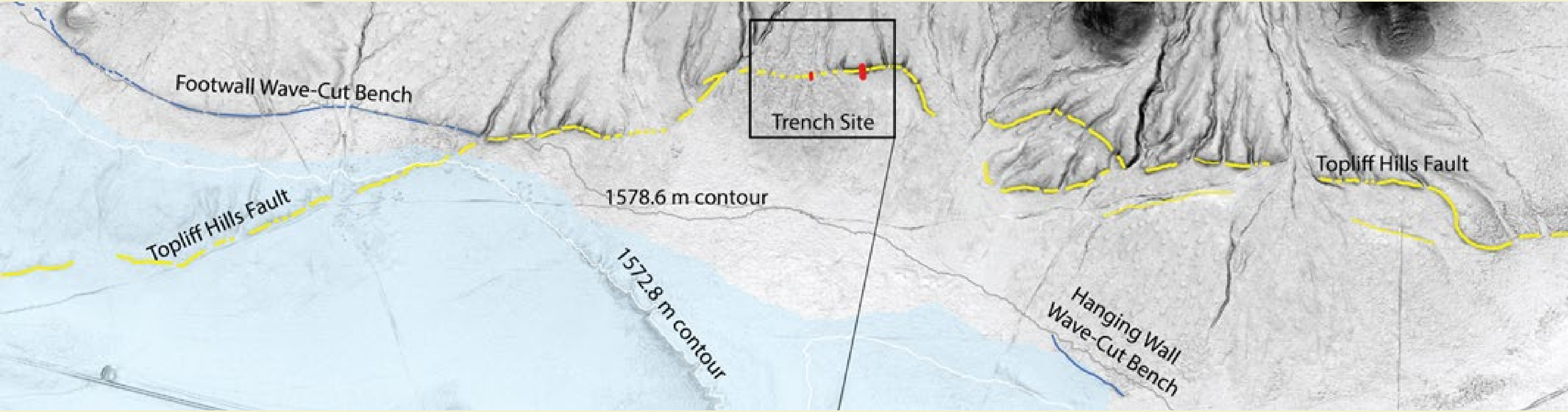

Profile 4
1555.5
1555.0
1554.5
1554.0
1553.5
1553.0
Elevation (m)
0
5
10
15
20
25
Profile Distance (m)
0.99 m
VE = 2

Preliminary Results

- Scarps do not consistently correlate to lithologic contacts, which would be expected if scarps were formed by differential erosion.
  - Nonresistant rock is found on the upthrown and downthrown side of the fault.
- Scarps cross Quaternary surfaces of multiple ages, based on relative surface heights and published Quaternary mapping
- These lines of evidence suggest that the Duchesne-Pleasant Valley fault is Quaternary-active

Questions?

Late Quaternary Earthquake History of the Topliff Hills Fault in Rush Valley, Utah



UVU Faculty: Nathan Toké[1], and Michael P. Bunds[1]
UVU Students: Rachel Richards[1], Alex Tolman[1], Brigham Whitney[1], and Sally Ward[1]
The USU Luminescence Lab: Tammy Rittenour[2] and Carlie Ideker[2]

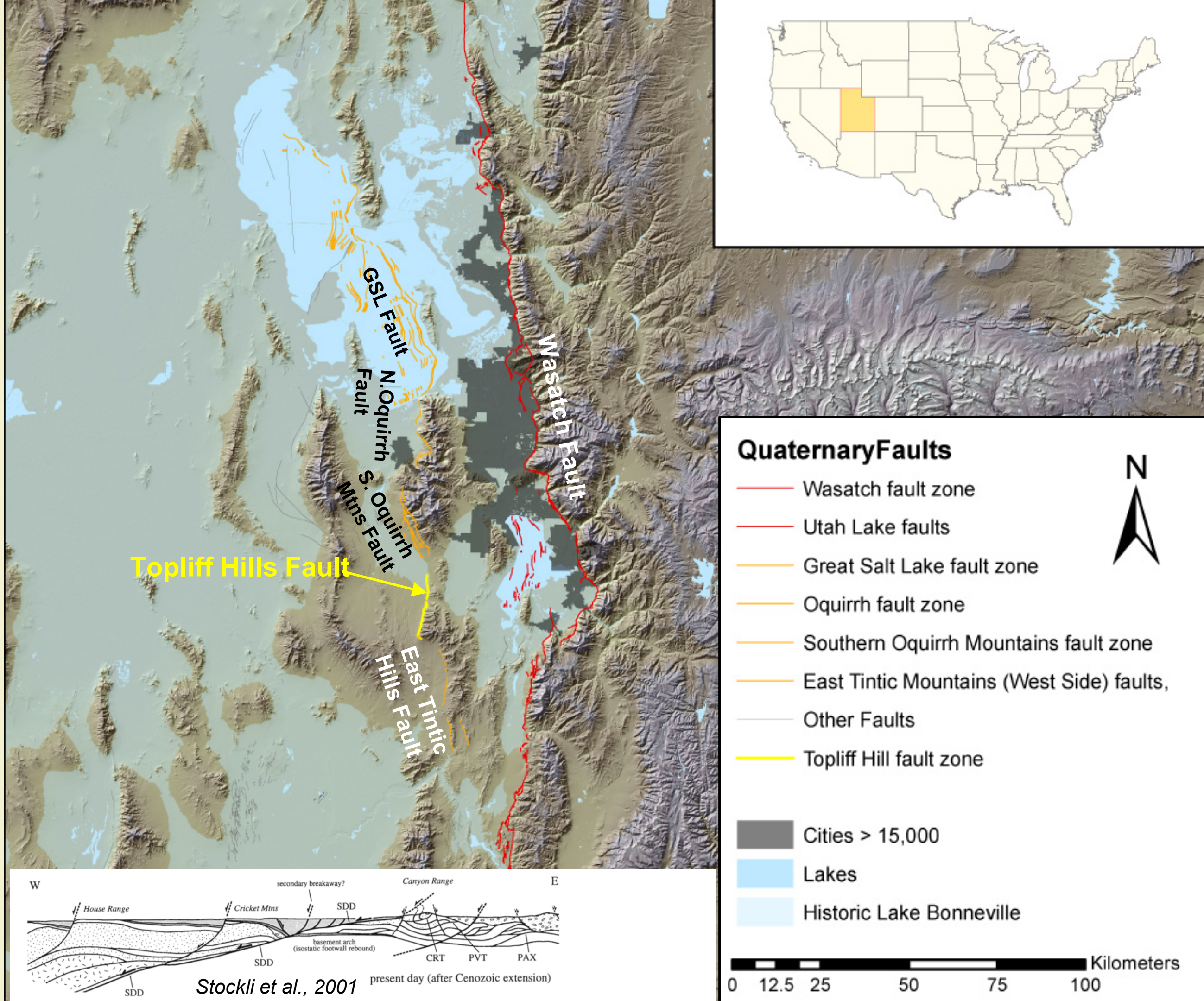
UTAH VALLEY UVU UNIVERSITY Department of EARTH SCIENCE

[1]Department of Earth Science, Utah Valley University
[2]Department of Geology, Utah State University

department of geology UtahStateUniversity

Topliff Hills Fault

- 25 km -long, west - dipping fault
- South Oquirrh Mountains fault is structurally -aligned
- Utah's second longest Fault system, >250 km length
- Within 40 km of the Wasatch front



Stockli et al., 2001

CHANG ET AL.: GPS OBSERVATIONS OF THE WASATCH FAULT

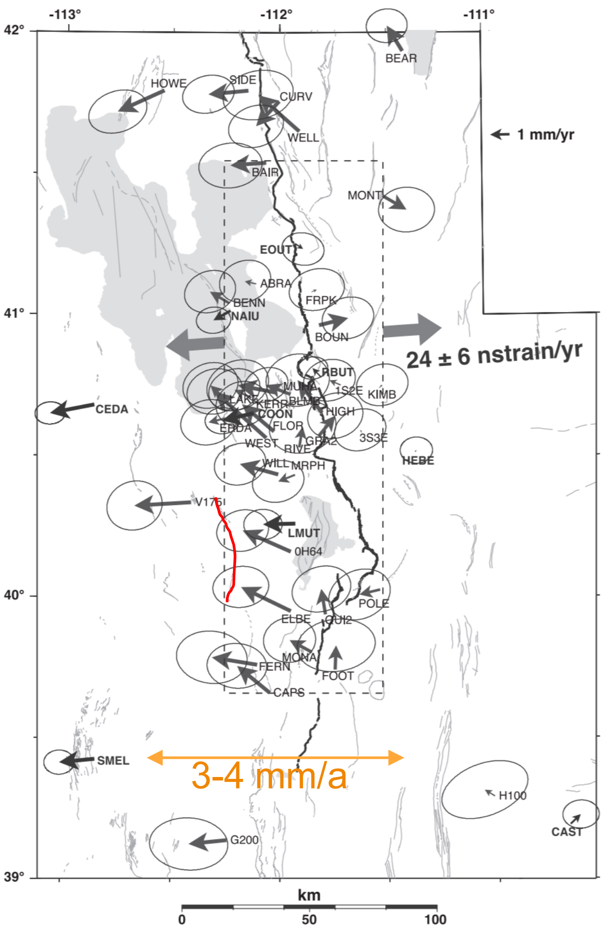


Figure 5. Horizontal velocity vectors, in a stable North America reference frame, derived from the 1997–2004 continuous and the University of Utah 1992–2003 campaign GPS observations. Weighted error ellipses (see text) represent the 95% confident intervals. Gray lines are Quaternary faults, and black lines highlight the Wasatch fault. Thick gray arrows represent the direction of the principal extension assuming a homogeneous strain field in the dashed box.

Earthquake Probabilities for the Wasatch Front Region

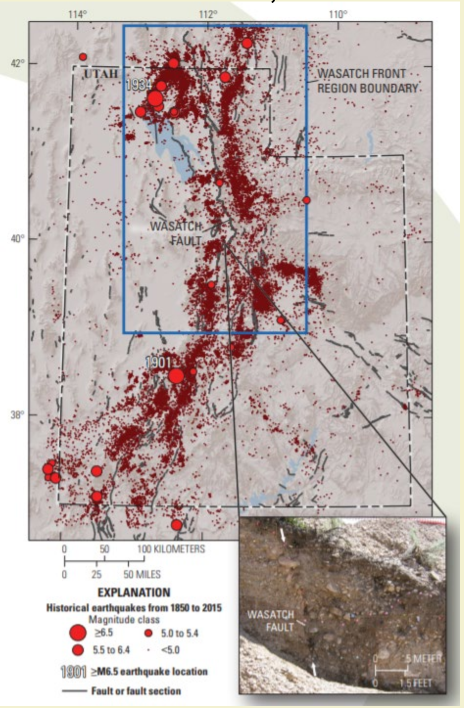
	M6.0 or greater	M6.75 or greater
Wasatch fault zone	18%	18%
Oquirrh-Great Salt Lake fault zone	7%	6%
Other faults in the region[1]	34%	25%
Background earthquakes	14%	NA[2]
Wasatch Front region total	57%	43%

Probabilities are for one or more earthquakes in the next 50 years (WGUEP, 2016).

[1]Combined probability for the 45 other faults or fault sections in the region.

[2]Probability not calculated for background earthquakes.

WGUEP, 2016



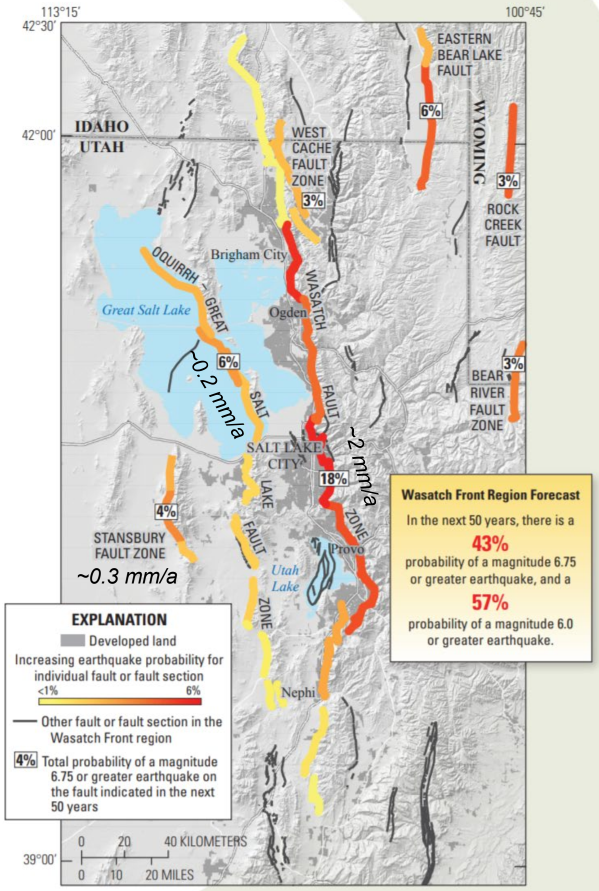
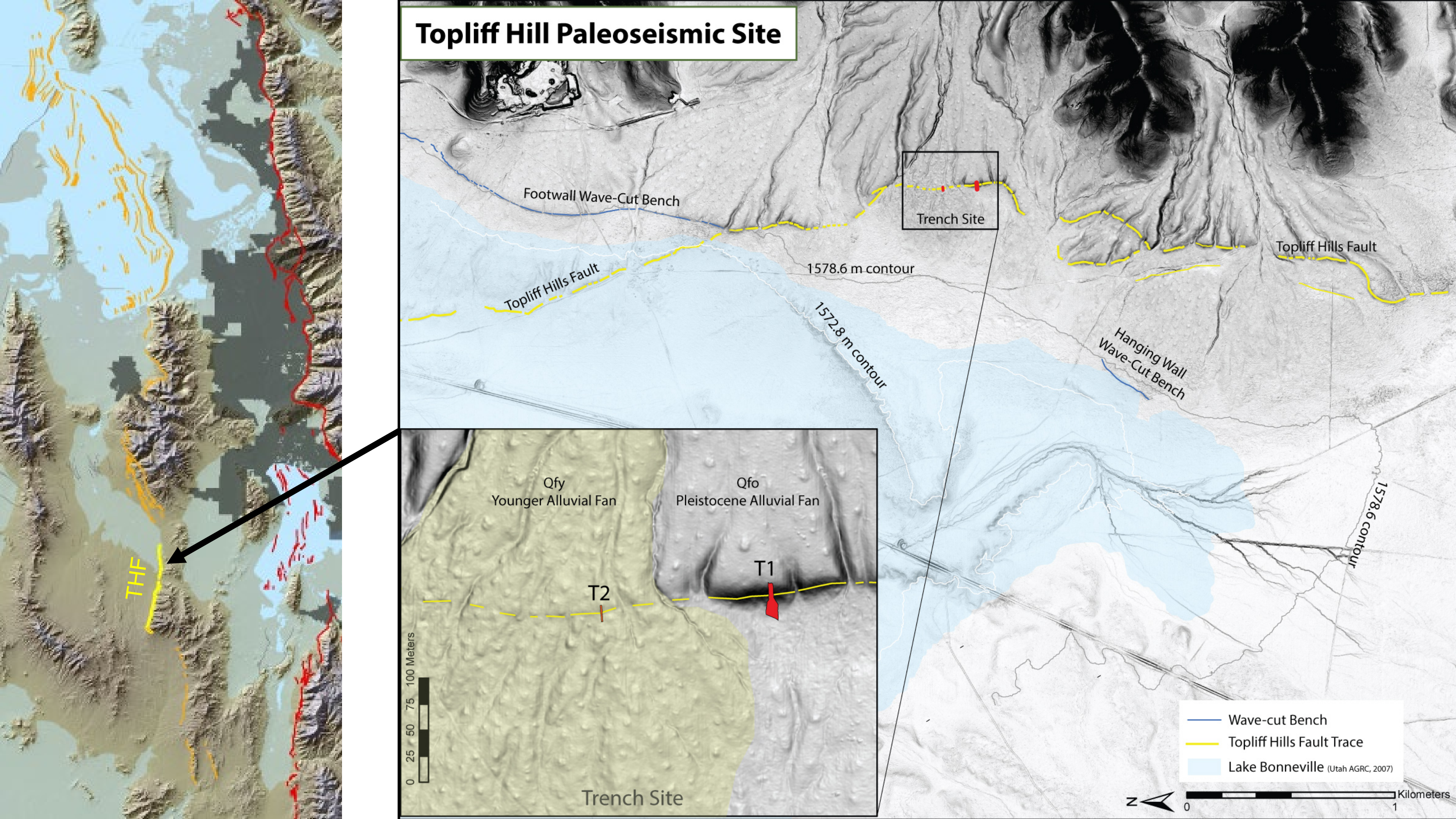
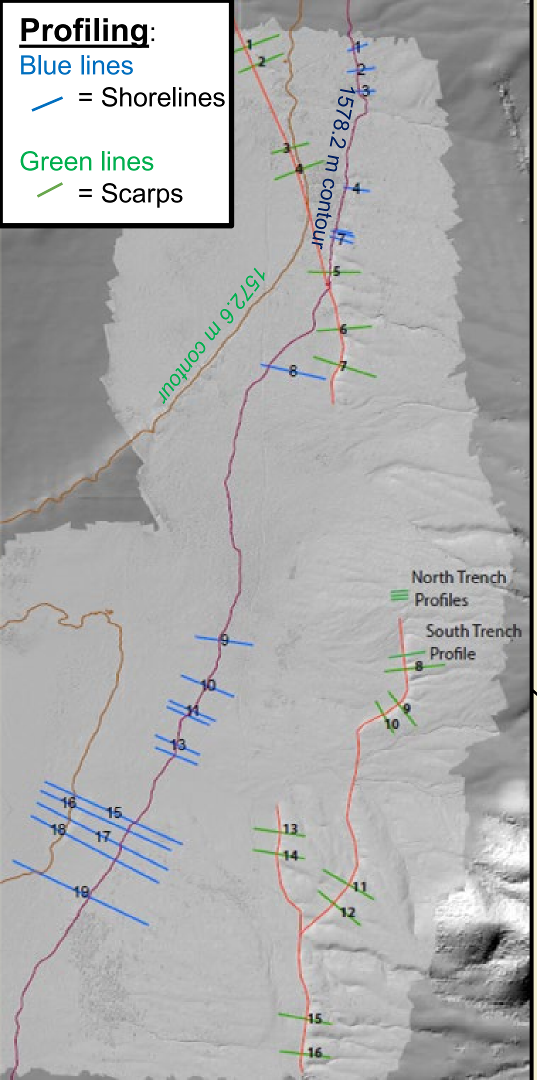
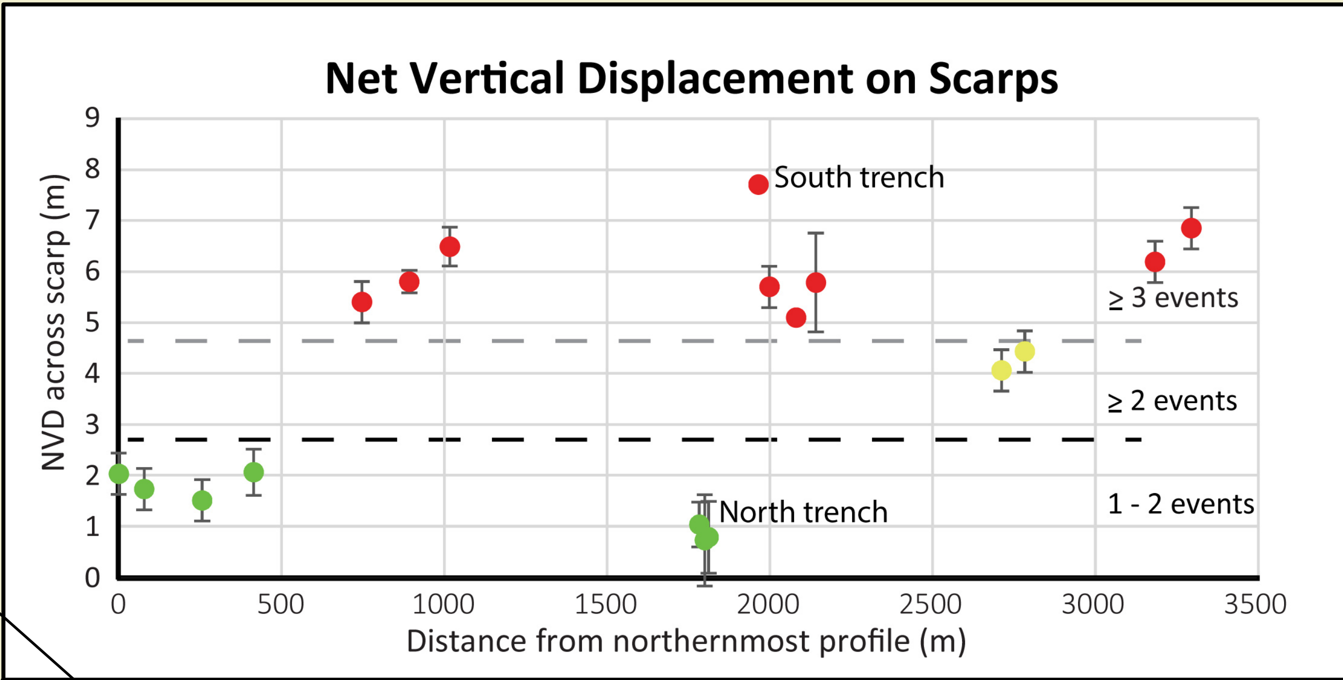


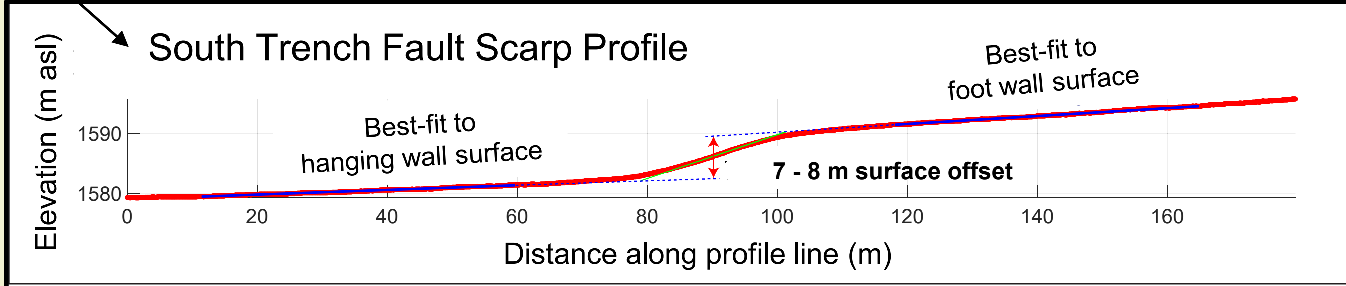
Figure 1. Magnitude 6.75 or greater earthquake probabilities may vary along faults (yellow to red fault colors), but entire fault probabilities are labeled. For example, the total probability for the entire Wasatch fault is 18 percent. Only faults with a probability of 2 percent or greater are shown. Modified from Working Group on Utah Earthquake Probabilities (2016). (%, percent)

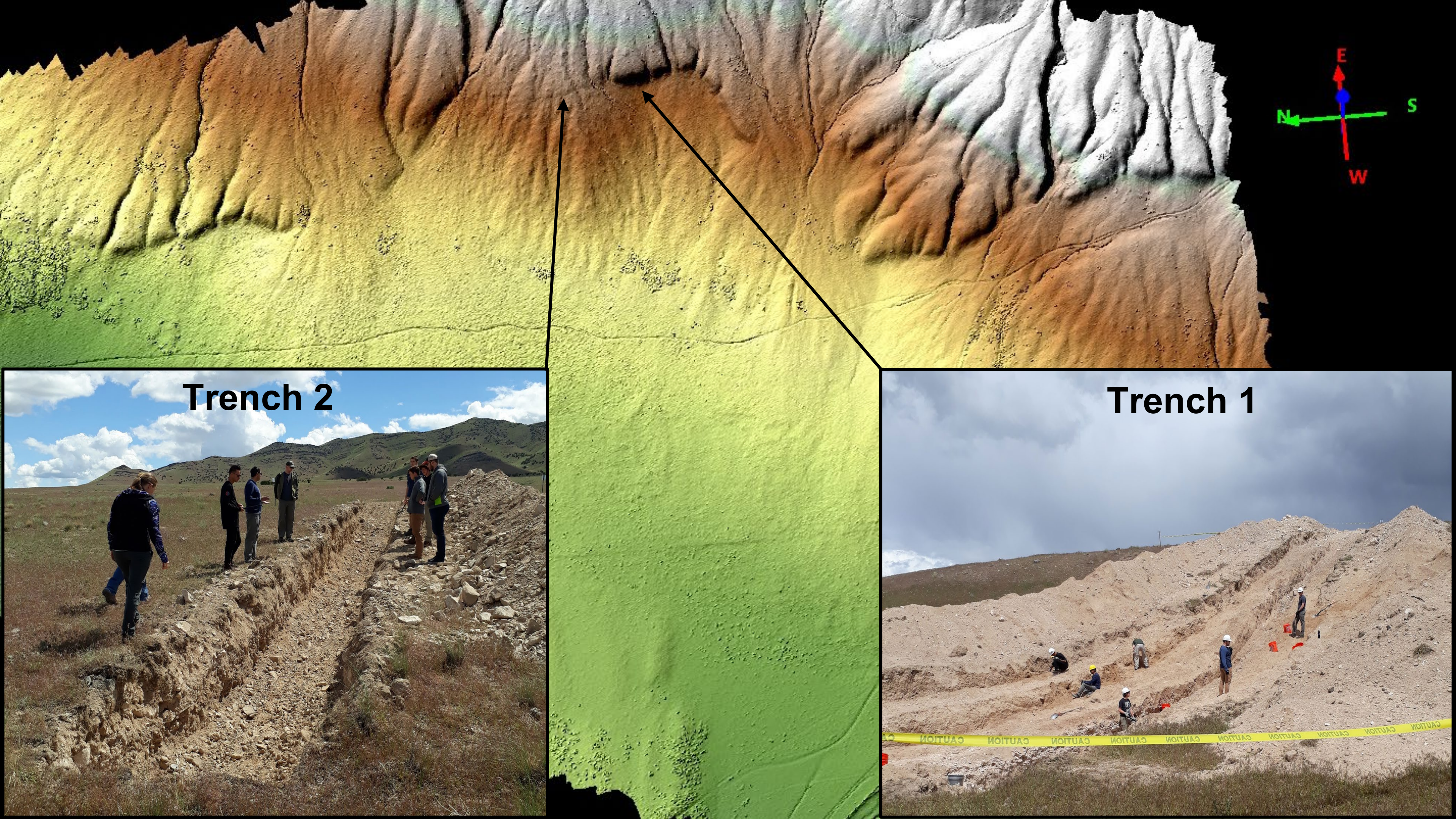

THF
Topliff Hill Paleoseismic Site
Footwall Wave-Cut Bench
Trench Site
Topliff Hills Fault
Topliff Hills Fault
1578.6 m contour
1572.8 m contour
Hanging Wall Wave-Cut Bench
1578.6 m contour
Qfy
Younger Alluvial Fan
Qfo
Pleistocene Alluvial Fan
T1
T2
0 25 50 75 100 Meters
Trench Site
Wave-cut Bench
Topliff Hills Fault Trace
Lake Bonneville (Utah AGRC, 2007)
N
0 1 Kilometers

Scarp Height Profiling



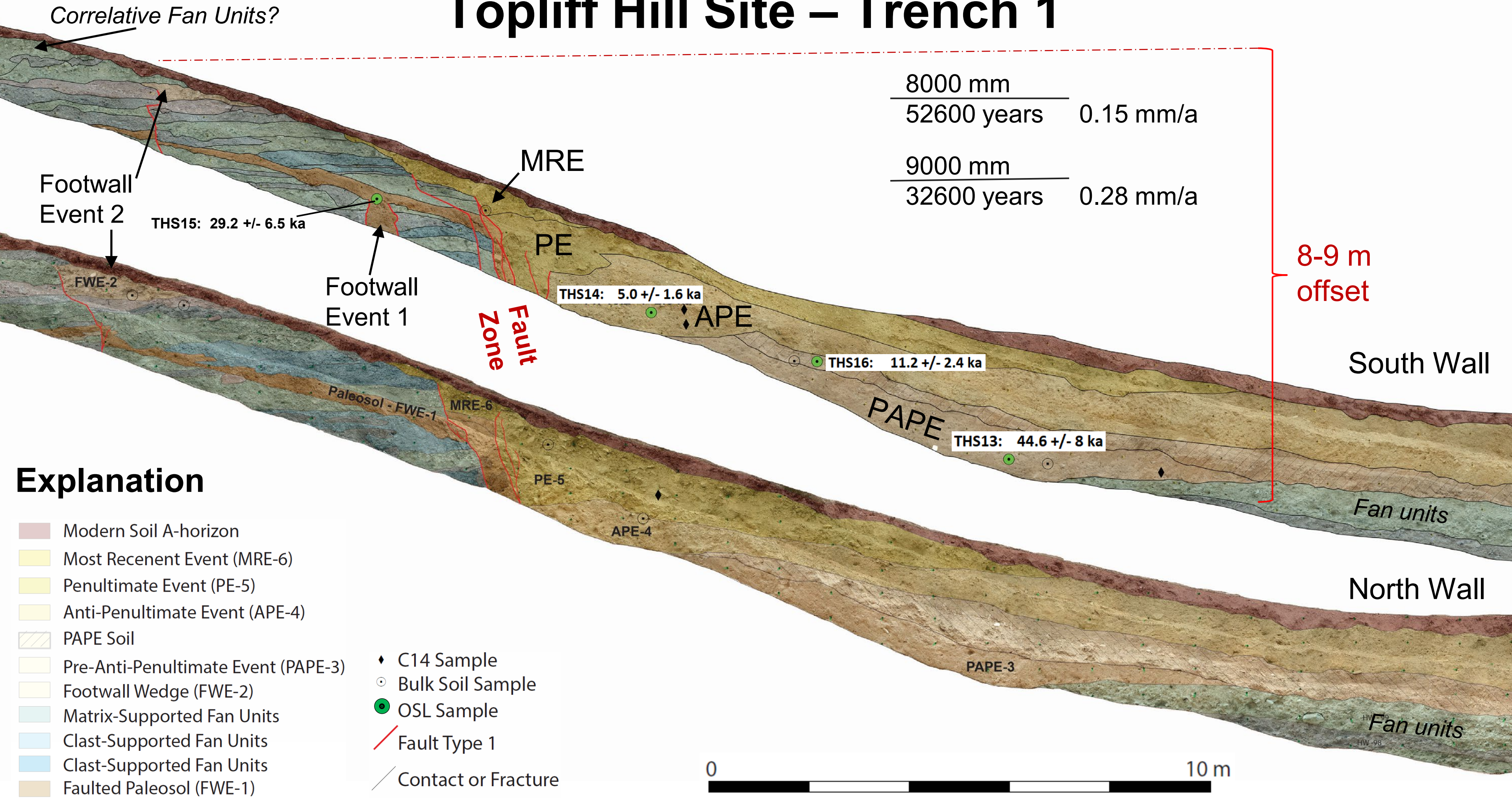






E
N
S
W
Trench 2
Trench 1

Topliff Hill Site – Trench 1

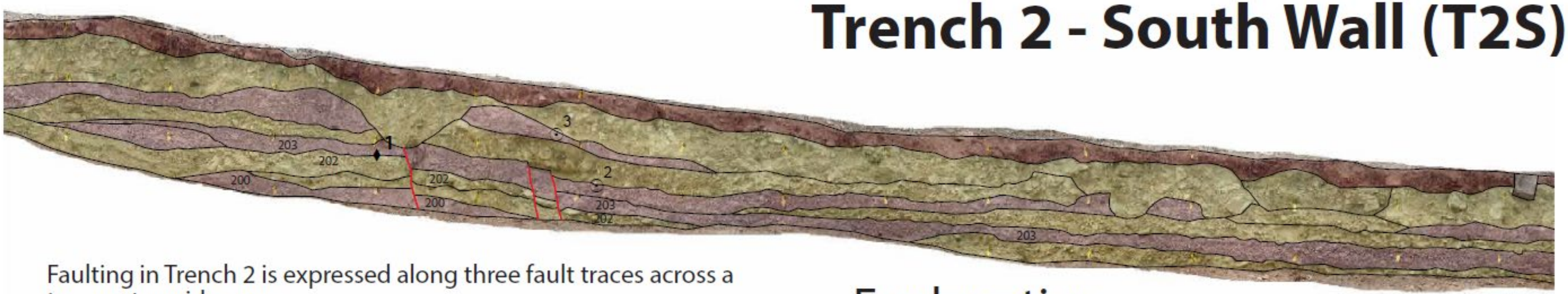


Explanation

- Modern Soil A-horizon
- Most Recenent Event (MRE-6)
- Penultimate Event (PE-5)
- Anti-Penultimate Event (APE-4)
- PAPE Soil
- Pre-Anti-Penultimate Event (PAPE-3)
- Footwall Wedge (FWE-2)
- Matrix-Supported Fan Units
- Clast-Supported Fan Units
- Clast-Supported Fan Units
- Faulted Paleosol (FWE-1)

- C14 Sample
- Bulk Soil Sample
- OSL Sample
- Fault Type 1
- Contact or Fracture

Trench 2 - South Wall (T2S)



Faulting in Trench 2 is expressed along three fault traces across a two-meter wide zone.

Cumulative displacement is 0.5 +/ 0.05 meters.

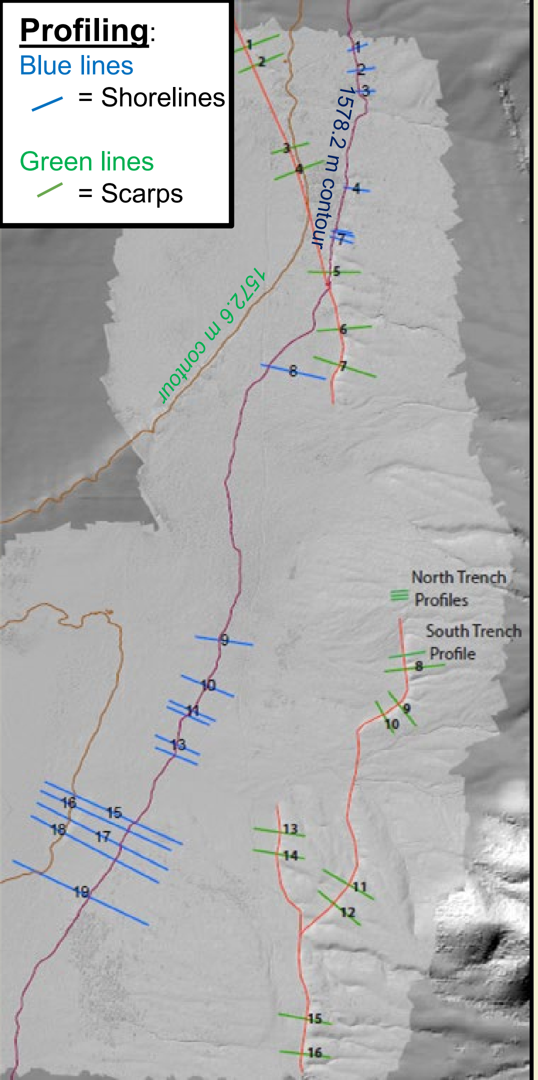
The fault zone is overlain by several younger fan deposits.

This event evidence contributes at least part of the two-meter displacement of the Bonneville highstand.

Explanation

- ⊙ Bulk Soil Sample
- ♦ C14 Sample
- Fault
- 0 — 2 m

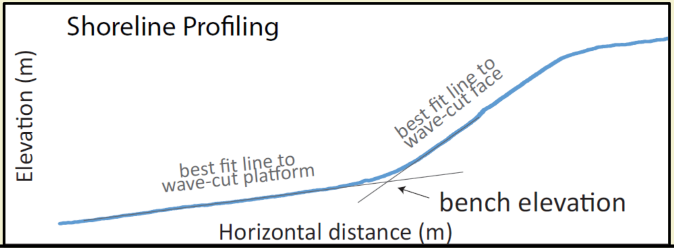
- Soil A-Horizon
- Boulder
- Clast-Supported
- Matrix-Supported



Shoreline Profiling

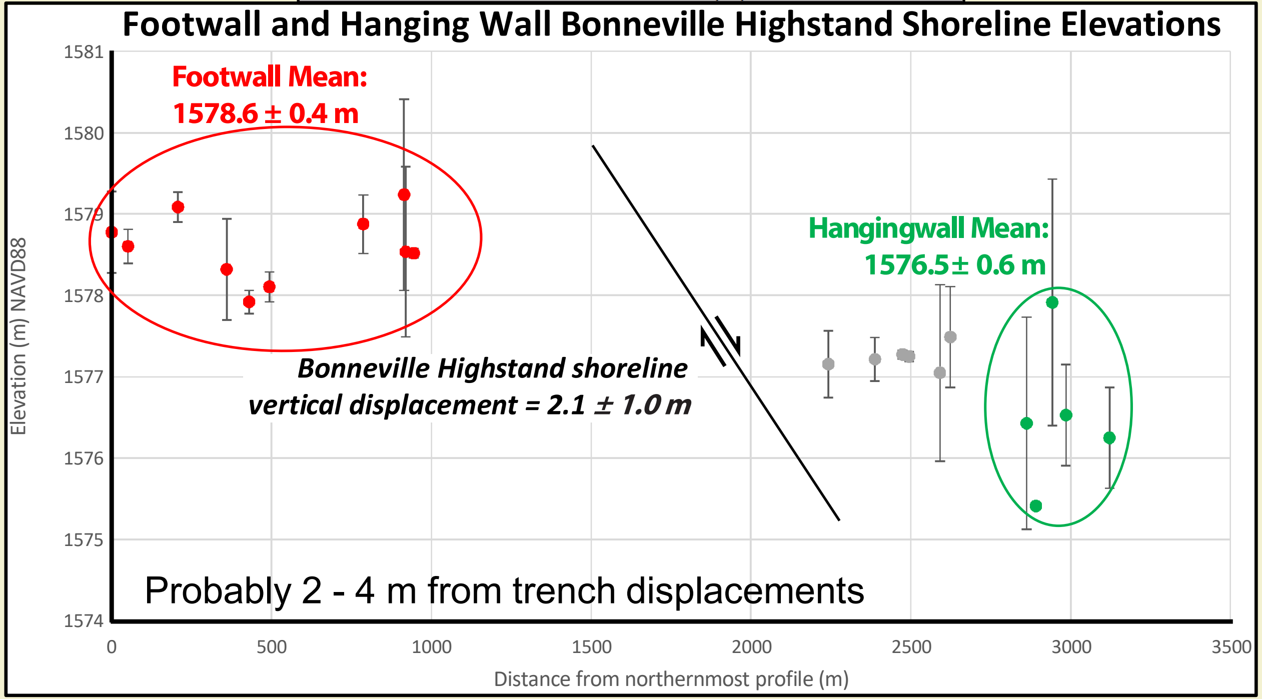
$\frac{1100 \text{ mm}}{18500 \text{ years}}$

=0.06 mm/a

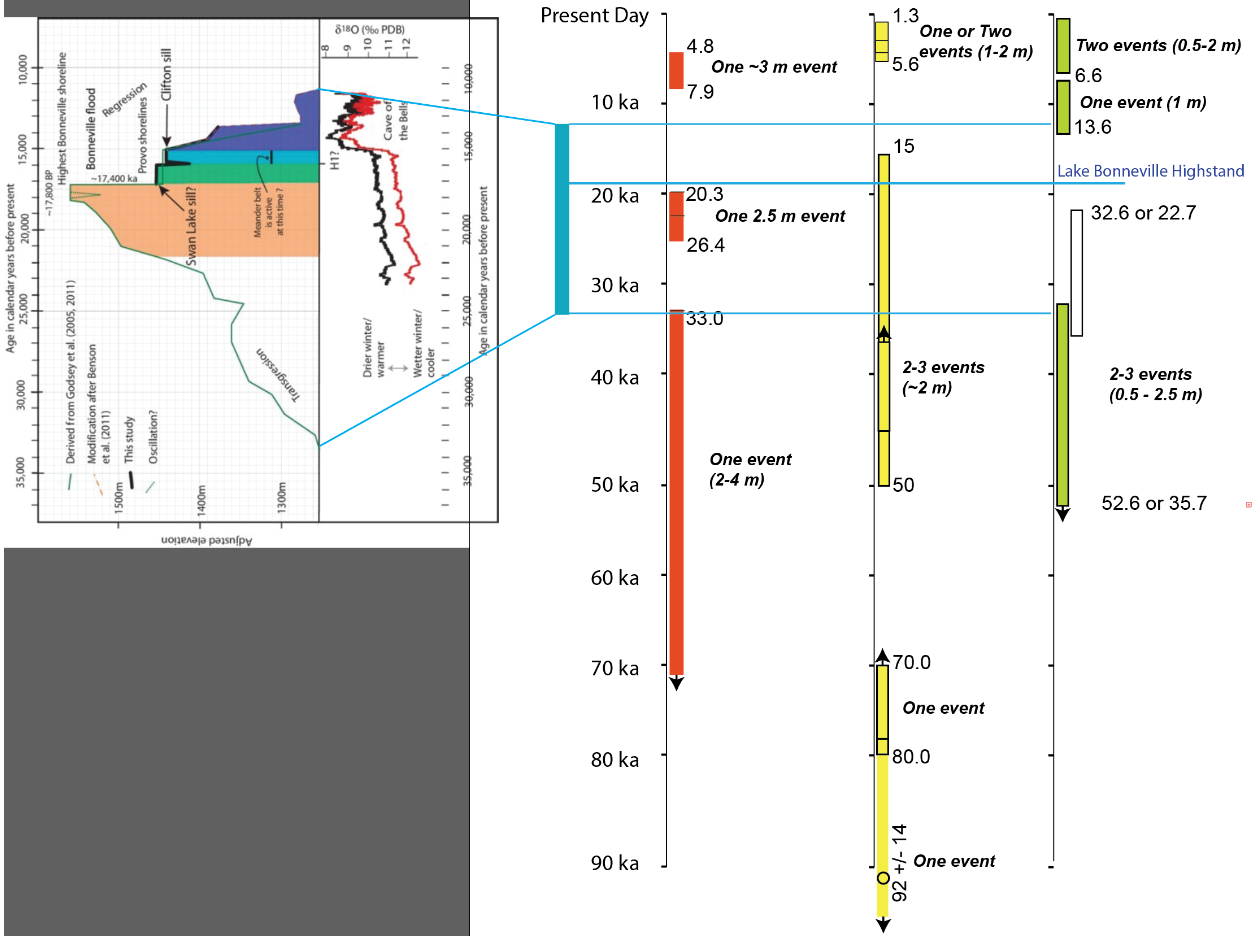


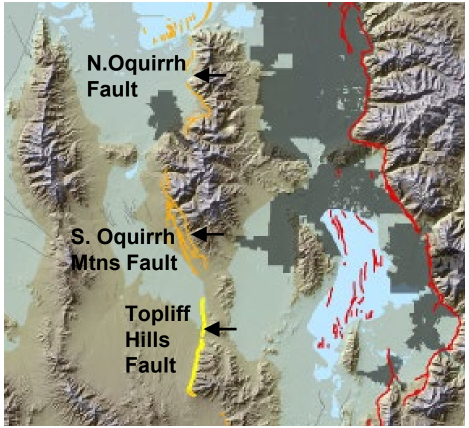
$\frac{3100 \text{ mm}}{17500 \text{ years}}$

=0.18 mm/a



Timing of Ruptures





Evidence for 6 events (0.5 -2.5 m/event)

3 events since 13.6 ka (post -Bonneville)

3 events prior to 23 or 33 ka

Recurrence Rate :

4.5 ka/event (post -Bonneville)

6-8 ka/event long -term average

Slip rate : 0.1 - 0.25 mm/a

Acknowledgements

The SfM point cloud for this site was generated as a UVU Geospatial Field Methods (GEOG 4100) class project (2017). We thank *Marissa Keck, McKenzie Ranney, Serena Smith, Joseph Phillips, Jeremy Saldivar, and Logan Woolstenhulme*

Reconnaissance mapping was conducted by Jacob Stallings and paleoseismic field work was conducted by the 2019 UVU Geology Field Camp (GEO 4600) including: the four student authors and *Nicholas Udy, Nathan Thurman, Spencer Larsen, Megan Harrison, Nicole Christensen, and Dylan Butt.*

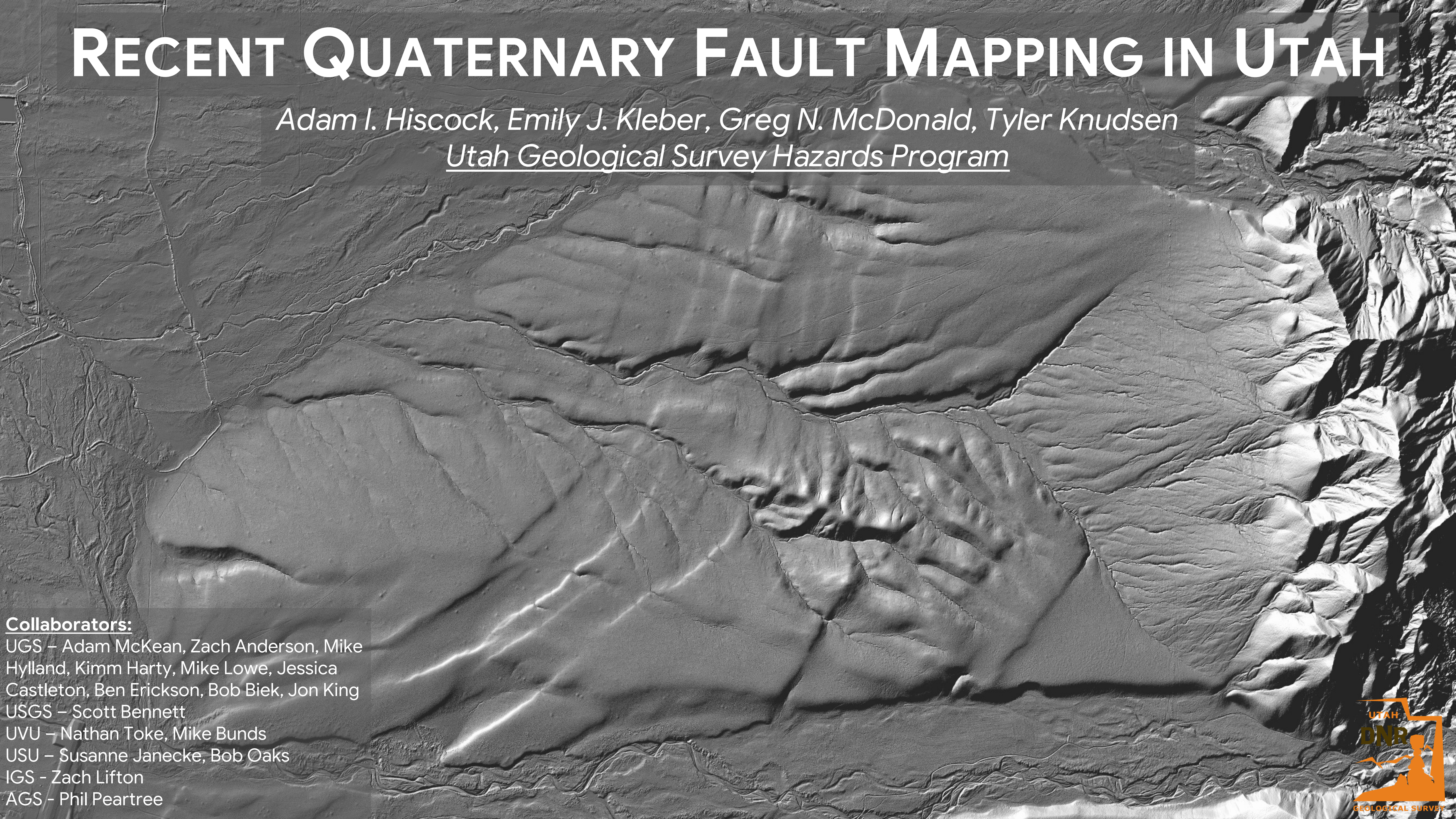
Funding for field work was provided by the UVU College of Science Scholarly Activities Program, and by the UVU Office of Engaged Learning (GEL and URSCA programs).

We are grateful for field review from the Utah Geological Survey and for the availability of lidar datasets from the Utah AGRC.

We thank NVIDIA for support via an Education GPU grand and Trimble, Septentrio, Sensefly, and RDO Controls for their educational acquisition programs.

References

- Barnhard , T.P. and R.L. Dodge, 1988, Map of fault scarps formed on unconsolidated sediments, Toole 1E x 2E quadrangle, northwestern Utah: US Geological Survey Miscellaneous Field Studies Map, MF -1990, Scale: 1:250,000.
- Bunds, M.P., J.Andreini , M. Arnold, K. Larsen, A. Fletcher, and N. Toke, 2016, New Data on Quaternary Surface Offset and Slip Rates of the Oquirrh Fault (Utah, USA) from DSMs Made with Structure from Motion Methods, Fall AGU meeting, San Francisco, CA.
- Janecke, S.U. and R.Q. Oaks Jr., 2011, New insights into the outlet conditions of late Pleistocene Lake Bonneville, southeastern Idaho, USA.
- Kaliser, B.N. and B.L. Everitt, 1980, Geology for assessment of seismic risk in the Tooele and Rush Valleys; Tooele, County, Utah, Special Studies – Utah Geological and Mineral Surveys (51).
- Olig, S.S., W.R. Lund, B.D. Black, and B.H. Mayes, 1996, Paleoseismic Investigation of the Oquirrh Fault Zone, Tooele County, Utah, in The Oquirrh Fault Zone, Tooele County, Utah: Surficial Geology and Paleoseismcity, W.R. Lund ed., Special Study 88, Utah Geological Survey.
- Olig, S.S., A.E. Gorton, B.D. Black, and S.L. Forman, 2001,Paleoseismicity of the Mercur fault and segmentation of the Oquirrh -East Great Salt Lake fault zone, Utah: Oakland, California URS Corportation (No. 98HQGR1036), Unpublished technical report for the US Geological Survey.
- Petersen, M.D., Y. Zeng, K.M. Haller, R. McCaffrey, W.C. Hammond, P. Bird, M. Moschetti, Z. Shen, J. Bormann, and W. Thatcher, 2013, Geodesy- and Geology-Based Slip-Rate Models for the Western United States (Excluding California) National Seismic Hazard Maps, US Geological Survey Open-File Report 2013-1293.
- Smith S., M. Keck, M. Ranney, L. Woolstenhulme, J. Phillips, J. Saldivar, N. Toke and M.P. Bunds, 2018, A preliminary look at the Earthquake Chronology of the Topliff Fault, Utah from Offset Pluvial Shorelines Mapped with UAS and Structure from Motion, 2018 AAG Annual Meeting, New Orleans, LA.
- U.S. Geological Survey, Utah Geological Survey, 2019, Quaternary fault and fold database for the United States, accessed 12/4/2019.
- Working Group on Utah Earthquake Probabilities (WGUEP), 2016, Earthquake probabilities for the Wasatch Front region in Utah, Idaho, and Wyoming: Salt Lake City, Utah Geological Survey Miscellaneous Publication 16–3, 164 p., 5 appendixes. [Also available at http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/utah-earthquake-probabilities/
- Wells D.L. and K.J. Coppersmith, 1994, New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement, Bulletin of the Seismological Society of America, Vol. 84, no. 4 pp. 974-1002.



Recent Quaternary Fault Mapping in Utah

Adam I. Hiscock, Emily J. Kleber, Greg N. McDonald, Tyler Knudsen

Utah Geological Survey Hazards Program

Collaborators:

UGS – Adam McKean, Zach Anderson, Mike Hylland, Kimm Harty, Mike Lowe, Jessica Castleton, Ben Erickson, Bob Biek, Jon King

USGS – Scott Bennett

UVU – Nathan Toke, Mike Bunds

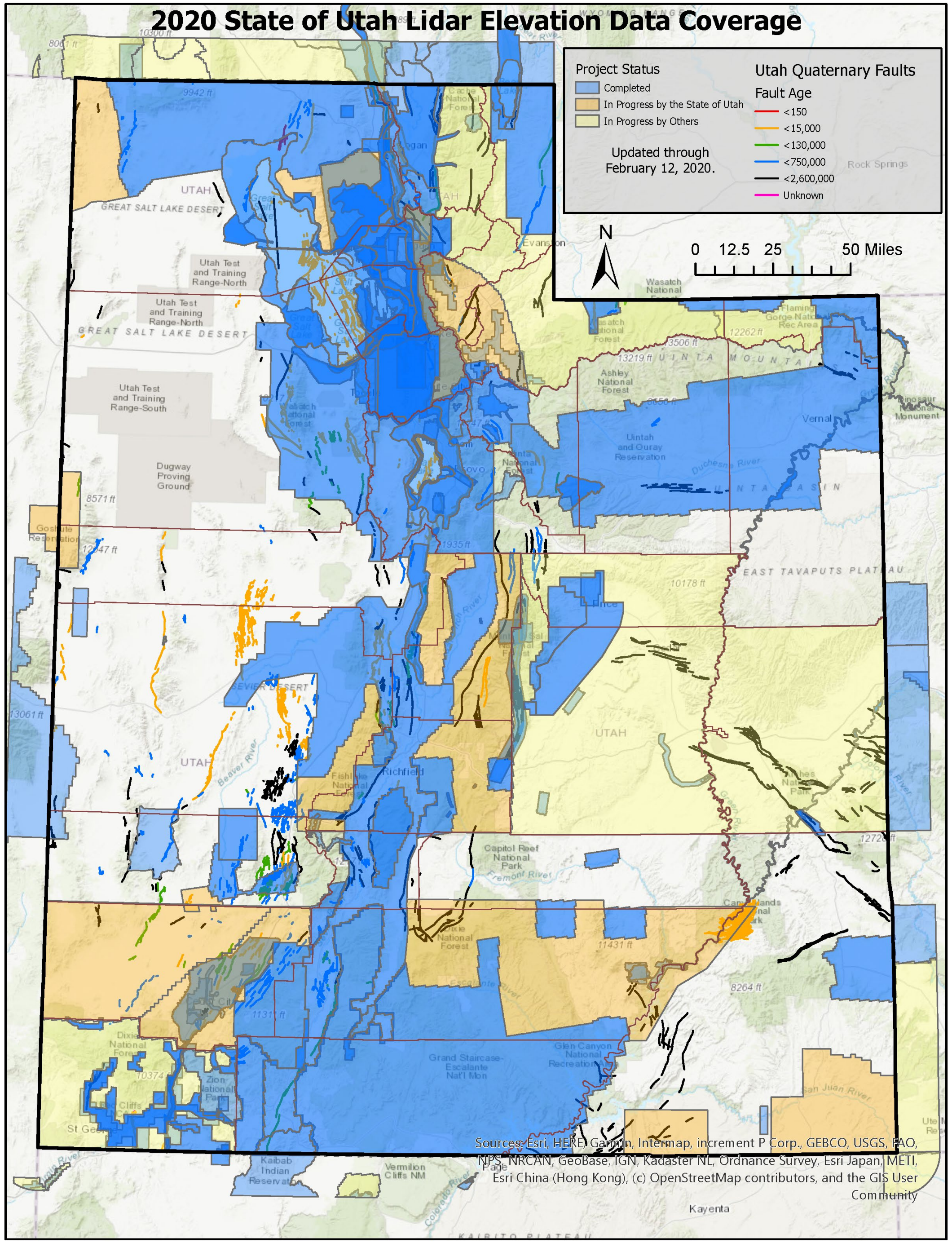
USU – Susanne Janecke, Bob Oaks

IGS - Zach Lifton

AGS - Phil Peartree

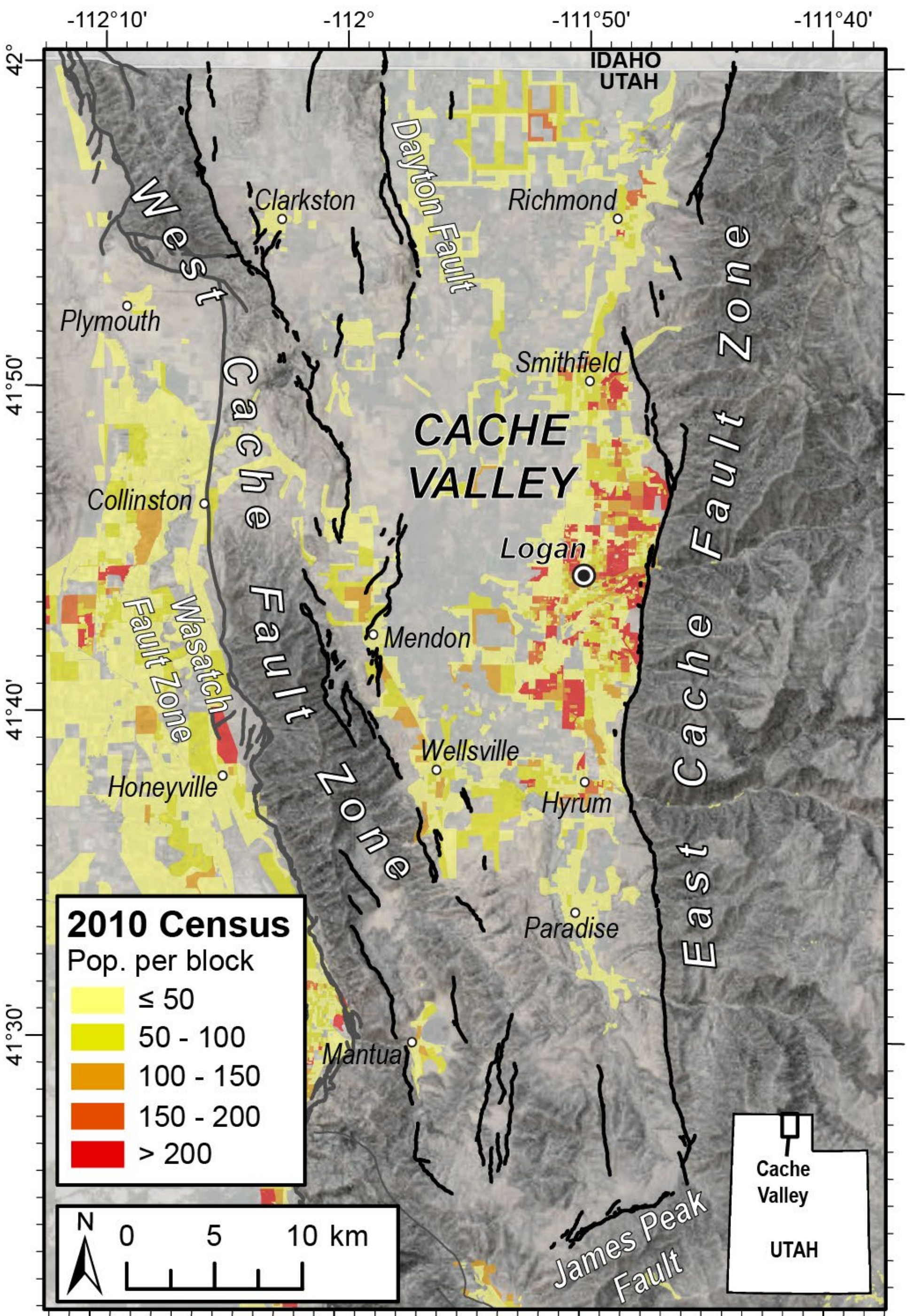
Objectives

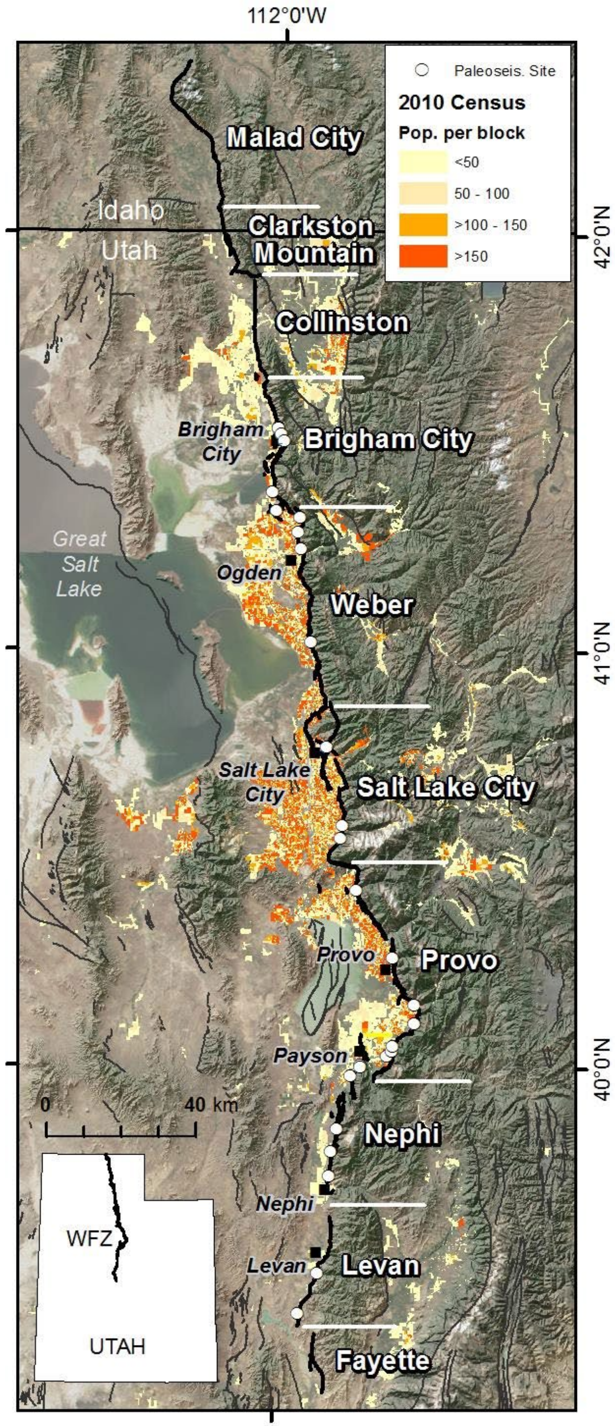
- Availability of high resolution lidar data has expanded greatly in the past decade - great tool for characterizing and identifying active faults
- The UGS has been involved in multiple USGS External Grants funded fault mapping projects since 2014
- New mapping available through the UGS's *Utah Geologic Hazards Portal,* and will be used for updates to the USGS National Sesimic Hazard Maps.
- Necessary to help characterize and identify active faults in rapidly growing and urbanizing parts of Utah
- Identify potential paleoseismic trenching sites



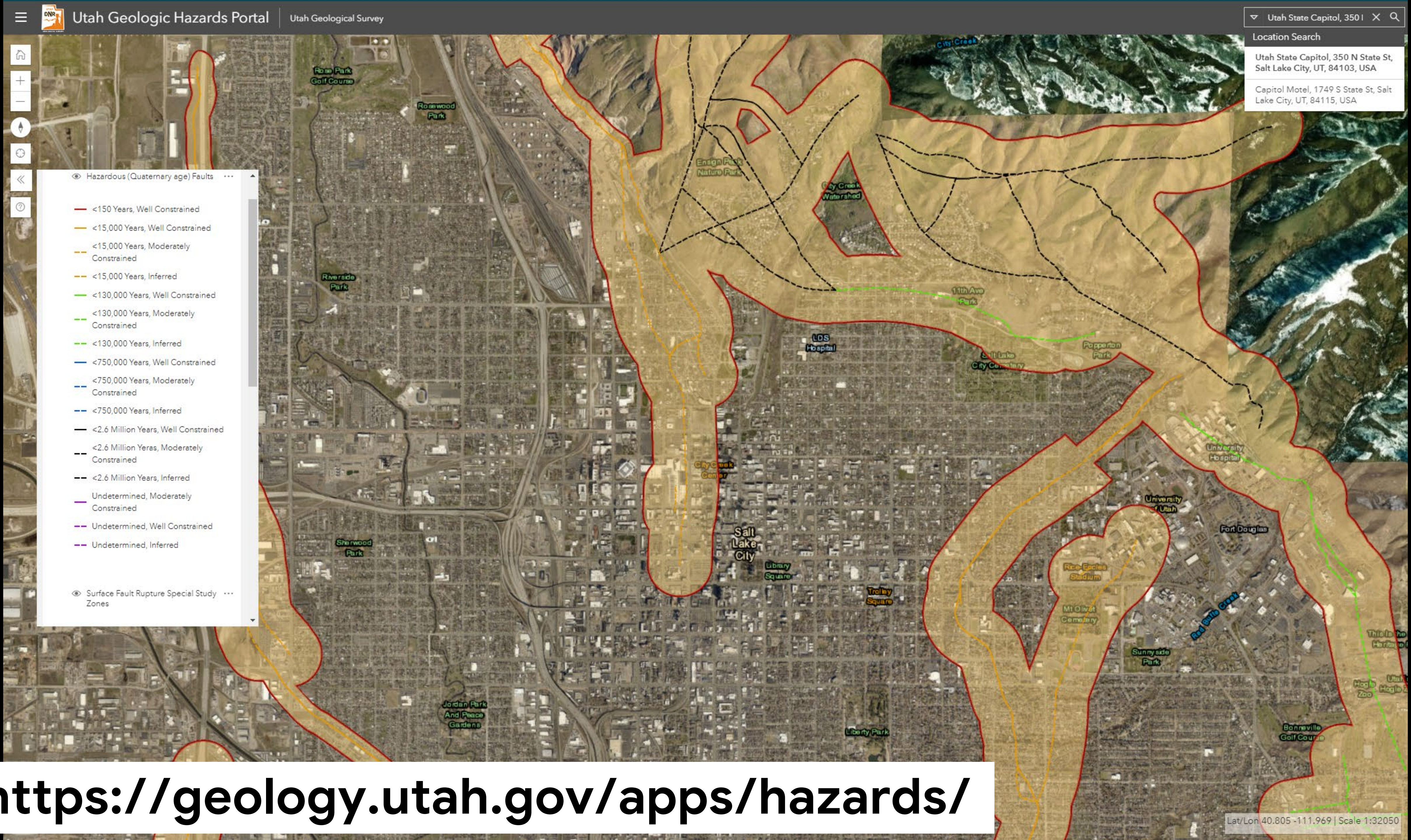
Recently Completed Fault Mapping

- Wasatch Fault Zone (UGS RI-280): re-mapped at 1:24,000 scale (or better) – available in UGS's *Utah Geologic Hazards Portal*
- East and West Cache Fault Zones (USGS FTR): re-mapped 14 1:24,000 scale quadrangles. Available in the *Utah Geologic Hazards Portal* in spring/early summer 2021

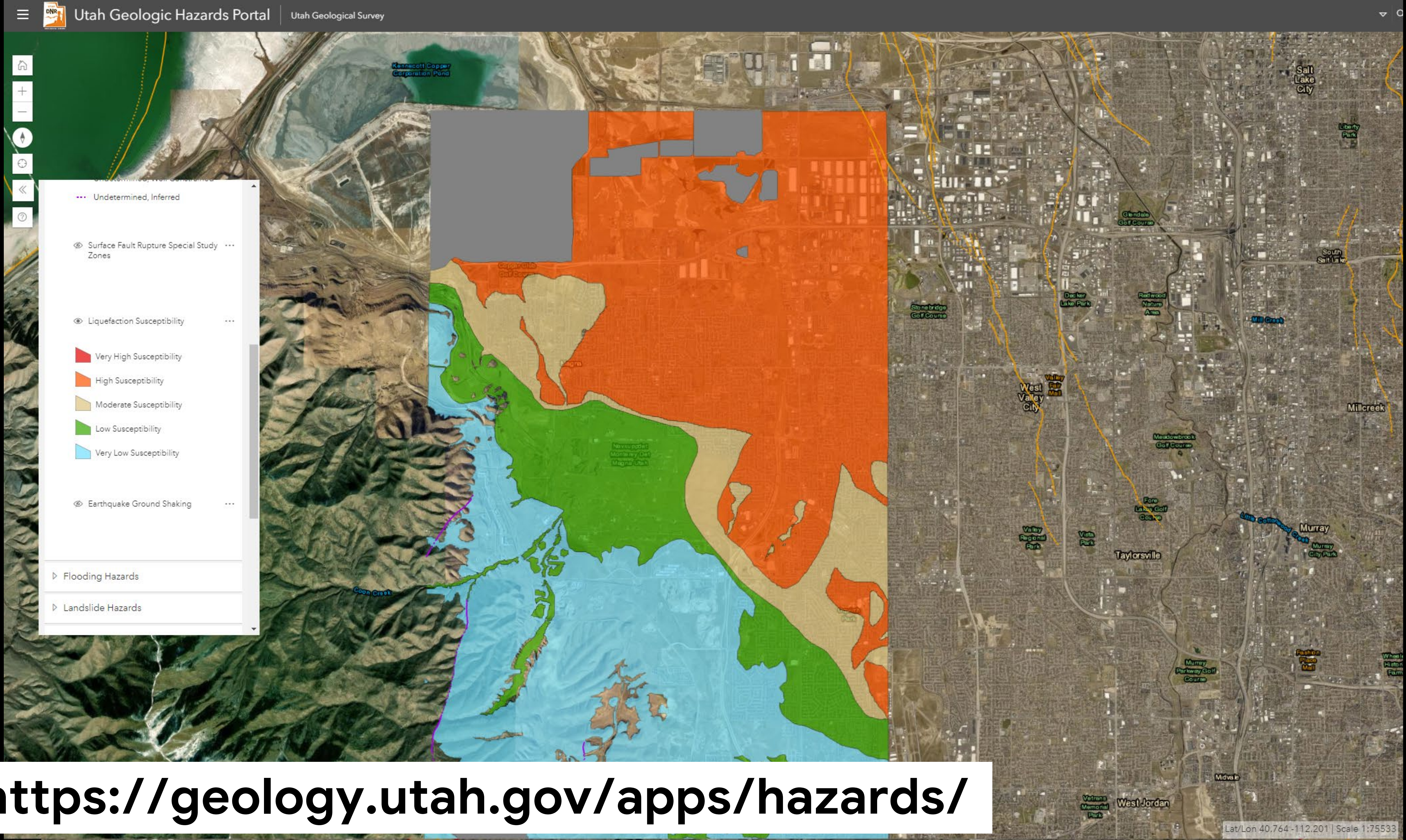




UTAH DNR GEOLOGICAL SURVEY
UTAH GEOLOGICAL SURVEY



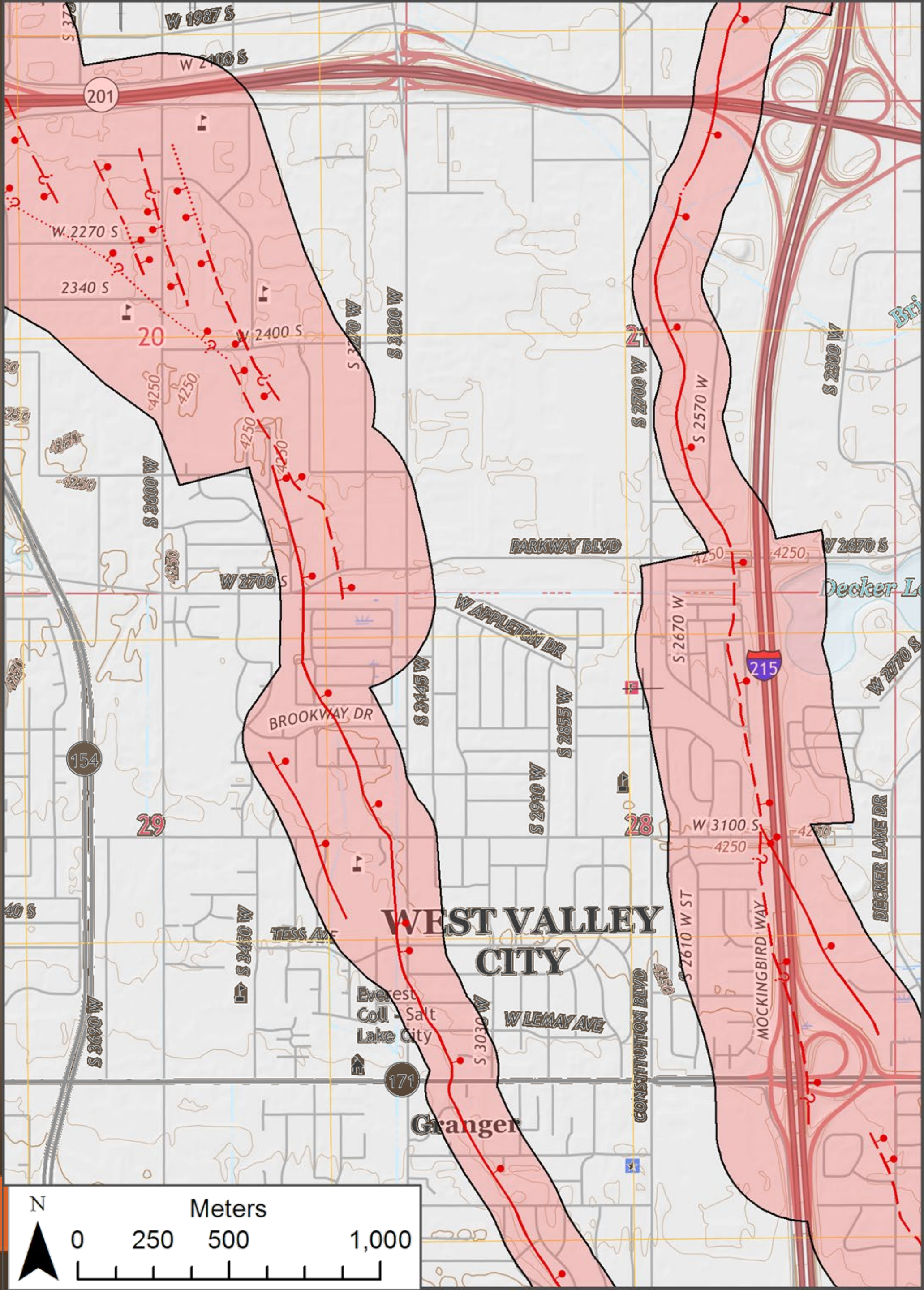
https://geology.utah.gov/apps/hazards/



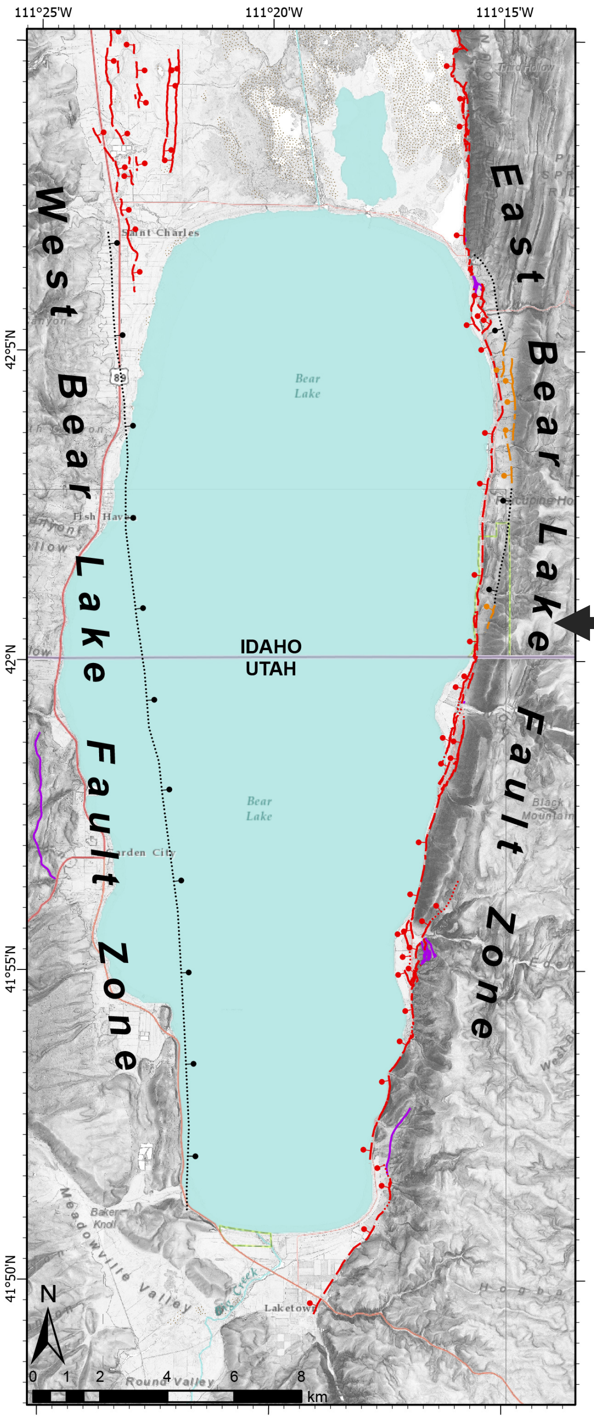
https://geology.utah.gov/apps/hazards/

Special-Study-Zones

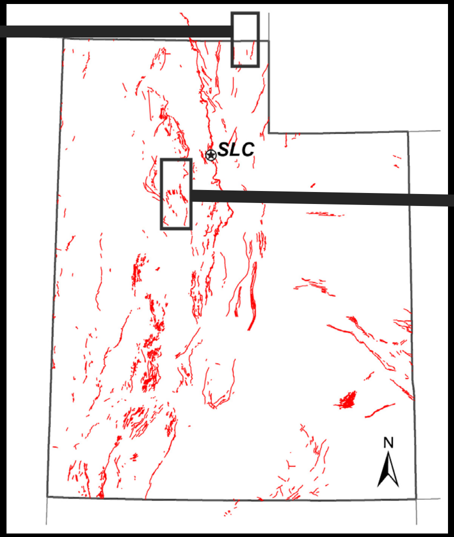
- Special-study-zones are delineated around each mapped trace
- Assist local governments with urban planning and developing hazard ordinances
- Help facilitate understanding of the hazard by triggering additional surface faulting studies



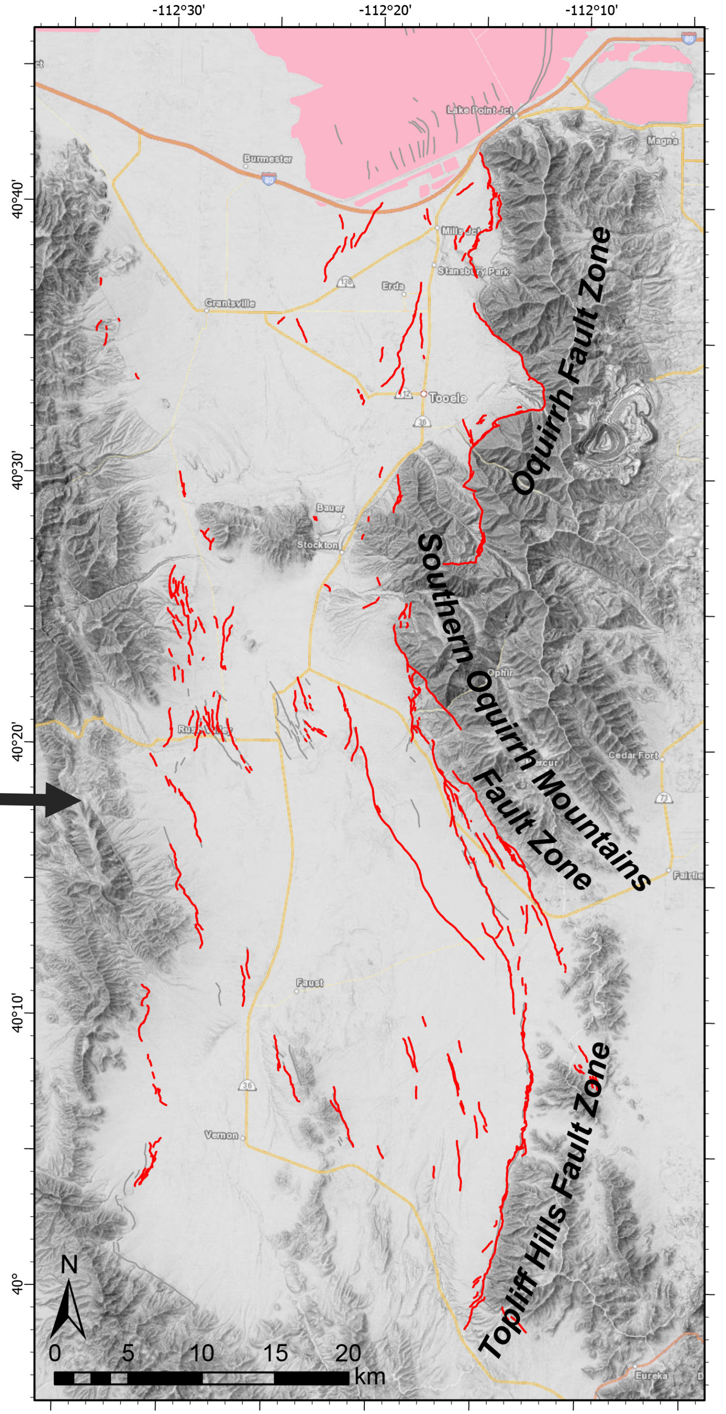
East and West Bear Lake Faults & Oquirrh-Topliff Hills Fault Zones



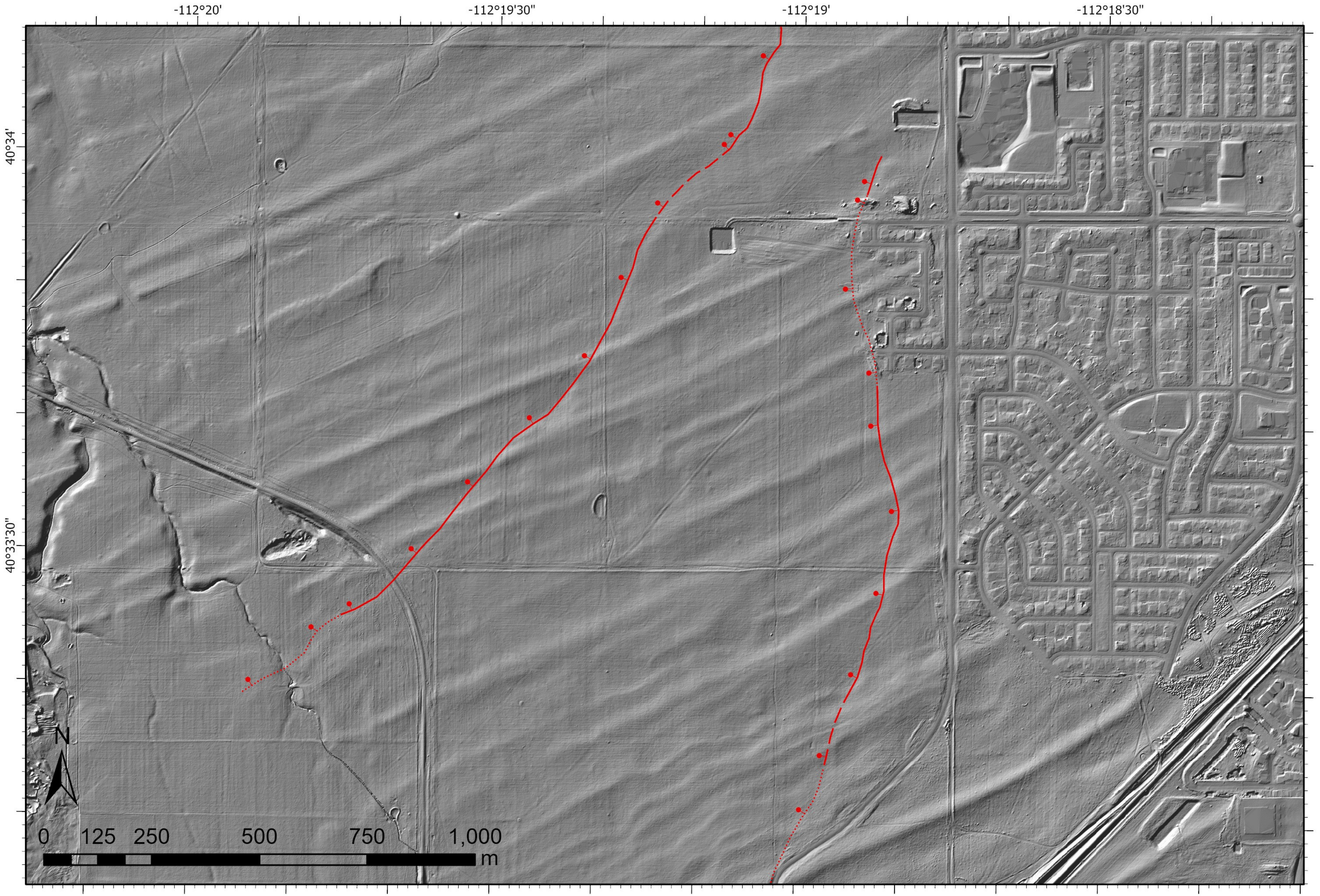
- Collaborative project with Idaho Geological Survey (Z. Lifton)
- Consistent cross-border fault geometry & attributes (BRPEWG Priority)



- Identified and extended many intra-basin faults in the Tooele and Rush Valleys



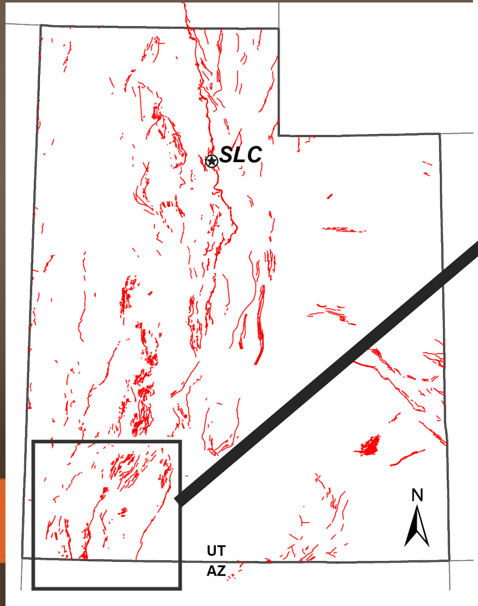

-112°20'
-112°19'30"
-112°19'
-112°18'30"
40°34'
40°33'30"
N
0
125
250
500
750
1,000
m

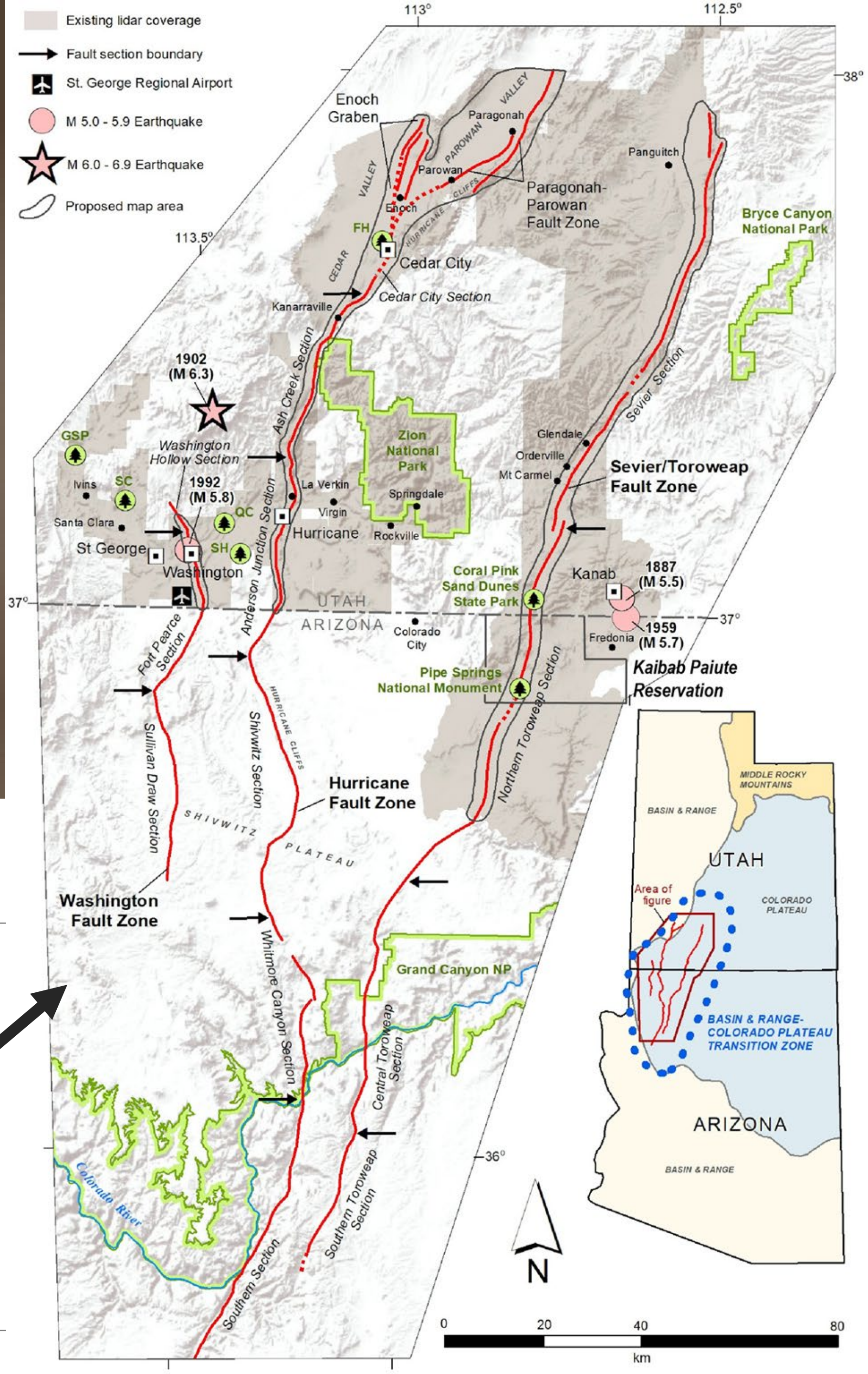


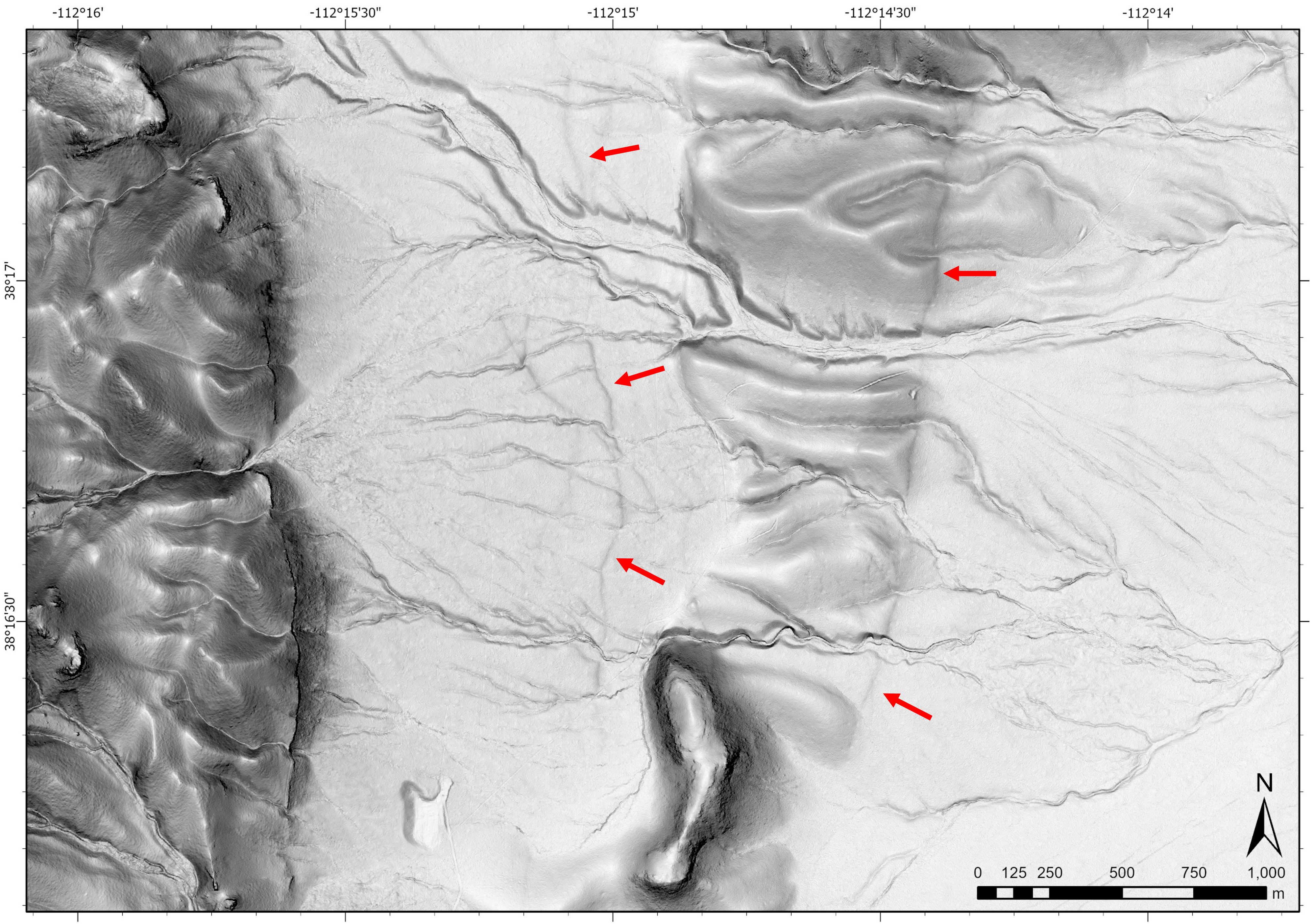
-112°20'
-112°19'30"
-112°19'
-112°18'30"
40°34'
40°33'30"
N
0 125 250 500 750 1,000
m

Southern Utah Fault Mapping

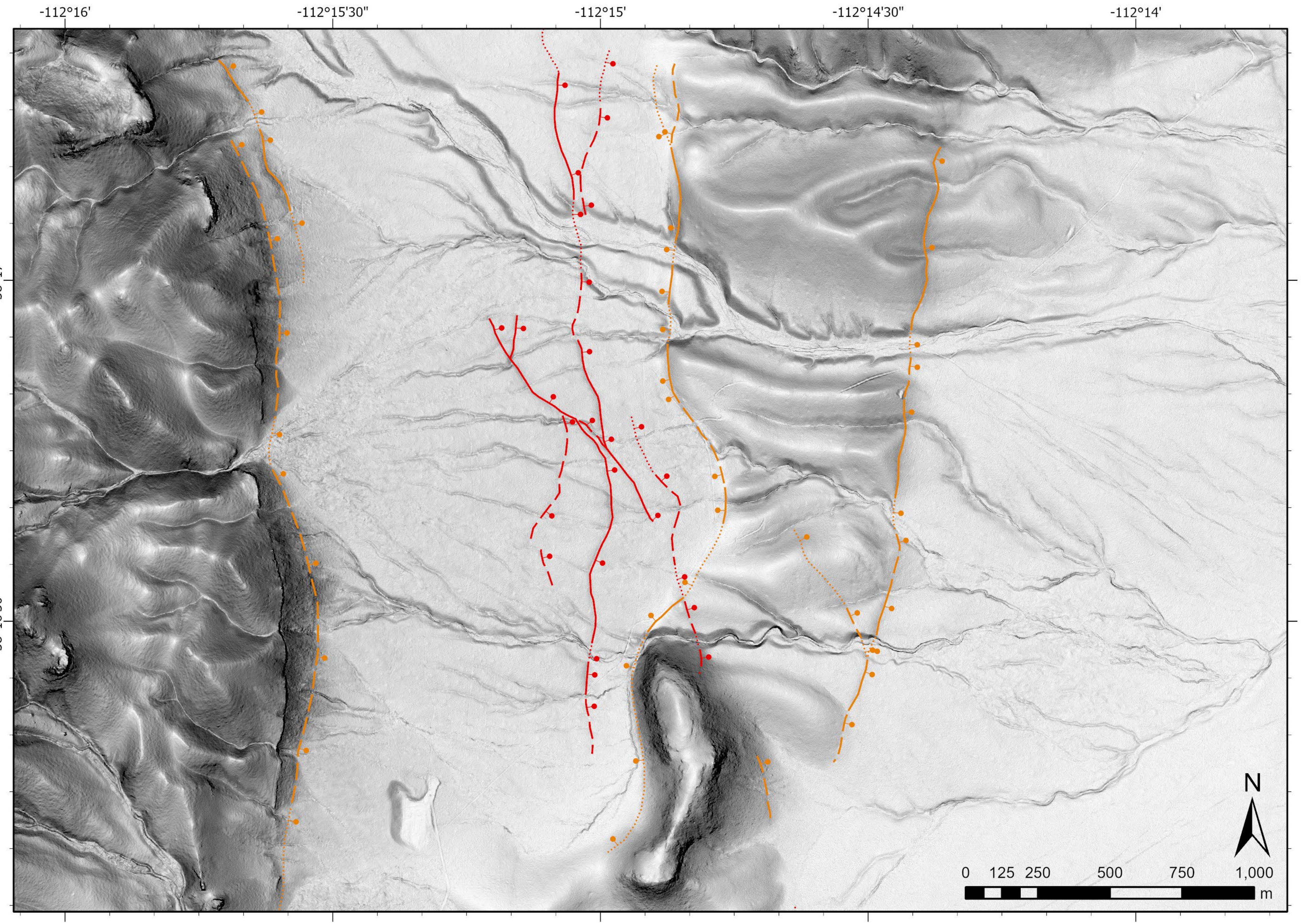
- Hurricane, Washington, and Sevier/Toroweap faults
- Collaborative with the Arizona Geological Survey
- St. George - largest population center in Utah outside of the Wasatch front, fastest growing metro area in the U.S. (2000-2006)
- Consistent cross-border fault geometry & attributes (BRPEWG priority)







-112°16'
-112°15'30"
-112°15'
-112°14'30"
-112°14'
38°17'
38°16'30"
N
0 125 250 500 750 1,000
m


-112°16'
-112°15'30"
-112°15'
-112°14'30"
-112°14'
38°17'
38°16'30"
N
0 125 250 500 750 1,000
m

Additional & Future Mapping

- USGS GeMS Program – funding for many quads around the state of Utah
  - UGS Mapping Program - Geologic mapping around the state of Utah, specifically along the Wasatch Front
  - Identifying new faults, integrating with UGS Hazards Portal when published
- UGS Hazard Mapping - working on other various 7.5 minute quads (Cedar Fort, Saratoga Springs, Jordan Narrows, Lehi, etc.)
- Future Q-Fault Mapping (USGS EHP External Grants Funding) –
  - Hansel Valley – Utah's only historic surface-rupturing earthquake

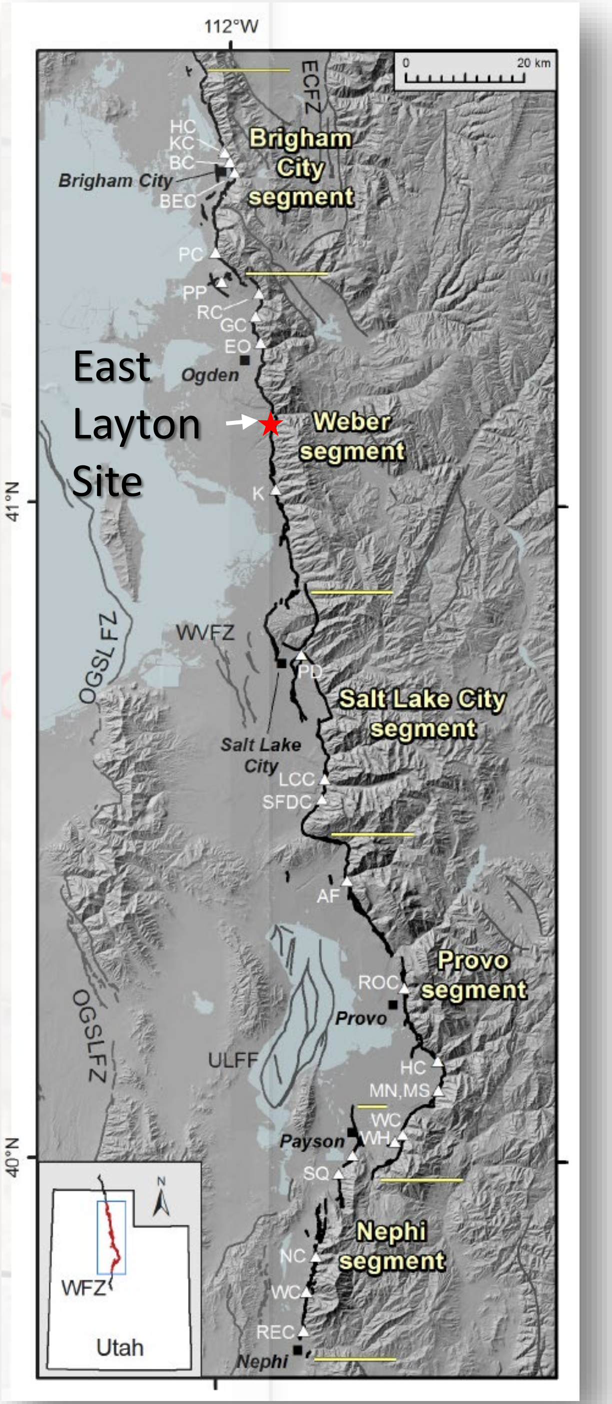
Fault Investigation Along the Central Weber Segment of the Wasatch Fault, Layton, Utah: Evidence for 4-5 Recent Paleoseismic Events

Robert Givler and Christopher Bloszies,
Lettis Consultants International, Inc.
and Pete Doumit
IGES

Lettis Consultants International, Inc.
EARTH SCIENCE CONSULTANTS

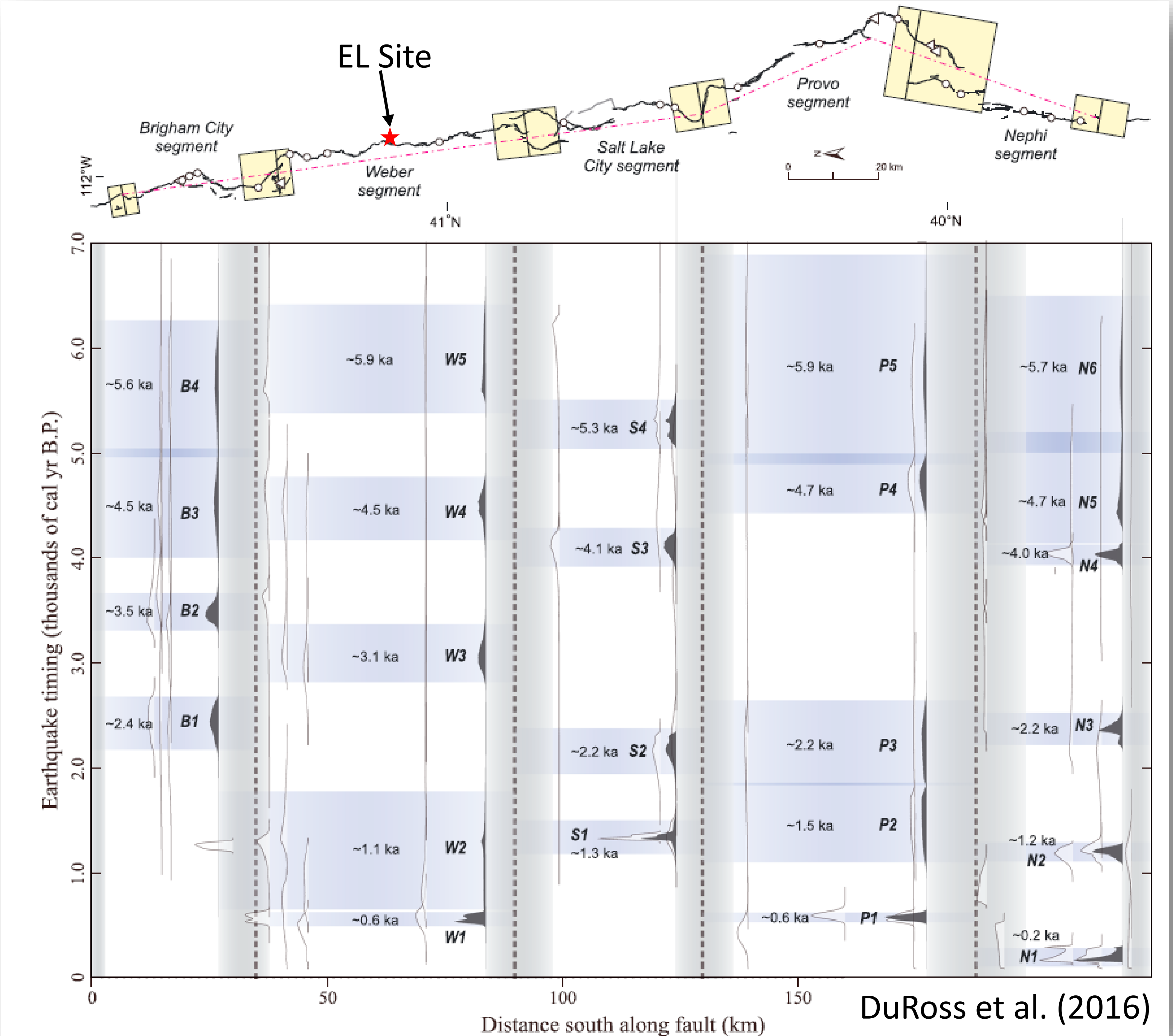
Introduction

- Fault investigation for a water conveyance pipeline seismic resiliency study
- East Layton Site located along the Weber Segment of the Wasatch Fault zone
- Purpose was to evaluate the location and width of faulting
- Focus of presentation
  - Trench results
  - Summary of evidence for paleoseismic events



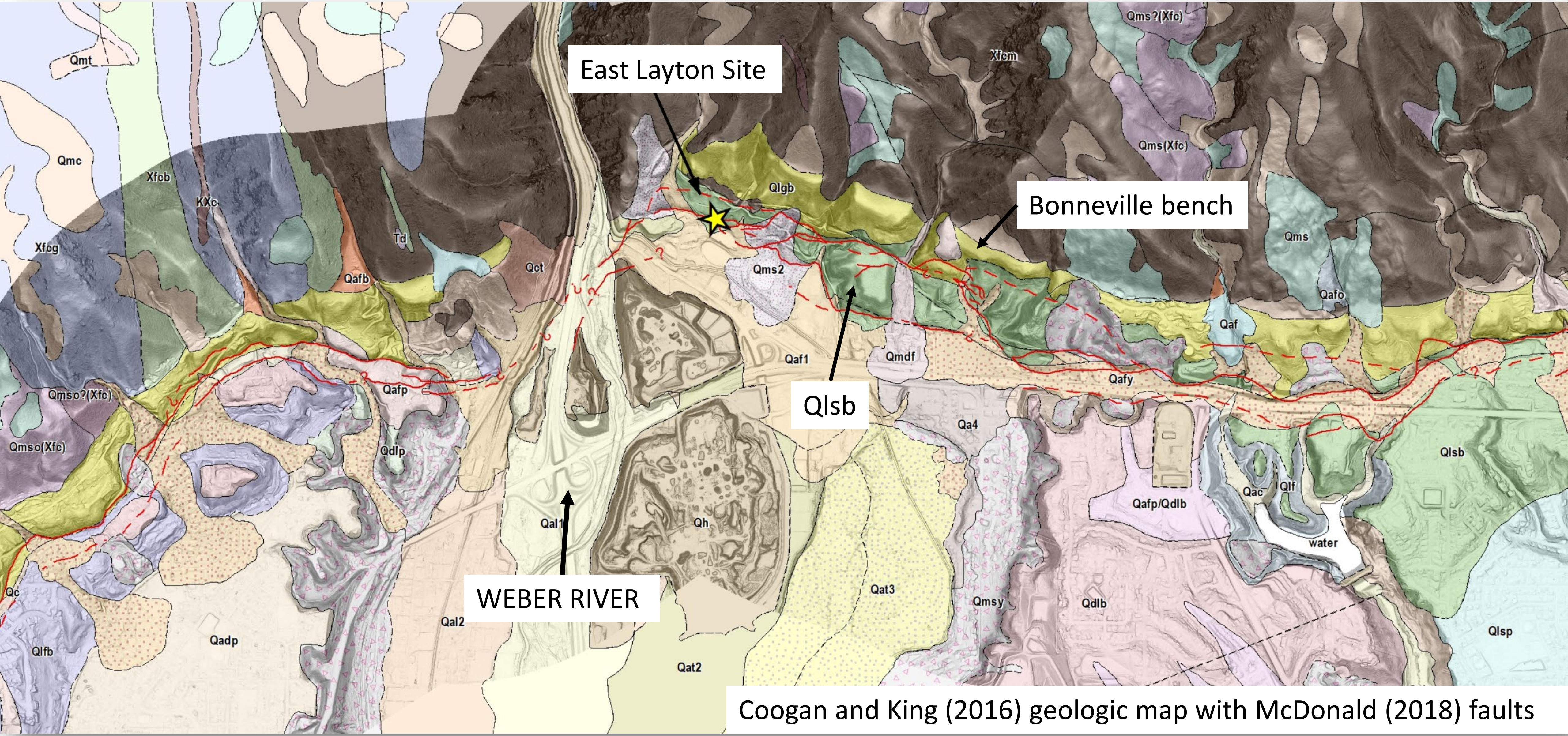
Existing Weber Segment Event Chronology

- 5 events in 6 ka
- Only RC Site has all 5
- K site is the only site near the middle of the segment



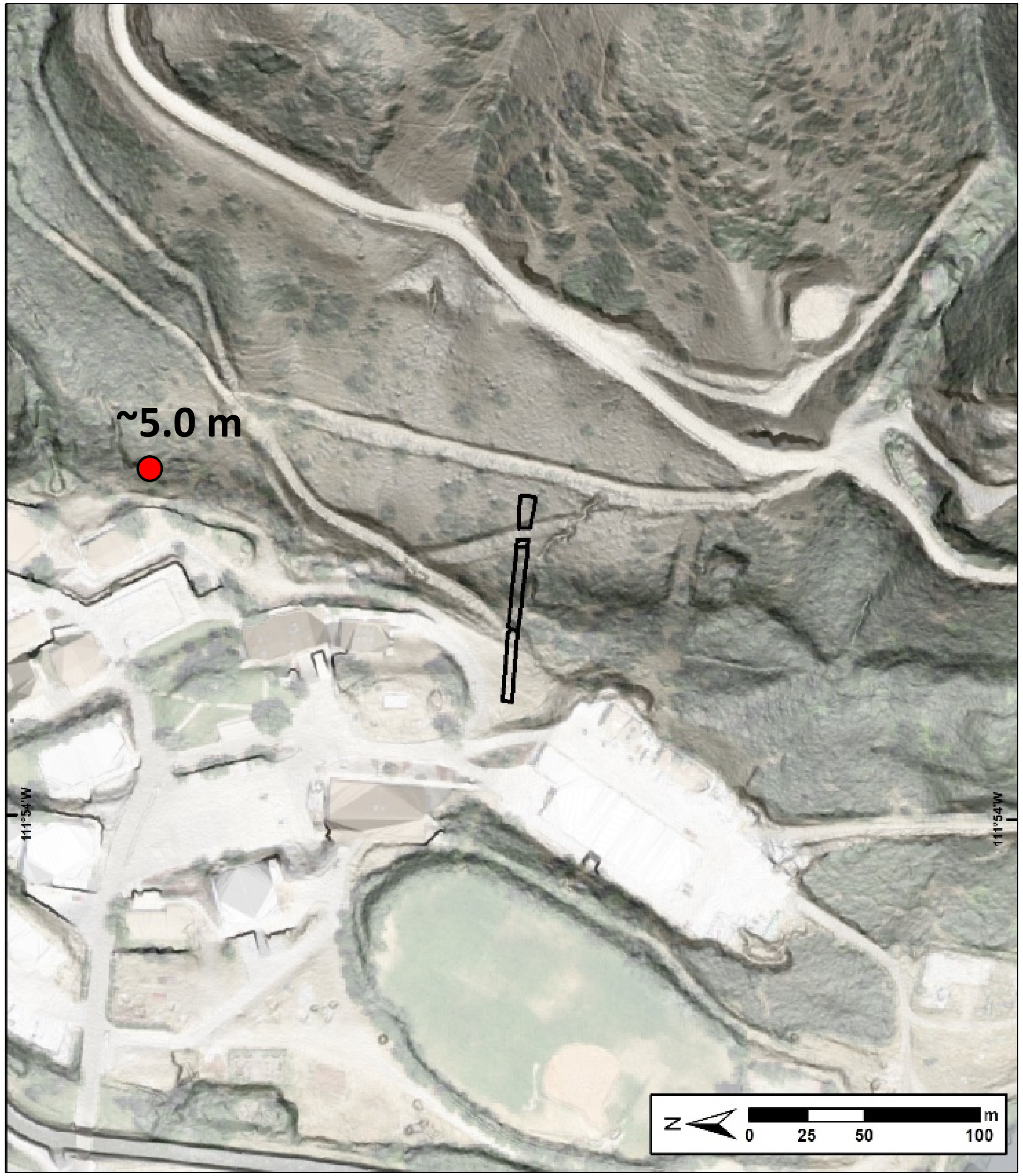
DuRoss et al. (2016)

Geologic mapping

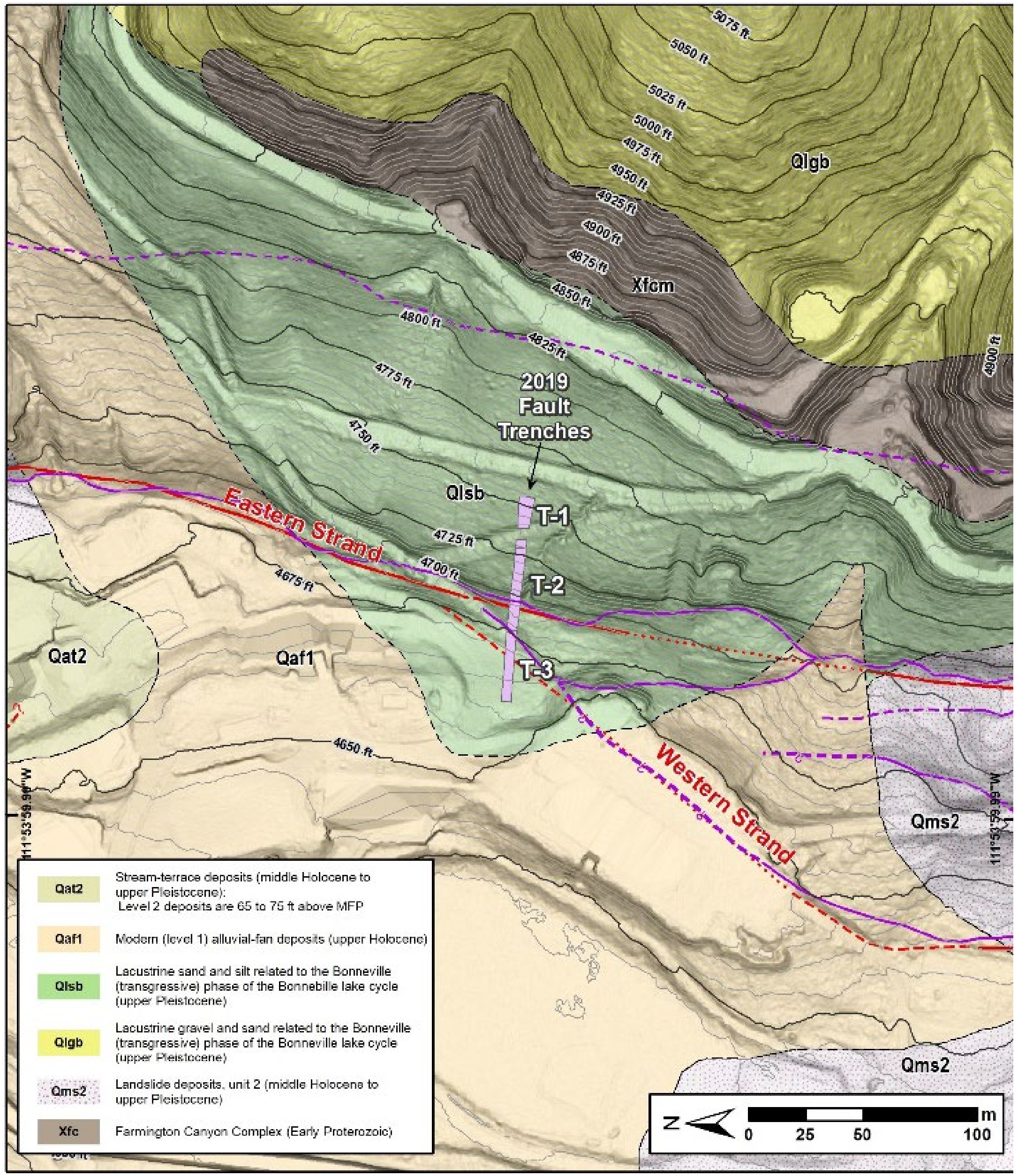


Coogan and King (2016) geologic map with McDonald (2018) faults

B
B
B
East Layton Site
2016 LiDAR
N
0
100
200
400
m
1947
N
0
100
200
400
m

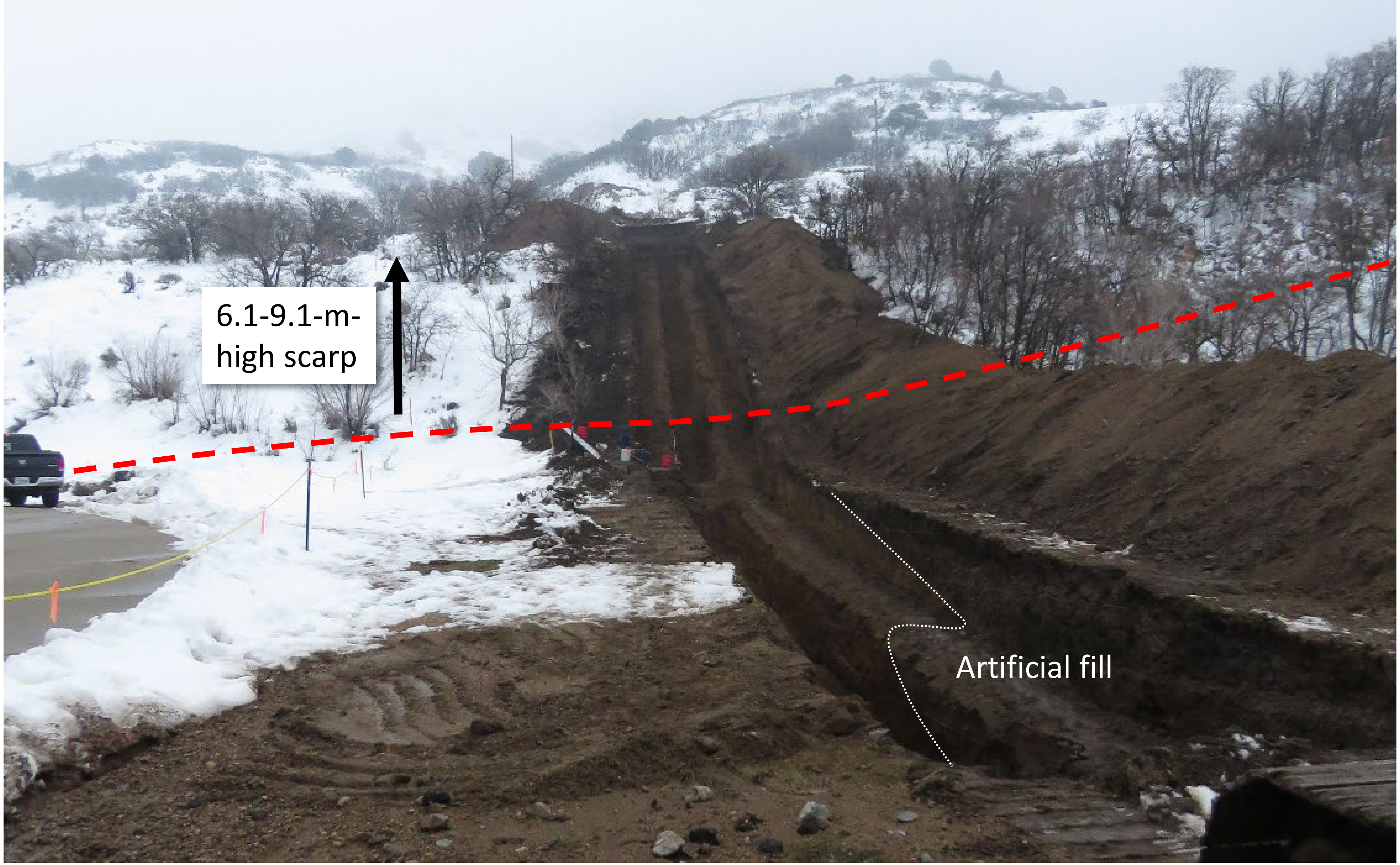


Bare-earth LIDAR draped on satellite image (NAIP, 2016)



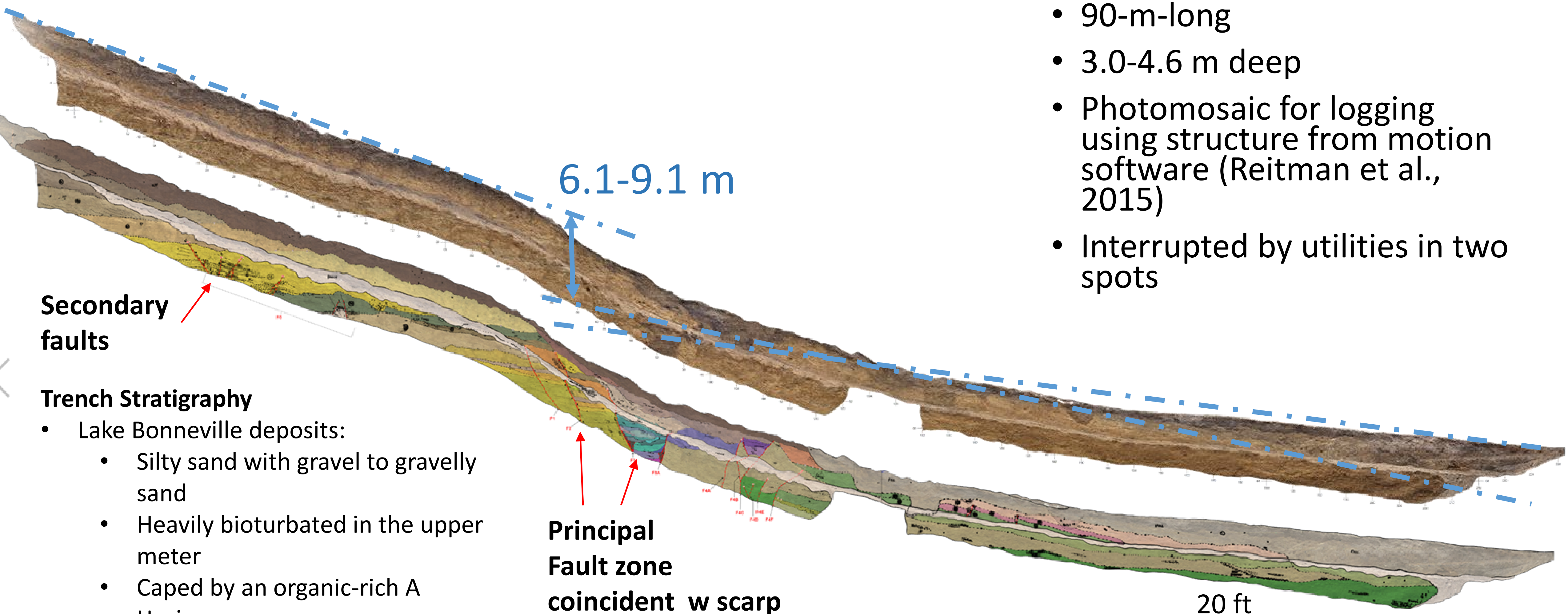
Geologic mapping (Coogan and King, 2016) with faults from McDonald et al. (2018)

Looking east



EL Site – Trench South Wall

- 90-m-long
- 3.0-4.6 m deep
- Photomosaic for logging using structure from motion software (Reitman et al., 2015)
- Interrupted by utilities in two spots



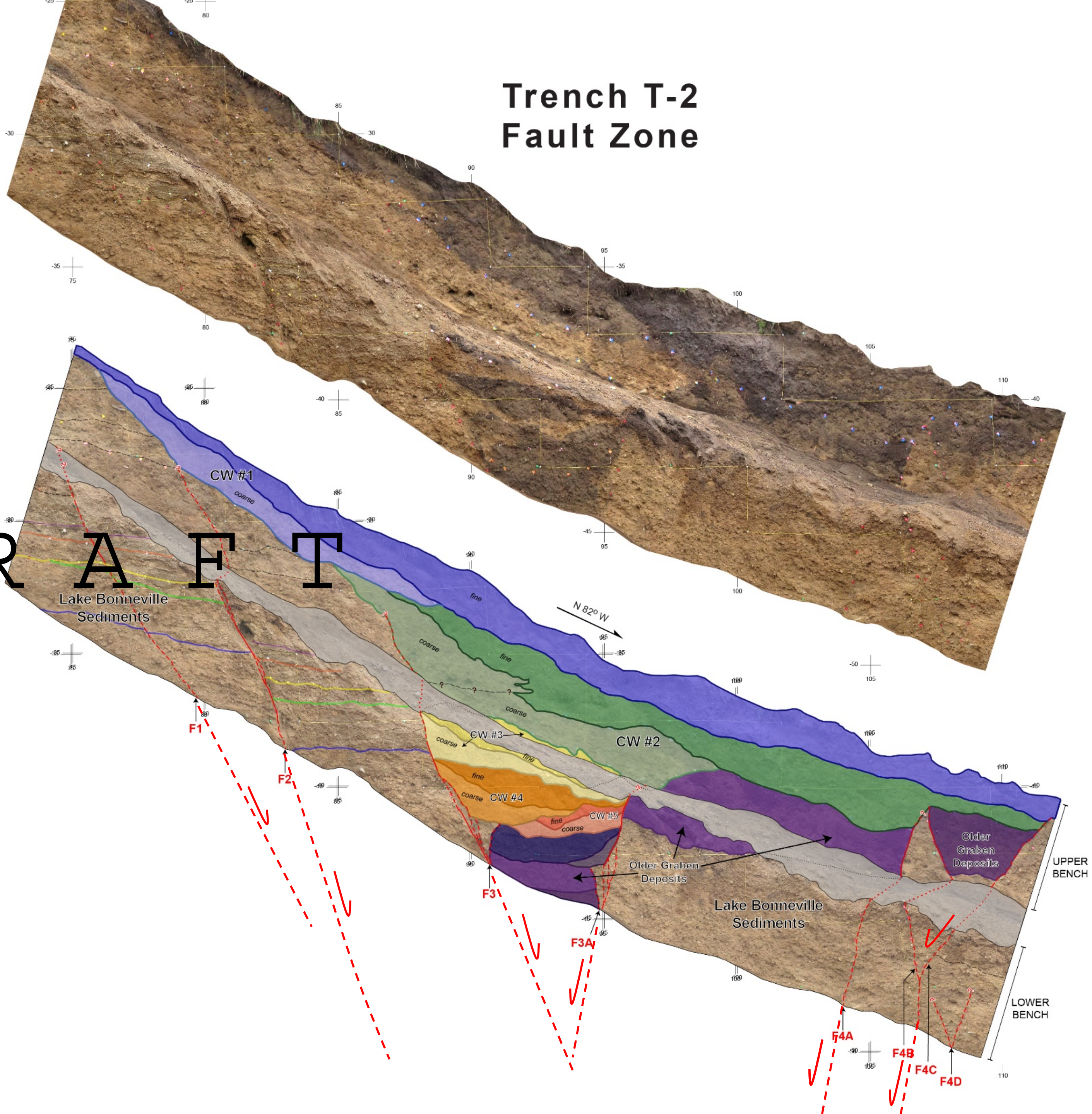
Trench Stratigraphy

- Lake Bonneville deposits:
  - Silty sand with gravel to gravelly sand
  - Heavily bioturbated in the upper meter
  - Caped by an organic-rich A Horizon
- Scarp-derived colluvia
- Artificial fill – western portion of trench

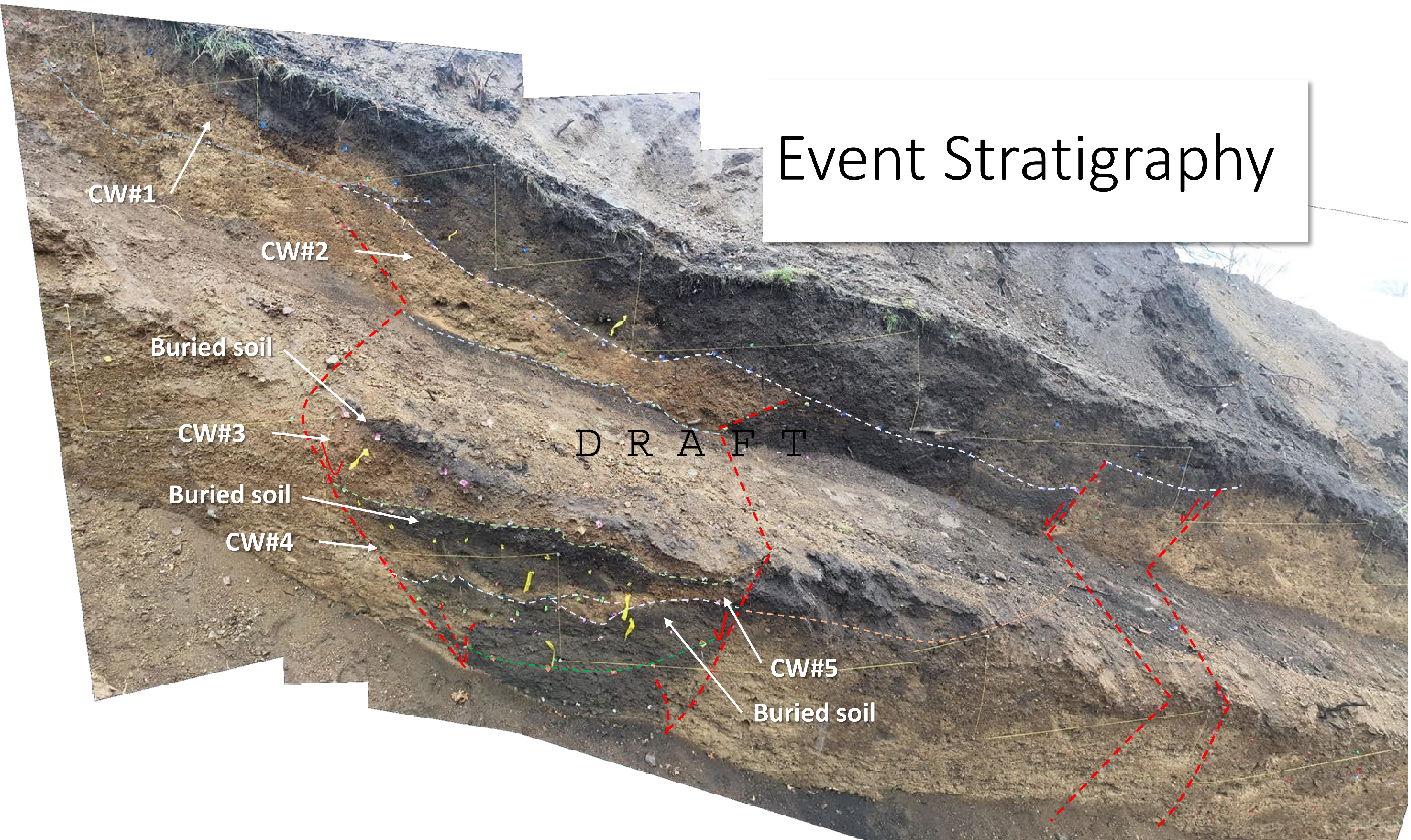
Fault zone structure

- 12-m-wide graben
- Faults labeled F1-F10
- Bonneville gravel and sand interbeds correlated across F1 and F2
- Small degree of E-tilting within graben
- Antithetic faults also fault shallow A-horizons

D R A F T

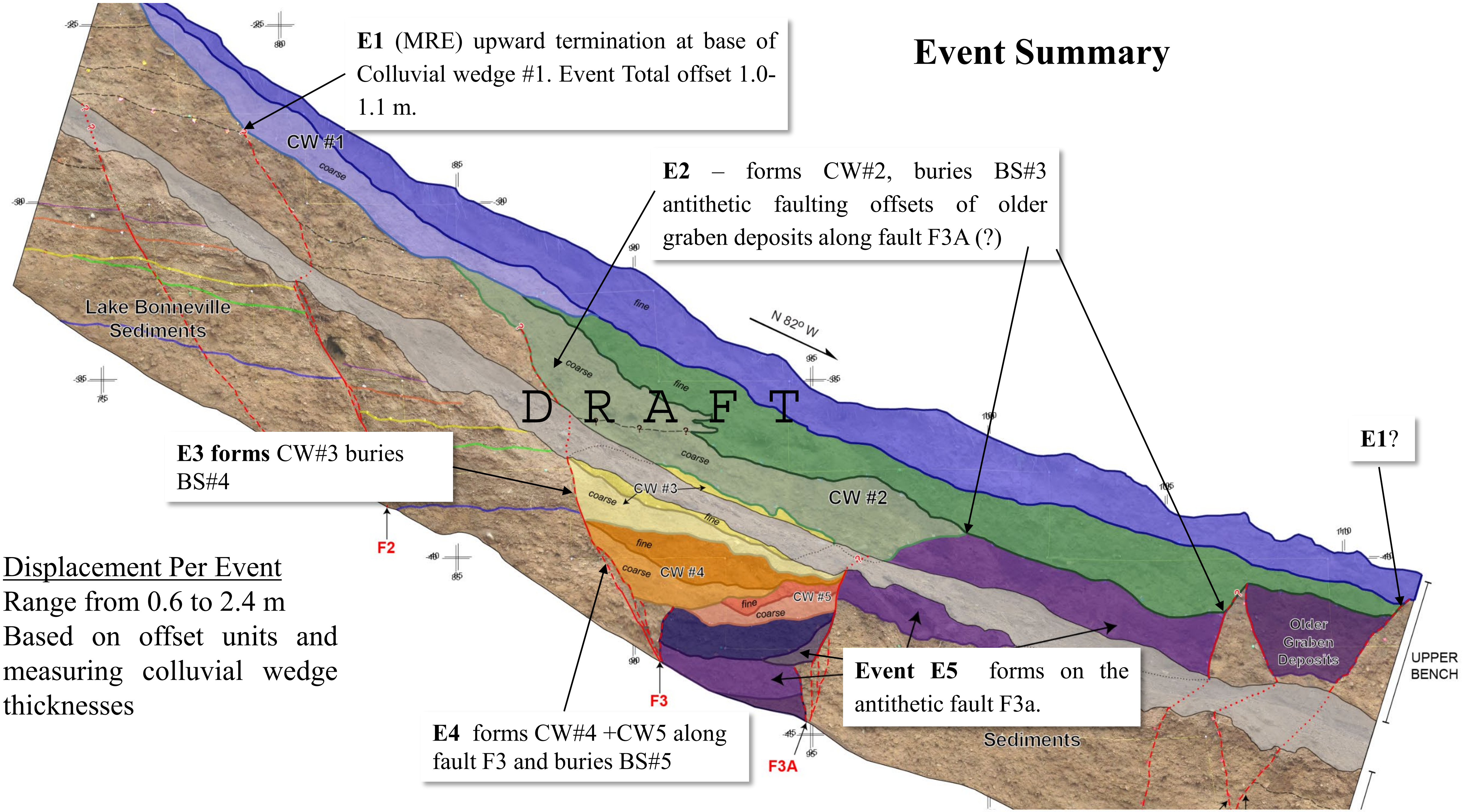


Event Stratigraphy



D R A F T

Event Summary



E1 (MRE) upward termination at base of Colluvial wedge #1. Event Total offset 1.0-1.1 m.

E2 – forms CW#2, buries BS#3 antithetic faulting offsets of older graben deposits along fault F3A (?)

E3 forms CW#3 buries BS#4

E4 forms CW#4 +CW5 along fault F3 and buries BS#5

Event E5 forms on the antithetic fault F3a.

E1?

Displacement Per Event

Range from 0.6 to 2.4 m

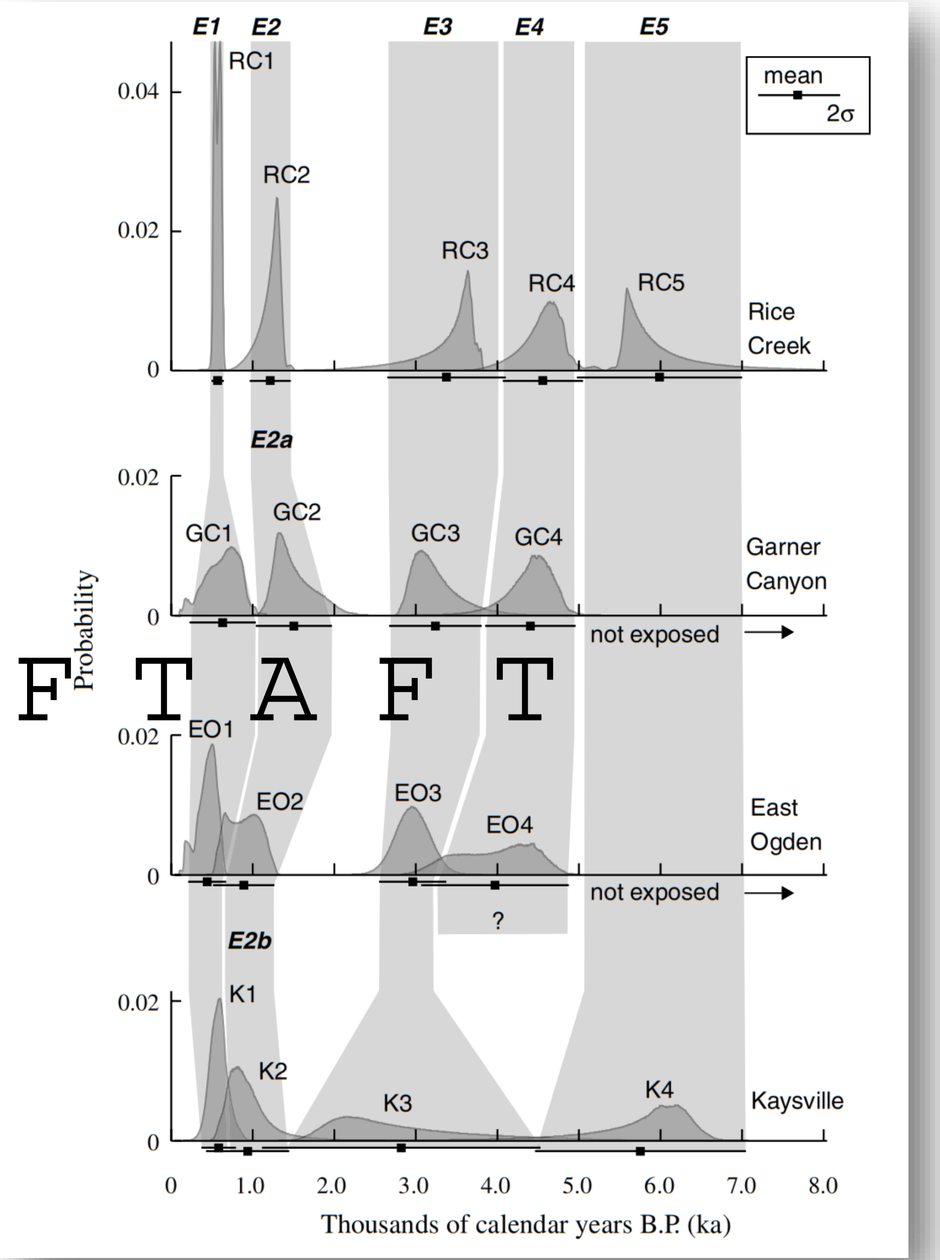
Based on offset units and measuring colluvial wedge thicknesses

Discussion

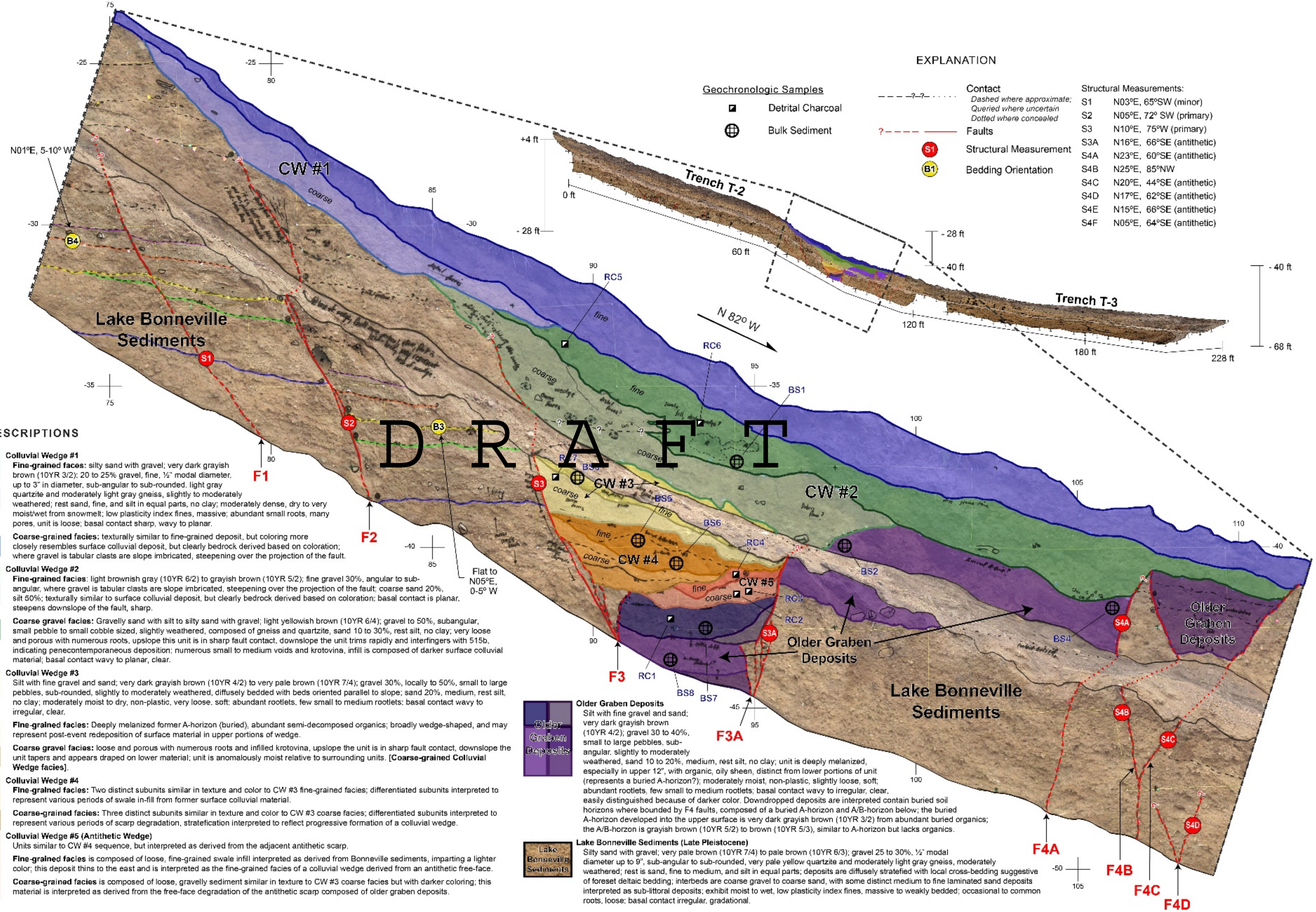
- Why are these result interesting and useful?
  - Constrain events further especially for the oldest events.
  - A data point constraining timing within the middle portion of the segment
  - Understanding the extent of Weber Segment ruptures and possible multi-segment ruptures
  - Possibly displacement per event (challenges)
- Next steps – secure funding for dating.
  - Samples (7 macro samples, 8 bulk samples)

D R D R A F T A F T

Questions?



DuRoss et al. (2011)



DRAFT

UNIT DESCRIPTIONS

Colluvial Wedge #1 (CW #1)

fine — **Fine-grained faces:** silty sand with gravel; very dark grayish brown (10YR 3/2): 20 to 25% gravel, fine, ½" modal diameter, up to 3" in diameter, sub-angular to sub-rounded, light gray quartzite and moderately light gray gneiss, slightly to moderately weathered; rest sand, fine, and silt in equal parts, no clay; moderately dense, dry to very moist/wet from snowmelt; low plasticity index fines, massive; abundant small roots, many pores, unit is loose; basal contact sharp, wavy to planar.

coarse — **Coarse-grained facies:** texturally similar to fine-grained deposit, but coloring more closely resembles surface colluvial deposit, but clearly bedrock derived based on coloration; where gravel is tabular clasts are slope imbricated, steepening over the projection of the fault.

Colluvial Wedge #2 (CW #2)

fine — **Fine-grained facies**: light brownish gray (10YR 6/2) to grayish brown (10YR 5/2); fine gravel 30%, angular to sub-angular, where gravel is tabular clasts are slope imbricated, steepening over the projection of the fault; coarse sand 20%, silt 50%; texturally similar to surface colluvial deposit, but clearly bedrock derived based on coloration; basal contact is planar, steepens downslope of the fault, sharp.

coarse — **Coarse gravel facies:** Gravelly sand with silt to silty sand with gravel; light yellowish brown (10YR 6/4); gravel to 50%, subangular, small pebble to small cobble sized, slightly weathered, composed of gneiss and quartzite, sand 10 to 30%, rest silt, no clay; very loose and porous with numerous roots, upslope this unit is in sharp fault contact, downslope the unit trims rapidly and interfingers with 515b, indicating penecontemporaneous deposition; numerous small to medium voids and krotovina, infill is composed of darker surface colluvial material; basal contact wavy to planar, clear.

Colluvial Wedge #3 (CW #3)

Silt with fine gravel and sand; very dark grayish brown (10YR 4/2) to very pale brown (10YR 7/4); gravel 30%, locally to 50%, small to large pebbles, sub-rounded, slightly to moderately weathered, diffusely bedded with beds oriented parallel to slope; sand 20%, medium, rest silt, no clay; moderately moist to dry, non-plastic, very loose, soft; abundant rootlets, few small to medium rootlets; basal contact wavy to irregular, clear.

fine — **Fine-grained facies:** Deeply melanized former A-horizon (buried), abundant semi-decomposed organics; broadly wedge-shaped, and may represent post-event redeposition of surface material in upper portions of wedge.

coarse — **Coarse gravel facies:** loose and porous with numerous roots and infilled krotovina, upslope the unit is in sharp fault contact, downslope the unit tapers and appears draped on lower material; unit is anomalously moist relative to surrounding units. [**Coarse-grained Colluvial Wedge facies**].

Colluvial Wedge #4 (CW #4)

fine — **Fine-grained facies:** Two distinct subunits similar in texture and color to CW #3 fine-grained facies; differentiated subunits interpreted to represent various periods of swale in-fill from former surface colluvial material.

coarse — **Coarse-grained facies:** Three distinct subunits similar in texture and color to CW #3 coarse facies; differentiated subunits interpreted to represent various periods of scarp degradation, stratefication interpreted to reflect progressive formation of a colluvial wedge.

Colluvial Wedge #5 (Antithetic Wedge) (CW #3)

Units similar to CW #4 sequence, but interpreted as derived from the adjacent antithetic scarp.

fine — **Fine-grained facies** is composed of loose, fine-grained swale infill interpreted as derived from Bonneville sediments, imparting a lighter color; this deposit thins to the east and is interpreted as the fine-grained facies of a colluvial wedge derived from an antithetic free-face.

coarse — **Coarse-grained facies** is composed of loose, gravelly sediment similar in texture to CW #3 coarse facies but with darker coloring; this material is interpreted as derived from the free-face degradation of the antithetic scarp composed of older graben deposits.

Older Graben Deposits (Older Graben Deposits)

Silt with fine gravel and sand; very dark grayish brown (10YR 4/2); gravel 30 to 40%, small to large pebbles, sub-angular, slightly to moderately weathered, sand 10 to 20%, medium, rest silt, no clay; unit is deeply melanized, especially in upper 12", with organic, oily sheen, distinct from lower portions of unit (represents a buried A-horizon?); moderately moist, non-plastic, slightly loose, soft; abundant rootlets, few small to medium rootlets; basal contact wavy to irregular, clear, easily distinguished because of darker color. Downdropped deposits are interpreted contain buried soil horizons where bounded by F4 faults, composed of a buried A-horizon and A/B-horizon below; the buried A-horizon developed into the upper surface is very dark grayish brown (10YR 3/2) from abundant buried organics; the A/B-horzon is grayish brown (10YR 5/2) to brown (10YR 5/3), similar to A-horizon but lacks organics.

Lake Bonneville Sediments (Late Pleistocene) (Lake Bonneville Sediments)

Silty sand with gravel; very pale brown (10YR 7/4) to pale brown (10YR 6/3); gravel 25 to 30%, ½" modal diameter up to 9", sub-angular to sub-rounded, very pale yellow quartzite and moderately light gray gneiss, moderately weathered; rest is sand, fine to medium, and silt in equal parts; deposits are diffusely stratefied with local cross-bedding suggestive of foreset deltaic bedding; interbeds are coarse gravel to coarse sand, with some distinct medium to fine laminated sand deposits interpreted as sub-littoral deposits; exhibit moist to wet, low plasticity index fines, massive to weakly bedded; occasional to common roots, loose; basal contact irregular, gradational.

BOISE STATE UNIVERSITY

FAULT DISPLACEMENT/DEFORMATION AND SITE RESPONSE FOR SALT LAKE CITY: SEISMIC RESULTS AND ADDITIONAL OPPORTUNITIES

Lee M. Liberty, Boise State University

SUMMARY

- >9000 dispersion curves provide input for shear wave velocity (Vs) and near-surface site amplification maps.
- Seismic first arrivals (Vp tomography) define depth to water saturation.
- Vp and Vs results were combined to assess liquefaction susceptibility.
- Reflection results show offset and tilted strata that are consistent with active faulting. Highly variable reflection results.
- Limitations on our reflection imaging capabilities is mostly from limited geophone aperture (land streamer=60 m) and complex near surface.
- To identify late Quaternary faults and slip rates, deeper imaging is needed.
- A seismic reflection campaign using cabled or Nodal geophones is within a NEHRP-scale proposal budget. This approach will provide the needed offsets to image to the base of Quaternary strata

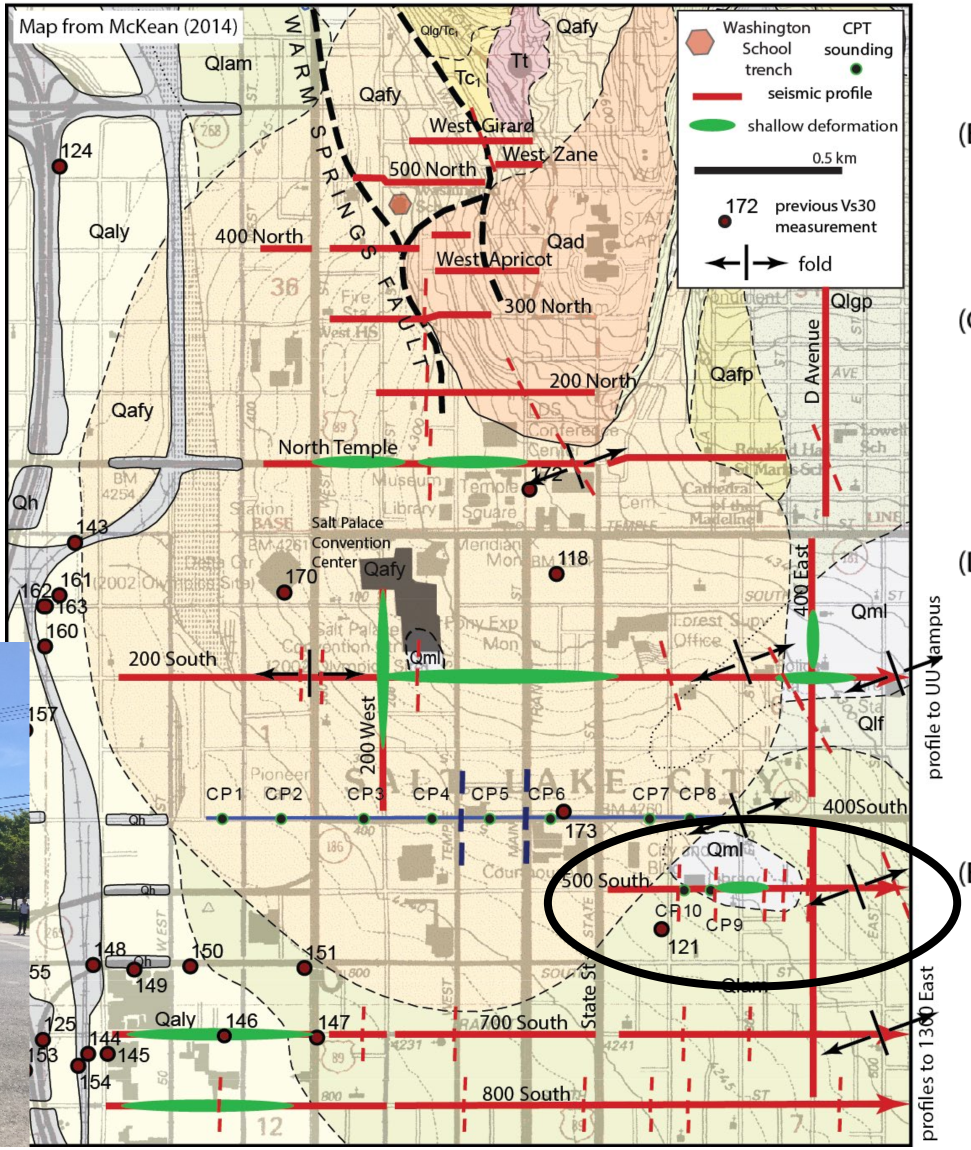
SEISMIC LAND STREAMER RESULTS: 2018 FIELD CAMPAIGN

Deformation evidence:

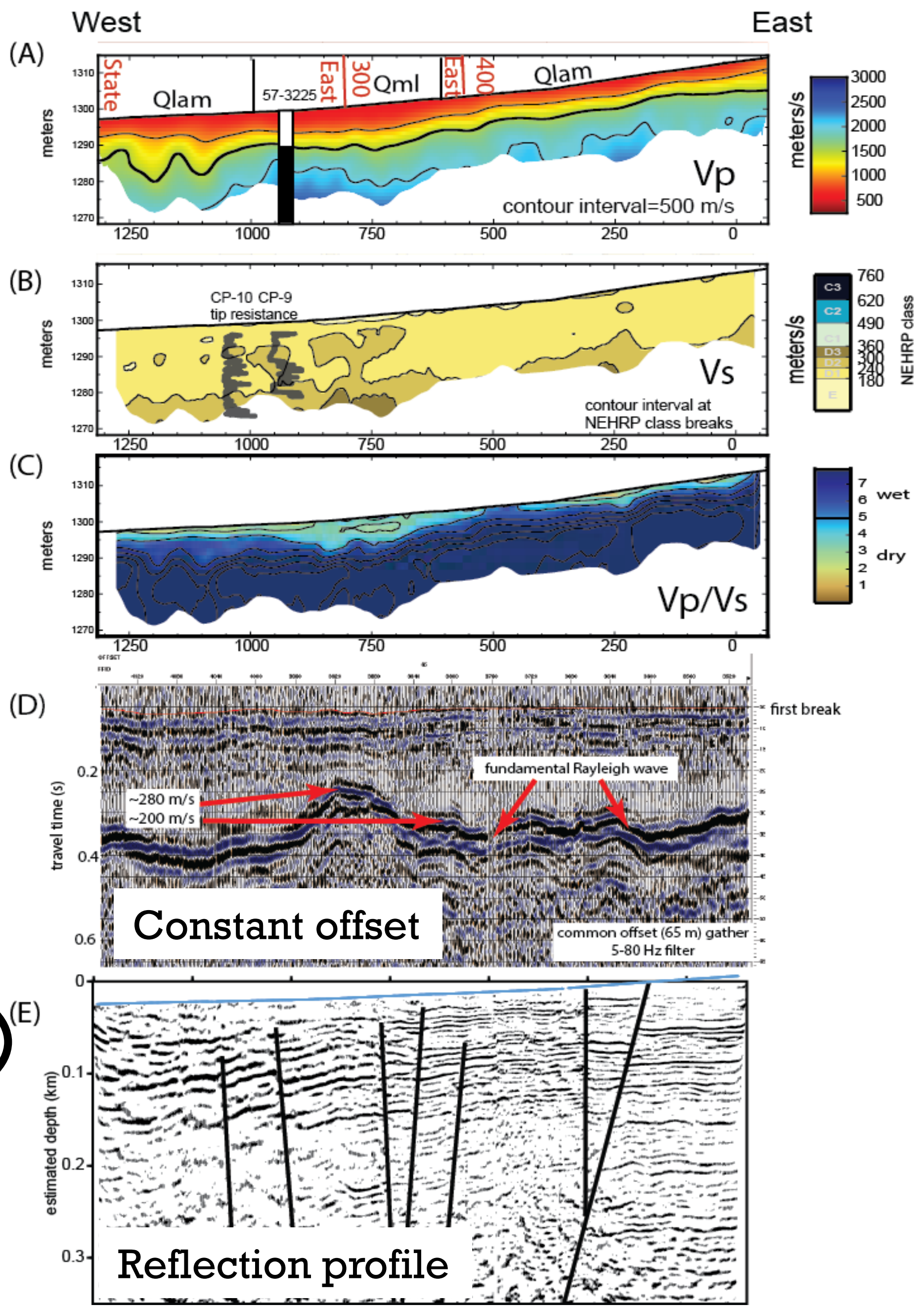
Complex Vp/Vs in the upper few meters suggests Holocene deformation

Offset reflections suggest late Quaternary faulting

Liberty et al (in revision)



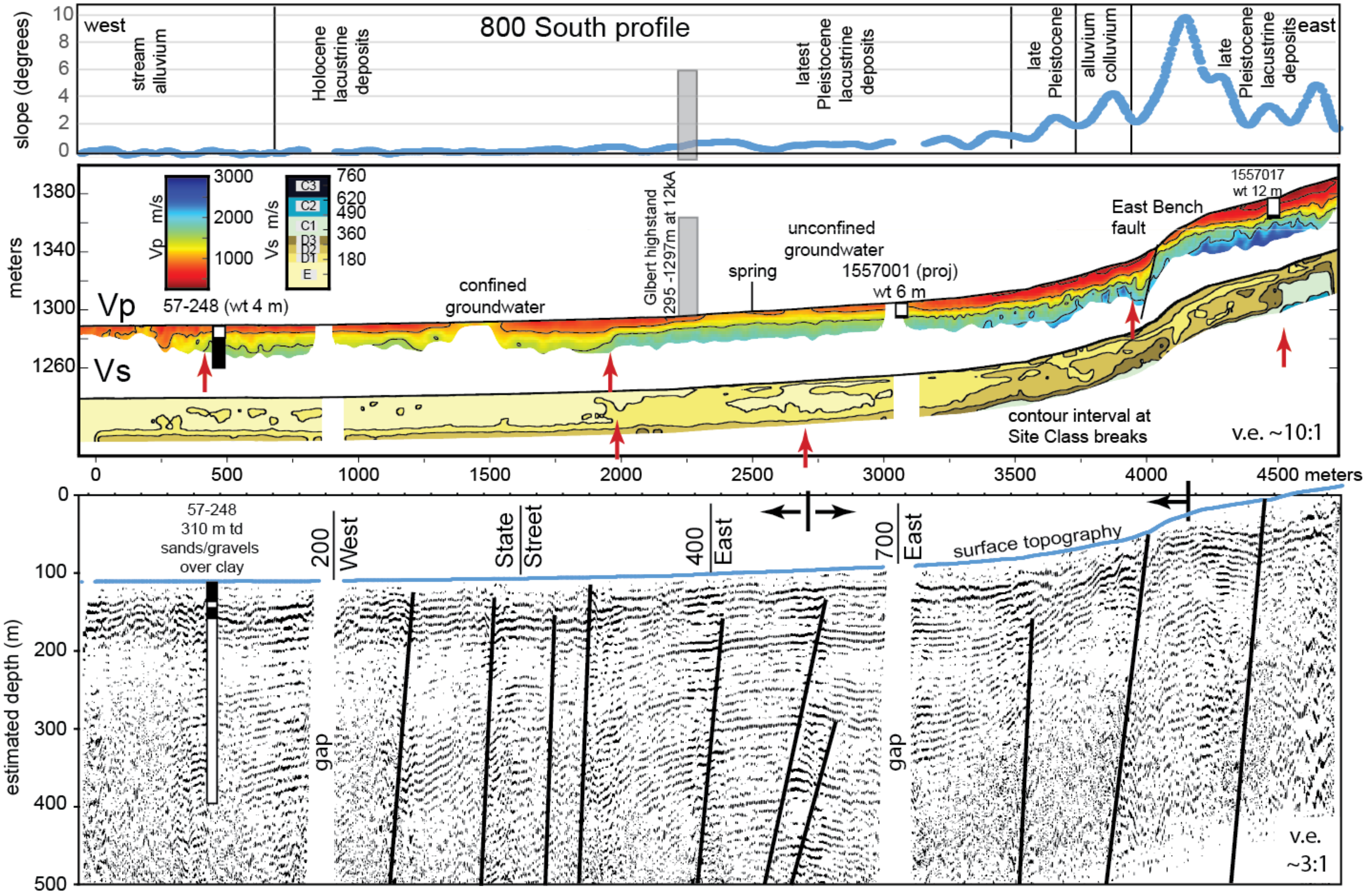
500 South



800 SOUTH PROFILE

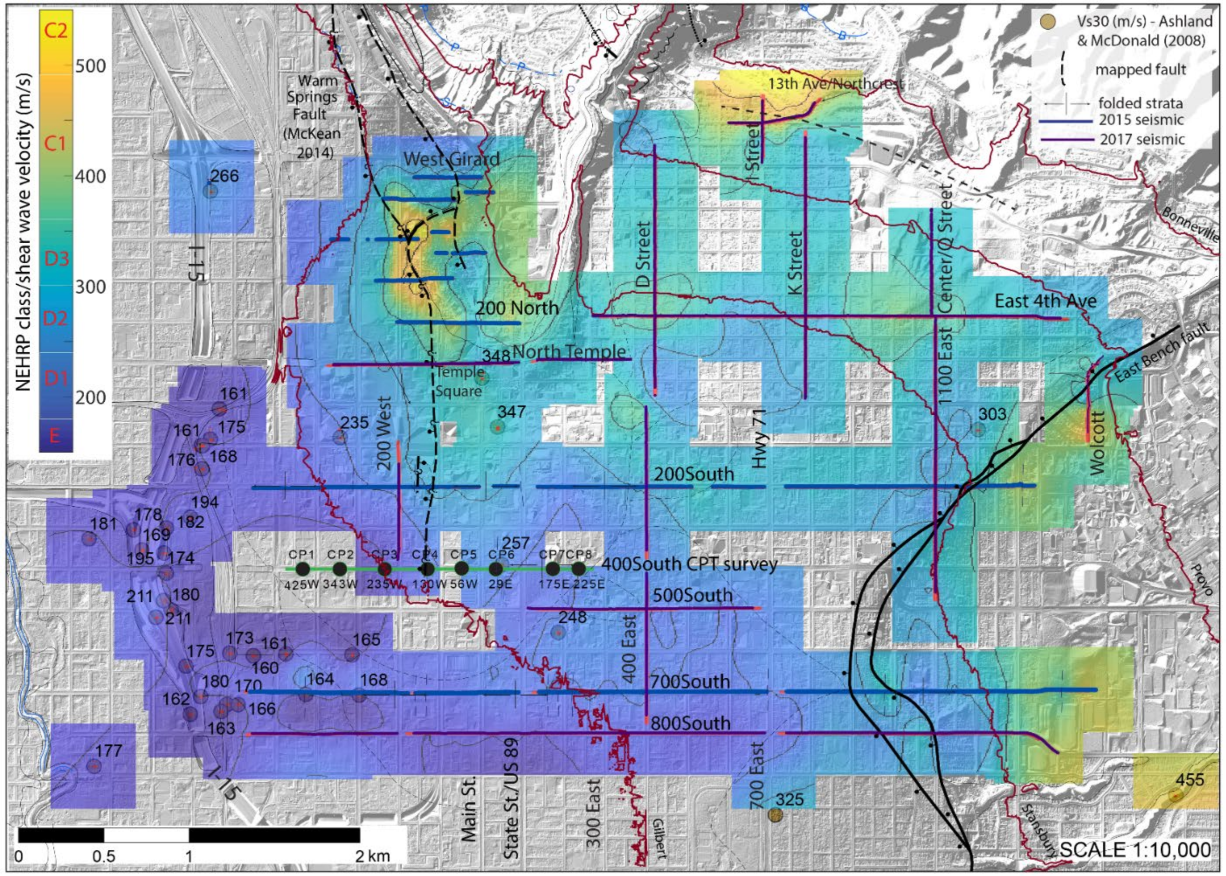
- Vp shows a transition from an unconfined to confined groundwater system near 200 East
- Well defined colluvial wedge (low Vp) in the hanging wall of EBF
- Class E soils (upper 20 m) mapped to the west of 200 West
- Soft (Class C) rock within the EBF zone
- Vp and Vs step near 1300 East may represent a second strand of the EBF

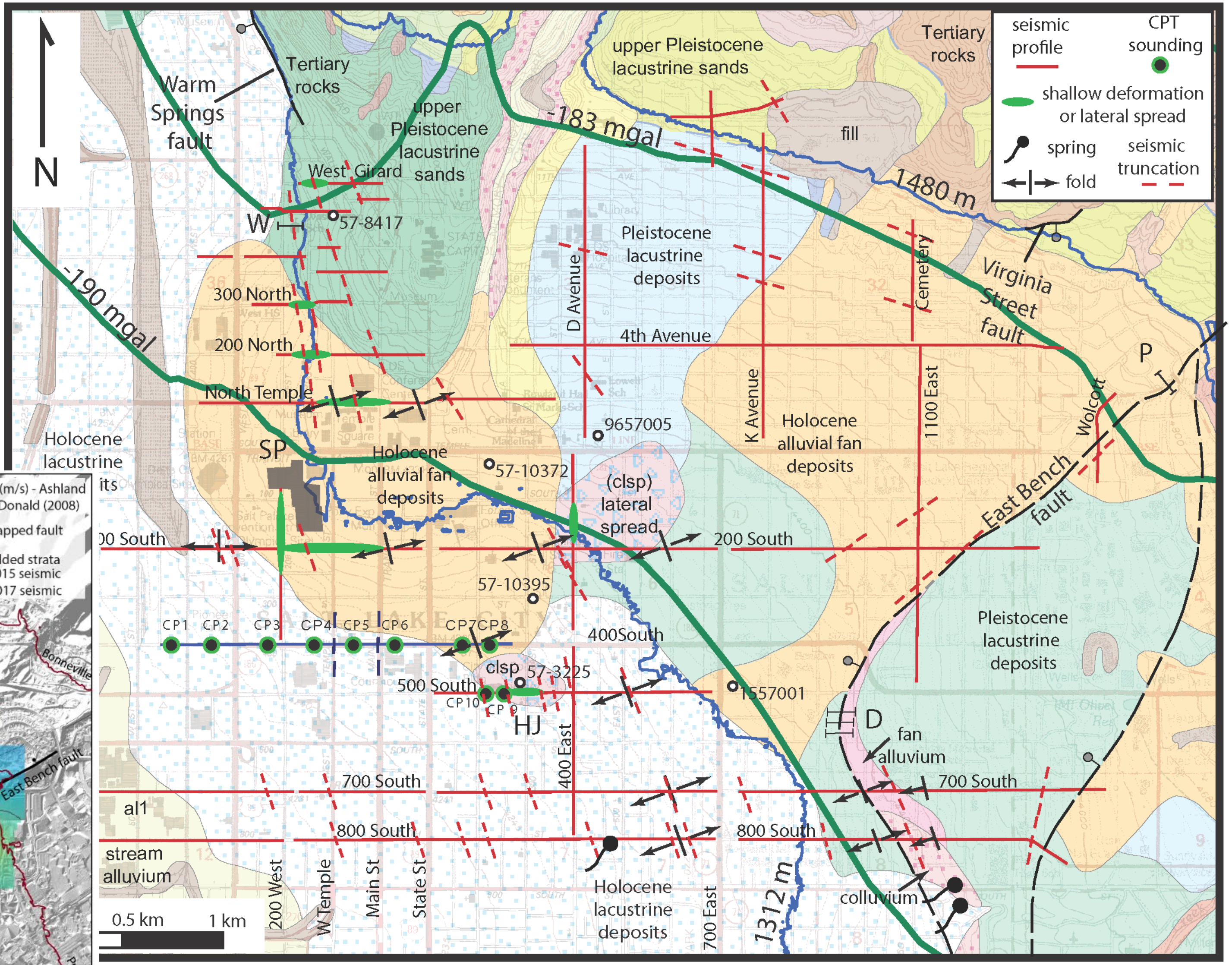
- Folded and faulted strata suggest a distributed fault zone between WSF and EBF
- Poor reflectivity beneath stream alluvium



Liberty et al (in revision)

VS30 AND DEFORMATION MAP FOR SALT LAKE CITY

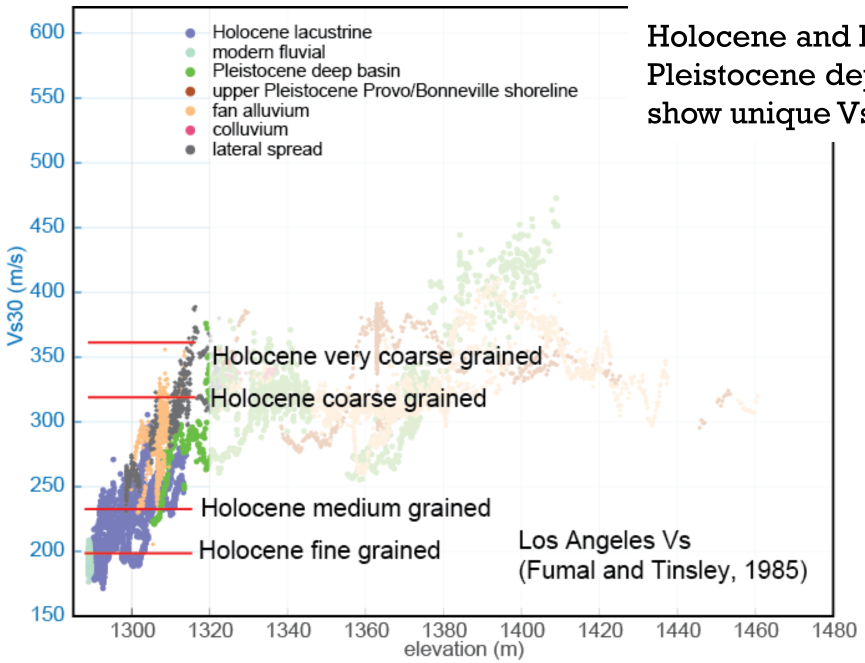




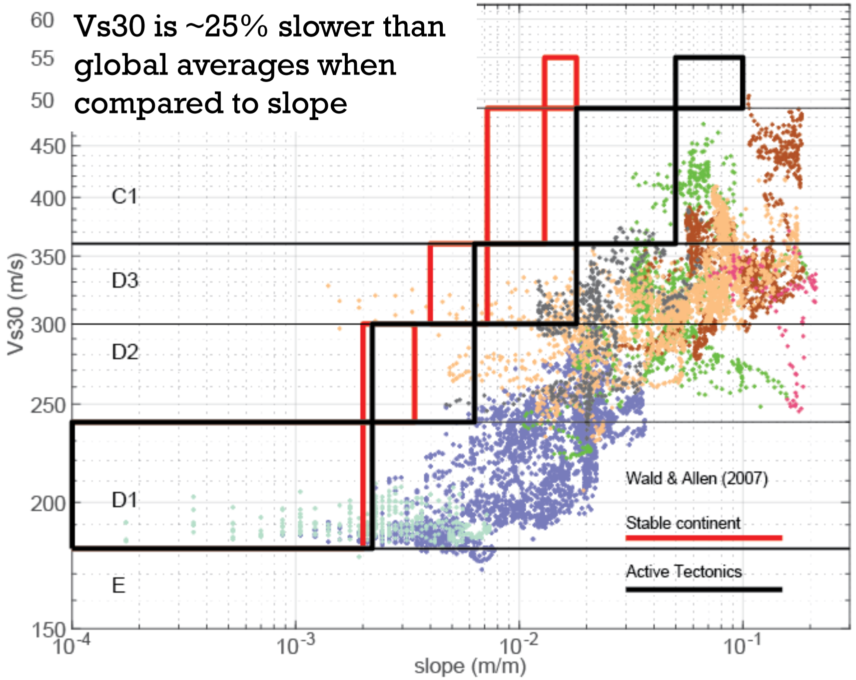
Map from Personius et al (1992)

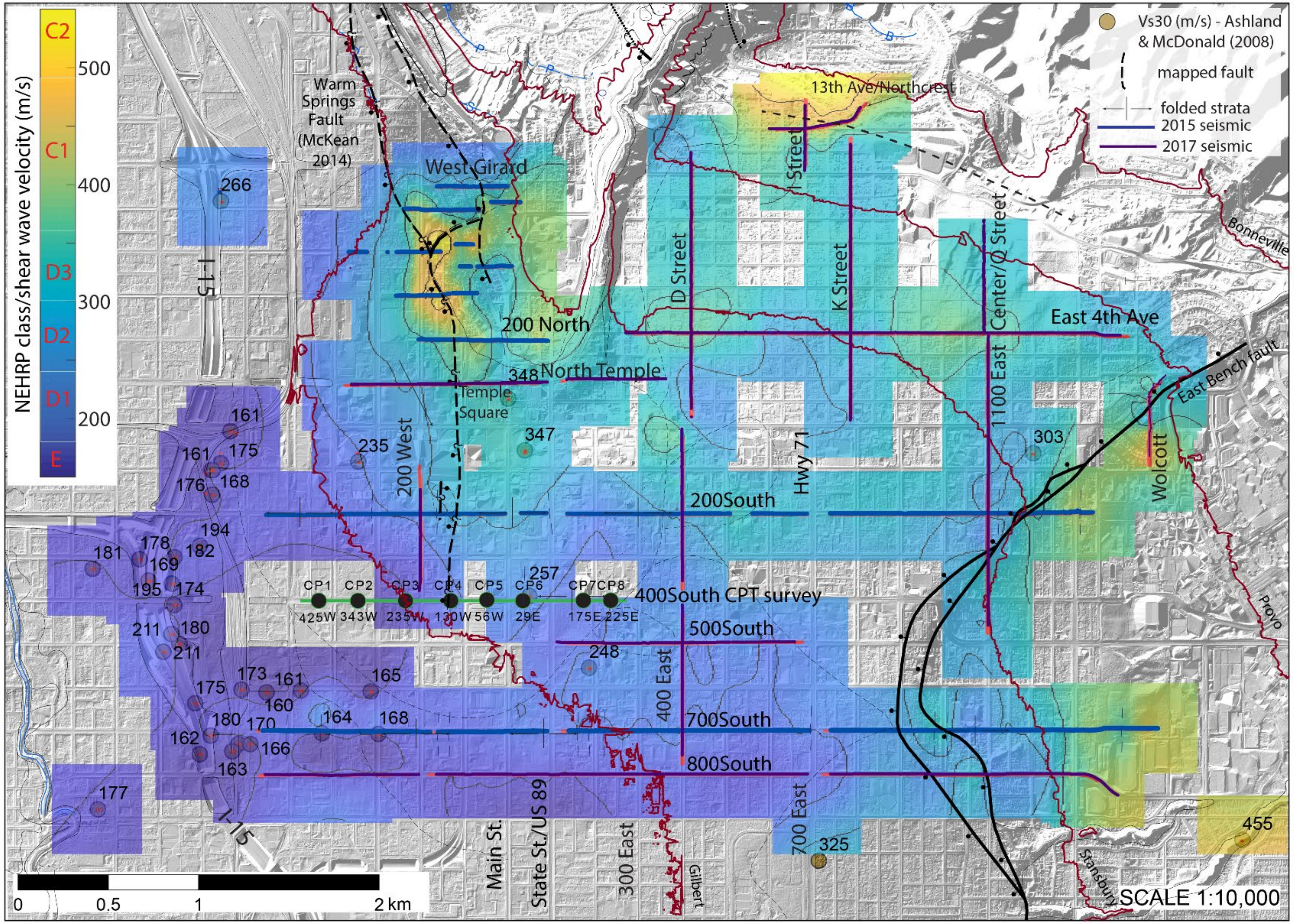
VS30 RELATIONSHIPS

Holocene and late Pleistocene deposits show unique Vs patterns

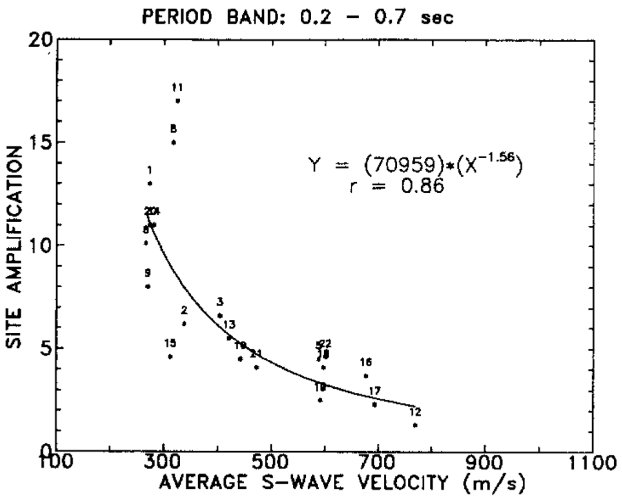


Vs30 is ~25% slower than global averages when compared to slope

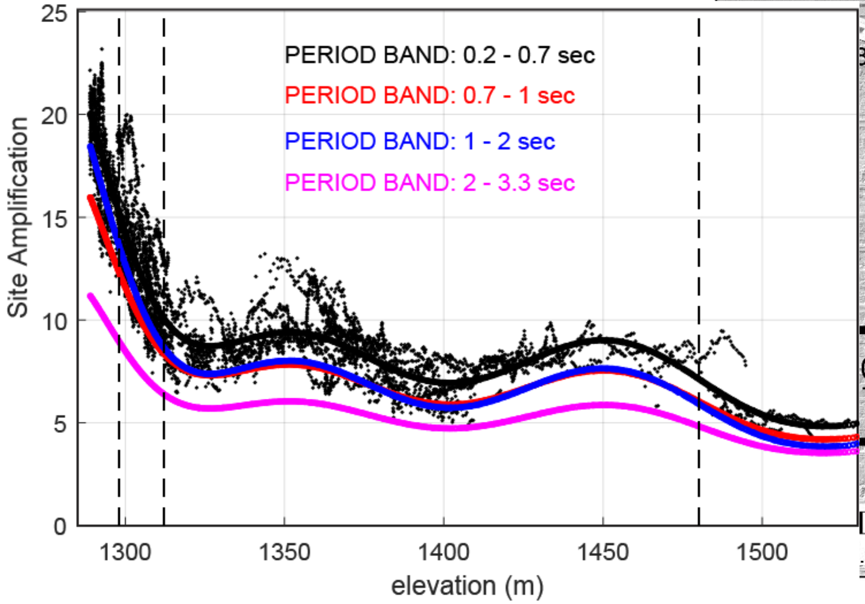


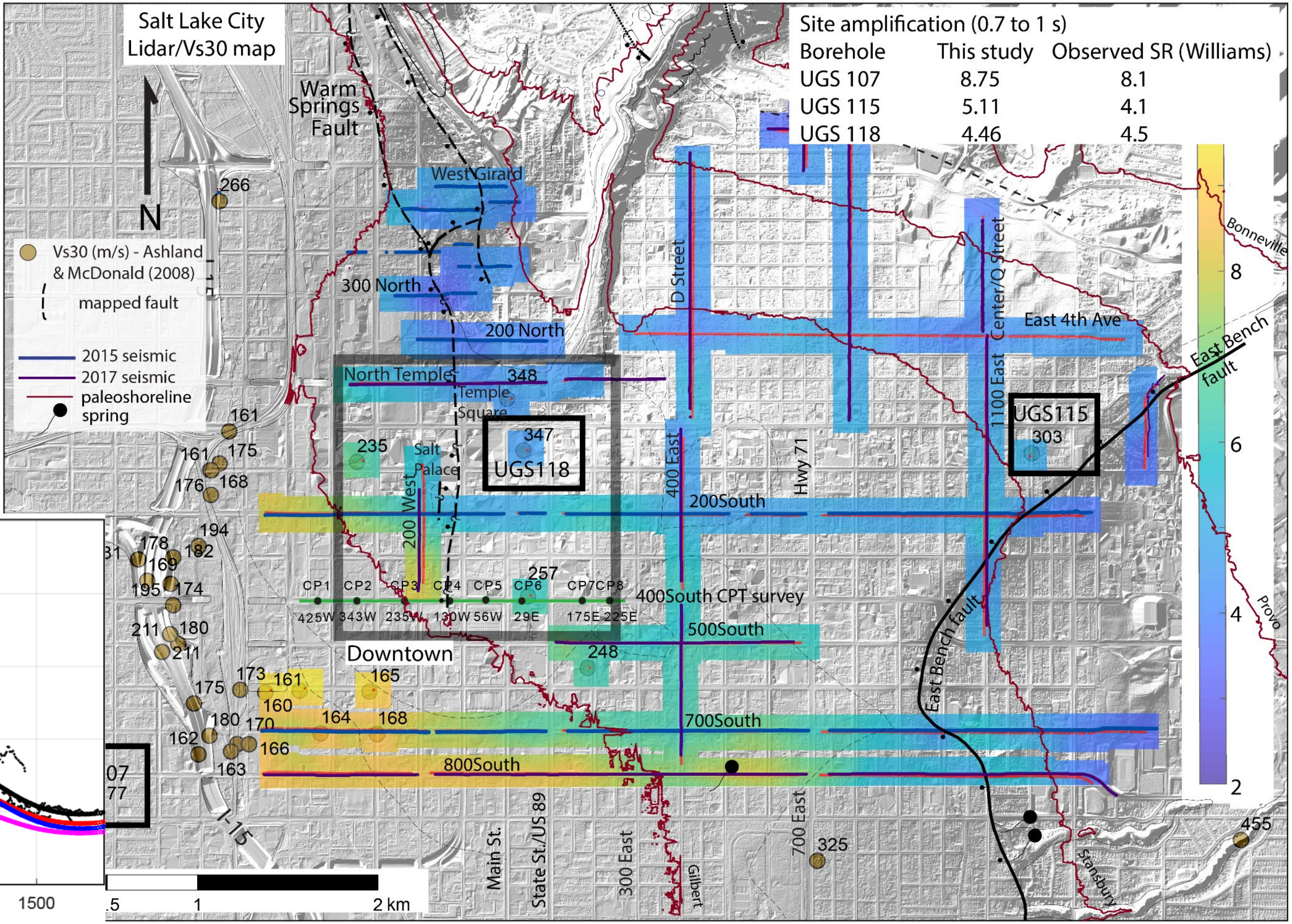


SITE AMPLIFICATION



From Williams et al, 1993



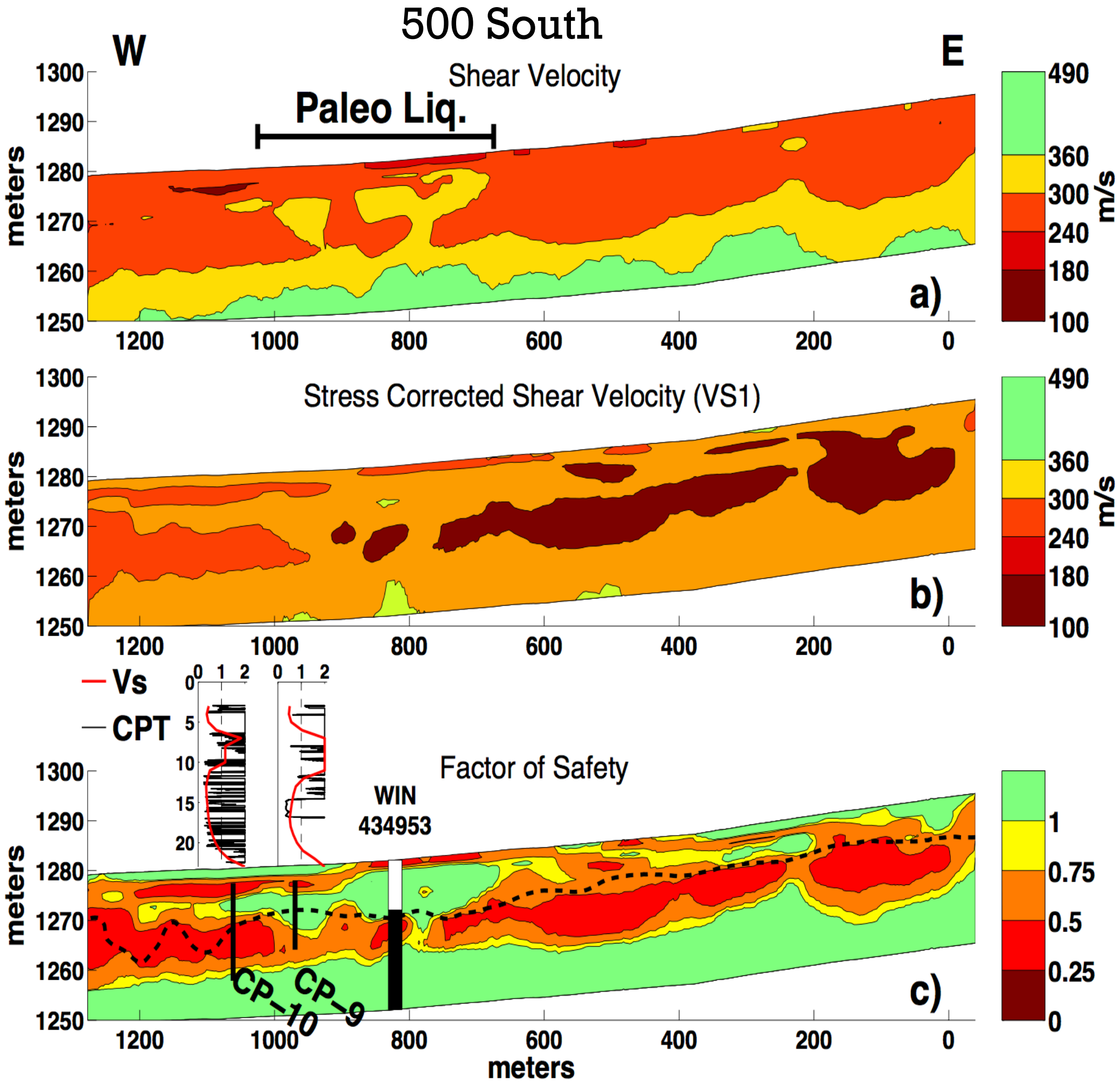


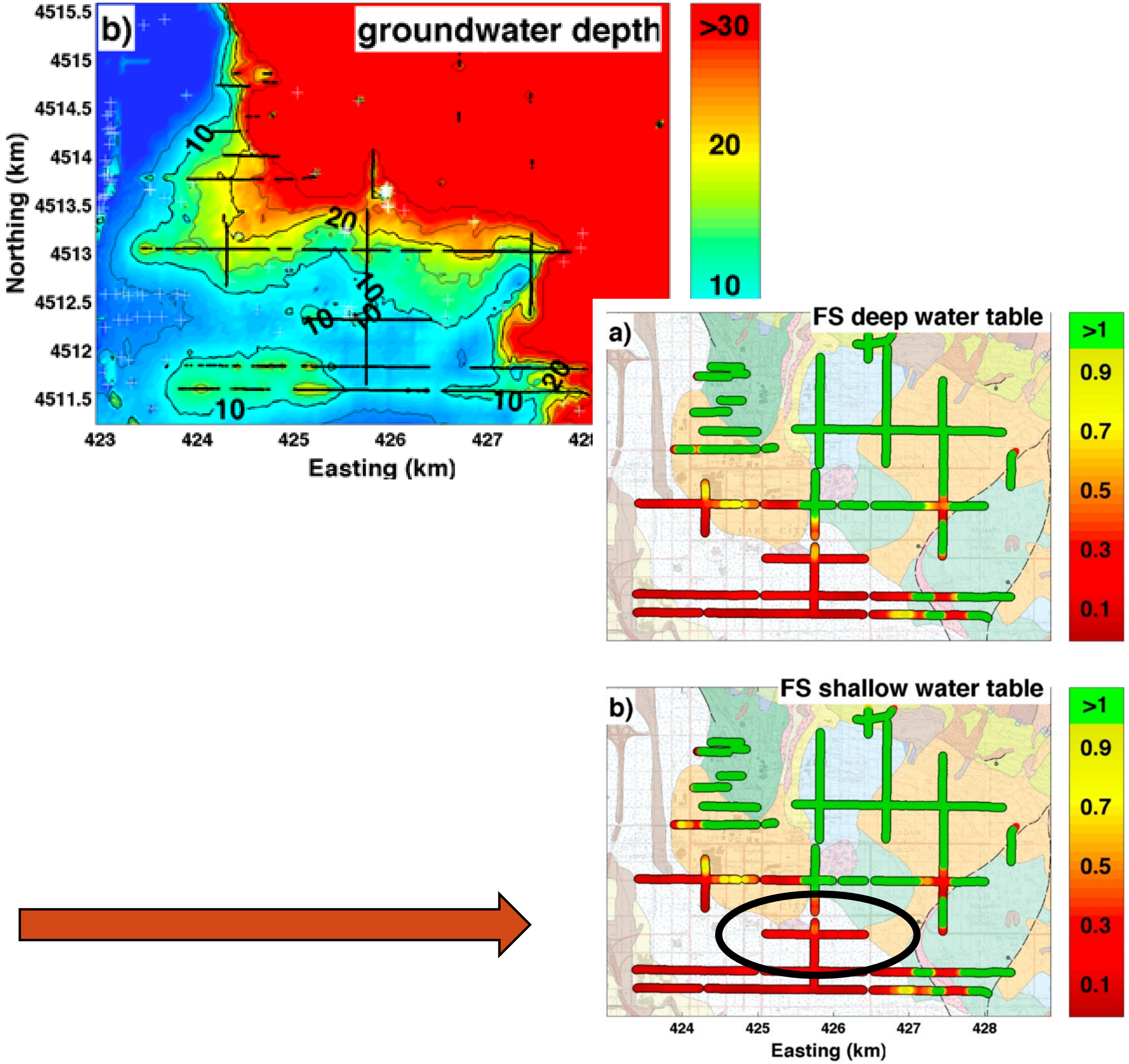
Site amplification (0.7 to 1 s)

Borehole	This study	Observed SR (Williams)
UGS 107	8.75	8.1
UGS 115	5.11	4.1
UGS 118	4.46	4.5

LIQUEFACTION-INDUCED DEFORMATION

St. Clair and Liberty, in revision

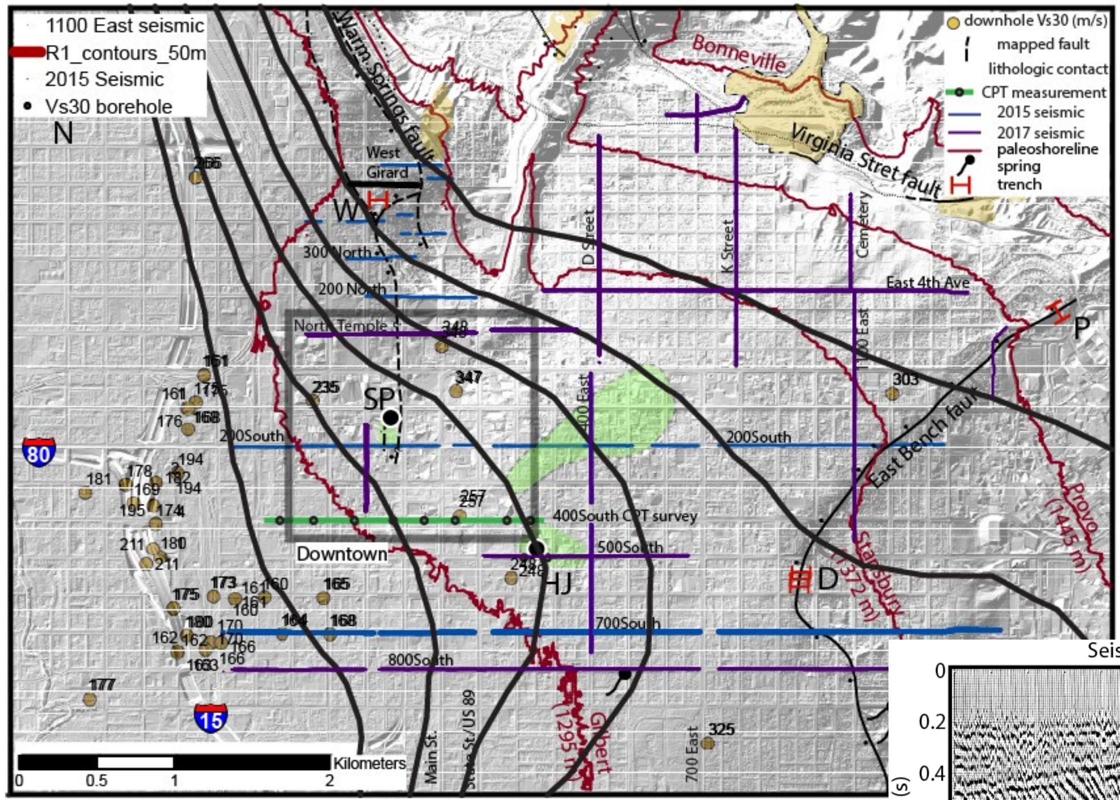


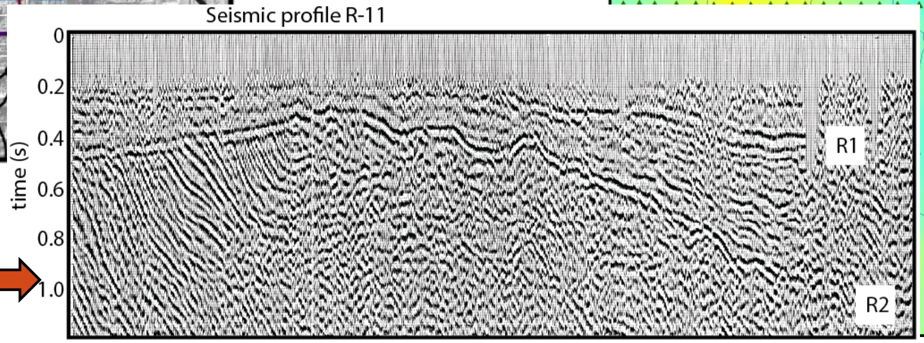


HOW DEEP DO WE NEED TO IMAGE BENEATH SLC TO IDENTIFY/CHARACTERIZE ACTIVE FAULTS?

R1=BOUNDARY BETWEEN TERTIARY AND QUATERNARY STRATA

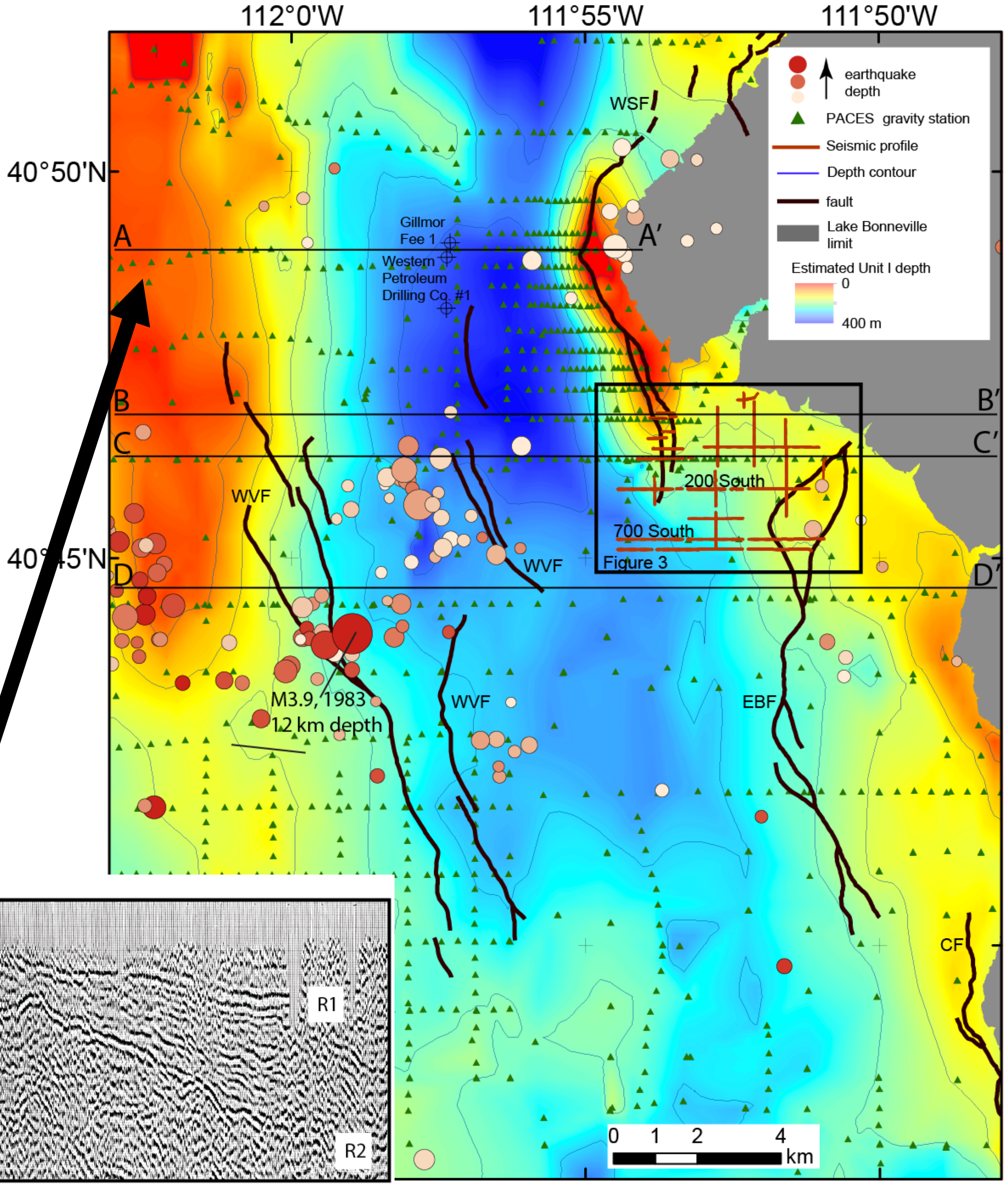
Estimated depth to R1 boundary





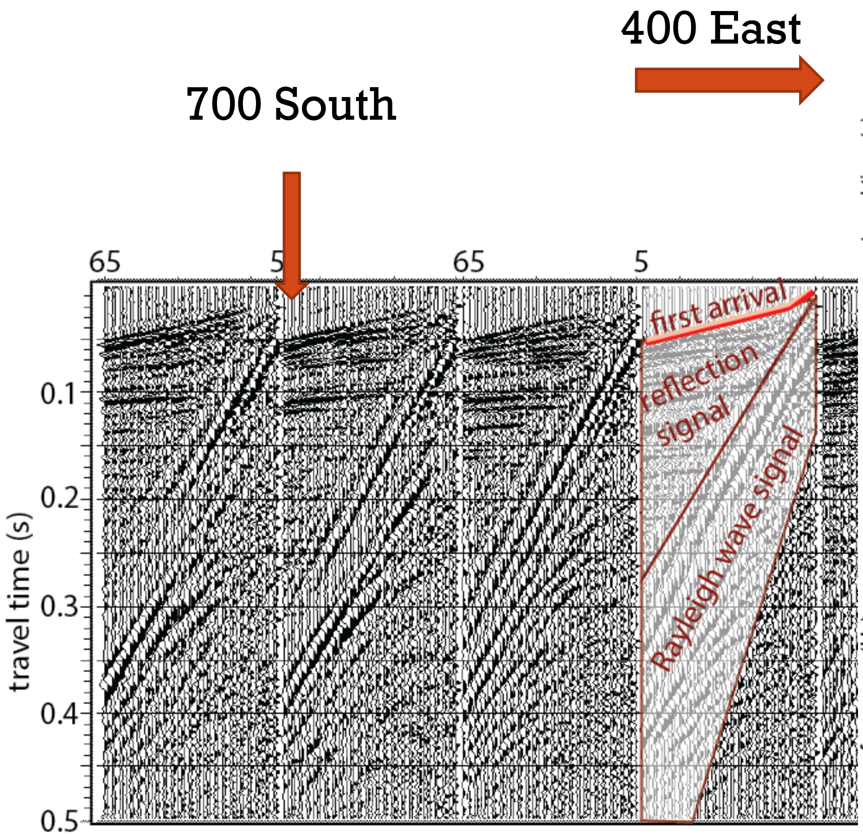
From Radkins et al., 1989

Gravity-derived R1 Depth estimate

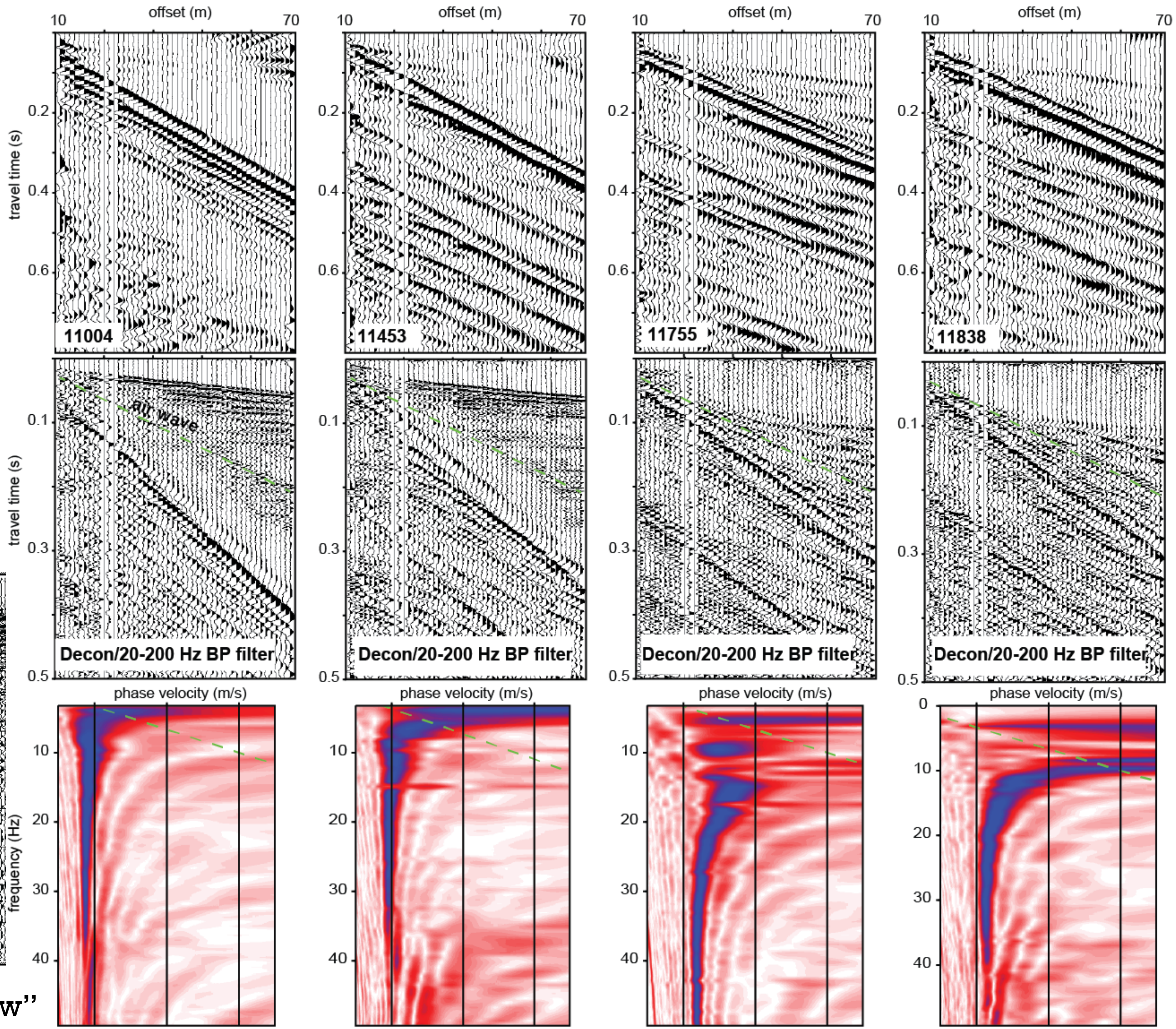


WEIGHT DROP/STREAMER:
CAPABILITIES AND LIMITATIONS

SURFACE WAVES LIMIT REFLECTION CAPABILITIES TO ABOUT 200 M DEPTH IN SLC WITH OUR STREAMER

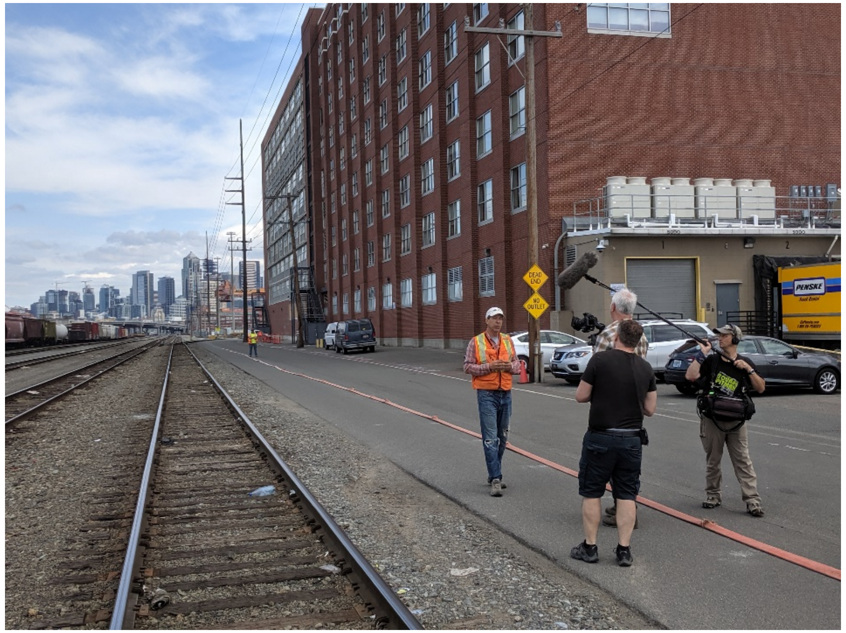


Reflection signal lives in the "optimum window"

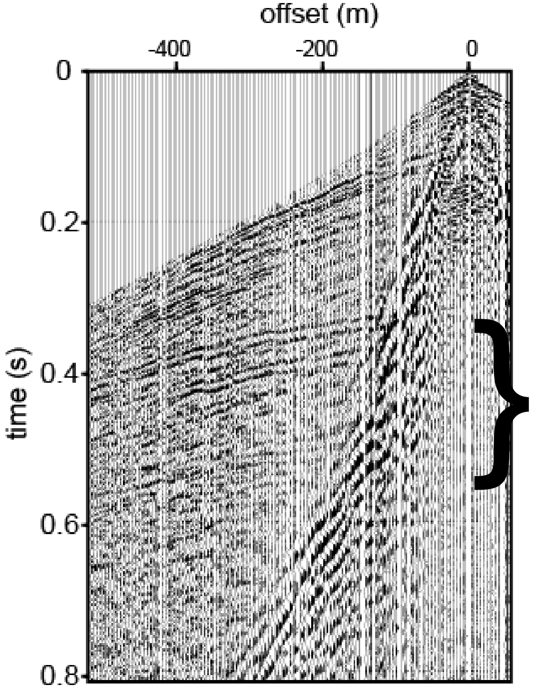


DOWNTOWN SEATTLE:

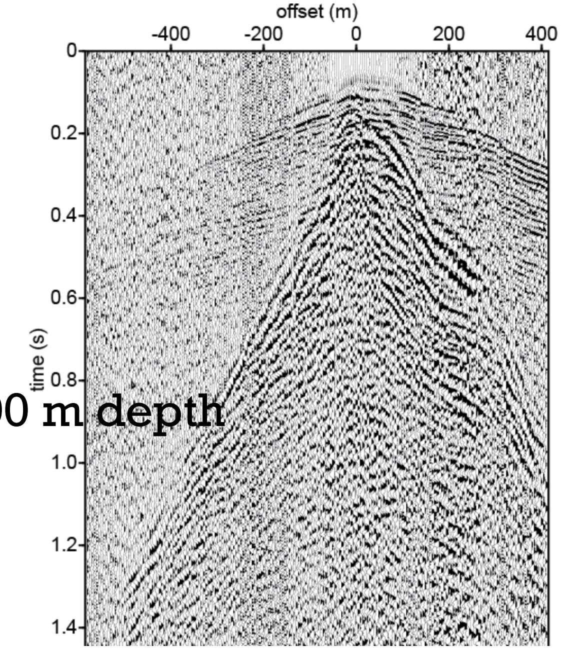
DEEPER TARGETS WITH SAME SEISMIC SOURCE



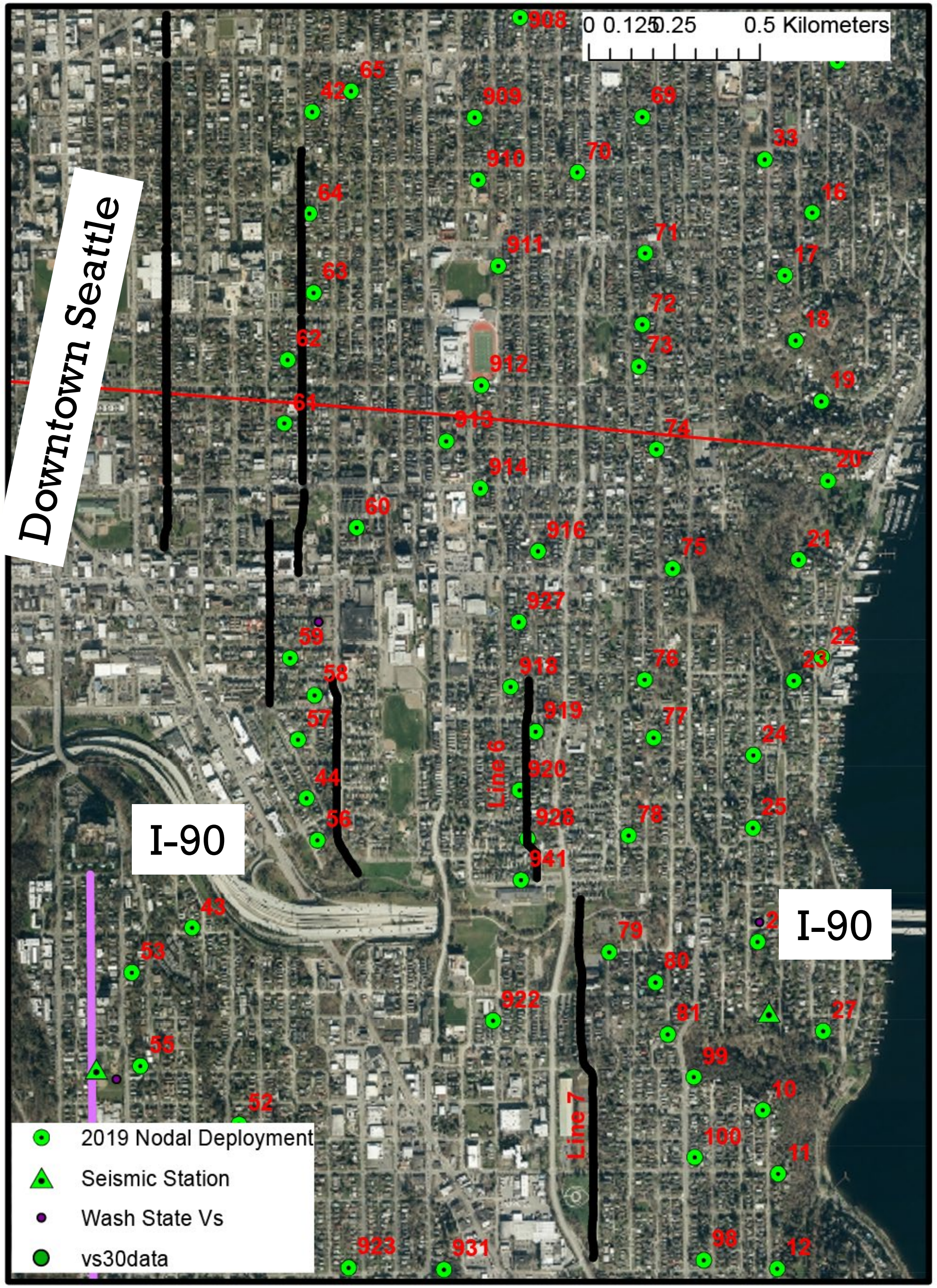
Cabled shot gather

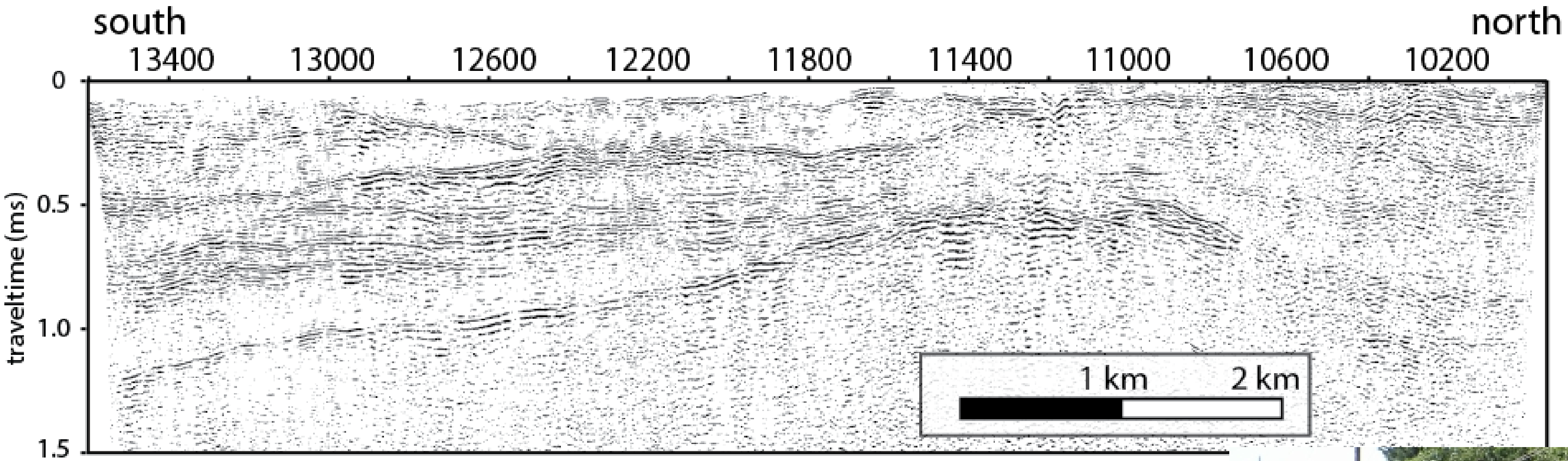


Nodal receiver gather

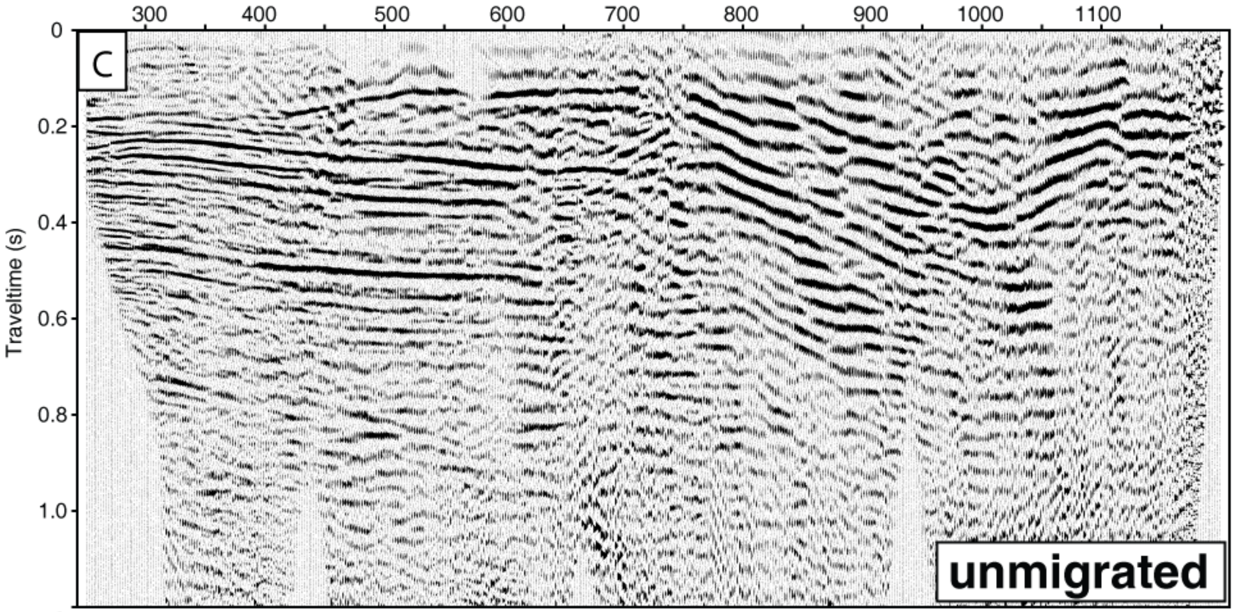


} 500 -800 m depth





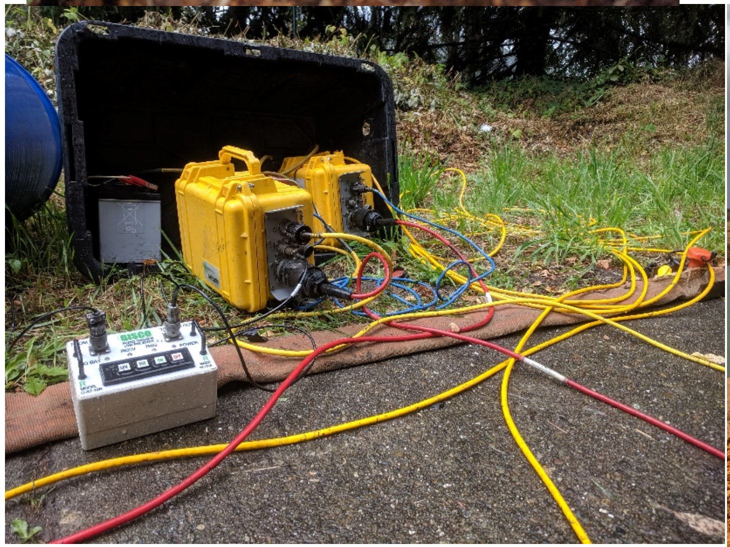
WEIGHT DROP SEISMIC CAPABILITY: IMAGES TO >1 KM DEPTH



NODES AND CABLED SEISMIC SYSTEMS INTEGRATED WITH WEIGHT DROP SOURCE

GPS trigger timing from hammer source

Programmed weight drop



Smart Solo 3C 4.5 Hz Node

SUMMARY

- >9000 dispersion curves provide input for shear wave velocity (Vs) and near-surface site amplification maps.
- Seismic first arrivals (Vp tomography) define depth to water saturation.
- Vp and Vs results were combined to assess liquefaction susceptibility.
- Reflection results show offset and tilted strata that are consistent with active faulting. Highly variable reflection results.
- Limitations on our reflection imaging capabilities is mostly from limited geophone aperture (land streamer=60 m) and complex near surface.
- To identify late Quaternary faults and slip rates, deeper imaging is needed.
- A seismic reflection campaign using cabled or Nodal geophones is within a NEHRP-scale proposal budget. This approach will provide the needed offsets to image to the base of Quaternary strata

Is There a Potential Surface Fault Displacement/Deformation Hazard in Downtown Salt Lake City?

(I hope not)

Ivan G. Wong
Senior Principal Seismologist
Lettis Consultants International

(with contributions from Susan Olig & Jim Pechmann)

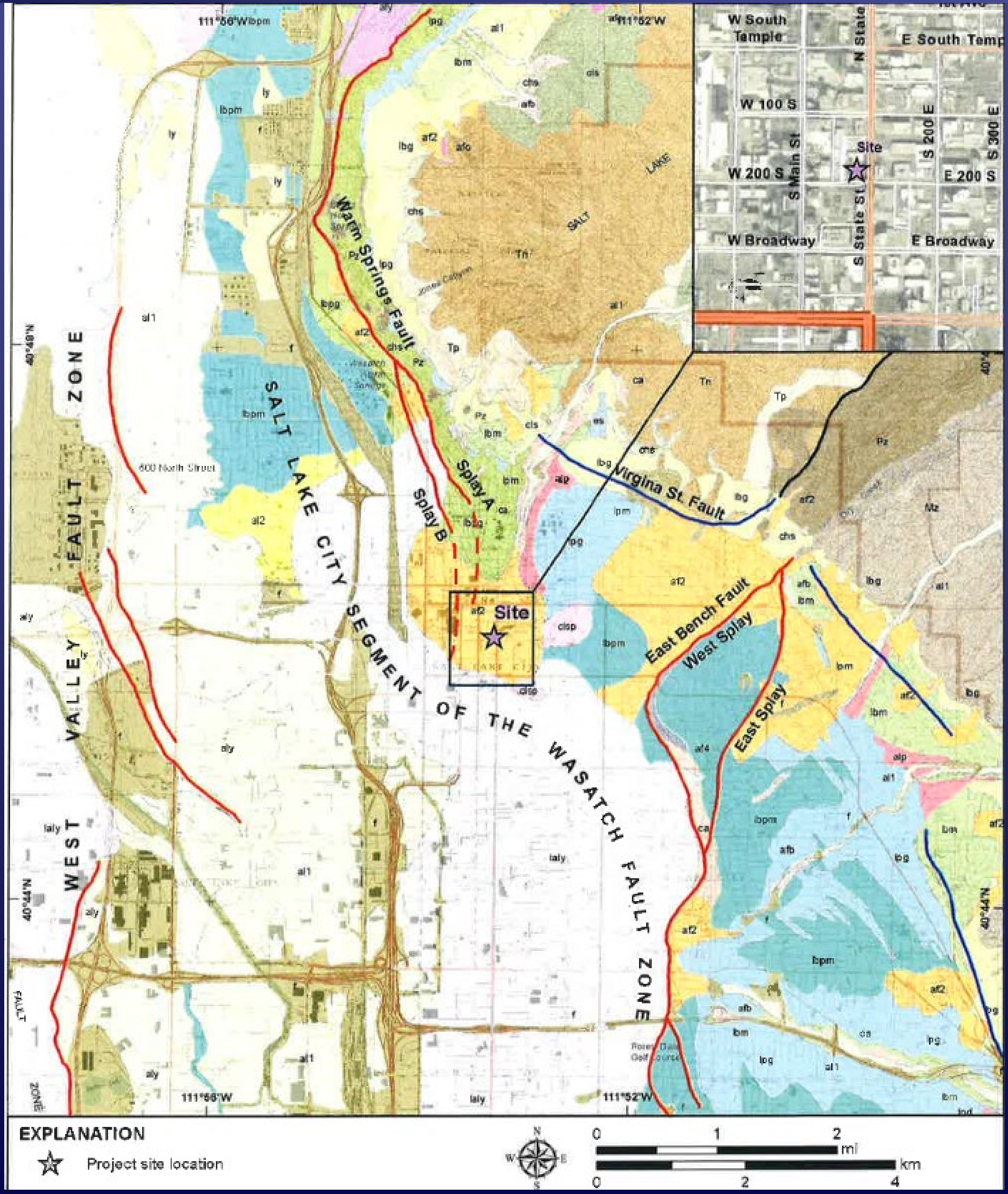
2021 Utah Quaternary Fault Parameters Working Group

2 February 2021

Questions

- What is the potential for primary and secondary surface fault displacement and deformation hazard in downtown Salt Lake City?
- Given the large uncertainties regarding such potential, what investigations and mitigative measures should be taken to reduce the potential hazard?

Faulting in and Around Downtown SLC



3

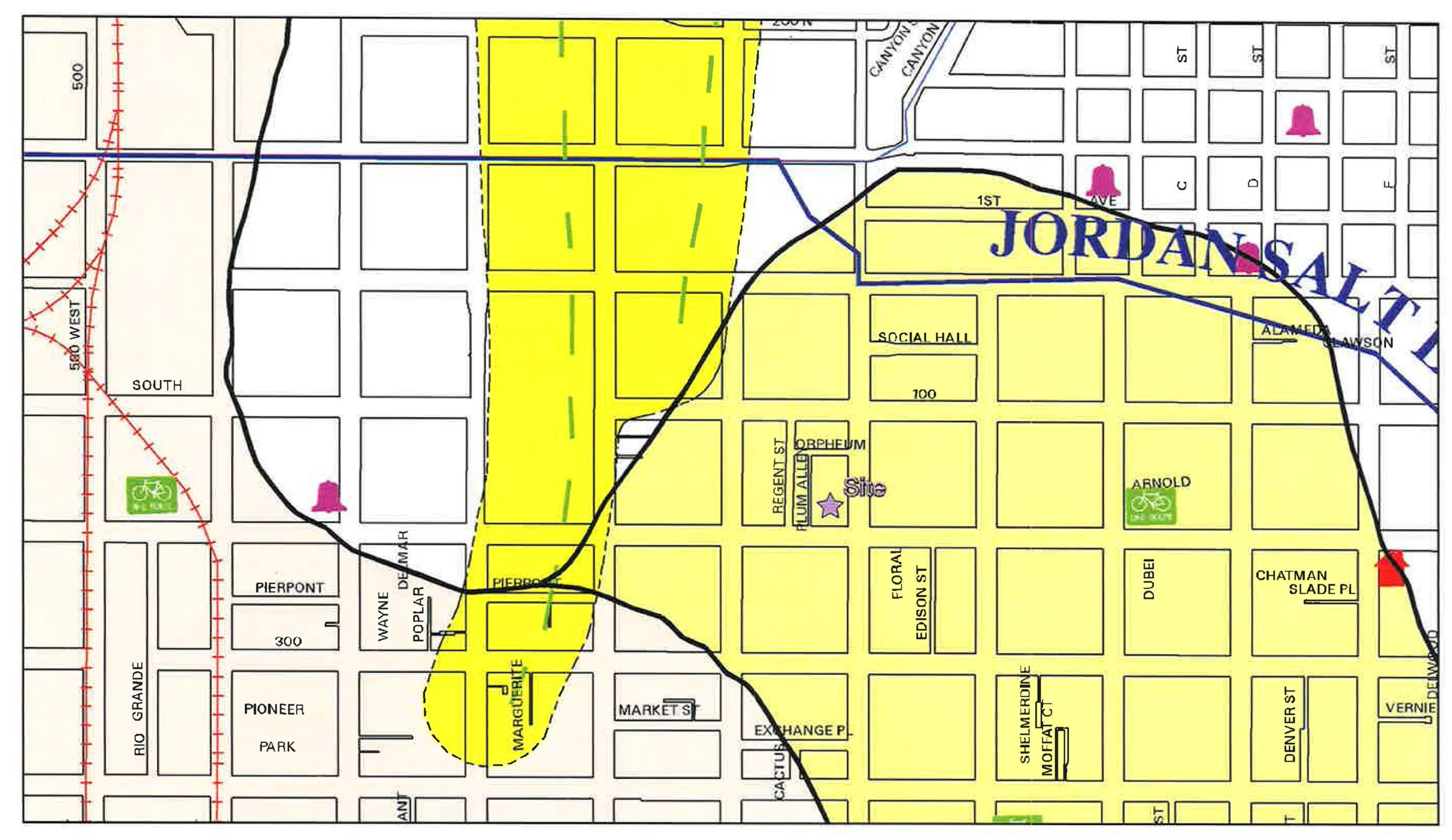
Introduction

- Downtown Salt Lake City is located in a complex left step-over between the Warm Springs and East Bench sections of the Salt Lake City segment of the Wasatch fault.
- Earliest issues were 1) how do the two sections connect in the subsurface and 2) what is the nature of the Warm Springs fault and how far south does it extend into the city?
- Recent investigations by Lee Liberty at Boise State indicate that the downtown area is underlain by numerous faults distributed throughout much of the area (yikes).
- Significant urban development has occurred in the downtown area in the past decade and is continuing so this potential hazard has become more relevant.

Guidelines, Regulations, and Research

- *Fault setback requirements to reduce fault rupture hazards in Salt Lake County* by Batatian and Nelson (1999)
- *Salt Lake County Geologic Hazards* (2002)
- *New Guidelines for Evaluating Surface Fault Rupture Hazards in Utah* by Christenson, Batatian, and Nelson (2003)
- *Guidelines for Evaluating Surface Fault Rupture Hazards in Utah* by Lund et al. (2020) in UGS Circular 122
- Delineation of Special Study Zones based on Lidar mapping of the Wasatch fault by McDonald, Hiscock, Kleber and others (2020)

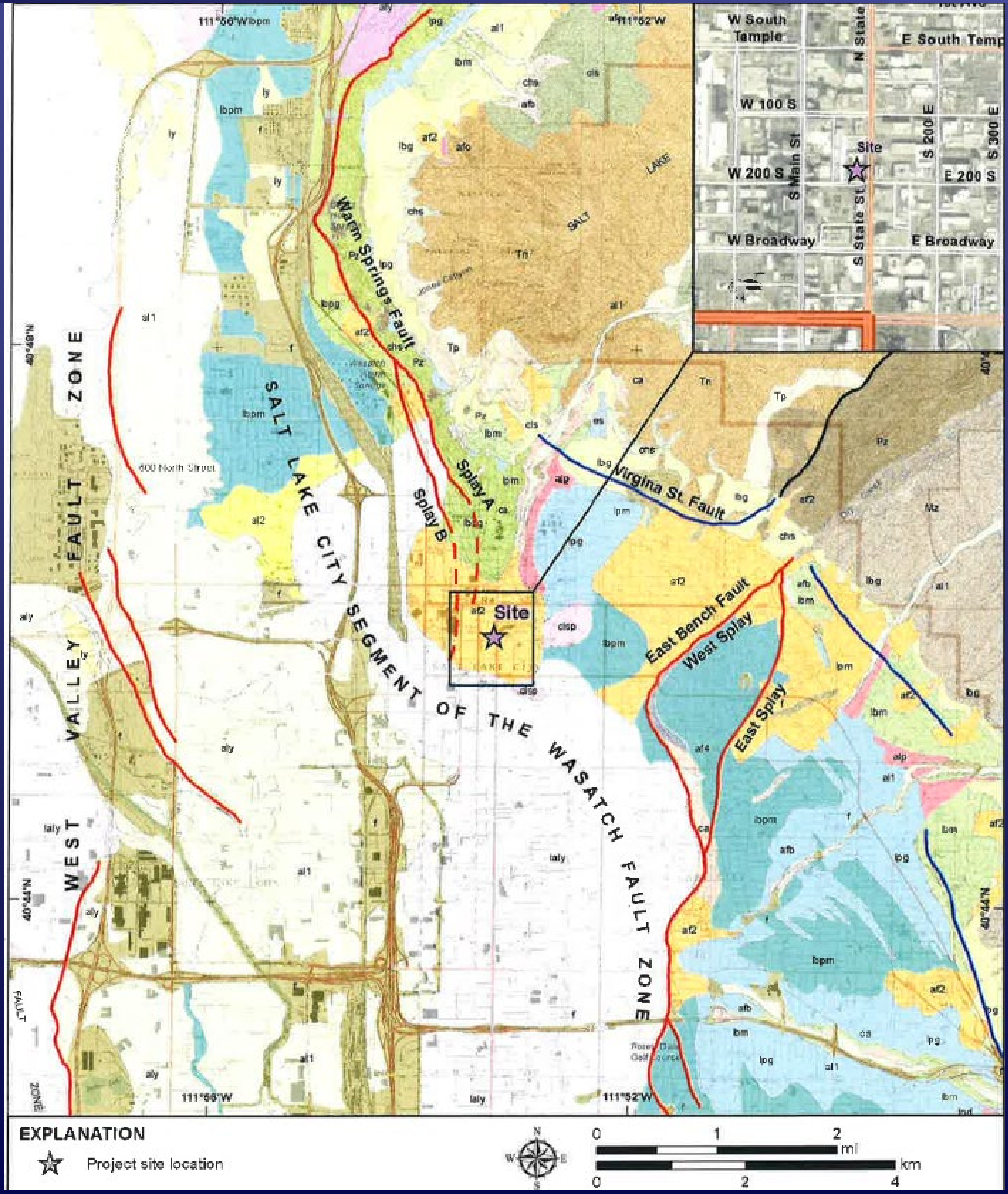
Salt Lake City Surface Rupture Special Study Areas



Salt Palace Convention Center Lessons From Simon and Bymaster (1999)

- An approximately 220-foot wide zone of deformation and ground failure is present in the eastern half of the site.
- The zone of deformation and ground failure is characterized by north-south trending, fault-bounded grabens with vertical displacement up to five feet, and by sand and gravel-filled dikes trending northeast and northwest.
- Seismicity induced liquefaction occurred at the site as evidenced by sand and gravel-filled dikes.
- Three reasonable hypotheses were examined to explain the zone of deformation, ground failure, and faults; in our opinion, the preponderance of evidence indicates that the zone of deformation, ground failure, and faults documented are a result of on-site tectonic faulting.
- The on-site faults and grabens probably resulted from a single seismotectonic event.
- The grabens are essentially coincident with the southern most extension of the Warm Springs fault as documented on published geologic maps of the Salt Lake City area.

Faulting in and Around Downtown SLC



Warm Springs Fault

- Geomorphic and subsurface data indicate fault Splay B extends at least as far south as Washington Elementary School, where 12 m of down-to-the-west displacement was observed in borings and trenches (Robison and Burr, 1991).
- There is evidence that post-Bonneville faulting along Splay B may extend as far south as 4th South (Simon and Shlemmon, 1999; Leeflang, 2008)
- In contrast, direct evidence for Holocene faulting along Splay A has not been found and recent excavations north and northeast of Temple Square suggest that either Holocene faulting on Splay A dies out somewhere north of 1st North, or this trace may be located slightly east and closer to Main Street.

Warm Springs Fault

- Based on differences in stratigraphic elevations interpreted from CPT borings, Leeflang (2008) interpreted vertical offsets related to faulting and that fault Splays A and B to extend to 4th South.
- Given the spacing between Leeflang's (2008) boreholes (200 to 300 m), the differences in elevation are relatively small (≤ 8 m) and could easily be related to paleo-topography on the pre-Bonneville City Creek fan surface, instead of being caused by faulting.
- A primary consideration in evaluating the possibility for secondary surface-deformation is whether the Warm Springs and East Bench faults rupture together in large earthquakes.
- If they do, there is a possibility for associated secondary surface faulting, warping and/or tilting, depending on the geometry of the subsurface connection between the faults.

Warm Springs Fault

- Based on map and inferred structural relations, previous investigators have all considered the Warm Springs and East Bench faults to be part of the Salt Lake City segment, inferring that they rupture together in large earthquakes.
- However, it is noteworthy that because the area has long been urbanized, the timing of earthquake ruptures on the Warm Springs fault is poorly constrained, with all of the detailed paleoseismic history coming from sites on the southern, less urbanized part of the Salt Lake City segment and on the East Bench fault (DuRoss et al., 2012).
- Therefore, it is possible that the Warm Springs fault may rupture with the Weber segment, but based on the geomorphic and structural relations, it is still more likely it ruptures with the East Bench fault as interpreted by numerous previous studies.

Connection Between Warm Springs and East Bench Sections

- Another important consideration in evaluating the potential for secondary surface-deformation at the site is the geometry and kinematics of the subsurface connection between the Warm Springs and East Bench faults.
- In the past, some investigators have speculated that that the short east-west striking Virginia Street fault along the southern margin of the Salt Lake salient may serve to transfer slip between the East Bench and Warm Springs fault (Bruhn et al., 1992).
- Another linkage possibility is that of a buried oblique-slip fault connecting the East Bench fault with Scott and Shroba's (1985) Splay A of the Warm Springs fault, as inferred and used by Roten et al. (2011) in their ground motion analysis.

Rupture Scenarios A and B for the Warm Springs-East Bench Fault Stepover

BSU Investigation

- The most significant evaluation of primary and secondary surface faulting in Salt Lake City was performed by Boise State University (BSU) as described in Liberty et al. (2018).
- Liberty et al. (2018) acquired 35 km of new seismic land streamer data over two field seasons, 2015 and 2017, sponsored by USGS NEHRP funding. The surveys revealed a complex pattern of faulting, folding, and shallow deformation in downtown Salt Lake City.
- Based on the surveys that extended as far south as 800 South, Liberty et al. (2018) suggested that the Warm Springs fault extends into downtown Salt Lake City as a broad zone of faulting.
- The seismic reflection images show folding and faulting beneath lateral-spread deposits and in the area between the East Bench and Warm Springs faults in the downtown area (Liberty et al., 2018). Most significantly, the zone of distributed faulting extends to within a few meters of the ground surface.

Summary

- In summary, there is considerable uncertainty as to the southern extent and geometry of the Warm Springs fault and how it connects to the East Bench fault, which in turn affects the surface faulting hazard.
- It appears (my interpretation) that the potential for primary surface faulting hazard is not significant based on the existing studies and the BSU investigations.
- Also based on the BSU analyses, the potential for significant secondary surface faulting hazard also appears to be low although the uncertainty in this assessment is larger than for primary faulting.

Summary

- To my knowledge, no building in the downtown Salt Lake City has been designed for surface faulting or deformation.
- Inspection of at least three excavations in the downtown area has shown no surface deformation although deformation may be localized depending on the local site conditions and/or below the threshold of detectability.
- The only detailed trench investigation that has been performed in the downtown area was for the Salt Lake City Emergency Operations Center (3rd E and 5th S) yielded no evidence of surface deformation.
- So is there a significant surface faulting/deformation hazard to mitigate in downtown SLC?

Backprojection imaging of the 2020 Magna, Utah earthquake using a local dense strong motion network

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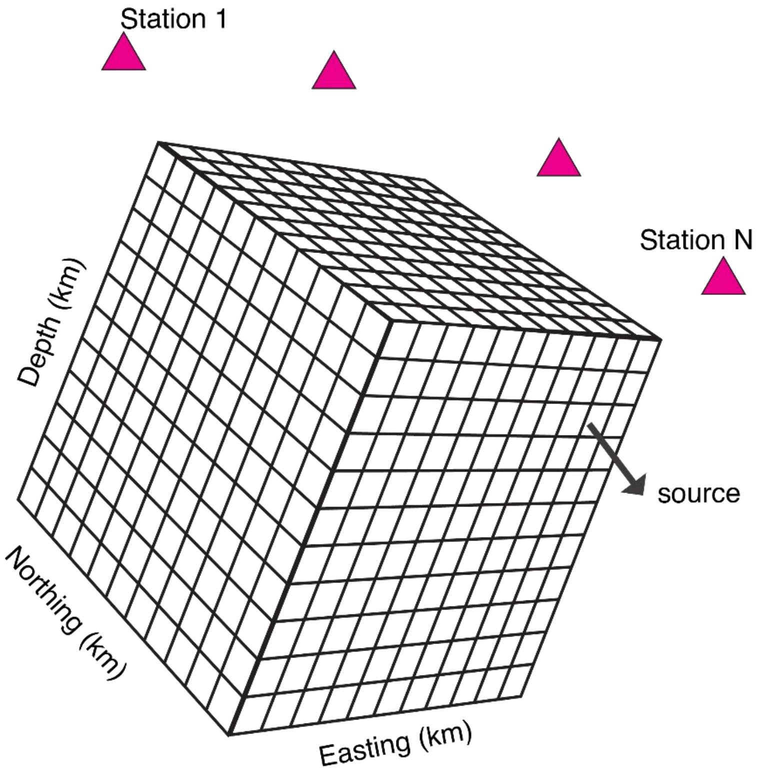
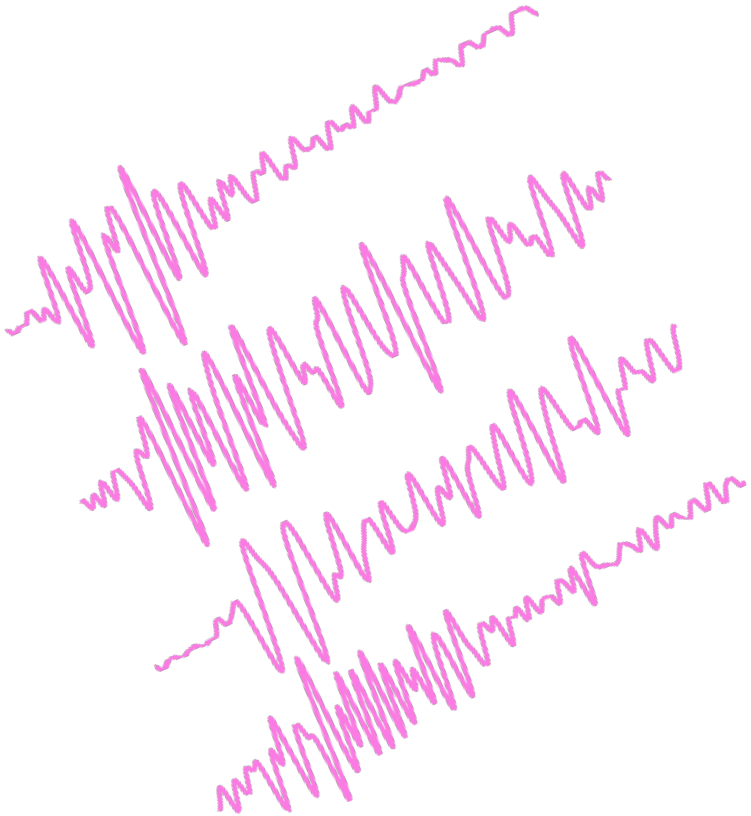
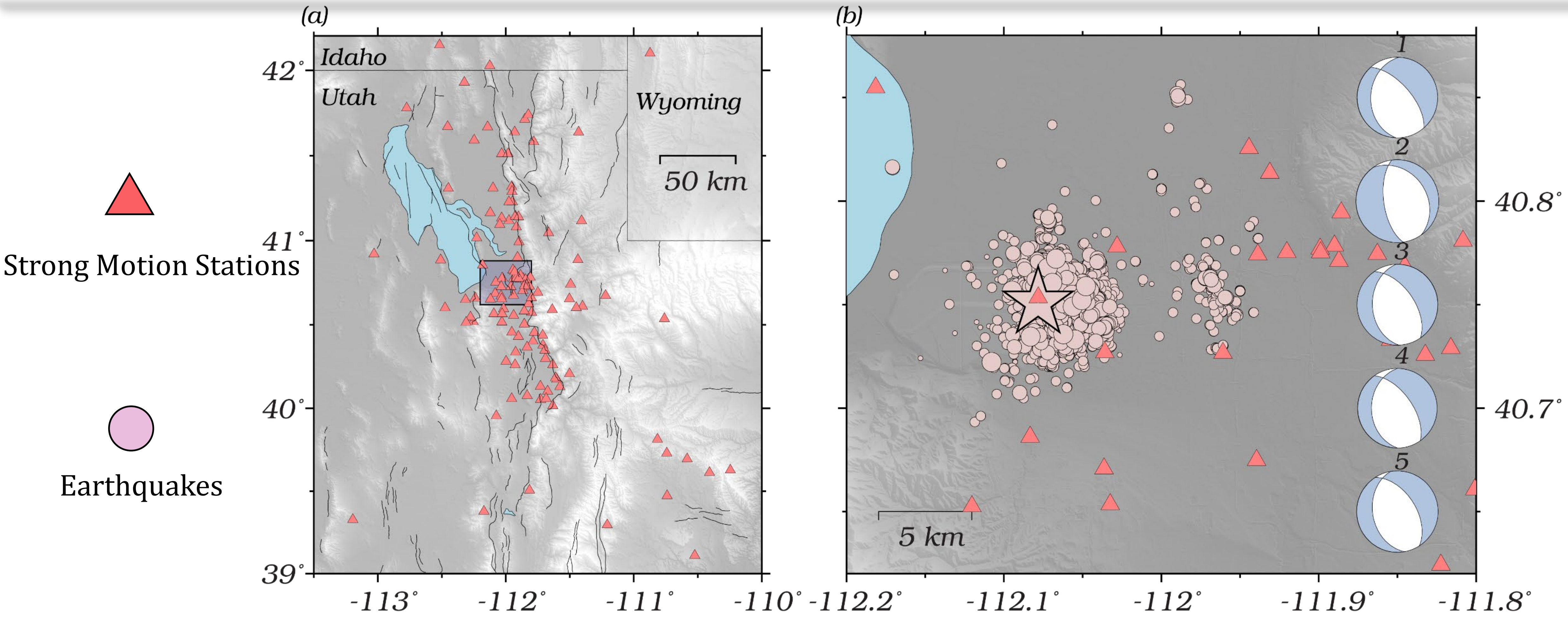
Outline



1. *Introduction*
2. *Data and processing*
3. *Results*
4. *Resolution Tests*
5. *Conclusions*



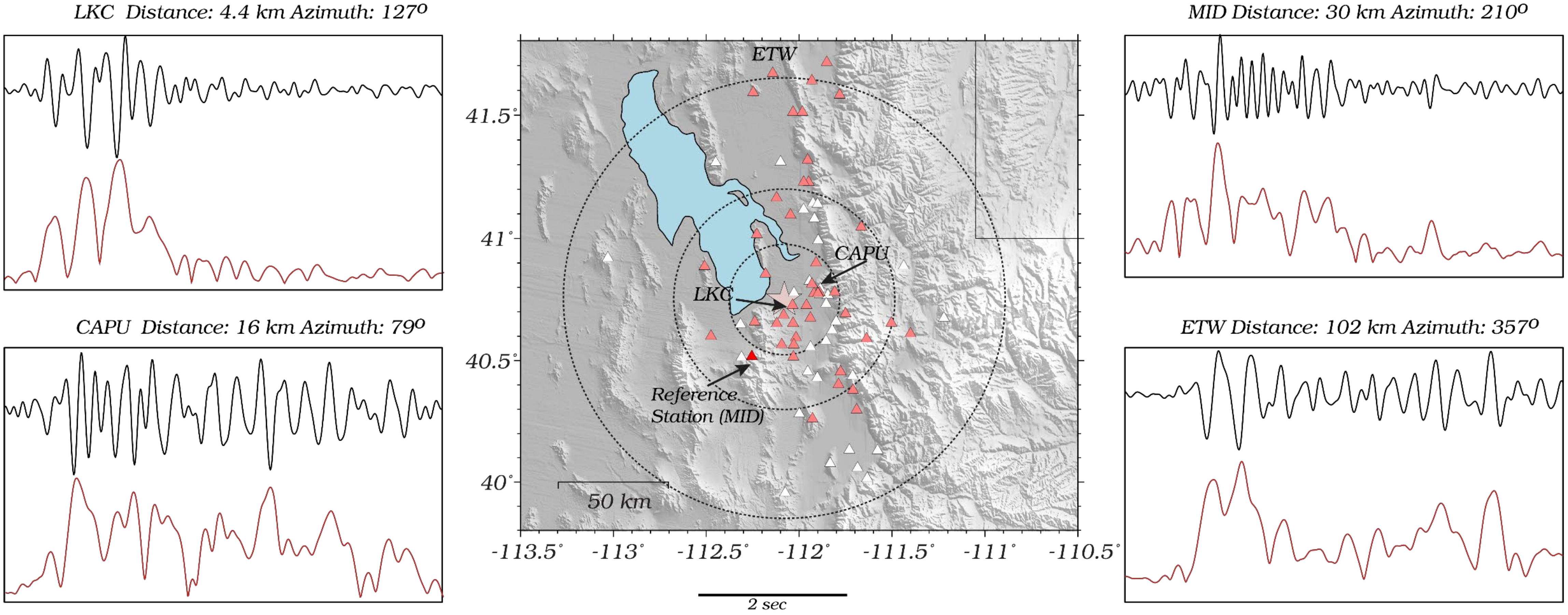
1. Introduction



(a) Overview of the **UUSS regional strong motion network** (triangles). Shaded box denotes the aftershock area. (b) The M_w 5.5 mainshock (star) and its aftershock sequence (solid circles) (Pang *et al.*, 2020)

Mesimeri et al., 2020 SRL

2. Data and Processing

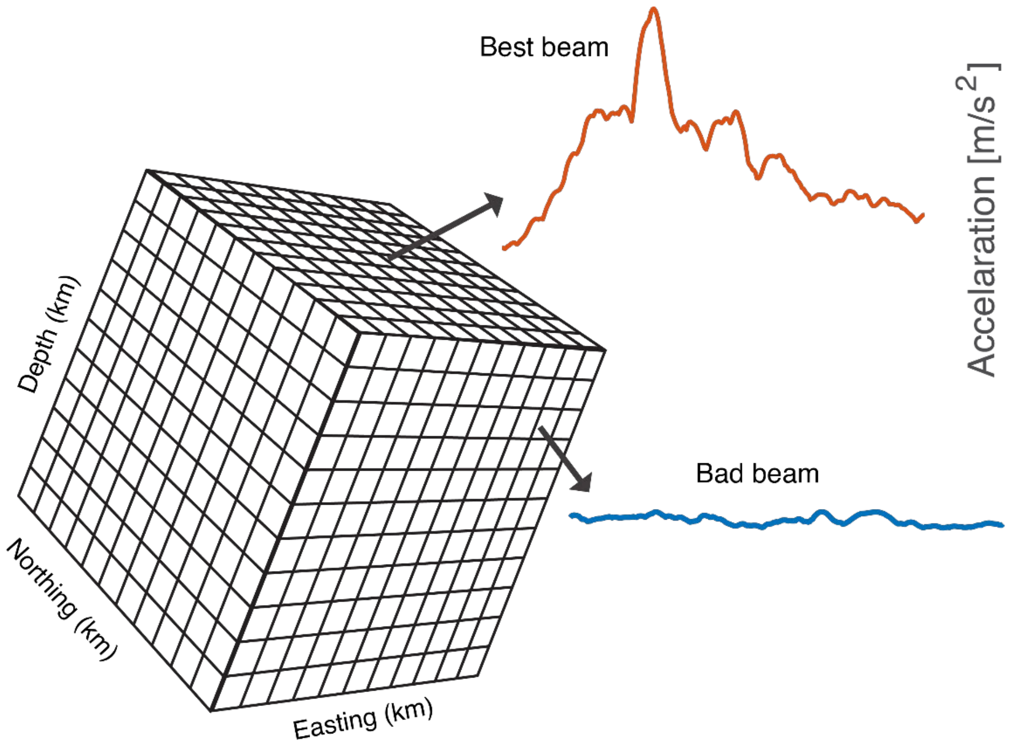


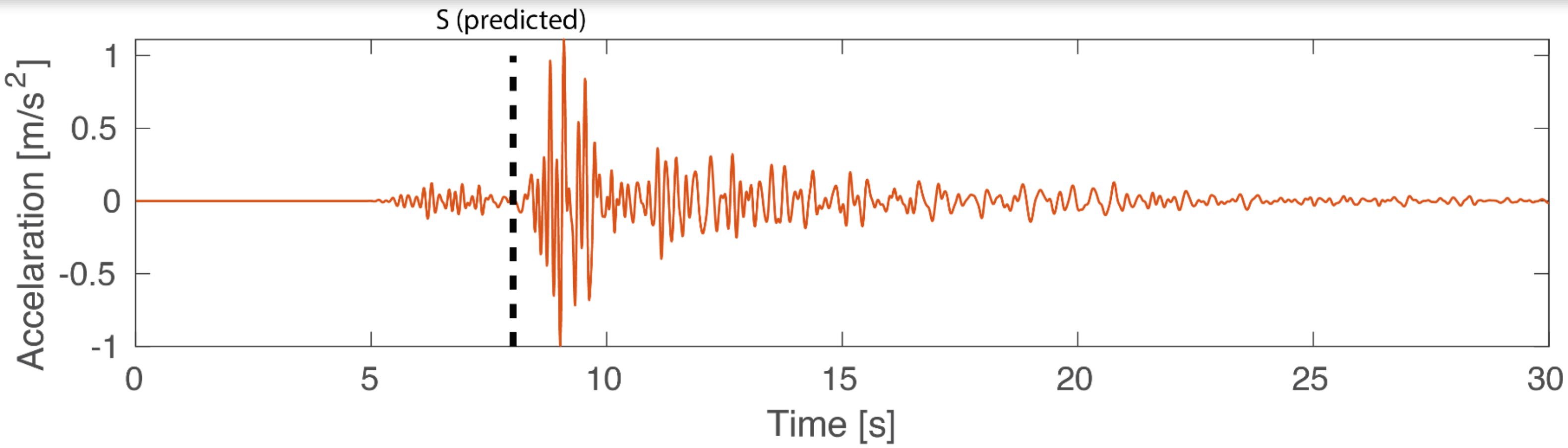
- Pick S-phases on the horizontal components
    - Rotate to the direction of the Mainshock
- Keep the transverse component
    - Compute envelopes

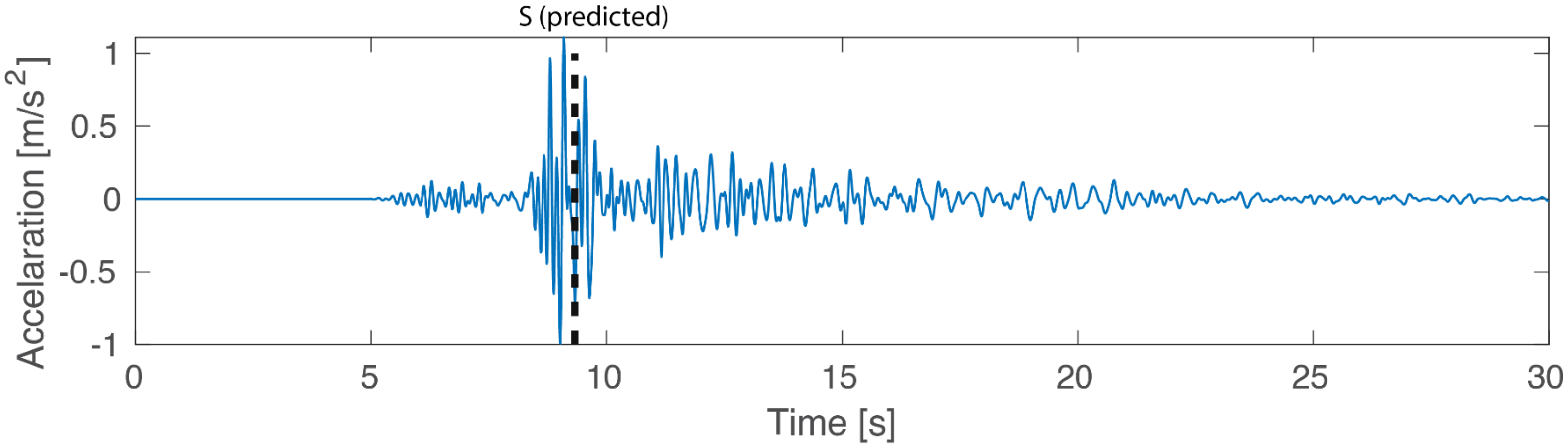
Mesimeri et al., 2020 SRL

2. Data and Processing

Sum all waveforms starting at the predicted travel time and get one beam





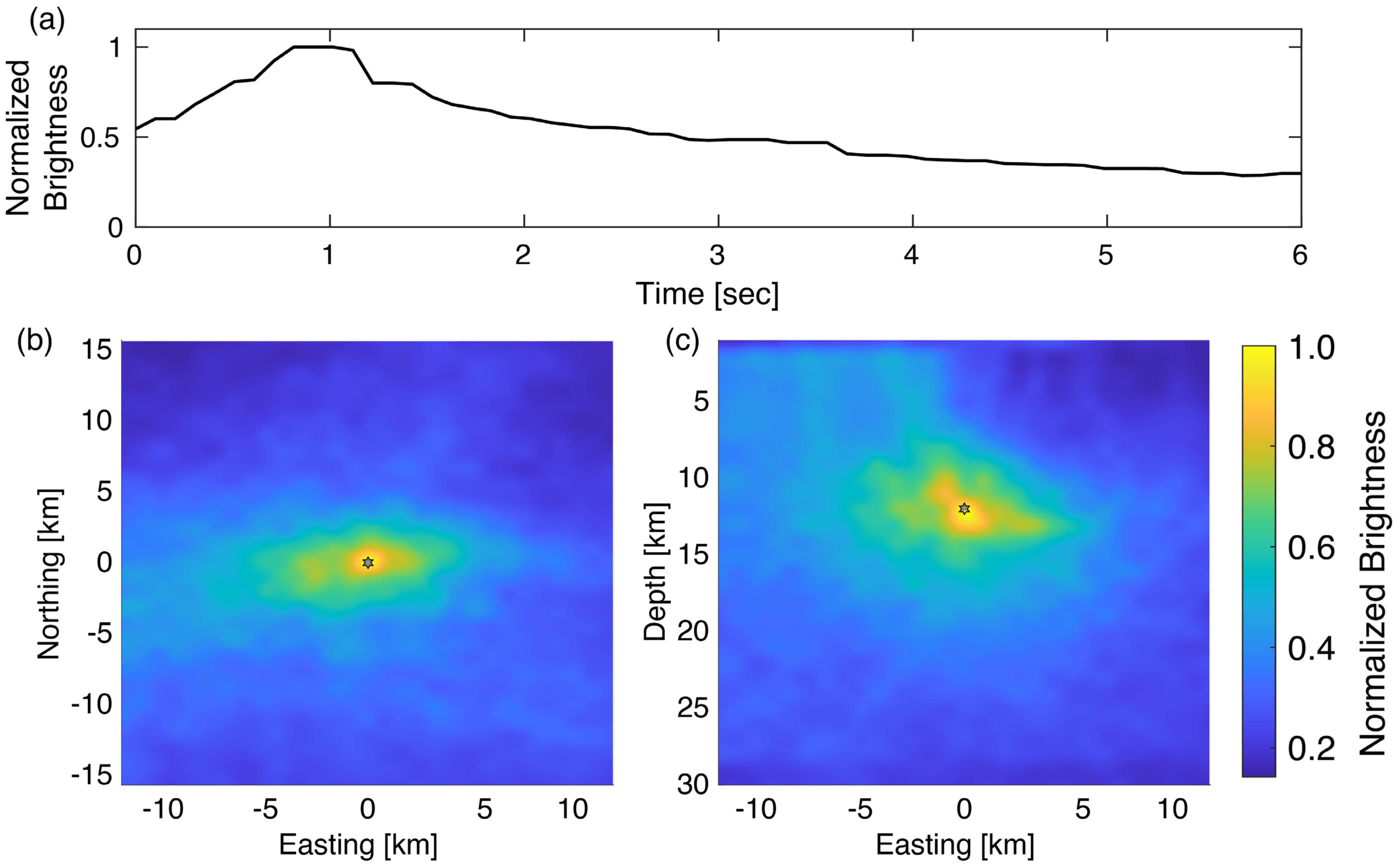


3. Results

(a) Composite normalized [0–1] brightness function with time for fixed depth [12 km]. Zero time corresponds to the S-arrival.

(b) Epicentral location obtained with the backprojection method.

(c) Depth vs easting for the mainshock obtained with the backprojection method.

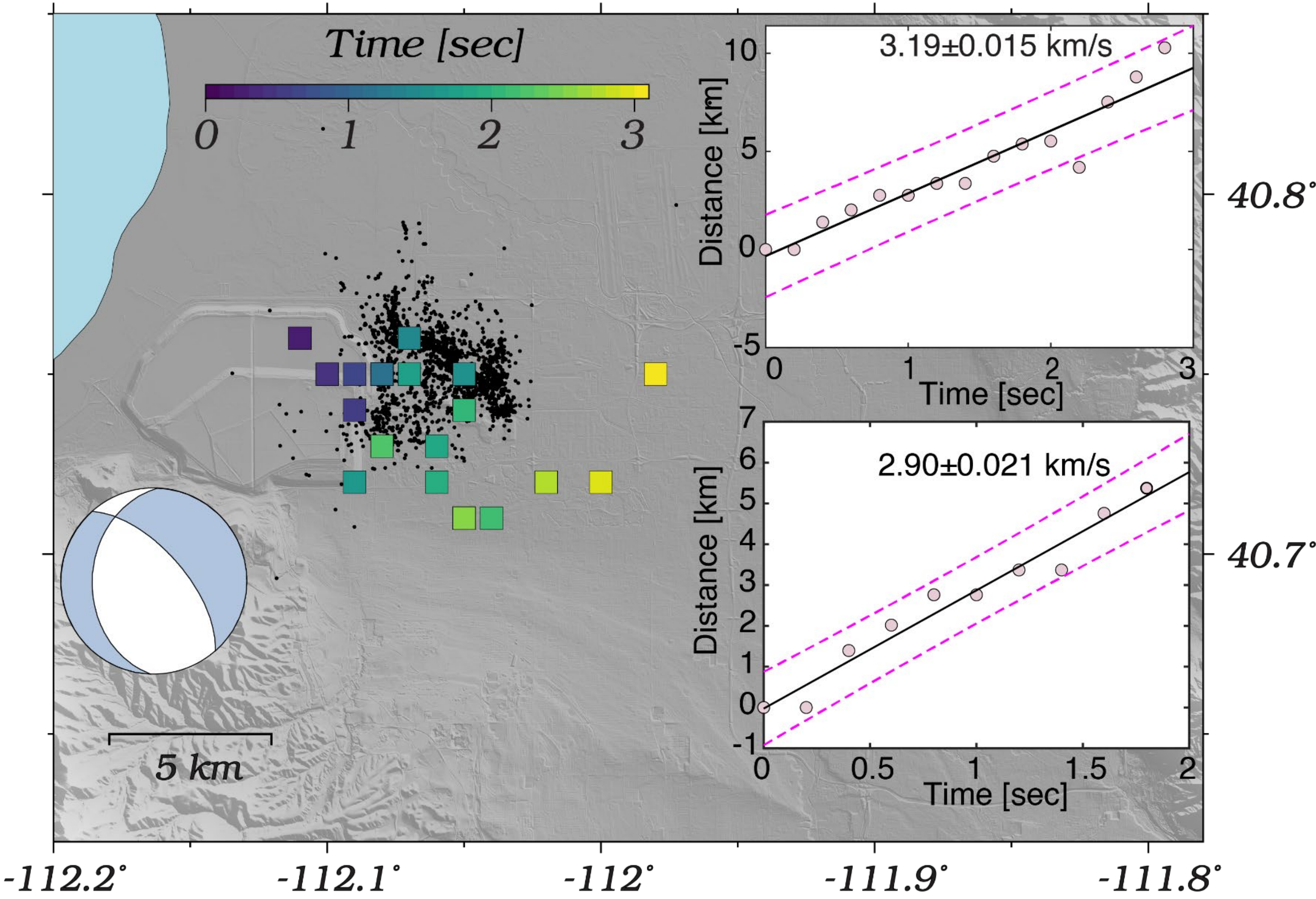


Mesimeri et al., 2020 SRL

Spatial distribution of the maximum normalized brightness for each time step (**squares**).

Black **dots** show aftershocks during the first 24 hours (Pang *et al.*, 2020).

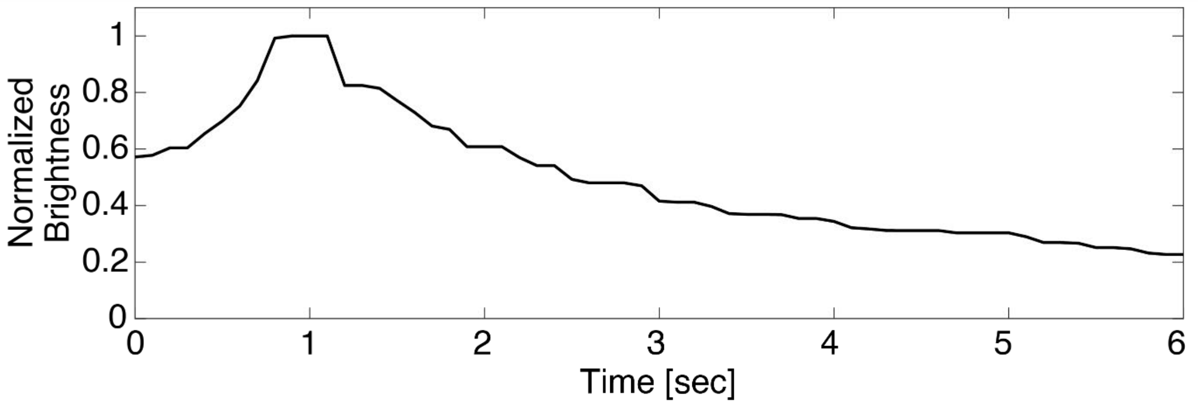
Inset plots: Distance vs time for the maximum normalized brightness.



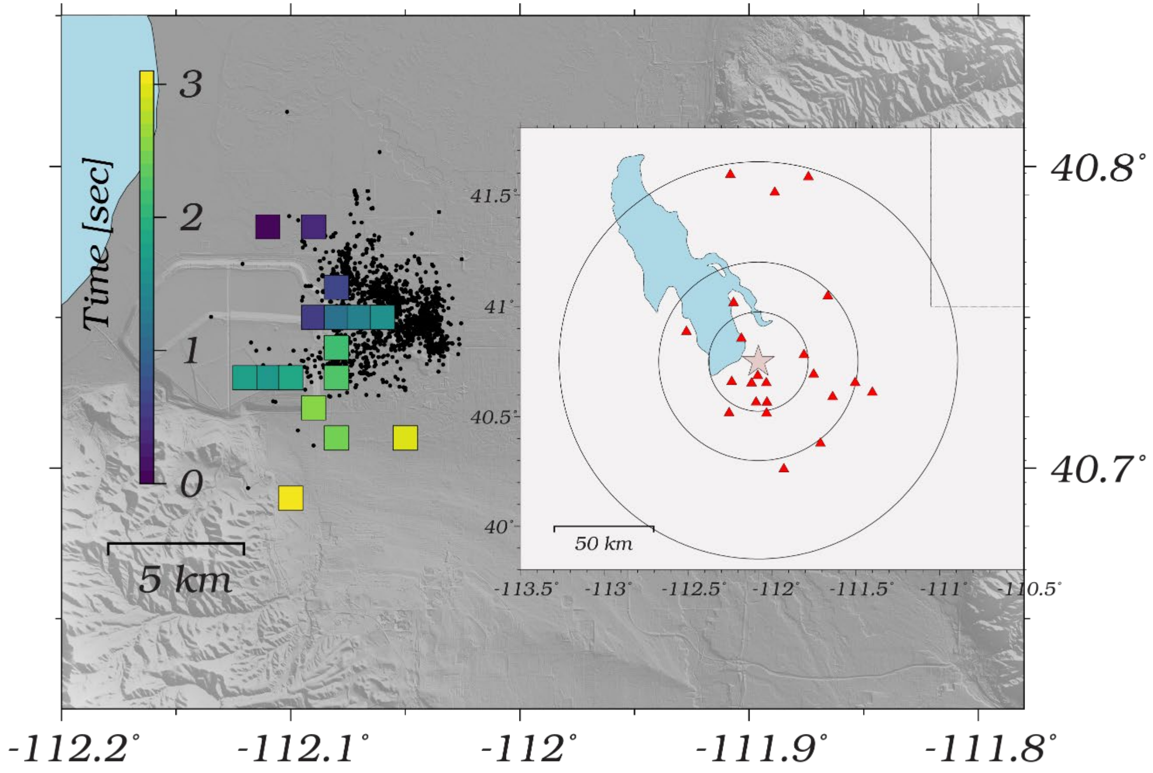
Mesimeri et al., 2020 SRL

Backpojection results for strong motion stations located on rock sites.

Composite normalized [0–1] brightness function with time for fixed depth [12 km]. Zero time corresponds to the S-arrival.



Spatial distribution of the maximum normalized brightness for each time step (**squares**). Black dots show aftershocks during the first 24 hours (Pang *et al.*, 2020). **Inset map**: Map of strong motion stations located on rock sites



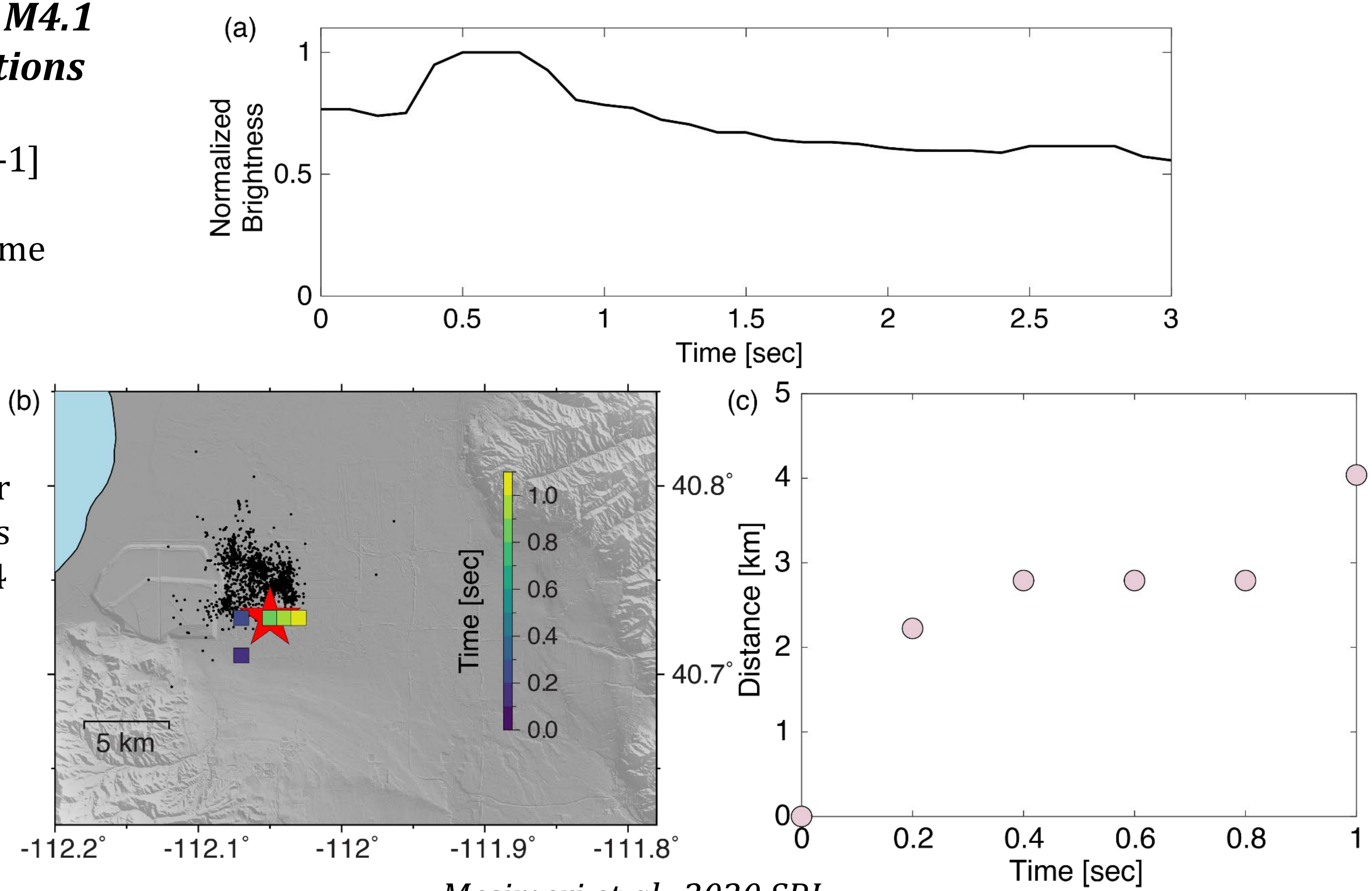
Mesimeri et al., 2020 SRL

Backprojection results for a M4.1 aftershock using all the stations

(a) Composite normalized [0–1] brightness function with time for fixed depth [8 km]. Zero time corresponds to the S-arrival.

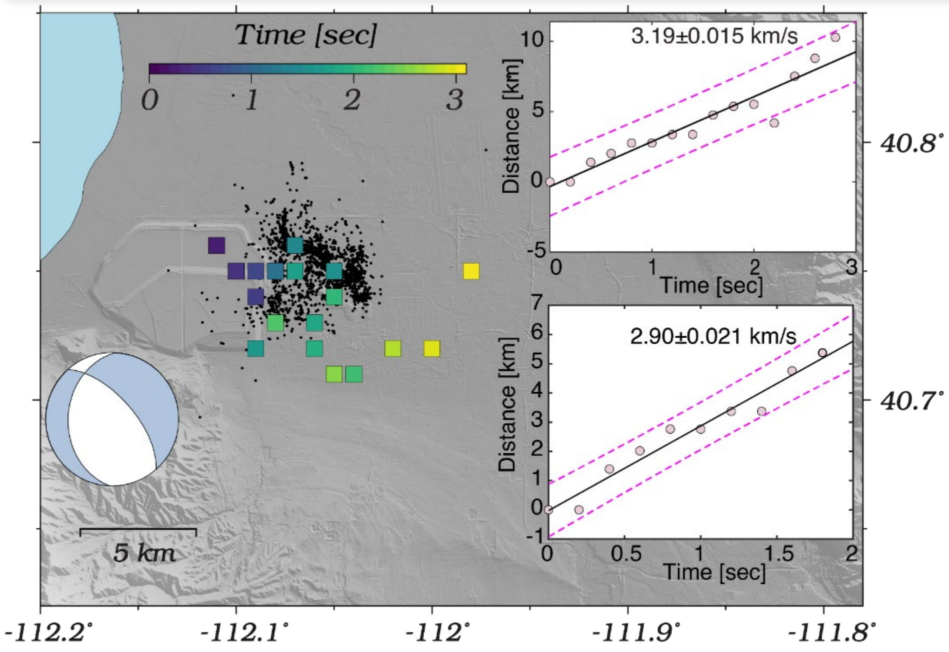
(b) Spatial distribution of the maximum normalized brightness for each time step (**squares**). Black dots show aftershocks during the first 24 hours (Pang *et al.*, 2020). Red star denotes the M4.1 aftershock epicenter.

(c) Distance Vs time for the maximum normalized brightness.



Mesimeri et al., 2020 SRL

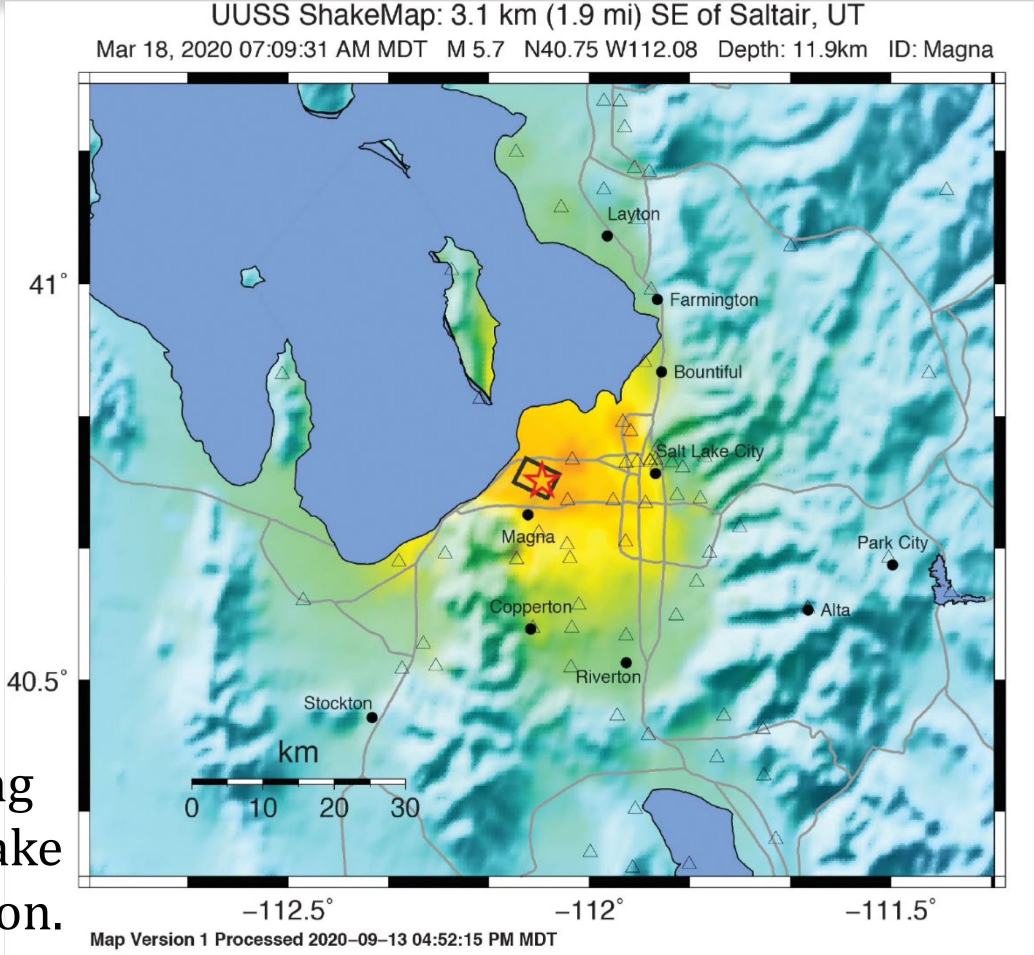
5. Conclusions



Mesimeri et al., 2020 SRL

- Up-dip unilateral WNW-ESE rupture
- Average rupture speed 2.9–3.2 km/s

ShakeMap showing shaking intensities within the Salt Lake Valley and surrounding region.

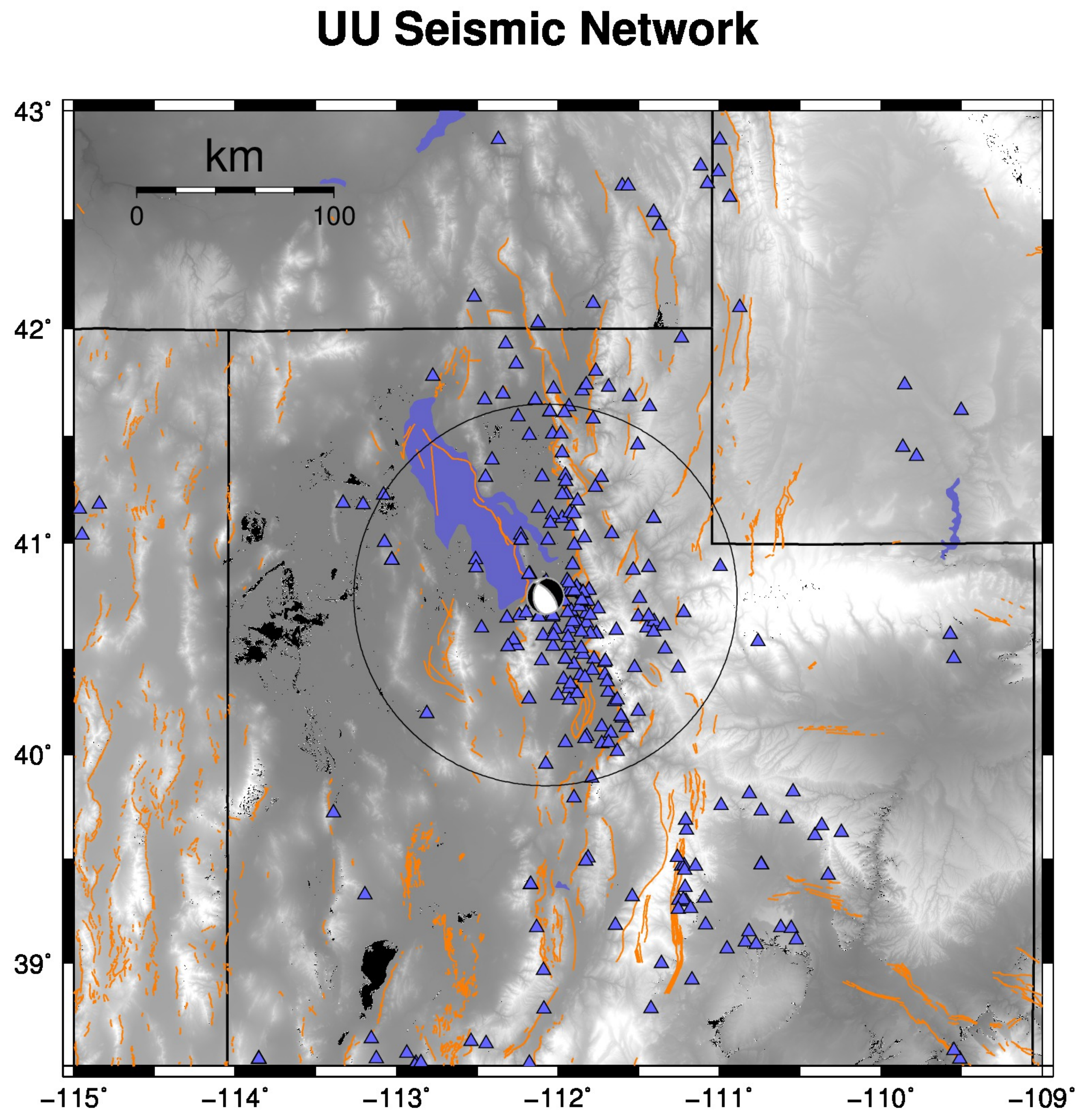


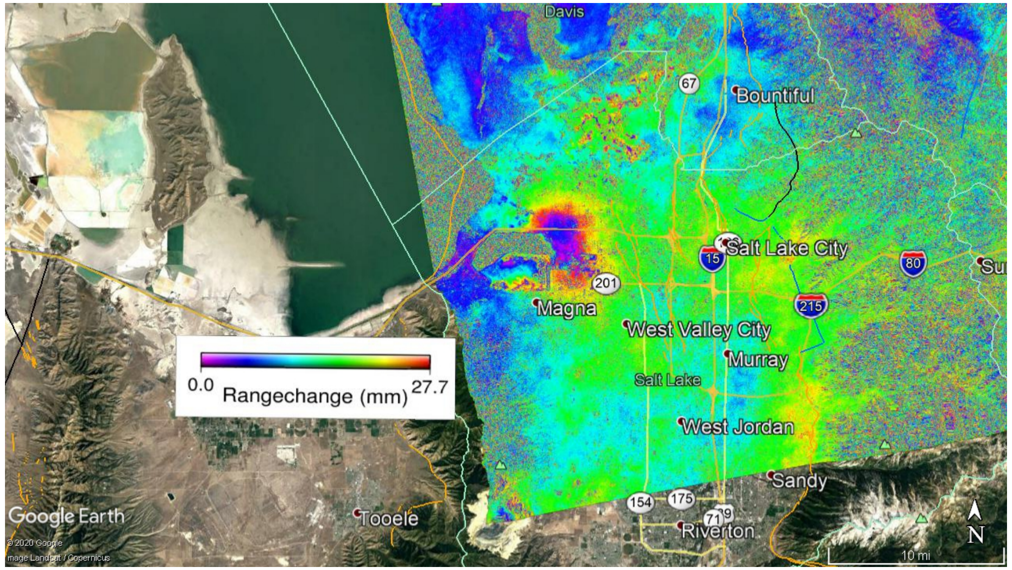
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	None	None	None	Very light	Light	Moderate	Mod./heavy	Heavy	Very heavy
PEAK ACC.(%g)	<0.1	0.5	2.4	6.7	13	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	11	22	43	83	>160
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, *et al.*; 1999

Pankow et al., 2021 SRL

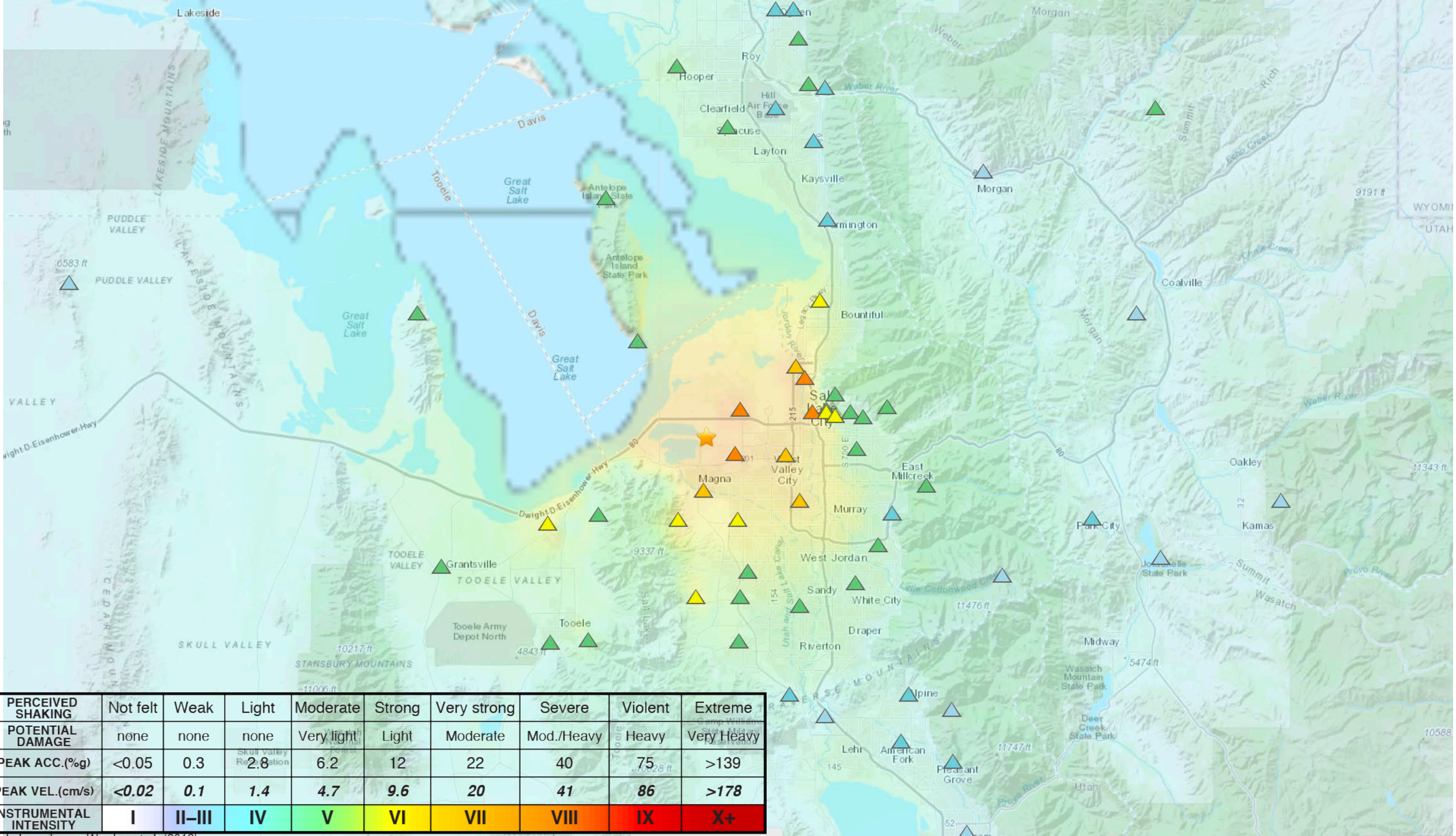
Coseismic slip and afterslip of the M5.7 March 18, 2020 Magna, Utah earthquake



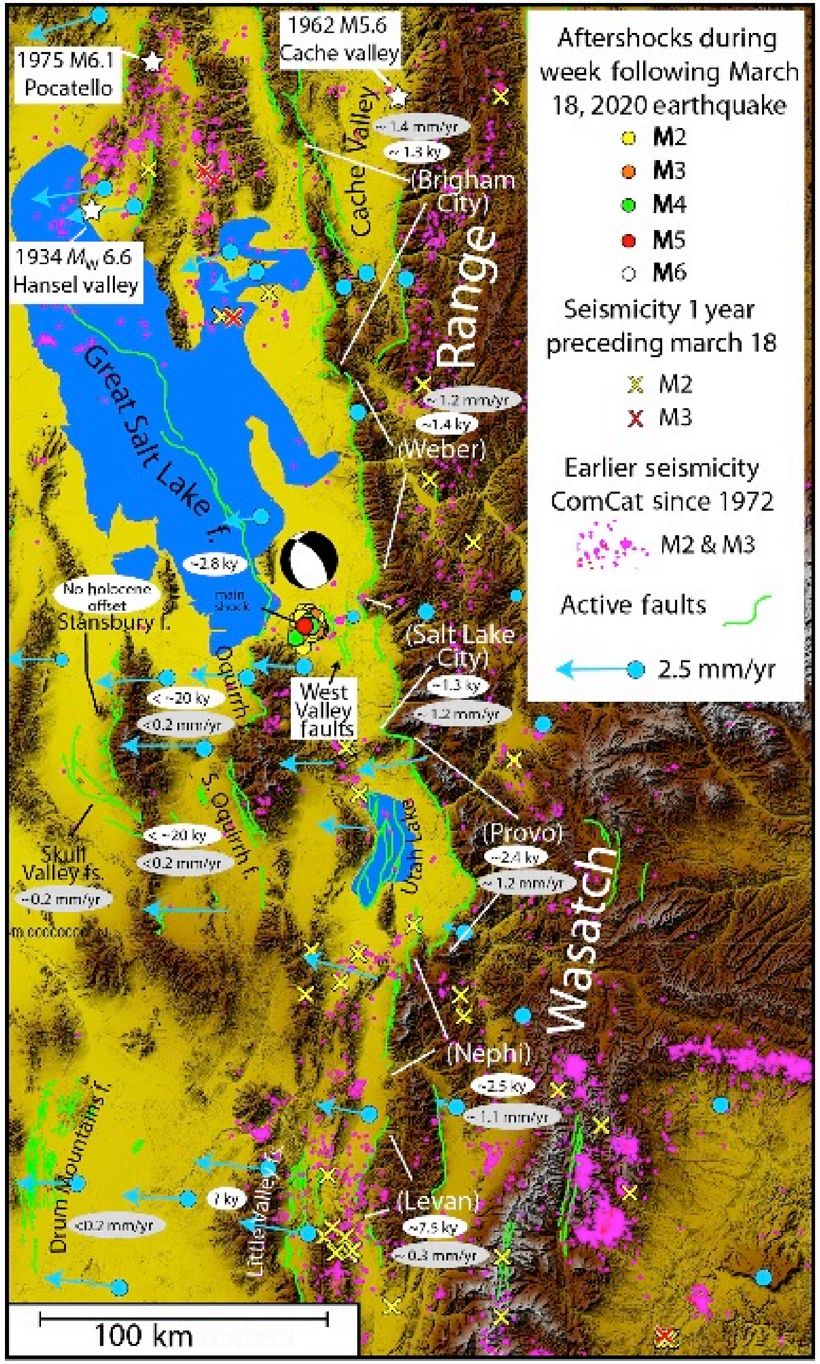


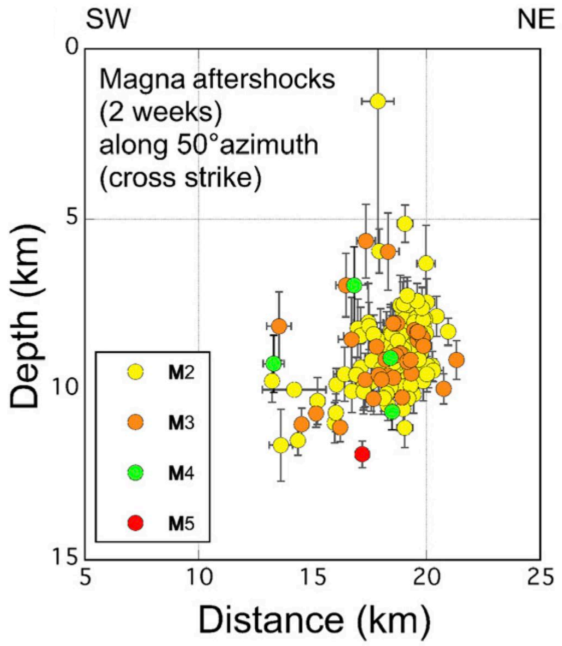
Kinematic slip modeling of the M5.7 March 18, 2020 Magna, UT earthquake

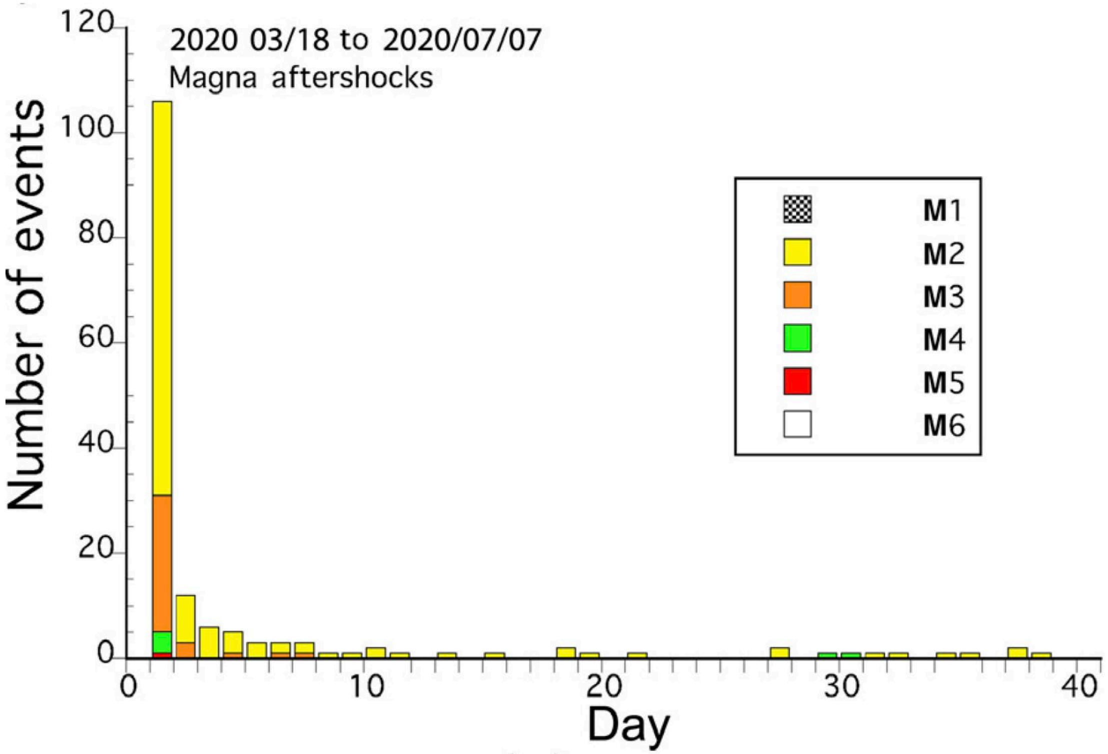
- Model InSAR, GPS & seismic data
- Test different trial fault geometries



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

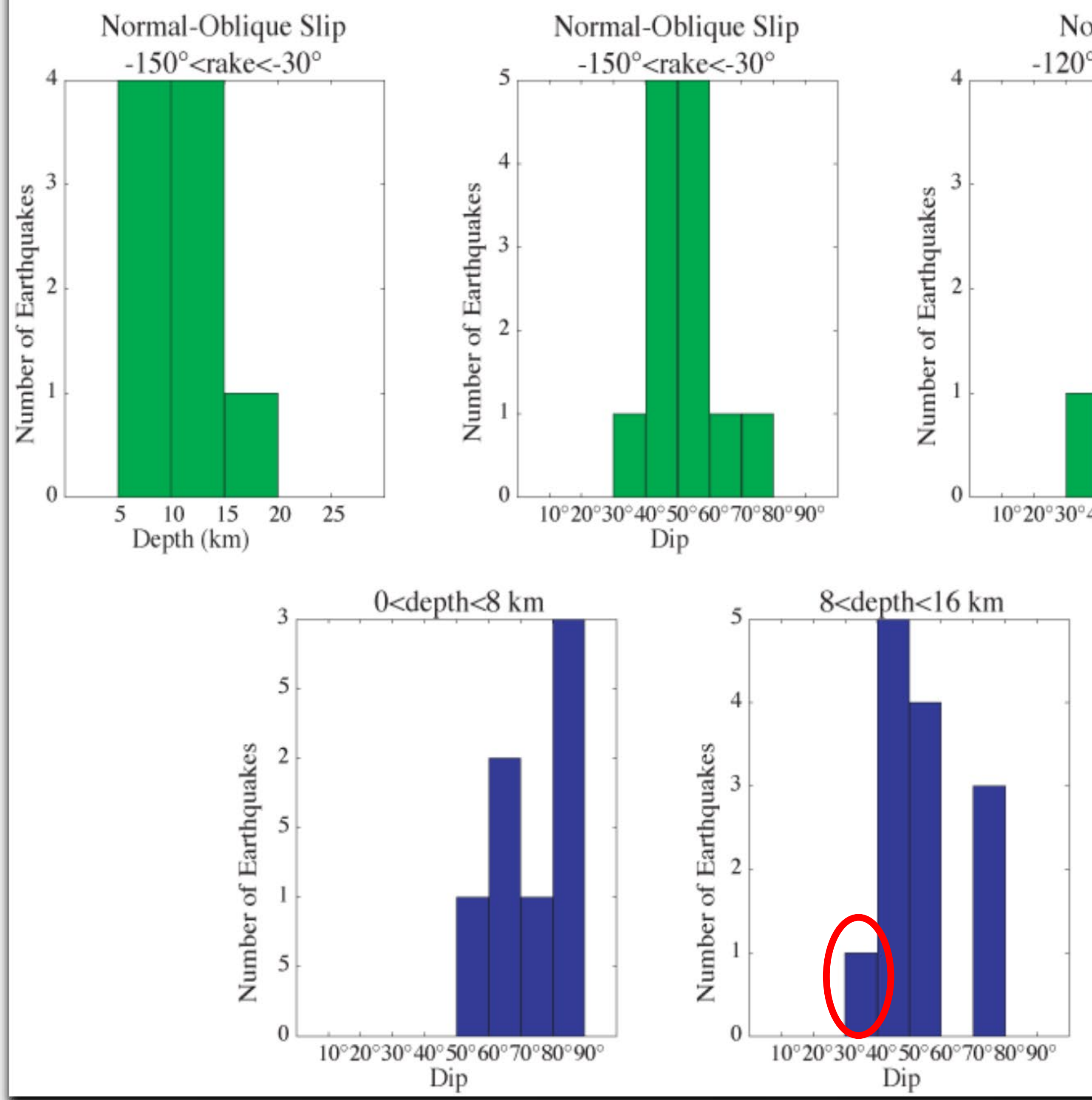






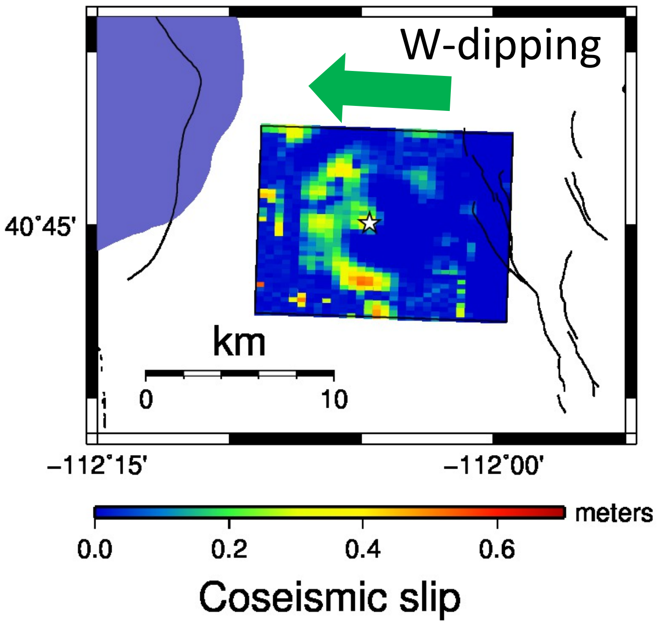
Wesnousky (2021)

Depth and Dip Histograms of Large Normal Faulting Earthquakes

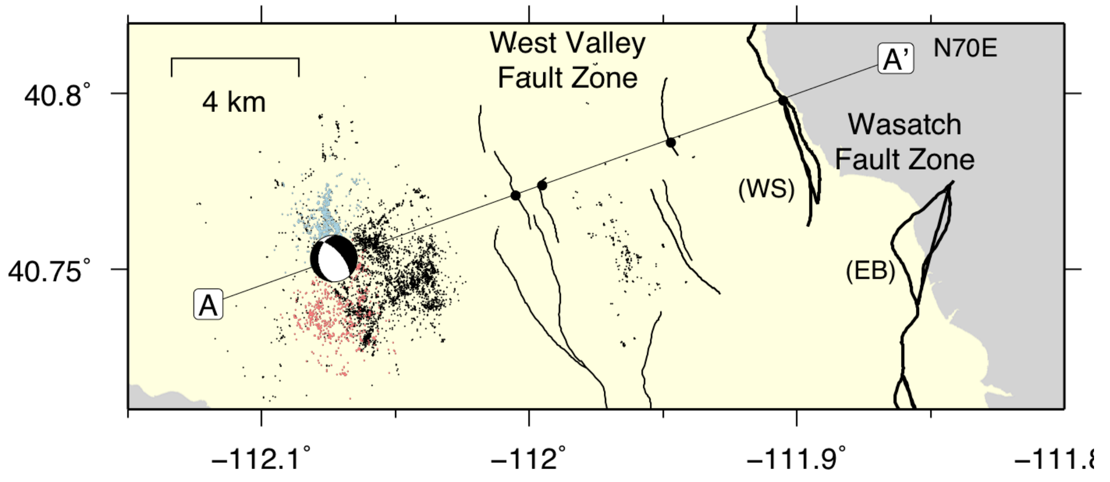


Data from focal mechanisms (Doser and Smith, 1982, Jackson, 1987, Pezzopane and Dawson, 1998)

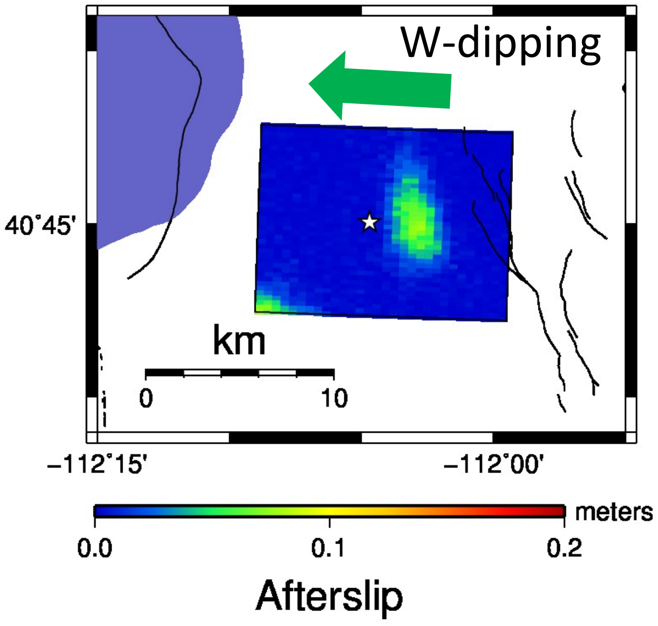
Courtesy of Bob Smith

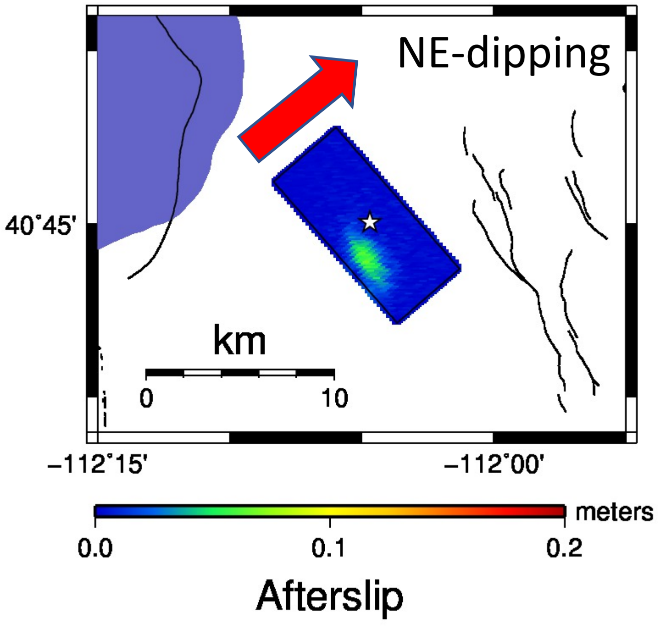


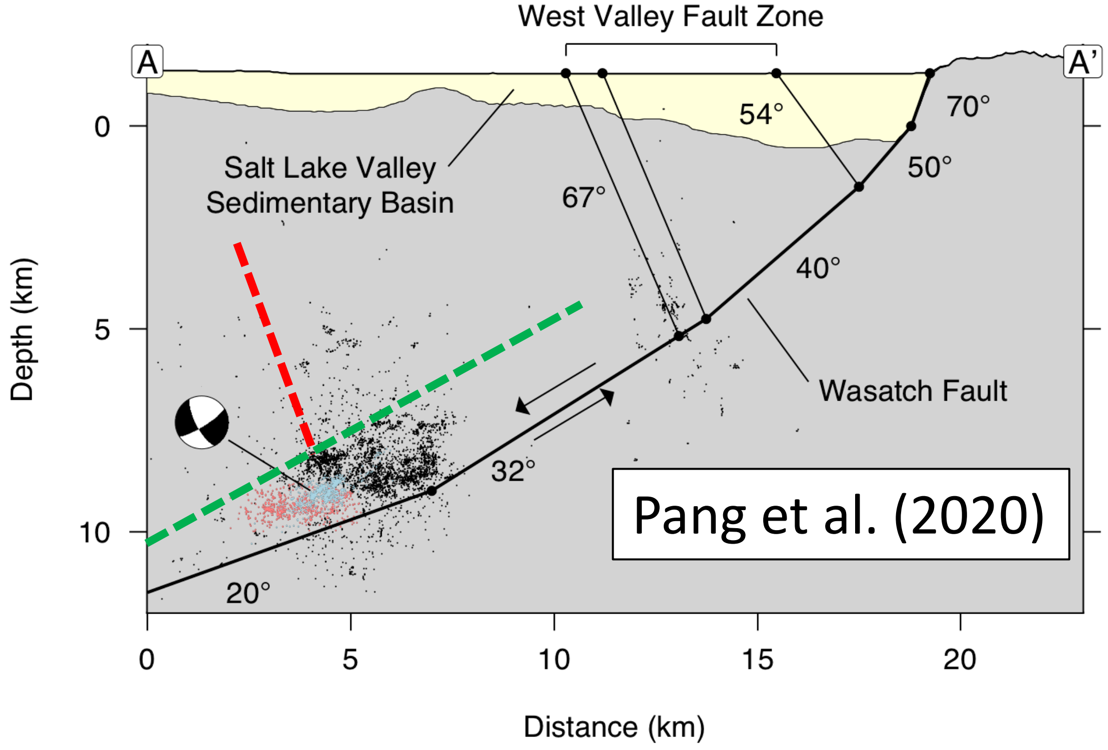
Coseismic slip on the W-dipping Wasatch fault at depth + triggering of afterslip updip of the hypocenter



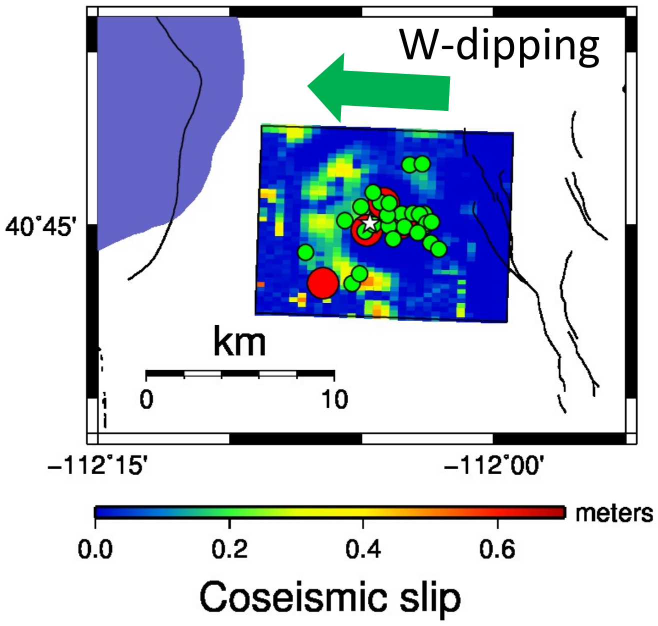
Pollitz et al. (2020)





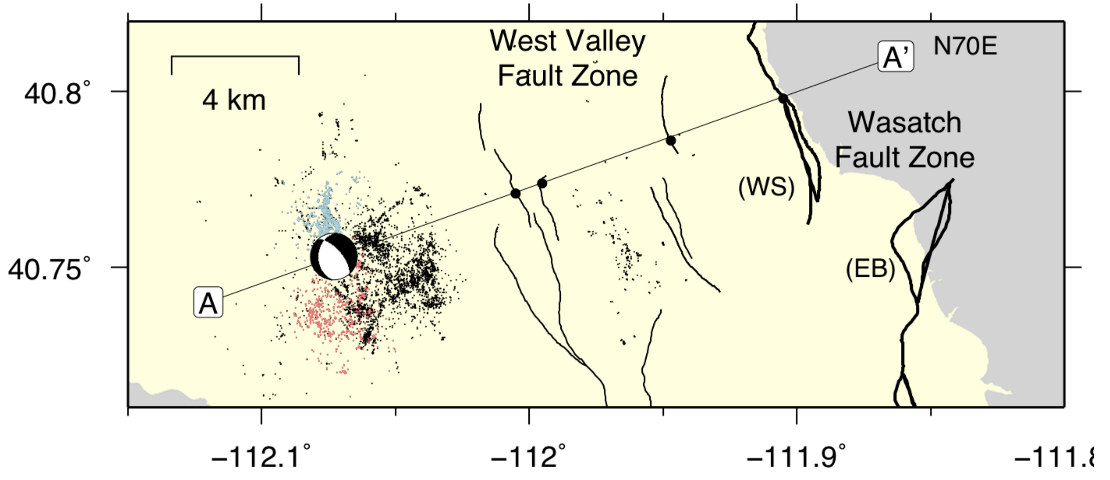


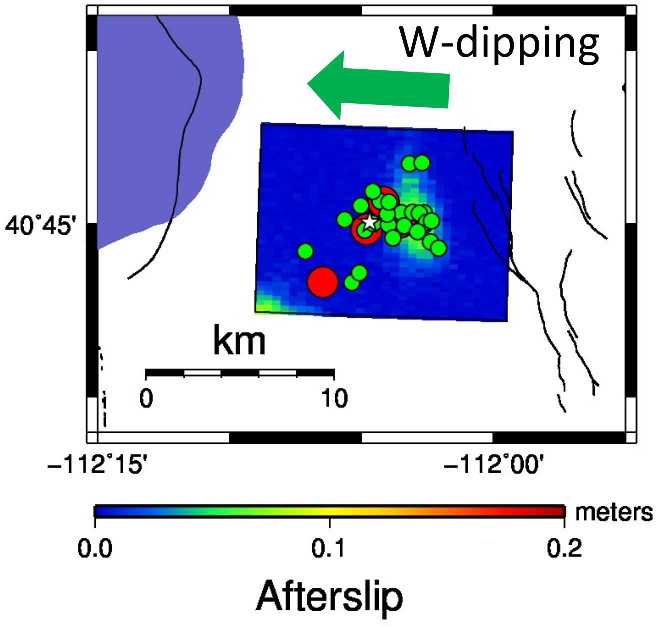
Pang et al. (2020)

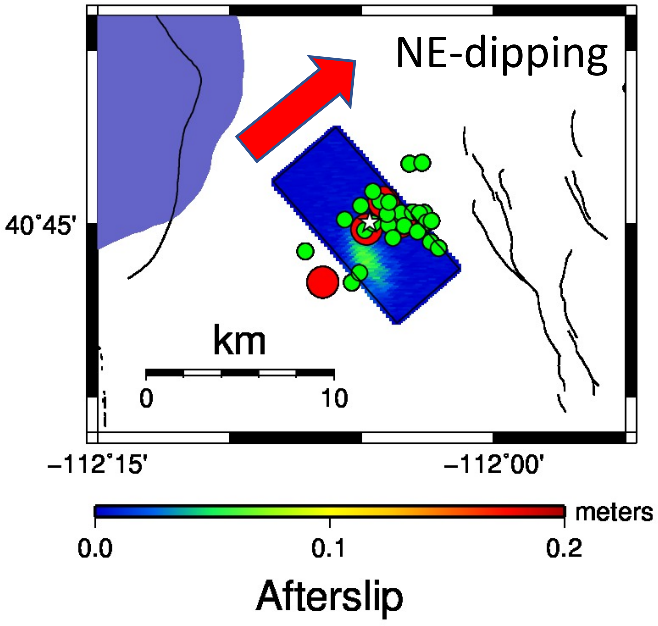


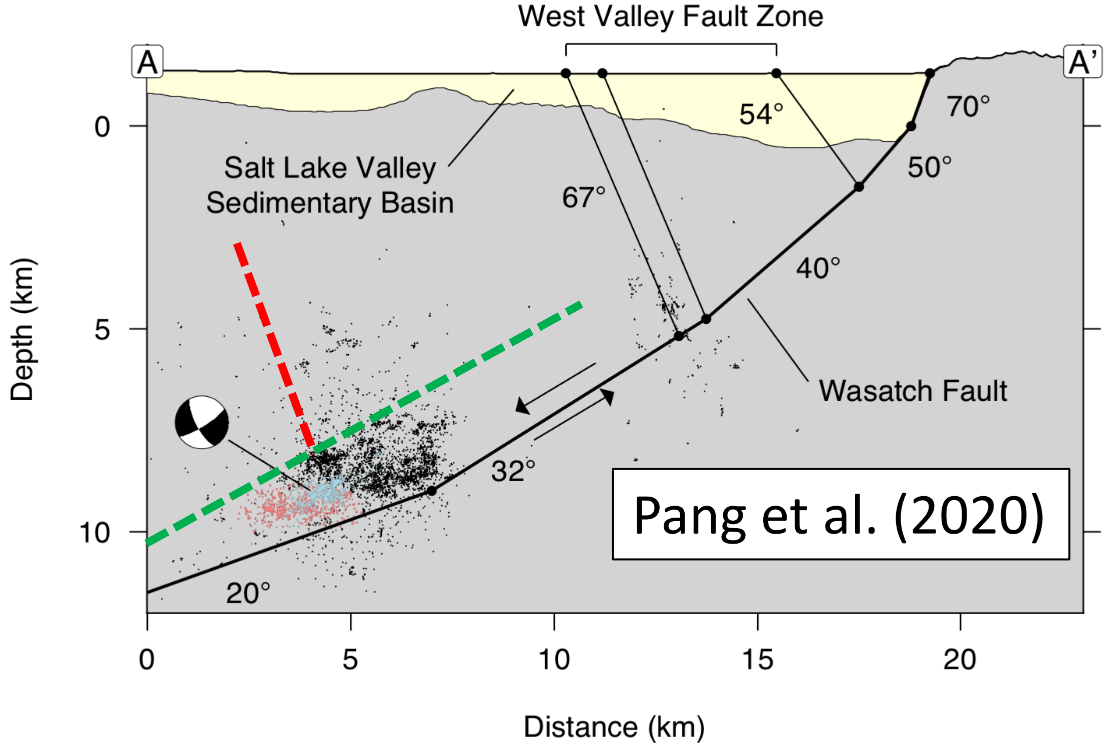
Coseismic slip on the W-dipping Wasatch fault at depth + triggering of afterslip updip of the hypocenter

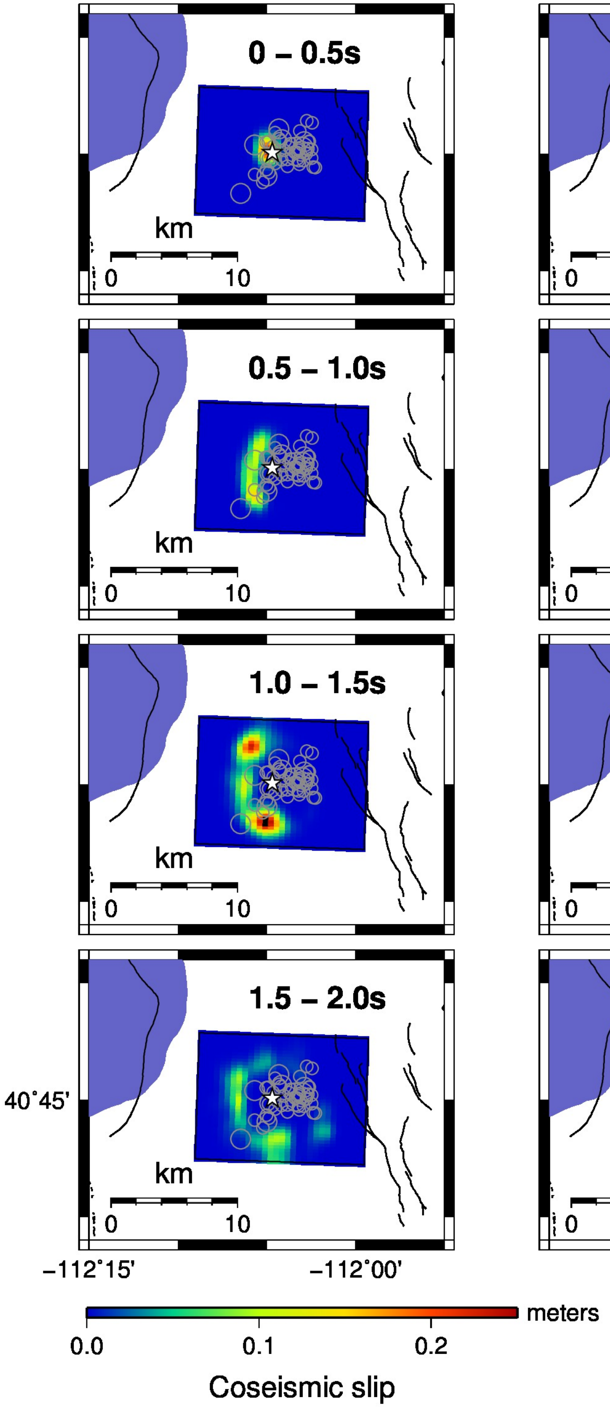
Pollitz et al. (2020)



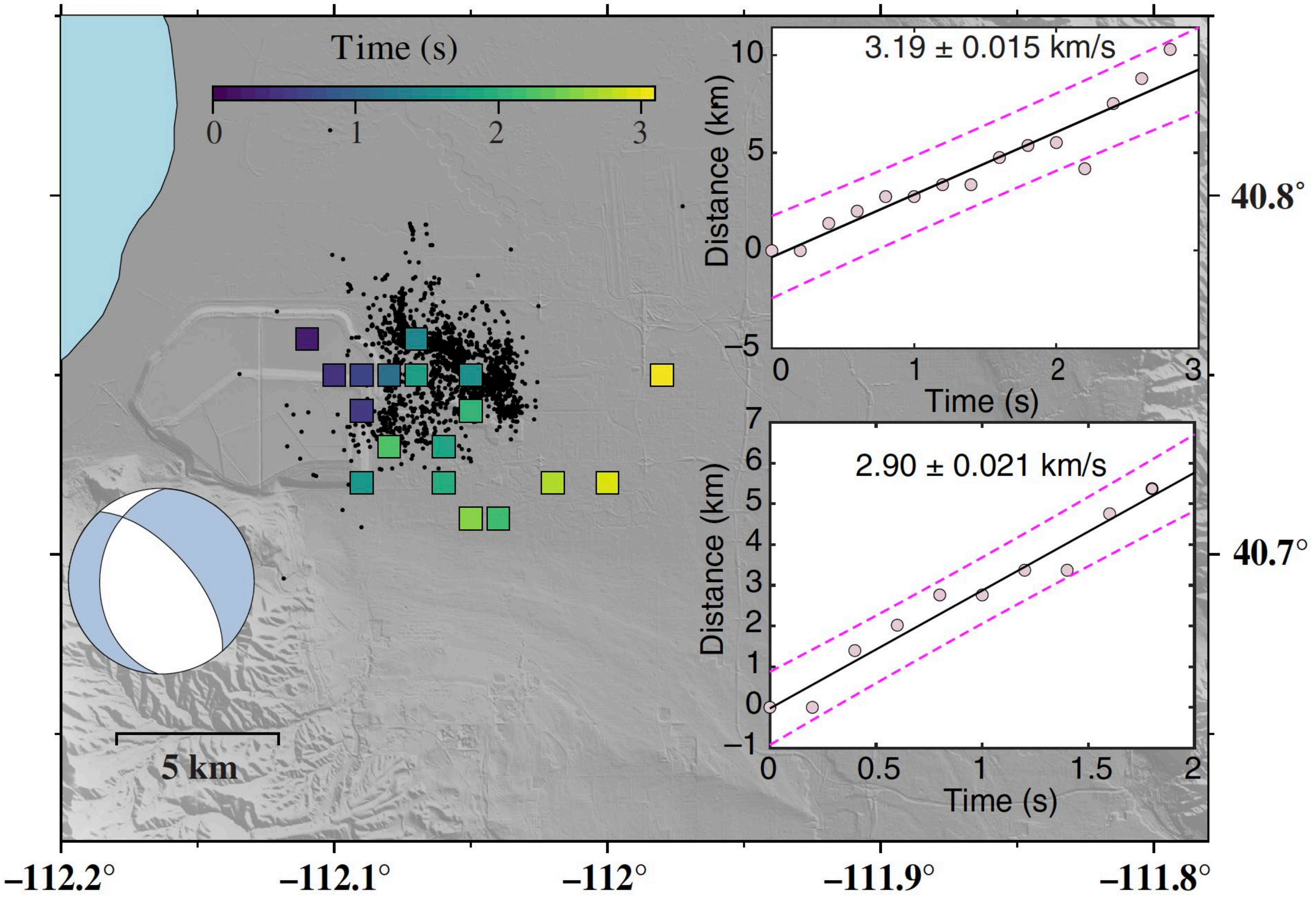








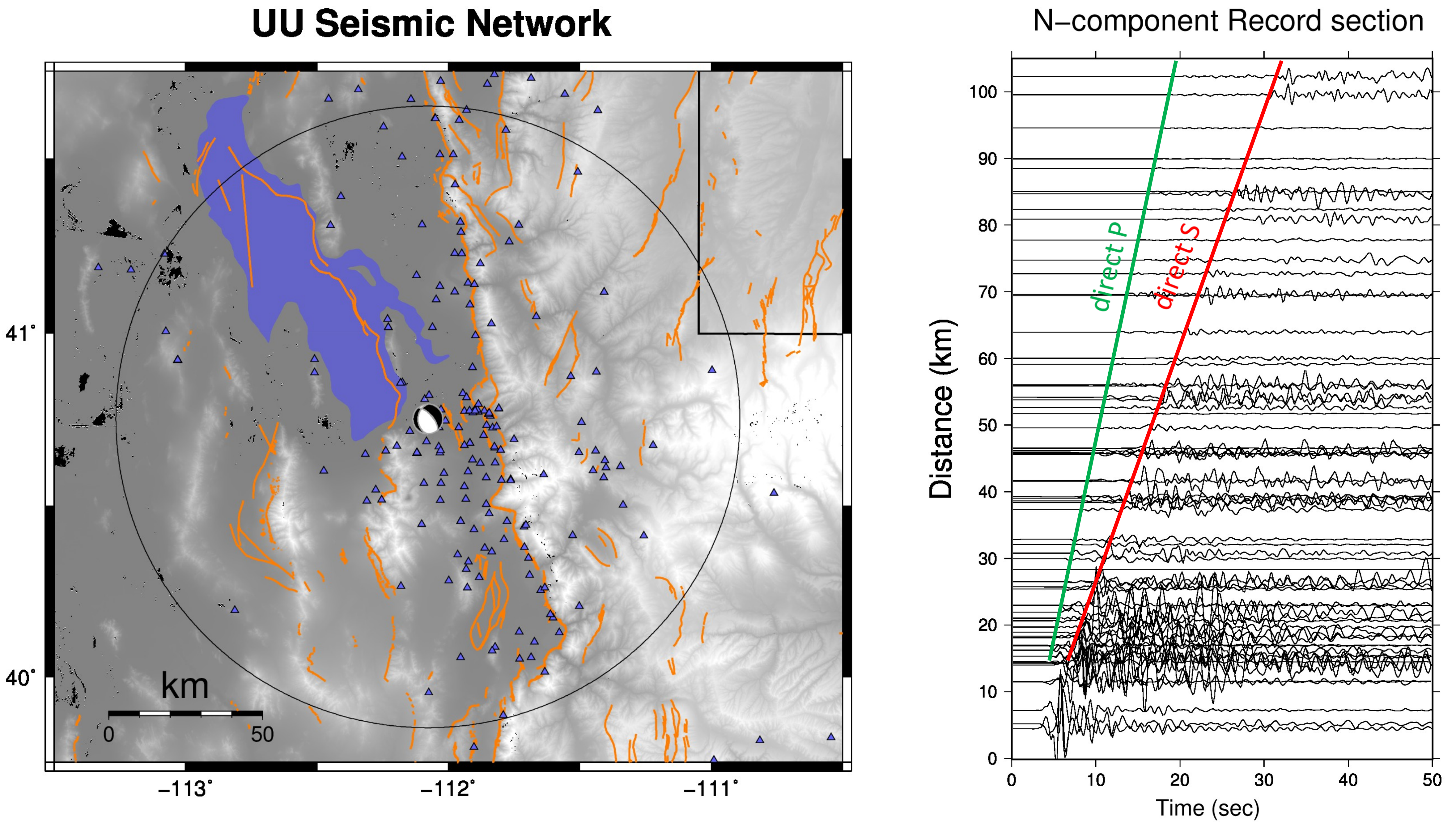
Pollitz et al. (2020)



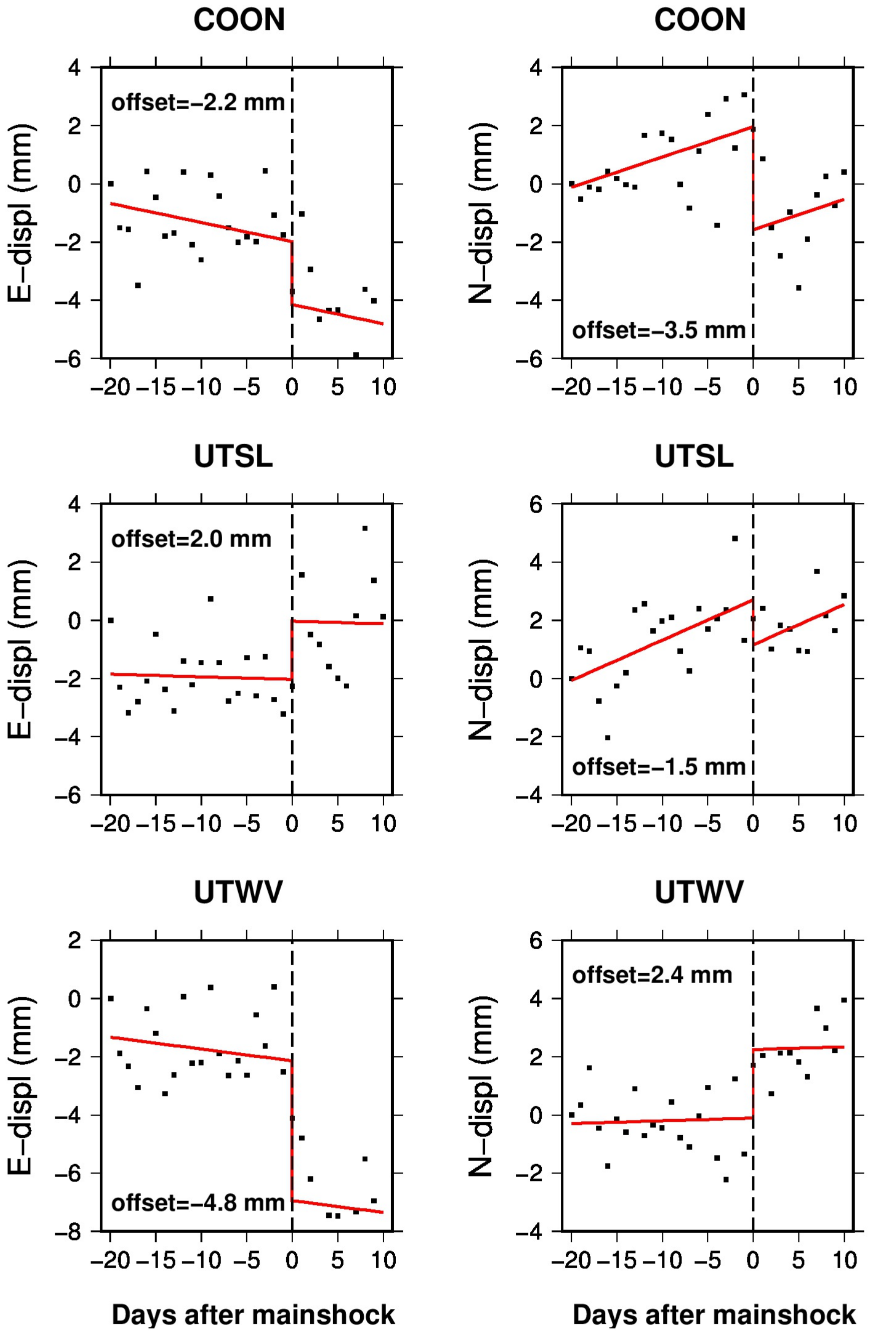
Mesimeri et al. (2020)

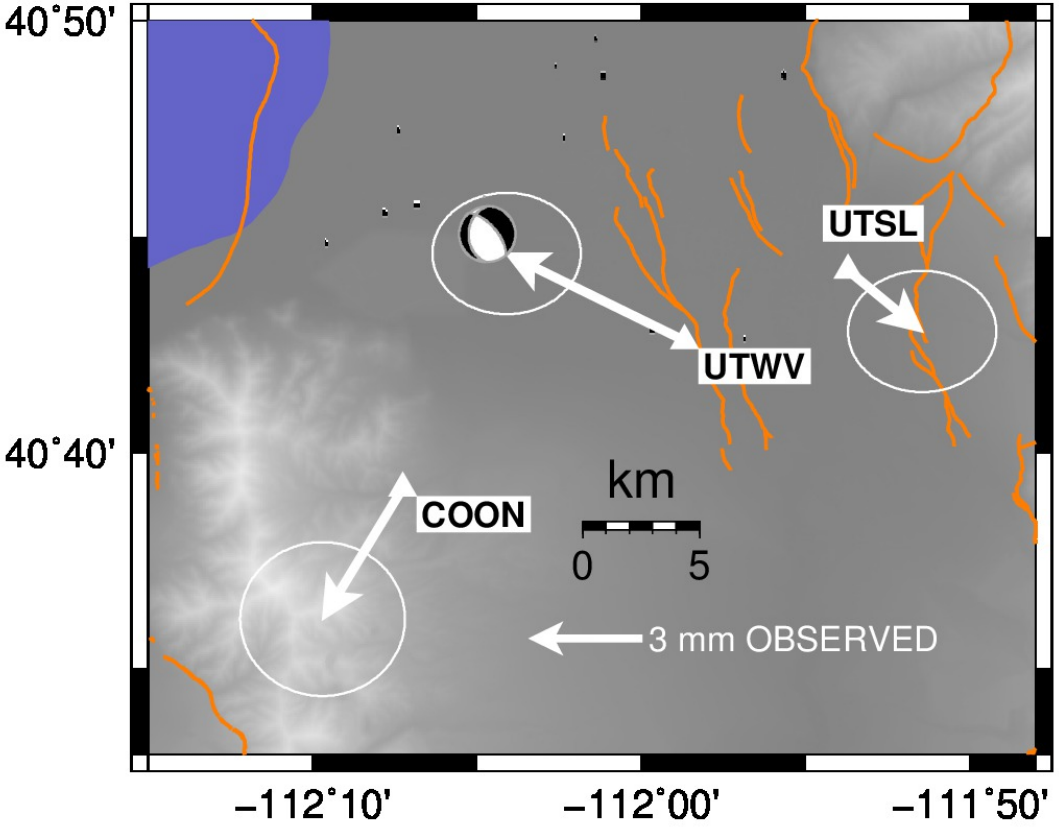
Data Set

- Seismic Waveforms from UU Seismograph Stations
  - 3-component seismograms; Δ from 0 to 100 km
  - bandpass filtered between 0.05 and 0.25 Hz
  - first 36 sec of all records used in the modeling
- Static Offsets
  - GPS (three sites with resolvable signal)
  - InSAR (Sentinel-1 ascending, Sentinel-1 descending)

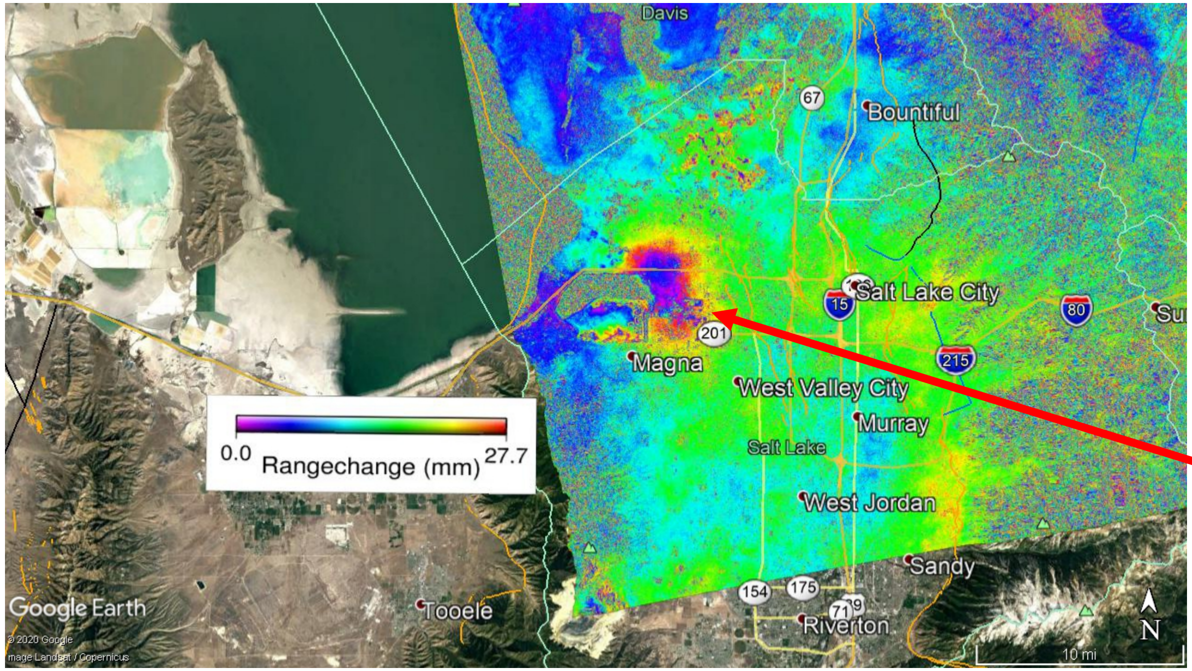


UU Seismic Network
41˚
40˚
km
0
50
−113˚
−112˚
−111˚
N−component Record section
Distance (km)
Time (sec)
direct P
direct S
0
10
20
30
40
50
60
70
80
90
100



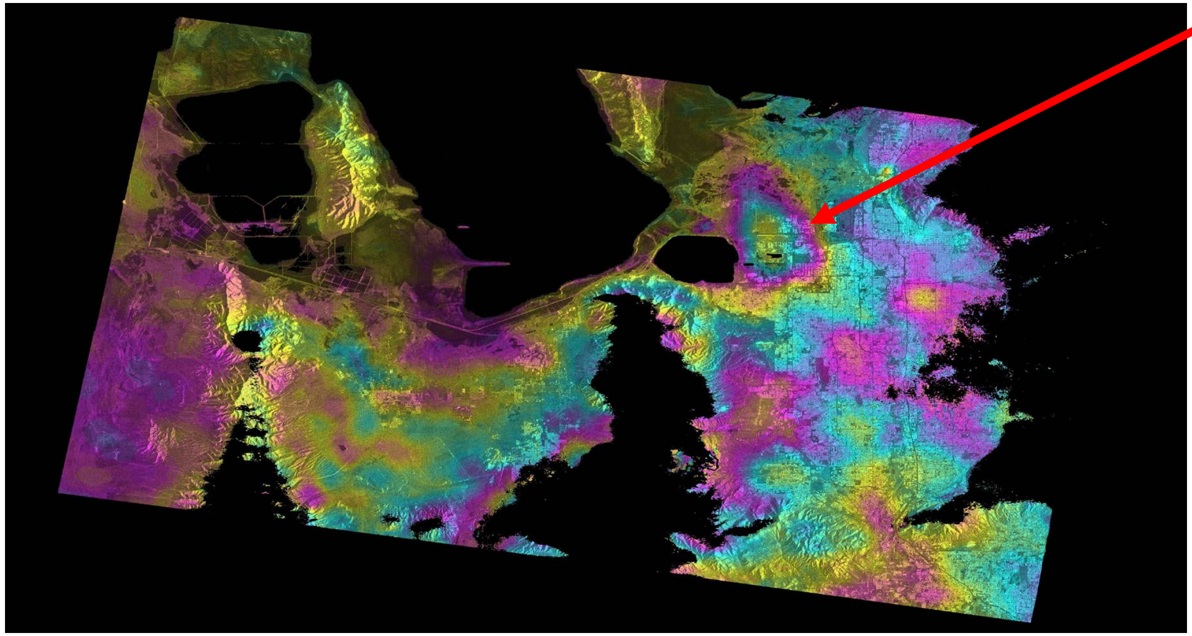


GPS data are consistent with east-west normal faulting

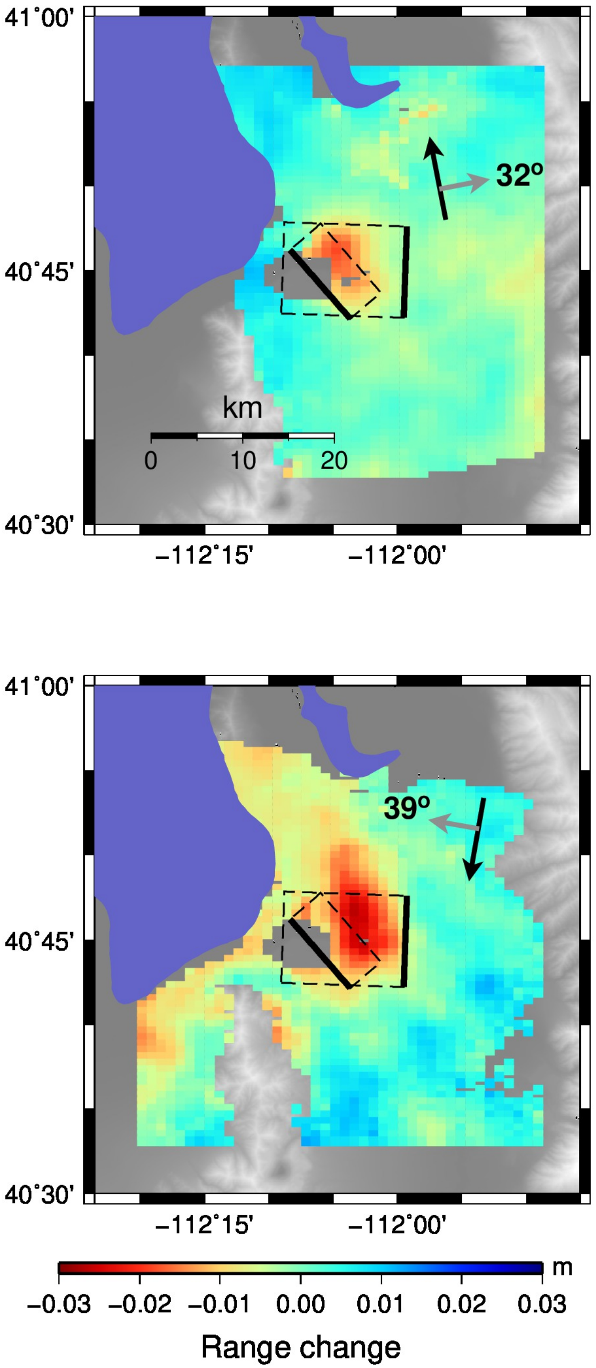


Sentinel-1 ascending interferogram
March 10 – March 22, 2020

~ 2 cm subsidence



Sentinel-1 descending interferogram
March 2 – April 7, 2020



Sentinel-1 ascending interferogram
March 10 – March 22, 2020

~ 2 cm subsidence

Sentinel-1 descending interferogram
March 2 – April 7, 2020

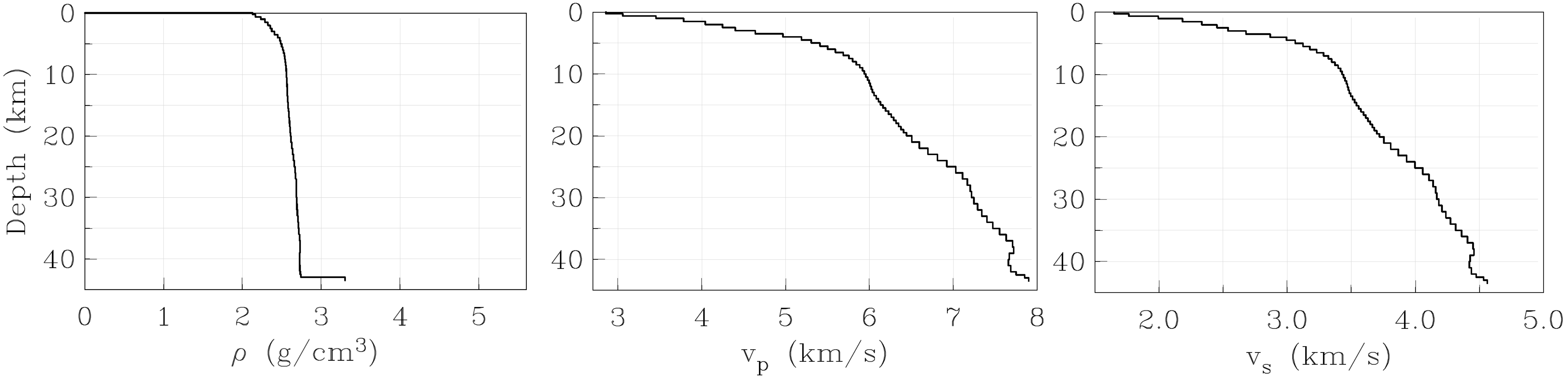
Slip Inversion

- o Seismic structure defined by Wasatch Fault Community Velocity Model
- o Simulated annealing for joint coseismic slip and afterslip
- fixed rake
- positivity constraints
- smoothing applied to all slip distributions
- specified range of local rupture velocity
- specified maximum rise time

Model Issues

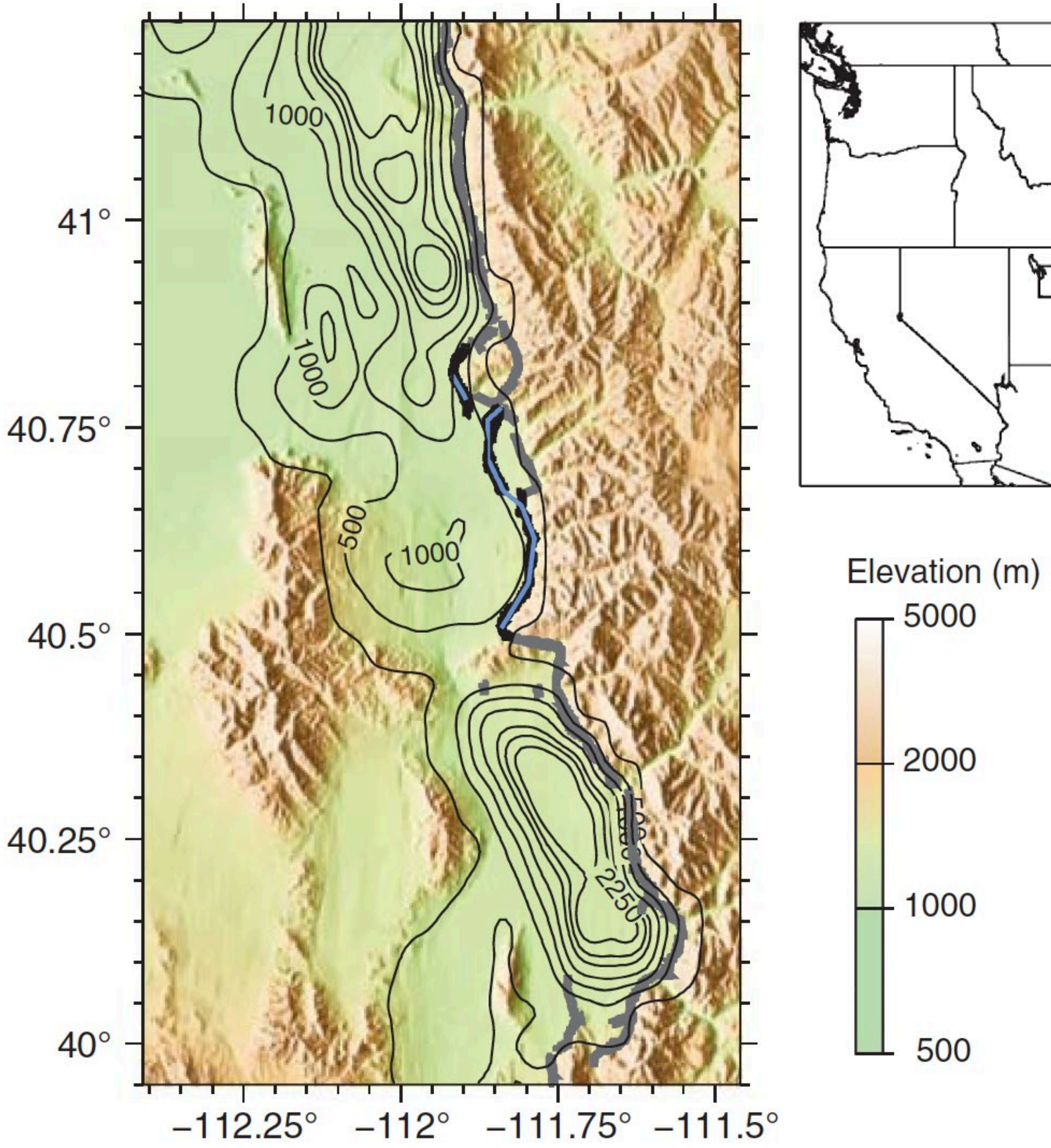
- Resolve fault geometry for coseismic slip and afterslip
- Tradeoffs with choices of hypocenter, limits on rupture velocity, rise time, etc.
- Method limited by choice of single reference seismic structure
  – site effects impact many seismic waveforms and cannot be be modeled

Seismic Structure

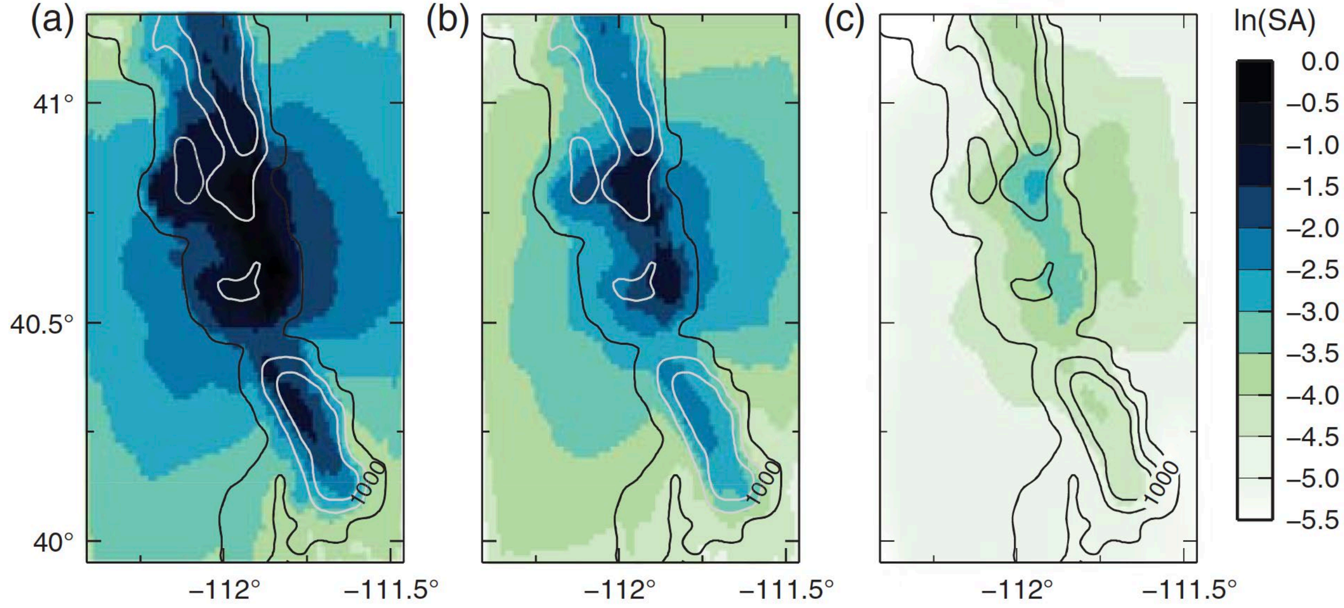


Single profile from 3D Wasatch Fault Community Velocity Model
(Magistrale et al., 2008)

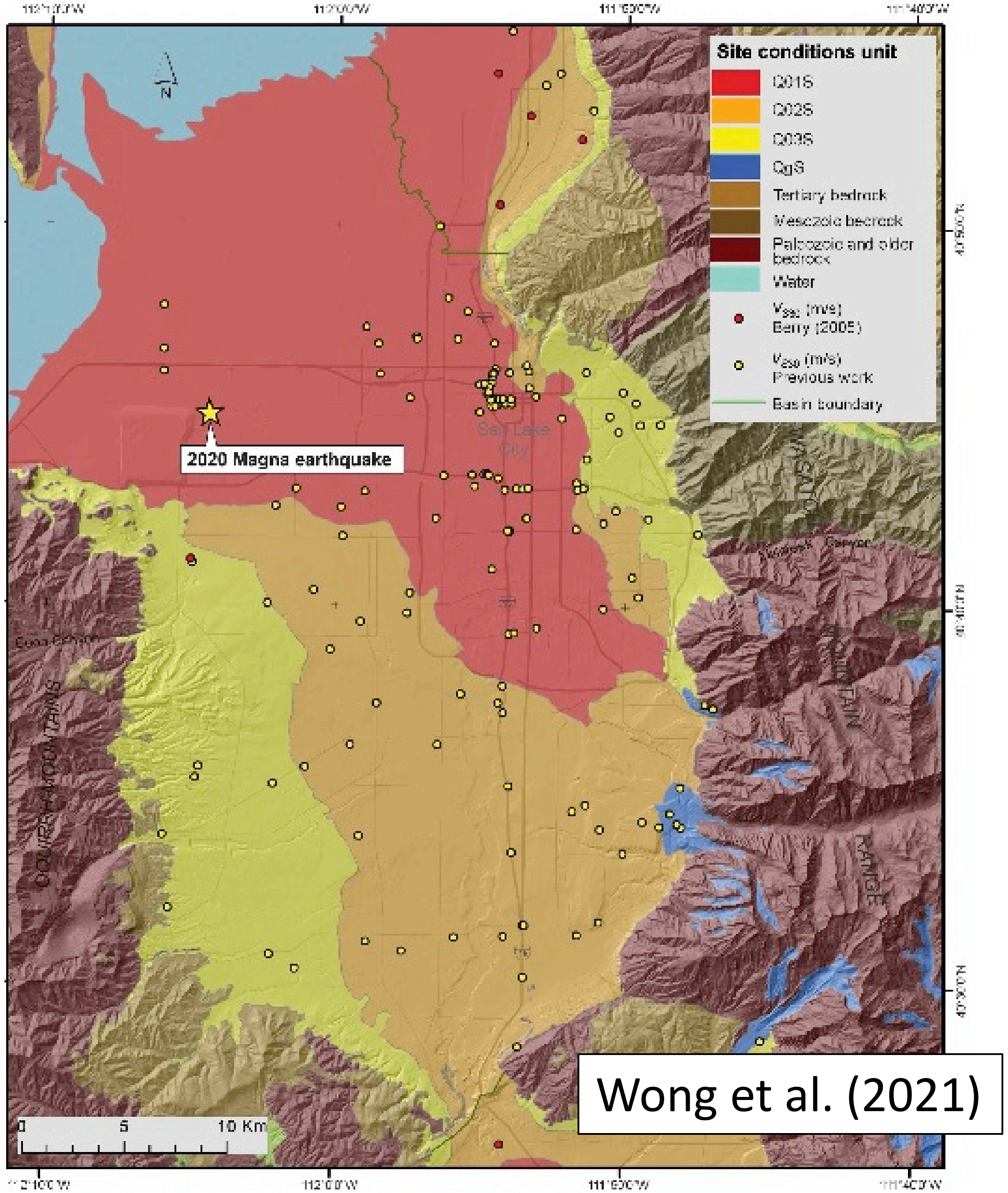
Long period (~4 sec) response depends highly on shallow shear-velocity/density structure



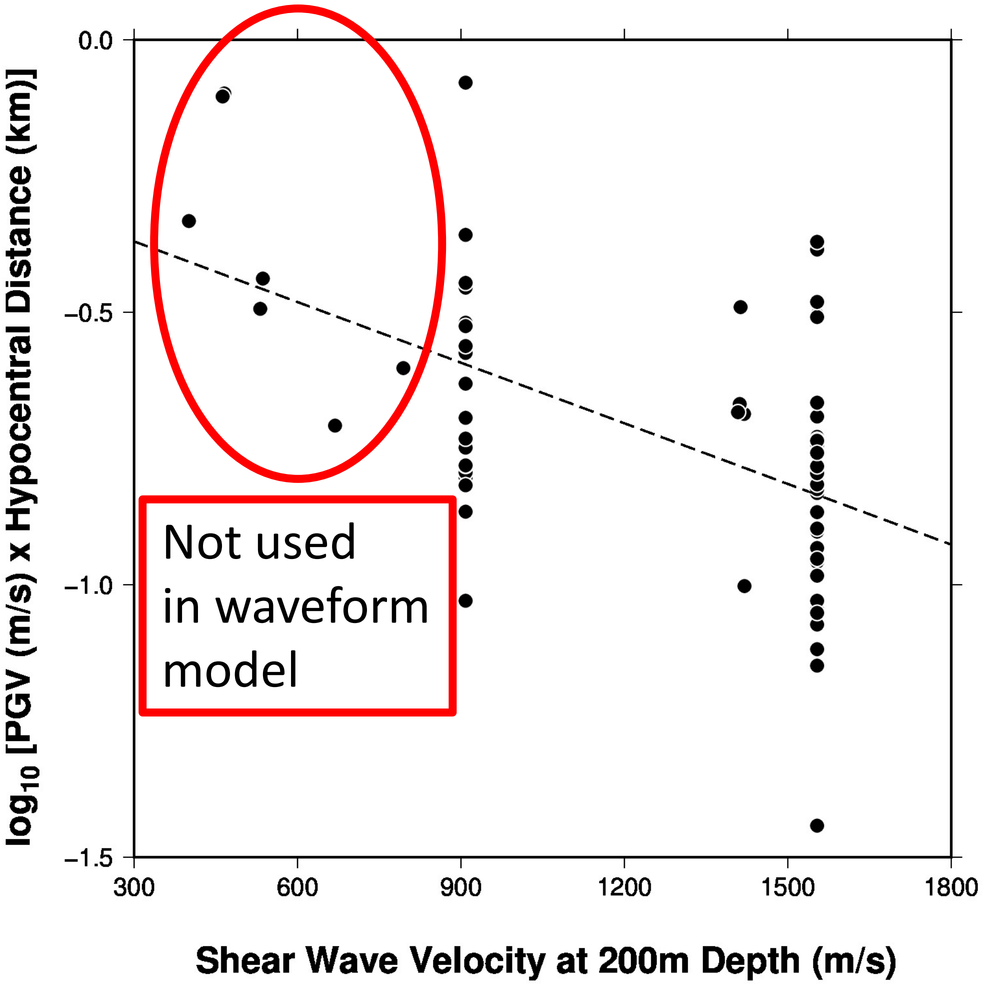
1.5 s 3.0 s 7.5 s

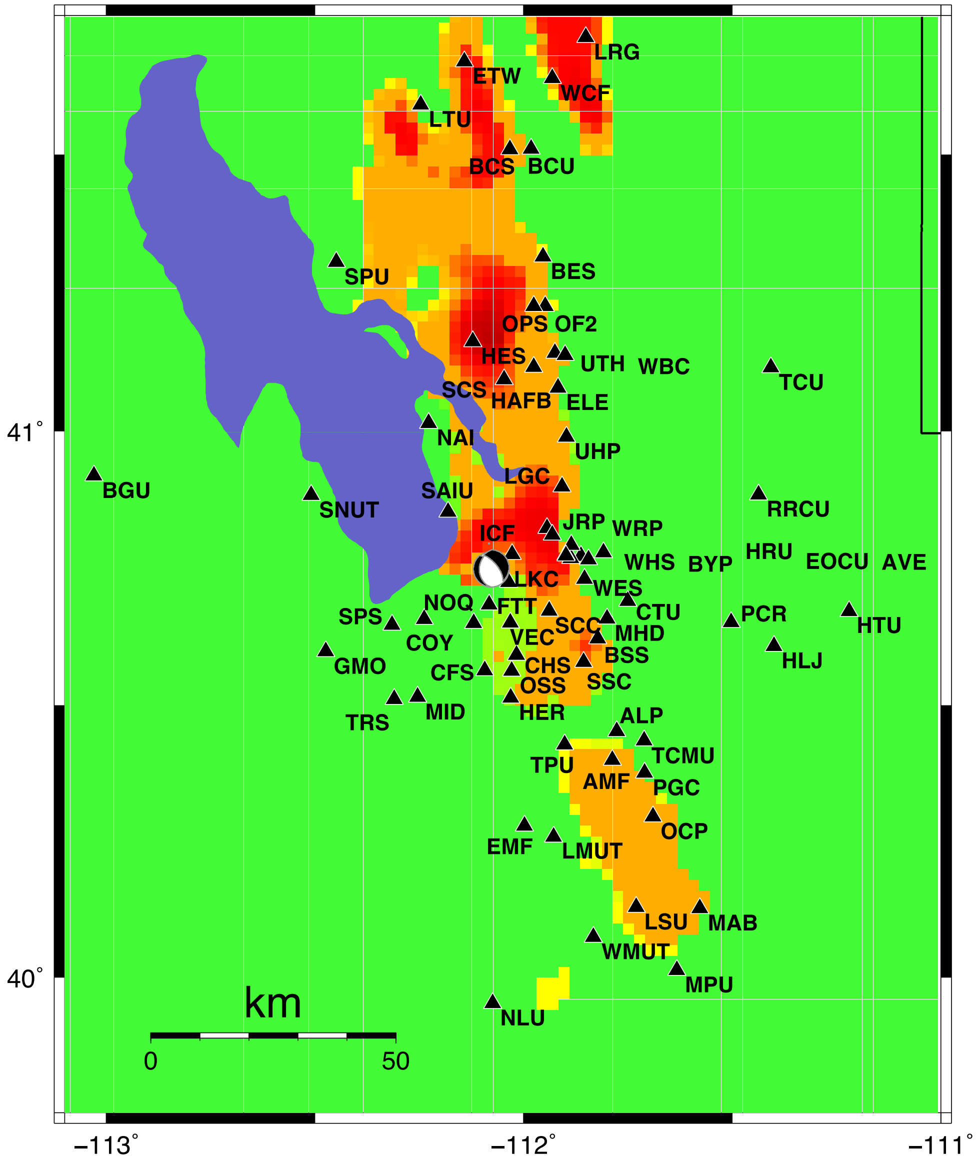


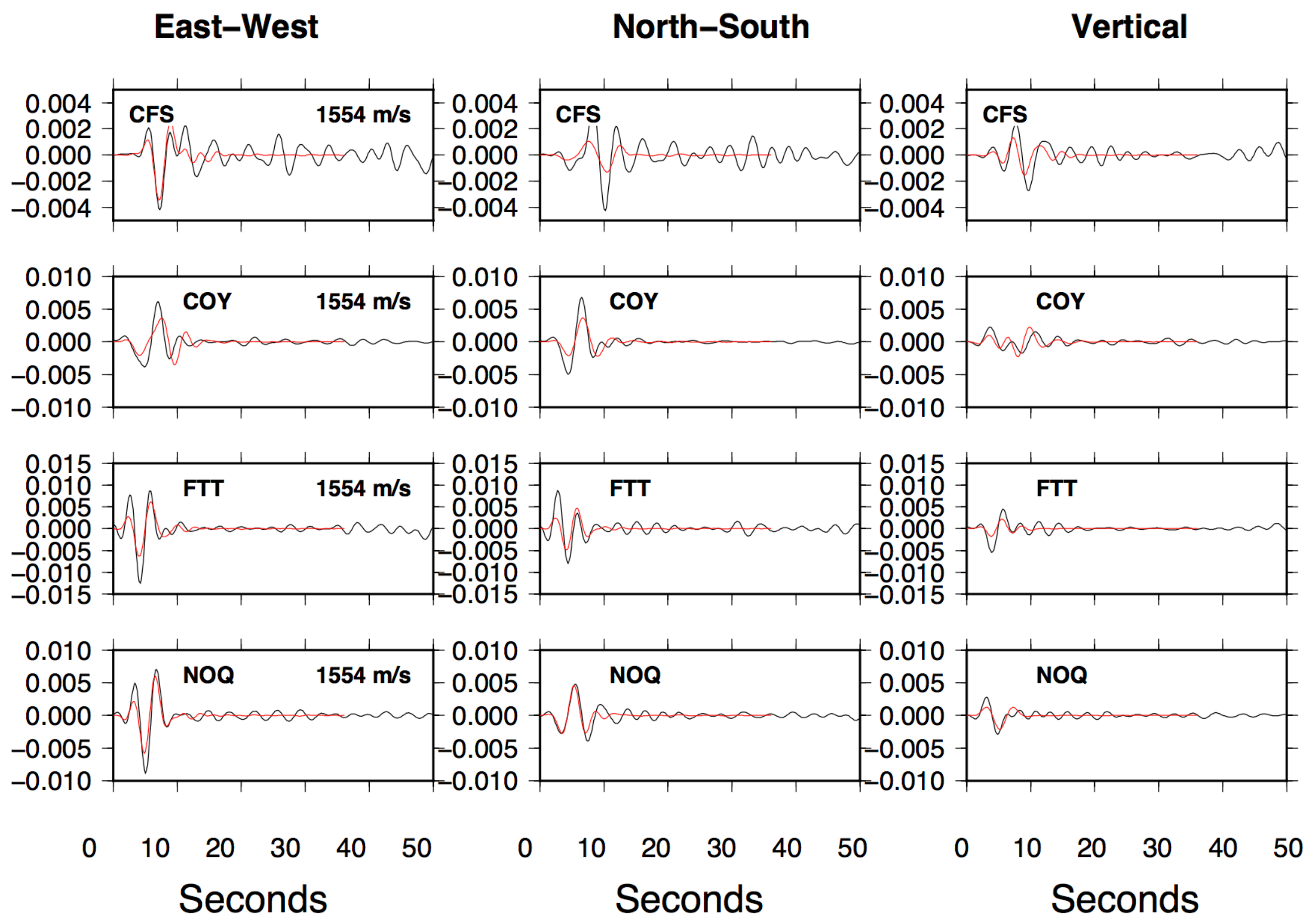
Moschetti et al. (2017)



Long period (~4 sec) response depends highly on shallow shear-velocity/density structure

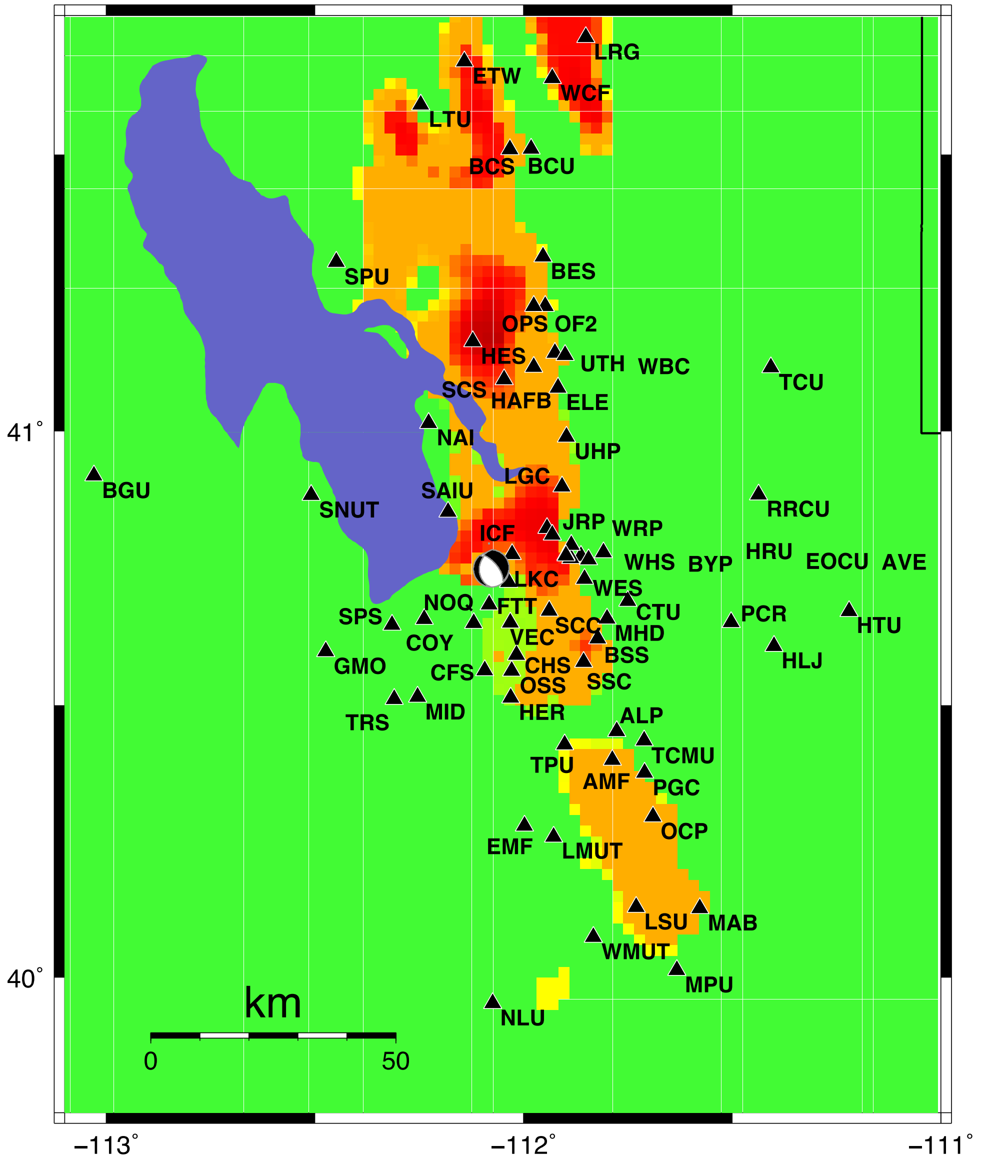


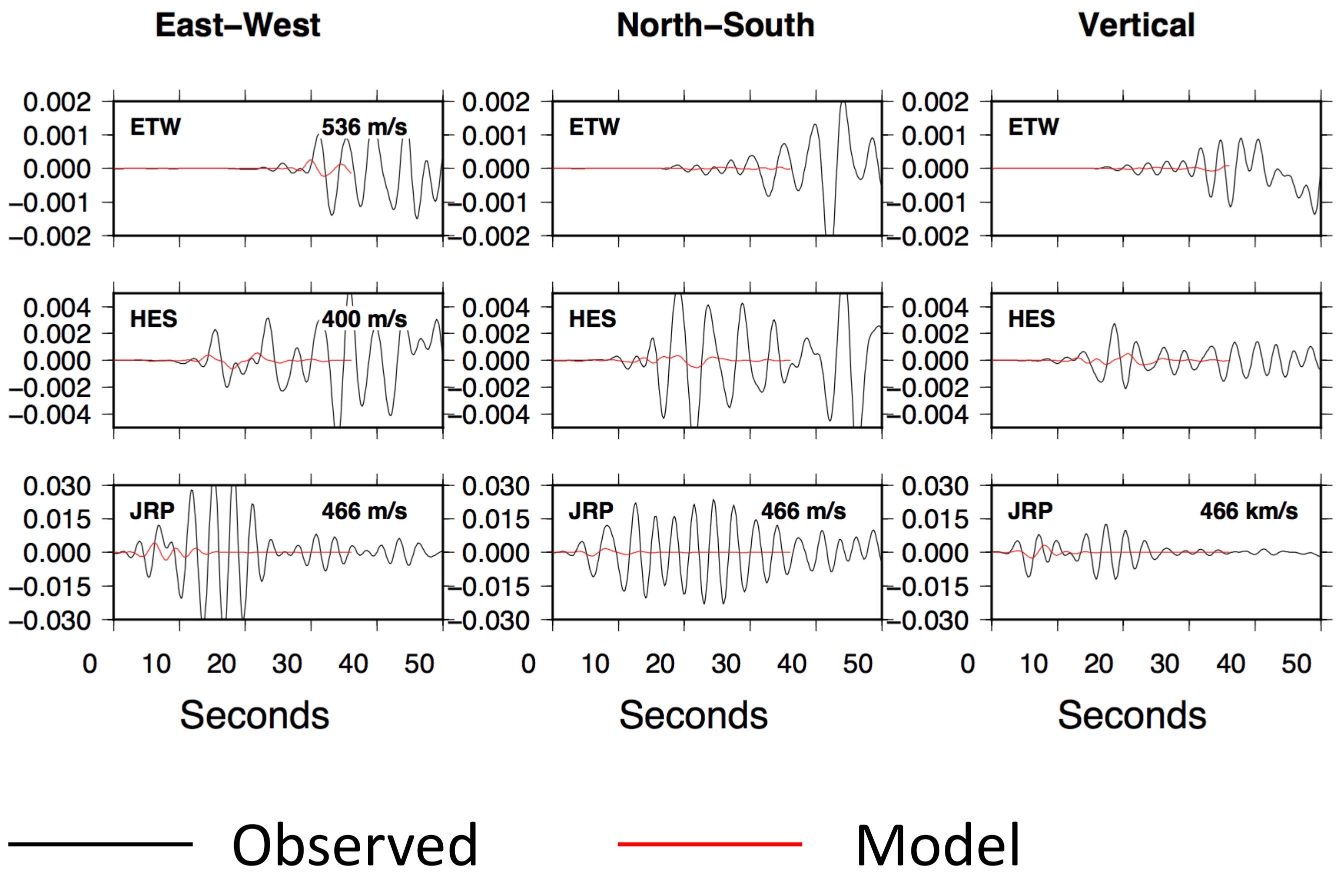




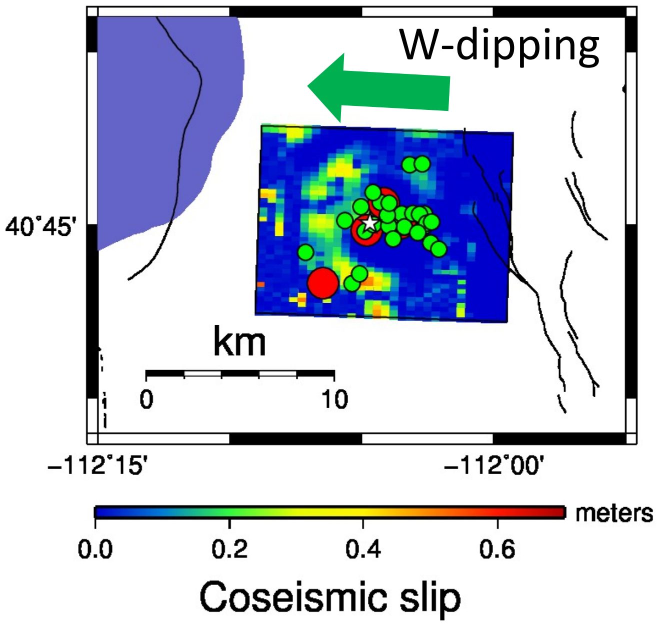
Observed — Model

Seismic response at hard rock sites





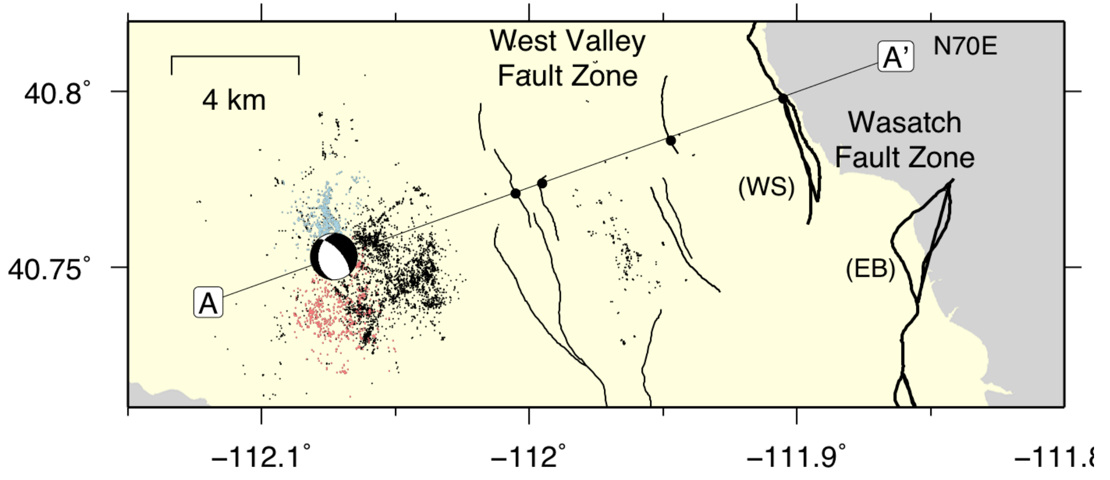
Seismic response at low-velocity sediment sites

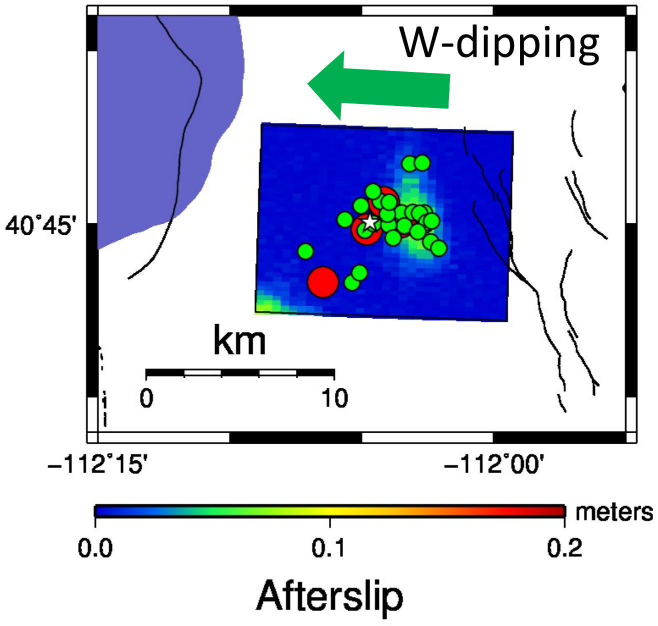


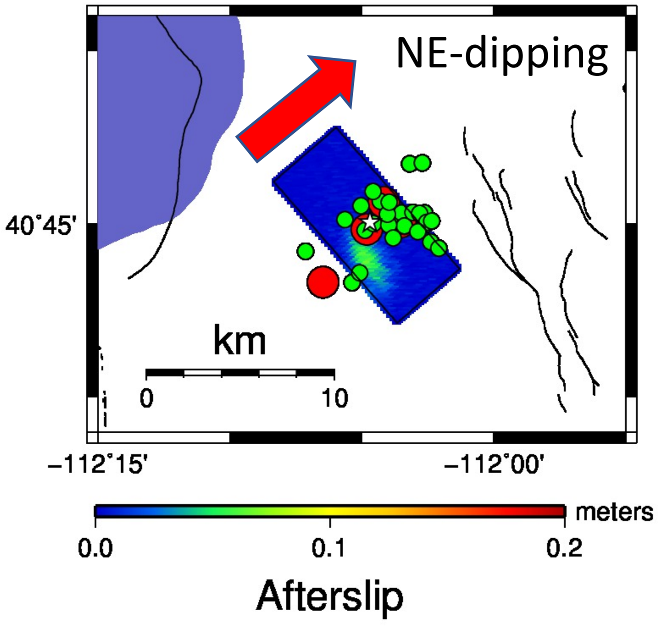
Coseismic slip on the W-dipping Wasatch fault at depth + triggering of afterslip updip of the hypocenter

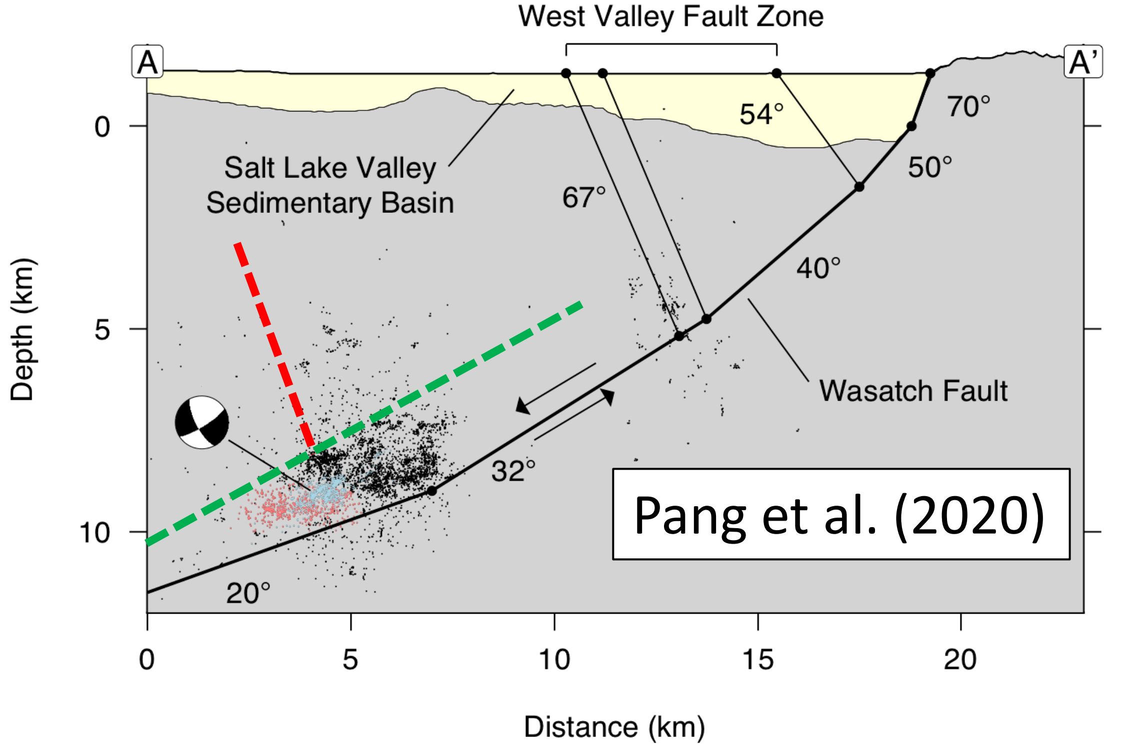
$M_0 = 2.7 \times 10^{17}$ Nm

→ M_w=5.6

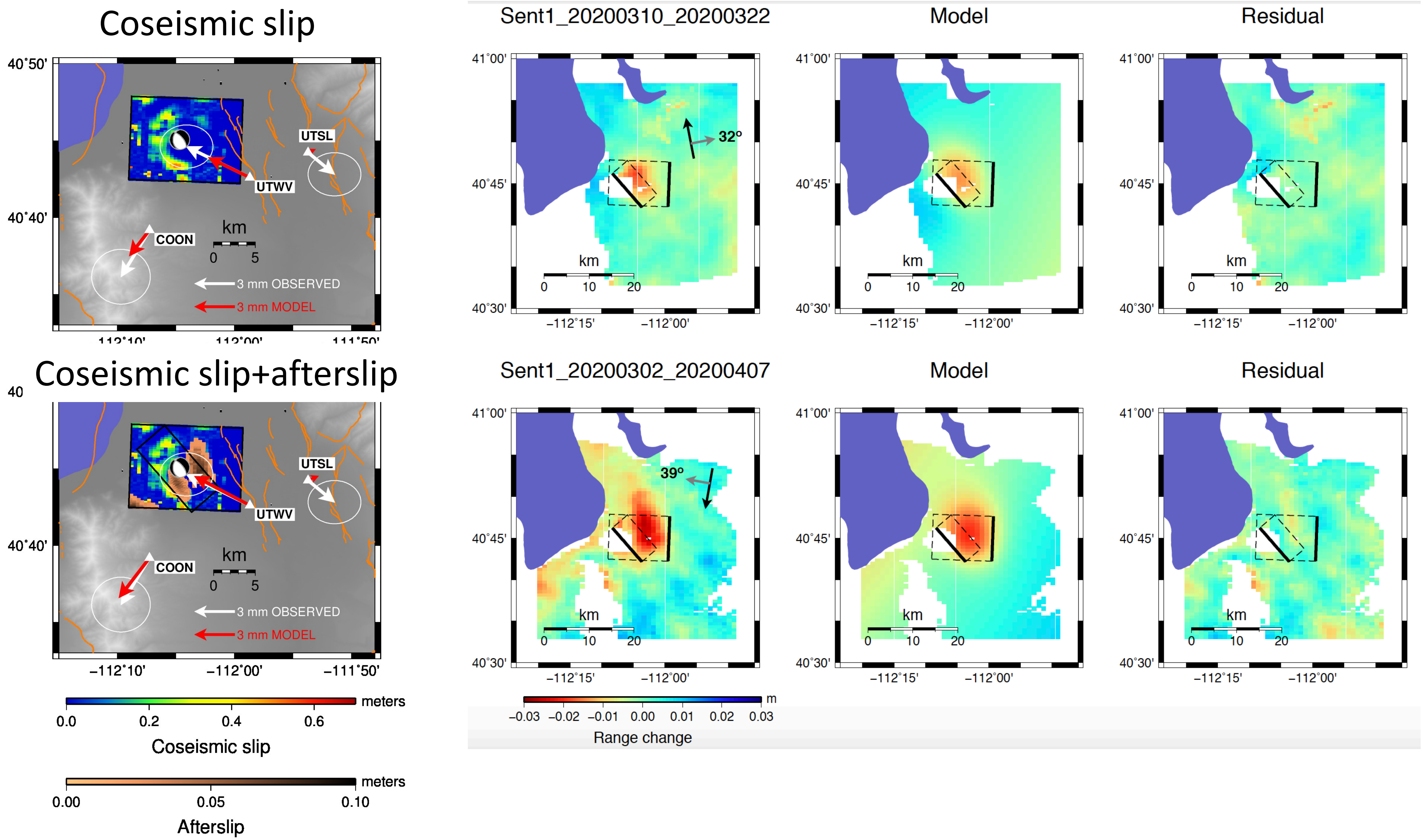




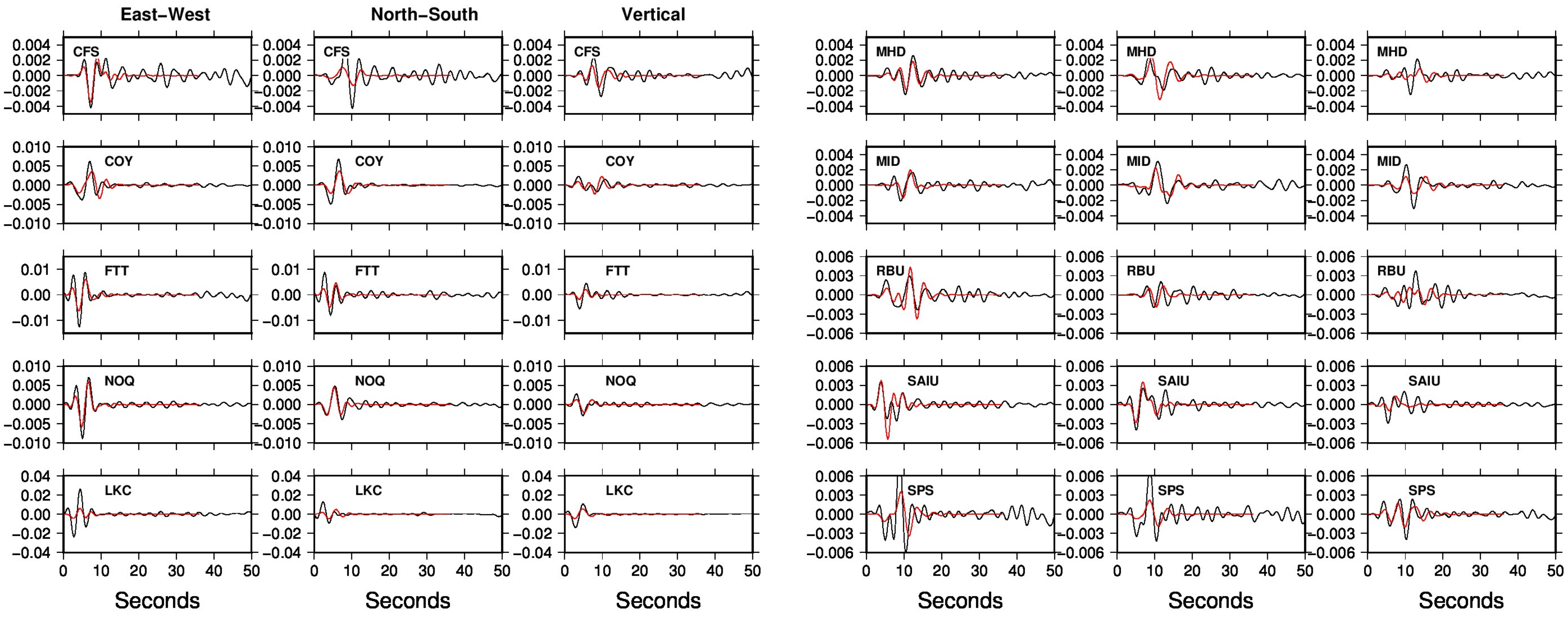




Pang et al. (2020)

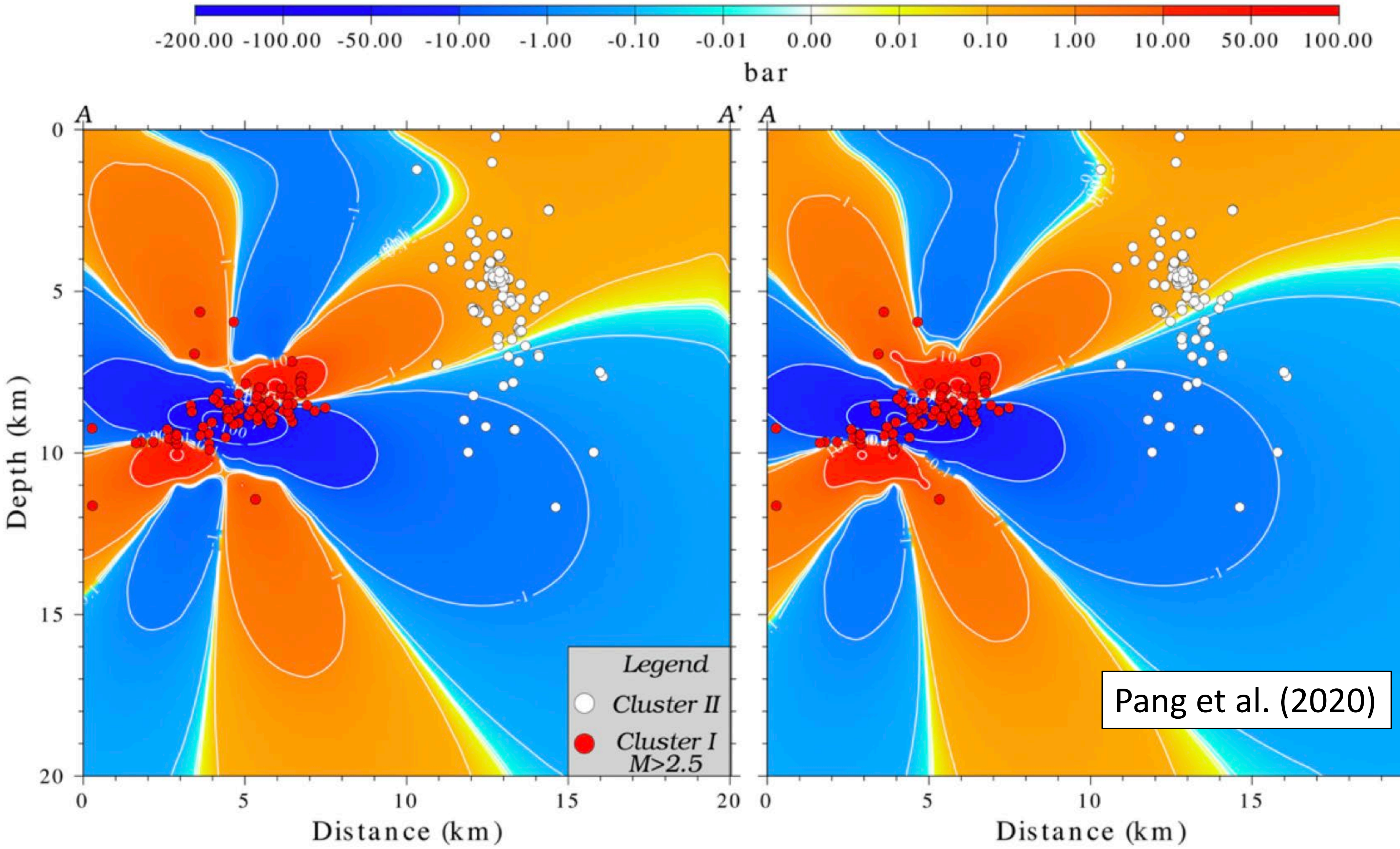

Coseismic slip
40°50'
40°40'
UTSL
UTWV
COON
km
0
5
3 mm OBSERVED
3 mm MODEL
Coseismic slip+afterslip
40°40'
UTSL
UTWV
COON
km
0
5
3 mm OBSERVED
3 mm MODEL
−112°10'
−112°00'
−111°50'
meters
0.0
0.2
0.4
0.6
Coseismic slip
meters
0.00
0.05
0.10
Afterslip
Sent1_20200310_20200322
Model
Residual
41°00'
40°45'
40°30'
32°
km
0
10
20
−112°15'
−112°00'
Sent1_20200302_20200407
Model
Residual
39°
m
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
Range change

Fit to seismic waveforms at hard rock sites



Observed

Model



-200.00 -100.00 -50.00 -10.00 -1.00 -0.10 -0.01 0.00 0.01 0.10 1.00 10.00 50.00 100.00
bar
A
A'
Depth (km)
Distance (km)
Legend
Cluster II
Cluster I M>2.5
Pang et al. (2020)

Conclusions

- Seismic waveforms and geodetic data constrain the estimation of coseismic slip and afterslip
- The models most consistent with the seismic waveform and InSAR data involve coseismic slip on a W-dipping fault, plus up to ~10 cm afterslip on the W-dipping fault updip of the hypocenter, possibly augmented by afterslip on a NE-dipping fault
- Shallow afterslip reaching ~5 km depth was likely triggered by coseismic slip on the deeper section of the Wasatch fault.

Hypothetical Structural Model for the March 18 M_w 5.7 Magna, Utah, Earthquake

Adam McKean

Mapping Geologist with the Geologic Hazards Program

UGS Collaborators: Christian Hardwick, Mike Hylland, Zach Anderson, Grant Willis, Emily Kleber, Don Clark, Bob Biek, Adam Hiscock, Greg McDonald, Gordon Douglass, Steve Bowman, and Ben Erickson

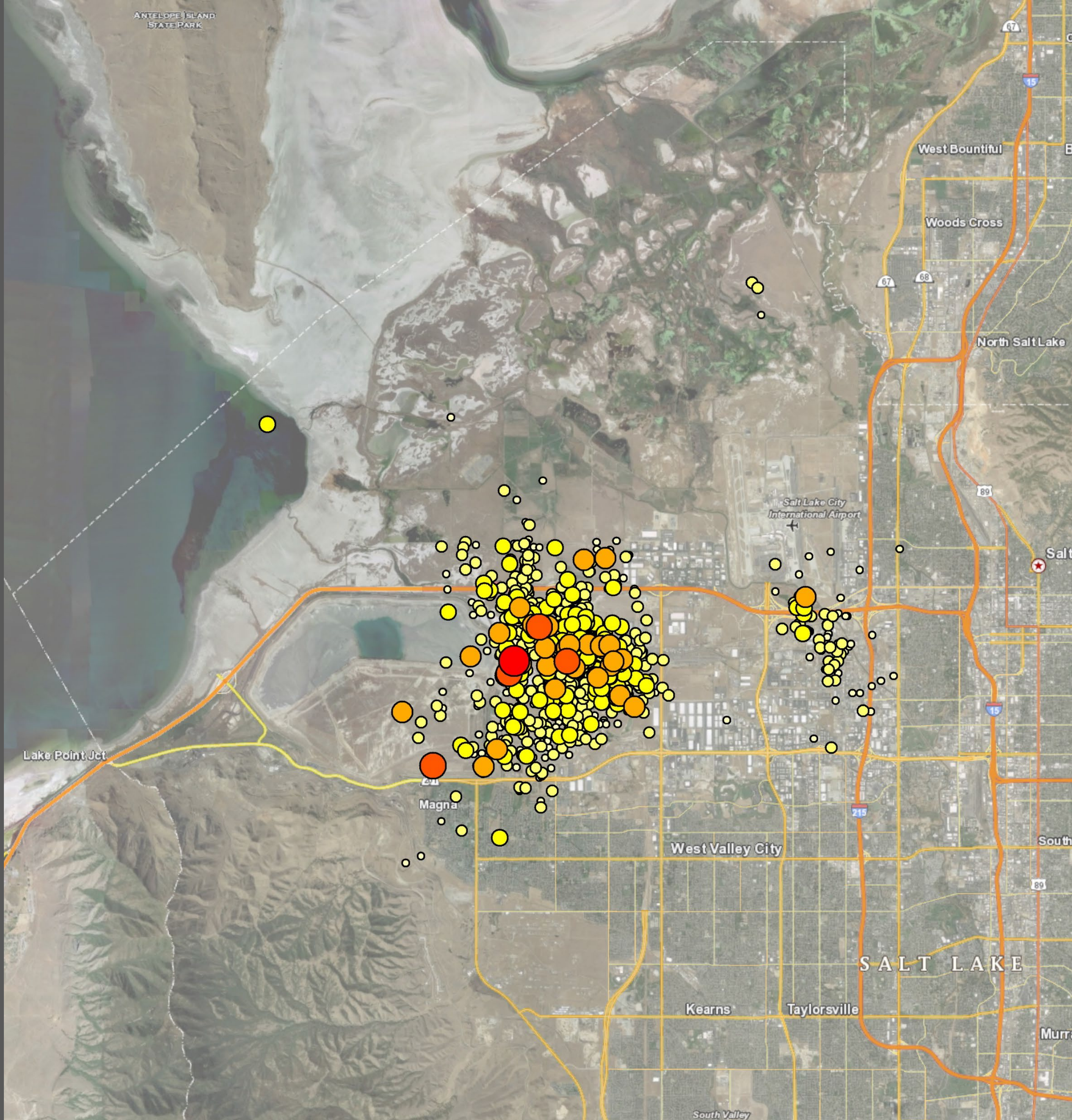
Outline

Questions

- What fault did the Magna M 5.7 earthquake rupture?
- How do nearby faults interact at depth?

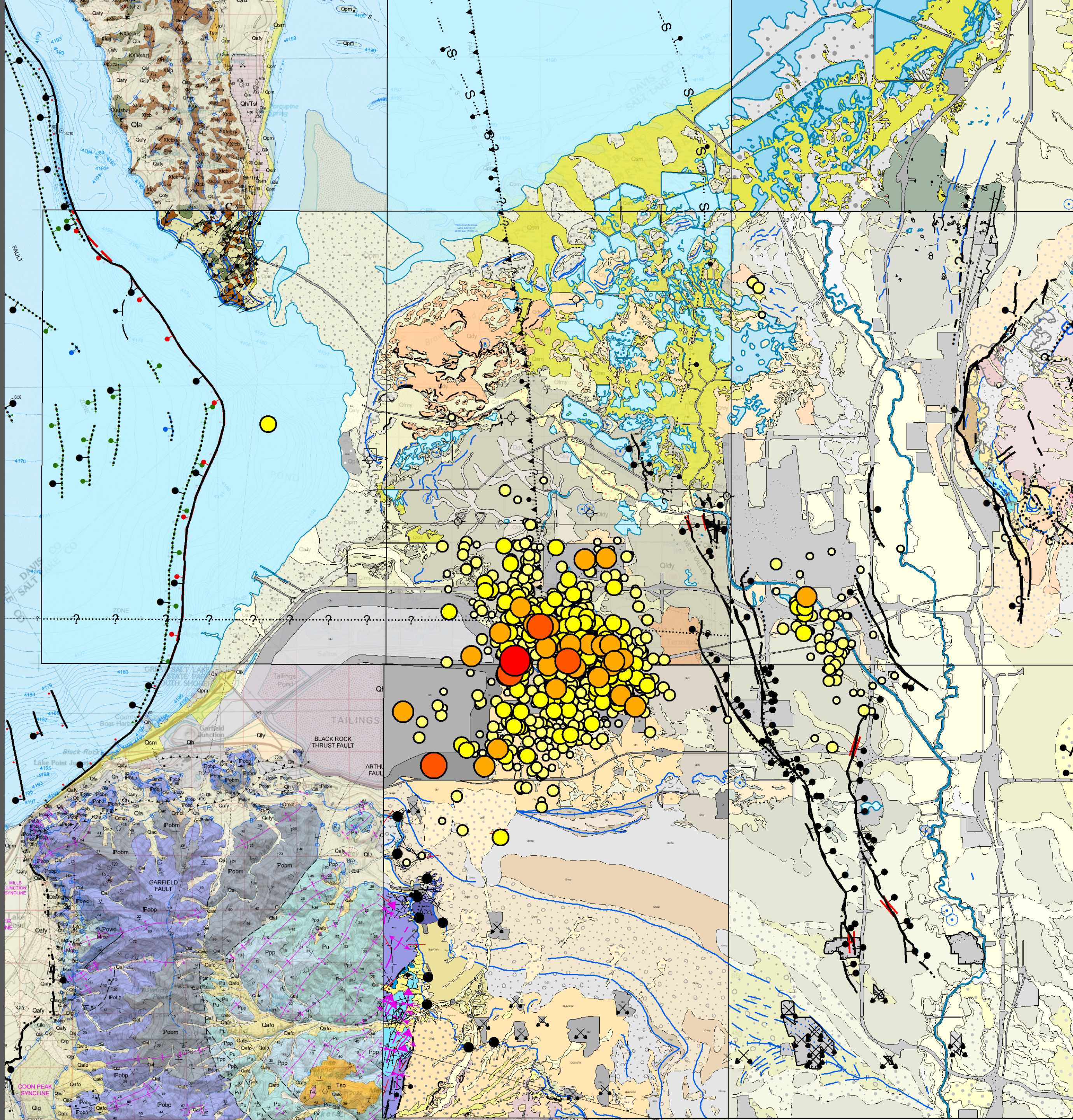
Models

- Structural model
- Analog clay models
- Accommodation fault model



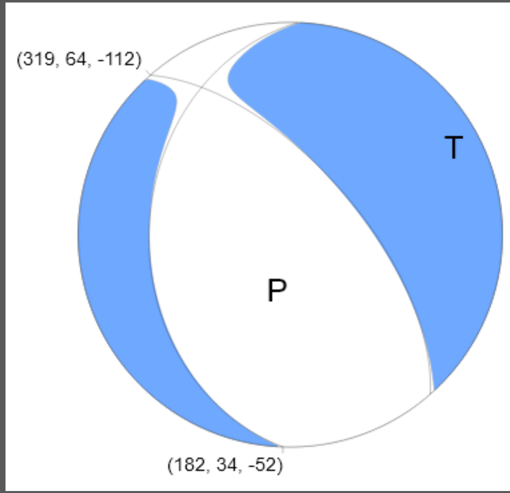
Geologic Studies

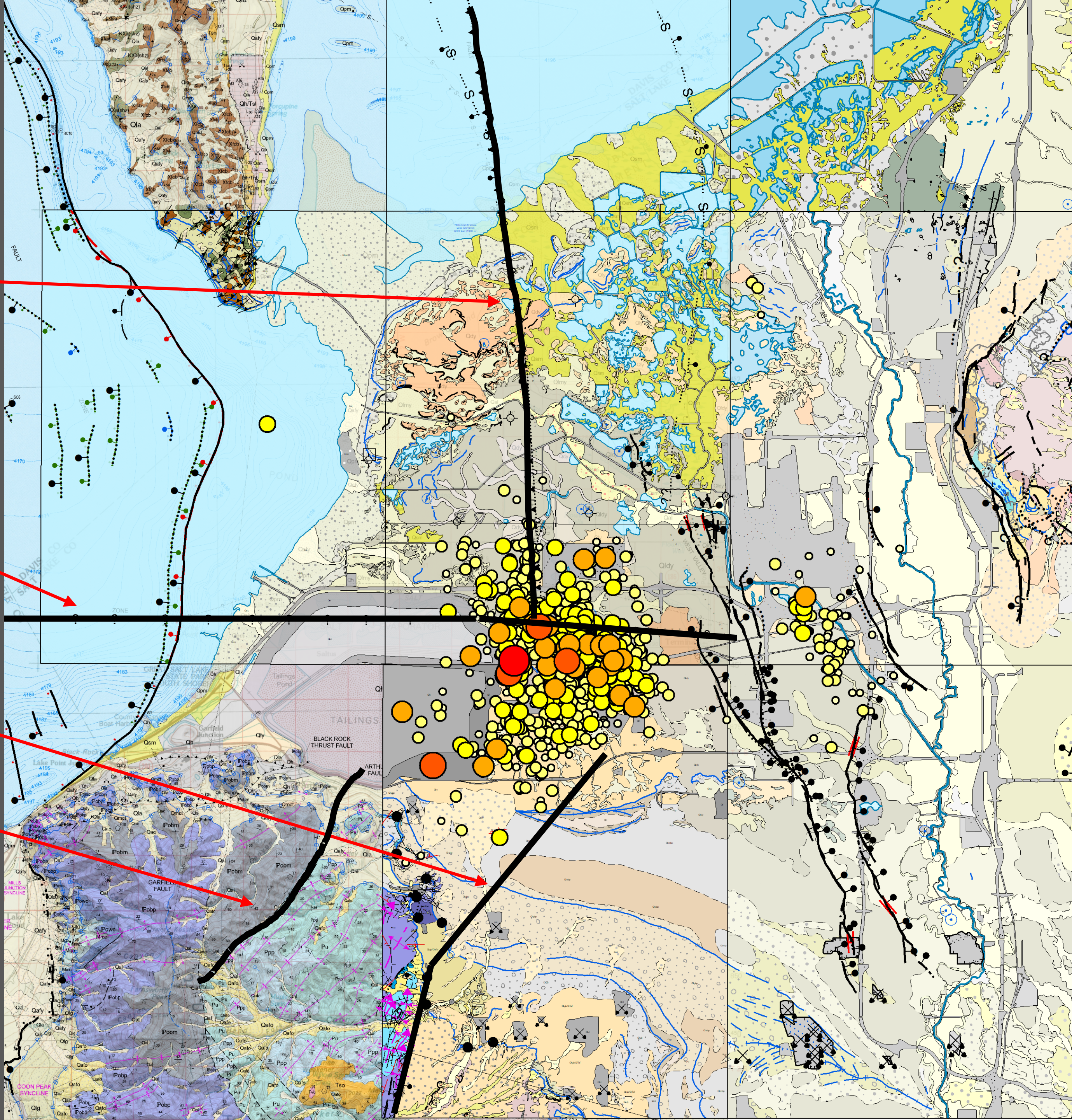
- More than 8 recent UGS geologic mapping projects in the immediate area
- Recent UGS completion of Wasatch and West Valley fault zone mapping and UGS-USGS paleoseismic investigations



Fault Suspects

- Reactivated Ogden Thrust
- Inferred Transverse fault zone
- Harkers fault
- Arthur fault



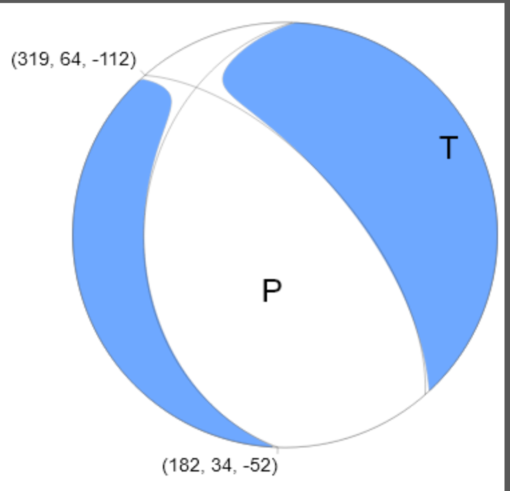


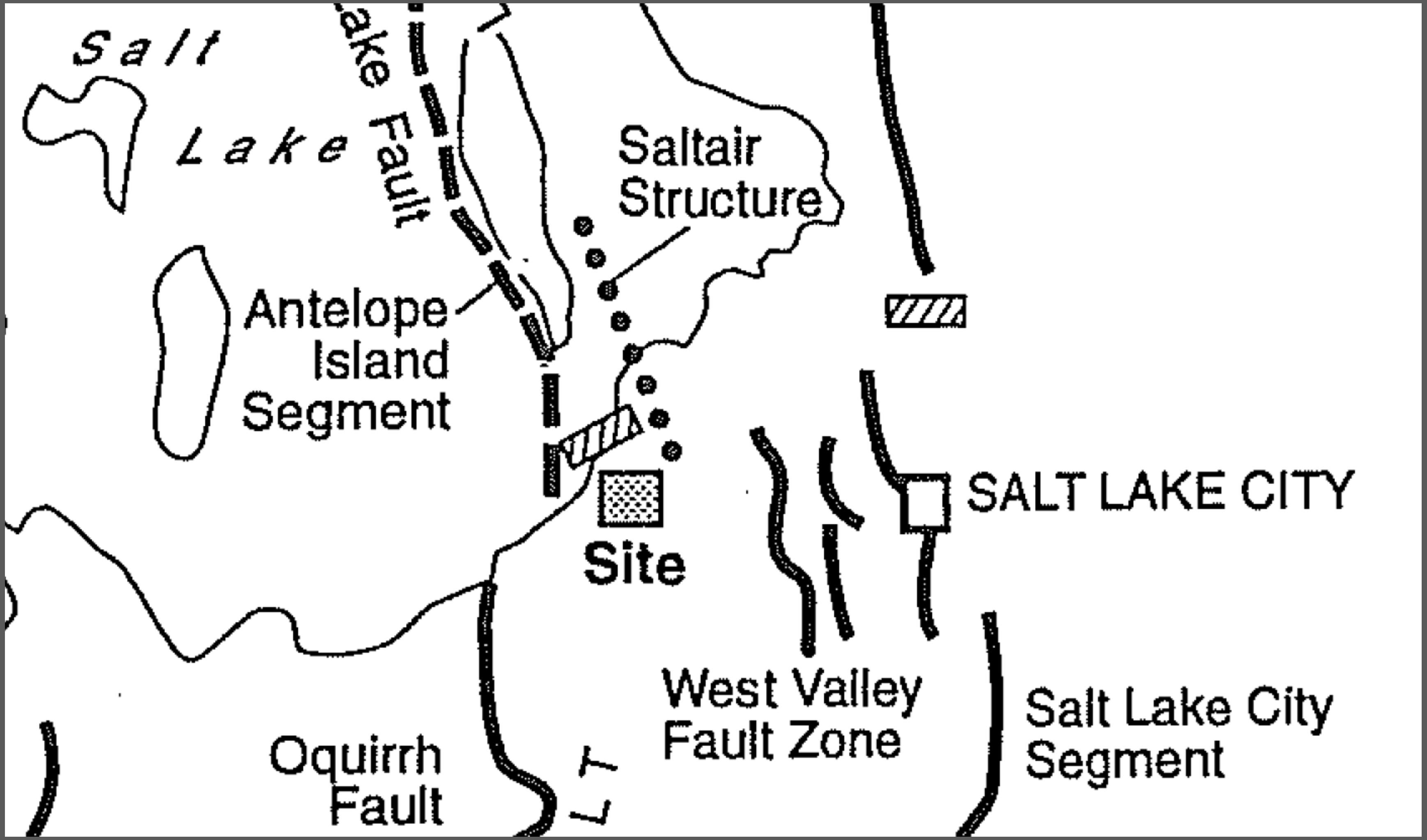
Fault Suspects

- Saltair Structure

Wong et al. (1995) describe an eastward-dipping structure along a gravity low with some seismicity

- Wasatch fault zone





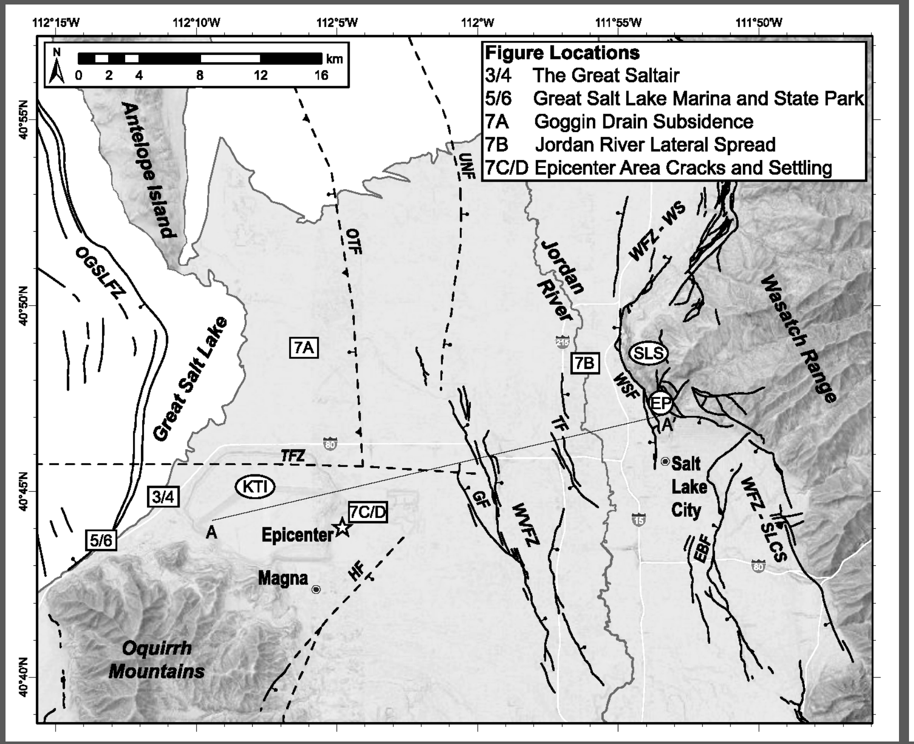
Wong et al., 1995, Seismic Hazard Evaluation of the Magna Tailings Impoundment

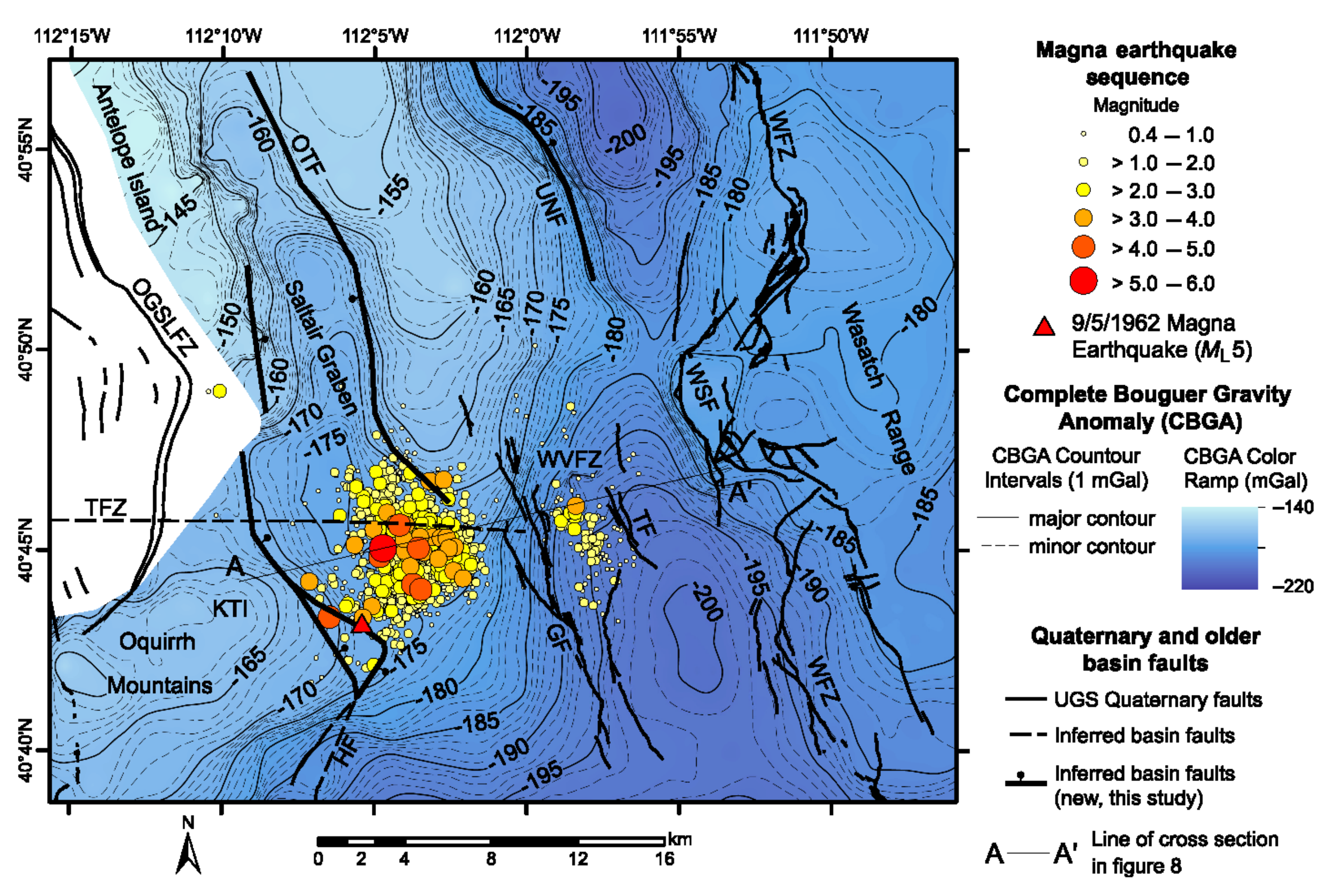
New Draft Complete Bouguer Gravity Anomaly (CBGA) Map

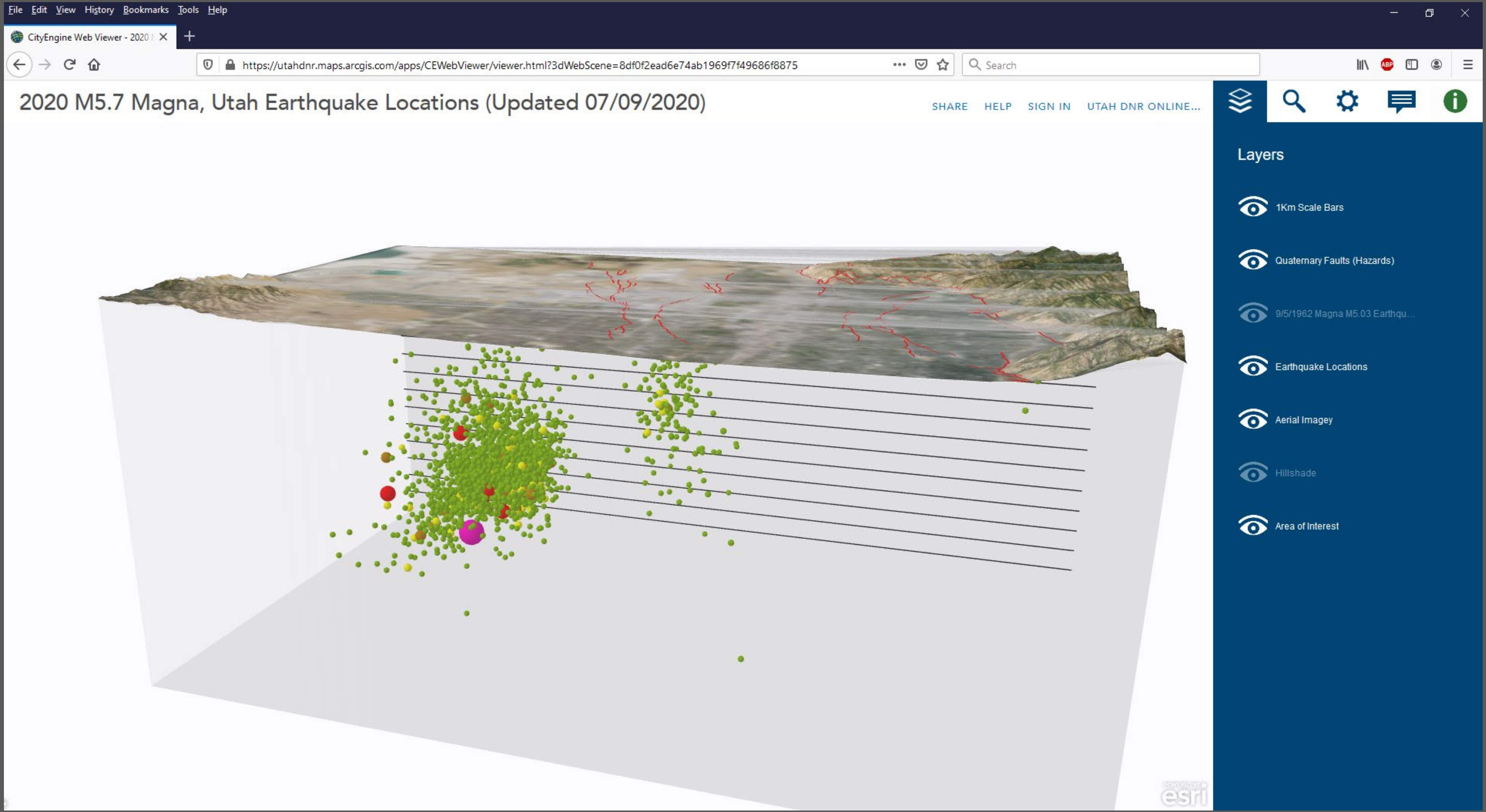
Focus Section: Intermountain West Earthquakes

Geologic Setting, Ground Effects, and Proposed Structural Model for the 18 March 2020 M_W 5.7 Magna, Utah, Earthquake

Emily J. Kleber*[1], Adam P. McKean[1], Adam I. Hiscock[1], Michael D. Hylland[1], Christian L. Hardwick[1], Greg N. McDonald[1], Zachary W. Anderson[1], Steve D. Bowman[1], Grant C. Willis[1], and Ben A. Erickson[1]

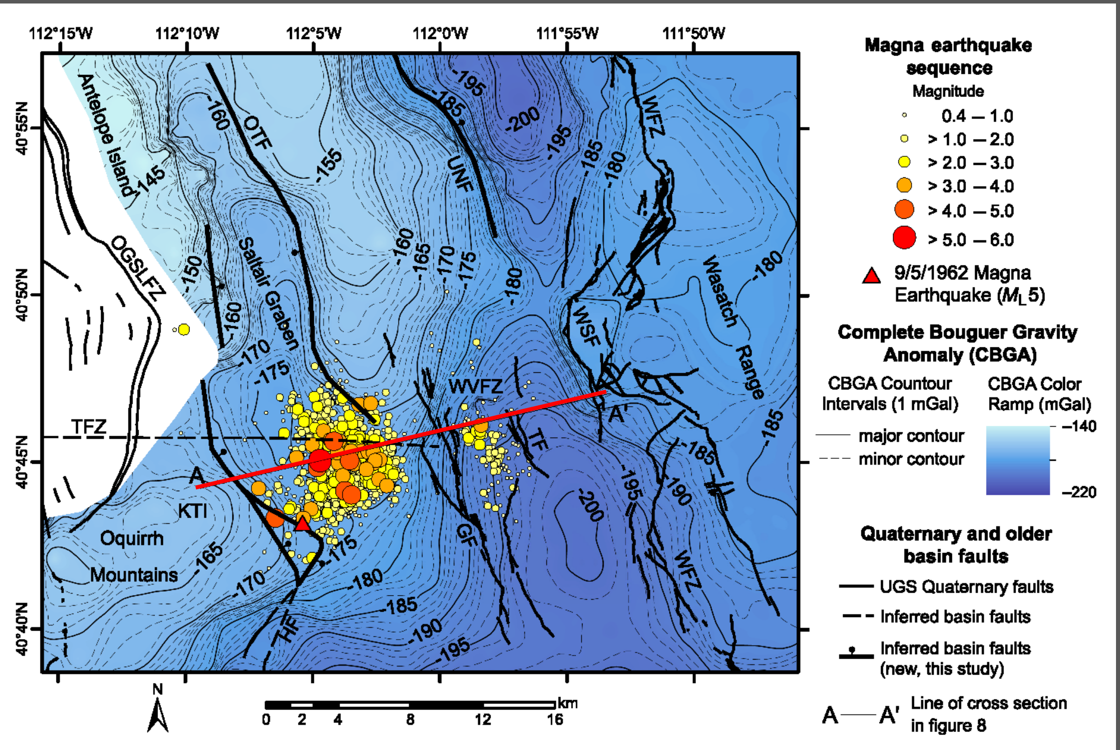


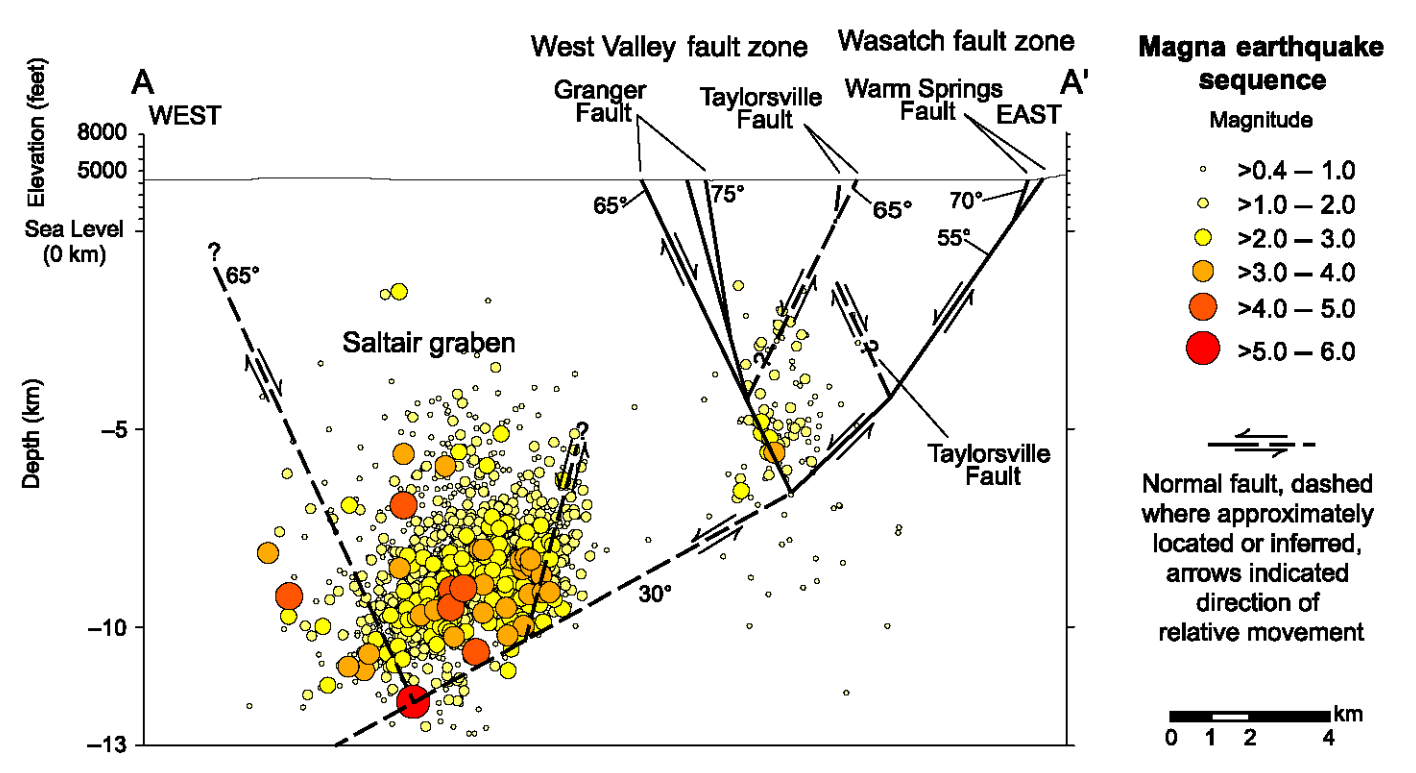




UGS, Gordon Douglass

Hypothetical Structural Model of the Causative Fault





Focus Section: Intermountain West Earthquakes

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Geophysical Research Letters

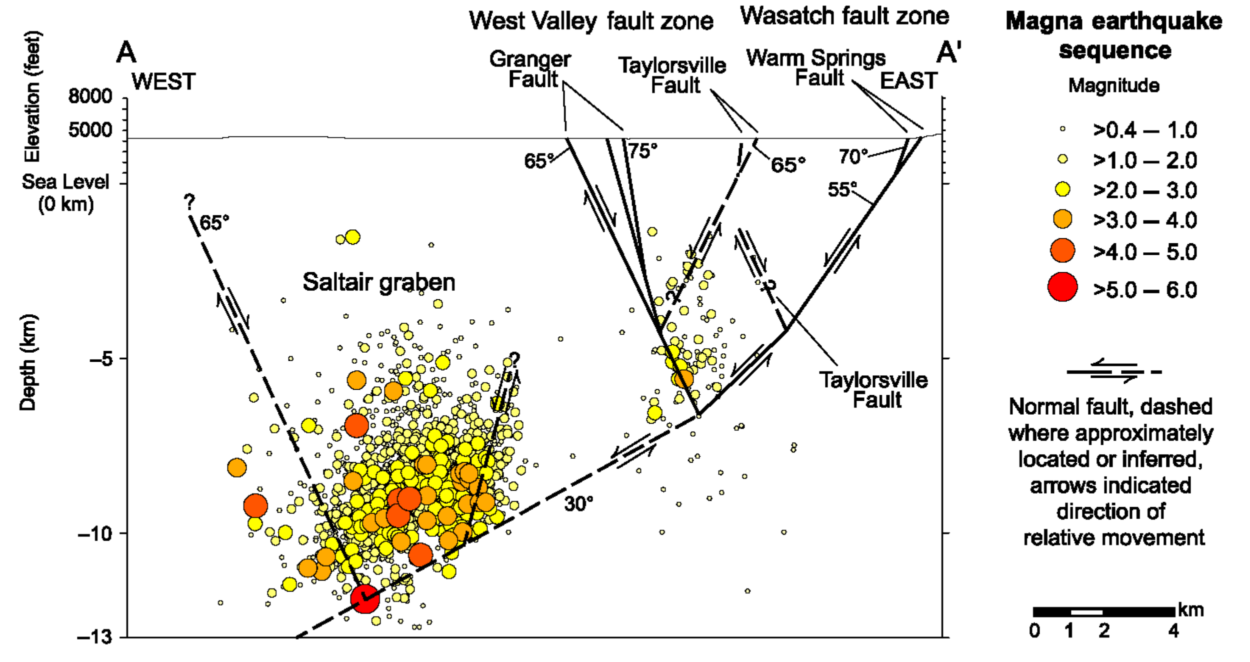
RESEARCH LETTER
10.1029/2020GL089798

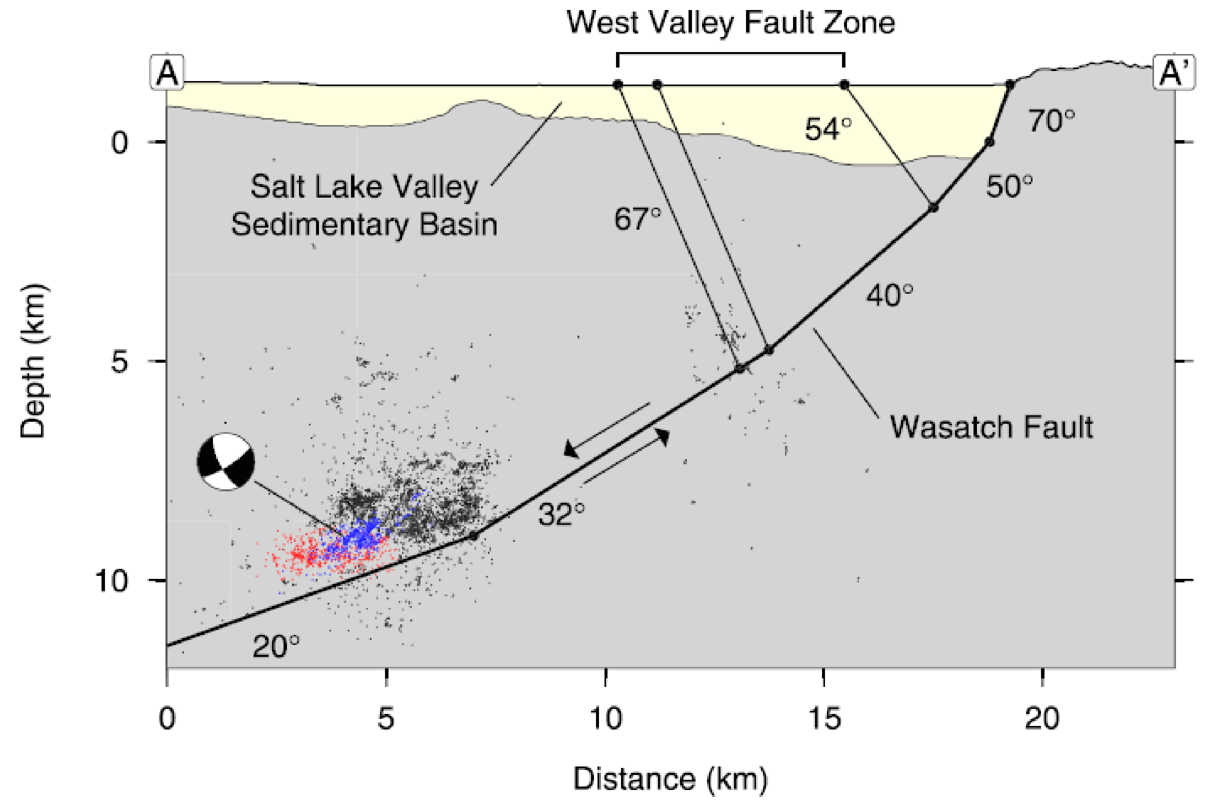
Seismic Analysis of the 2020 Magna, Utah, Earthquake Sequence: Evidence for a Listric Wasatch Fault

Guanning Pang[1], Keith D. Koper[1], Maria Mesimeri[1], Kristine L. Pankow[1], Ben Baker[1], Jamie Farrell[1], James Holt[1], J. Mark Hale[1], Paul Roberson[1], Relu Burlacu[1], James C. Pechmann[1], Katherine Whidden[1], Monique M. Holt[1], Amir Allam[1], and Christopher DuRoss[2]

[1]Department of Geology and Geophysics, University of Utah, Salt Lake City, UT, USA, [2]Geologic Hazards Science Center, U.S. Geological Survey, Golden, CO, USA

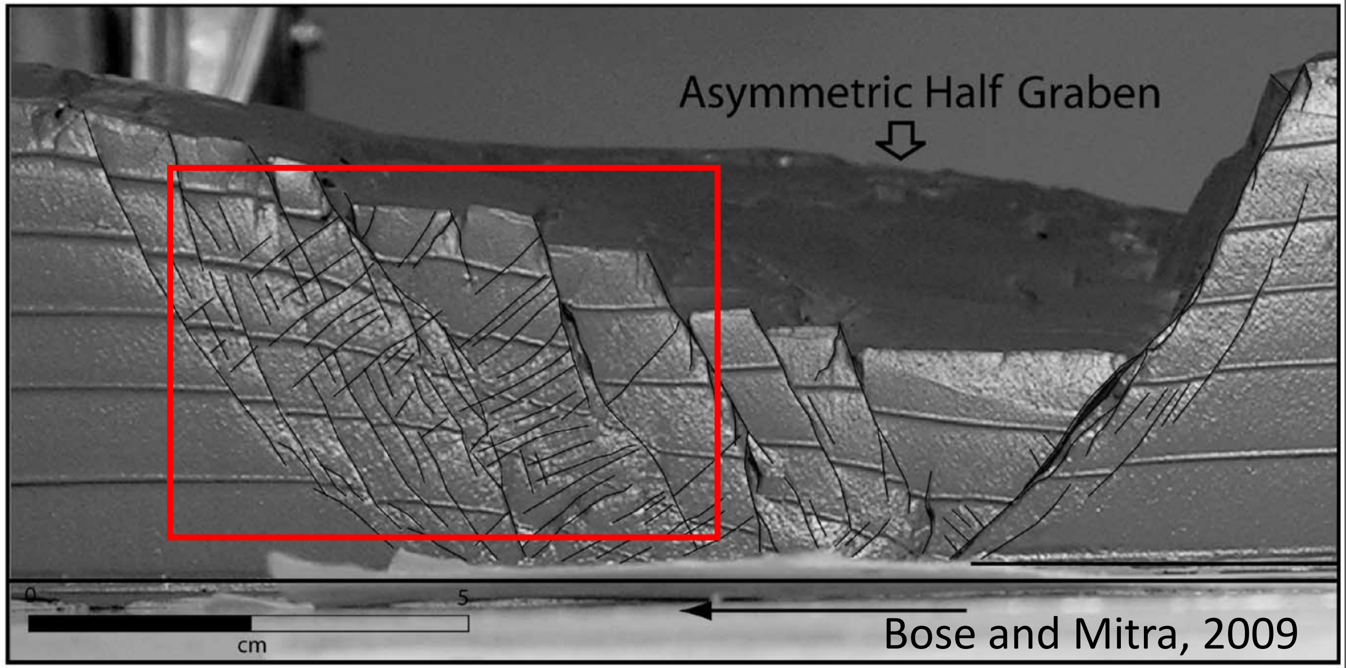
Key Points:
- High-precision relocation of the Magna, Utah, aftershocks supports a listric model for the Salt Lake City segment of the Wasatch fault
- The shallow dip of planar aftershock patterns—and many nodal planes—suggests that shallow-dipping normal faults can fail seismically

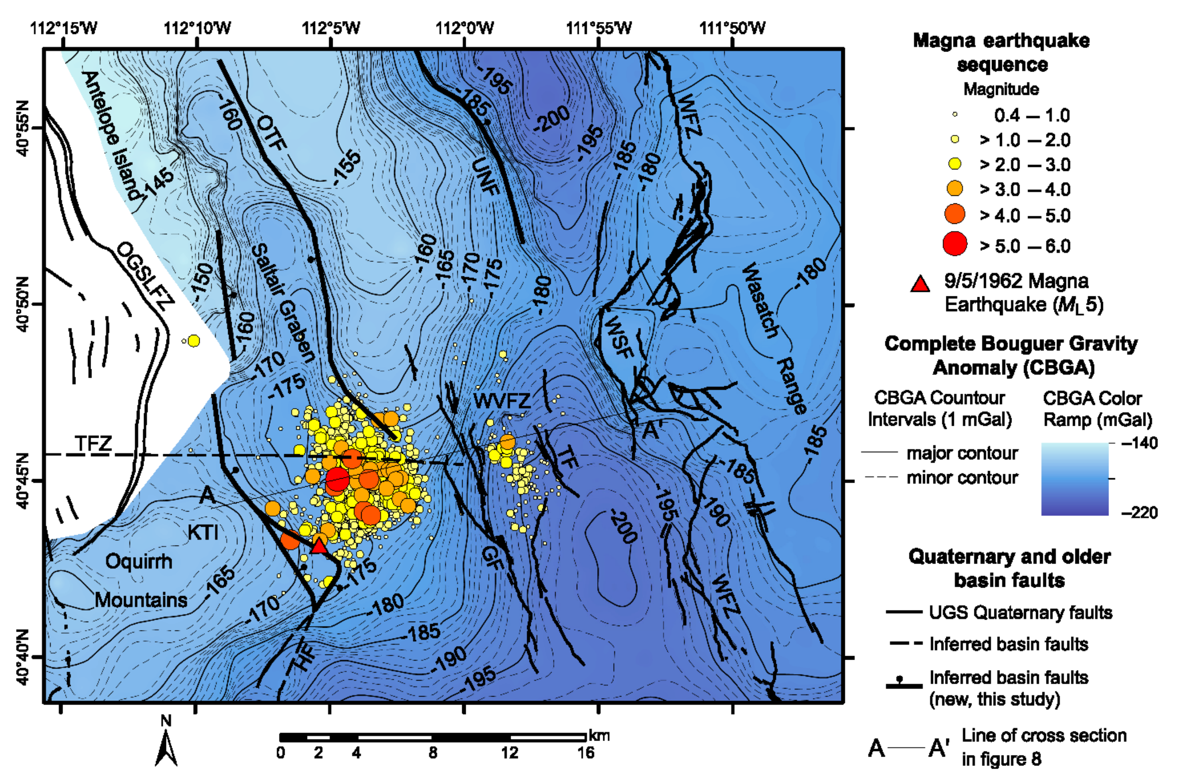


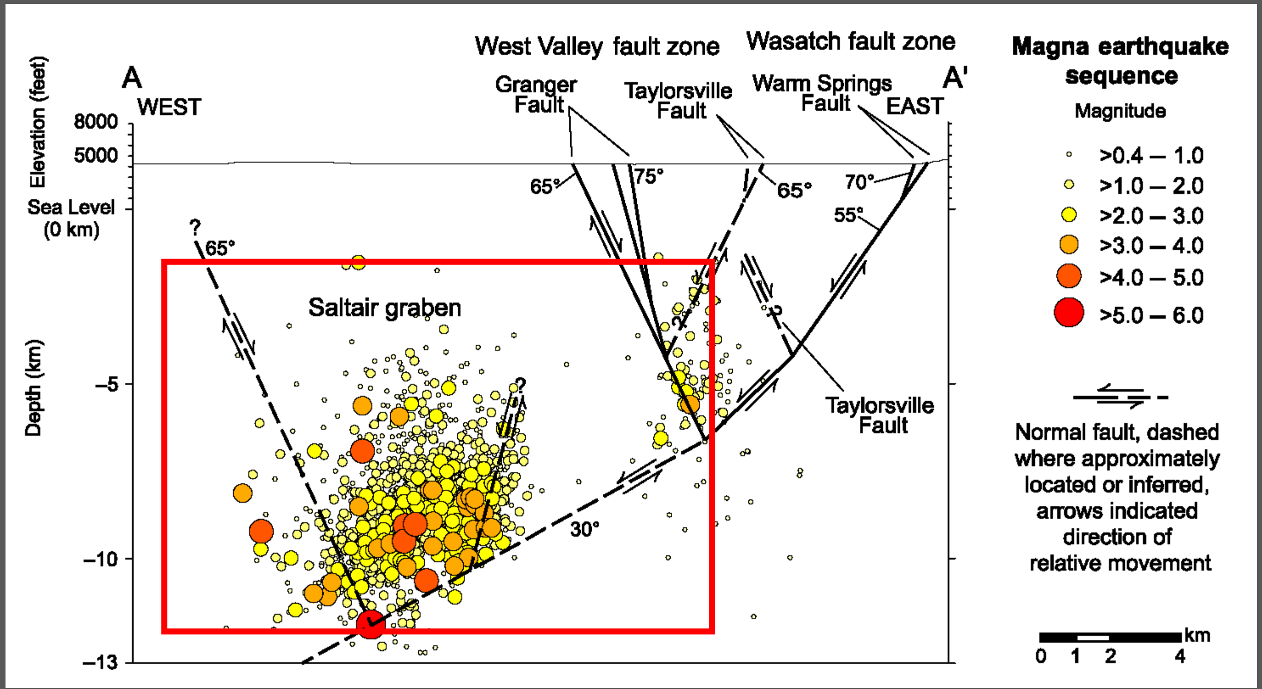


Aftershocks seem to mostly be occurring in the Saltair graben and a few in the West Valley fault zone.

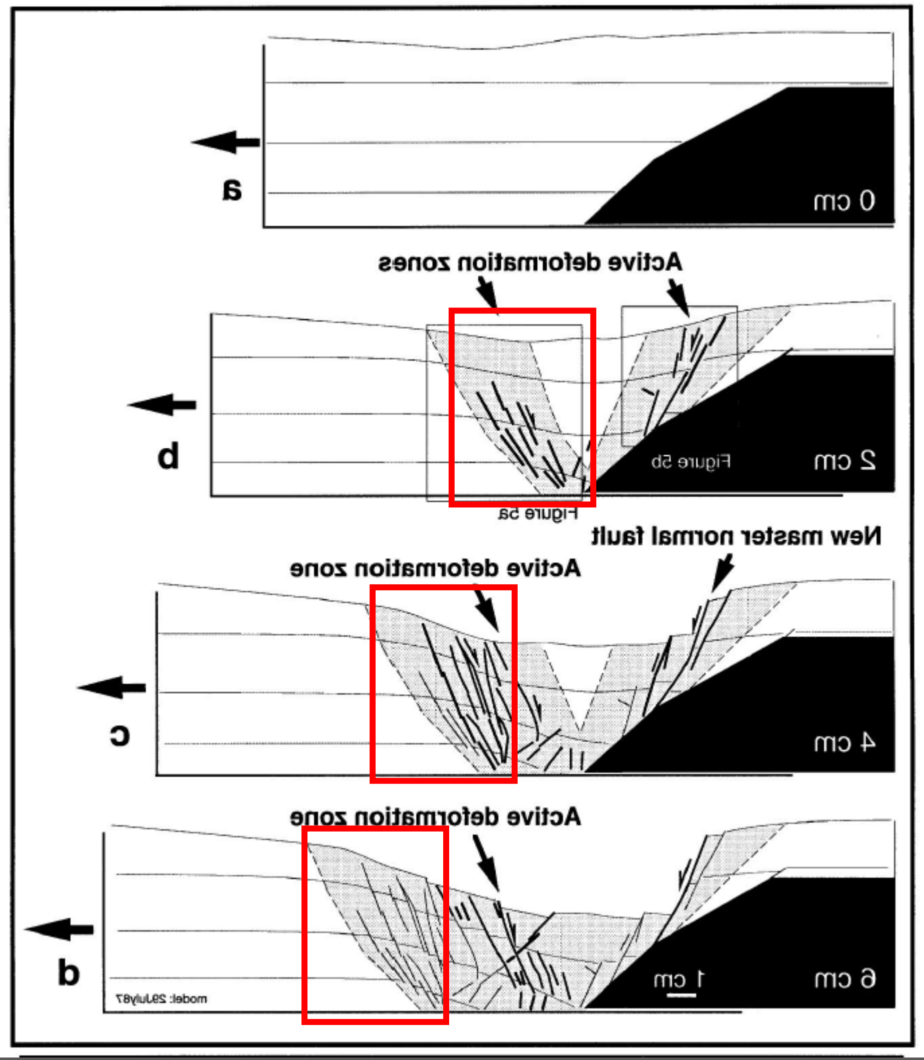
Perhaps the aftershocks are occurring in an area of hanging wall damage? See clay example of criss-crossing faults.



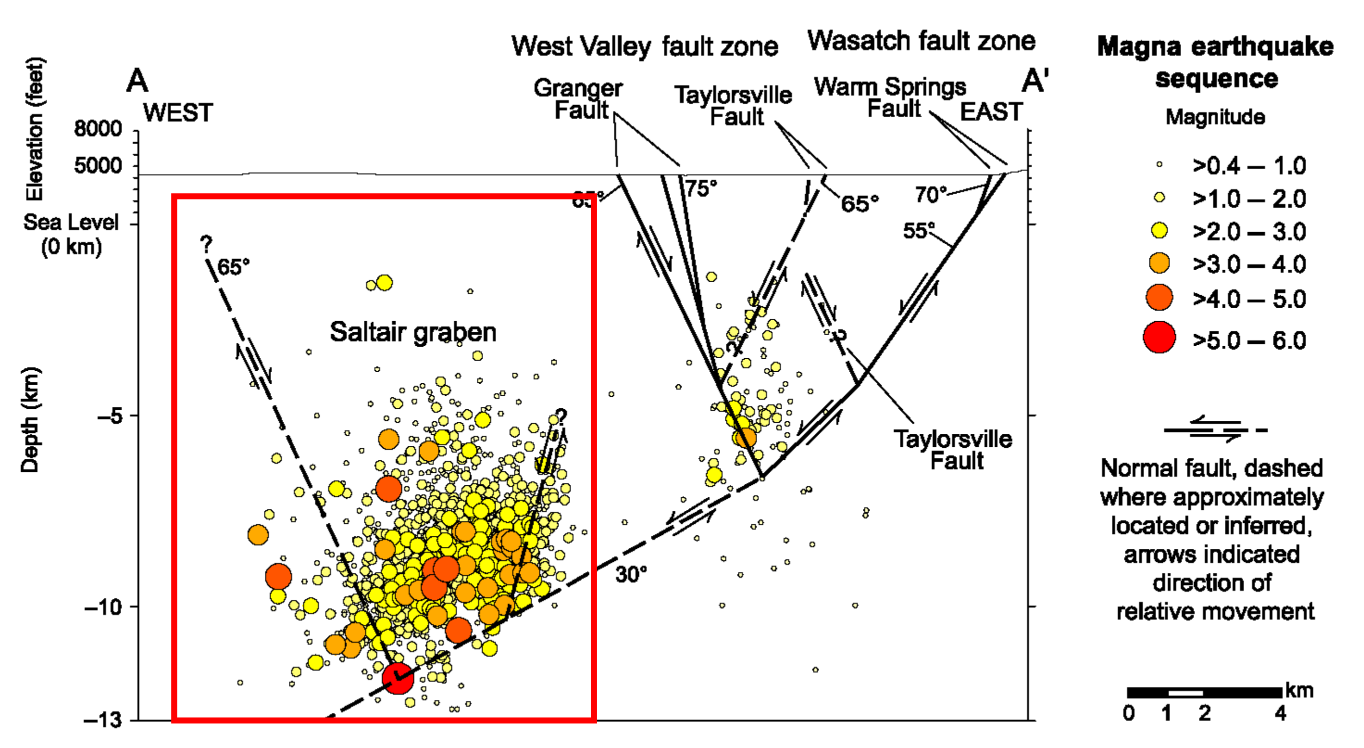




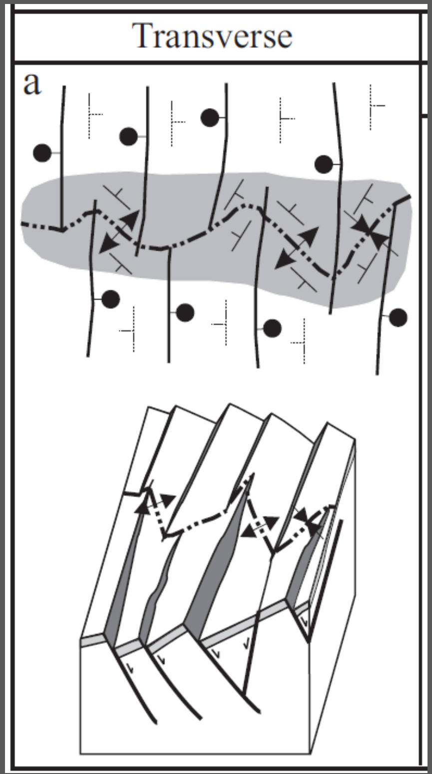
Perhaps Saltair graben is an older zone of deformation on the west side of the valley. Geologic data from the north suggest it is a Basin and Range extension feature that faulted units as young as Salt Lake Formation (8 to 11 Ma).



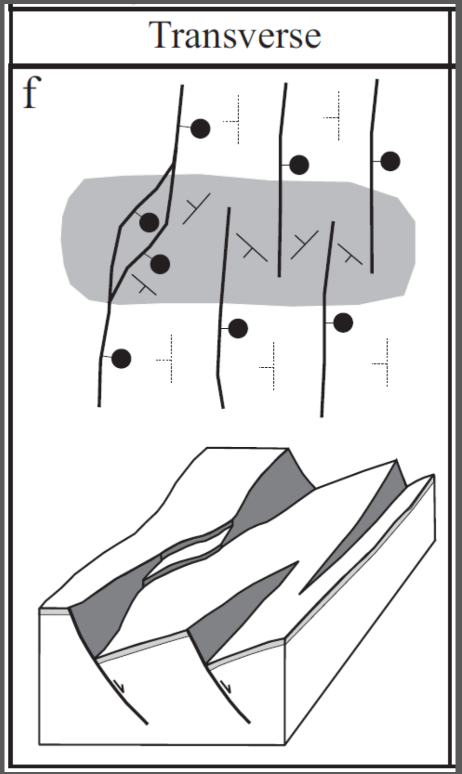
Withjack et al., 1995



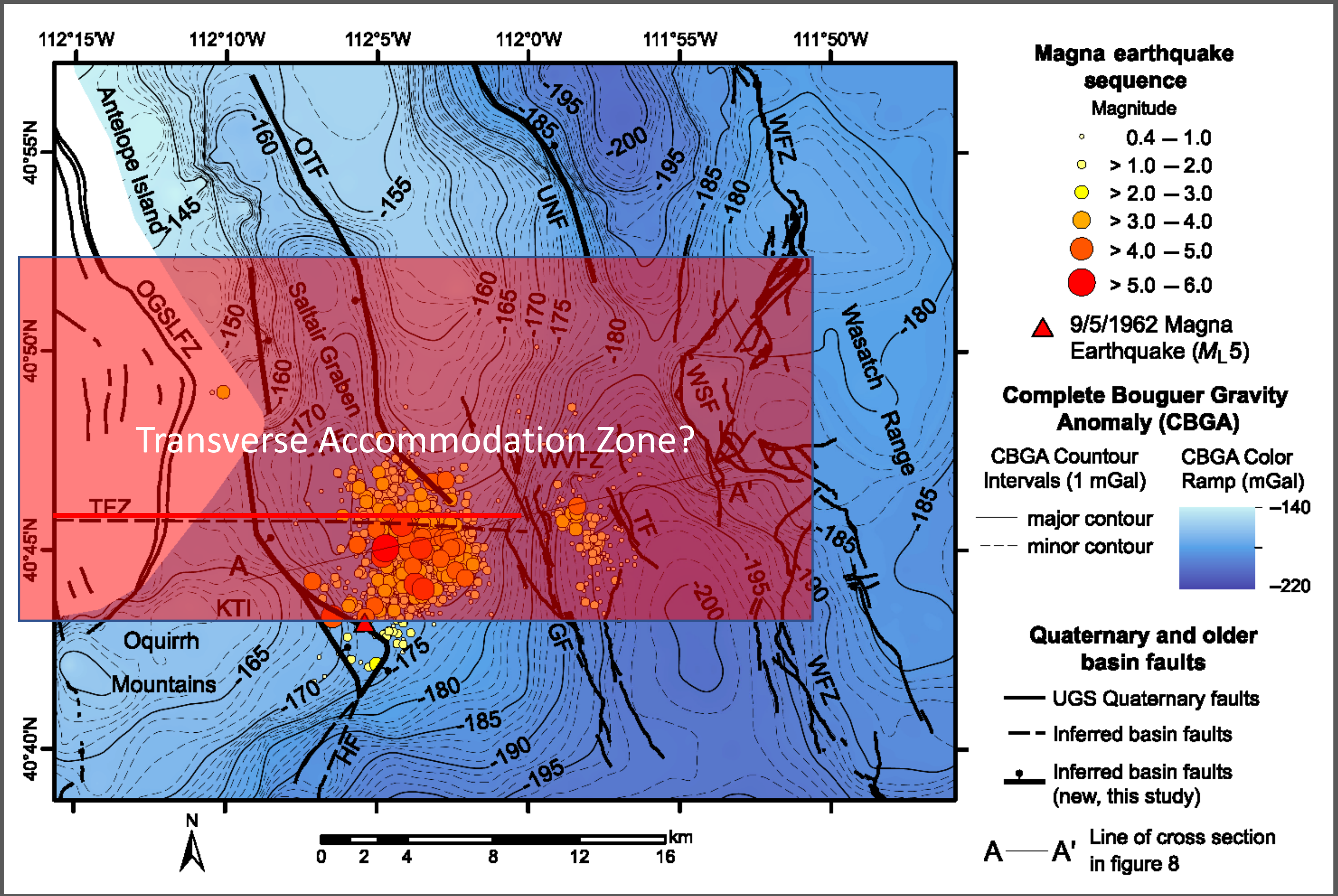
Transverse Accommodation Zone



Antithetic

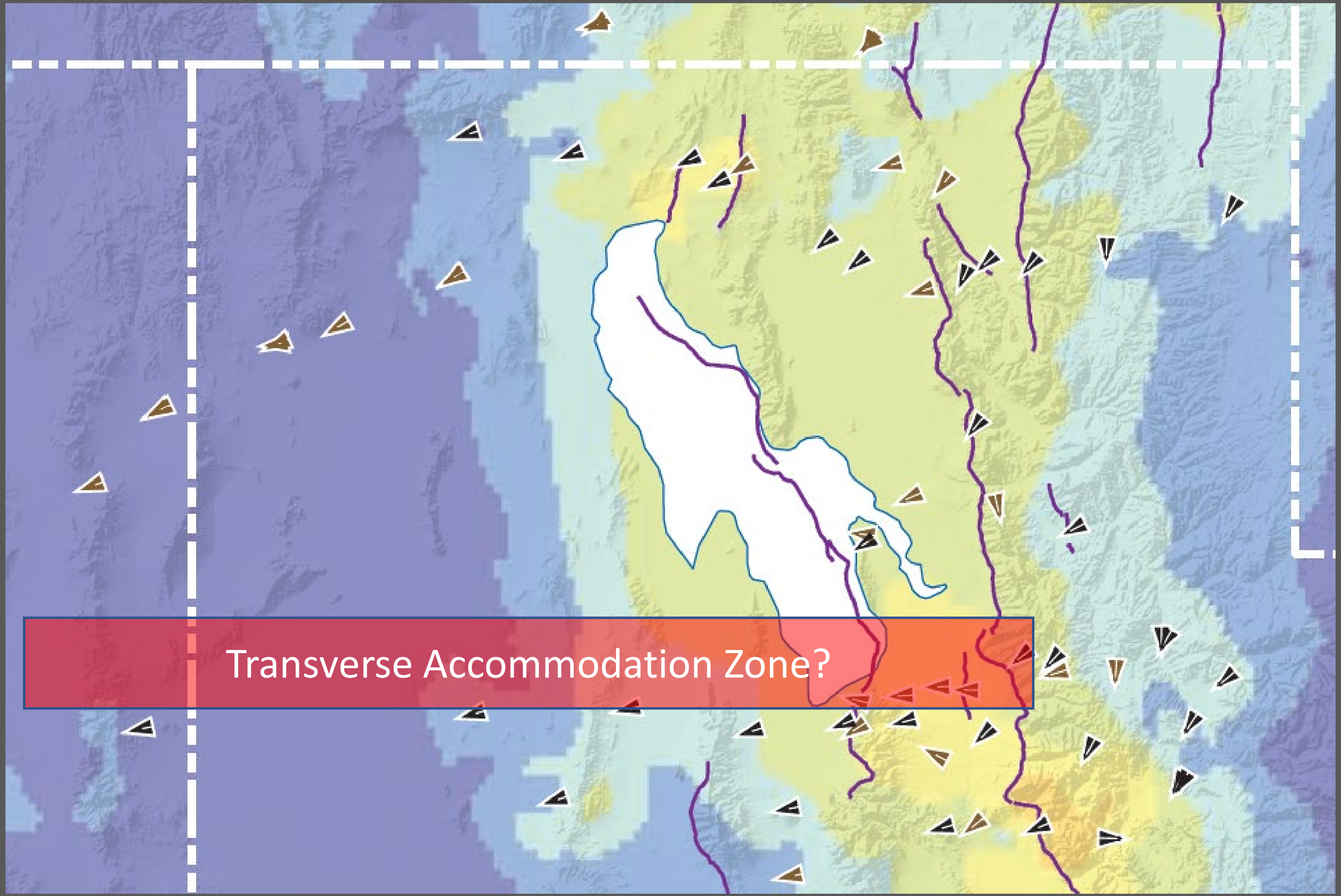


Synthetic



“We define an accommodation zone as the group of structures that accommodate the transfer of strain between overlapping zones or systems of normal faults” (Faulds and Varga, 1998)

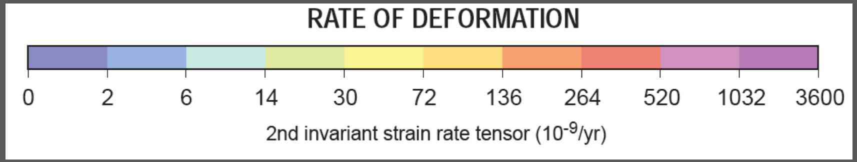
Geodetic Strain Rate Model



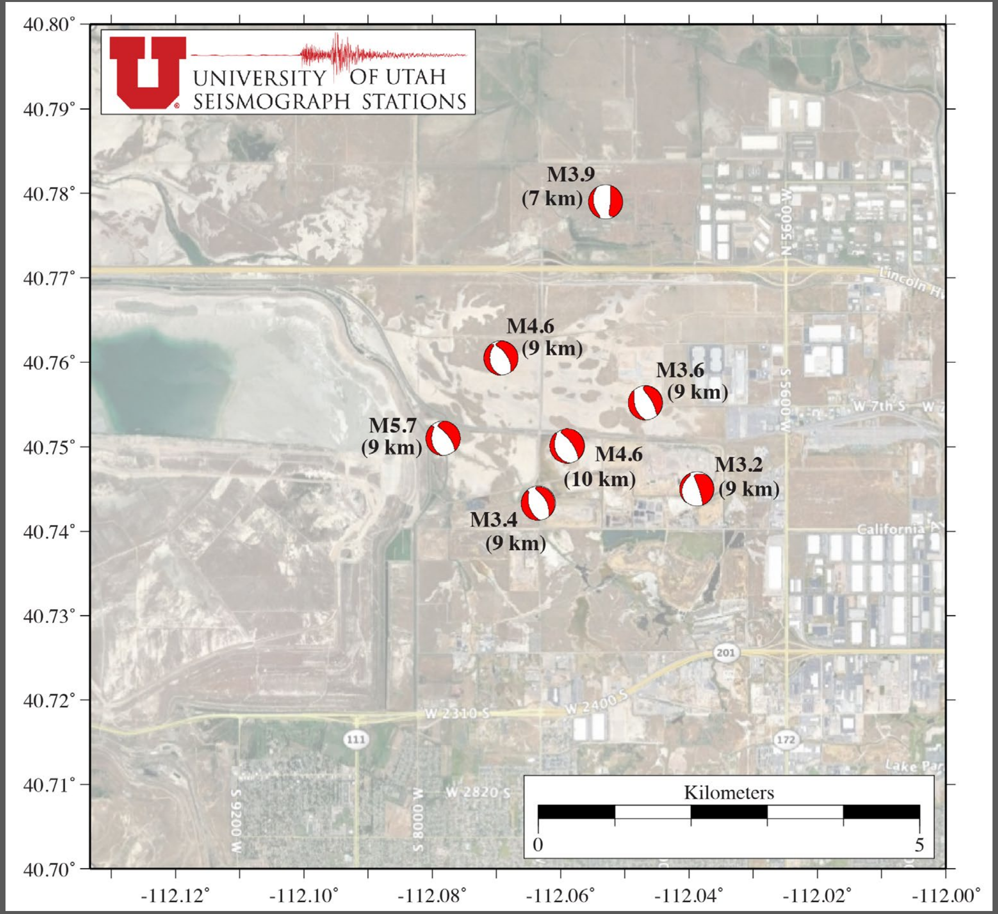
GEODETIC VELOCITIES RELATIVE TO NORTH AMERICA

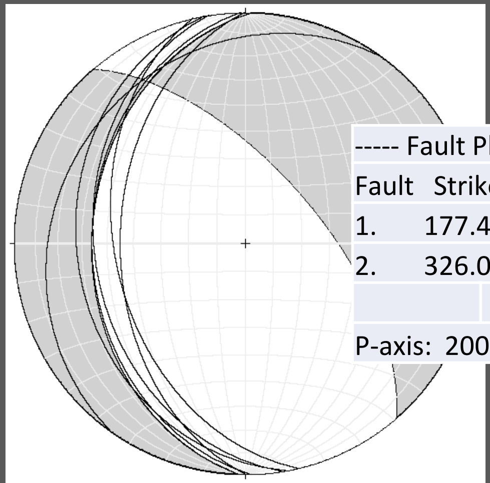
10 MM/YR →

50 MM/YR →



Kreemer et al., 2012





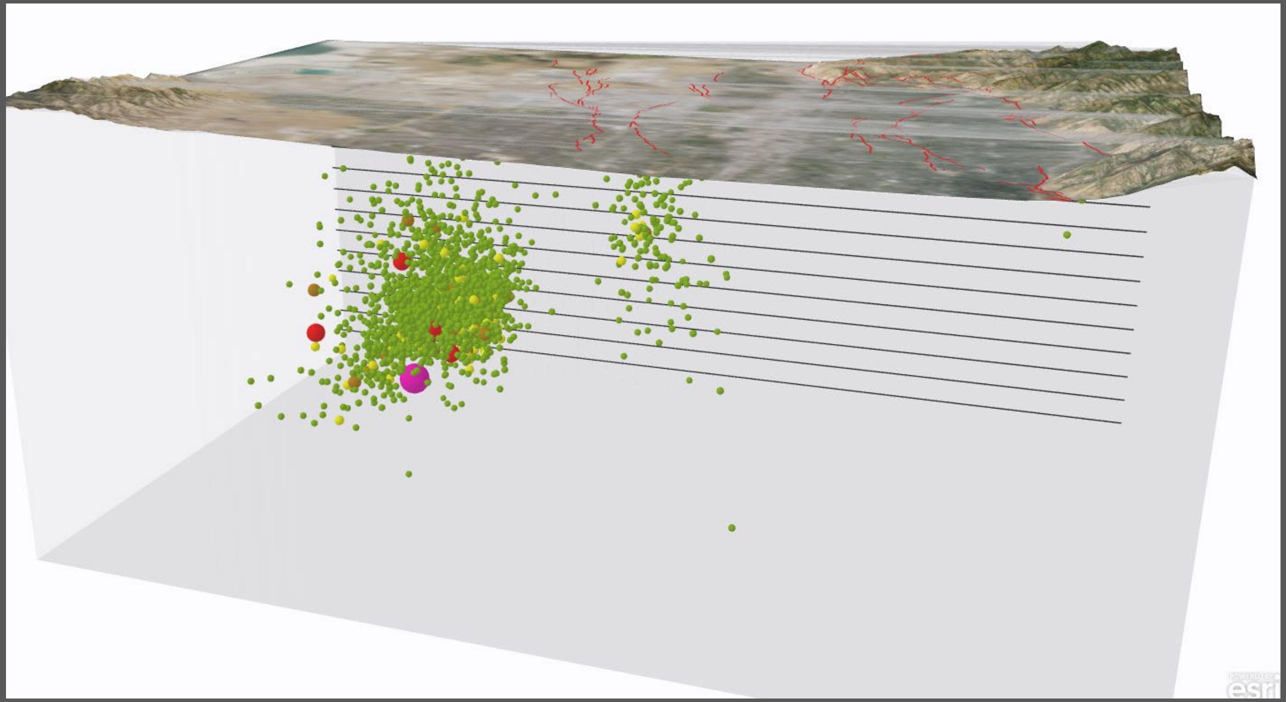
----- Fault Plane Solution | 4/2/2020 at 4:12 PM -----

Fault	Strike	Dip	Trend	Plunge	Slip Sense
1.	177.4	33.4	236.0	29.3	
2.	326.0	60.7	087.4	56.6	

P-axis: 200.5, 69.6; T-axis: 068.1, 14.1

Results from **FaultKin 6**

Conclusions



We hypothesize that:

- Magna earthquake occurred on a listric Warm Springs fault with a complex system of faults in the hanging wall.
- Saltair graben and West Valley fault zone may be constraining the aftershock locations.
- Clay models infer how the hanging wall of the Wasatch fault zone may look in the subsurface and evolved over time.
- A transverse accommodation zone, may be accommodating differential strain between the Weber and Salt Lake City segments

Thank you

Alternative Models for the Subsurface Geometry of the Wasatch Fault in Light of the 2020 Magna, Utah, Earthquake

by

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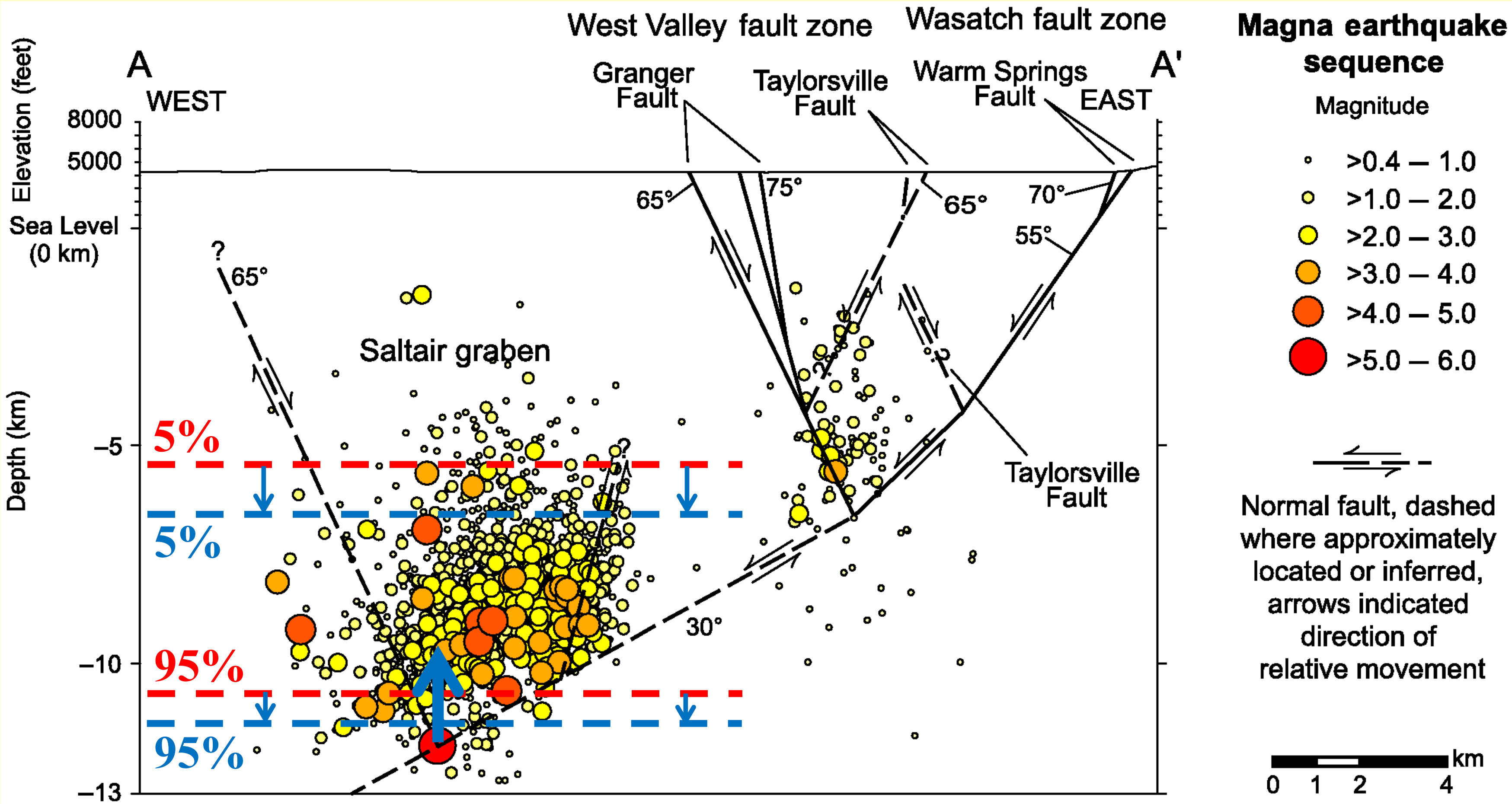
with thanks to Ivan Wong, members of the Working Group on Utah Earthquake Probabilities, and others:

Chris DuRoss, Mike Hylland, Tony Crone,
Steve Personius, Adam McKean, Walter Arabasz,
David Schwartz, Susan Olig, Bill Lund,
David Dinter, Bob Smith, and Mark Petersen

Alternative Models for the Subsurface Geometry of the Salt Lake City Segment (SLCS), Wasatch Fault

Alternative models are important for:

- **Probabilistic seismic hazard analyses**
- **Good science**

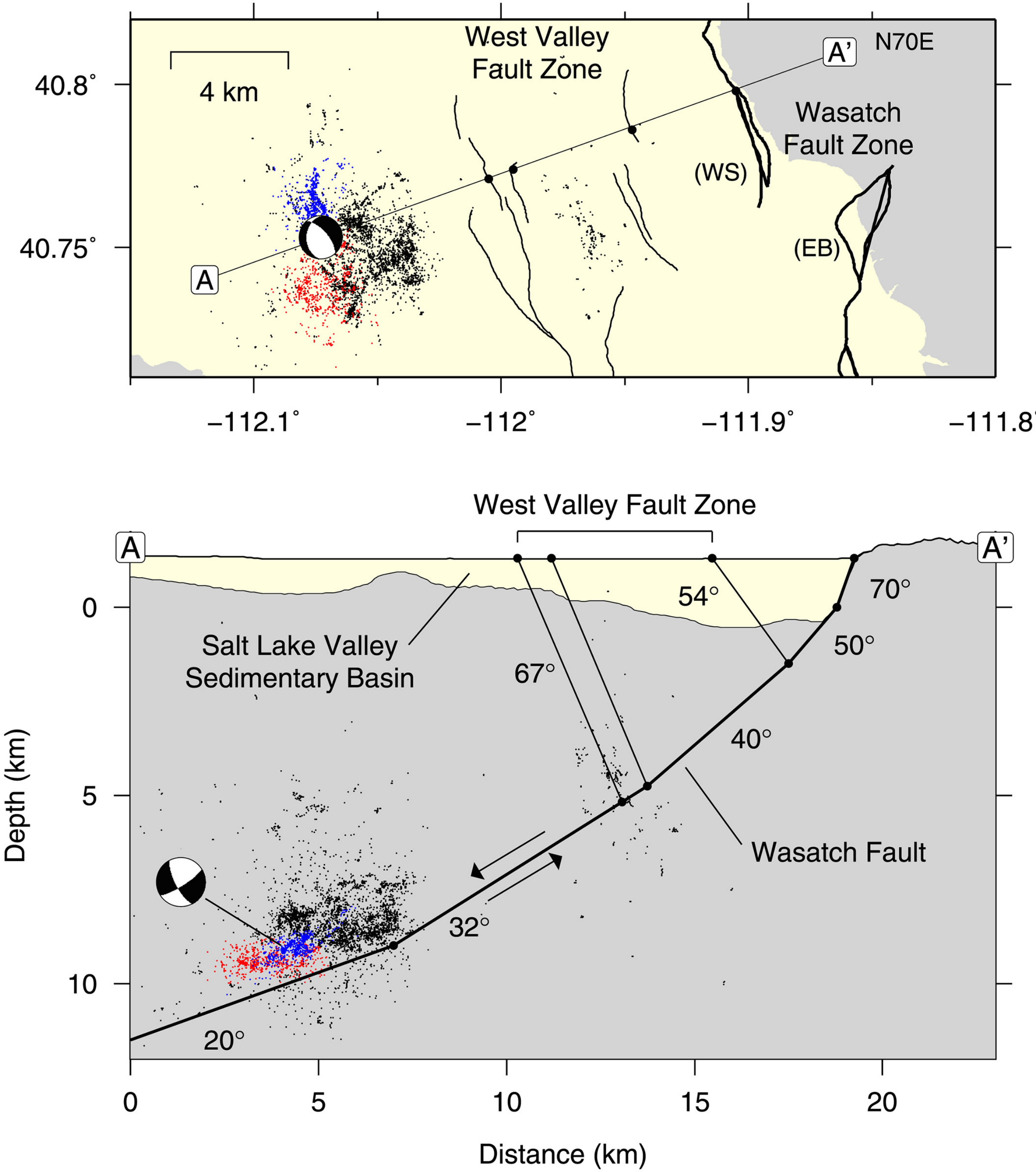


Red: Focal depth percentiles for UUSS catalog locations

Blue: Focal depth percentiles for relocations with 2 velocity models

Modified from Kleber et al. (2021)

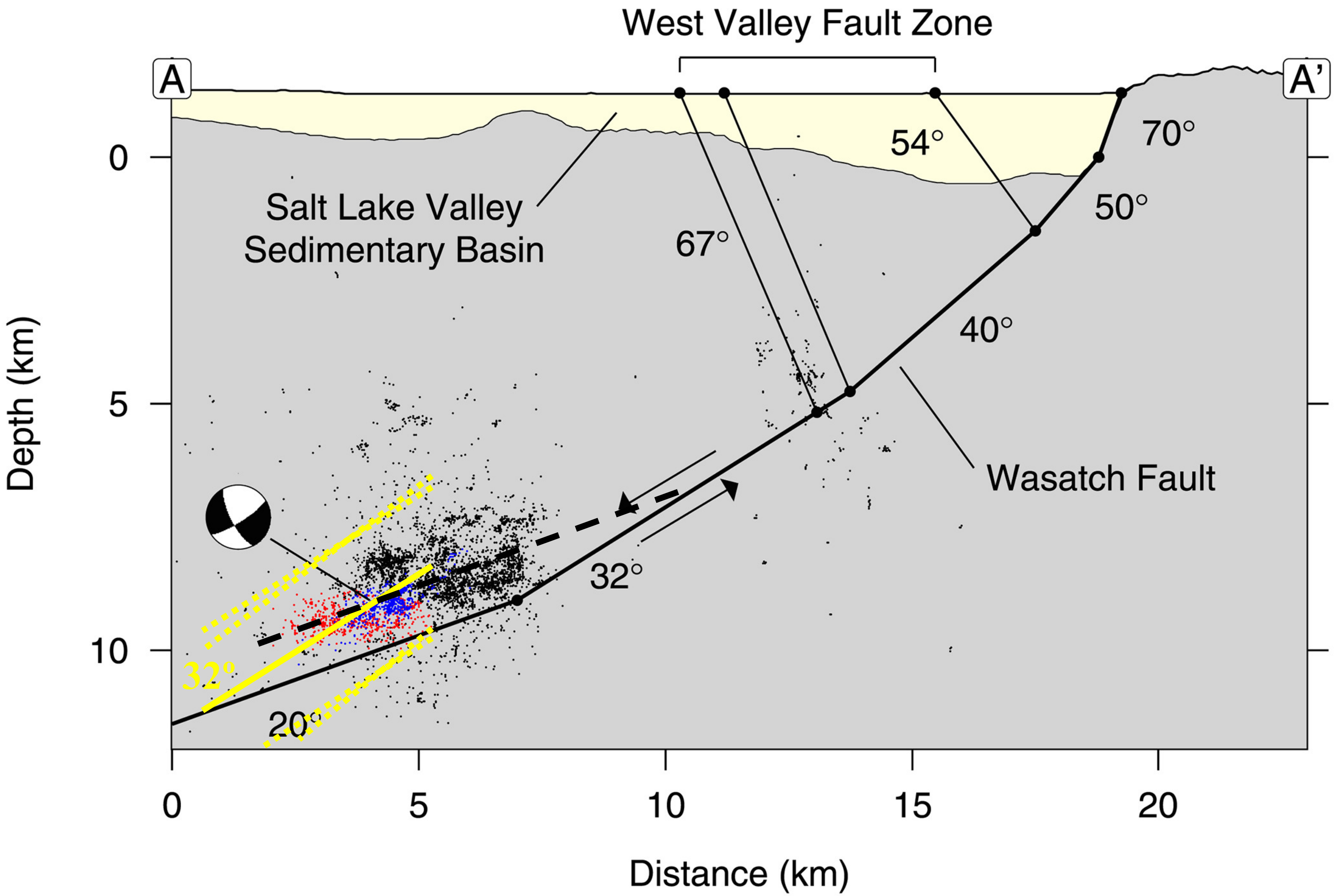
From Pang et al. (2020)



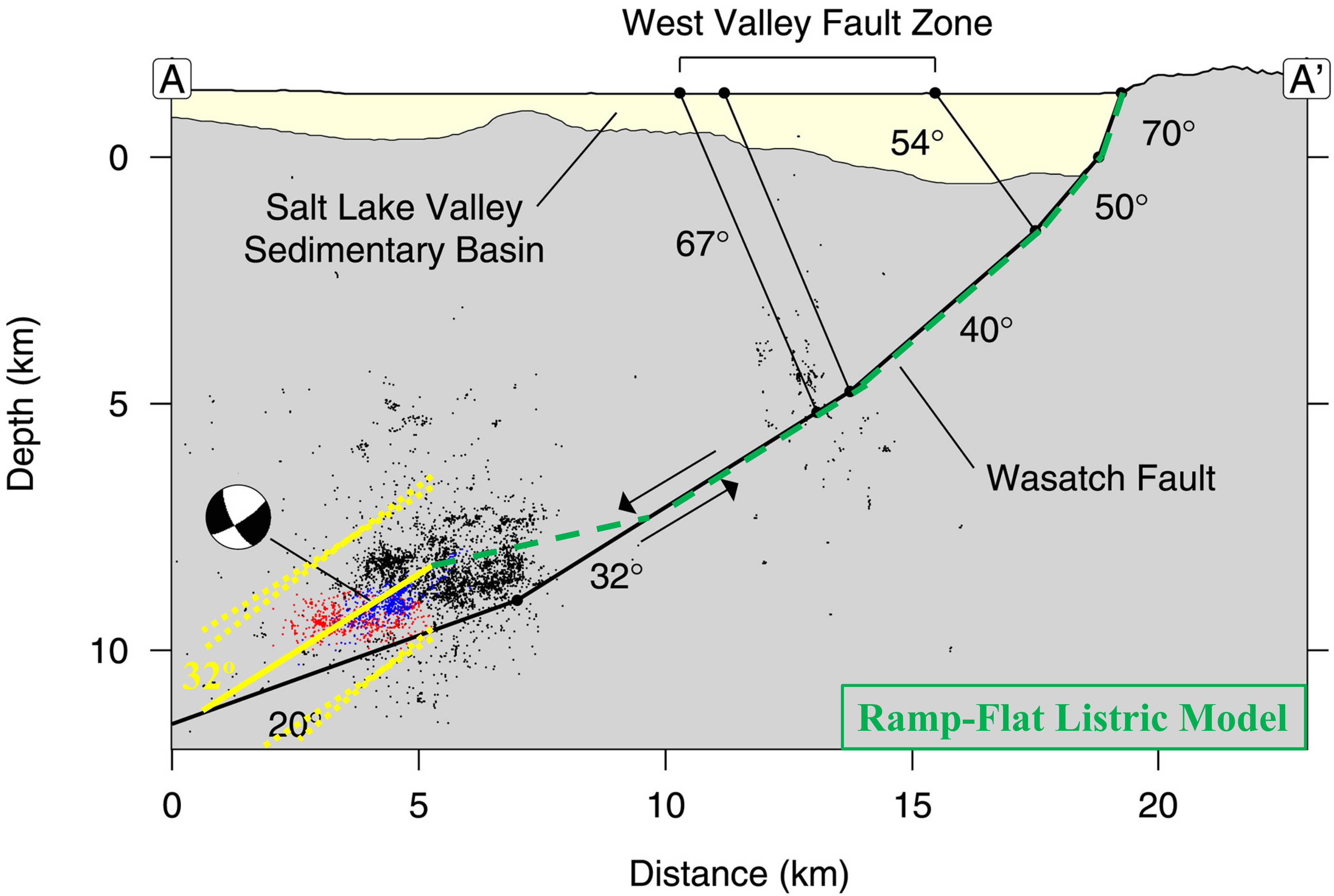
Aftershock zone dip = 21º ± 1º-2º (nominal uncertainty)

Moment Tensor Solutions: 2020 Magna, Utah, Earthquake

Source	Type	Depth Below SL (km)	W-Dipping Plane		
			Strike (deg)	Dip (deg)	Rake (deg)
UUSS	TDMT	7.5	182	34	–52
SLU	Waveform Inversion	10.5	180	35	–60
USGS	Regional	7.5	178	38	–63
Global CMT	CMT	10.5	170	39	–72



Modified from Pang et al. (2020)



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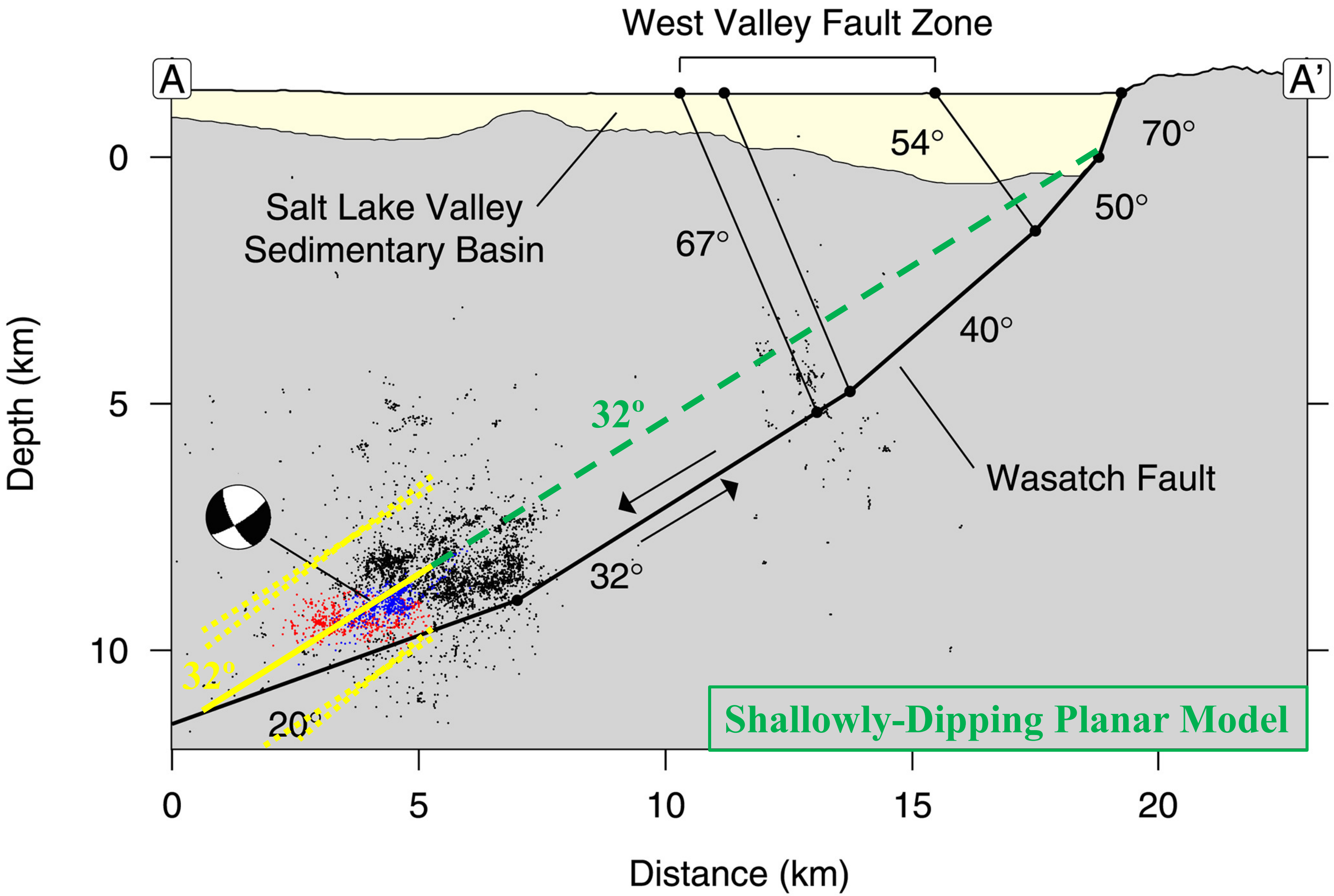
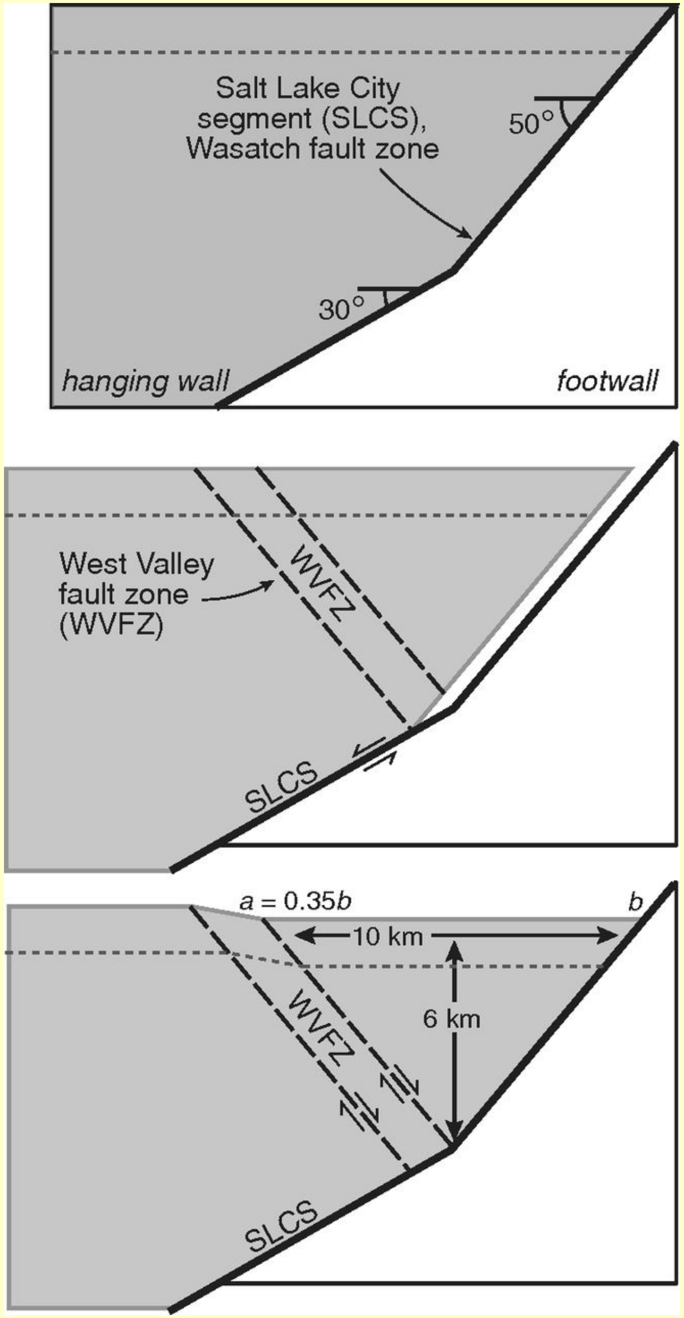


Modified from Pang et al. (2020)



Backtilt Graben Model for the West Valley Fault Zone (WVFZ)

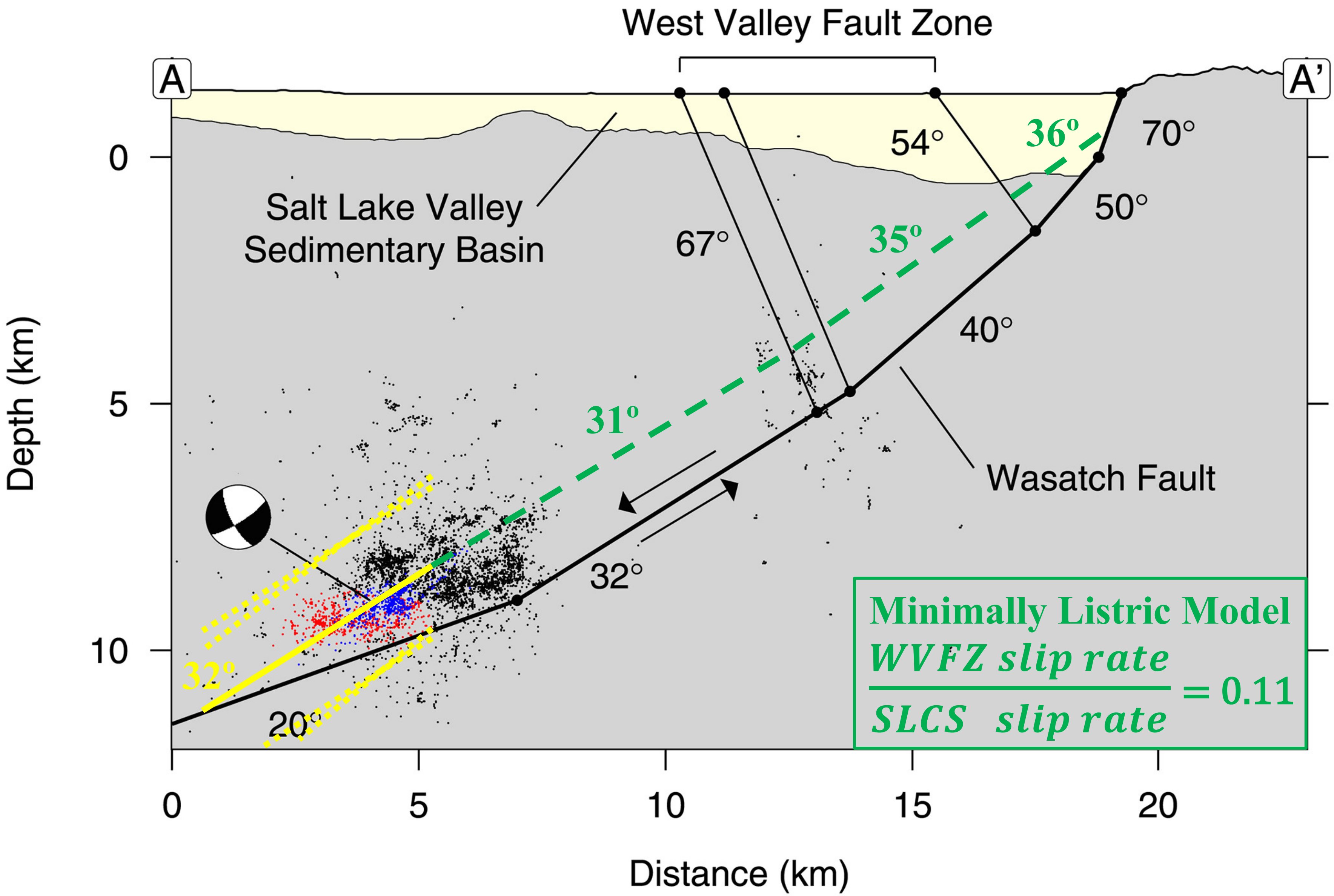
(DuRoss and Hylland, 2015; after Xiao and Suppe, 1992)

(1) "Mean WVFZ per-event vertical displacement (~0.5 m) is 26% – 42% of that for the SLCS (~1.2 – 1.9 m)"

(2) "WVFZ earthquakes occur with every one to three SLCS earthquakes"

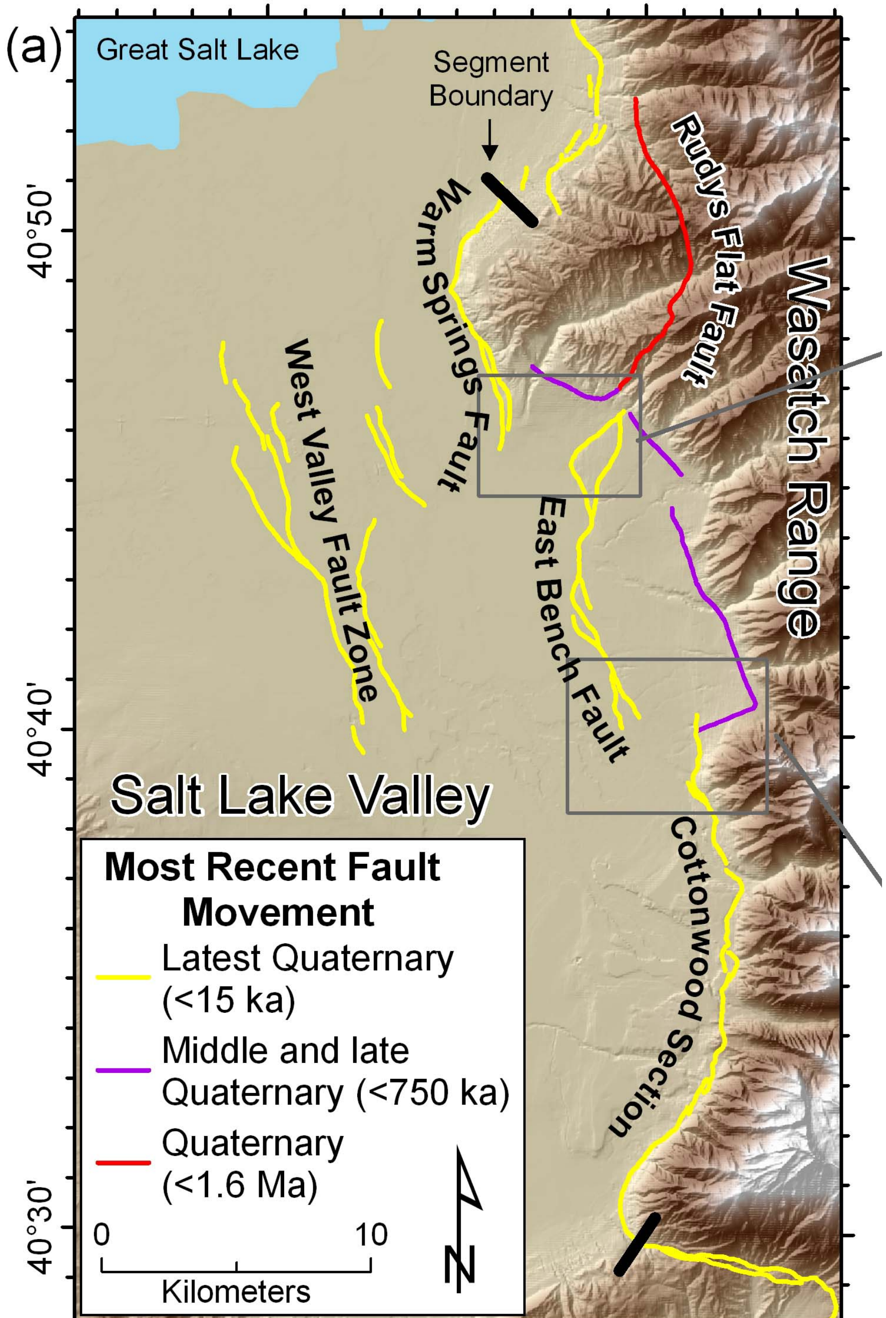
(1), (2) ===>

$$\frac{\textit{WVFZ vertical slip rate}}{\textit{SLCS vertical slip rate}} = 0.09 \text{ to } 0.42$$

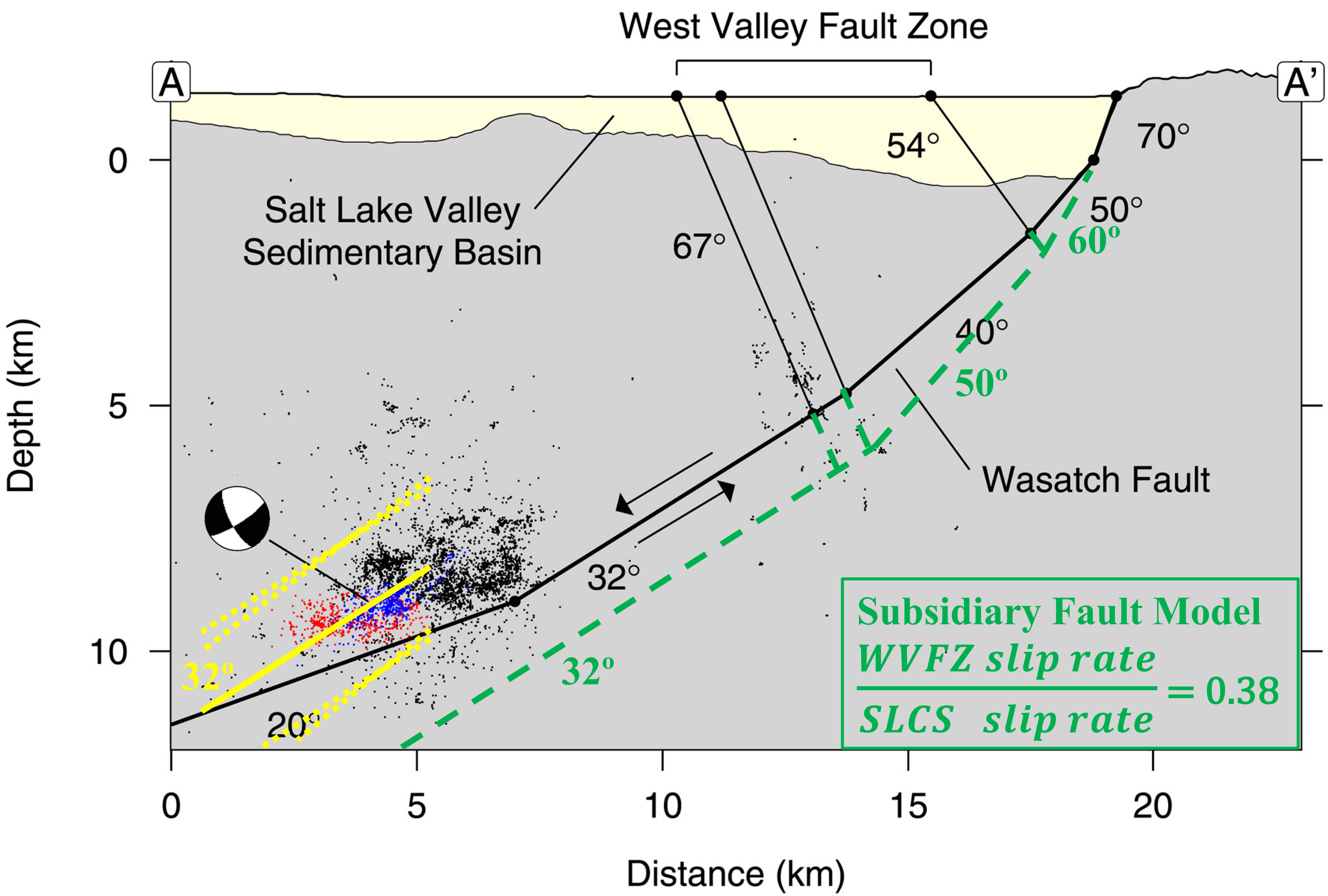


Modified from Pang et al. (2020)

(a)



Great Salt Lake
Segment Boundary
Rudys Flat Fault
Warm Springs Fault
Wasatch Range
West Valley Fault Zone
East Bench Fault
Salt Lake Valley
Cottonwood Section
Most Recent Fault Movement
Latest Quaternary (<15 ka)
Middle and late Quaternary (<750 ka)
Quaternary (<1.6 Ma)
0
10
Kilometers
N
40°50'
40°40'
40°30'
-112°0'
-111°50'



Modified from Pang et al. (2020)

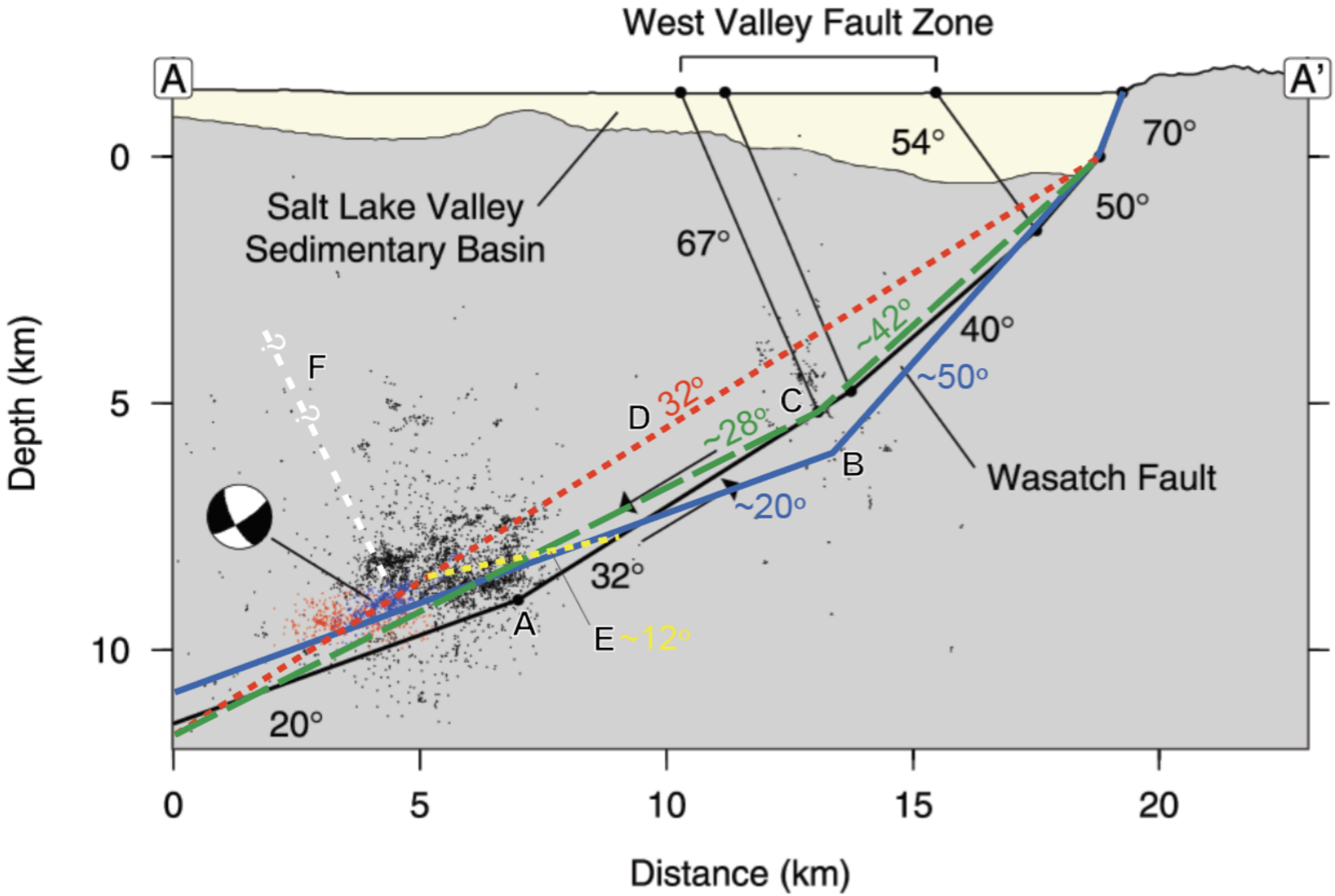


Figure from Chris Duross (2021)

Conclusions

- The 2020 M 5.7 Magna earthquake likely occurred on the Warm Springs section of the SLCS (N end).
- It is also possible that the Magna event was on a subsidiary fault in the hanging wall of the SLCS.
- If the Magna earthquake was on the SLCS Warm Springs section, a listric fault with a "flat" above the rupture is one possible model for this section.
- Weakly listric or shallowly-dipping ($35^{o} \pm 5^{o}$), nearly planar fault models for the Warm Springs section are also consistent with the data.
- The inferred listric geometry for the Warm Springs section probably extends the length of the W Valley fault zone, encompassing the N half of the SLCS.