Welcome to the 2019 Basin and Range Province Earthquake Working Group (BRPEWG) Meeting

Utah Geological Survey

Utah Geological Association

Utah Geological Association

BRPEWG Introduction and overview

- 2006, to develop consensus recommendations from a broad-based group of technical experts on seismic-hazard issues in the Basin and Range Province (BRP) important to the U.S. Geological Survey (USGS) for the 2007 update of the National Seismic Hazard Maps.
- BRPEWGI- 2006, under the auspices of WSSPC and the USGS NSHM Project and National Earthquake Hazards Reduction Program.
- BRPEWGII- 2011 BRPEWGII meeting, similarly cosponsored by WSSPC, to address eight questions and provide consensus recommendations on how to accommodate them in the 2013 USGS NSHM update.
- 2018- first meeting of group since 2011.

USGS Earthquake Geology Intermountain West (IMW)

Ryan Gold, USGS Intermountain West Regional Coordinator

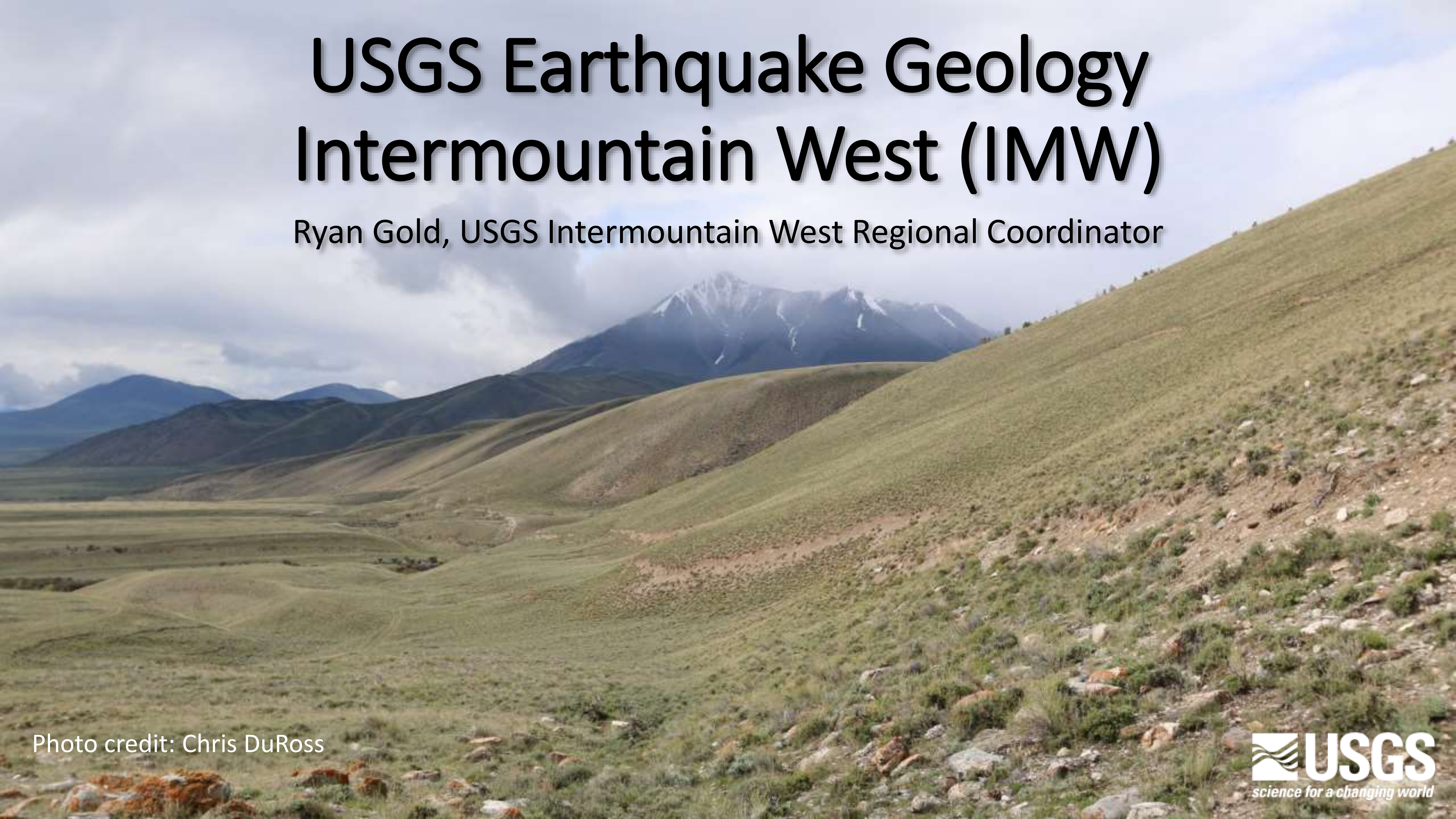


Photo credit: Chris DuRoss

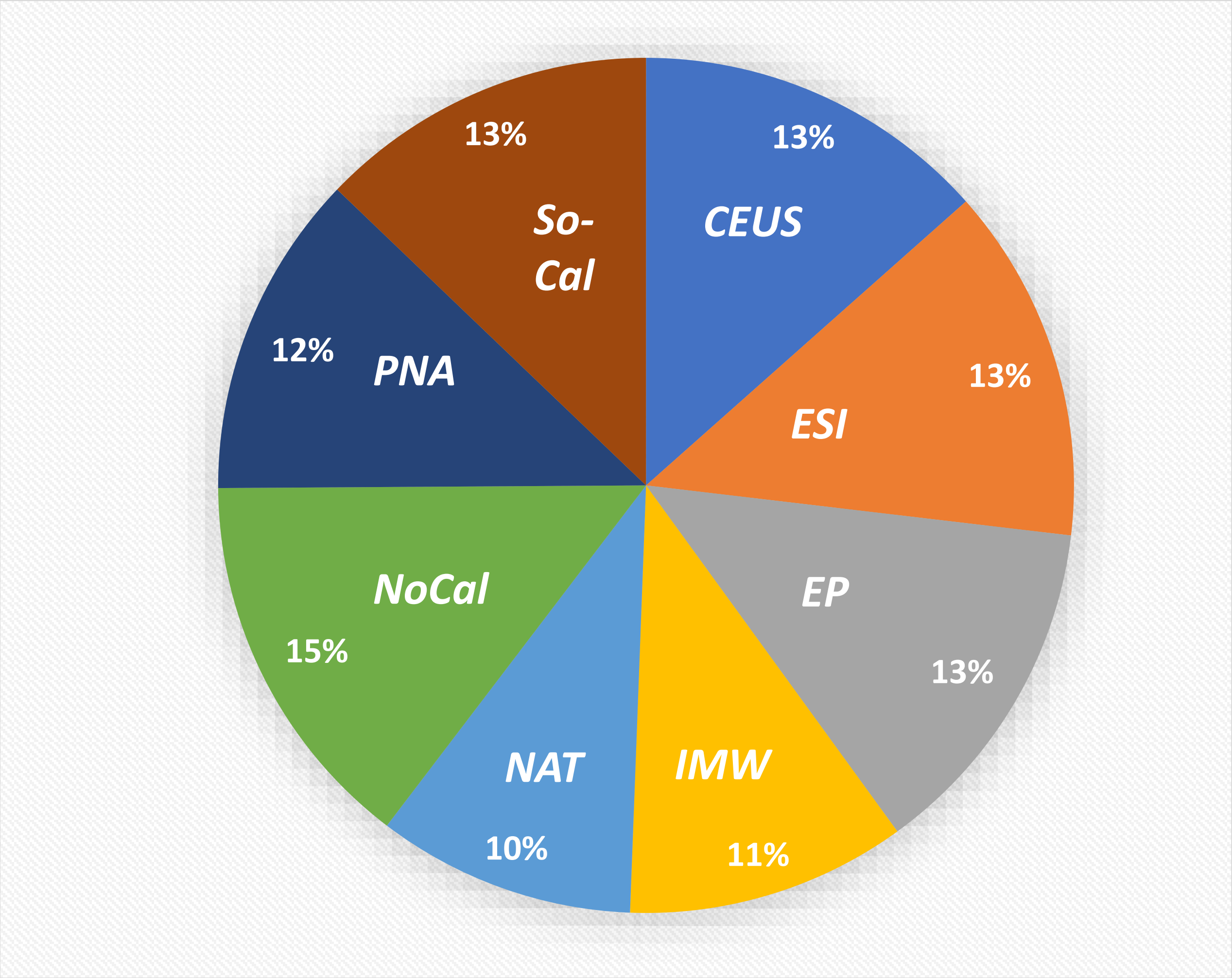
USGS science for a changing world

USGS - Ongoing Research and Collaboration in IMW

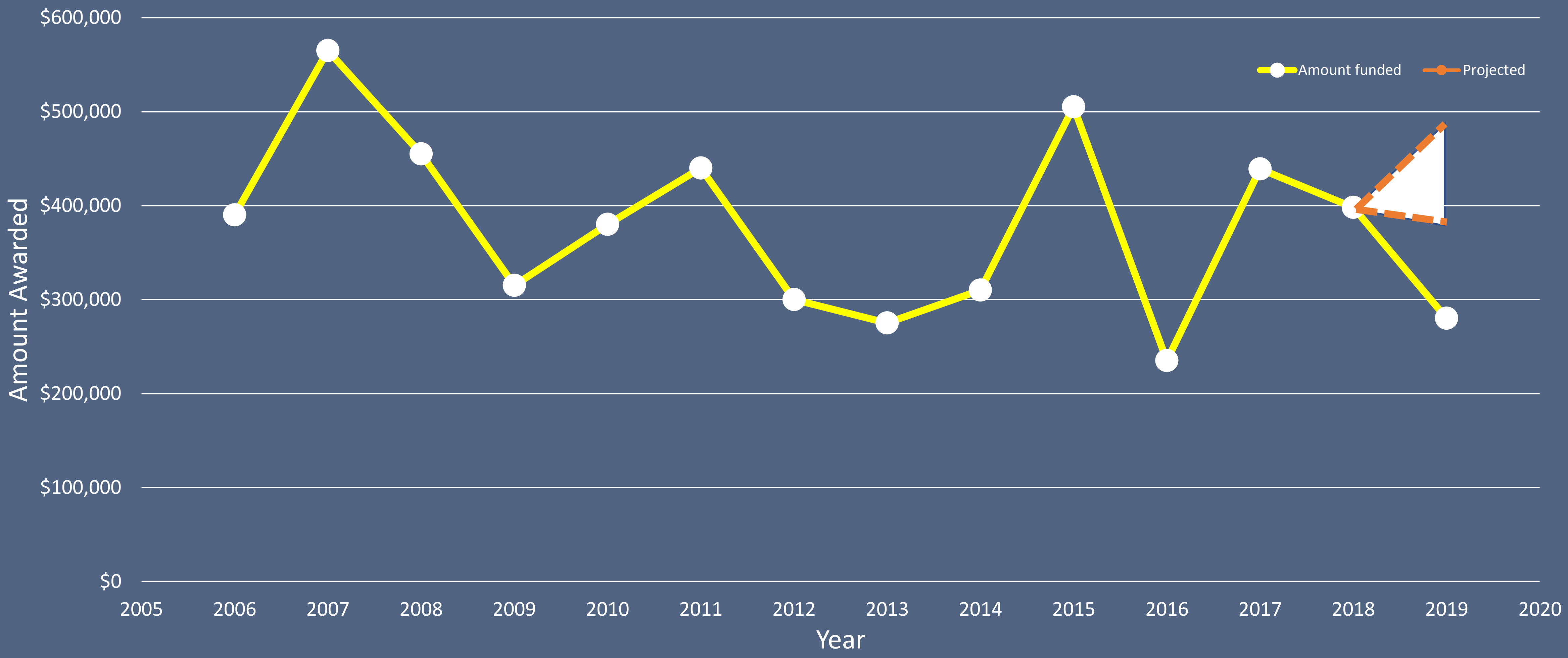
- *Wasatch Front* ***(UGS, UVU)***
- *Teton Range* ***(BoR, USFS, WGS, Univ. of ID, Occidental)***
- *Las Vegas* ***(NBMG, UNR, UNLV)***
- *NE California* ***(PG&E, Univ. of Oregon)***
- *Walker Lane* ***(NBMG, UNR)***
- *Borah Peak, Idaho* ***(UVU)***

USGS External Grants Program, FY2018 (last year)

- $3.78M competitive research grants funded
- 199 Proposals received, 60 funded (~30% success rate)
- IMW funded 9 proposals ($398.1k)



Intermountain West External Grants funding



IMW External Grants FY2019

- IMW received 23 proposals (up from 16 proposals in FY18).
- Total request \$1.35M. Best case scenario: \$520k will be funded.
- Average proposal in fund/fund if possible category: \$57.7k (FY19), up from ~\$45k in FY17 and FY18. *In the likely event of flat funding, 1-2 fewer proposals will be funded.*
- Funding by state
  - NV: 4 grants funded; 2 in "hold" status
  - UT: 1 grant in "hold" status
  - ID: 1 grant in "hold" status
  - AZ: 1 grant in "hold" status

External Grants – guidance going forward (FY20)

- Look for program announcement in March 2019.
- Proposal dues in ~May 2019.
- Panel meets in August – please send me an email 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).
- *Data management plan – now a requirement. Include subsection on this topic.*
- Cost sharing a plus.
- Panels increasingly scrutinizing history of publishing USGS-funded research.

Idaho Earthquakes and Active Faults

2019 Basin and Range Province Earthquake Working Group

February 6, 2019

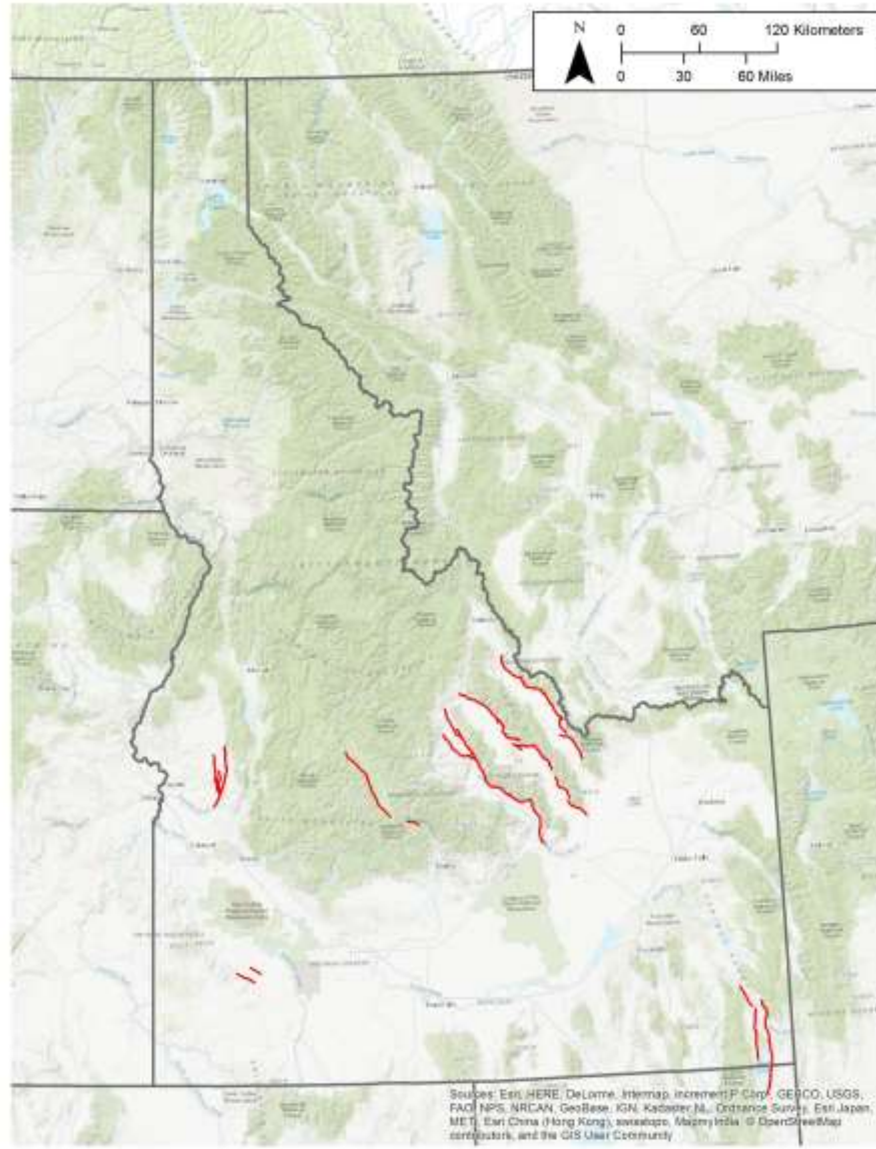
Zach Lifton

Idaho Geological Survey

Idaho Fault Priorities

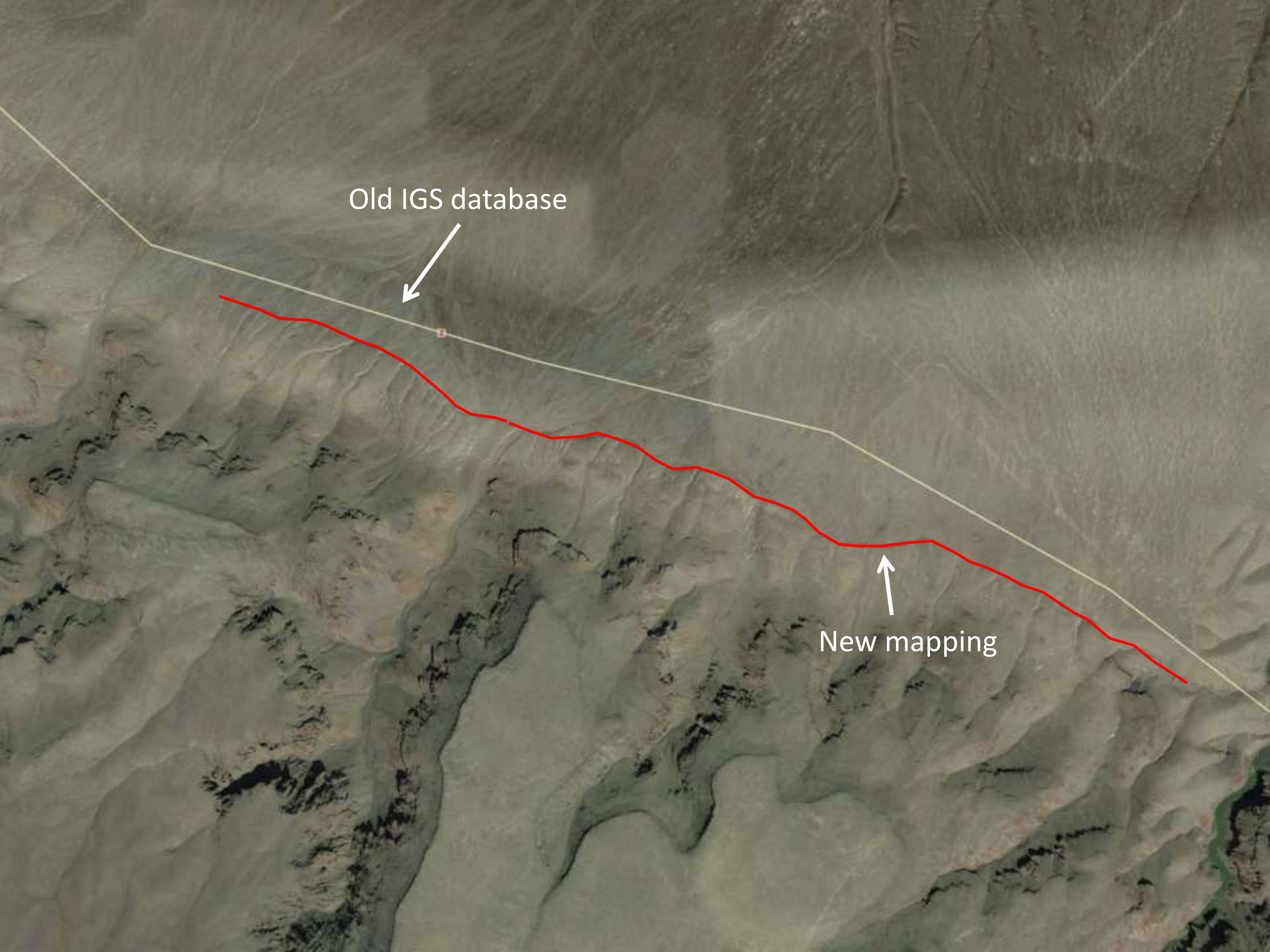
- Lost River*
- Squaw Creek*-Jakes Creek-Big Flat
- E & W Bear Lake
- Sawtooth*-Boulder Front
- Owyhee
- Beaverhead*
- Lemhi*

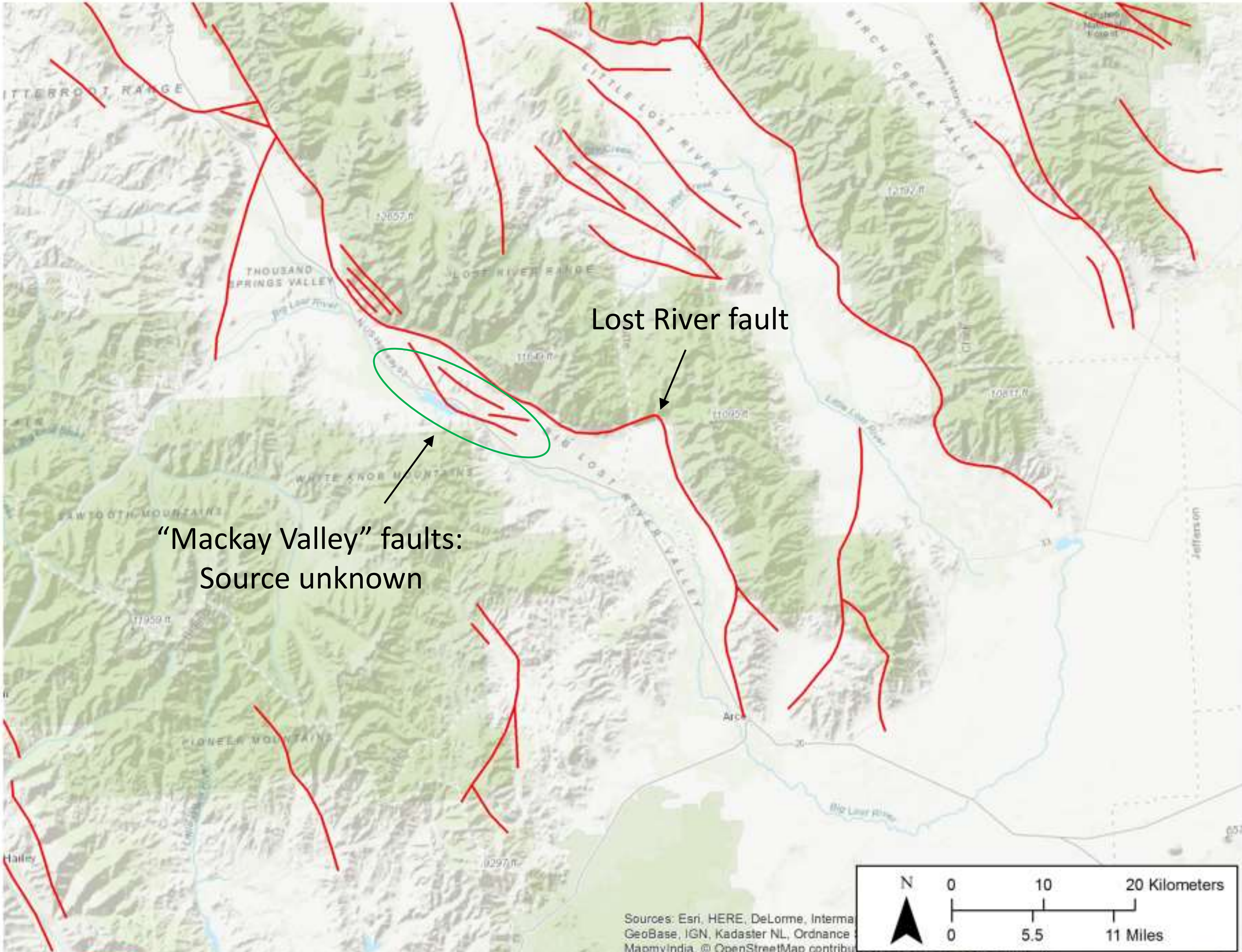
*Priority faults suggested at BRPSHS III (2014)



Idaho Fault Database

- Current ID database vs USGS database
  - USGS is more up-to-date
  - USGS line work is more detailed
  - ID includes some faults that are not included in USGS
- What standard to meet to include in USGS database?
- IGS is working on updating the fault database
  - Better imagery (Google Earth, etc.)
  - More LiDAR available and more coming soon
  - Working toward a more modern model (perhaps following UCERF3 database)
    - More parameters
    - Defined uncertainties


Old IGS database
New mapping



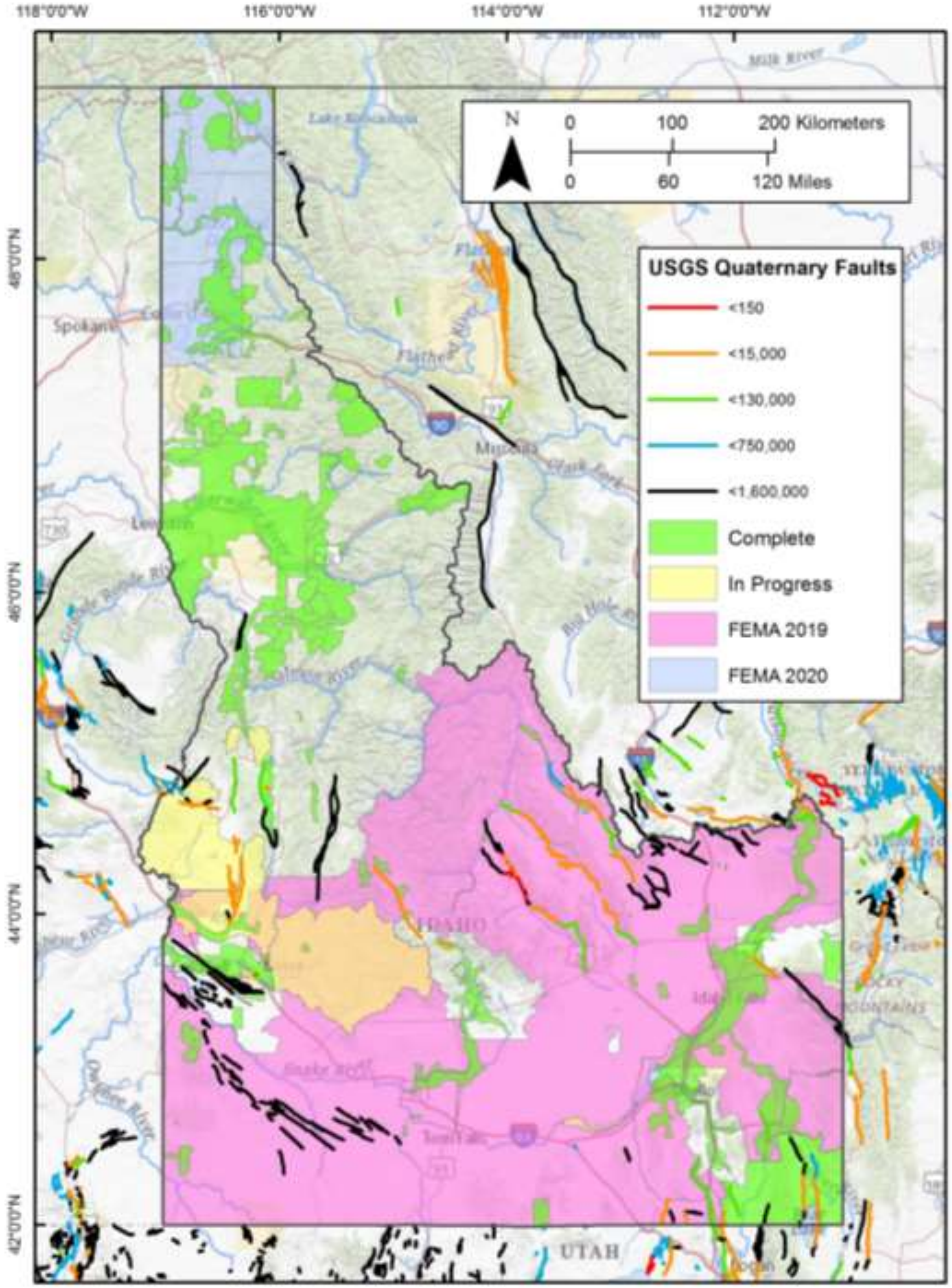
Lost River fault
"Mackay Valley" faults: Source unknown
LITTLE LOST RIVER VALLEY
BIRCH CREEK VALLEY
LOST RIVER RANGE
THOUSAND SPRINGS VALLEY
BIG LOST RIVER VALLEY
WHITE KNOB MOUNTAINS
SAWTOOTH MOUNTAINS
PIONEER MOUNTAINS
Arco
Sources: Esri, HERE, DeLorme, Interma
GeoBase, IGN, Kadaster NL, Ordnance
MapmyIndia, © OpenStreetMap contribu
N
0 10 20 Kilometers
0 5.5 11 Miles

ID database attributes

- ID
- Name
- Synopsis
- Geologic Setting
- Segment
- Geomorphic Expression
- Age of Faulted Deposits
- Timing
- References

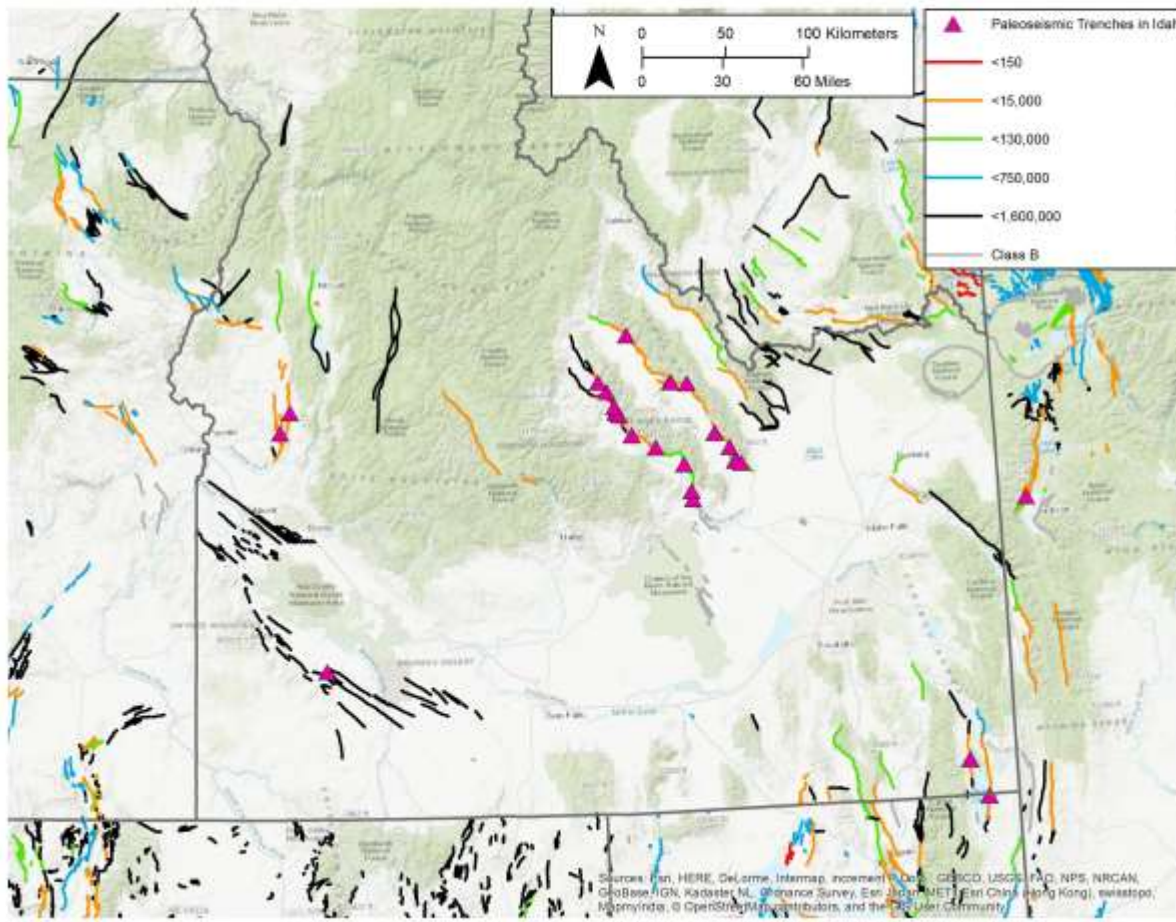
LiDAR Data Availability

- Current coverage
- New datasets
- Forthcoming datasets



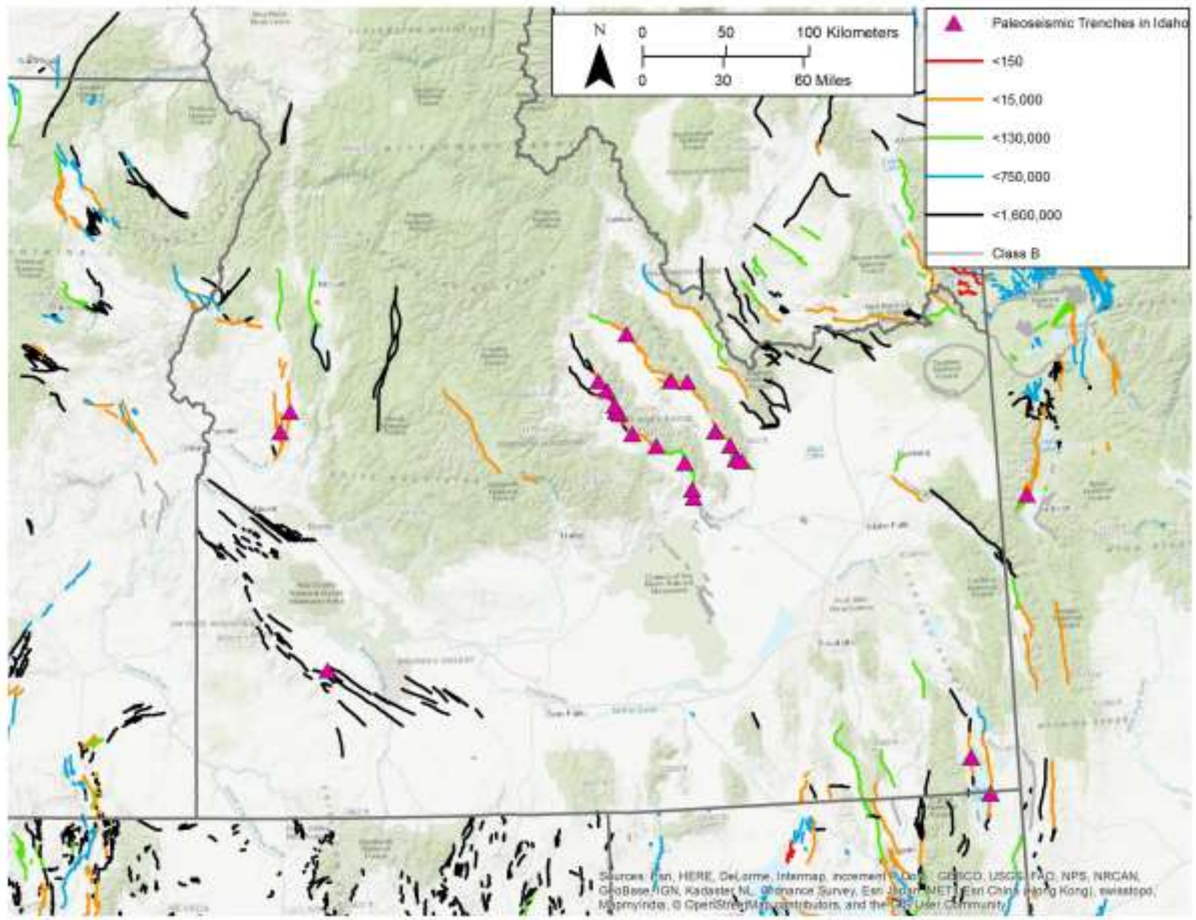
Paleoseismology

- Older trenches:
  - Lost River fault: 12 trenches (1969-1995)
  - Lemhi fault: 11 trenches (1969-1992)
  - Squaw Creek and Jakes Flat: 1 trench each (1983)
  - Owyhee fault: 1 trench (1997)
  - West Bear Lake fault: 1 trench (1989)
  - East Bear Lake fault: 2 trenches on Utah side (1990)



Paleoseismology

- Sawtooth fault:
  - Glenn Thackray and others at ISU (Thackray et al. 2013 Geology; Johnson 2009 thesis) have done mapping, hand trenching, and lake coring
  - Small portions of fault covered by lidar; fault is not completely mapped
  - Length of rupture, possible segmentation is unknown
  - Relatively high slip rate: 0.5-0.9 mm/yr
  - 2-3 post-14 ka events; ~4100 yr BP and ~7500 yr BP



2019 NEHRP Proposal

- Collaborative proposal with UGS
- Use new lidar to map surface fault traces
  - East Bear Lake fault (ID/UT)
  - West Bear Lake fault (ID/UT)
  - Oquirrh fault zone (UT)
  - South Oquirrh Mountain fault zone (UT)
  - Topliff Hill fault zone (UT)
- Identify sites for paleoseismic trenching
- In the “hold” category, pending funding

SE Idaho EQ Fact Sheet

Earthquake Occurrence in Southeast Idaho

A project of the Idaho Seismic Technical Working Group, this fact sheet conveys the frequency of earthquakes in the Intermountain Seismic Belt in Southeastern Idaho. This region shares major faults with the neighboring state of Utah. In particular, the Wasatch, Eastern Bear Lake, and West Cache Fault zones are highlighted in addition to other faults noted for a high frequency of earthquakes in the region.

IDAHO

EERI

Idaho's Seismic History

Geologic evidence shows that movement on Idaho's faults could produce magnitude (M) 7.0 and higher earthquakes, which could have catastrophic effects on the region. Meanwhile, knowledge is limited about Idaho's extensive fault systems, most of which are prehistoric and have not experienced activity for tens of thousands of years. Still, there are areas in Idaho that experience seismic activity regularly. Knowing little about Idaho's oldest fault systems makes it nearly impossible to calculate earthquake probability in Idaho. However, historical earthquake data shows the occurrence of earthquakes in the state, which is very useful for understanding risk.

Idaho Seismic Zones

Idaho's seismic zones consist of the north-south Intermountain Seismic Belt and the east-west Central Idaho (Centennial) Seismic Zone, making up one of the most seismically active regions in the state. Situated on the borders of Wyoming and Utah, the region has experienced earthquakes greater than M6.5 over an extended historical period. In 1884, Paris and Bear Lake Valley experienced a M6.0 earthquake that caused shaking and damage in the area. In 1934 in Utah, just 20 miles south of the Idaho border, a record M6.6 earthquake in Hansel Valley shook the region and caused widespread damage in both states.

The most active faults in the Belt are the Eastern Bear Lake, Wasatch, and West Cache Fault Zones, all located along the Utah-Idaho border (Figure 1). The notable M5.7 Richmond Earthquake occured at the West Cache Fault in 1962. The northern portion of the Wasatch fault extends into Idaho, and is the most dangerous fault in the Intermountain Seismic Belt. Located near Malad City and within 30 miles of Pocatello, geologic studies indicate that M7.0 earthquakes occur along the Wasatch fault every 300-400 years.

The seismic region near the volcanic areas west of of Yellowstone National Park contains many active faults, including the Sawtooth, Lost River, and Lemhi faults. Most of the faults in this region are not well known, and are considered "prehistoric," or formed before recorded history. Notably, a M6.9 earthquake occurred along the Lost River Fault in 1983, causing surface ruptures typical of earthquakes in this region as well as extensive aftershocks.

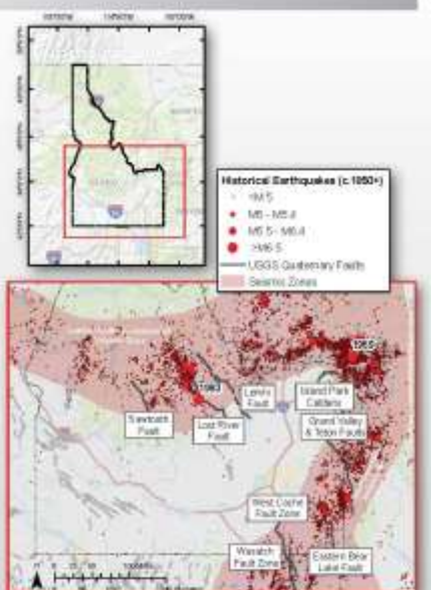


Figure 1. Historical Earthquakes in Idaho

Earthquakes in Idaho

Faults	Number of Earthquakes c.1925+
Eastern Bear Lake Fault	4
Grand Valley & Teton Fault	19
Lemhi Fault	7
Lost River Fault	13
Sawtooth fault	1
Wasatch Fault Zone	27
West Cache Fault Zone	7

Occurrence of Earthquakes

Based on earthquake frequency, we know Idaho is susceptible to two types of threats from earthquakes. The first threat includes infrequent, but large scale (>M6.5) earthquakes in Idaho's seismic zones over a time scale of hundreds to thousands of years. These events are predicted to be catastrophic, similar to the 1983 Borah Peak M6.9, or the 1934 Hansel Valley earthquakes, with strong shaking, fatalities, and major structural damage. Idaho's most active faults occur in the broader seismic zones amid a complex fault system (Figure 2).

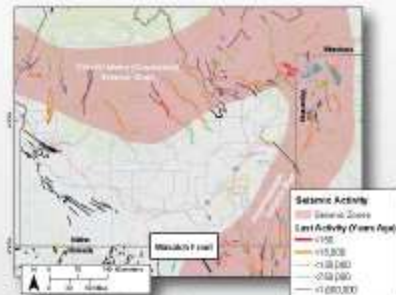


Figure 2. Major Fault Systems in Idaho

The second threat includes more frequent, but smaller scale (<M3.5) earthquakes that occur in swarms over many days, such as the 2005 Alpha Swarm near Cascade, Idaho, and most recently the 2017 Soda Springs swarm, which occurred over several weeks and shook buildings and residents, but produced little to no damage. While there is a low likelihood, there is a chance that swarms like these could lead to a much larger earthquake, causing considerable damage to developed areas. (Figure 3).

Figure 3. Earthquake Swarms in Idaho

The Importance of Preparation

Idaho's seismic zones are susceptible to high magnitude earthquakes, with many of the regions cities and small towns located near active faults. The Wasatch Front region is especially susceptible to strong shaking that affects large areas, including areas with higher population concentrations in both Utah and Idaho. Individuals should work to be prepared, and communities can advocate for more resilient earthquake design and disaster planning.

Shaking Intensity Depends on 3 main factors:

1. **Magnitude**
   Larger magnitudes means stronger shaking. Bigger earthquakes have higher magnitudes and affect larger areas.
2. **Distance**
   Shaking closer to the epicenter (source) of the earthquake, will be much stronger.
3. **Ground Material**
   Shaking will be changed and amplified by soils, versus solid bedrock which is hard and less responsive to shaking.

Further Information

Zach Lifton, Idaho Geological Survey (IGS)

Susan Cleverley, Idaho Office of Emergency Management (IOEM)

References

Idaho Bureau of Homeland Security. 2009. *Putting Down Roots in Earthquake Country - Your Handbook for Earthquakes in Idaho*

Acknowledgements

The Idaho Seismic Technical Working Group (ISTWG) team: Bill Phillips, Zach Lifton, Lee Liberty, Jerry Miller, Rich Gummersall, Kelsey Brown, Lorrie Pahl, Mary Mott, Lucille Webster; Susan Cleverley; The Earthquake Engineering Research Institute (EERI); and the Working Group on Utah Earthquake Probabilities (WGUEP) for their April 2016 Fact Sheet, on which this fact sheet is loosely based.

Clearinghouse Plan

- Operations plan for post-earthquake reconnaissance
- Physical and virtual clearinghouse
- Developed by IOEM, EERI, and IGS
- WSSPC is providing support to run a real-time exercise of the plan in March – partners from neighboring states are invited to participate

Building a Montana Q Faults Database

Petr Yakovlev and Mike Stickney

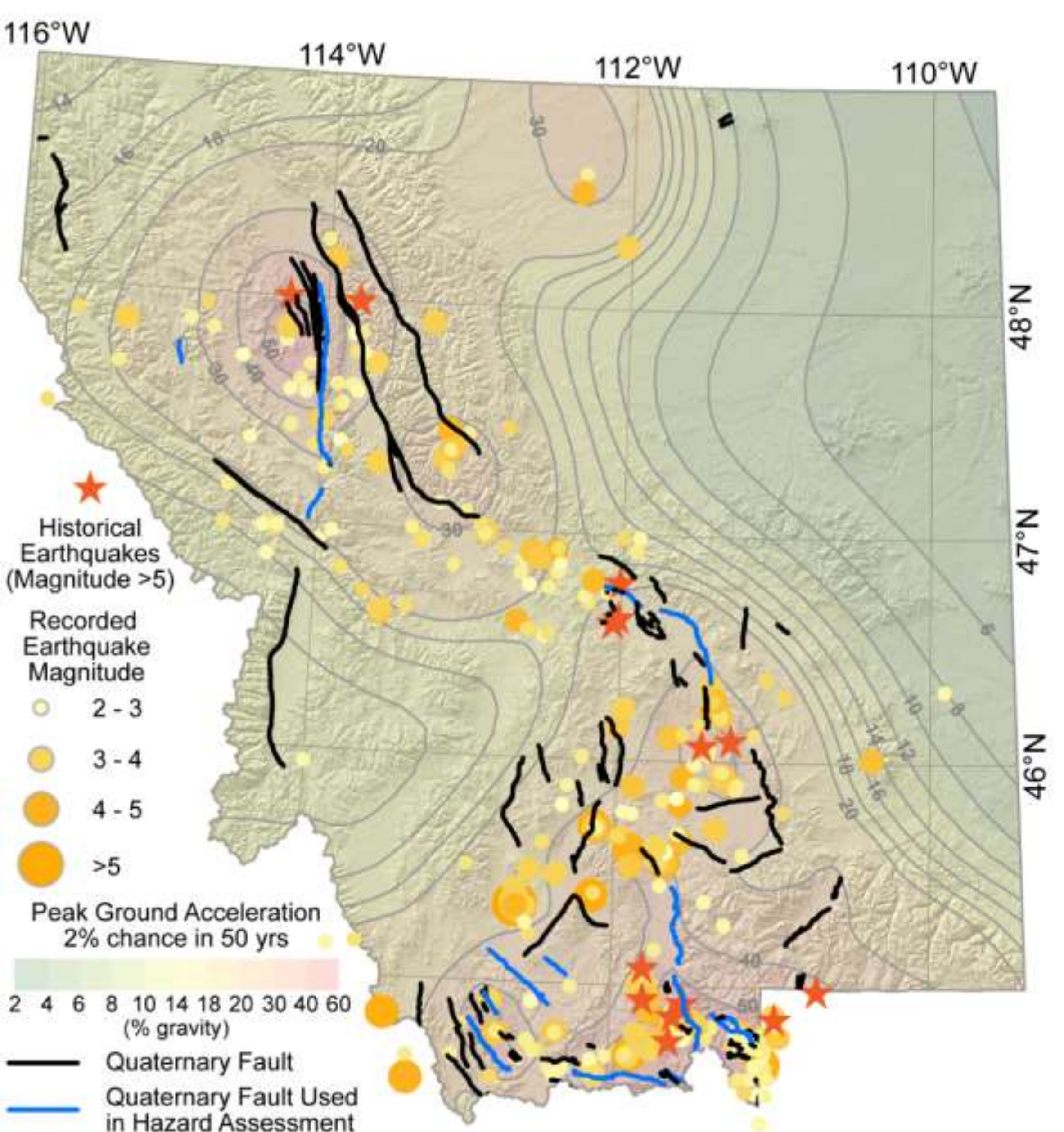
MBMG
Montana Bureau of Mines and Geology

Outline

- Existing USGS data
- Goals & Motivations
- Methods
- Results
- Discussion and Comparison
- Future Goals and Objectives
- Questions

Existing USGS Data

- Small number of large faults
- Few faults have slip rate data
- Few faults included in hazard assessments
- MBMG geologic mapping suggests there are many more Quaternary faults in Western Montana



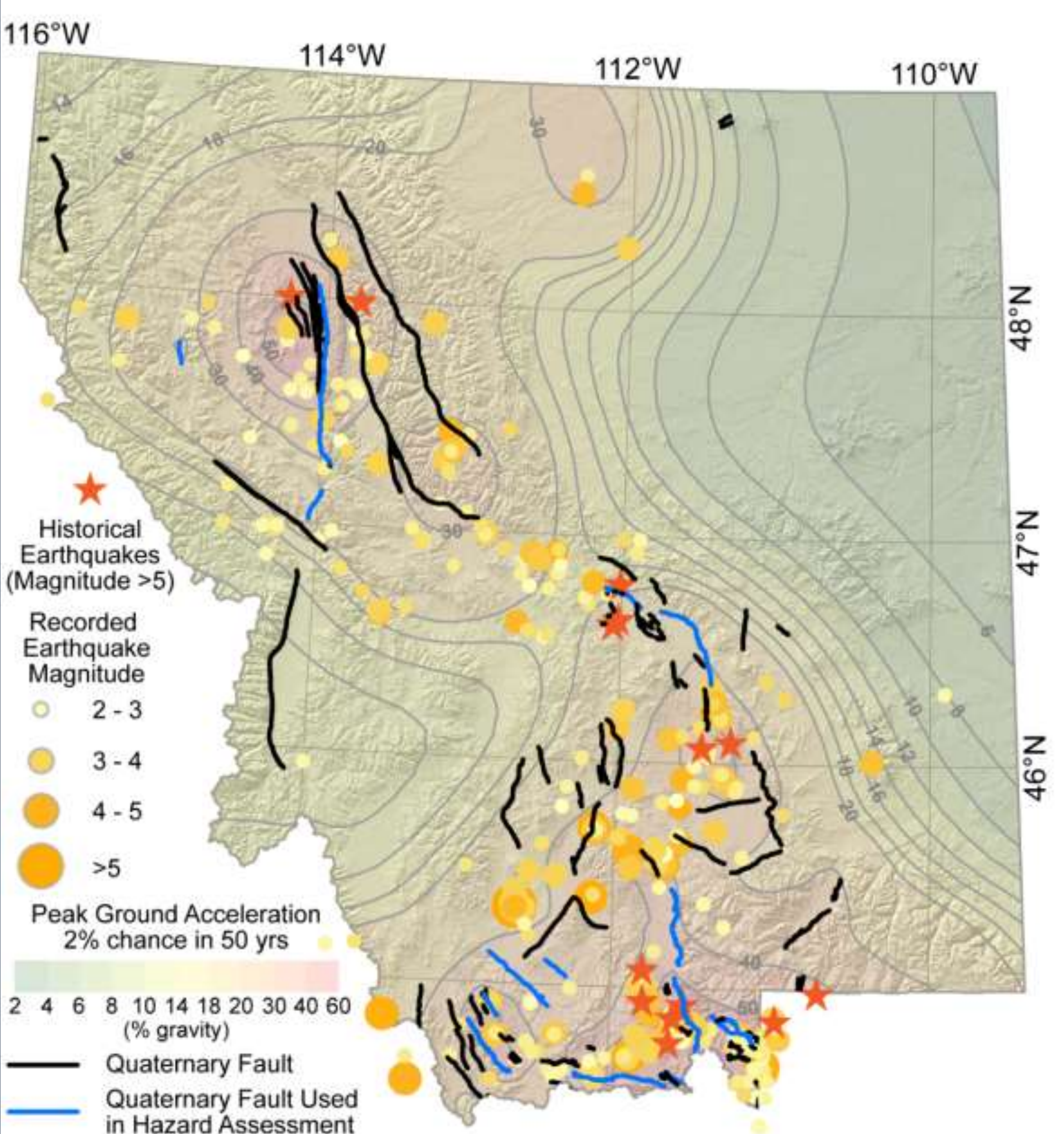
Goals & Motivations

Goals:

- Create a preliminary database of Quaternary, and potentially Quaternary faults ("known unknowns")
- Use database to identify faults for further geologic investigations
  - Understudied faults that require field checking (T or Q?)
  - Major potentially hazardous faults for slip rate assessments, paleoseismology

Method:

- Use existing 1:50k and 1:100k maps to locate potential Q faults, and add to database



Methods

Schema

- Generally follow USGS Fault database schema
- Eliminated some columns that are unused
- No additional slip rate data are available!
- Usefulness to modelers?

Table

MT_Q_Faults

FID	Shape *	Id	Source	ftype	fcode	dipdir	Scale	Age	slipsence	name	sliprate	sliprtmax	sliprtmin	sliprtsrc
1117	Polyline	0	seamless	Well constrained	1	SW	1:100,000	Q	N	Red Ro	<0.2	0.2	0	Regalla and oth
1118	Polyline	0	seamless	Well constrained	1		1:100,000	Q				0	0	
1119	Polyline	0	seamless	Well constrained	1		1:100,000	Q				0	0	
1120	Polyline	0	seamless	Well constrained	1		1:100,000	Q				0	0	
1121	Polyline	0	seamless	Well constrained	1		1:100,000	Q				0	0	
1122	Polyline	0	seamless	Inferred	3		1:100,000	T				0	0	

1 (0 out of 2278 Selected)

MT_Q_Faults

Methods

Fault classes

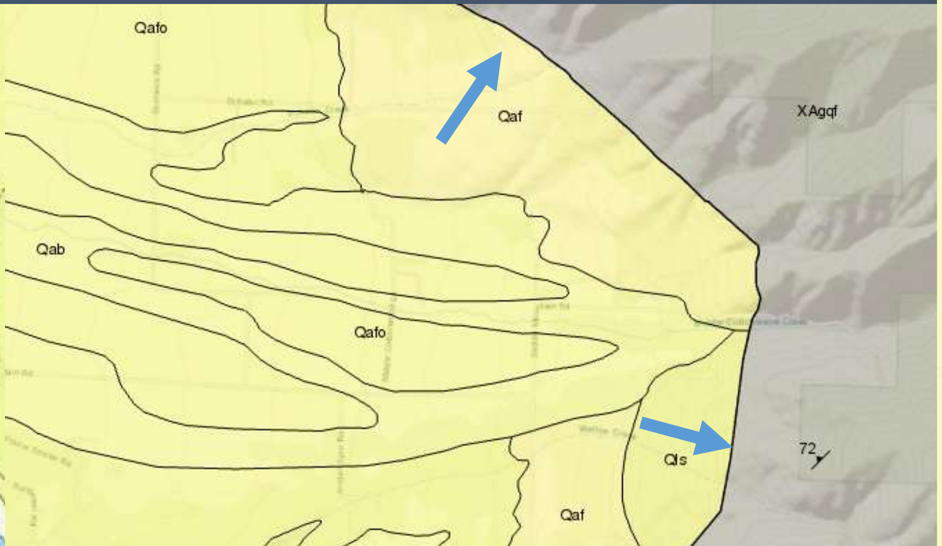
- Q – Definitely Quaternary
- QT – Possible Quaternary
- T – Tertiary (Low probability Quaternary)

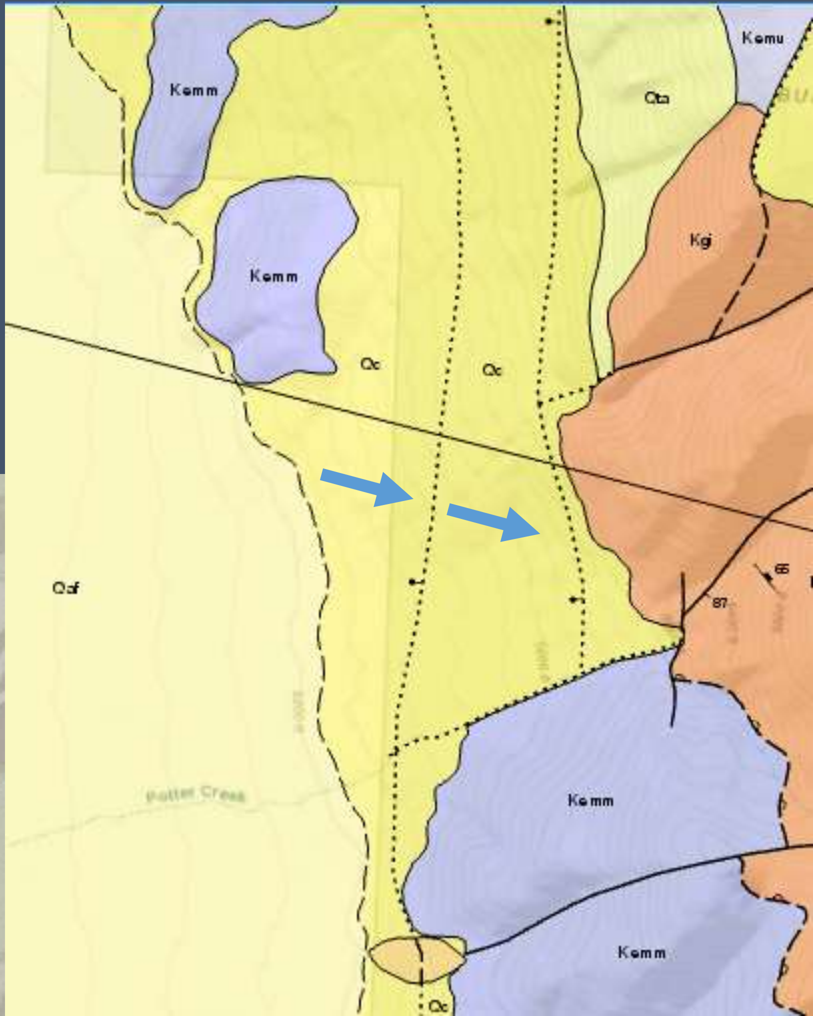
Methods

Fault classes

Q – Definitely Quaternary

- Offsets Quaternary units
- OR fault scarp present along fault
- OR fault has Quaternary units in hanging wall
- OR morphologies of Quaternary deposits suggest Quaternary movement on fault



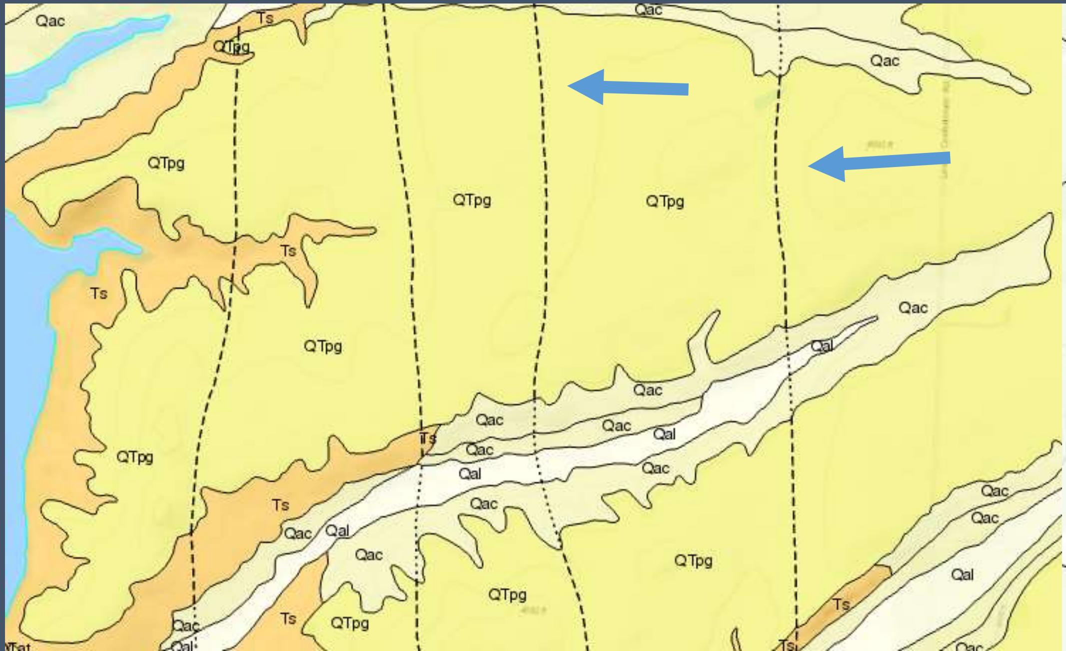


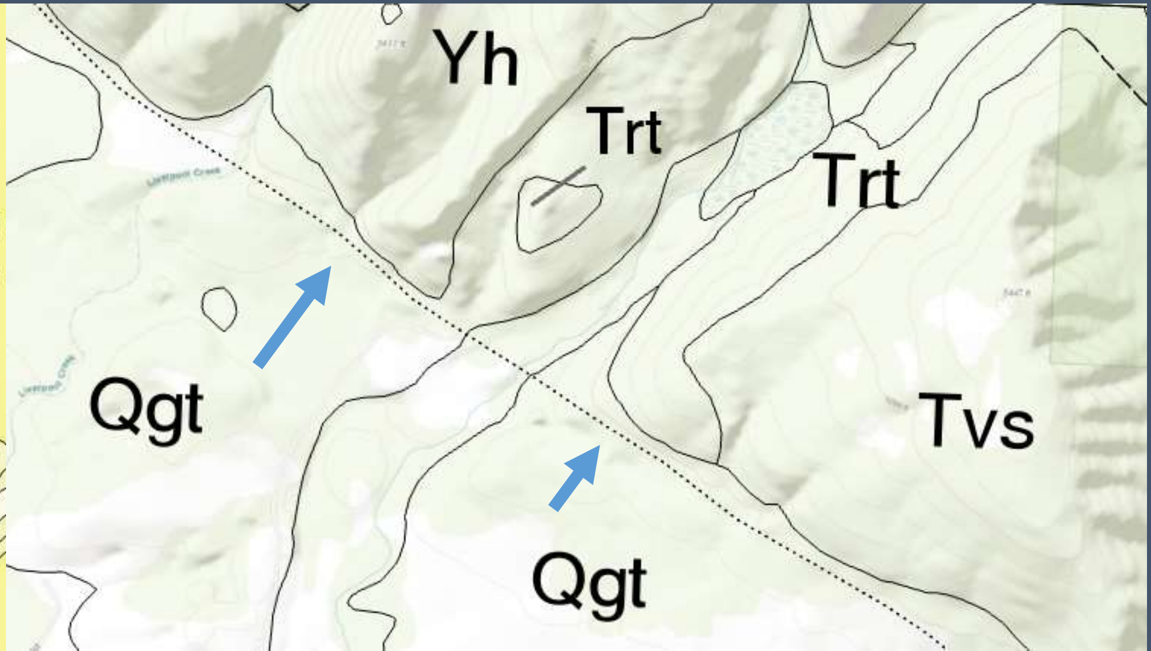
Methods

Fault classes

QT – Possible Quaternary

- Fault offsets deposits mapped as QT
- OR range front morphologies suggest Quaternary movement on fault
- OR fault may offset Quaternary units, but the relationship is unclear at scale of source map

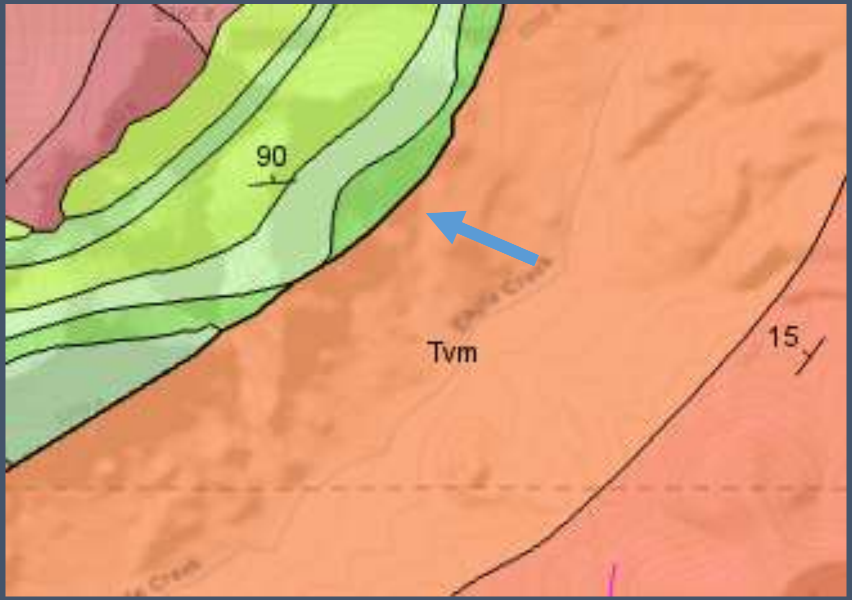


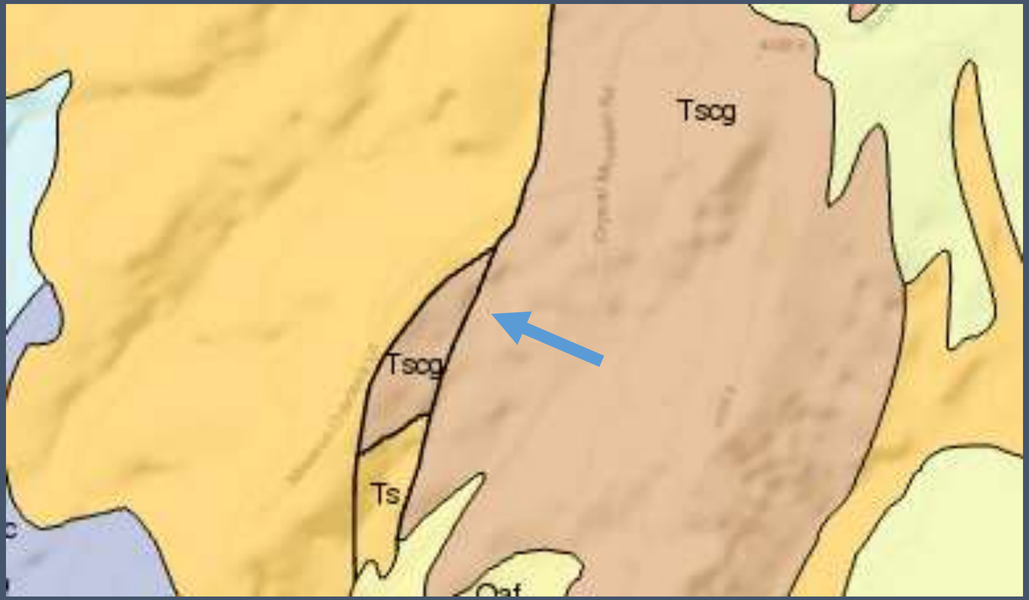


Methods

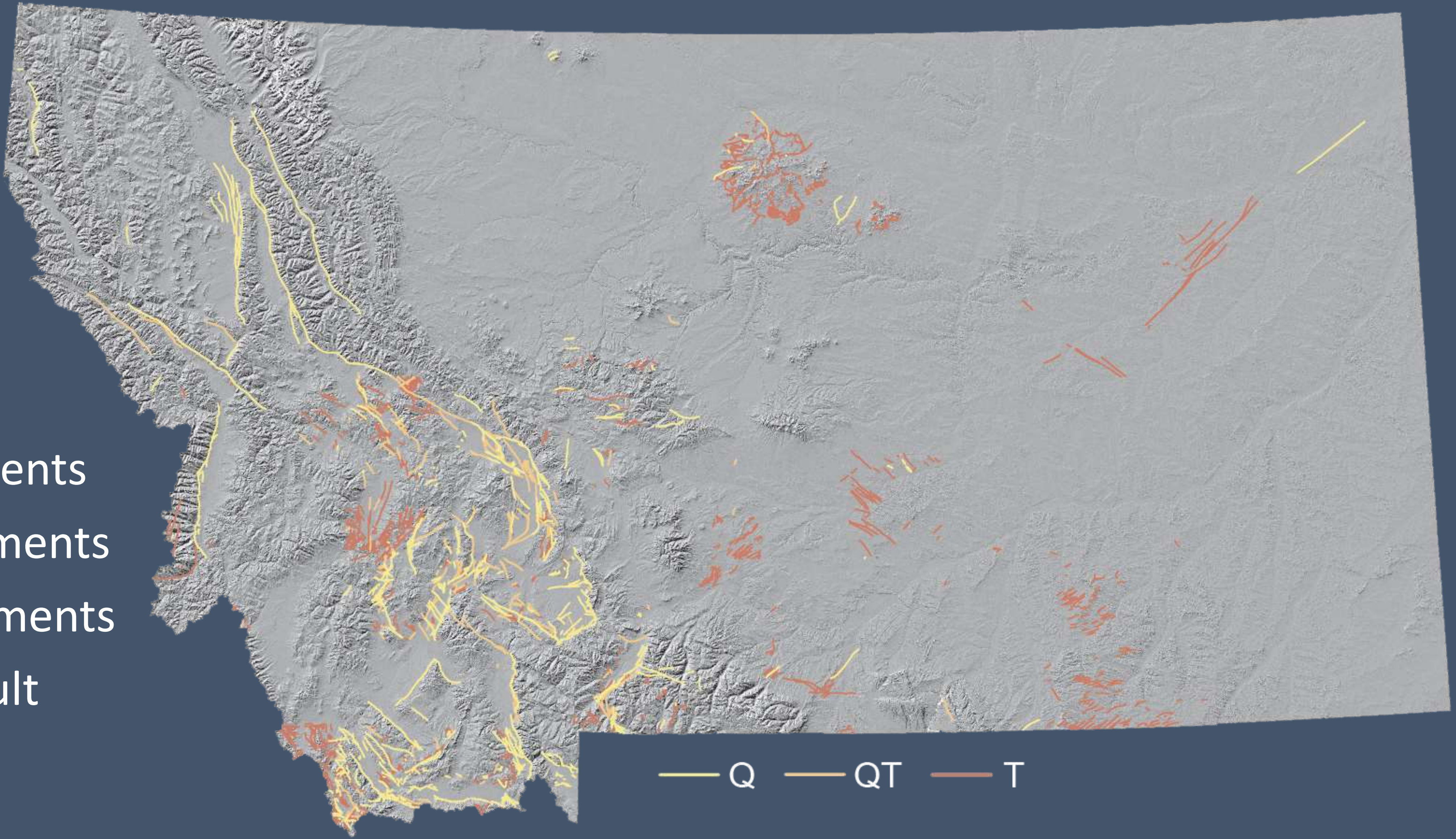
Fault classes

- T – Tertiary (Low probability Quaternary)
  - Fault offsets Tertiary deposits or igneous bodies





Results



Results

- 608 Q fault segments
- 275 QT fault segments
- 1,395 T fault segments
- USGS DB: 119 fault segments

Results: Example Q Faults

New Fault: Elk Park Fault

Results: Example Q Faults

New Fault: Lima Reservoir Fault

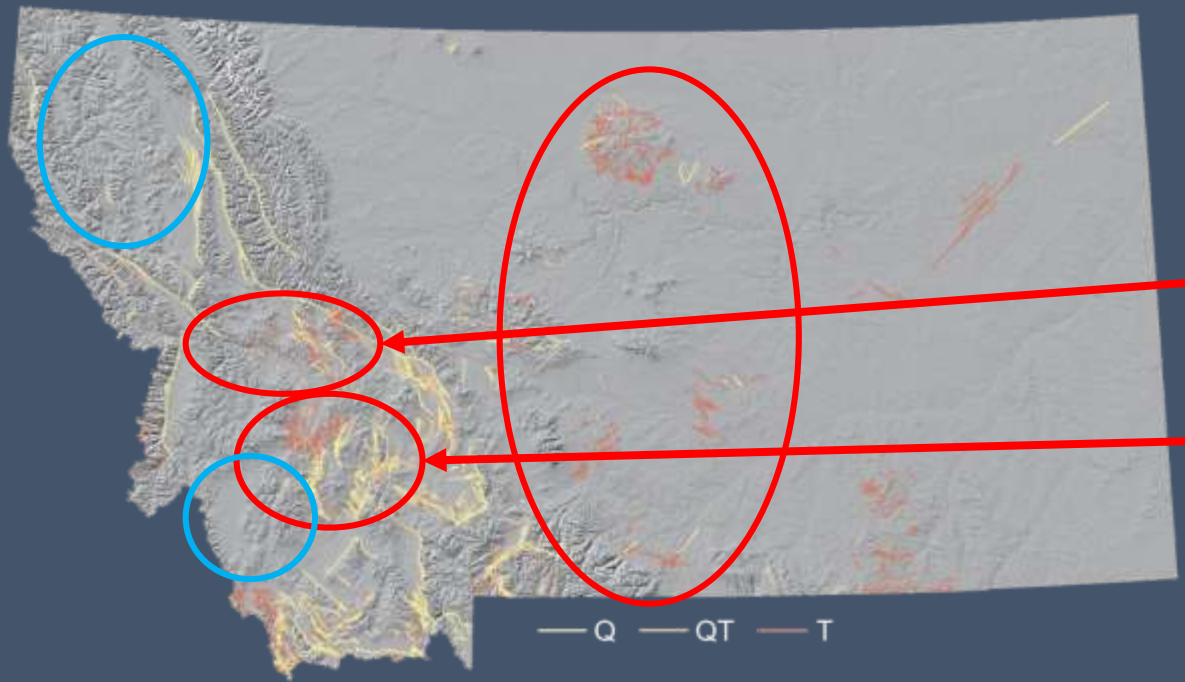
Results: Example Q Faults

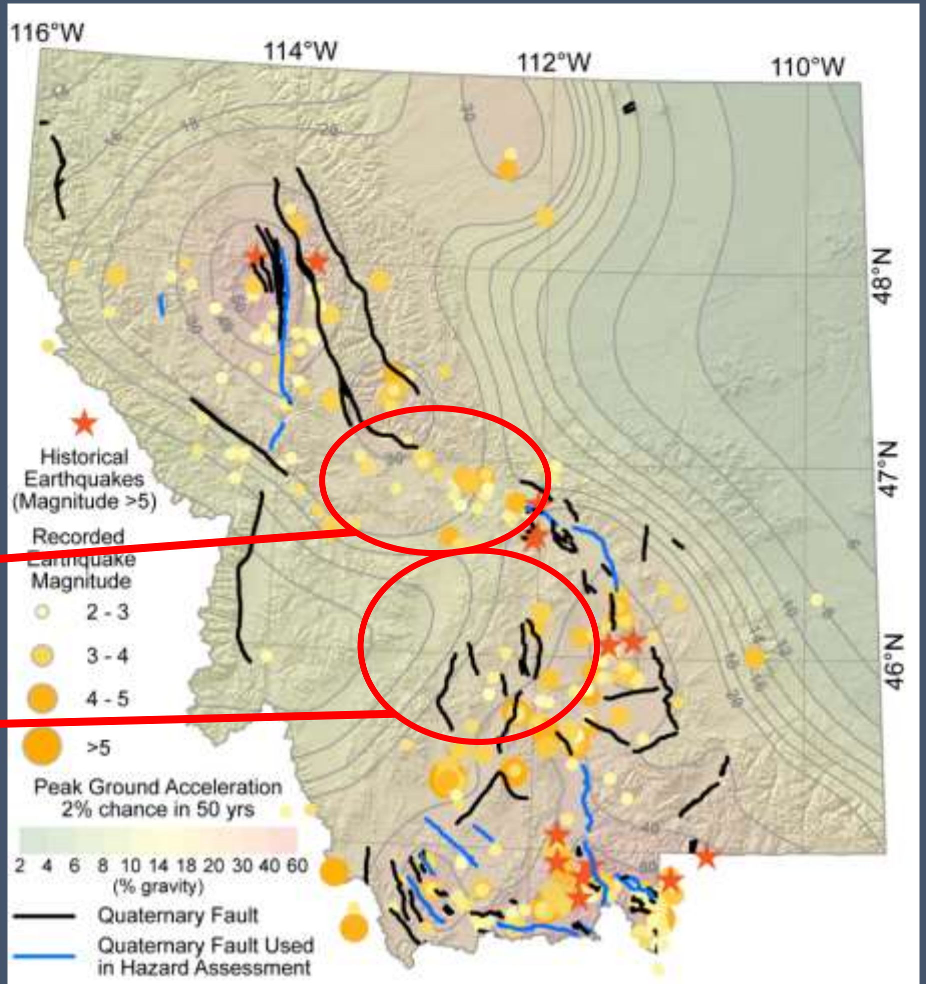
New Fault:

Bloody Dick Fault

Discussion: Comparison with USGS Database

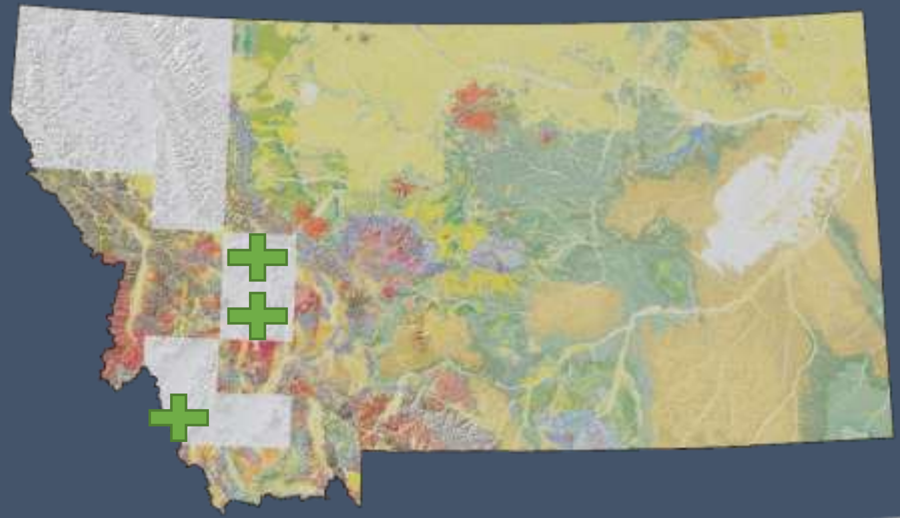
- Addition of potential Q faulting in central and eastern Montana
- Major addition of strike slip faults in Lewis and Clark Zone
- Smaller Q faults in prominent valleys
- Big picture pretty similar
- What about these data holes?

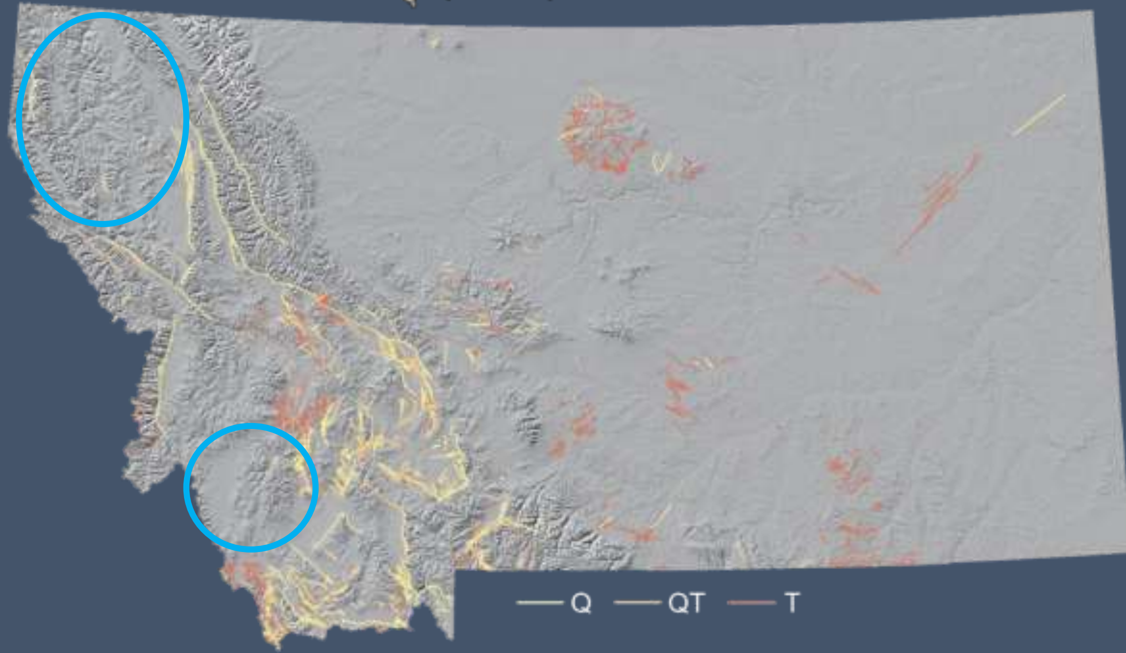




Quaternary Fault Database: Discussion

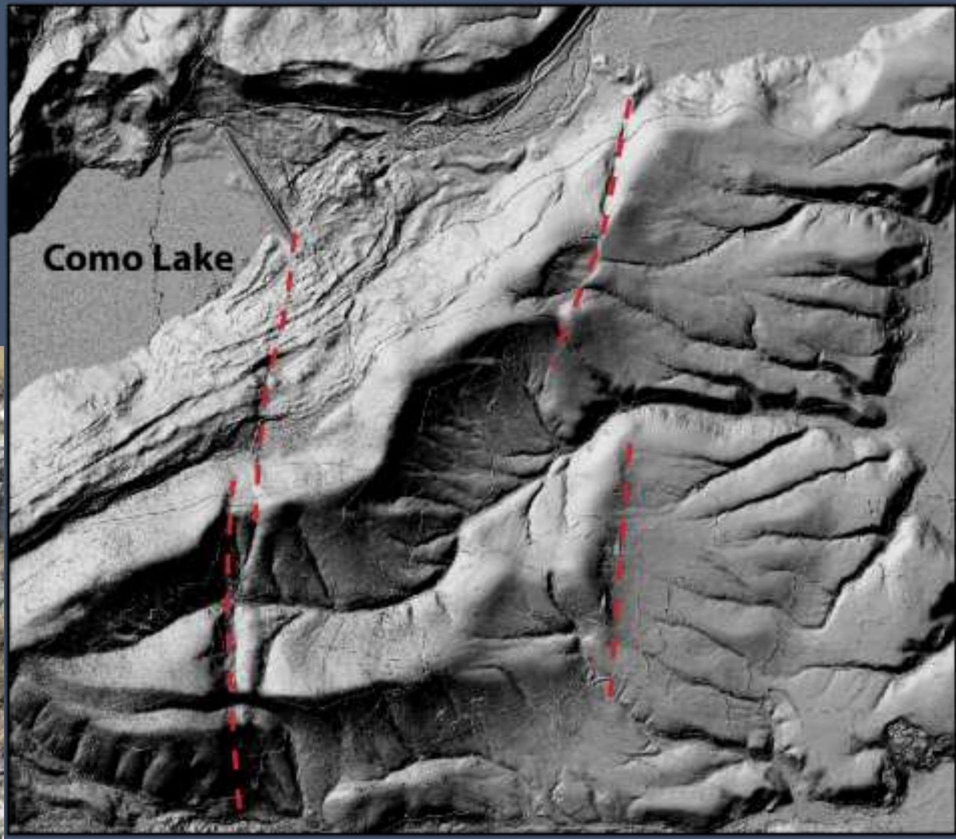
- No Q/T faults? End of Basin and Range?
- Boundaries of MBMG mapping
- No maps available at 1:100k scale or better
- Probably some missing Q faults…
- Add faults as mapping comes in





Future Goals and Objectives

- Use (very sparse) LiDAR data to confirm Q faults
- Field check T and QT faults
- Separate out confirmed Q faults in their own database
- Constrain slip rates on Q faults



Future Goals and Objectives

Move to GeoJSON framework?

- Non-proprietary data format
- Increased flexibility
- GitHub compatible for versioning and comments
- Compatibility with GEM Global Active Fault Database
- Not friendly with ArcGIS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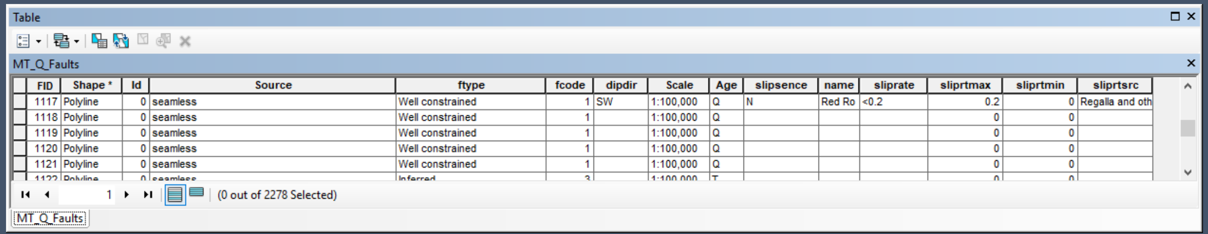
        ]
      }
    }
  ]
}
```

Questions

- What does the USGS need from us? (schema/file type/etc.)
- How useful is our database for hazards modeling?
- How do we make it more useful?
  - Fault continuity?
  - Surface deformation or inferred subsurface fault traces?



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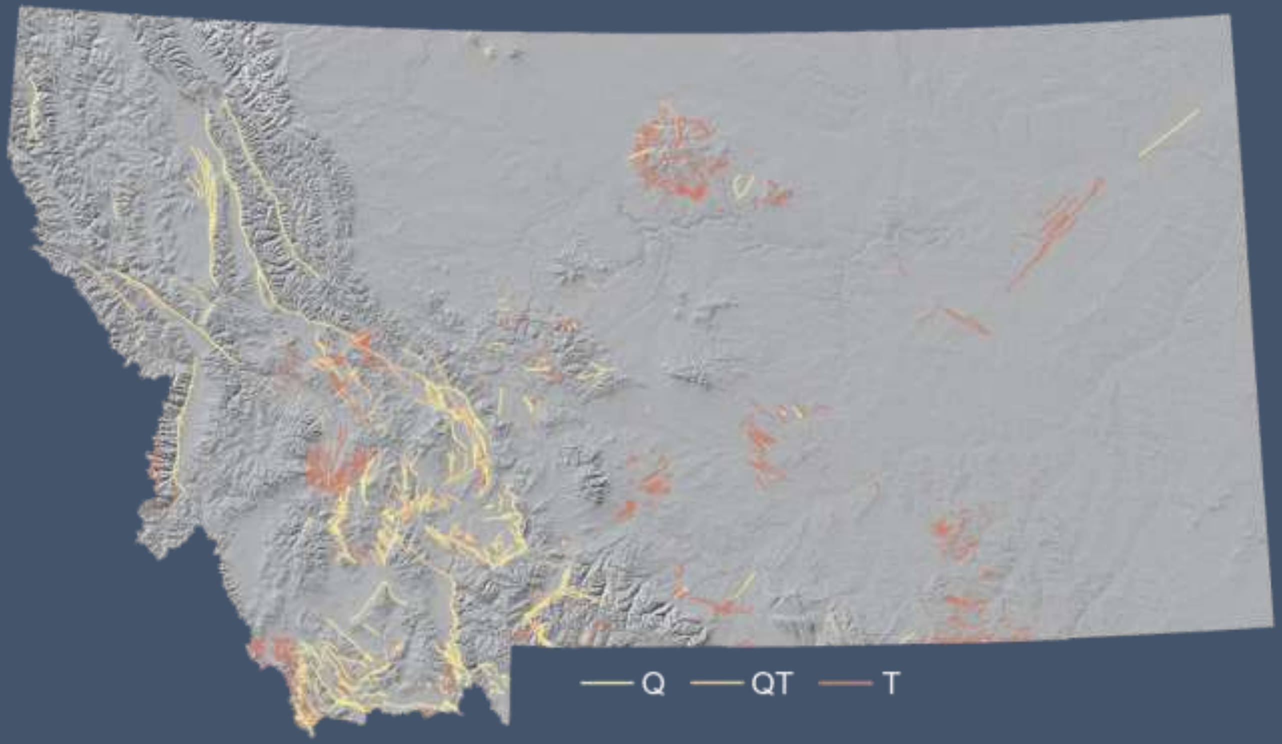
MT_Q_Faults



Thank you!

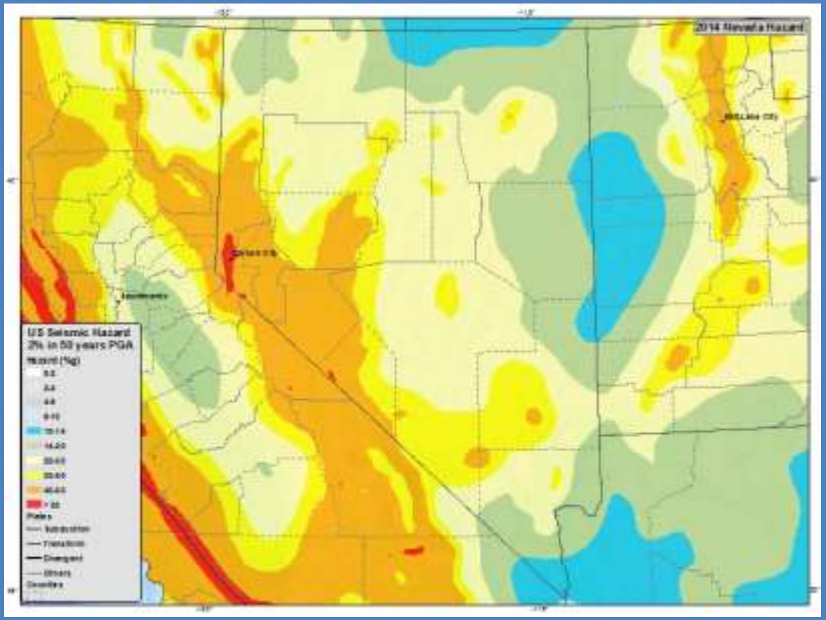
Earthquake Program at NBMG

Rich D. Koehler and Seth Dee

2019 Basin and Range Province
Earthquake Working Group Meeting
Nevada Bureau of Mines and Geology
February 6, 2019

Earthquake Hazards Group at NBMG

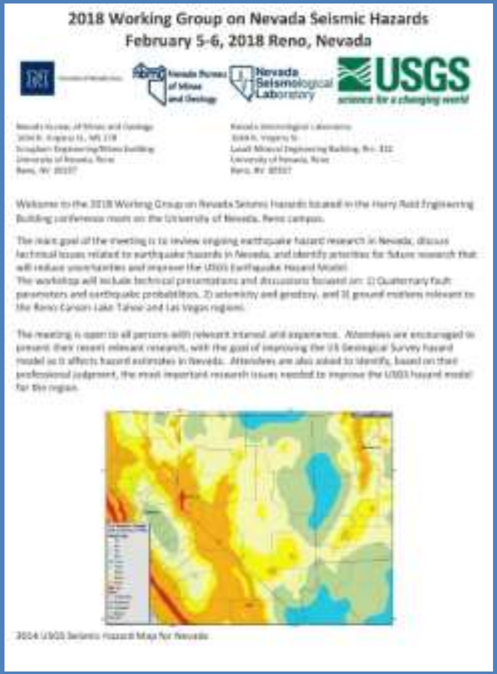
GEOLOGY	GEODESY
Rich Koehler	Bill Hammond
Seth Dee	Corne Kreemer
Craig dePolo	Geoff Blewitt
Alan Ramelli	
Graduate Students	
Conni De Masi	
Colin Chupik	



Earthquake hazards projects 2018-19

- Working Group on Nevada Seismic Hazards
- Published paper on current knowledge of faults in the North Valleys area.
- Nevada's Quaternary fault database
- Paleoseismic studies along active faults (5 projects)
- NBMG StateMAP projects
- New 3DEP lidar dataset
- Las Vegas Valley fault study

Working Group on Nevada Seismic Hazards

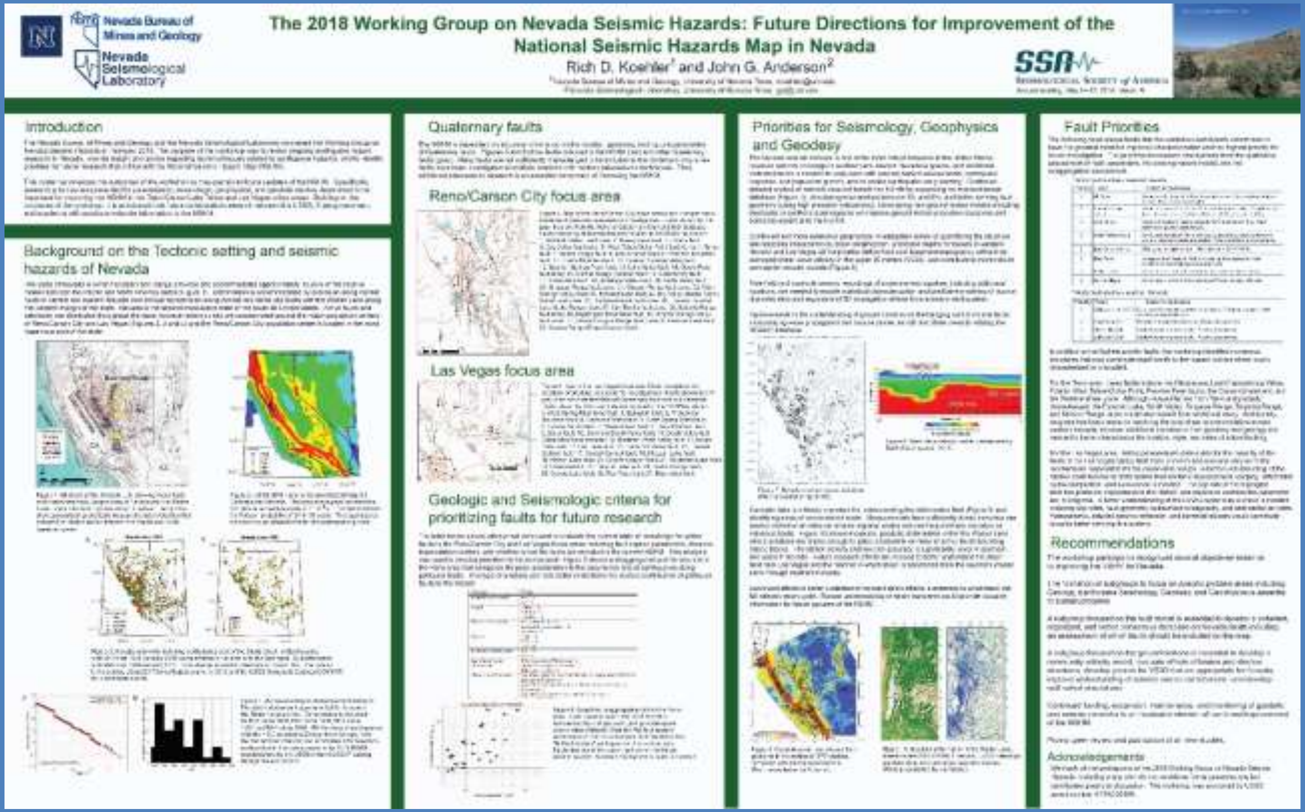

2018 Working Group on Nevada Seismic Hazards
February 5-6, 2018 Reno, Nevada

2014 USGS Seismic Hazard Map for Nevada

2-day workshop to discuss technical issues related to Earthquake hazards and prioritize future research priorities.

Priority issues tabulated and used in NEHRP rfp
http://www.nbmg.unr.edu/_docs/Earthquakes/NBMG_priorities_NEHRP.pdf.

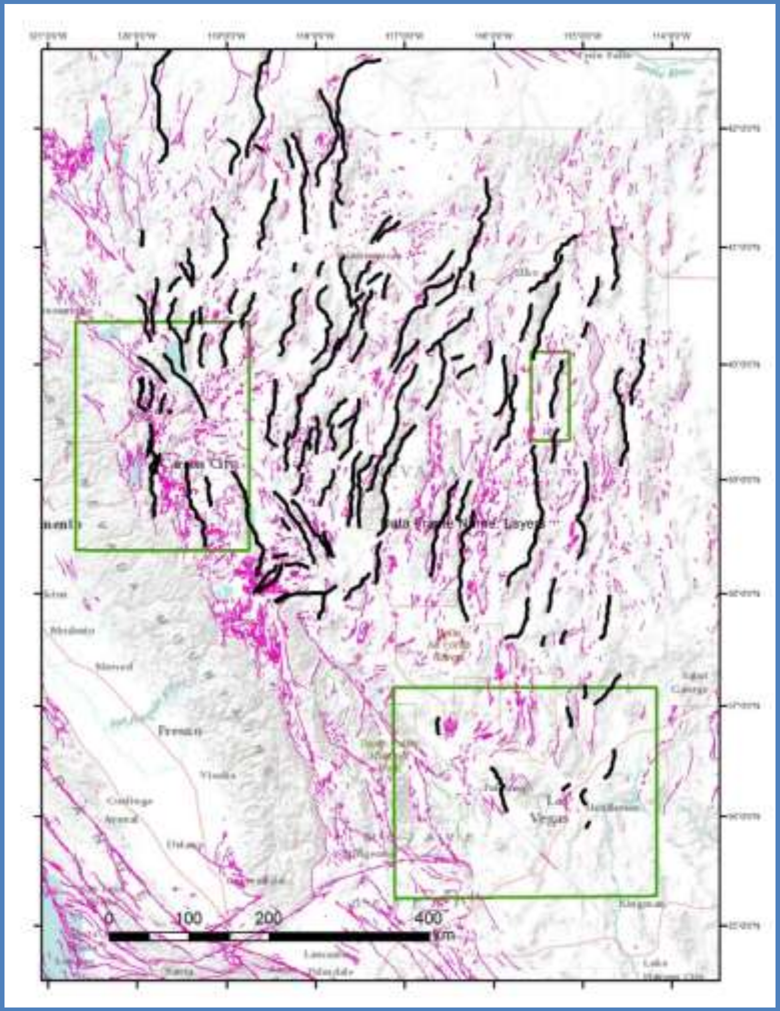
Results summarized in SRL (submitted) and NBMG Open-file report.

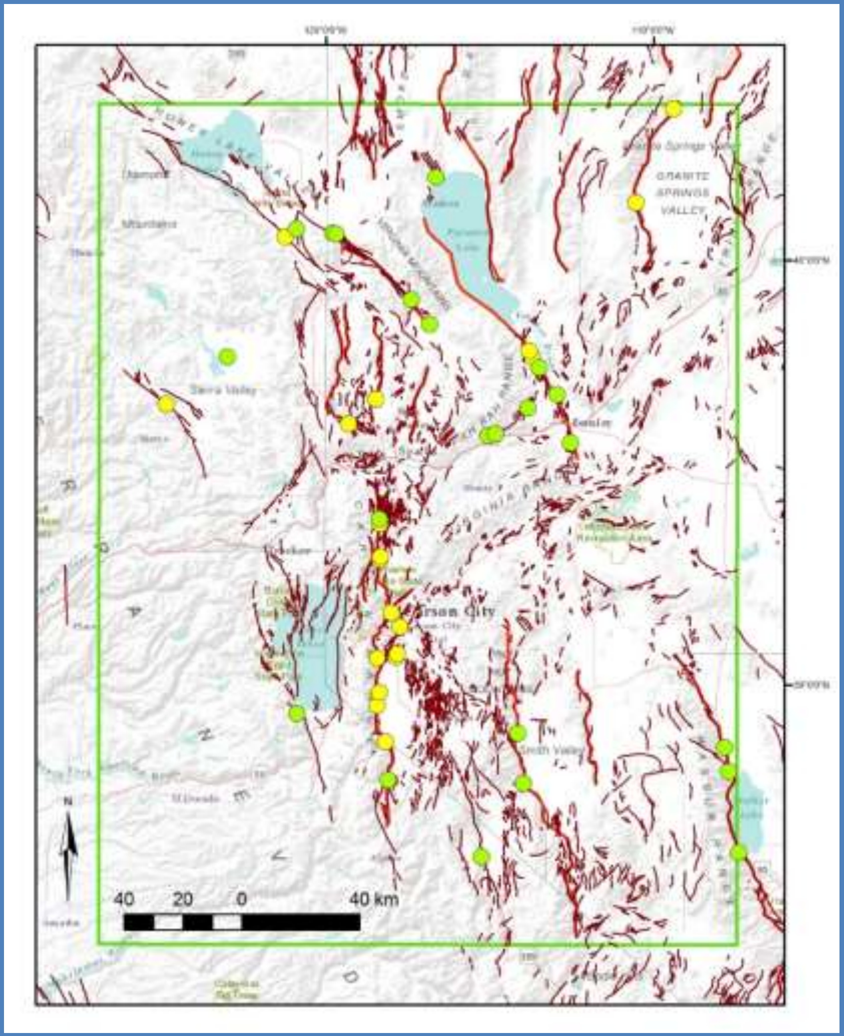

The 2018 Working Group on Nevada Seismic Hazards: Future Directions for Improvement of the National Seismic Hazards Map in Nevada
Rich D. Koehler[1] and John G. Anderson[2]

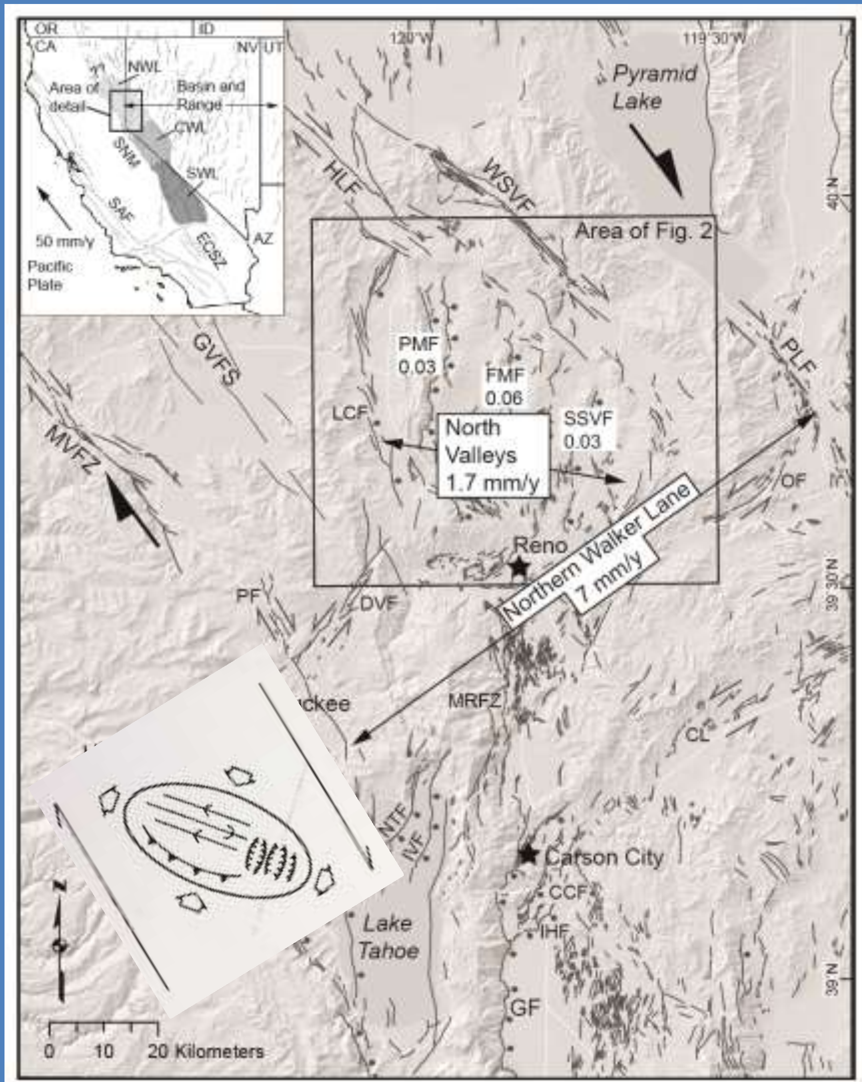
Poster presented at SSA, 2018

Nevada Bureau of Mines and Geology
University of Nevada, Reno

Develop prioritization criteria for future research







Main focus of recent efforts is in the North Valleys area

- Reconnaissance mapping
- Preliminary slip rates
- Trenching
- Searching lidar for more sites

ARTICLE IN PRESS

Geomorphology

Active faulting in the North Valleys region of Reno, Nevada: A distributed zone within the northern Walker Lane

Rich D. Koehler

ARTICLE INFO

ABSTRACT

1. Introduction

2. Geologic and tectonic background

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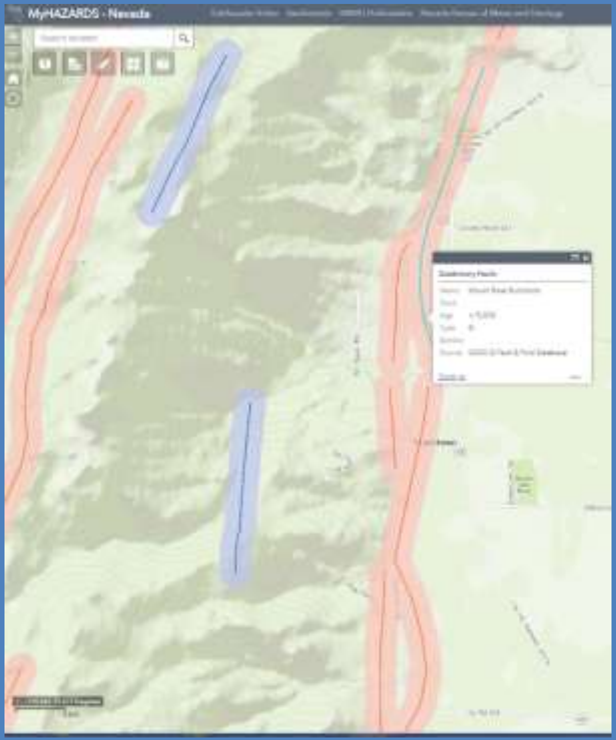
University of Nevada, Reno

https://www.sciencedirect.com/science/article/pii/S0169555X18303787?via%3Dihub

Nevada's Quaternary fault database



- Paper map MP167
- Antiquated web interface
- Dated fault parameter data
- Lack of references
- Problems with zoom and display options

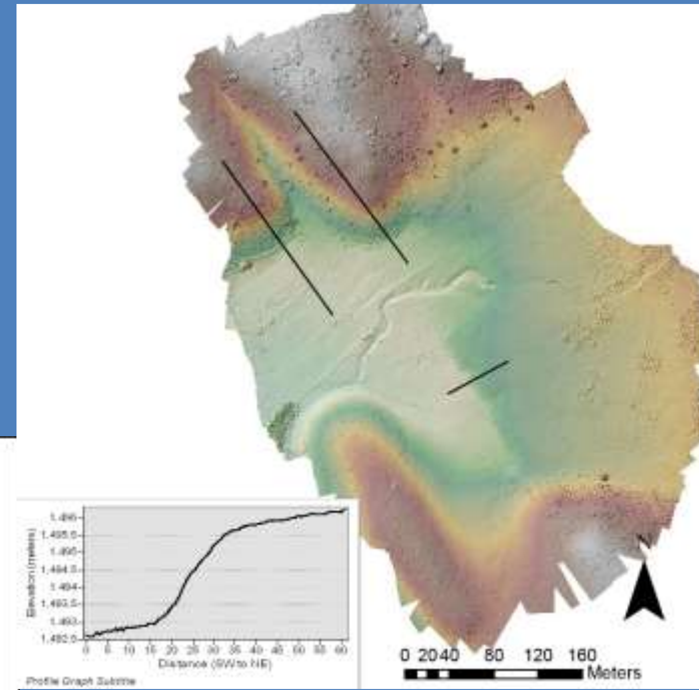
Nevada's Quaternary fault database

Nevada

USGS

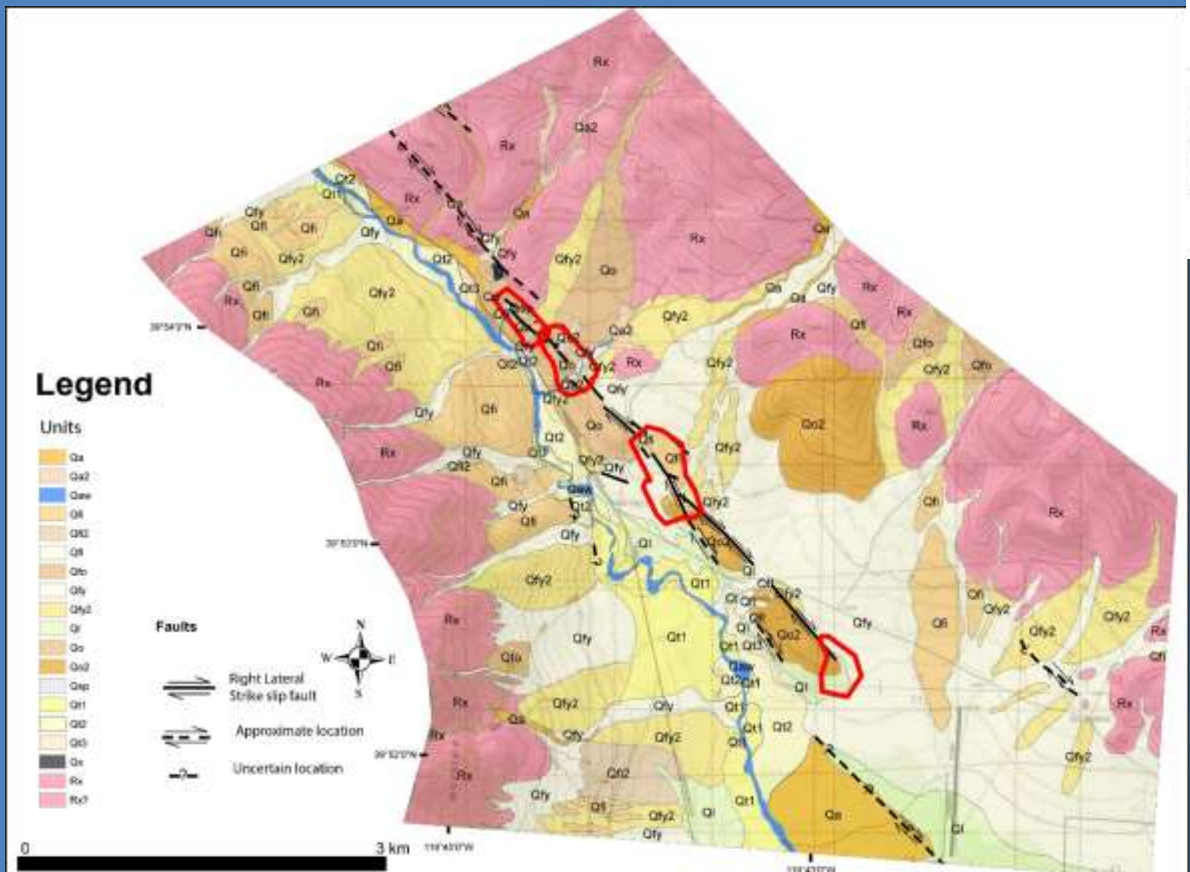
- Pilot study to build cyber infrastructure
- Review web interfaces used by other states
- Update parameters and references
- Review existing fault traces/resolve discrepancies
- Include recent StateMap results

Paleoseismic Trenching
Warm Springs Valley fault zone



Drone models

New mapping along southern part of fault



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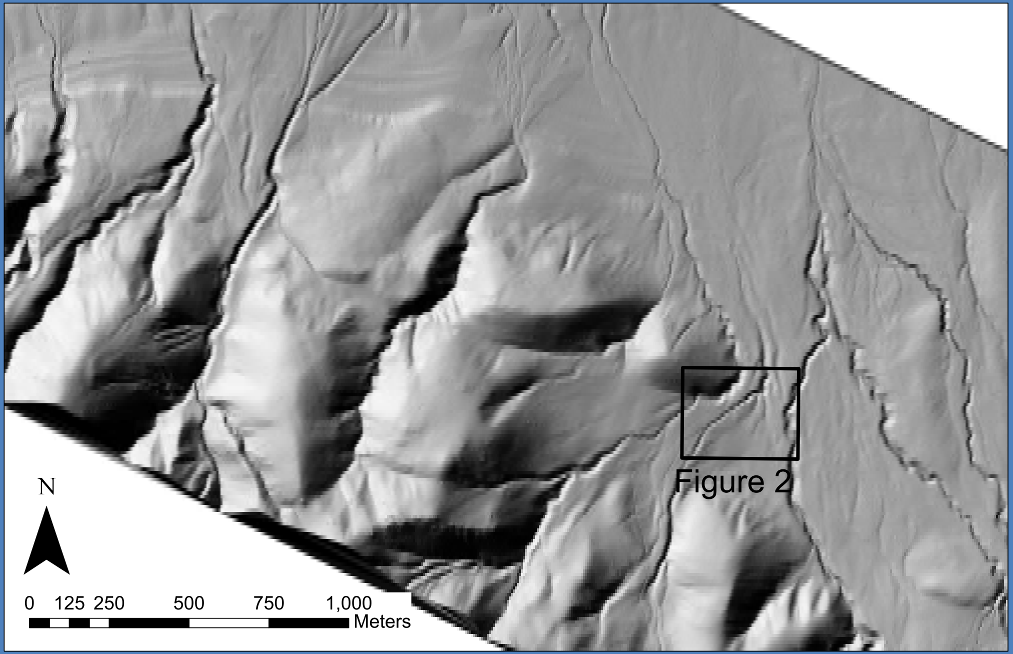
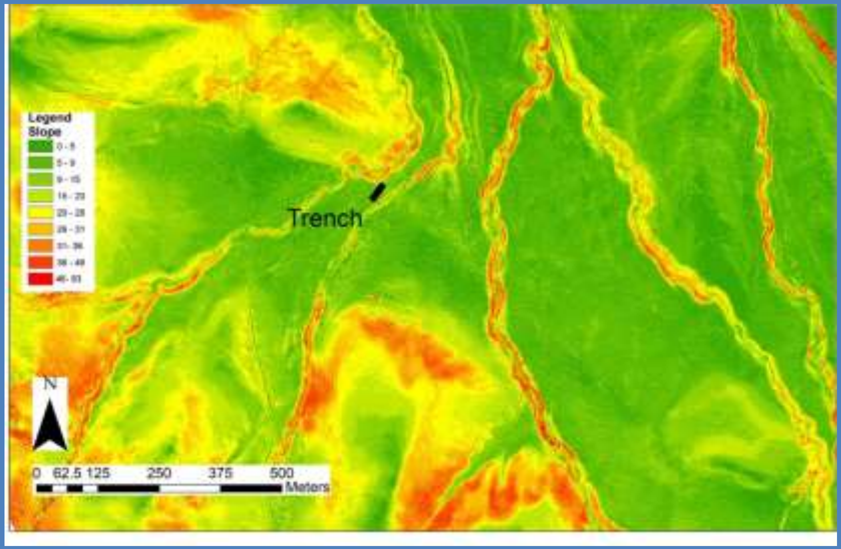
Paleoseismic Trenching
Warm Springs Valley fault zone





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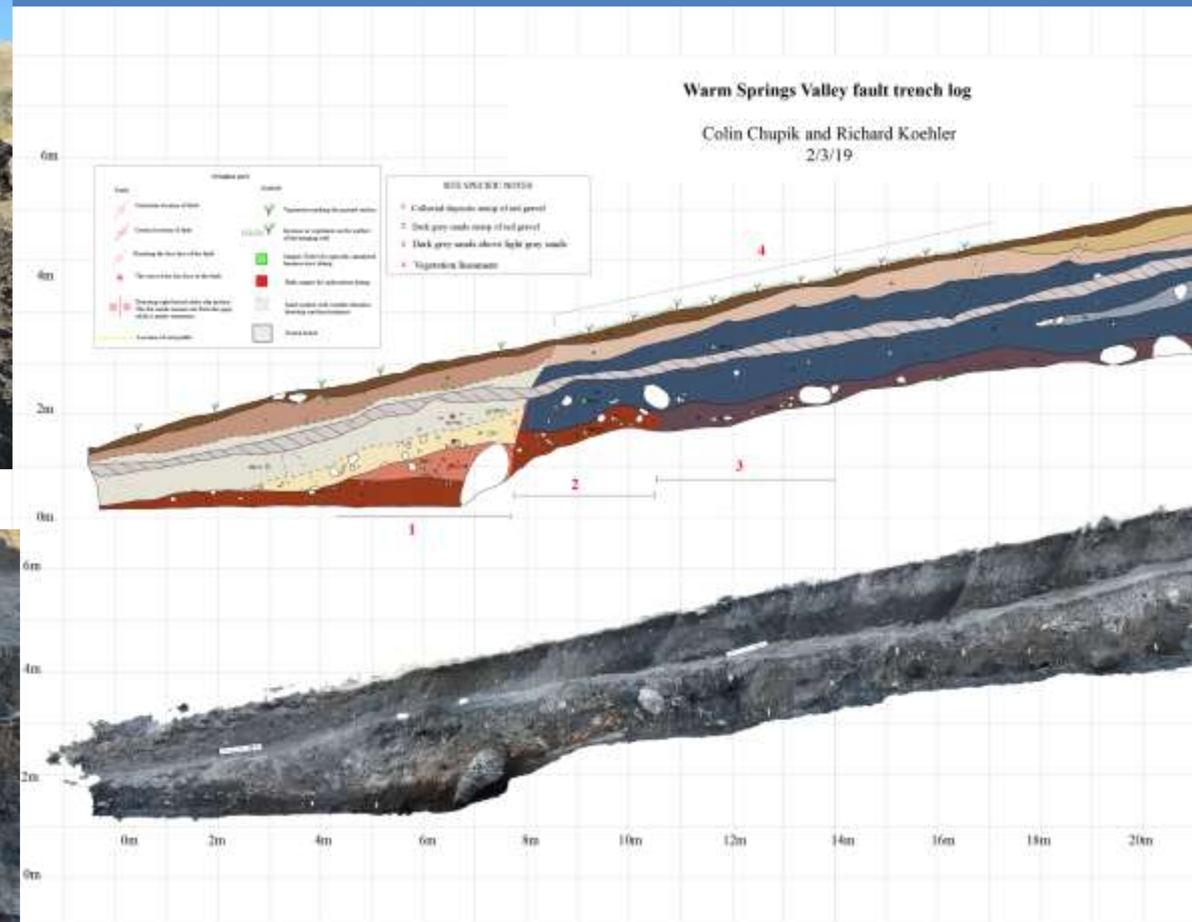
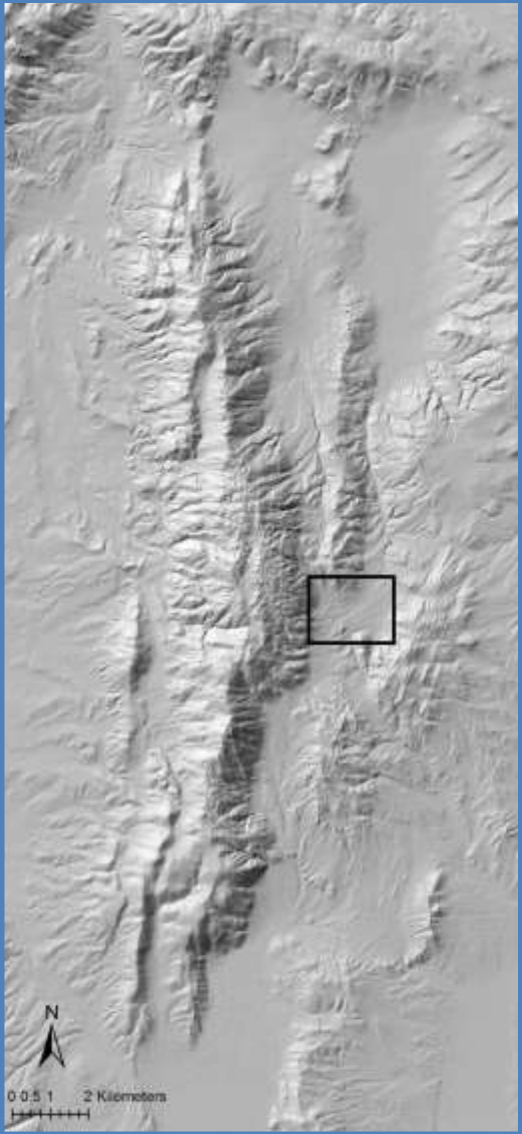
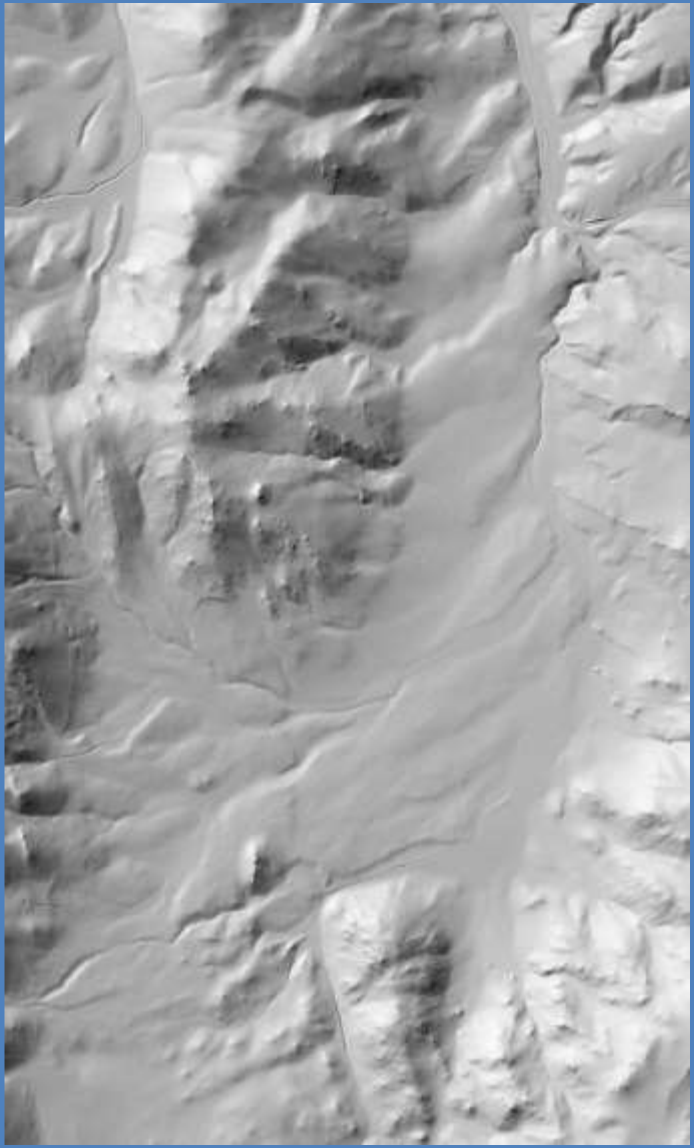
Warm Springs fault trench

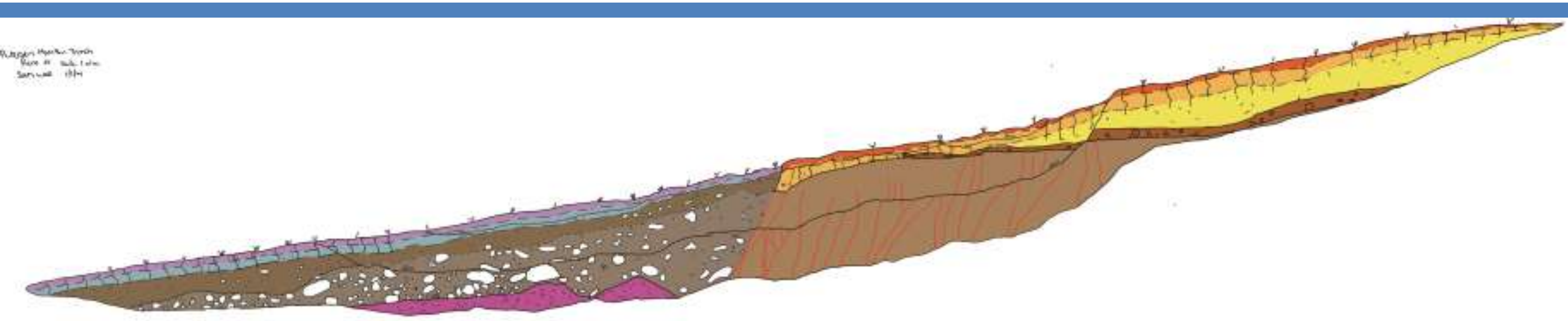


Paleoseismic Trenching
Petersen Mountain fault zone



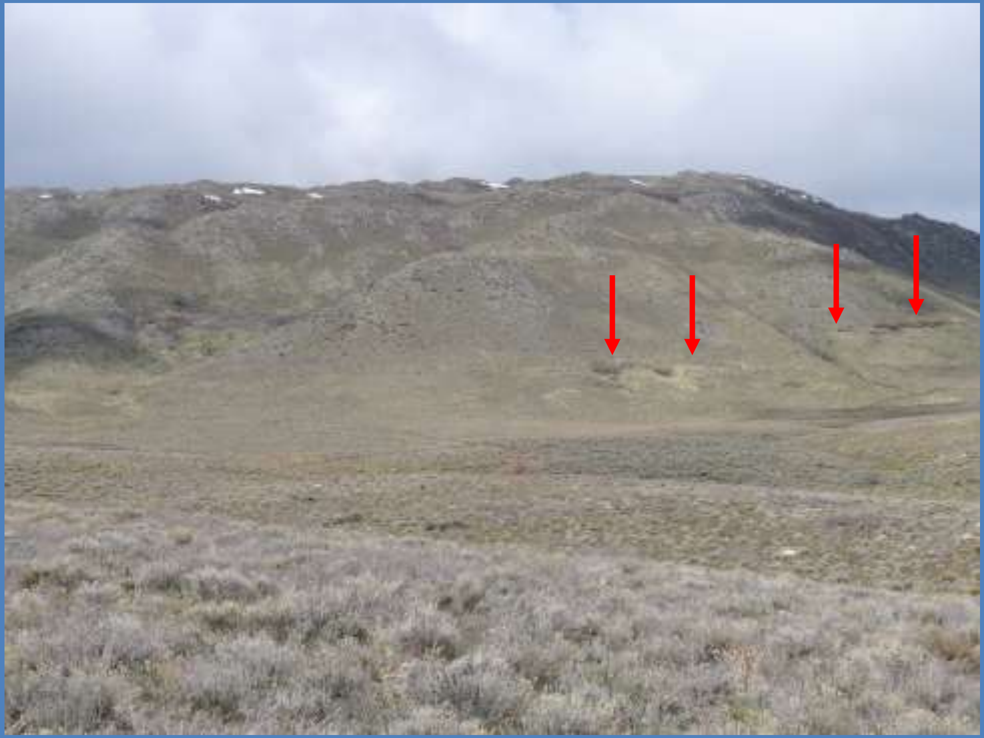


Petersen Mountain fault trench



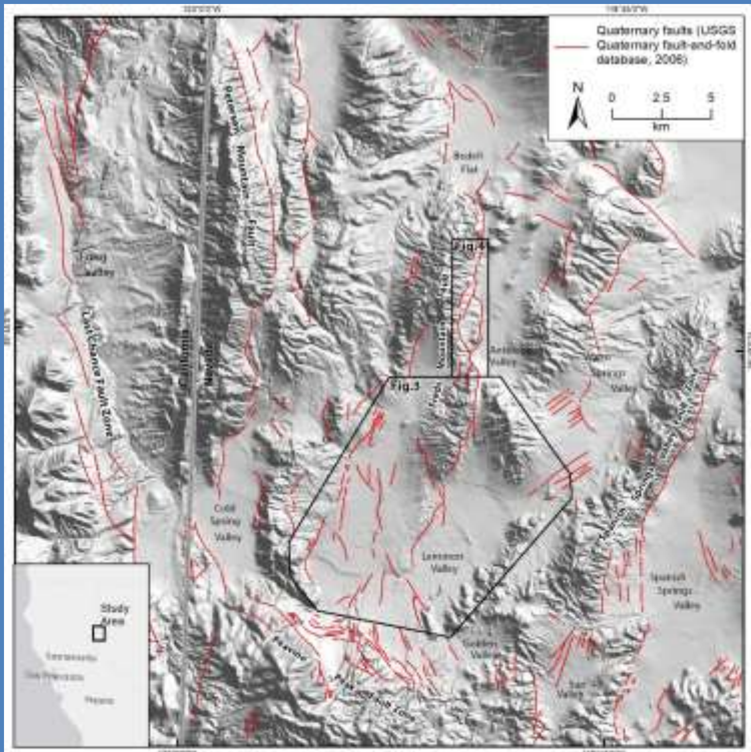


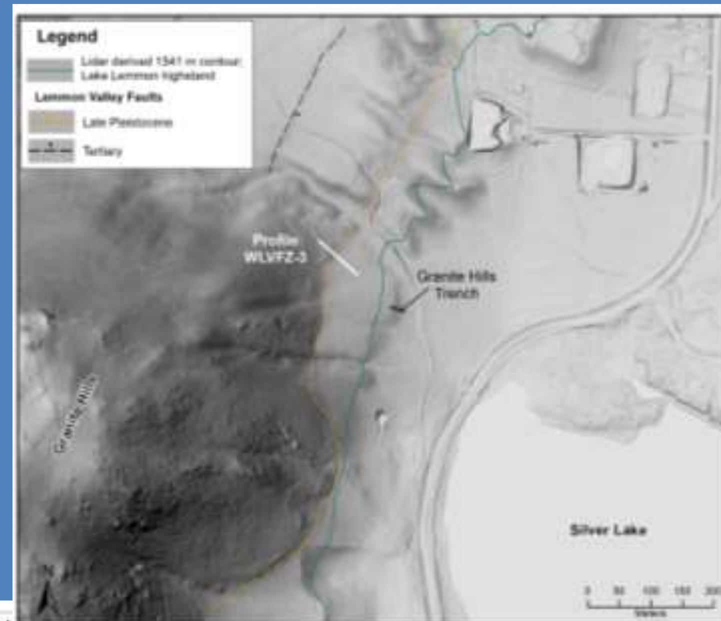

Petersen Mountain fault

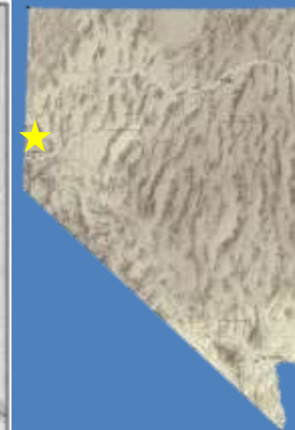


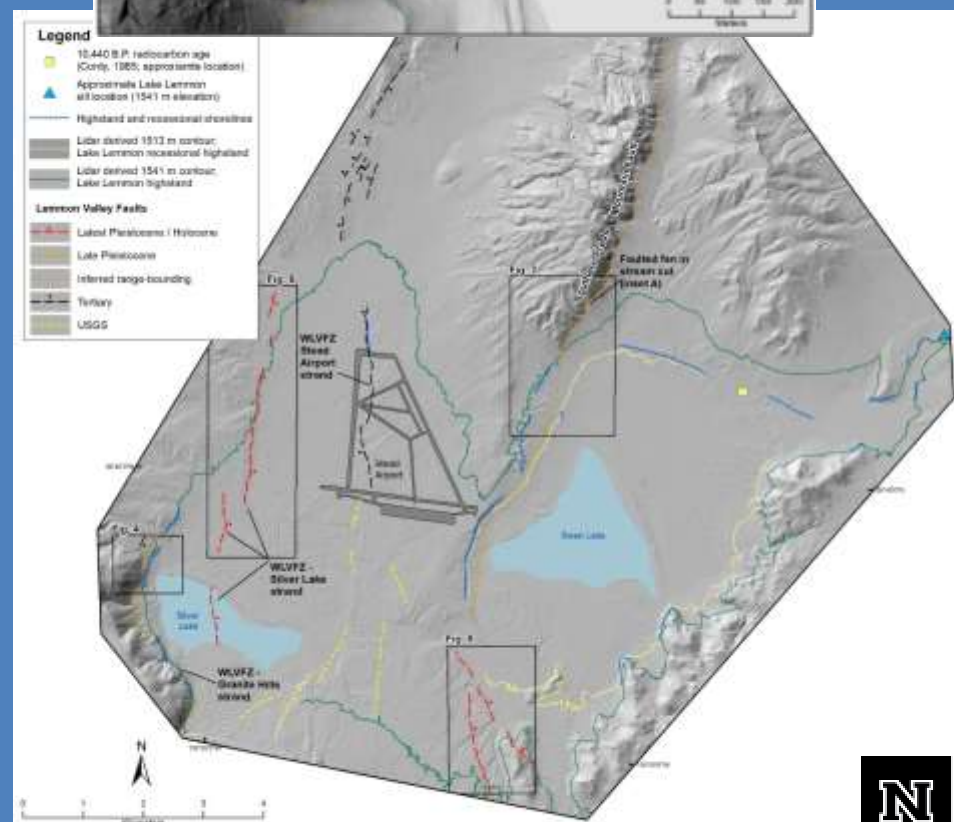
Potential overprint of Walker Lane strike-slip deformation on previously Basin and Range Normal fault structures

North Valleys Fault Study









- Pilot study to investigate faults in the North Valleys of Reno supported by USGS NEHRP
- Unsuccessful first trenching attempt in 2016
- Trench resulted in better understanding of pluvial lake history, improved fault mapping, and slip rate estimates

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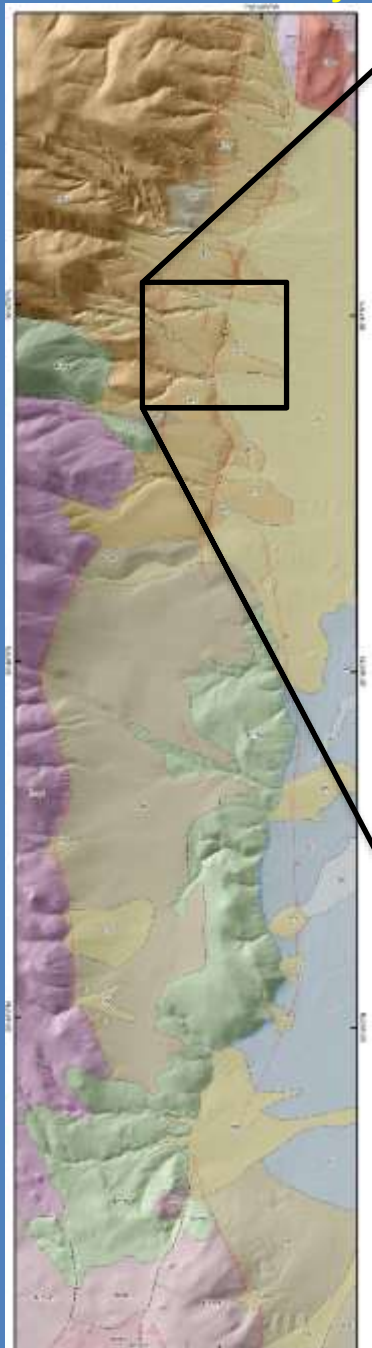
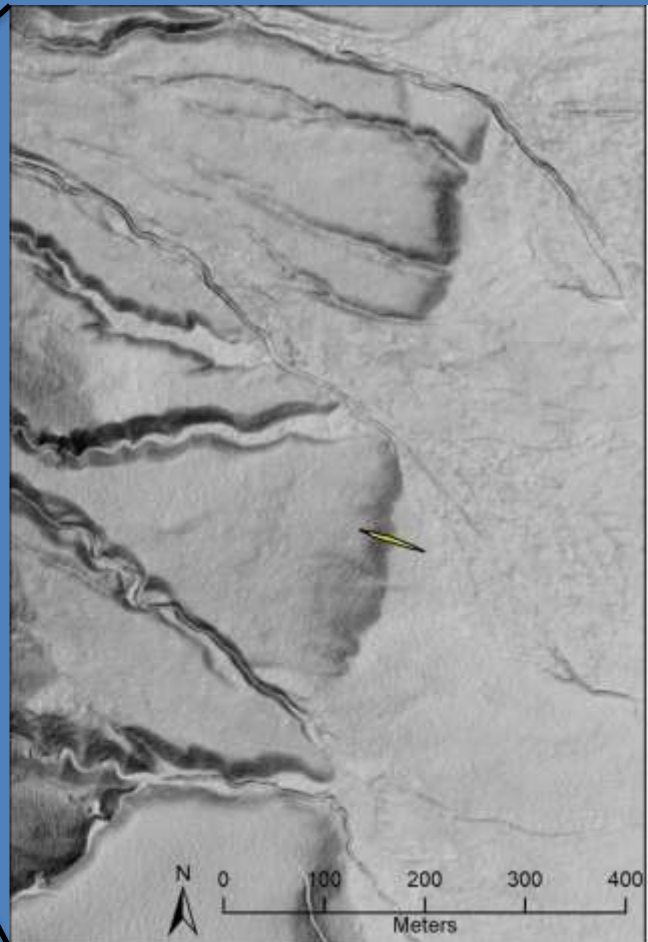
University of Nevada, Reno

North Valleys Fault Study





In May of 2018 excavated a new trench on a 9 m tall scarp on the Freds Mountain fault

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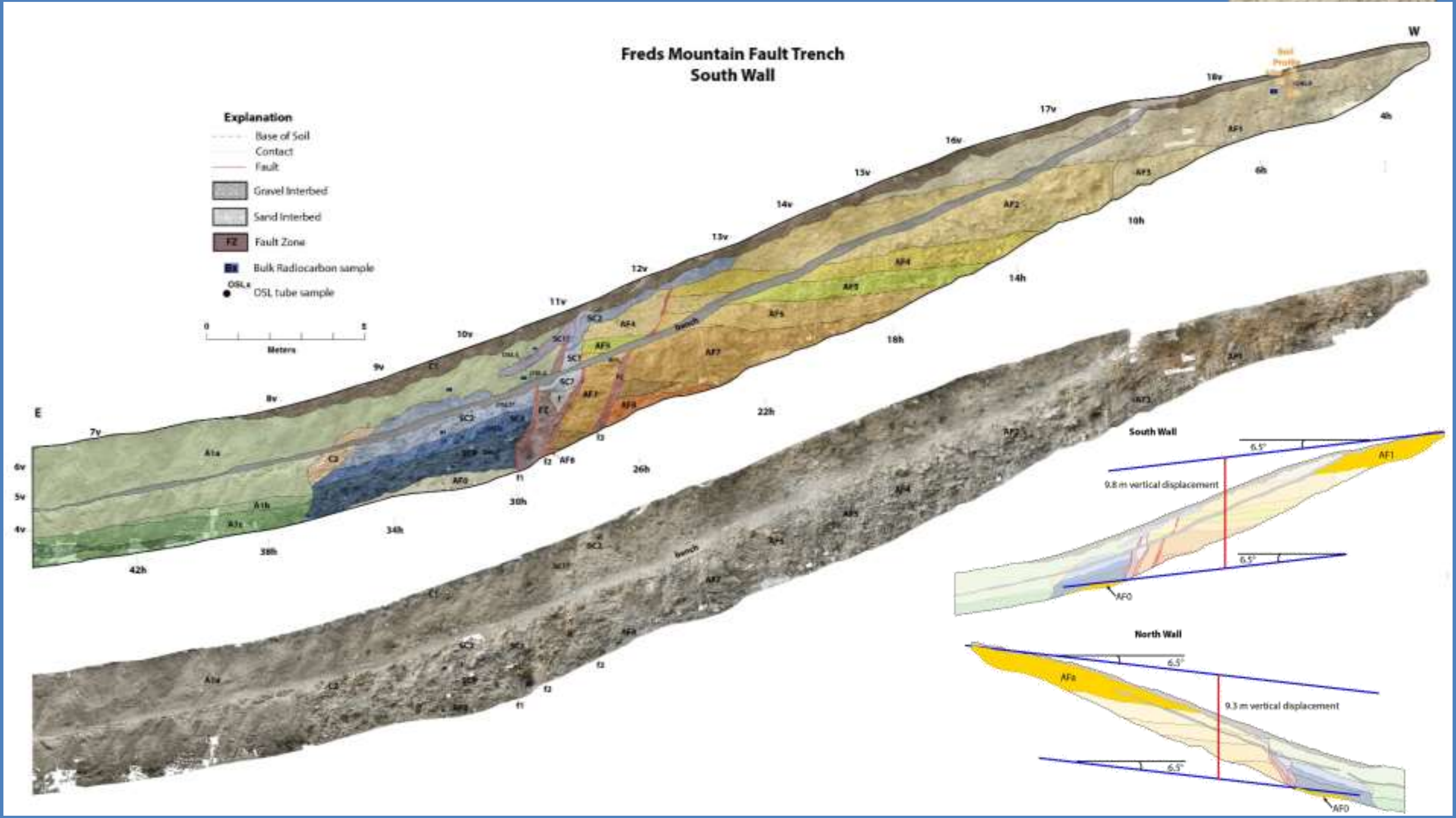
North Valleys Fault Study



- Trench evidence for 4 events. OSL and bulk radiocarbon ages pending.
- 9.3-9.8 m of vertical separation
- NEHRP FTR submitted

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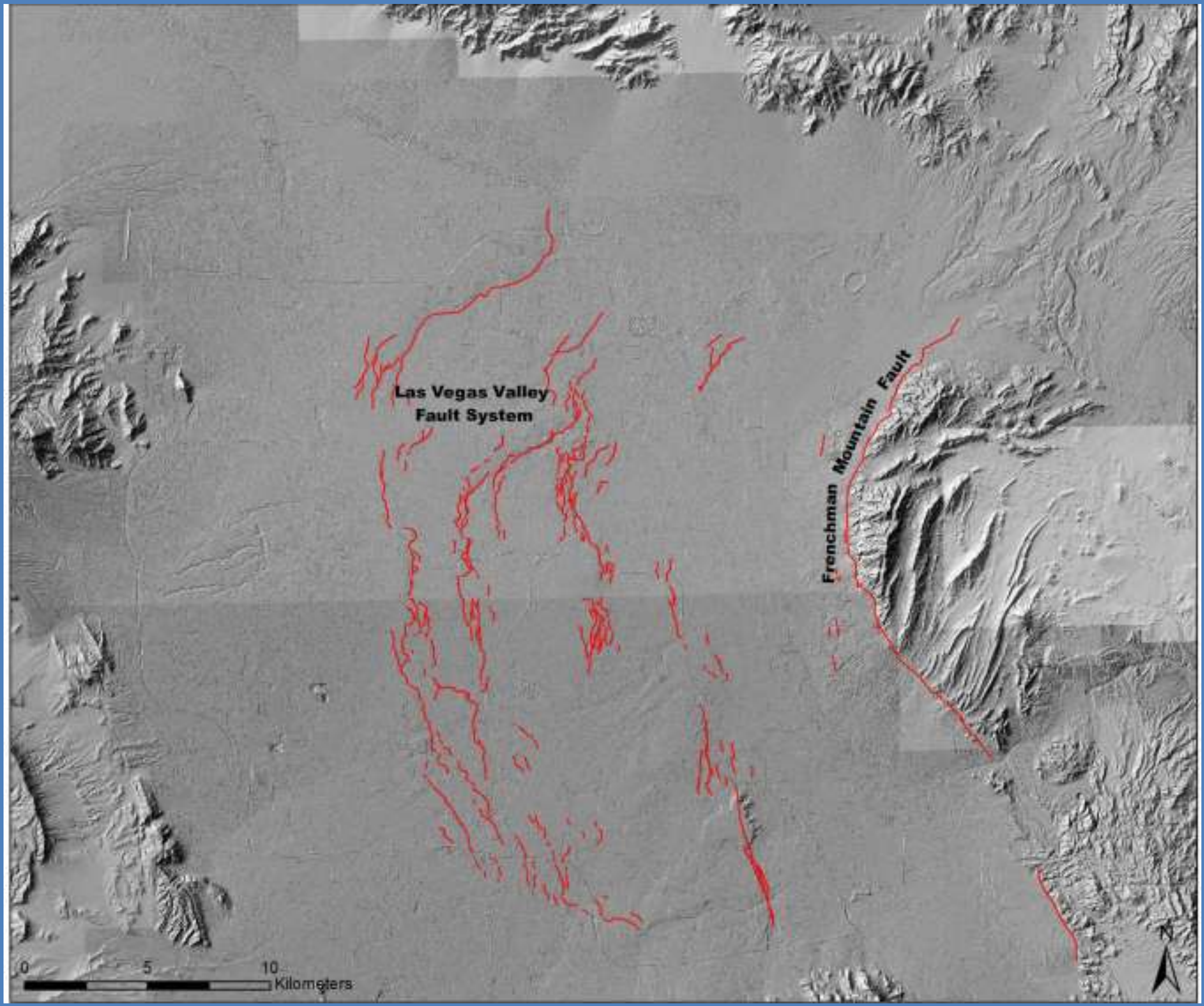
University of Nevada, Reno

Las Vegas Valley Fault Study



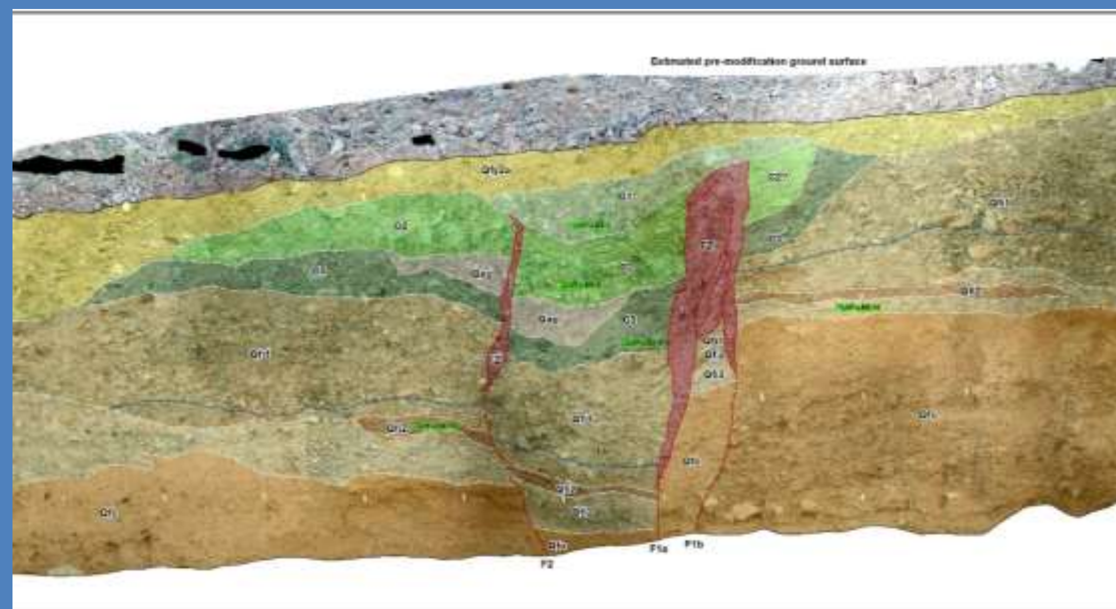
Study Goals:

- Seismogenic potential of the LVVFS
- Fault characterization
- OSL dating
- Quaternary geologic map compilation

Multi-year study to characterize the seismic hazard in Las Vegas Valley
Collaboration with NBMG, UNLV, and USGS

Nevada Bureau of Mines and Geology
University of Nevada, Reno

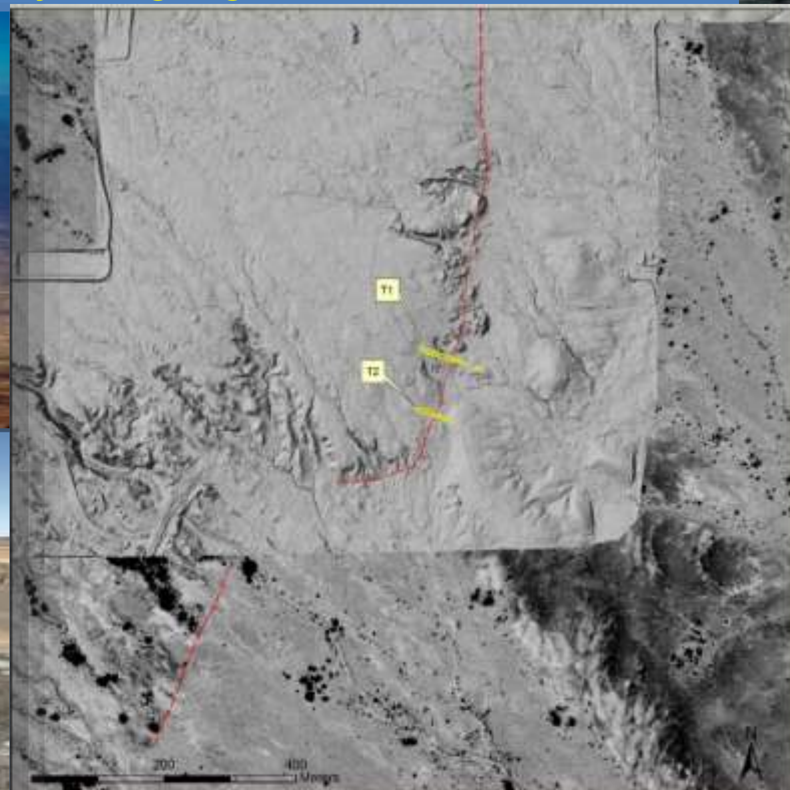
Las Vegas Valley Fault Study – Frenchman Mountain Fault



- 3 paleoearthquakes identified (~48 ka, ~25 ka, MRE pending)
- Total displacement ~1.6 m = slip rate of 0.02 – 0.03 mm/yr
- Long term slip rate pending OSL date

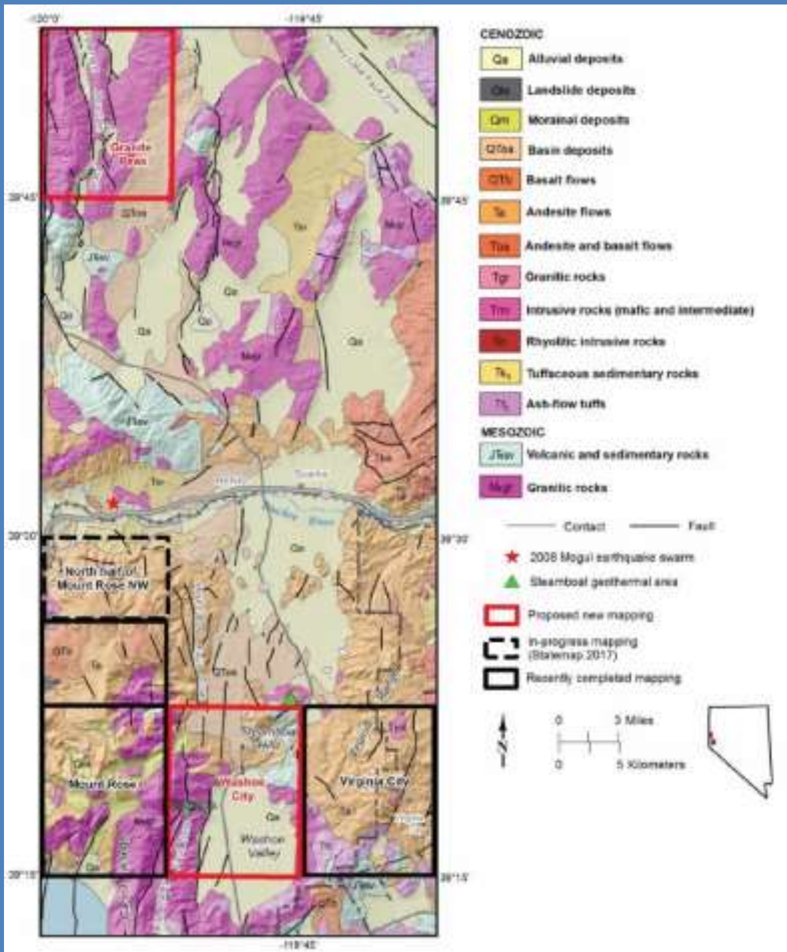
Nevada Bureau of Mines and Geology
University of Nevada, Reno

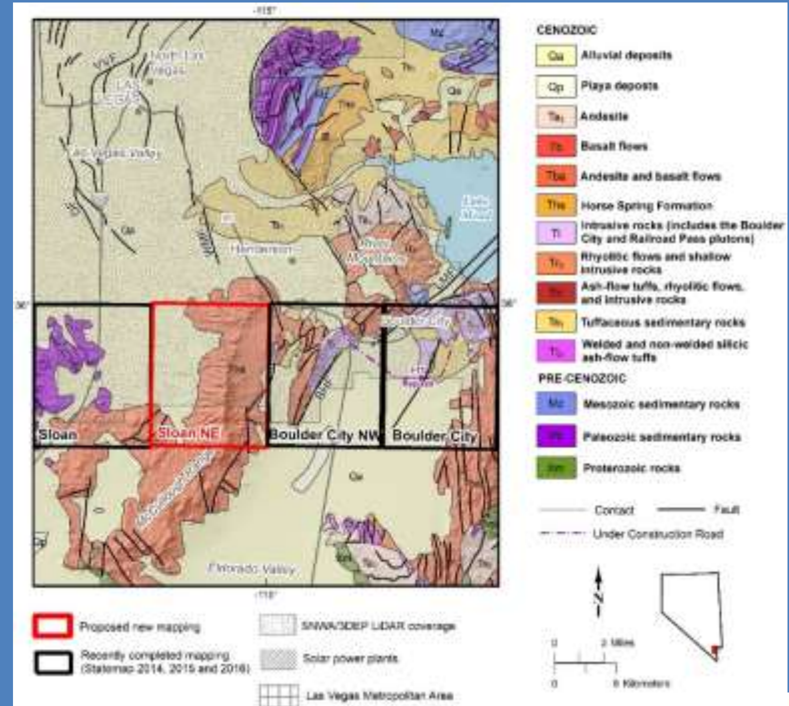
Las Vegas Valley Fault Study – Eglington Fault

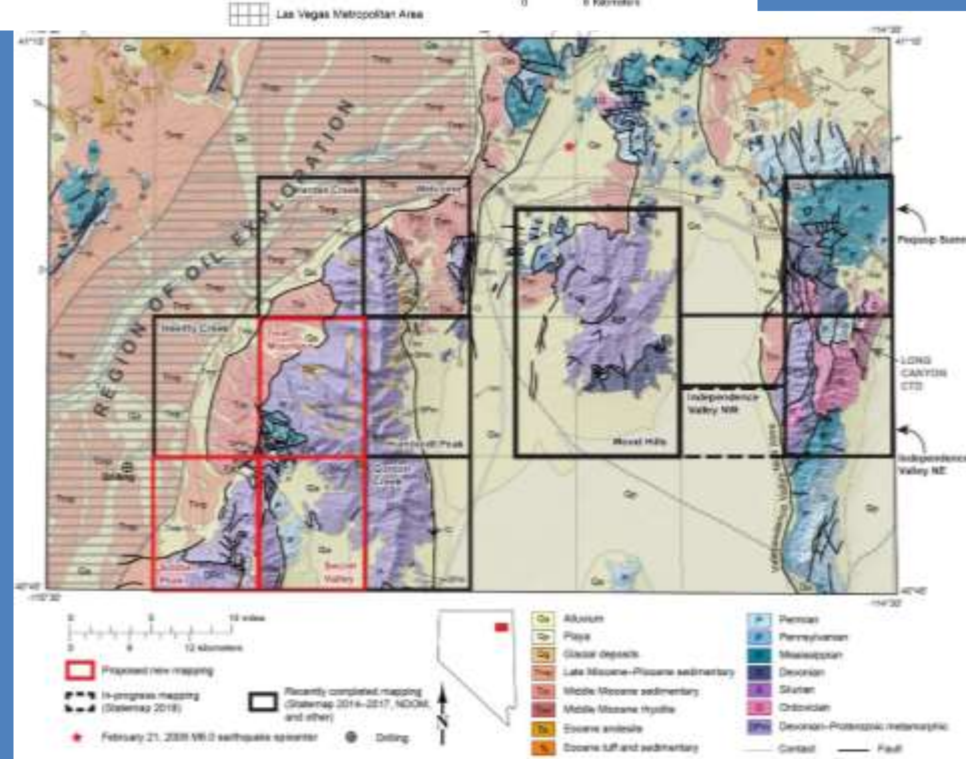


- Two trenches excavated in April 2018
- No evidence for faulting / surface rupture. Stratigraphy is broadly warped at the scarp. OSL dating in progress.
- Preliminary age estimates suggest warps developed between 30 ka and 7 ka with no displacement between 150 ka and 30 ka.
- Ongoing assessment of the mechanism of warp formation (blind tectonic normal fault, climatically driven differential compaction, other).

Geologic Mapping Program







- Most active 24k mapping areas contain Quaternary faults
- Most map areas now have lidar coverage

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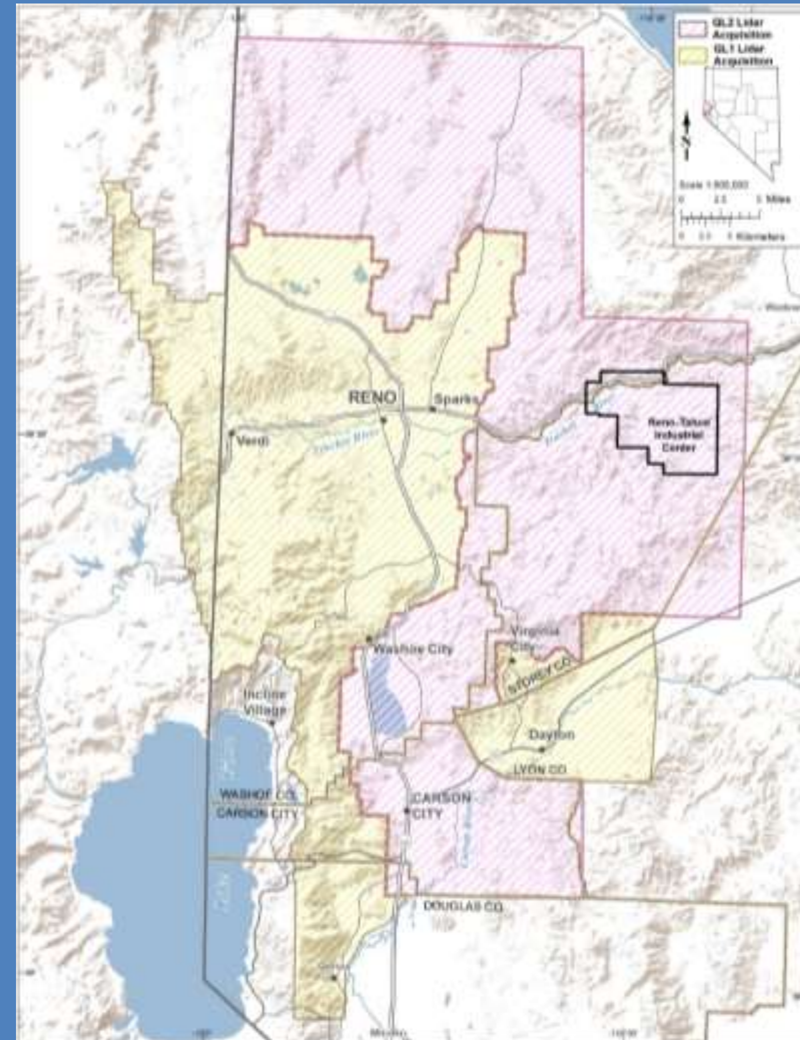
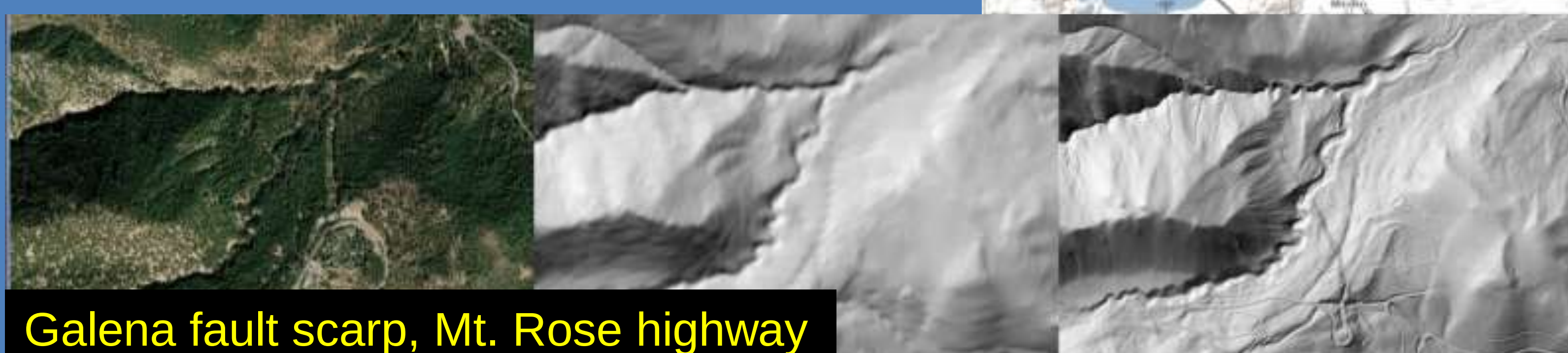
University of Nevada, Reno

New lidar for Reno area

- Lidar collected through the USGS 3DEP program
- Multi-agency funding parnership
- 4,023 sq/km of lidar data delivered in Summer 2018

Public outreach interactive web site



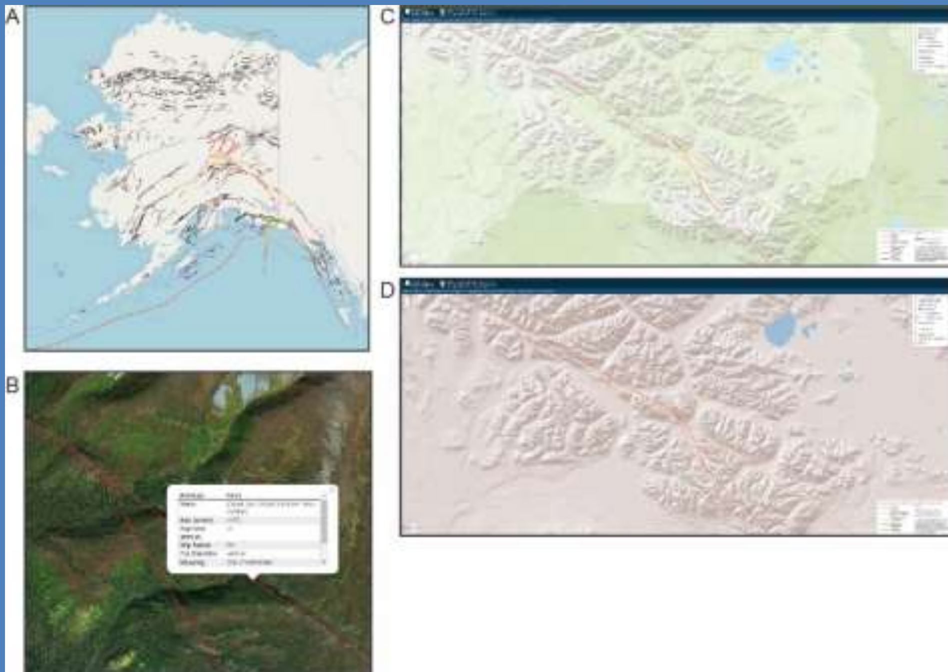


Galena fault scarp, Mt. Rose highway

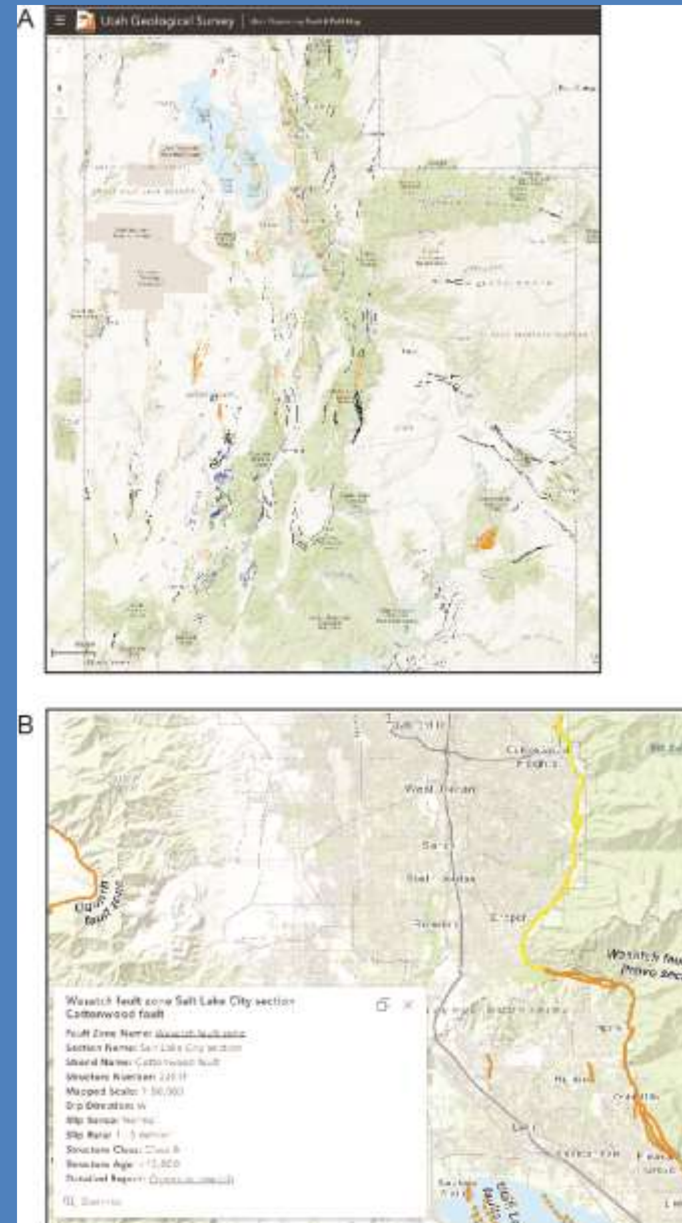
Thanks!




Database examples from other states



Alaska



Utah

Updates and Highlights from Wyoming

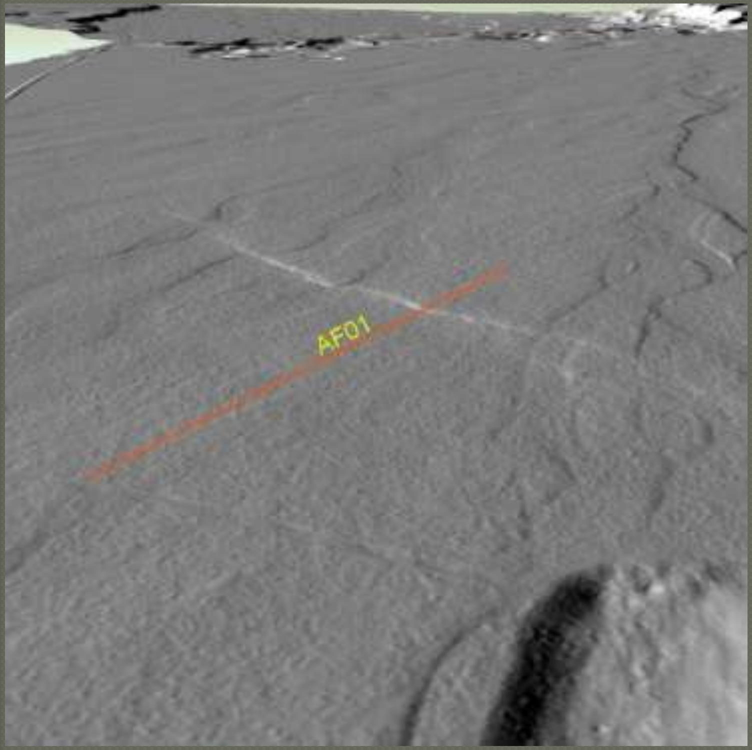
Seth Wittke
Wyoming Geological Survey
BRPEWG - 2019

Recent/Ongoing work

- Buffalo Bowl
  - Trenched in fall, 2017
  - Multiple agencies/groups
  - 3 Holocene events
    - ~5-10 ka
    - Confirms MRE documented at Granite Canyon

Antelope Flats

- Summer 2018
  - Two trenches
  - Glacial outwash fan
    - 18-21 ka



- 1-2 m discontinuous scarp zone
  - Single event
  - Antithetic to Teton fault
- Dating will constrain timing

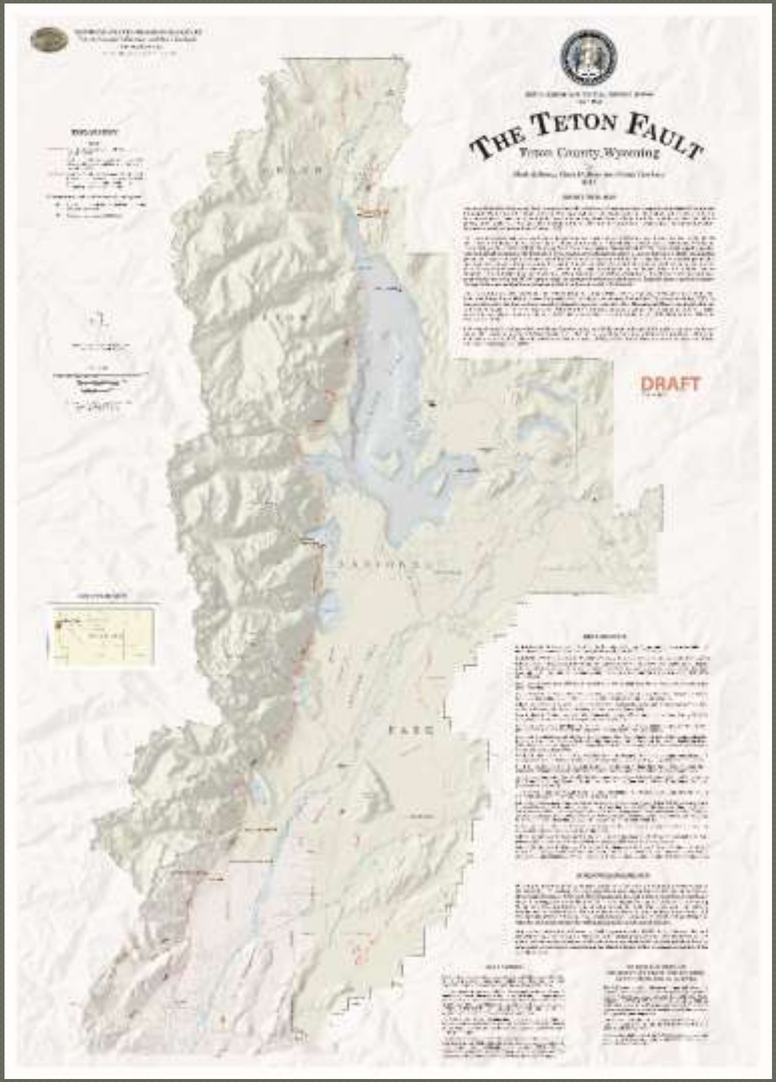
Antelope Flats

2019 (and beyond) work

- Ski Lake
  - Phillips Canyon fault
- Multi-group collaboration

Teton fault map

- 2019 release!



Backlogged Projects

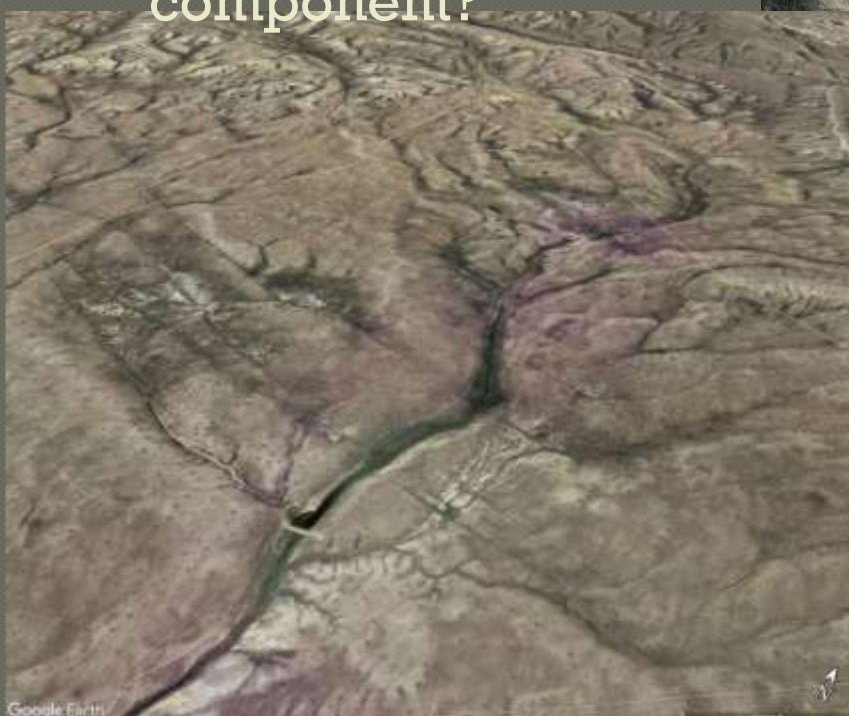
- New WSGS hire
  - Hazards background
- We can go back a few years and tie up a number of open projects!

Chicken Springs fault system

- Mapped in 2014

Chicken Springs fault system

- Obvious on photos
  - Not so much on the ground
  - Strike/slip component?



Greys River fault

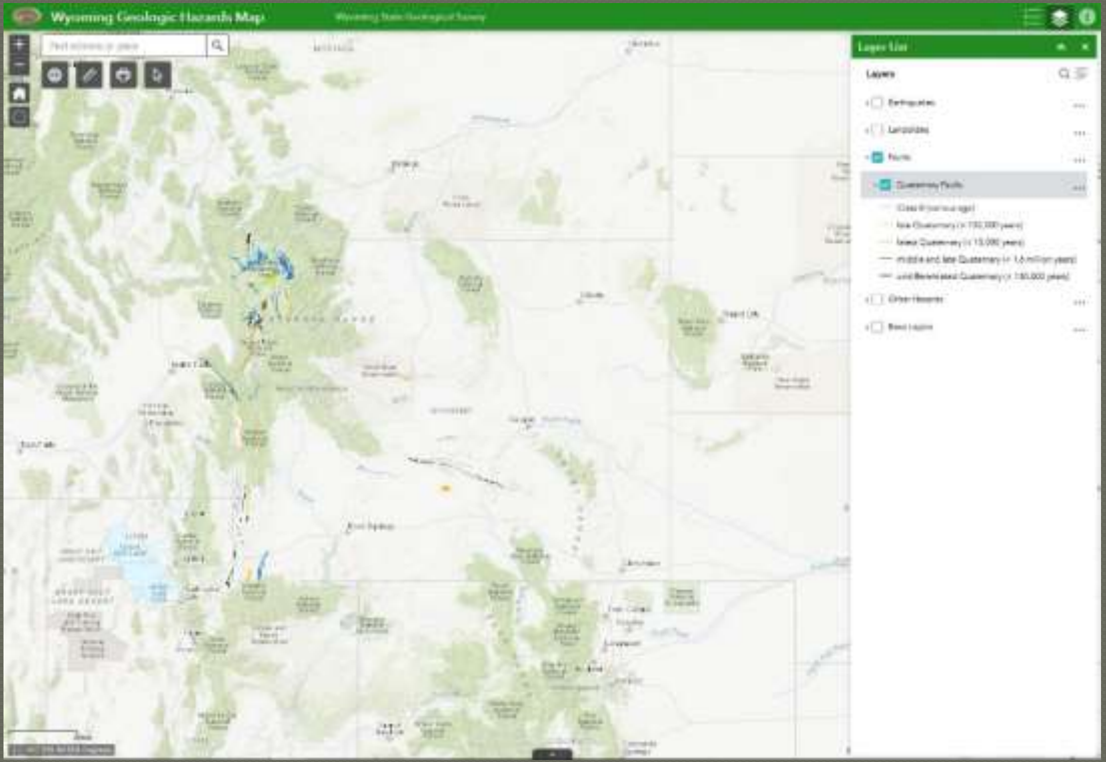
- Unmapped northern extent recognized in 2016
  - Fault trace currently ends at a map boundary
- Proposed STATEMAP FY19 project

Muddy Gap fault segment

- Mapped in 2017
- Part of the South Granite system
- Fault may have jumped to the south

Quaternary-aged fault database

- WSGS does not currently have it's own fault database
  - We are getting enough new data to start developing one
- WSGS Geological Hazards Map
  - Multiple hazards
  - Currently using USGS fault data



Summary

- New data continue to be created in the state
  - Extra hand will certainly help catch up
- WSGS will begin looking into our own database

Thank You

BASIN AND RANGE PROVINCE EARTHQUAKE WORKING GROUP

Utah Update

Wednesday, February 6, 2019

Utah Geological Survey

Geologic Hazards Program

Utah Geological Survey – Geologic Hazards Program

- **Respond** to geologic hazard emergencies and provide unbiased, scientific advice to local governments and incident commanders.
- **Investigate** and map geologic hazards in urban and other areas (publish and distribute PDFs and GIS spatial data).
- **Provide** geologic hazard related technical outreach, educational outreach, and information to inform Utah about hazards.


1999/2011+ Sherwood Hills Landslide

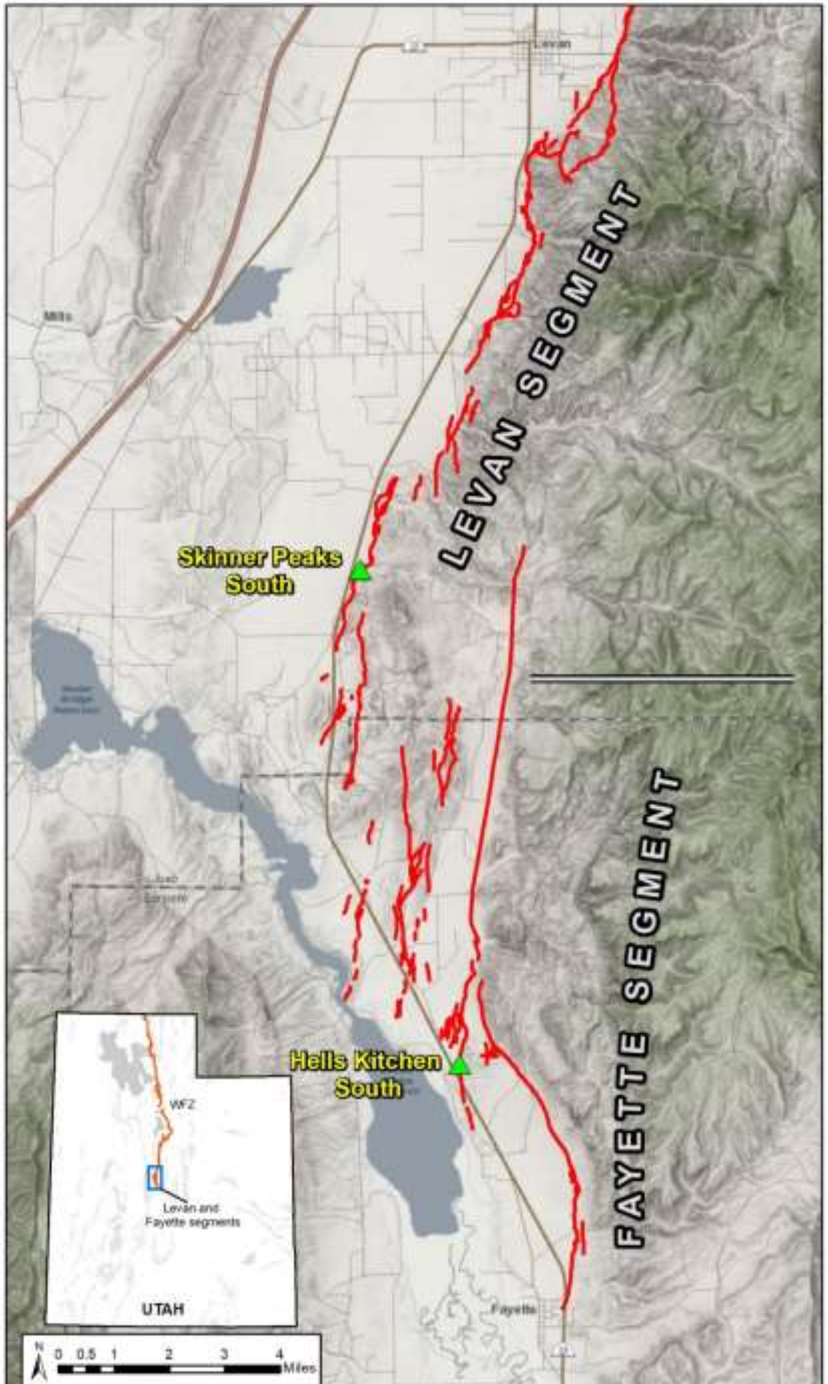

February 2010 Rockville Rock Fall

Hells Kitchen South Site

UGS Paleoseismic Investigation of the Levan and Fayette Segments of the Wasatch Fault Zone

Skinner Peaks South Site

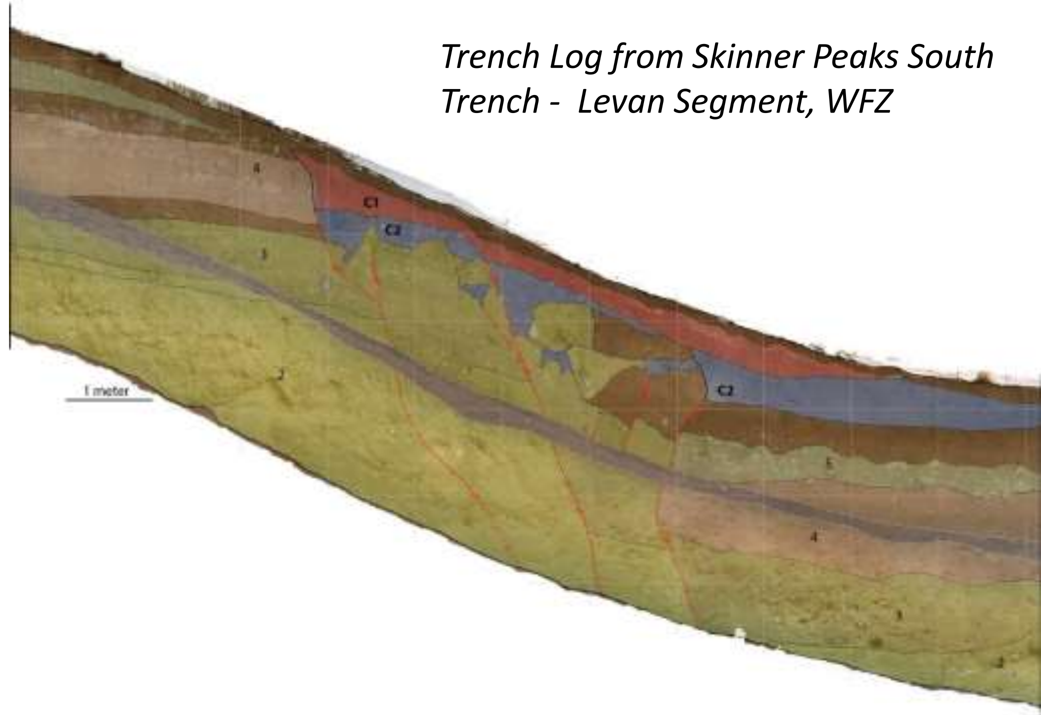
Funded with support from the U.S. Geological Survey National Earthquake Hazards Reduction Program

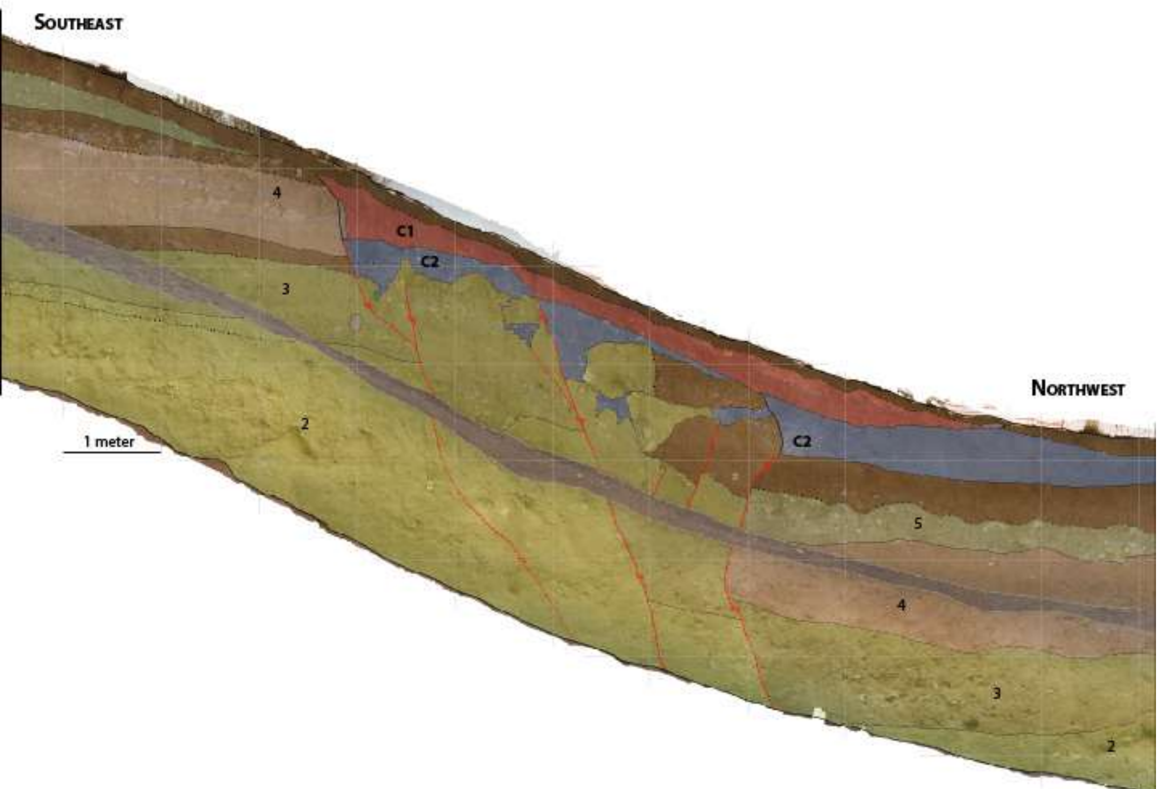


- Southernmost 2 segments of the WFZ
- Both segments show evidence of young faulting
- Mapped in high-detail using Lidar data in 2014 by Hiscock and Hylland.

- Evidence for 2 Earthquakes at the Skinner Peaks South site on the Levan Segment

Trench Log from Skinner Peaks South Trench - Levan Segment, WFZ



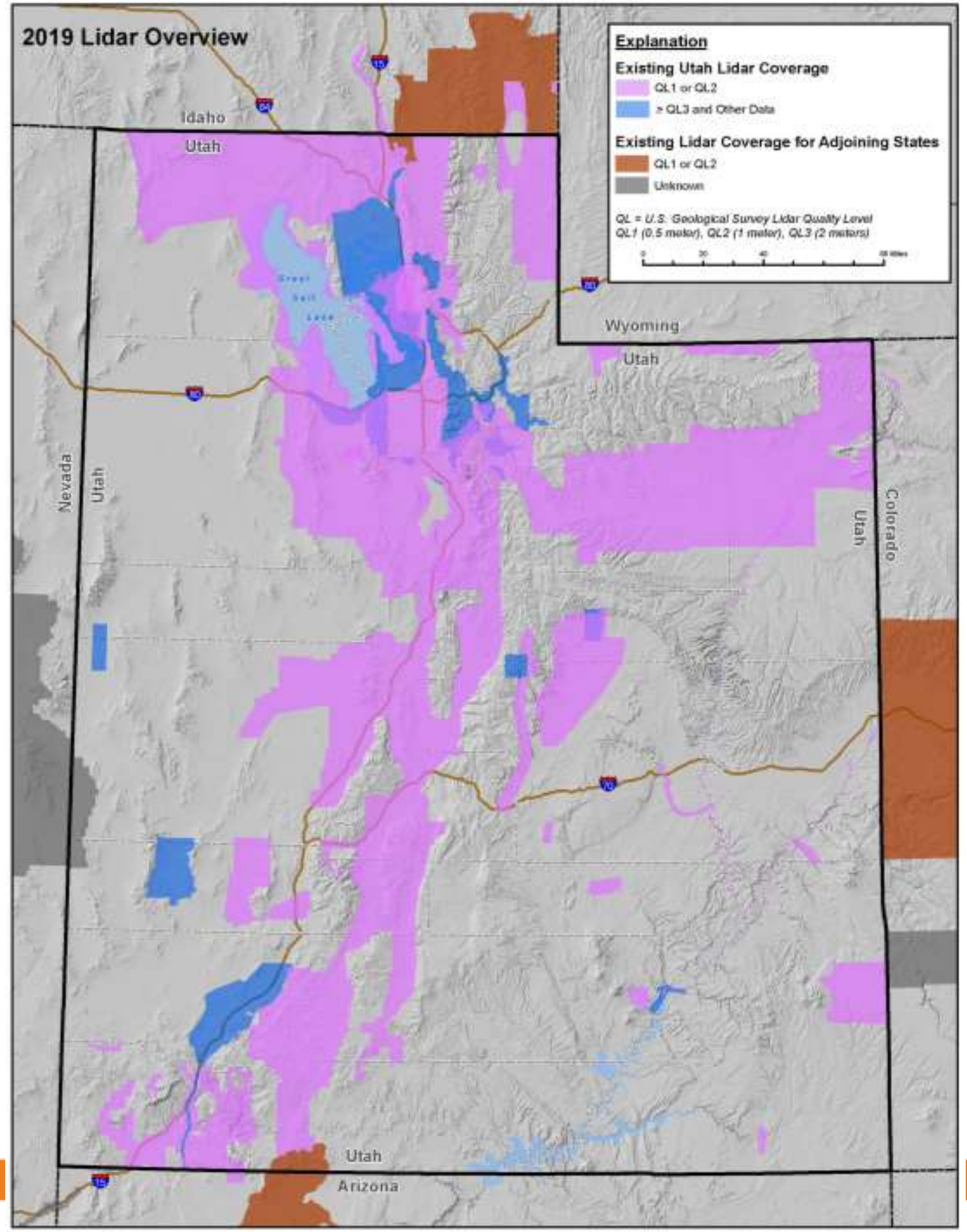


Trench Log from Hells Kitchen South Trench - Fayette Segment, WFZ

- 1 Earthquake at the Hells Kitchen South site on the Fayette Segment
- Preliminary earthquake timing: <u>**5.5 ± 0.1 ka (2σ)**</u>

Lidar

- 2011-present
- 2018: ~15,000 sq. mi collected
    - Scippio
    - West Side of Oquirrhs
    - Bear River/Bear Lake
    - Torowheap
    - Hurricane
- **Multi-agency partnerships are key to lidar acquisition success in Utah.**
- Data is extensively reviewed in house.



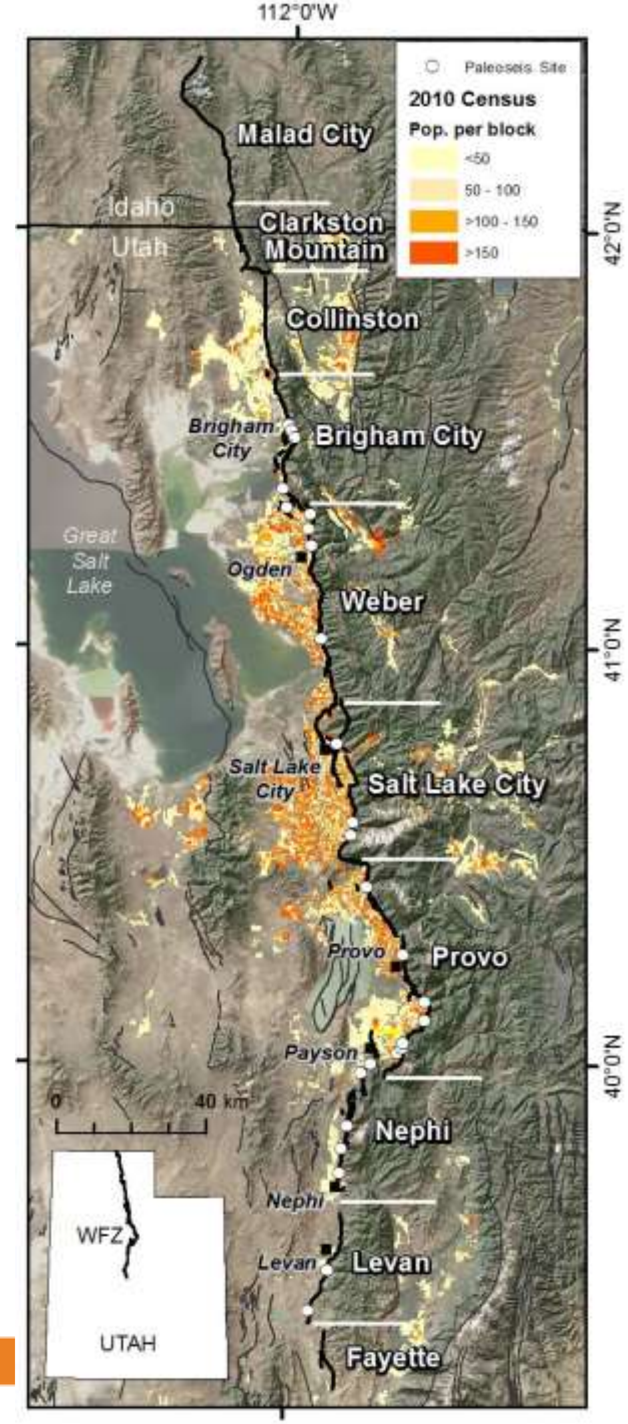
Utah Earthquake Program

an integrated Utah state agency and professional organization partnership to reduce earthquake risk

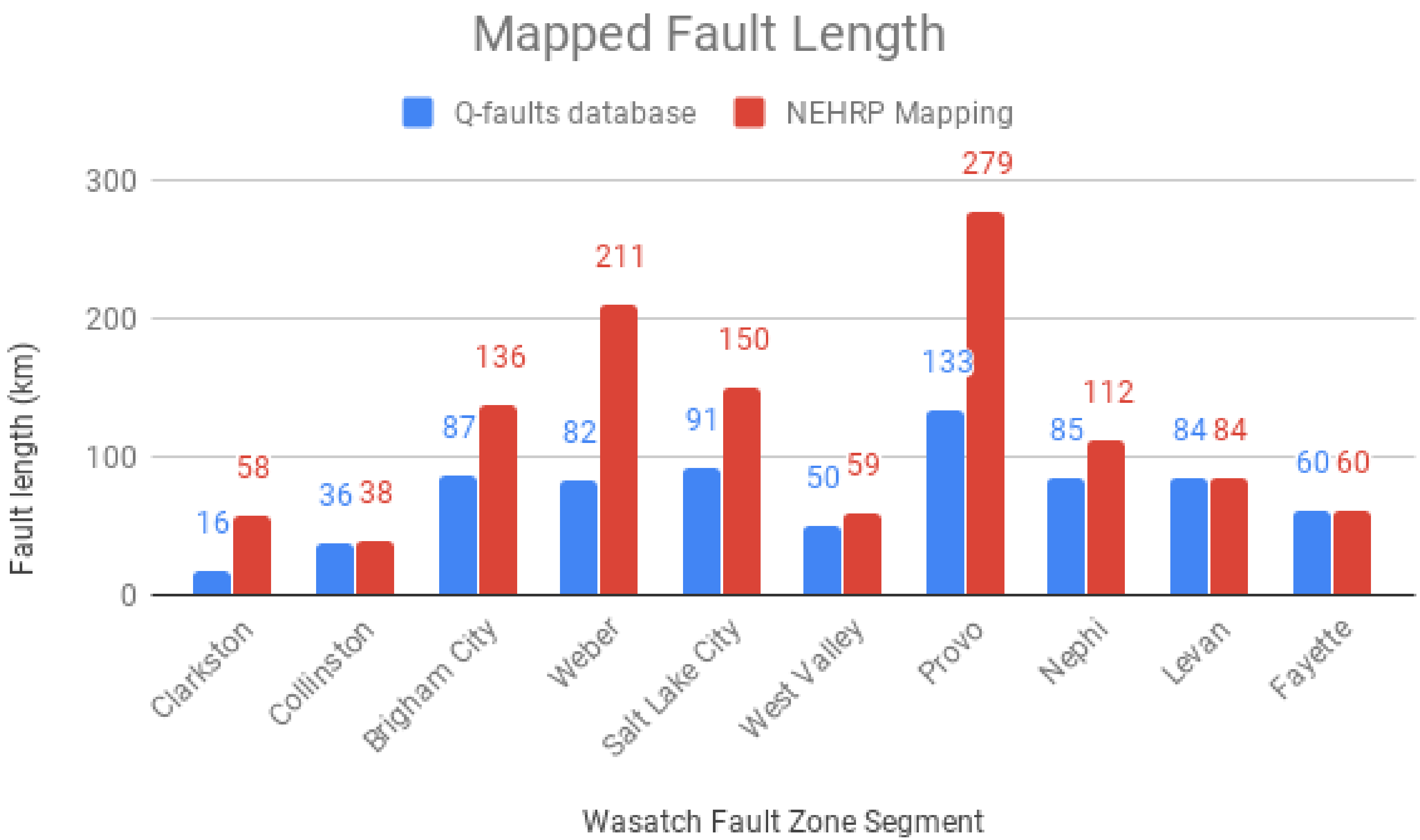
https://ussc.utah.gov

NEHRP funded Wasatch Fault Zone Mapping

- Detailed mapping using high-resolution lidar
  - supplemented with aerial photos and limited field reconnaissance
- Levan and Fayette segments (south end) mapped in 2014-15 by Hiscock and Hylland
- This project
  - Remaining 8 segments
  - 39 7.5-minute quadrangles in Utah; additional 5 quads in Idaho
  - Delineate surface-fault-rupture hazard special study areas
  - Identify potential paleoseismic investigation sites

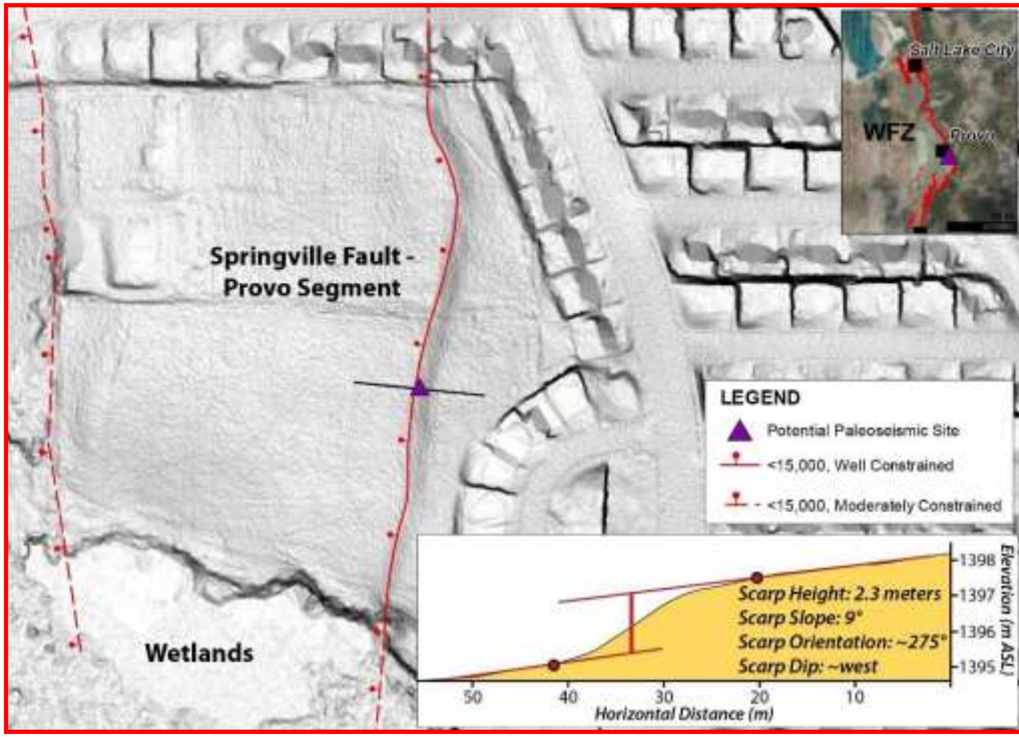


Results of Fault Mapping



Paleoseismic Sites

- 60 sites identified



Utah Quaternary Fault and Fold Map

- AKA- Utah Quaternary Fault and Fold Database (internal)
- Based on USGS database schema
- Keep track of updates internally

Updated by EK	Review by MH	MH comments addressed by EK	Sent to Gordon	Update sent to AGRC	Update sent to USGS	USGS Fault No.	Fault Name	Publication	Name	Author
1/2017	1/2017	-	-	1/2017	1/2017	2369d	Great Salt Lake fault zone, Antelope Island section	MP-15-5	BRPSHSIII Proceedings (poster); also see	Dinter & Pechmann, 2015
		-	-					OFR 644	Tooele 30x60	Clark et al, 2015
1/2017	1/2017	-	-	1/2017	1/2017	2369c	Great Salt Lake fault zone, Fremont Island section	MP-15-5	BRPSHSIII Proceedings (poster); also see	Dinter & Pechmann, 2015
1/2017	1/2017	-	-	1/2017	1/2017	2369b	Great Salt Lake fault zone, Promontory section	MP-15-5	BRPSHSIII Proceedings (poster); also see	Dinter & Pechmann, 2015
6/20/2017	6/20/2017	-	12/19/2018			2352b	East Cache fault zone, Central section	MF-2107	Surficial geologic map of the East Cache fault zone, Cache County, Utah (USGS)	McCalpin, 1989
1/3 - 1/9/2018	7/18/2018	-	12/19/2018			2351i	Wasatch fault, Levan section	OFR 640	Levan/Fayette SFR maps	Hiscock & Hylland, 2015
1/3 - 1/9/2018	7/18/2018	-	12/19/2018			2351j	Wasatch fault, Fayette section	OFR 640	Levan/Fayette SFR maps	Hiscock & Hylland, 2015
1/9/2018	7/18/2018	-	12/19/2018			2351h	Wasatch fault, Nephi section	Map 227	Spanish Fork 7.5	Solomon et al, 2007
1/9/2018	7/18/2018	-	12/19/2018			2386b	West Valley fault zone, Granger fault	Map 216	Magna 7.5	Solomon et al, 2007
1/9/2018	7/18/2018	-	12/19/2018			2422	Long Ridge (Northwest Side) fault	Map 272	Goshen 7.5	McKean et al, 2015
1/9/2018	7/18/2018	-	12/19/2018			2541 (new)	Goshen fault	Map 272	Goshen 7.5	McKean et al, 2015
1/9/2018 to [illegible]	[illegible]	-	[illegible]			2542 (new)	[illegible]	[illegible]	[illegible]	[illegible]

GIS Schema- Utah

- ObjectID (ArcGIS populated)
- Fault Number (text)
- Fault Zone (text)
- Fault Name (text)
- Section Name (text)
- Strand Name (text)
- Mapped Scale (text, domain)
- Dip Direction (text, domain)
- Slip Sense (text, domain)
- Slip Rate (text, domain)
- Mapping Constraints (text, domain)
- Fault Class (text, domain)
- Fault Age (text, domain)
- Shape (text, domain)- ESRI
- Label (text)
- Date Created (date, auto-populated)
- Last Modified (date, auto-populated)
- Shape Length (ArcGIS populated)

Quaternary Fault Database

Current Workflow

1. Peer-reviewed mapping published- Added to the que
2. Update fault attributes/geometries based on mapping in ArcGIS SDE (Spatial Database Engine)
3. Internal review in ArcGIS desktop (Mike Hylland)
4. Edits made
5. Mapping prepared for integration into ArcGIS web App
6. Mapping published to ArcGIS web app

BOISE STATE UNIVERSITY

SOIL, FLUID AND ROCK PROPERTIES DERIVED FROM SEISMIC DATA: HAZARD AND RESOURCE ASSESSMENTS

Lee Liberty – Boise State University

What do seismic velocities represent?

P wave and S wave velocities depend on physical properties of medium through which they travel

$$V = \sqrt{\frac{\text{modulus}}{\rho}}$$

$$V_P = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}$$

$$V_s = \sqrt{\frac{\mu}{\rho}}$$

Moduli are elastic constants (from Hooke's Law)

where: K = the bulk modulus, or the reciprocal of compressibility.

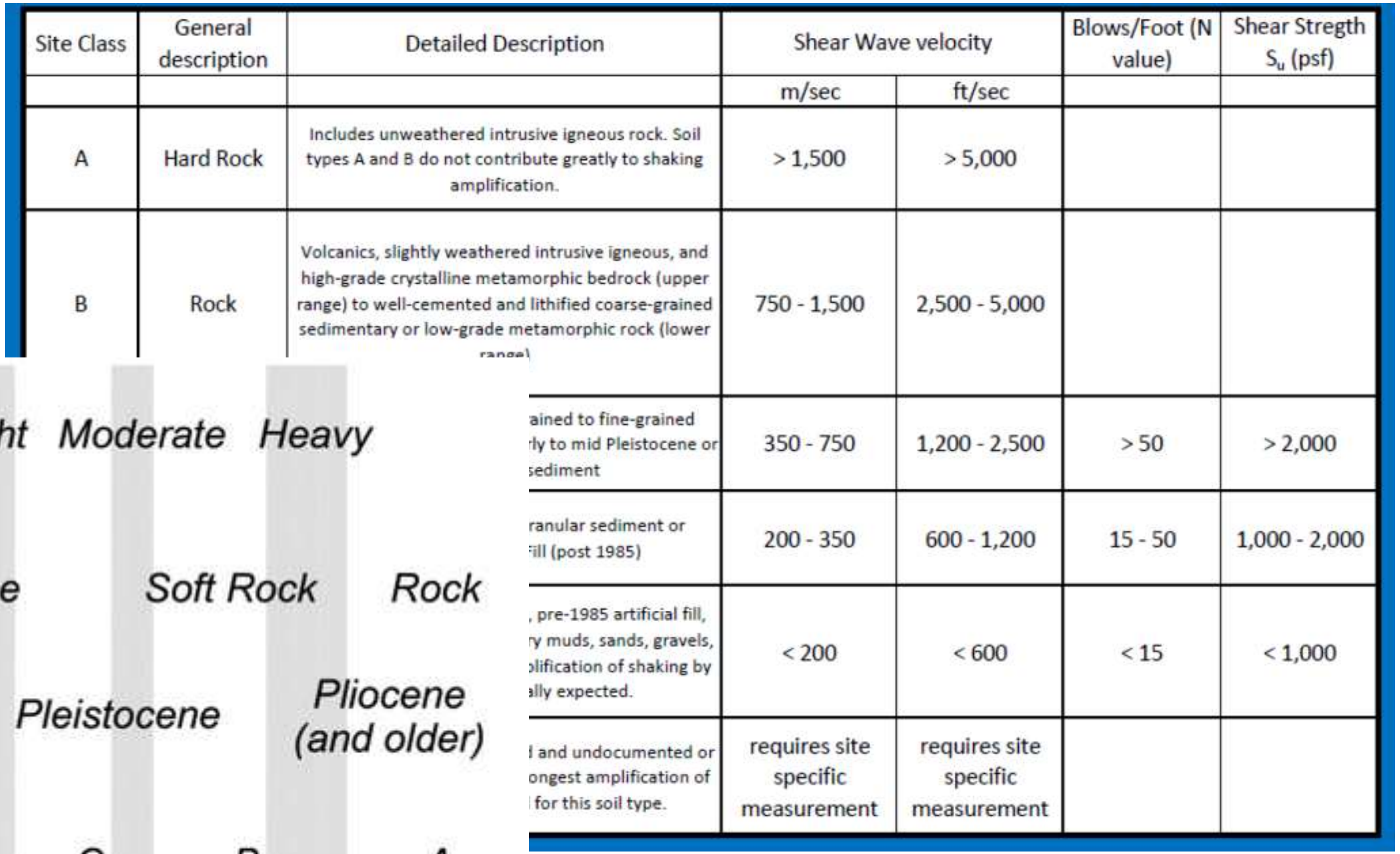
μ = the shear modulus, or how easy the rock can shear,

and ρ = density.

Influences on Rock Velocities

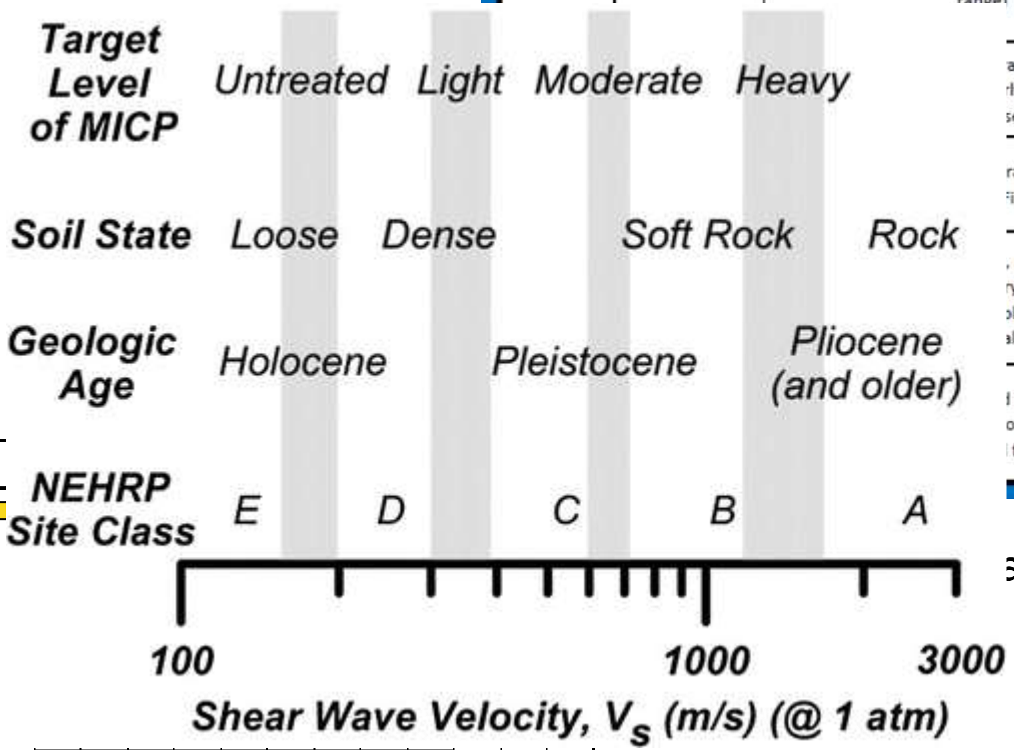
- Lithology
- Degree of compaction/lithification
- Stiffness/rock competency
- Confining pressure
- Porosity
- Pore space materials (dry, oil, water)
- Microcracks, bedding plane anisotropy

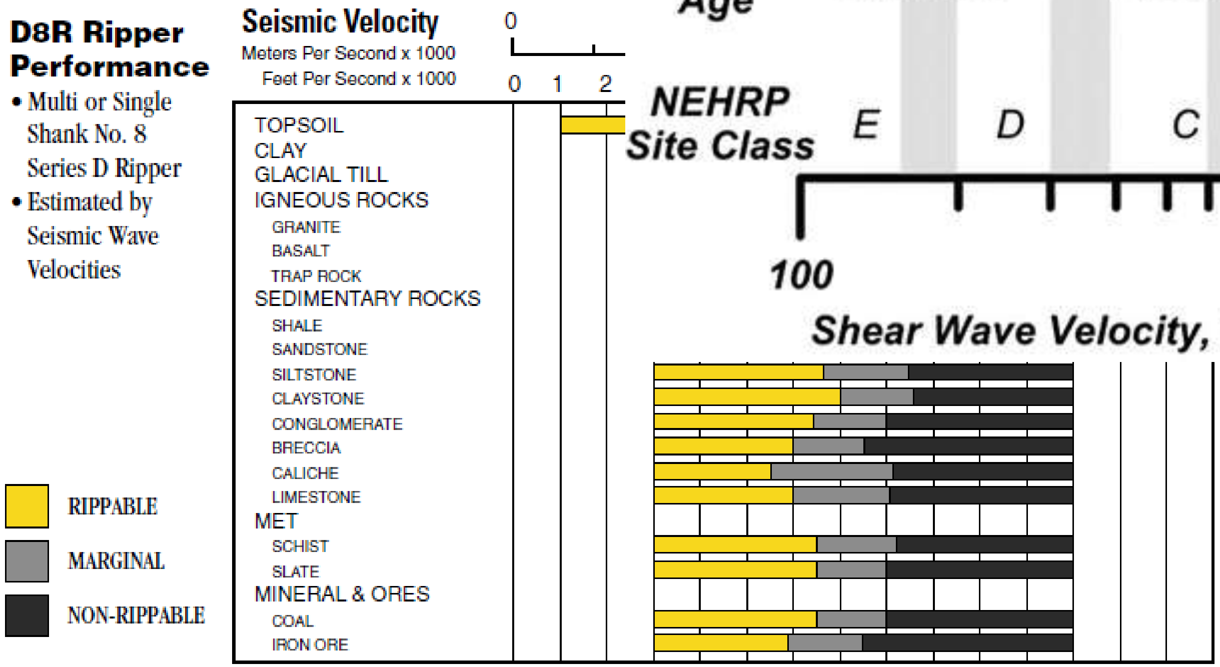
SOIL/ROCK SEISMIC PROPERTIES



Site Class	General description	Detailed Description	Shear Wave velocity m/sec	Shear Wave velocity ft/sec	Blows/Foot (N value)	Shear Stregth S_u (psf)
A	Hard Rock	Includes unweathered intrusive igneous rock. Soil types A and B do not contribute greatly to shaking amplification.	> 1,500	> 5,000		
B	Rock	Volcanics, slightly weathered intrusive igneous, and high-grade crystalline metamorphic bedrock (upper range) to well-cemented and lithified coarse-grained sedimentary or low-grade metamorphic rock (lower range)	750 - 1,500	2,500 - 5,000		
		ained to fine-grained rly to mid Pleistocene or sediment	350 - 750	1,200 - 2,500	> 50	> 2,000
		ranular sediment or ill (post 1985)	200 - 350	600 - 1,200	15 - 50	1,000 - 2,000
		, pre-1985 artificial fill, y muds, sands, gravels, lification of shaking by ally expected.	< 200	< 600	< 15	< 1,000
		l and undocumented or ongest amplification of for this soil type.	requires site specific measurement	requires site specific measurement		

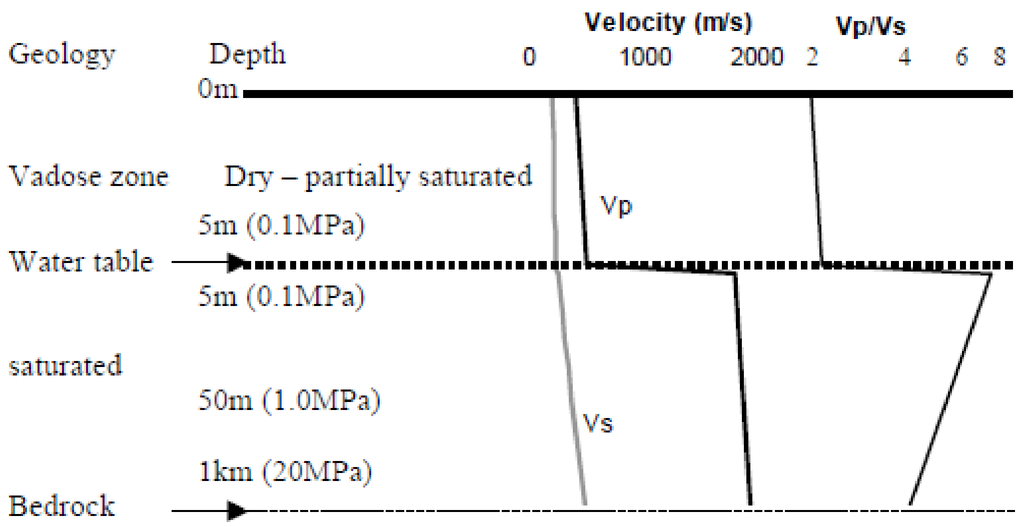
an Society of Civil Engineers, 2013

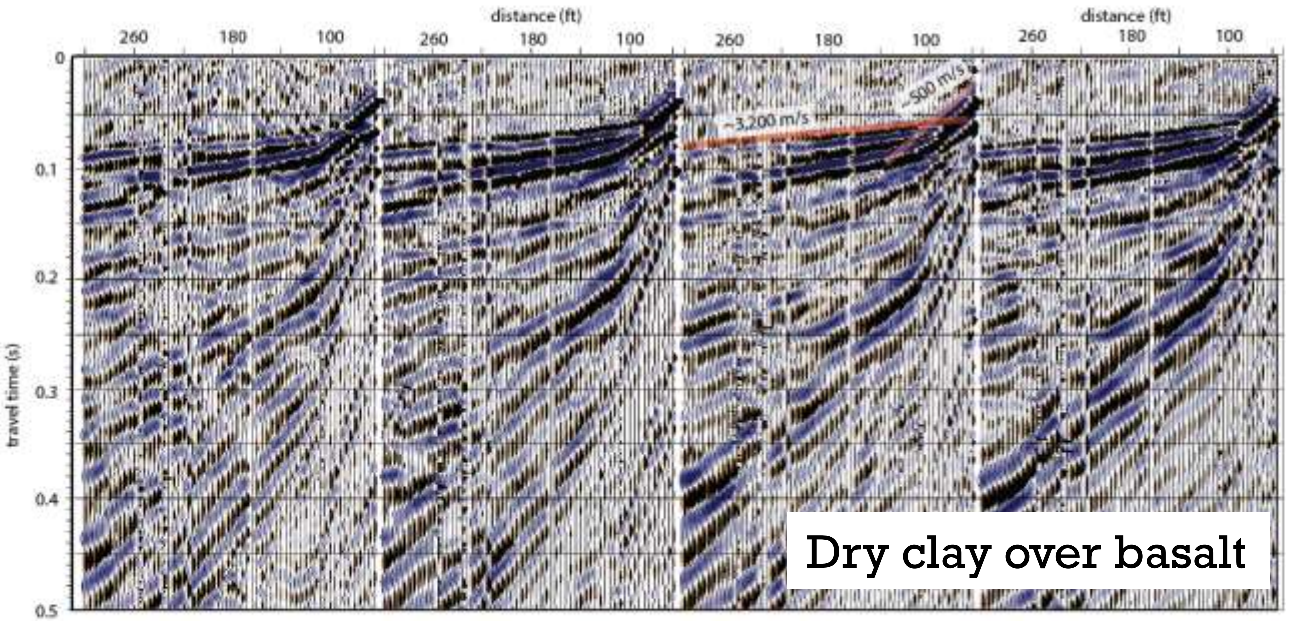


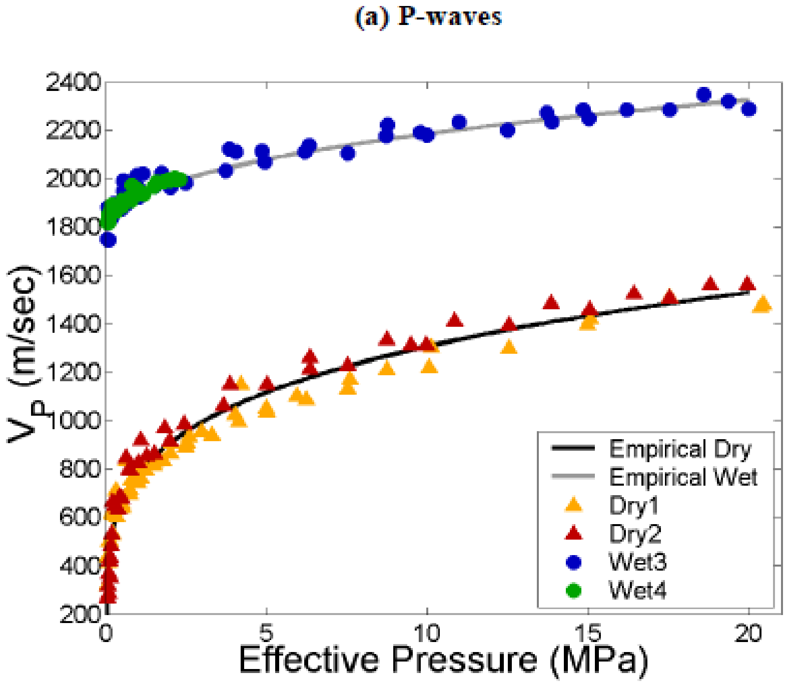


From Caterpillar "HANDBOOK OF RIPPING", 12th edition – first published in 1958

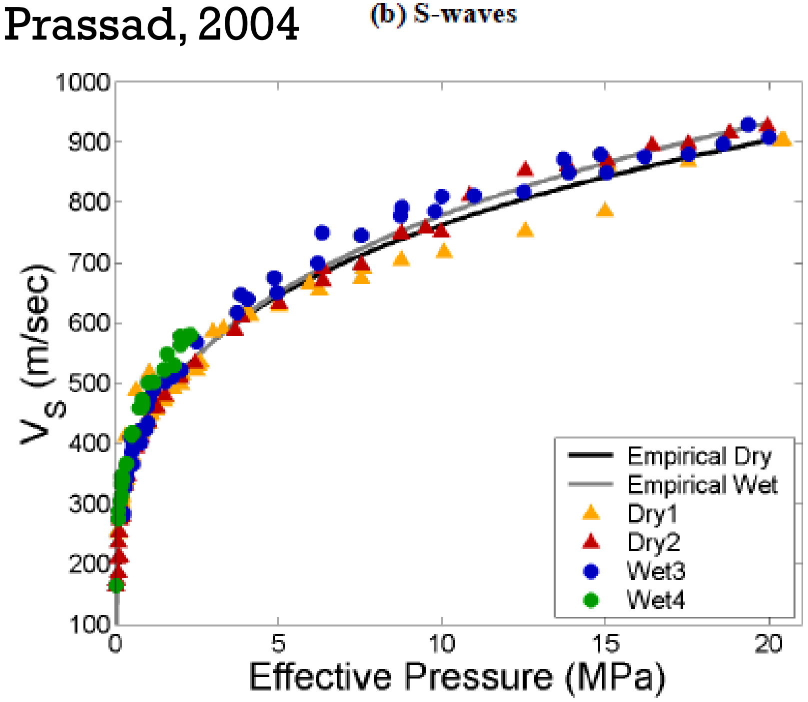
SEISMIC VELOCITIES IN SANDS (WET AND DRY)





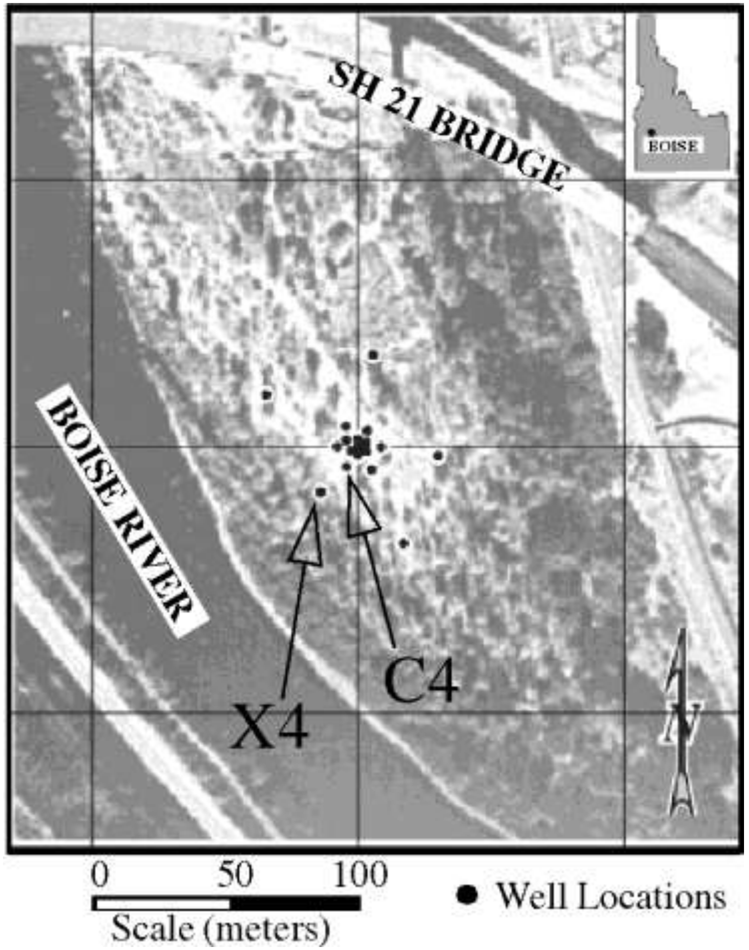


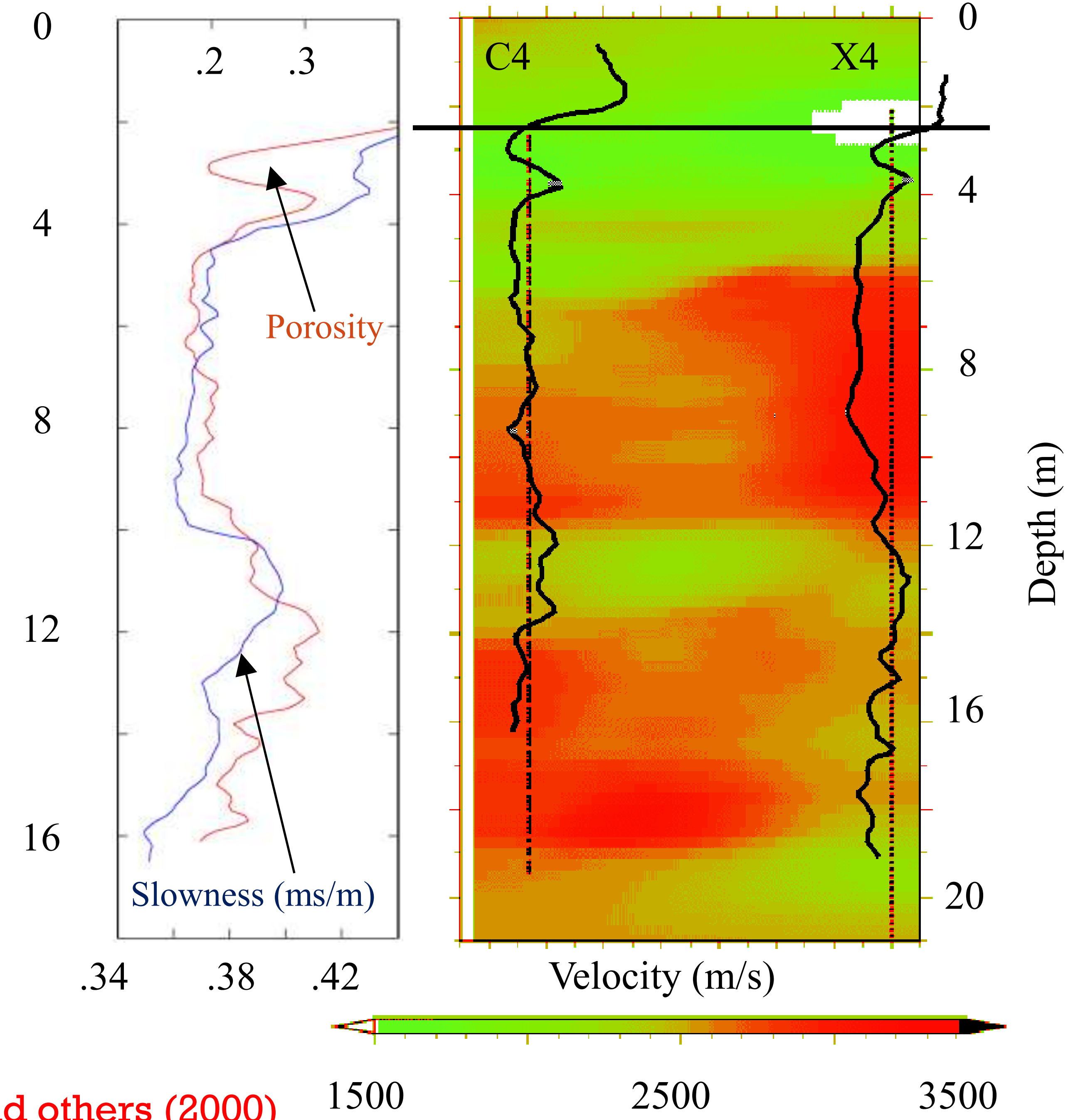
From Prassad, 2004



BOISE HYDROGEOPHYSICAL RESEARCH SITE (BHRS)

- Coarse-grained cobble-and-sand aquifer.
- Seismic velocity is tied to porosity for sands



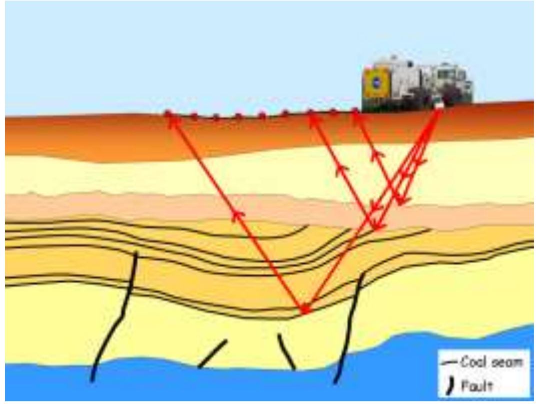


Liberty and others (2000)

SEISMIC SOURCES/RECEIVERS

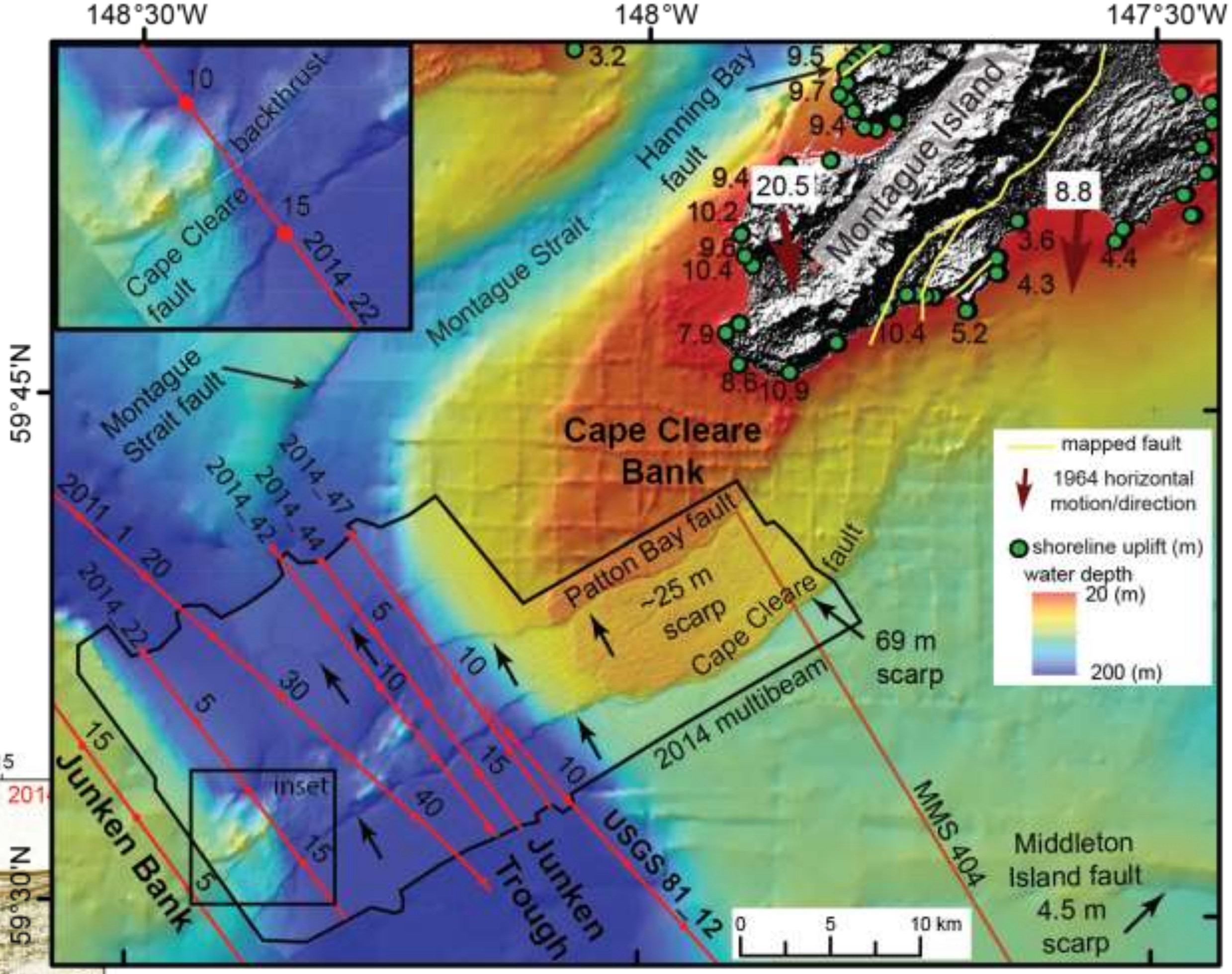
- Active Source
  - Hammer
  - Explosion
  - Vibroseis
  - Marine air gun
- Passive Source
  - Earthquakes
  - Fluid flow
  - Traffic

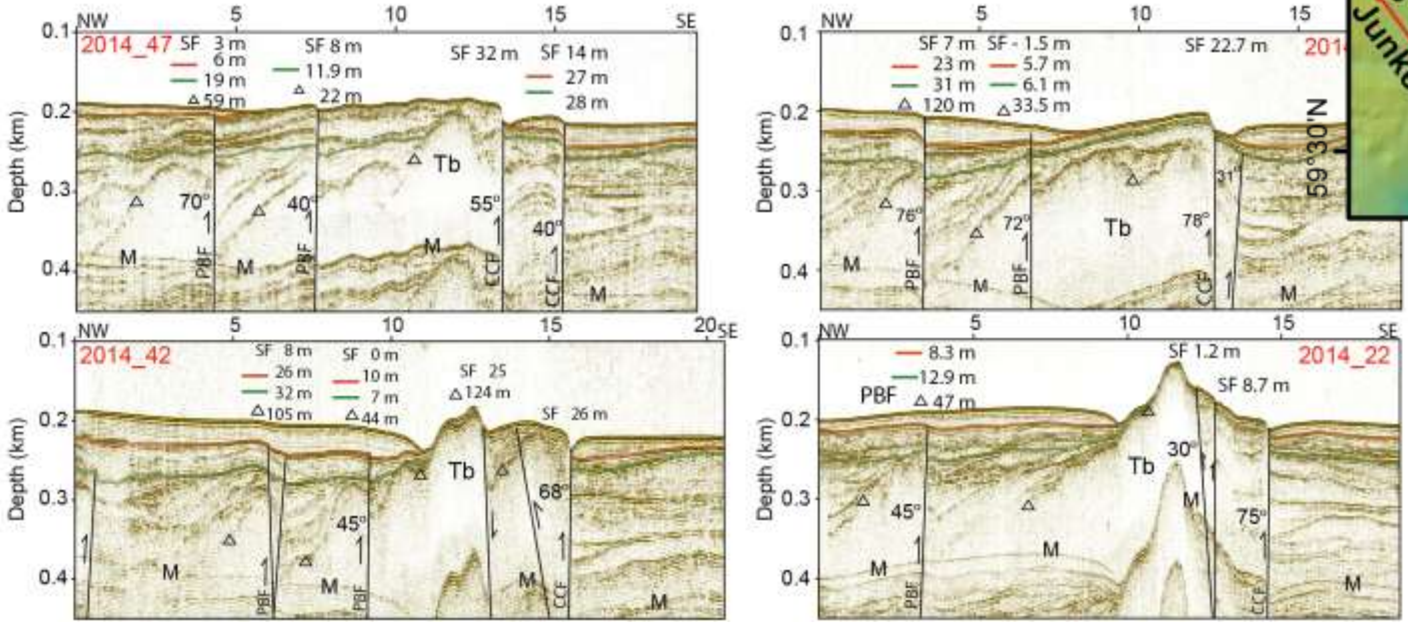
- Passive Source
  - Earthquakes
  - Fluid flow
  - Traffic



- Ground motion sensors
  - Geophones
  - Hydrophones/pressure transducer
  - Seismometers
  - Slinky spring w/ a weight
  - Bowling ball w a car spring
- Recorders
  - Seismographs
  - Chart recorders
  - Sound card in a pc

HOW DO WE COLLECT MARINE STYLE SEISMIC DATA ON LAND?



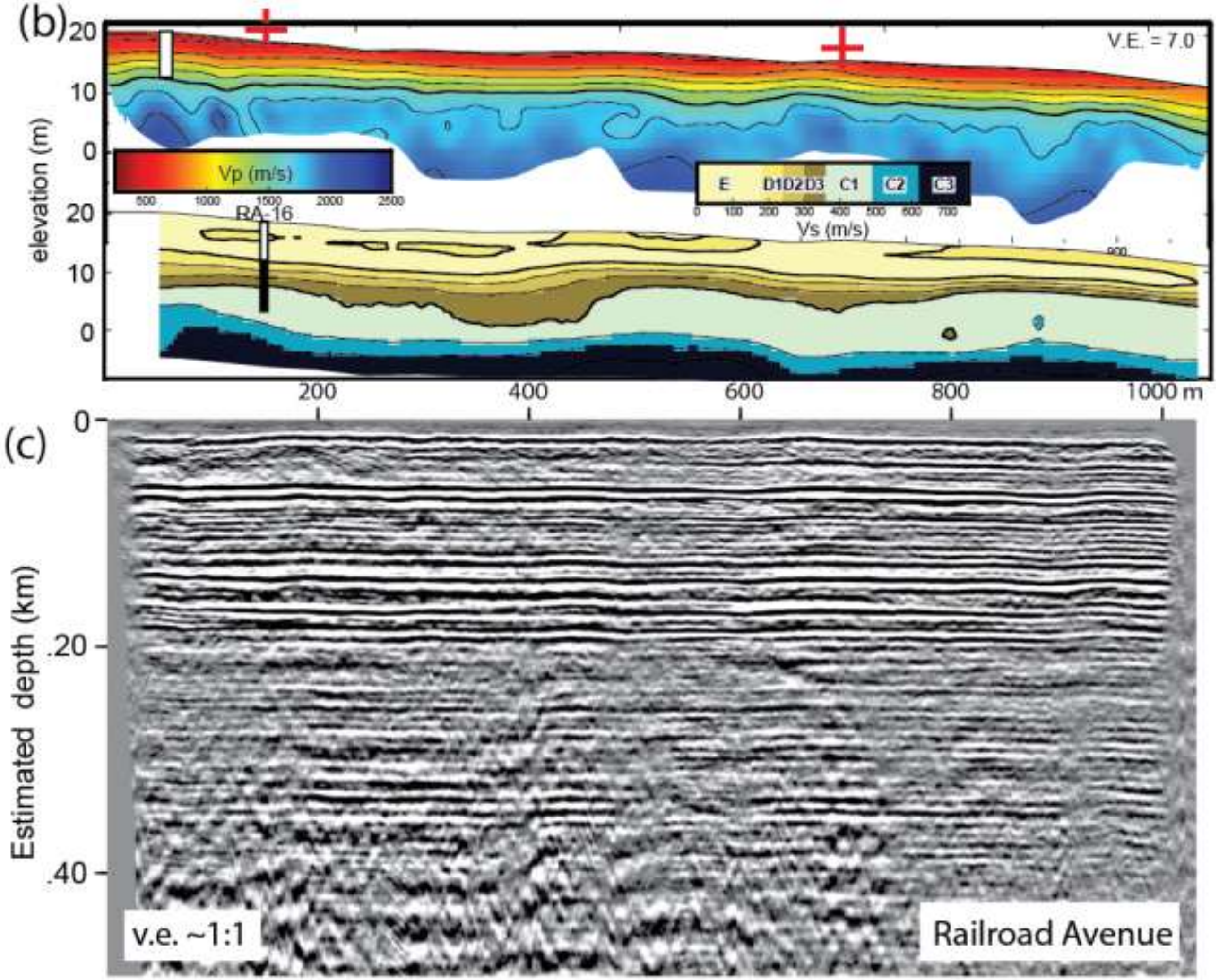


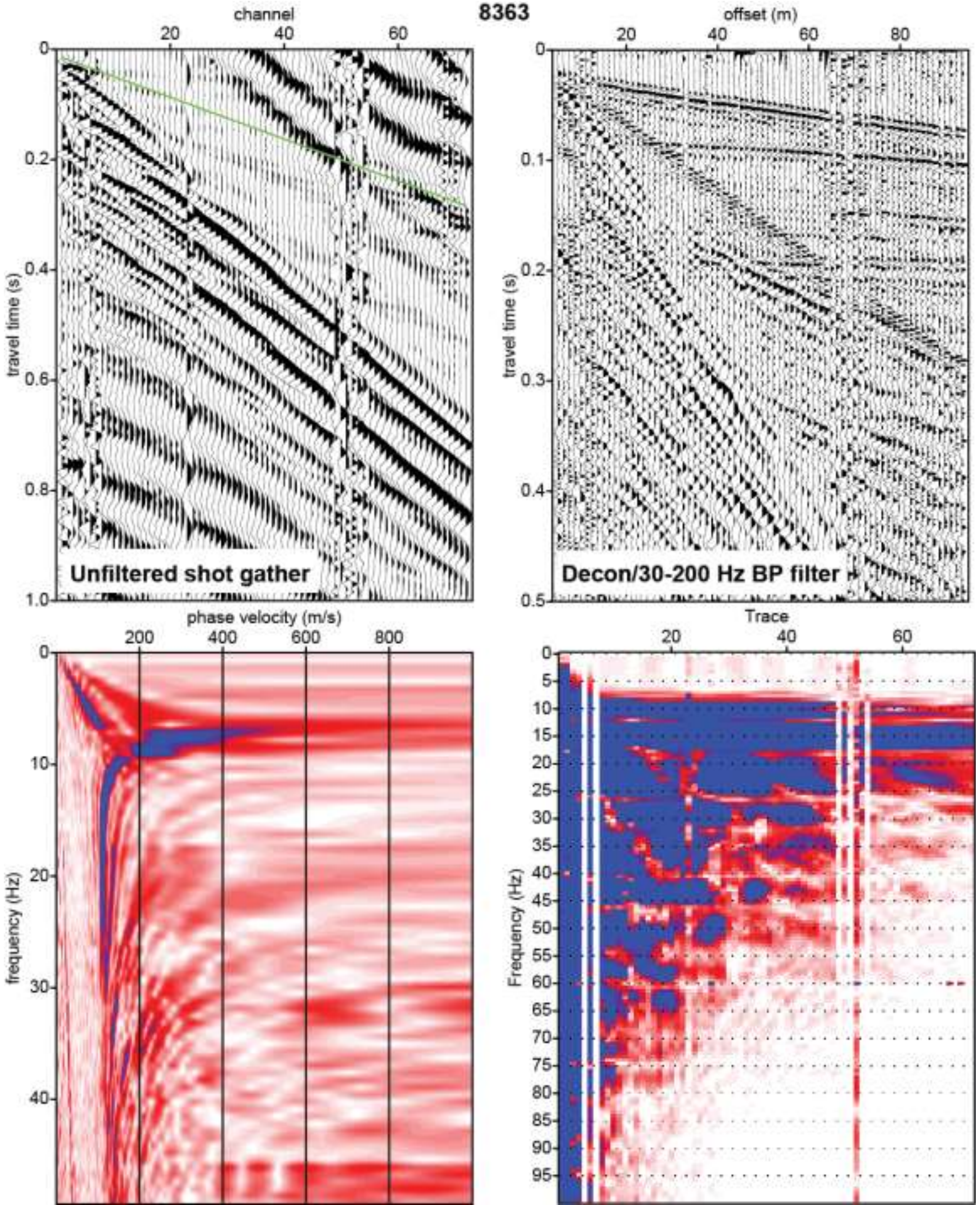
Liberty, Brothers, and Haeussler (accepted) - GRL

SEISMIC LAND STREAMER & WEIGHT DROP SYSTEM

- Rapid data collection – 4-5 km/day (@ 2m spacing)
- Minimal field crew – one person operation of all data collection operations (seismograph, weight drop source, GPS, source/receiver positioning, vehicle positioning)
- Directly operate on city streets without damage and to minimize traffic flow disruptions
- Predictable source/receiver geometry simplifies data processing (similar to marine seismic processing)
- Real time GPS positioning/integration of Lidar data
- Uniform physical properties of road and sub road reduces static effects from near surface heterogeneities
- Police or flagger assistance to control traffic - near continuous profiling
- Large seismic source relative to imaging depths allows for traffic noise during data collection

LAND STREAMER DATA



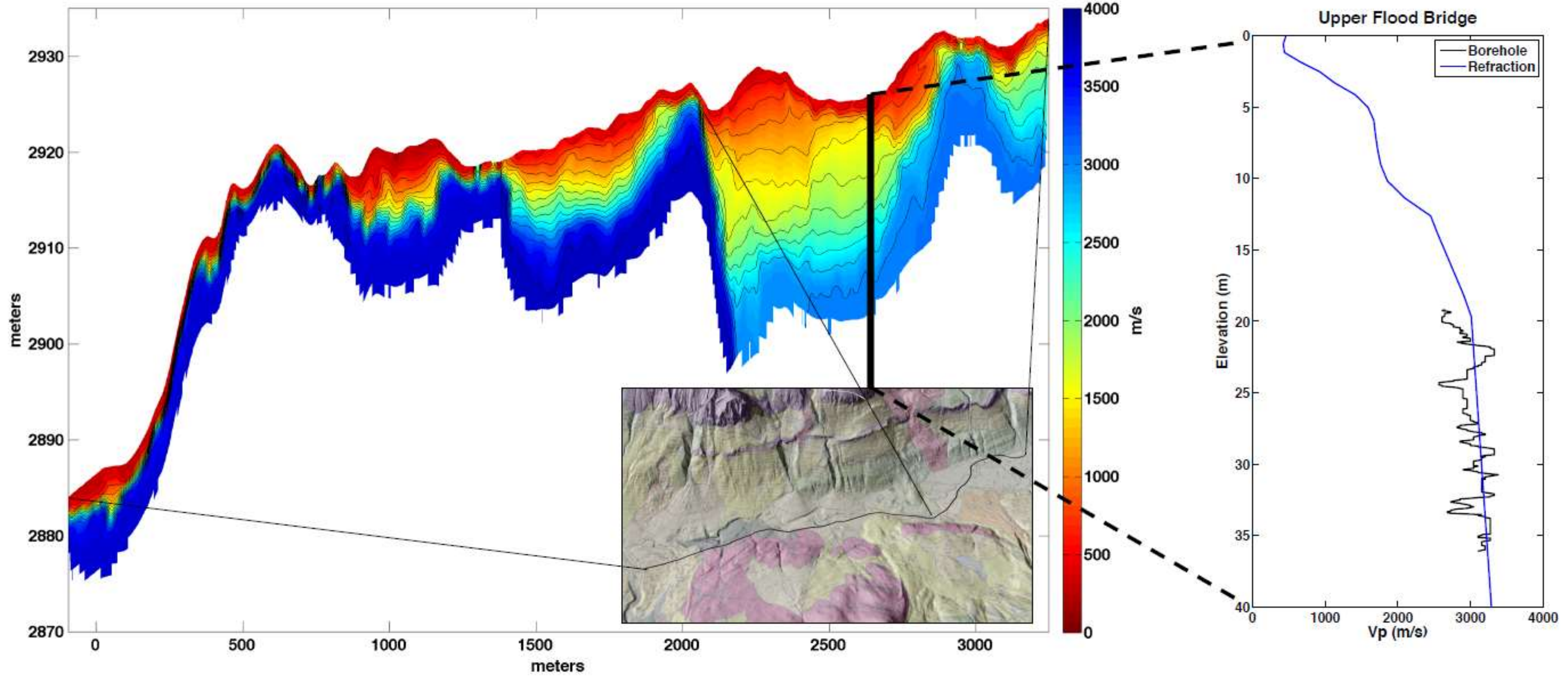


Liberty (2018 NEHRP report)

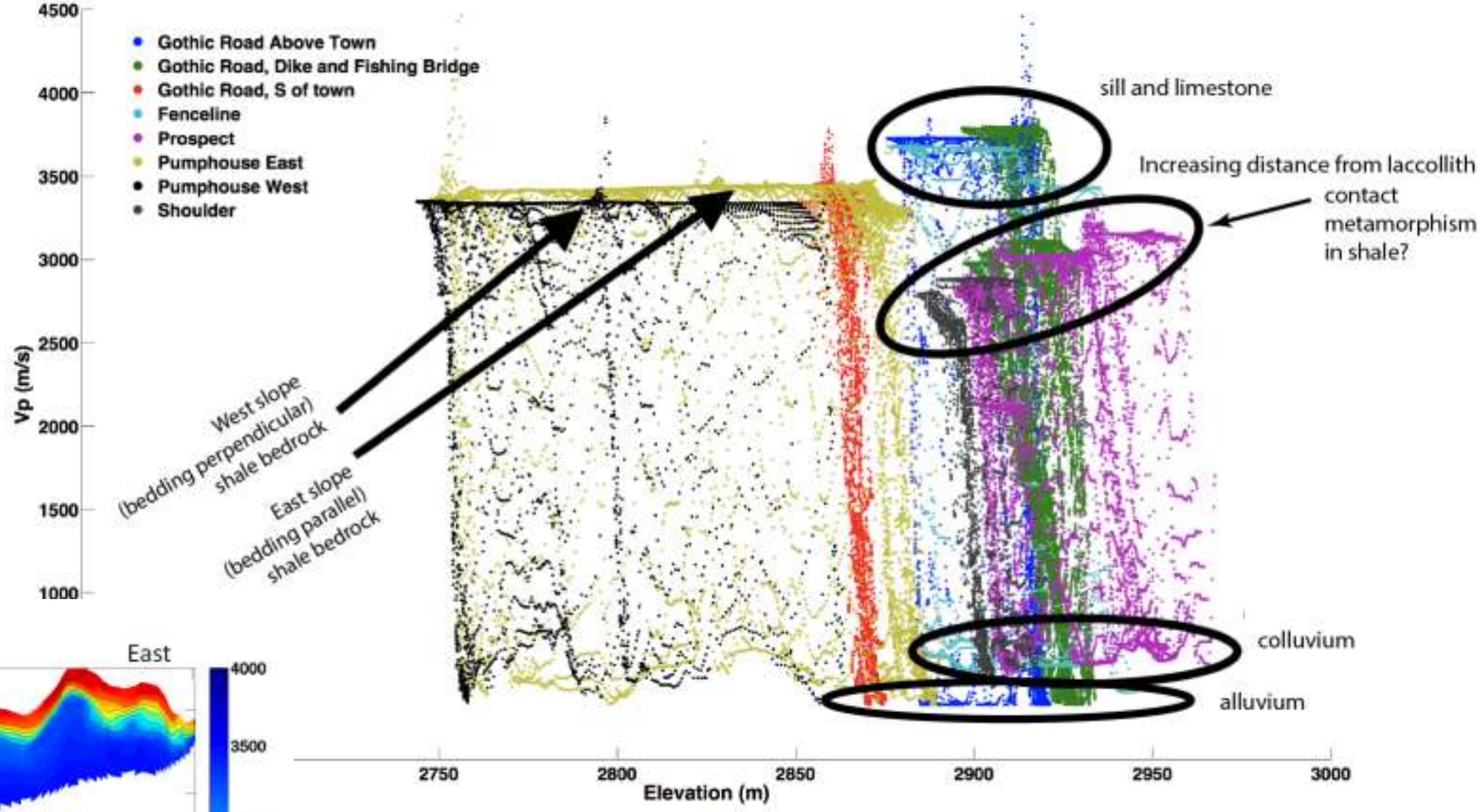
CRESTED BUTTE: EAST RIVER SEISMIC CAMPAIGN

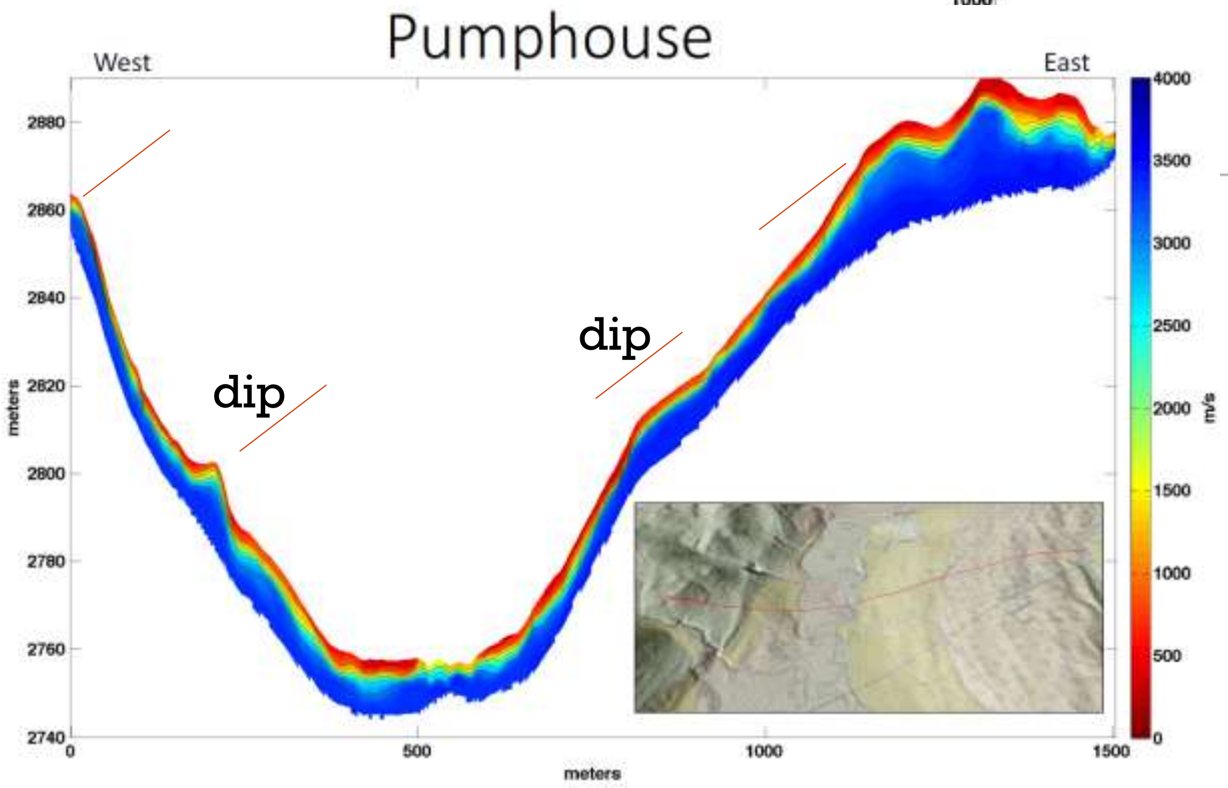
FIRST ARRIVAL TOMOGRAPHY

Gothic to Upper Flood Plain



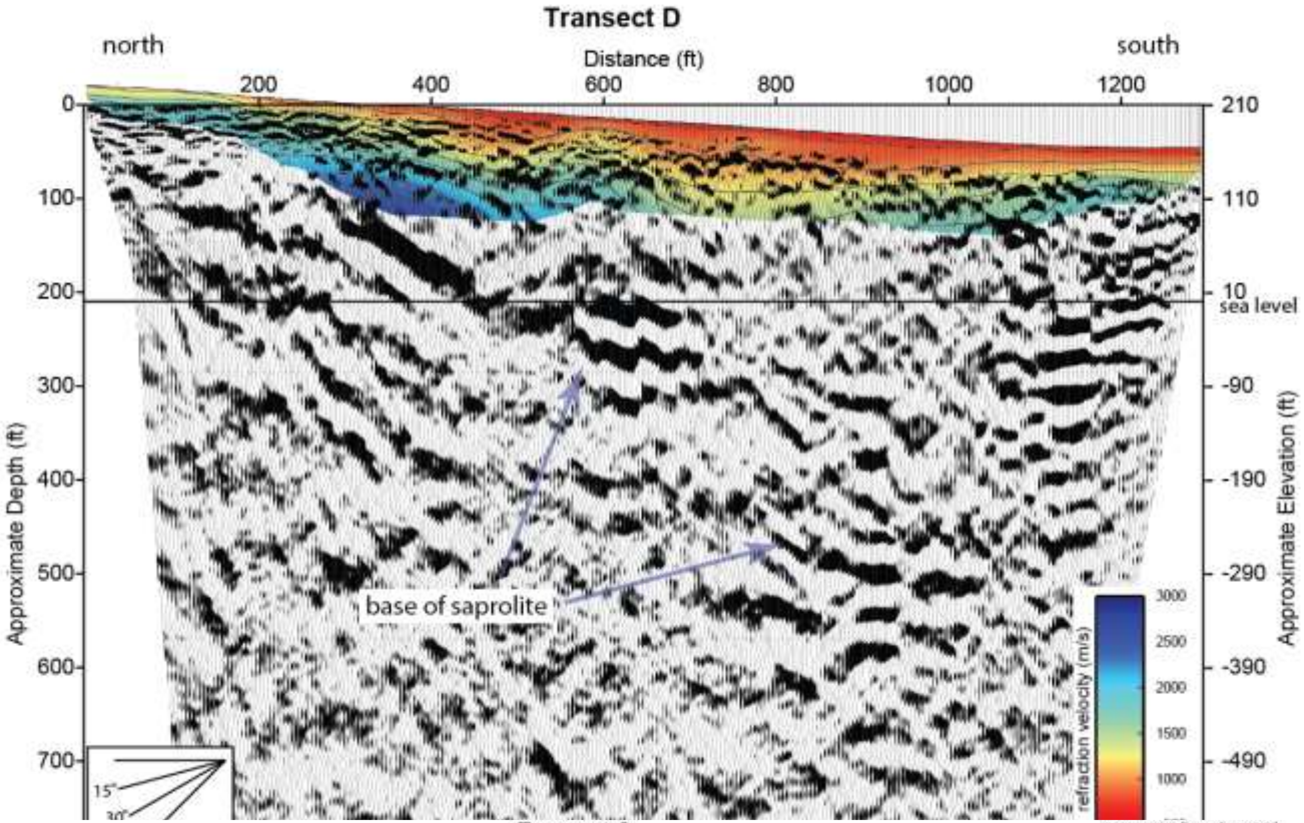
VP TO MAP BEDROCK PROPERTIES

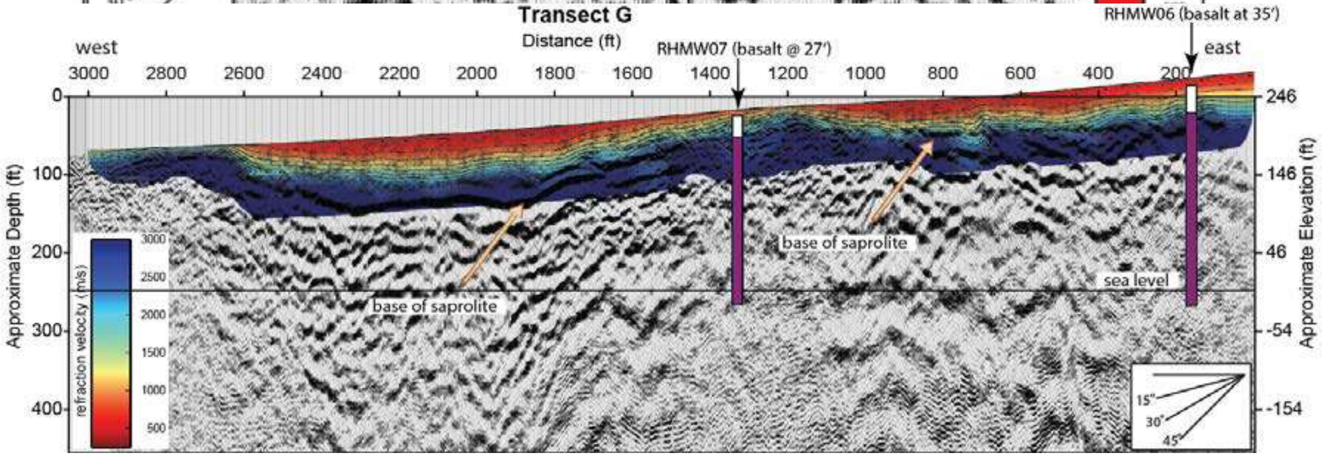


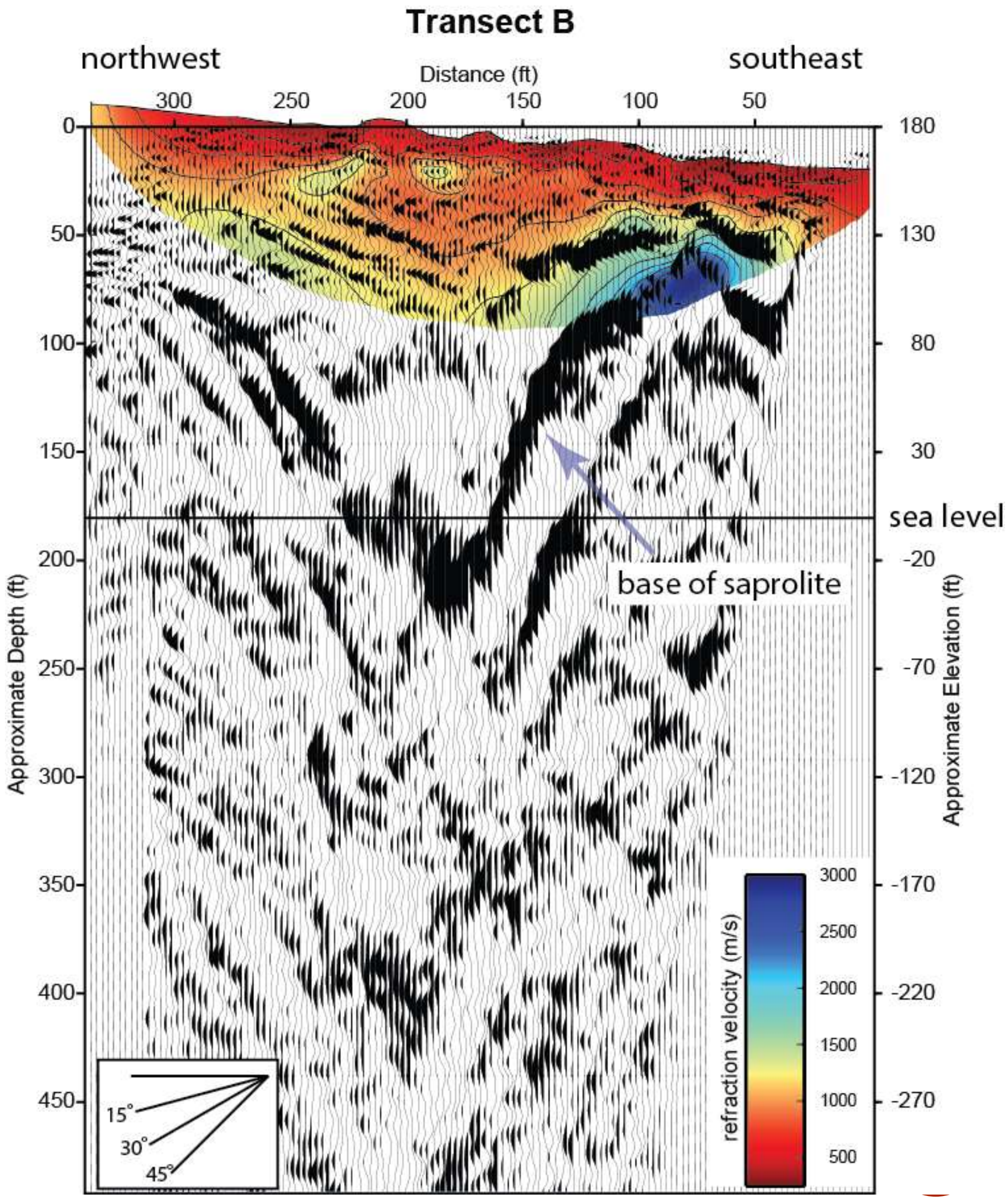


Velocities derived from first arrival tomography

REGOLITH DEVELOPMENT IN HAWAII VIA SEISMIC STREAMER

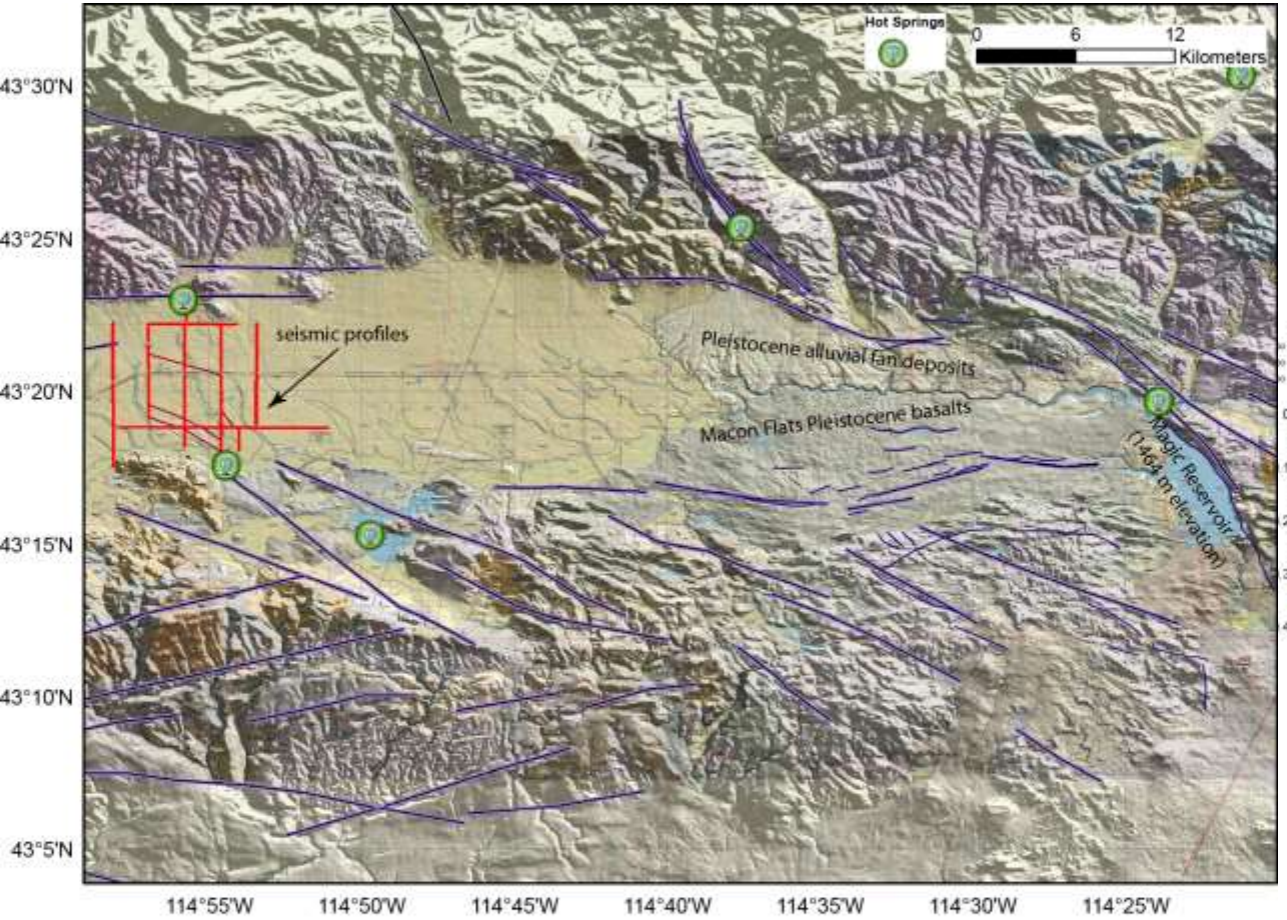


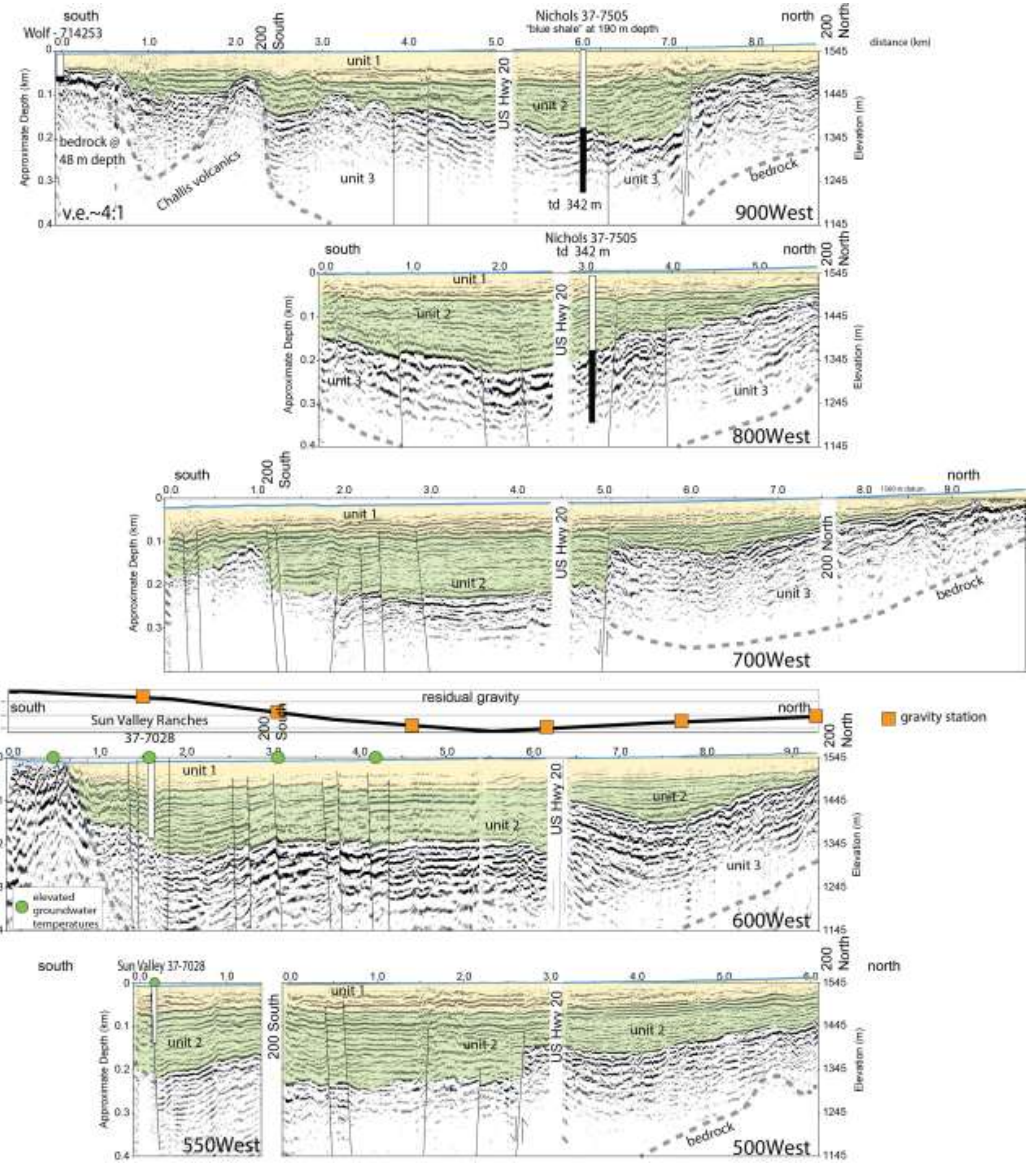




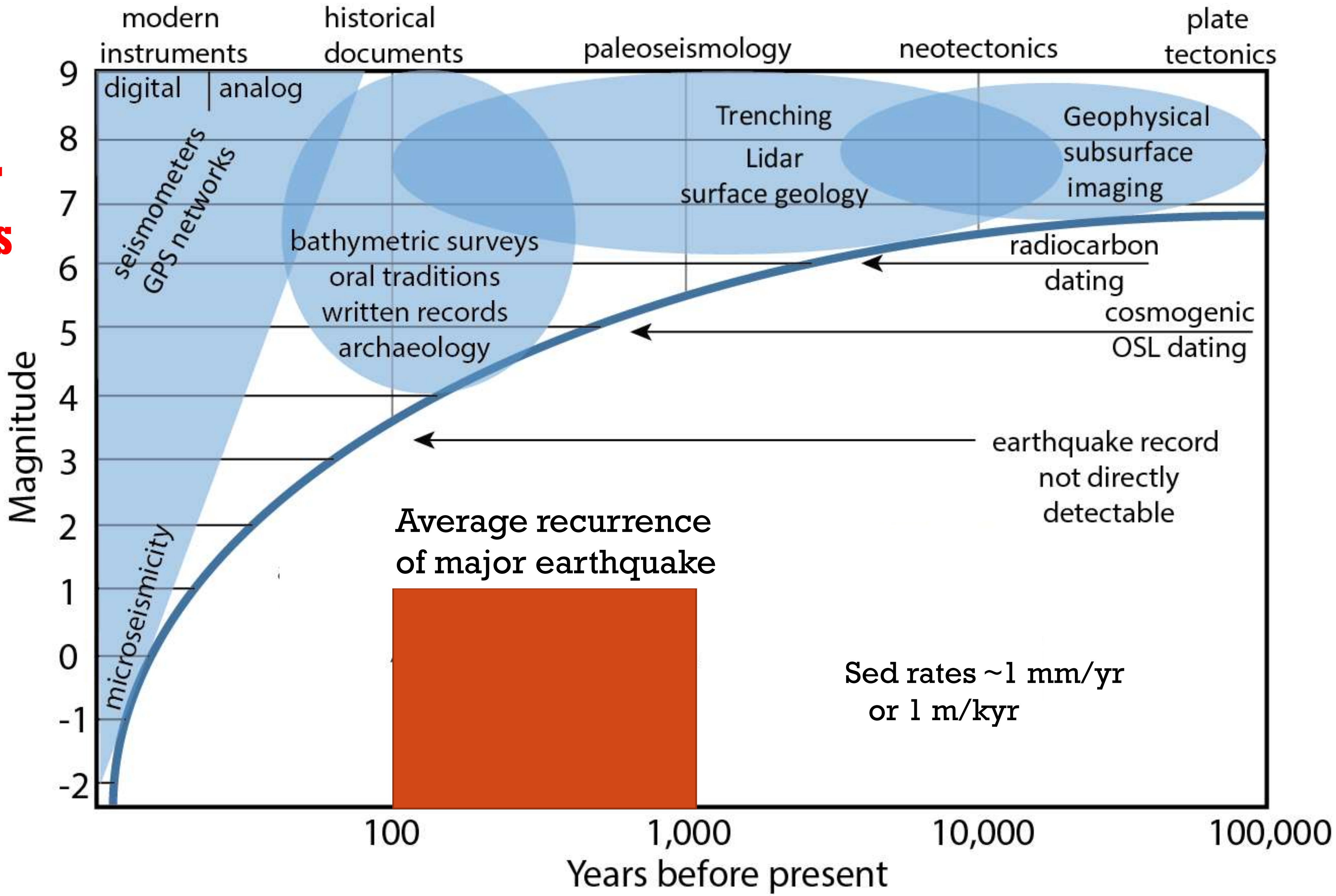
CAMAS PRAIRIE, IDAHO

55 km of seismic reflection data in 11 days
Stratigraphic and structural characterization of a hot-spot initiated graben
where to site a geothermal well





Seismic imaging for neotectonics



SEISMIC LAND STREAMER RESULTS HIGHLIGHT HIGH EARTHQUAKE RISKS FOR THE SALT LAKE CITY URBAN CENTER

- **L.M. Liberty[1], J. St. Clair[1], G. Gribler [1], A.P. McKean[2]**
- [1]Department of Geosciences, Boise State University.
- [2]Utah Geological Survey, Salt Lake City, Utah.
- Corresponding author: Lee Liberty (lliberty@boisestate.edu)

- **Key Points:**
- A zone of earthquake-induced liquefaction and faulting link strands of the Wasatch fault beneath Salt Lake City
- High liquefaction and site amplification potential raises the hazard by reducing earthquake magnitude where damage may occur
- Seismic land streamers are a new tool to identify and characterize soil, rock and fluid properties for urban hazard assessments

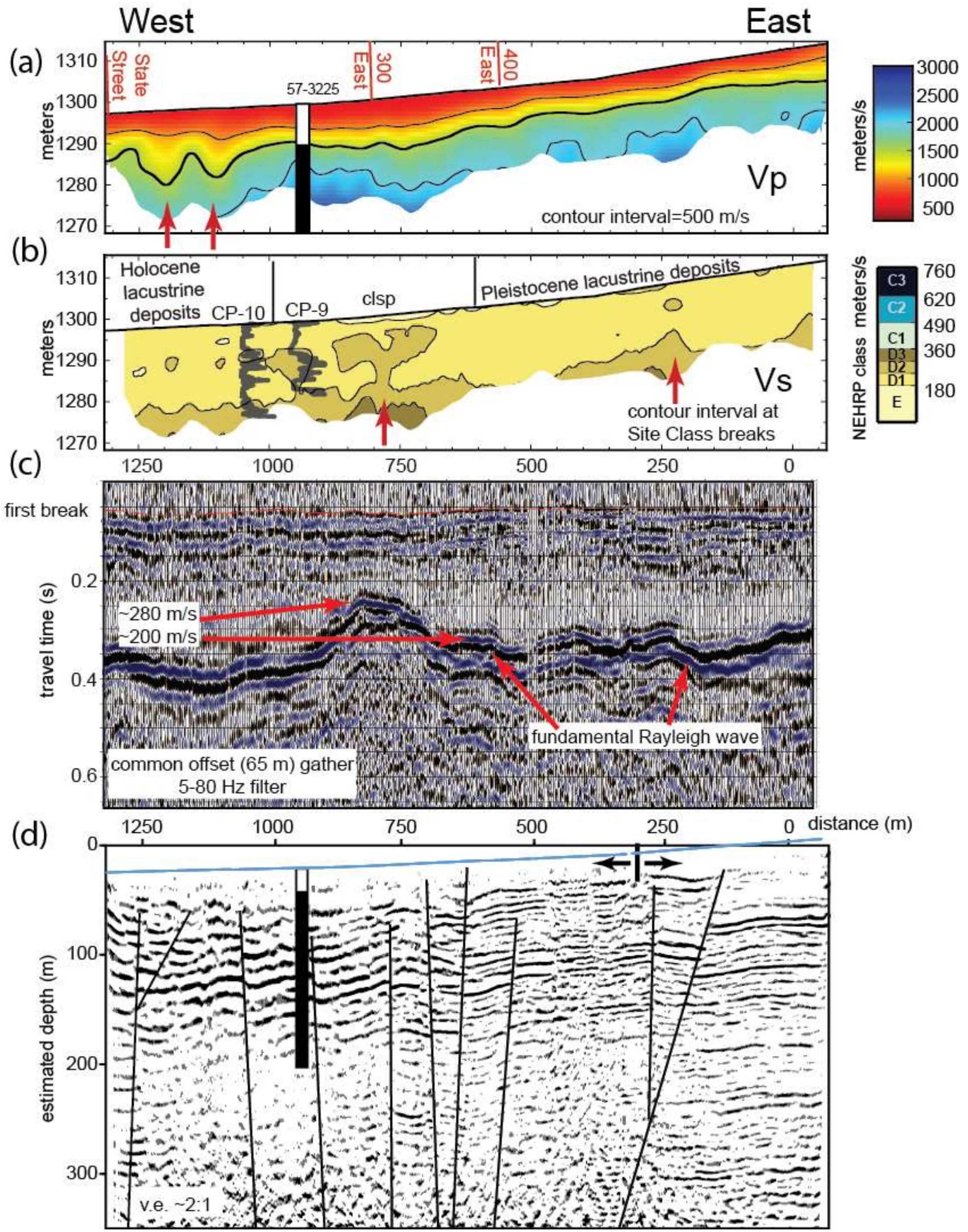
LAND STREAMER DATA – 500 SOUTH

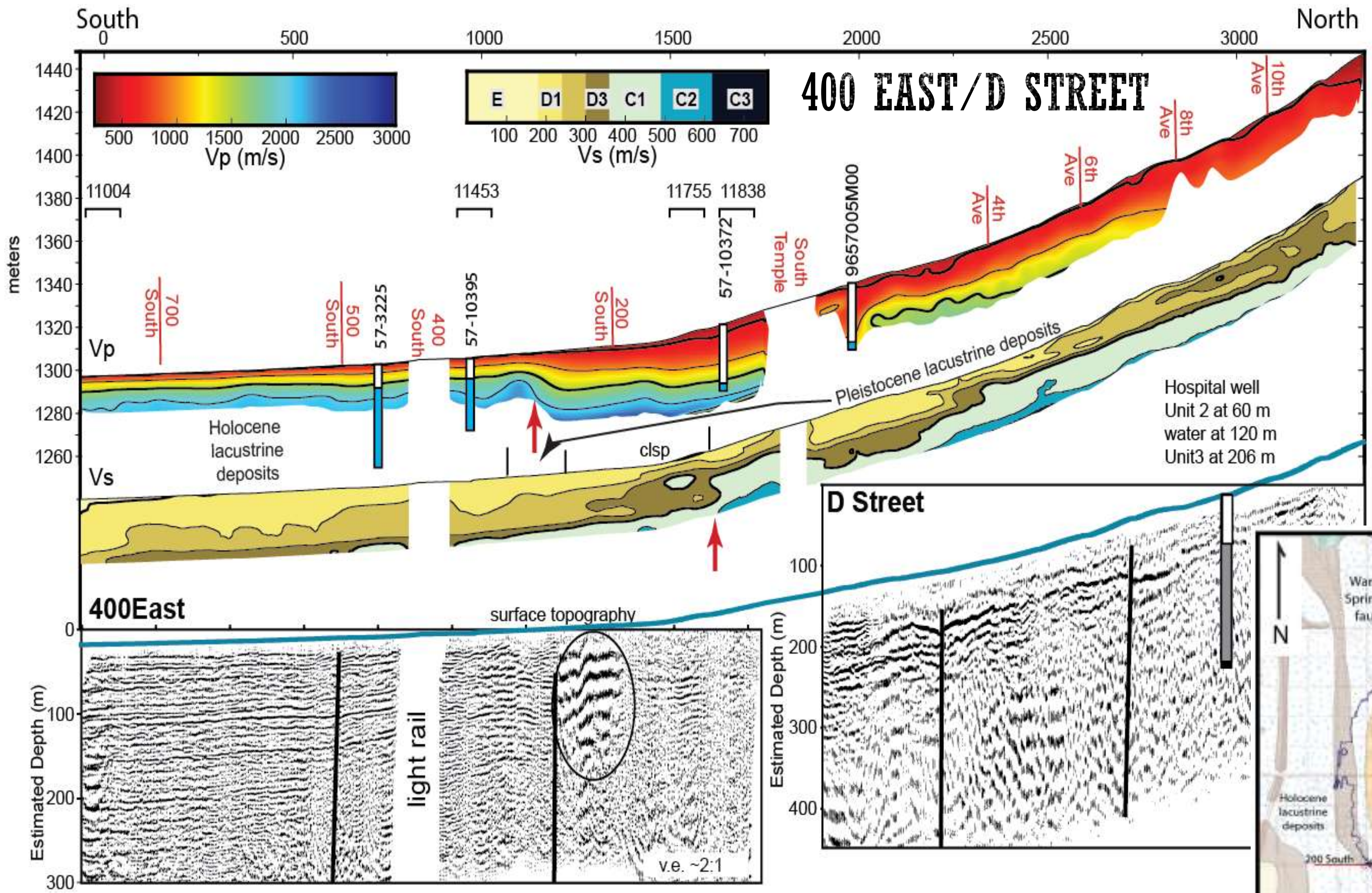
- Vp shows a near constant water table depth (1,500 m/s) along all but the western portions of the profile.

- Vs shows mostly Class D1 soils (180-240 m/s) for upper 20 m. Class D2 soils are measured at greater depths.
- A zone of shallow Vs>240 m/s is coincident with mapped lateral spread.

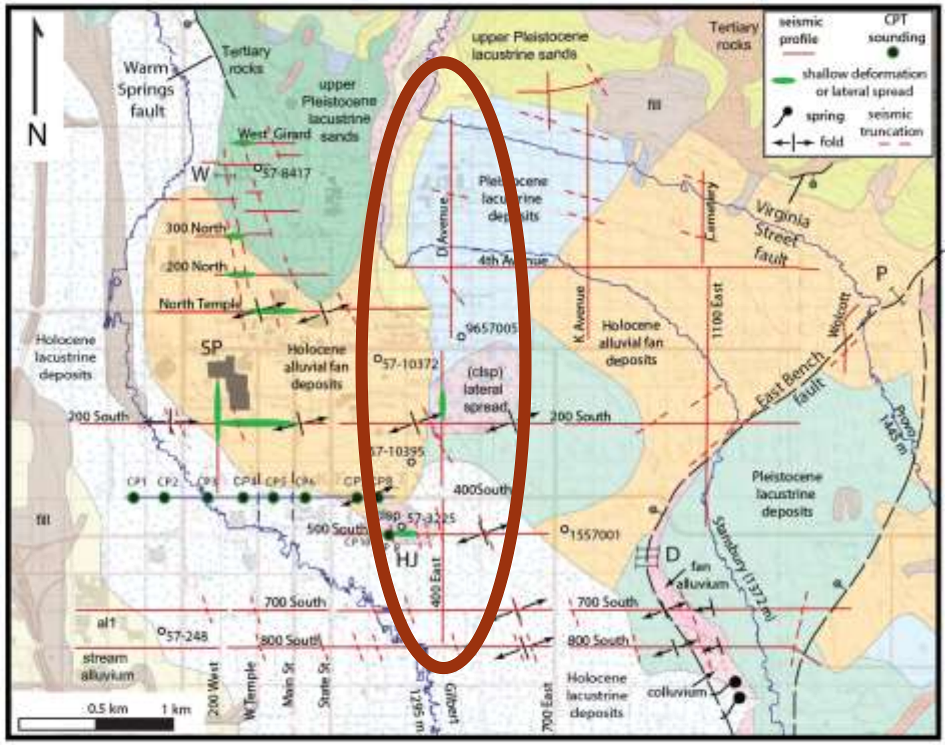
- Common offset field records clearly show that fast Rayleigh wave speeds relate to mapped lateral spread

- Mostly west-dipping (Lake Bonneville) reflectors showing lateral reflector truncations that is consistent with faulting.
- Change in reflection frequency coincident with zone of shallow heterogeneities.





- Vp shows prominent step in water table near 200/300 South
- Low Vp at high elevations relates to fan alluvium or older lake seds
- Class E soils transitions to Class C/D soils
- Stiff (Class D) soils near Salt Palace may represent lateral spread.

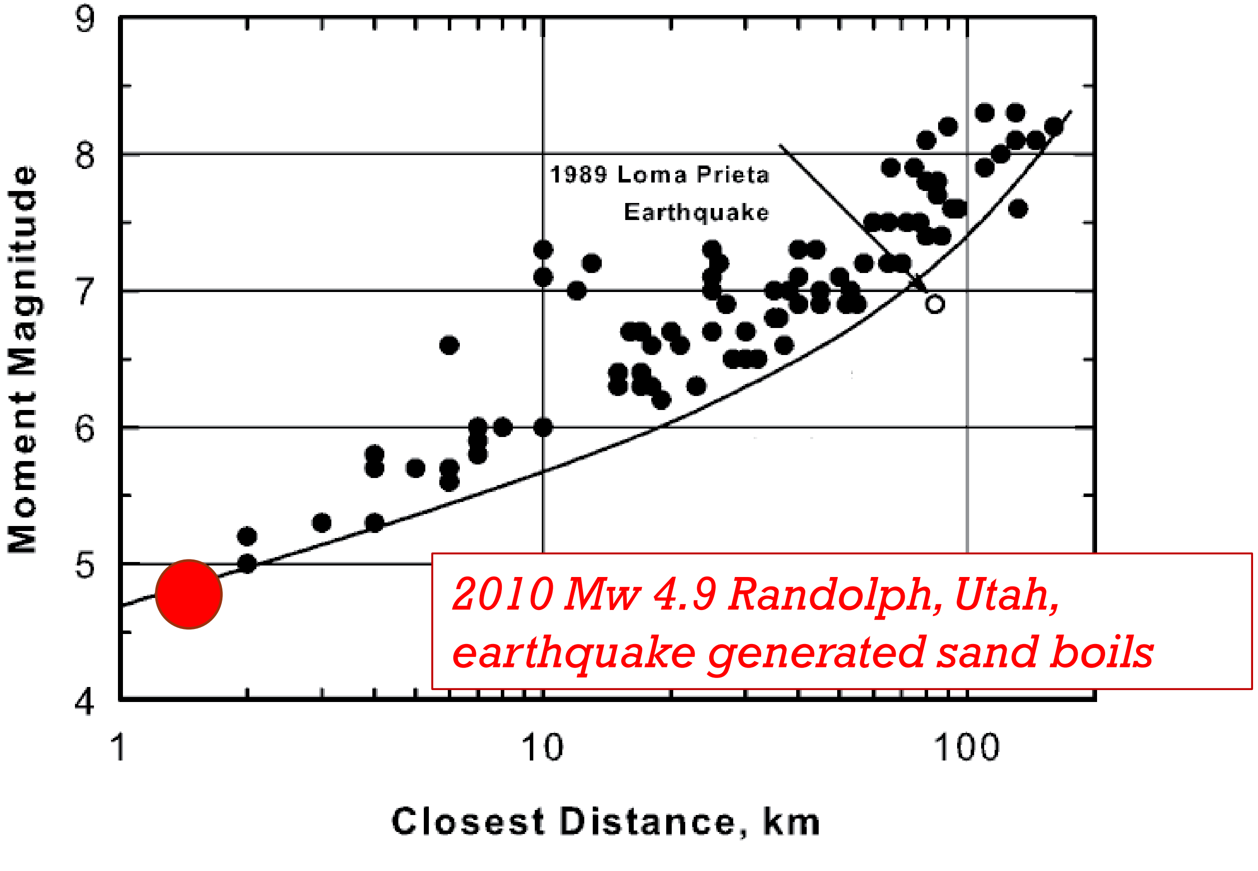


- Axial surface near 500 South
- Truncated reflectors near 200 South
- Water table reverberations near 200 South

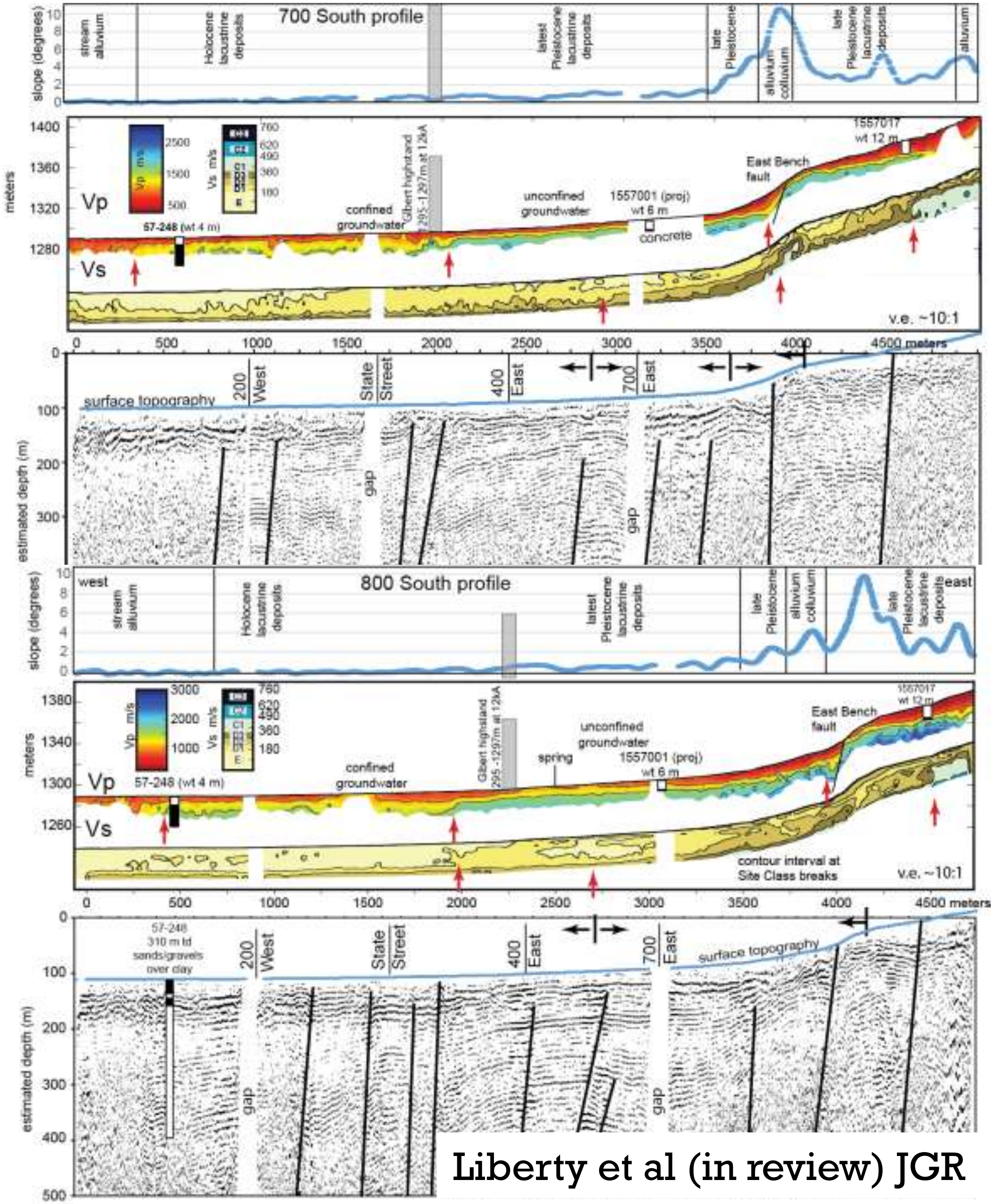
500 SOUTH PROFILE

Active faults + Liquefaction susceptible

- Reflection results show offset (faulted) Bonneville strata
- Vp (>1,500 m/s) maps shallow water table
- Vs < 240 m/s in upper 10 m



Predicted maximum distance to liquefaction versus moment magnitude (Ambraseys, 1988)



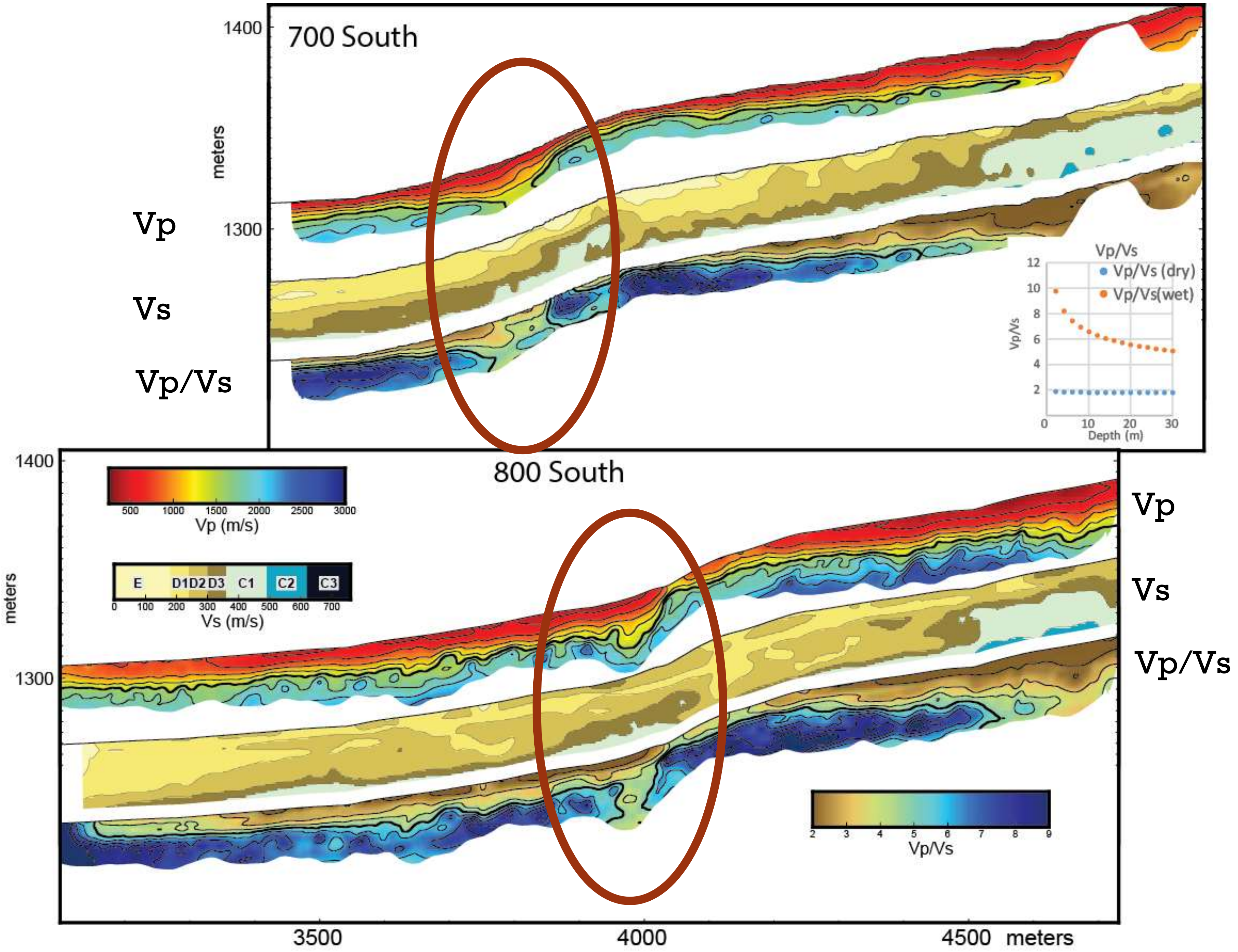
Liberty et al (in review) JGR

EAST BENCH FAULT ZONE

Hanging wall
- Slow Vp colluvium
- Slow Vs
- Dry sediments → Vp/Vs ratio < 3

Fault
- Low Vp (dry)
- High Vs (stiff)
- Low Vp/Vs ratio
- Dry, stiff soils

Footwall
- Faster Vp,Vs
- Groundwater springs
- Increased depth to Vp >1500 m/s (dry) farther east



VS_{30} MAP FOR DOWNTOWN SLC

36 Vs measurements

McDonald and Ashland (2008)

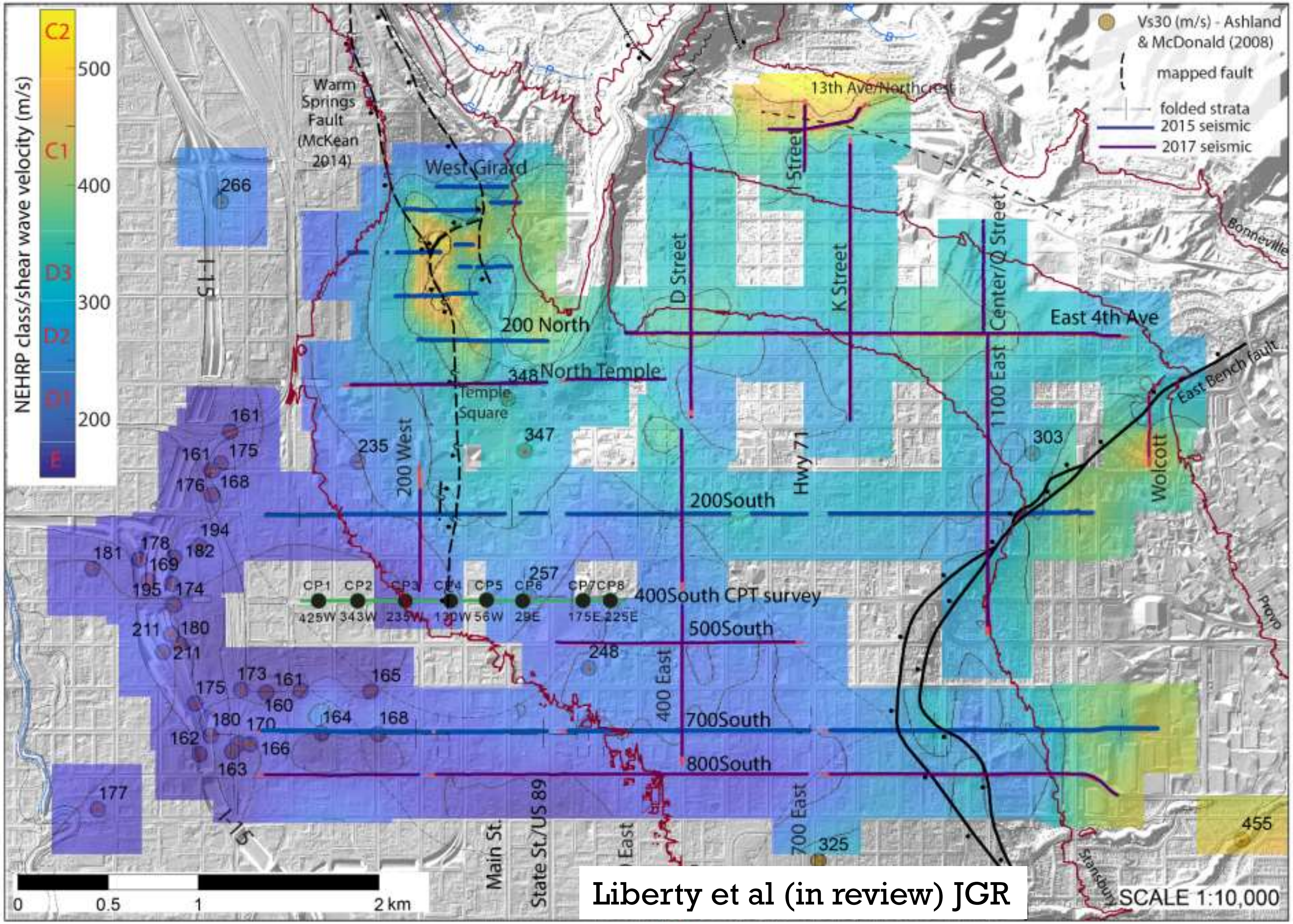
15,000 additional Vs measurements

via seismic land streamer

Low Vs for Bonneville deposits beneath western portions of downtown Salt Lake City

Increase in Vs30 from west to east

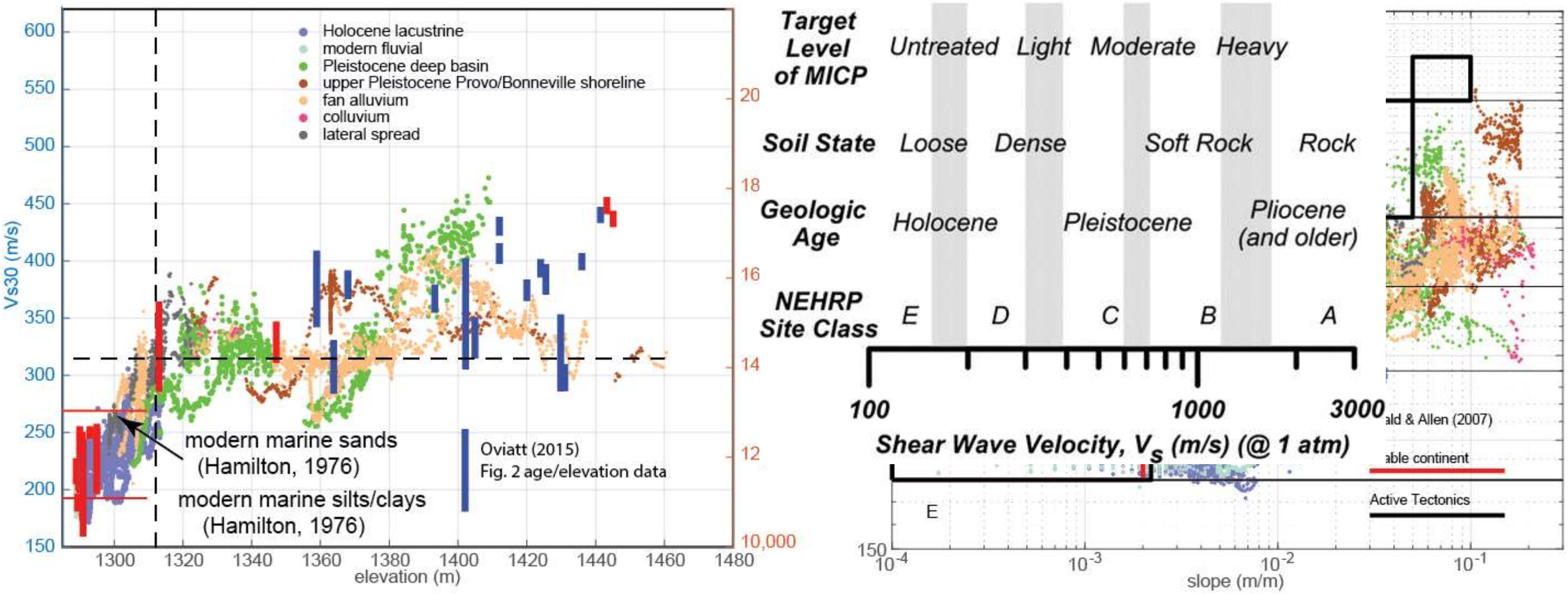
High Vs in the footwall or in fault zones



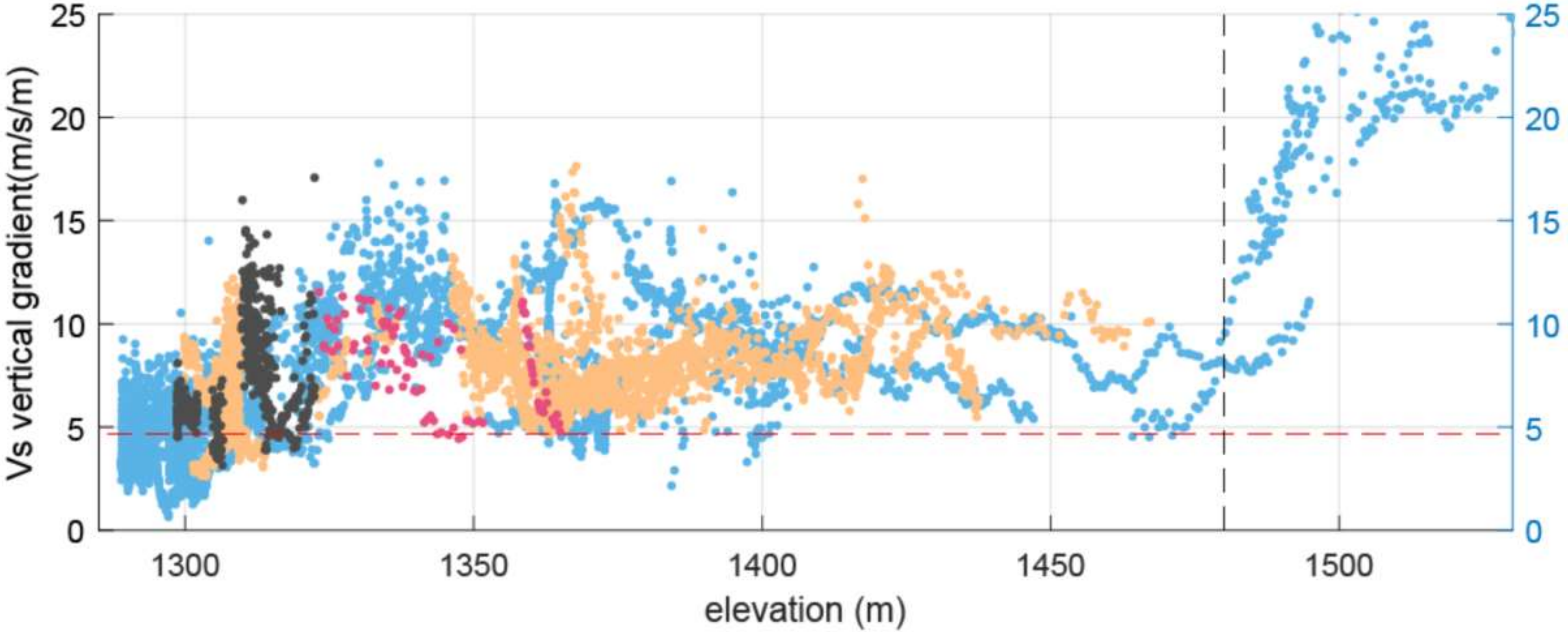
Liberty et al (in review) JGR

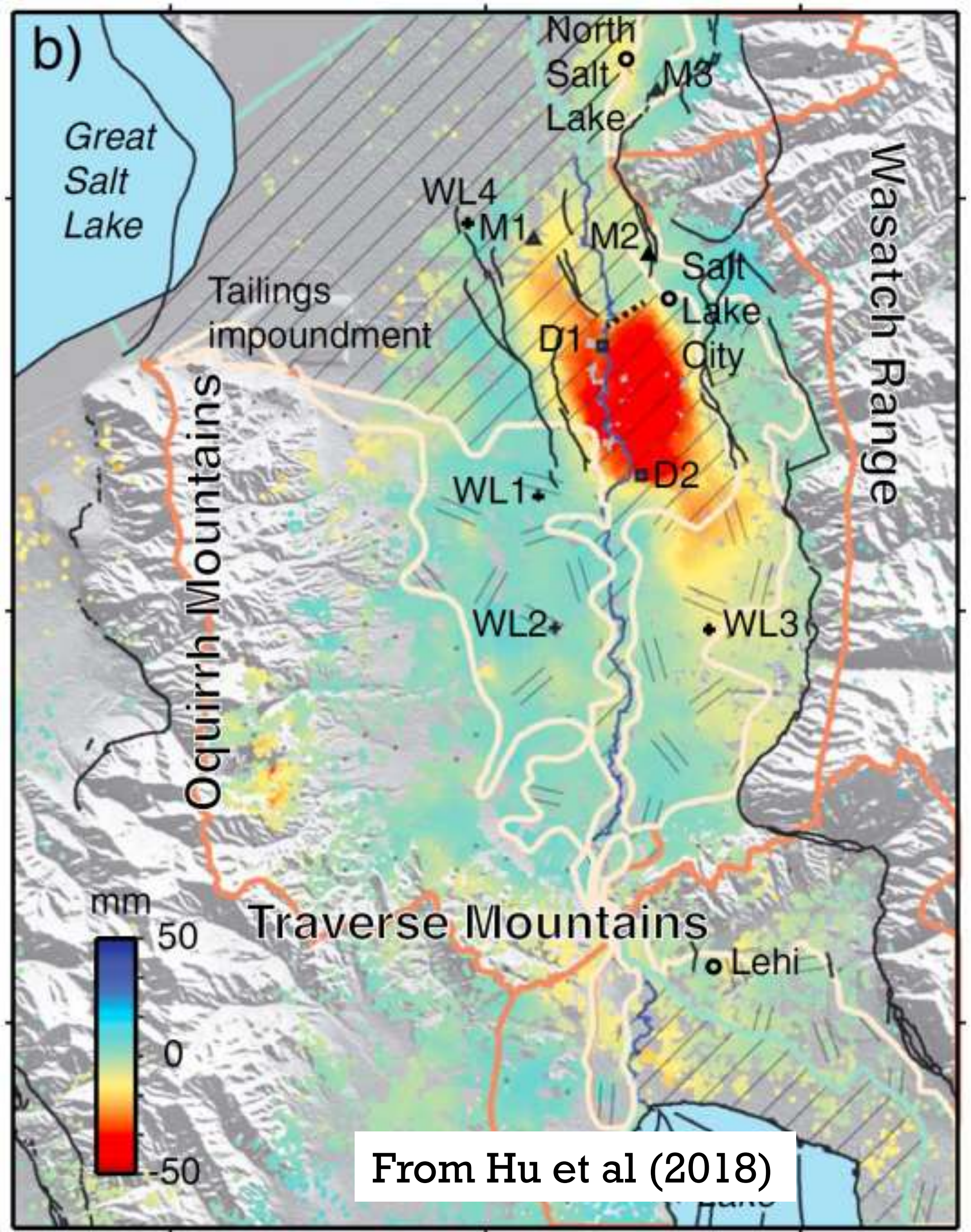
VS30 RELATIONSHIPS – TOPOGRAPHY AND SLOPE

Liberty et al, SSA 2019

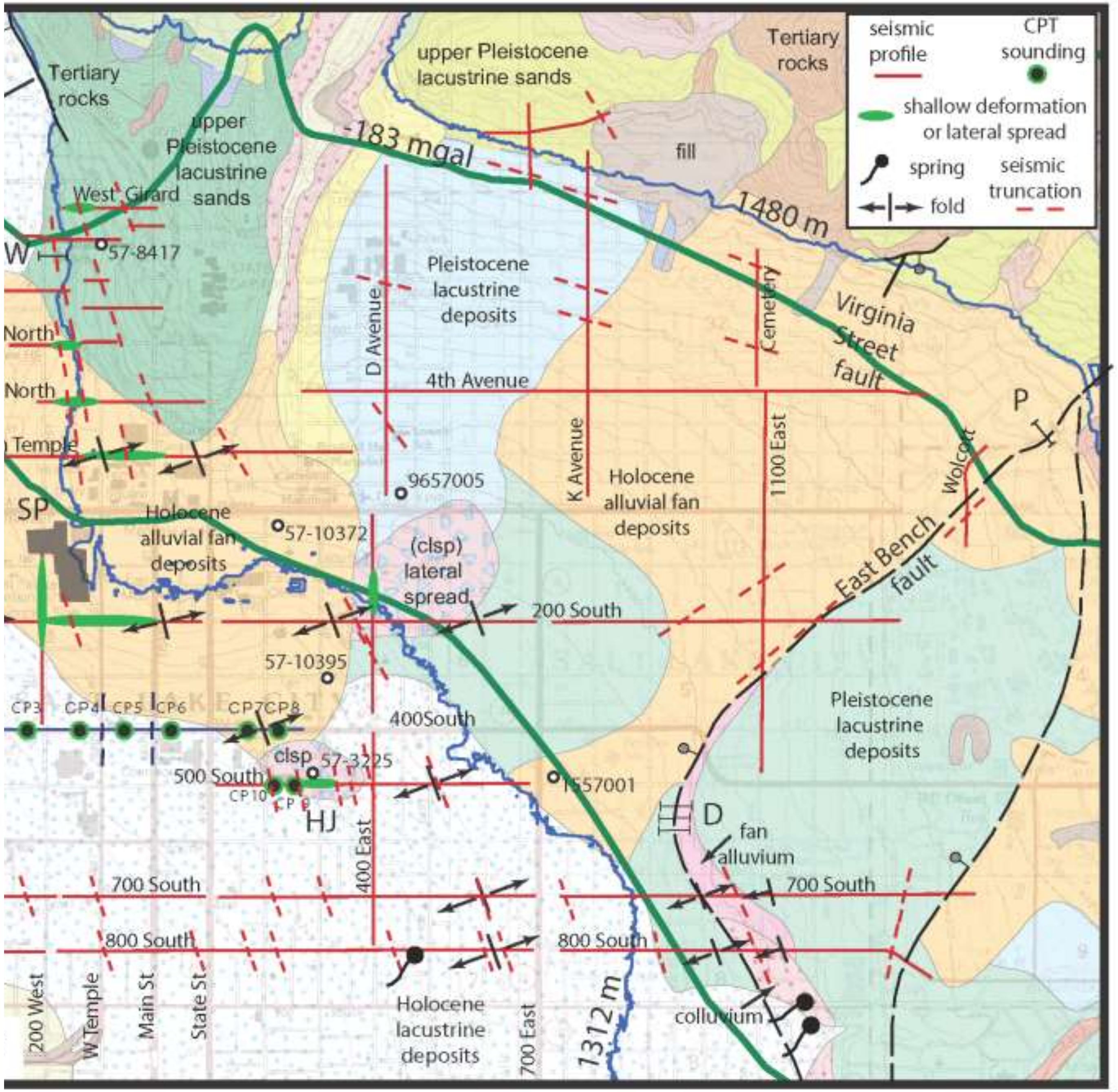


VS VERTICAL GRADIENT



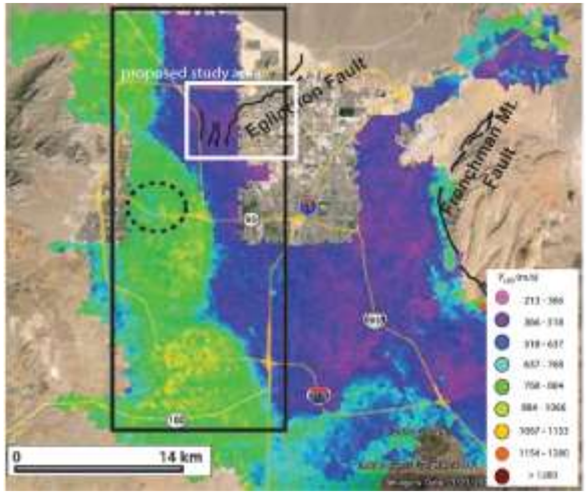


From Hu et al (2018)

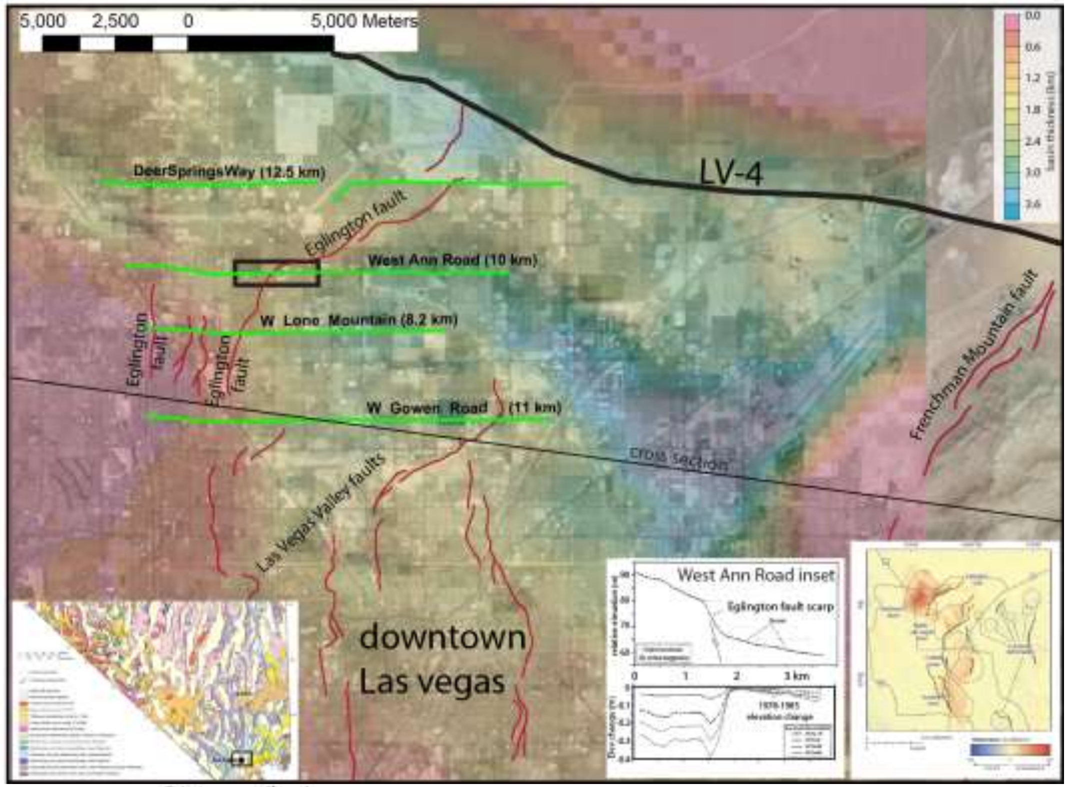


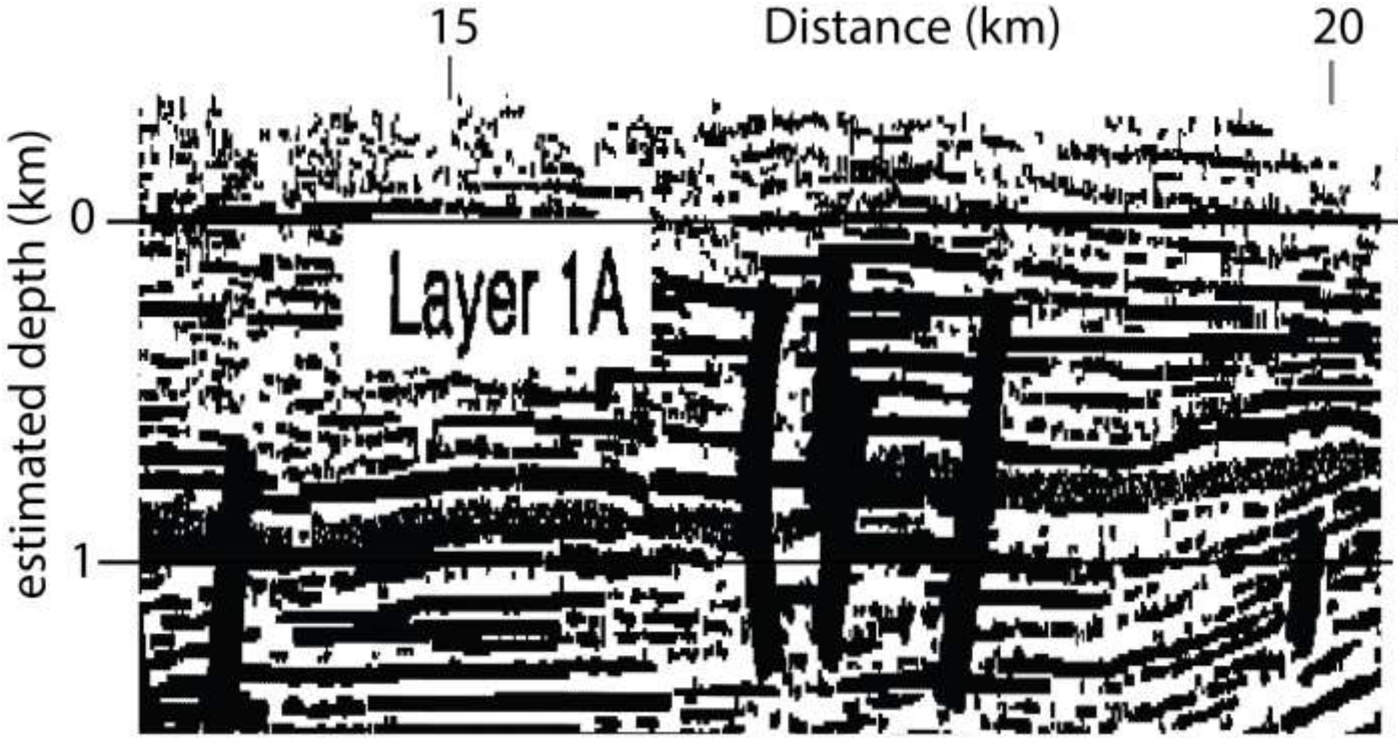
PLANNED SURVEYS

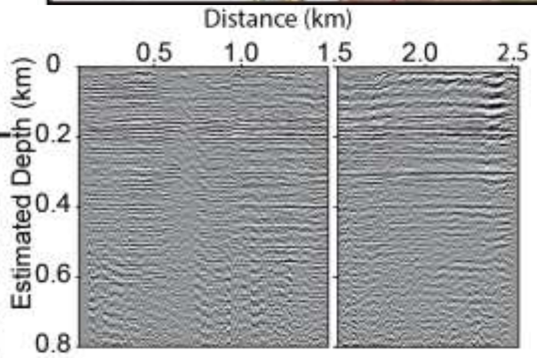
- Seismic profiling across the Eglington fault, Las Vegas, Nevada (recommended for funding from NEHRP)



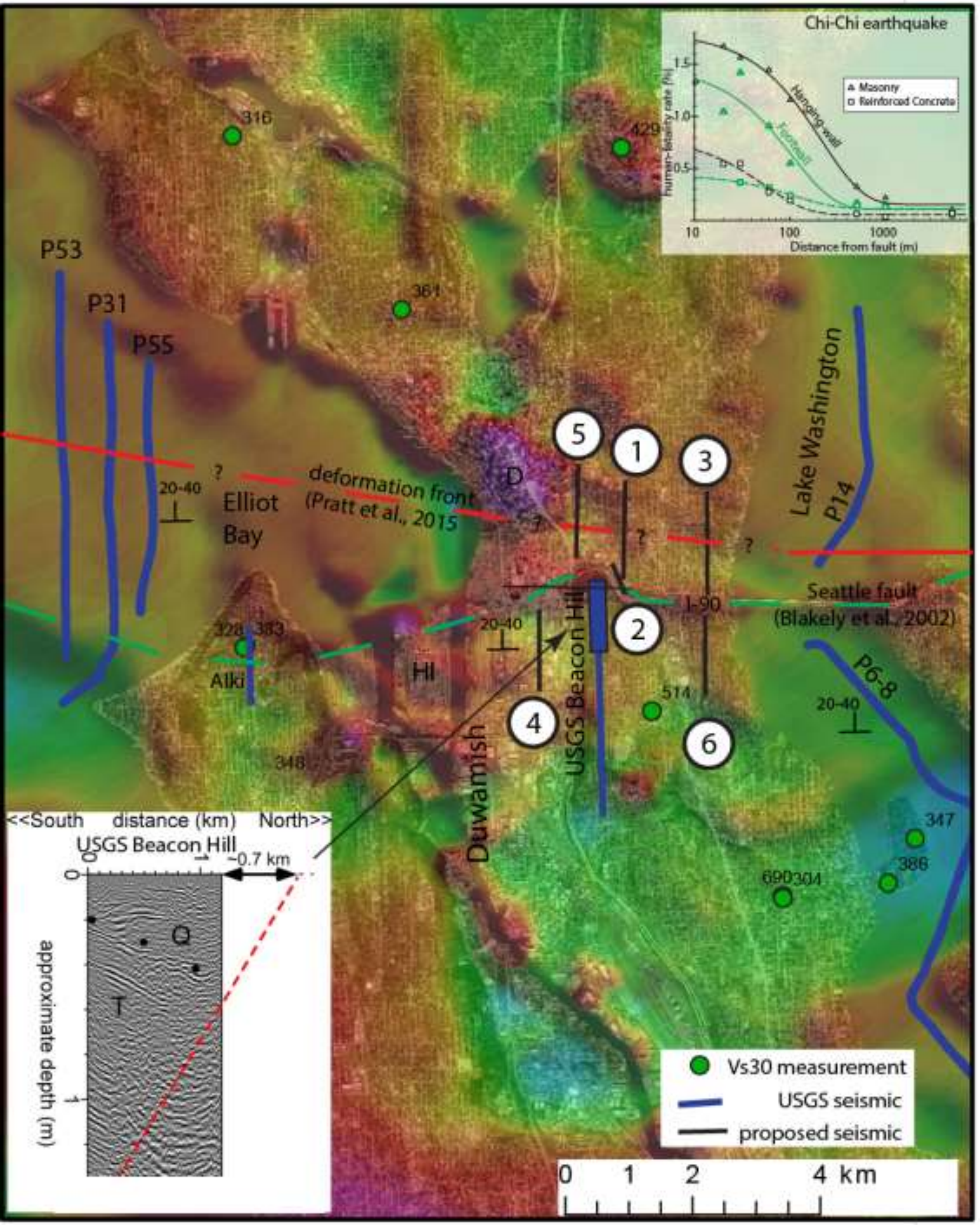
From Pancha et al (2017)





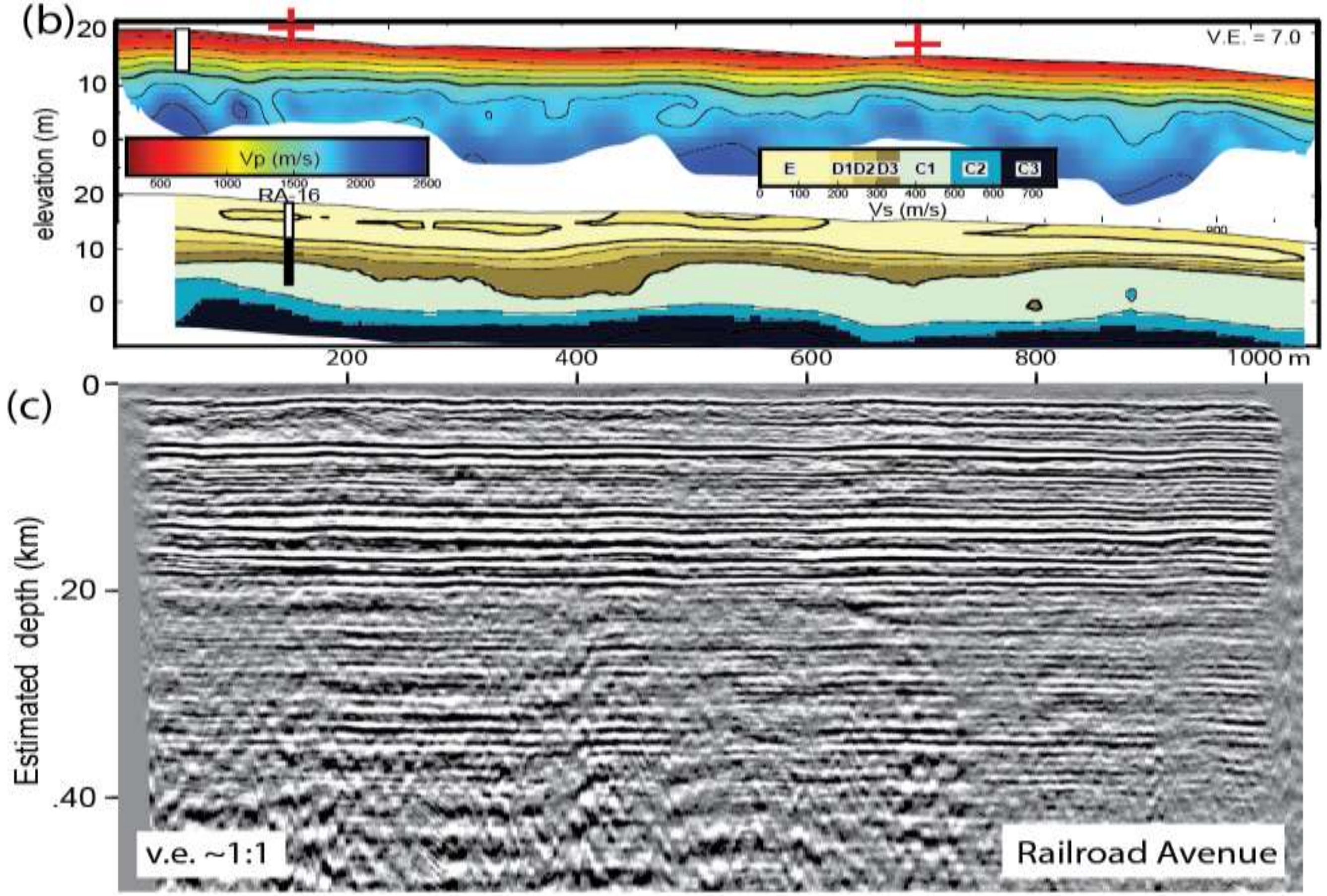


Industry seismic compared to Boise State seismic land streamer data



PLANNED SURVEYS

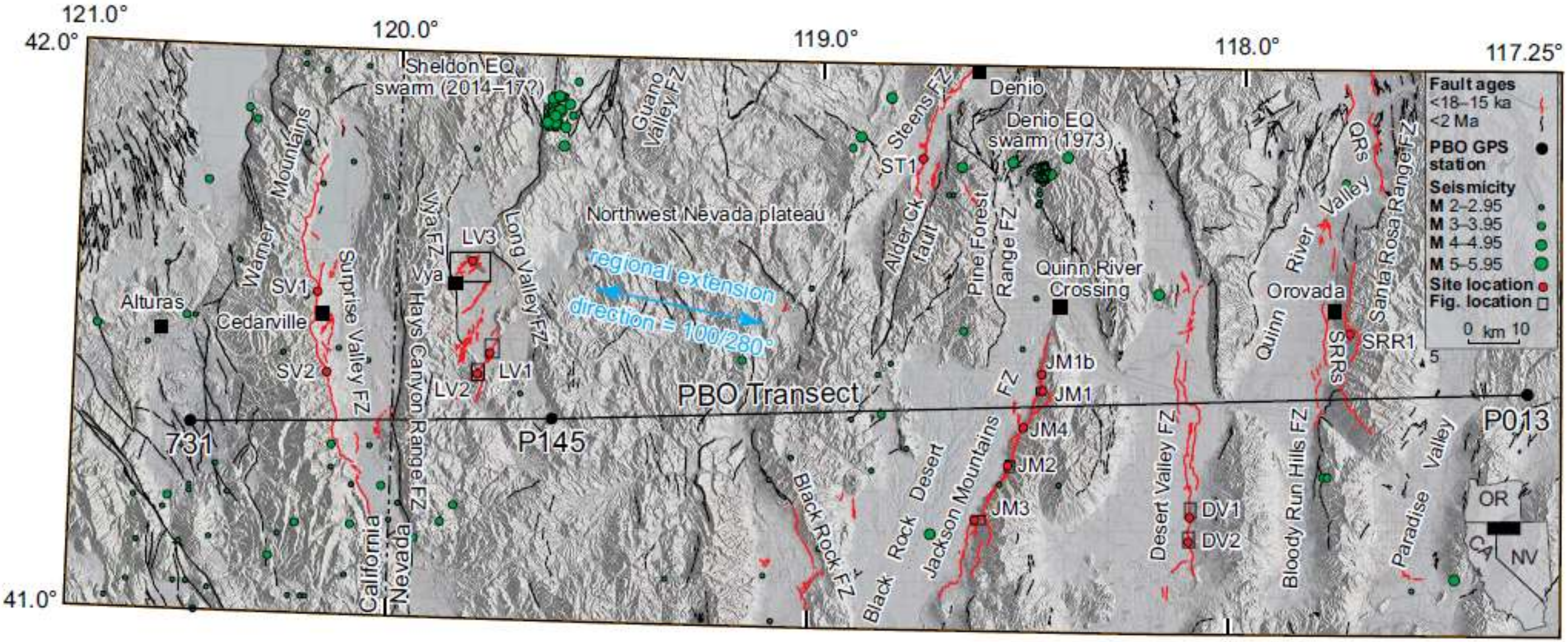
- Characterize the deformation front of the Seattle fault (NEHRP funded)
- Seismic profiling of faults related to the 1886 Charleston earthquake (recommended for funding)



A paleoseismic transect across the northwestern Basin and Range Province, northwestern Nevada and northeastern California, USA

Stephen F. Personius[1], Richard W. Briggs[1], J. Zebulon Maharrey[1,2], Stephen J. Angster[1,3], and Shannon A. Mahan[4]

[1]Geologic Hazards Science Center, U.S. Geological Survey, MS 966, PO Box 25046, Denver, Colorado 80225, USA
[2]Department of Geology and Geophysics, University of Alaska, Fairbanks, 900 Yukon Drive, PO Box 755780, Fairbanks, Alaska 99775, USA
[3]Center for Neotectonic Studies, University of Nevada, Reno, MS 174, 1664 N. Virginia Street, Reno, Nevada 89557, USA



A SEISMIC TRANSECT ACROSS IDAHO'S BASIN AND RANGE