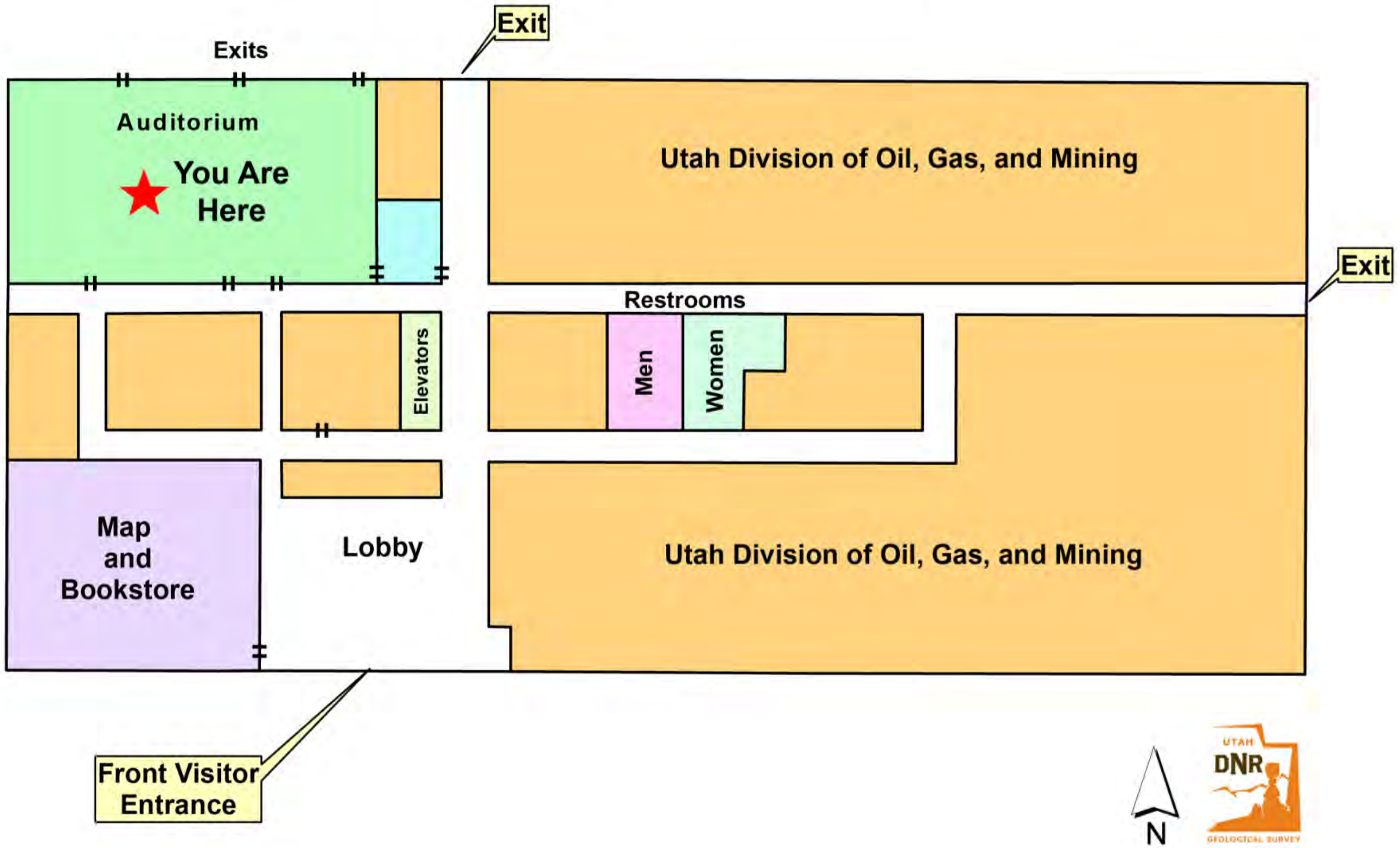
2025 Utah Quaternary Fault Parameters Working Group Meeting

February 10, 2025

Utah DNR Geological Survey

Department of Public Safety Division of Emergency Management Utah

Utah DNR 1st Floor Map

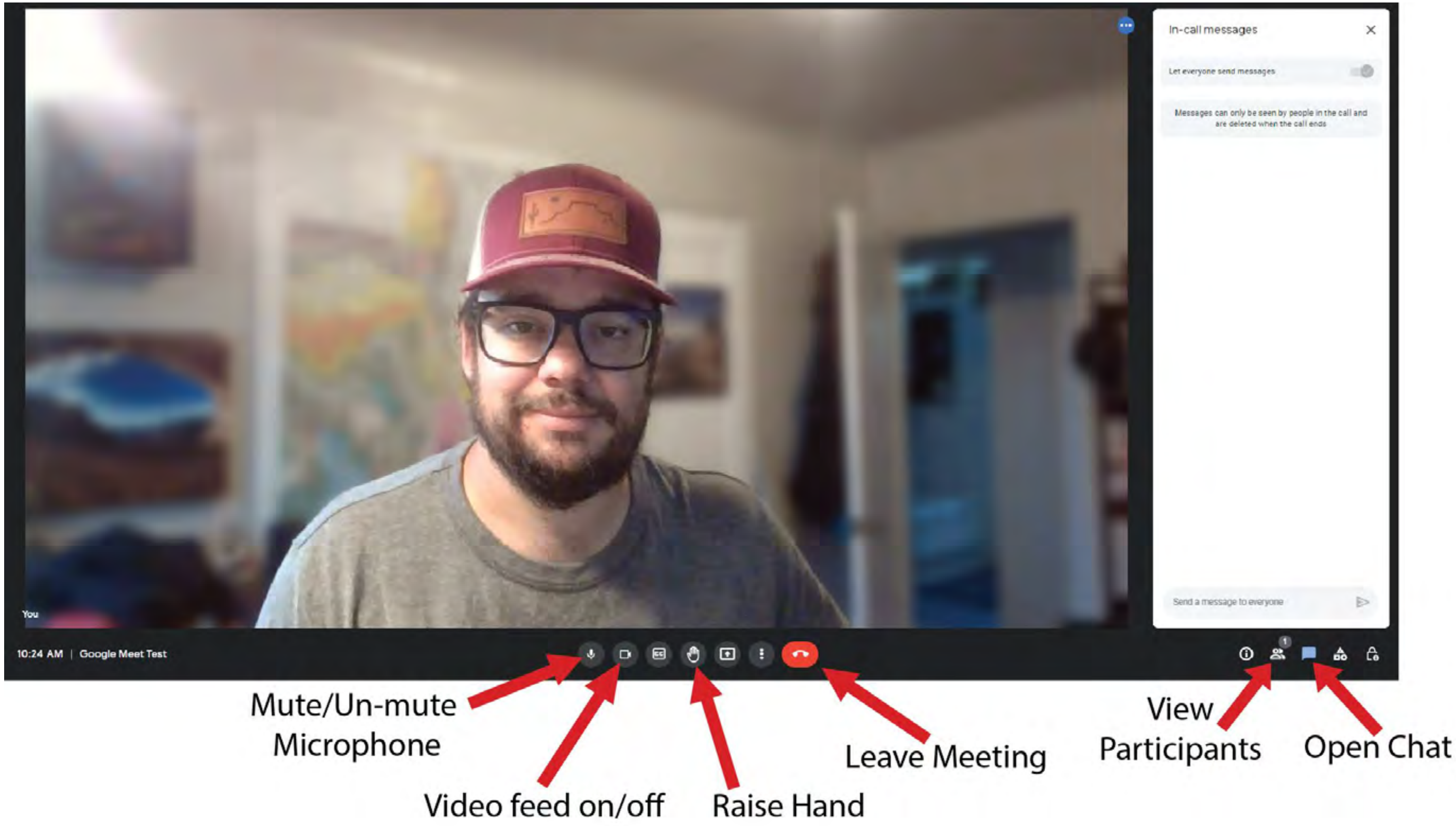


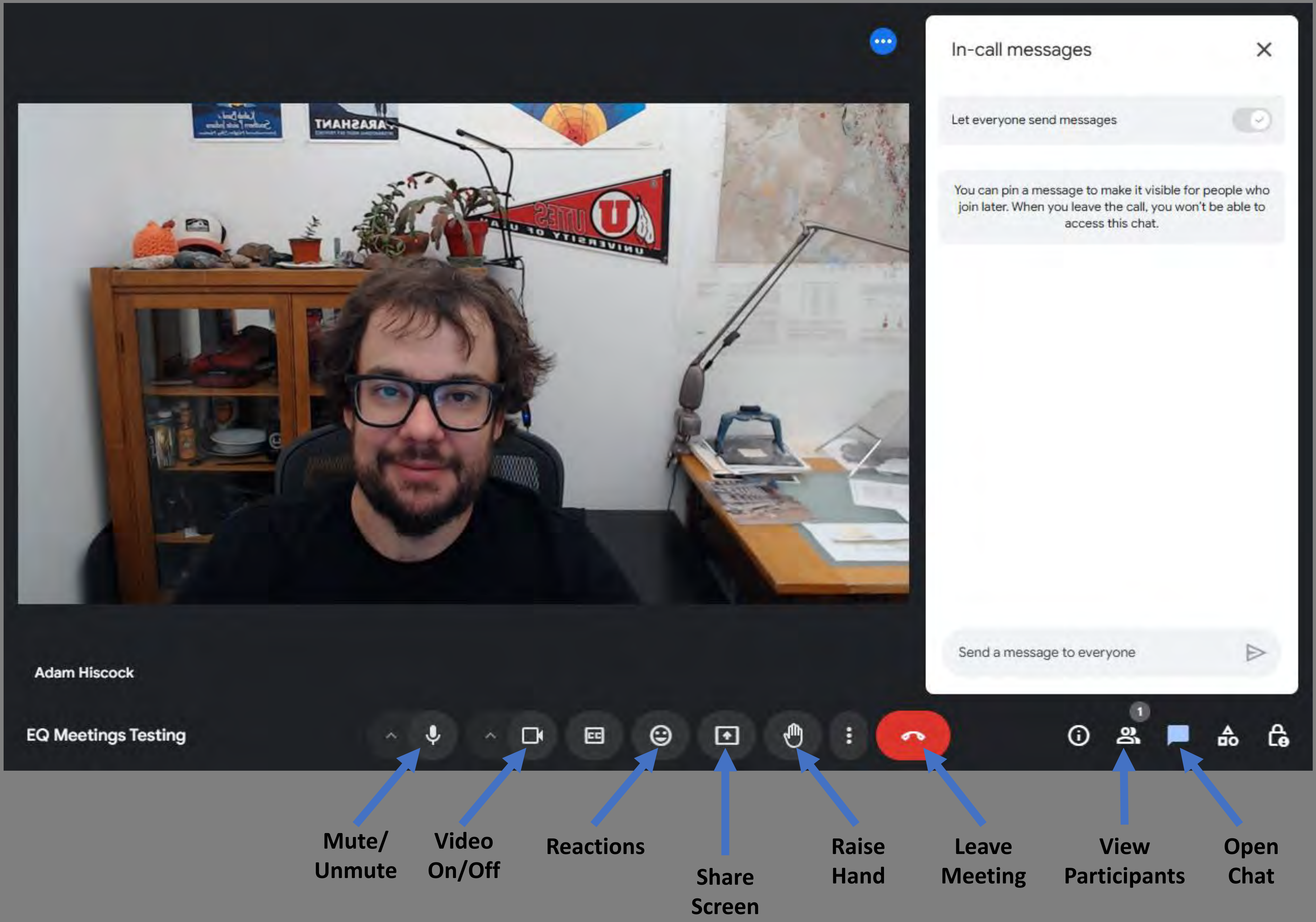
Presenters

- Speaker Timer in front of you to keep things on track!
    - We do have plenty of time in the agenda for discussion and Q/A.
- Meeting is being recorded
- Talk to me if you don't want the recording of your talk publicly available – we can remove it
- Make sure to stay in front of the podium so the mic's pick up your voice for virtual attendees to hear
- Q/A – Mics on each table are muted, if you'd like to ask a question, please use the mic and press the button to unmute before you talk
    - We also have handheld mics to pass around for QA
- Remote Q/A – Please put your questions into the meeting chat – we will read them in order when we get them.

Virtual Attendees – Google Meet Guide

- Please keep your microphone muted during talks
- Put Q/A in the meeting chat – we will read them in order after presentations





In-call messages
Let everyone send messages
You can pin a message to make it visible for people who join later. When you leave the call, you won't be able to access this chat.
Send a message to everyone
Adam Hiscock
EQ Meetings Testing
Mute/ Unmute
Video On/Off
Reactions
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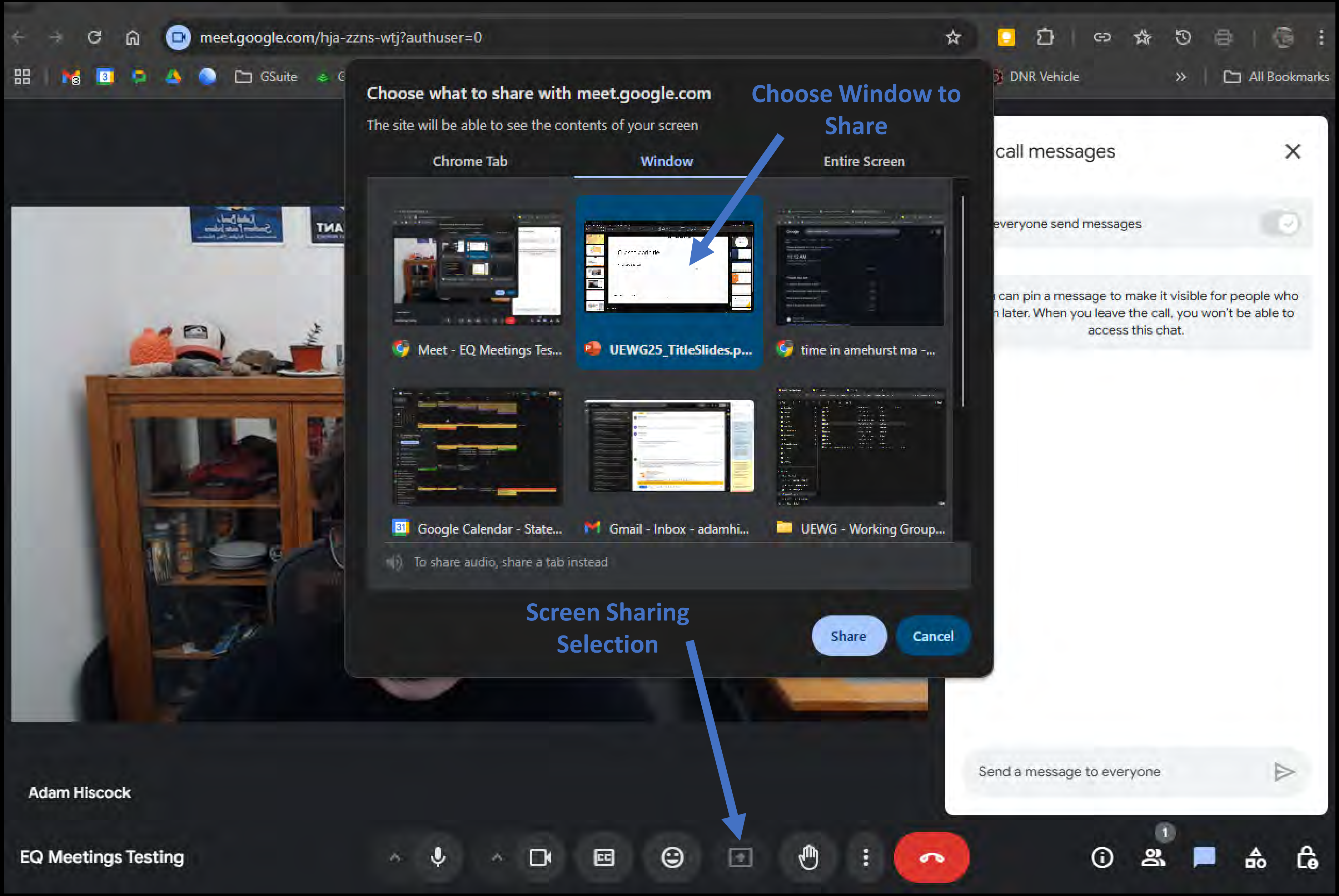
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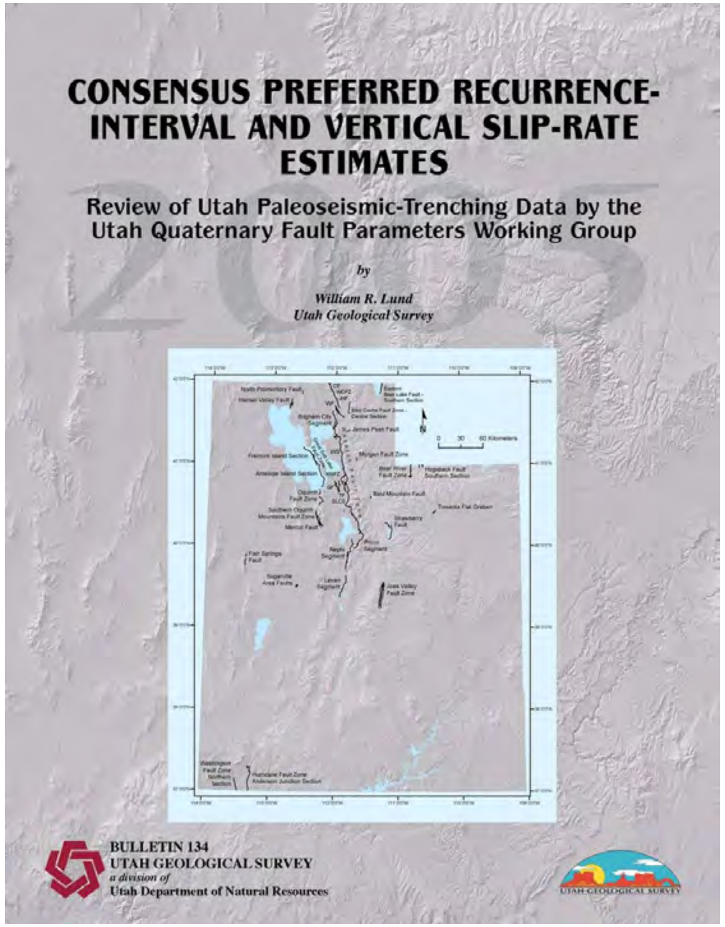
later. When you leave the call, you won't be able to
access this chat.
Send a message to everyone
Adam Hiscock
EQ Meetings Testing

UQFPWG History and Purpose

- Began in 2004 by developing consensus slip-rate and recurrence-interval data for all faults with paleoseismic data in Utah (UGS B-134, Lund, 2005).
- Group developed an initial priority list of Utah Quaternary faults requiring additional study, list updated annually and incorporated into the annual USGS Earthquake Hazards Program External Research Support funding announcements.
- Review ongoing paleoseismic, earthquake timing, and fault characterization studies ongoing in Utah with the goal of maintaining and updating consensus slip-rate recurrence intervals.
- Group is dependent on the active involvement of researchers (academic, government, etc), consultants, and the public.



2024 UQFPWG Review

- Adam Hiscock – Utah Geological Survey - Welcome and Introduction
- Chris DuRoss – U.S. Geological Survey - Earthquake Hazards Program – External Grants Updates
- Adam McKean, Christian Hardwick, Kayla Smith (UGS) – Towards an Improved Salt Lake Valley Community Velocity Model Through Seismic and Gravity Joint Inversion, Part I— New Geological Constraints and Geophysical Data
- Fan-Chi Lin (U of U) - Towards an Improved Salt Lake Valley Community Velocity Model Through Seismic and Gravity Joint Inversion, Part 2—Seismic Data and Joint Inversion
- Emily Kleber & Adam Hiscock (UGS) - New Paleoseismic Data and Challenges from the Urban Taylorsville Fault, West Valley Fault Zone, Utah
- Lee Liberty (Boise State) - Intrabasin Faulting Beneath Salt Lake City—New Seismic Data Map the West Valley and Downtown Fault Systems
- Nathan Toke (UVU) - The Most Recent Rupture of the Thousand Lake Fault (Post-LGM)—Examining Rupture Length and Average Displacement using Southern Utah Lidar Data
- Chris DuRoss (USGS) - The Great Salt Lake as a recorder of Sublacustrine Surface Rupture and Strong Shaking in the Wasatch Front Region

2024 UQFPWG Review

- Adam Hiscock (UGS) - Utah Quaternary Fault Mapping Updates, Including Cache Valley and Southern Utah
- Adam Hiscock (UGS) - Utah Paleoseismic Sites Database Update
- Ivan Wong (LCI) - Updating the Working Group on Utah Earthquake Probabilities Forecast for the Wasatch Front
- Jim McCalpin (GeoHaz Consulting) - Quaternary Faults of the Uncompahgre Plateau, Utah and Colorado—Are they Q and are they Faults?

2024 UQFPWG Priorities

- Acquire new paleoseismic information for areas with ongoing or completed lidar fault mapping projects:
  - Cache Valley faults – East Cache fault zone and West Cache fault zone
  - Five central segments of the Wasatch fault zone – Brigham City, Weber, Salt Lake City, Provo, and Nephi
  - Oquirrh fault zone
  - Washington, Hurricane, and Sevier fault zones
  - Thousand Lake fault
- "Salvage paleoseismology" (i.e., earthquake timing investigations as rapid development is encroaching on unmodified paleoseismic trenching sites:
  - West Valley fault zone – Granger and Taylorsville faults
  - Cache Valley faults – East and West Cache fault zones

2024 UQFPWG Priorities

- Use recently acquired lidar data to more accurately map fault traces. Specifically:
  - Basin and Range – Colorado Plateau Transition faults (Thousand Lake fault, Paunsaugunt fault, Joes Valley faults, etc.)
  - Faults in rural areas of western Utah (Escalante Desert, Sevier Desert, Pilot Valley, Tintic Valley, Skull Valley, Hansel Valley, Beaver Basin, Scipio Valley)
  - Faults that cross zones of critical infrastructure across Utah

2024 UQFPWG Priorities

- Opportunistic trenching sites – Funding for dating samples left over from other projects that have been stored and would be useful:
  - Joes Valley – U.S. Bureau of Reclamation Work?
  - Various research trenches on the Wasatch and West Valley fault zones

- Post-Magna earthquake research – Use geophysical methods to collect more data about the subsurface of the Salt Lake Valley:
  - 3D Basin structural model of the Salt Lake Valley using new gravity, existing well data, and seismic data
  - Community velocity model input improvements
  - Collect, compile, and analyze new geological and geophysical data to improve subsurface models of the Salt Lake basin. Improved basin models will enable more accurate numerical ground motion modeling and may provide insight into subsurface fault geometries.

2024 UQFPWG Priorities

- Utah Lake faults – Improve upon previous work to better map/characterize these faults. Use new methods and techniques to improve upon previous work on these faults.

- Quaternary faults in Utah not included in 2023 NSHM Update – Paleoseismic data and lidar-based fault geometry mapping needed for including these faults in the next update to the NSHM.

Intermountain West (IMW) Region External Grants – 2025 Update

Christopher B. DuRoss

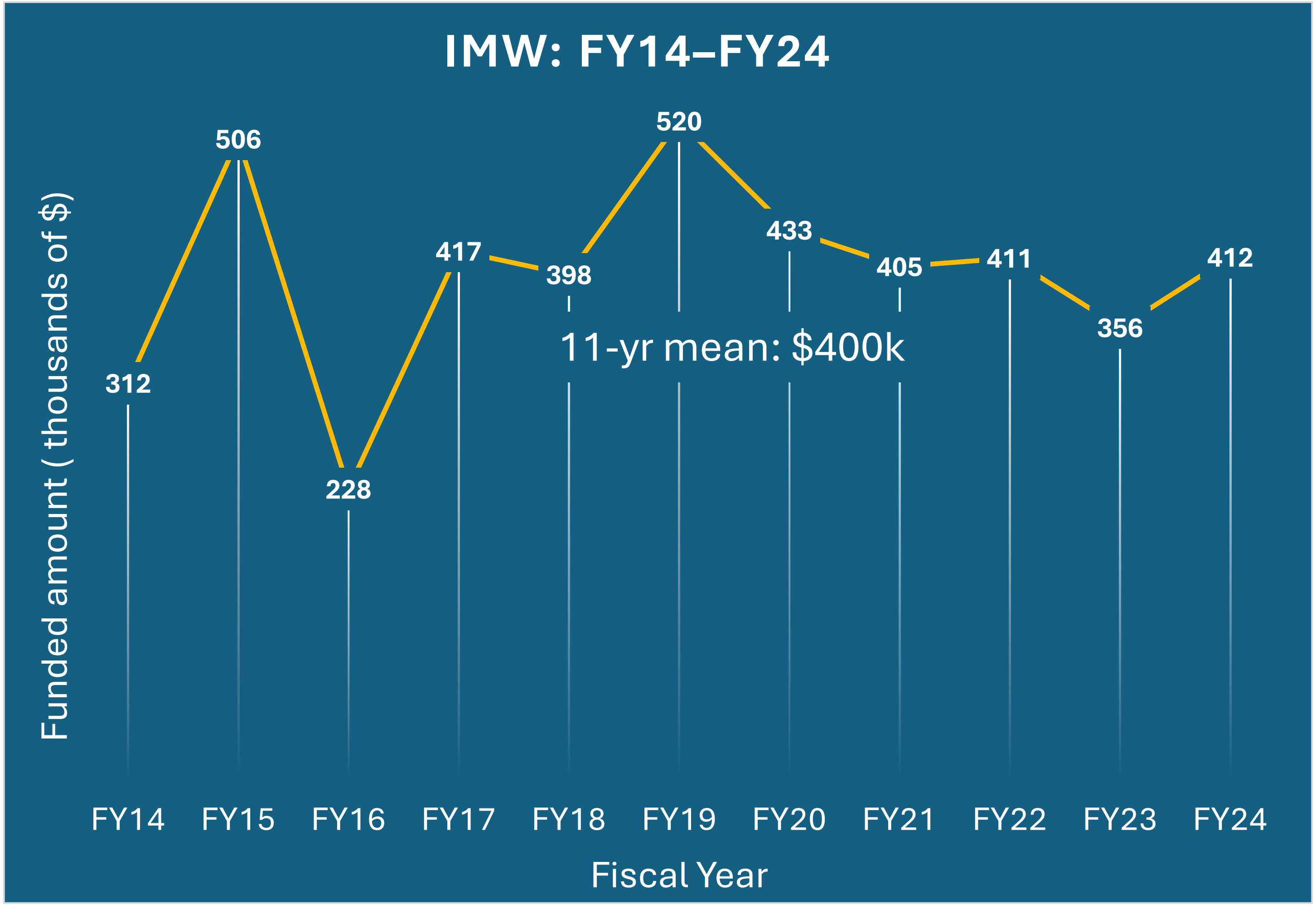
USGS Earthquake Hazards Program (EHP)
Intermountain West (IMW) Regional Coordinator

USGS
science for a changing world

IMW External Research

- **~$400k per year to external research in the IMW**

- **~10% of the the USGS External Grants portfolio (~$4M)**
  - **Five regions**
    - Central & Eastern U.S.
    - Intermountain West
    - Northern California
    - Southern California
    - Pacific Northwest & Alaska
  - **Five topical areas**
    - Earthquake Early Warning
    - Earthquake Rupture Forecasting
    - Earthquake Source Processes
    - Hazard, Impacts, and Risk
    - Ground Motion



USGS science for a changing world

IMW Region Priorities (FY25 – previous cycle)

➢Seismic source characterization

- Regional/state Quaternary fault compilations
- Geologic, geodetic, seismotectonic deformation models
- Seismic hazard analyses (especially for high-risk regions)

➢Earthquake processes

- Historical ruptures and prehistoric earthquake histories
- Spatial/temporal variability in fault/earthquake behavior (e.g., slip rate, segmentation)
- Subsurface structure of normal faults
- Lacustrine paleoseismic data
- Geophysical data to support subsurface mapping and community velocity models
- Effects of basin structure on strong ground motions and site amplification

➢Collaborative efforts

- Working groups, community outreach, urban risk reduction

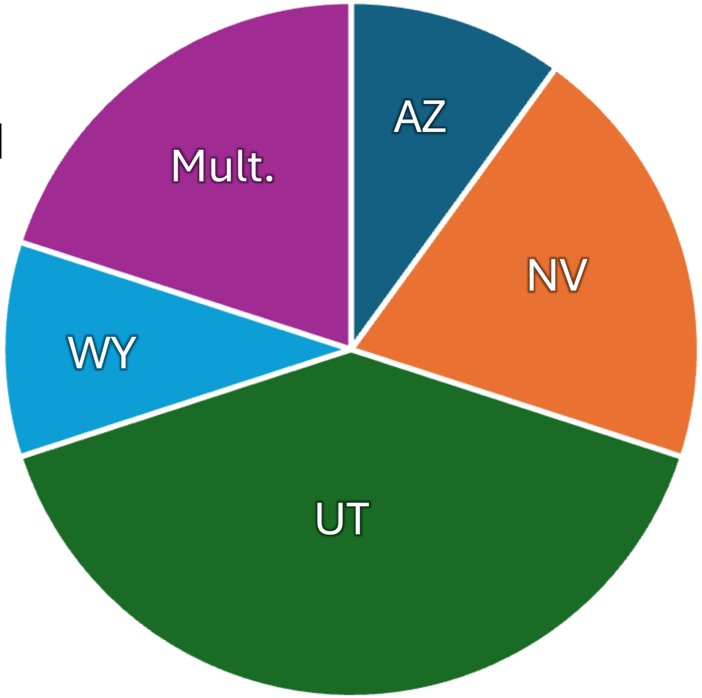
IMW Proposals (FY25)

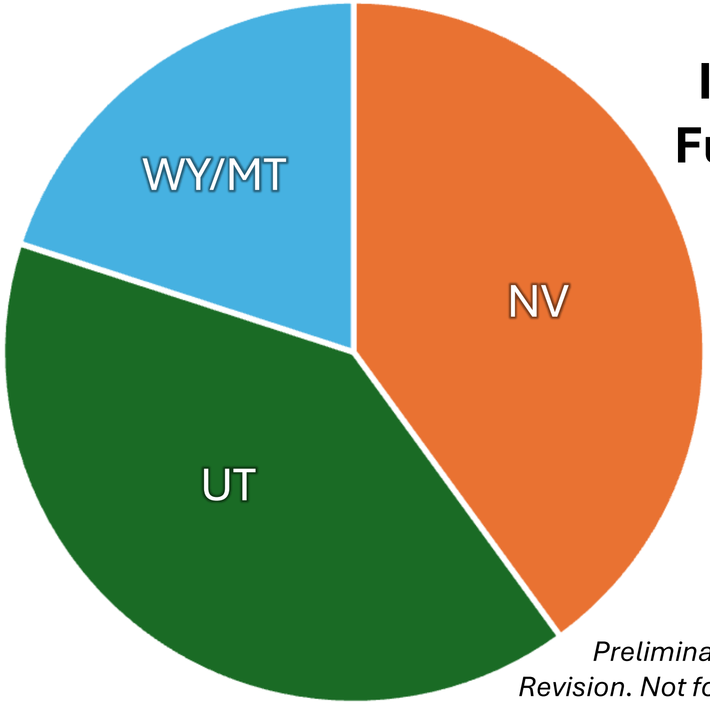
➢10 unique proposals (4 collaborative)

- $88k per proposal (summing collab budgets)
- Funding status (January 2025):
  - 1 – Fund (1 collab)
  - 4 – Hold (2 collab)
  - 5 – Do not fund (1 collab)

**Final funding decisions will be made once we have a budget (Continuing Resolution until March 14)*

IMW FY25 Submitted ($882k)





IMW FY25 Fund/Hold* ($498k)

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

USGS science for a changing world

FY26 (upcoming grant cycle)

- **FY26 Notice of funding opportunity** (NOFO) expected in mid March 2025
  - Proposals due late May 2025
  - Contact me (cduross@usgs.gov) if interested in serving on a review panel
  - Contact Jill Franks (jfranks@usgs.gov) for more information on the RFP

- **The USGS is conducting internal and external reviews of this program.** Please let me know if you have feedback, comments, areas for improvement.

- **Common and IMW-specific research priorities** – included in NOFO

DISCUSSION: IMW Priorities – Hazardous Faults

➢ Background

- Lists of high-priority faults in the IMW are used to define IMW priorities and guide funding decisions by USGS external grants review panels
- Utah and Nevada maintain separate lists
- A priority list for the rest of the IMW region has not been updated since 2015 (Briggs and Gold, 2015)

➢ Problem

- The IMW list is out of date
- Not all IMW states are included
- Some lists include priority faults (IMW) and others (UT and NV) have faults, regions, and topics

➢ Goal

- Create a stable one-stop landing page for priority faults/regions in the IMW, with yearly updates driven by member states

IMW Priorities

Priority Topics for Research in the Intermountain West (IMW) Coordinator:
Christopher DuRoss, cduross@usgs.gov

Priorities for research in the IMW focus on the collection of data that directly contribute to (1) regional seismic hazard assessments such as the USGS National Seismic Hazard Model (NSHM) and (2) our knowledge of earthquake occurrence in the region. High priority issues to be addressed in proposed work are listed below for each EHP program element, although other proposal topics will be considered.

In addition to the common priorities listed in section 3.3, the following priority tasks are identified under each element:

IMW Element I. **National and regional earthquake hazards assessments.**

Conduct scientific studies to improve our understanding of seismic hazard and its uncertainty in the IMW region:

- Improve seismic source characterization for IMW faults included in local to regional seismic hazard assessments such as the NSHM. These studies could include investigations of Quaternary fault extent using high-resolution data (e.g., lidar), paleoseismic chronologies, earthquake recurrence, slip rates, prehistoric rupture length and magnitude, and fault segmentation. Priority faults, topics, and regions deemed to need further study can be found at:
    - **IMW region**: http://ugspub.nr.utah.gov/publications/misc_pubs/mp-15-5/mp-15-5_workshop.pdf
    - **Nevada** (Nevada Bureau of Mines and Geology): http://www.nbmg.unr.edu/_docs/Earthquakes/NBMG_priorities_NEHRP.pdf
    - **Utah** (Utah Quaternary Fault Parameters Working Group): https://geology.utah.gov/hazards/info/workshops/working-groups/q-faults/
- Compile, and/or update regional information on Quaternary fault geometry and length to support the USGS Quaternary Fault and Fold Database and NSHM.

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In additi… …ed under each ele…

IMW E…

Criteria:

1. High-risk faults, such as those crossing or proximal to urbanized regions or critical facilities.
2. Faults or regions lacking adequate characterization for PSHA
3. Faults that can facilitate regional or topical earthquake research, such as characterizing faults in an unstudied region or advancing our understanding of earthquake rupture behavior.

Conduct… …the IMW region:

- Imp… …c hazard asse… …ult extent using high-resolution data (e.g., lidar), paleoseismic chronologies, earthquake recurrence, slip rates, prehistoric rupture length and magnitude, and fault segmentation. Priority faults, topics, and regions deemed to need further study can be found at:
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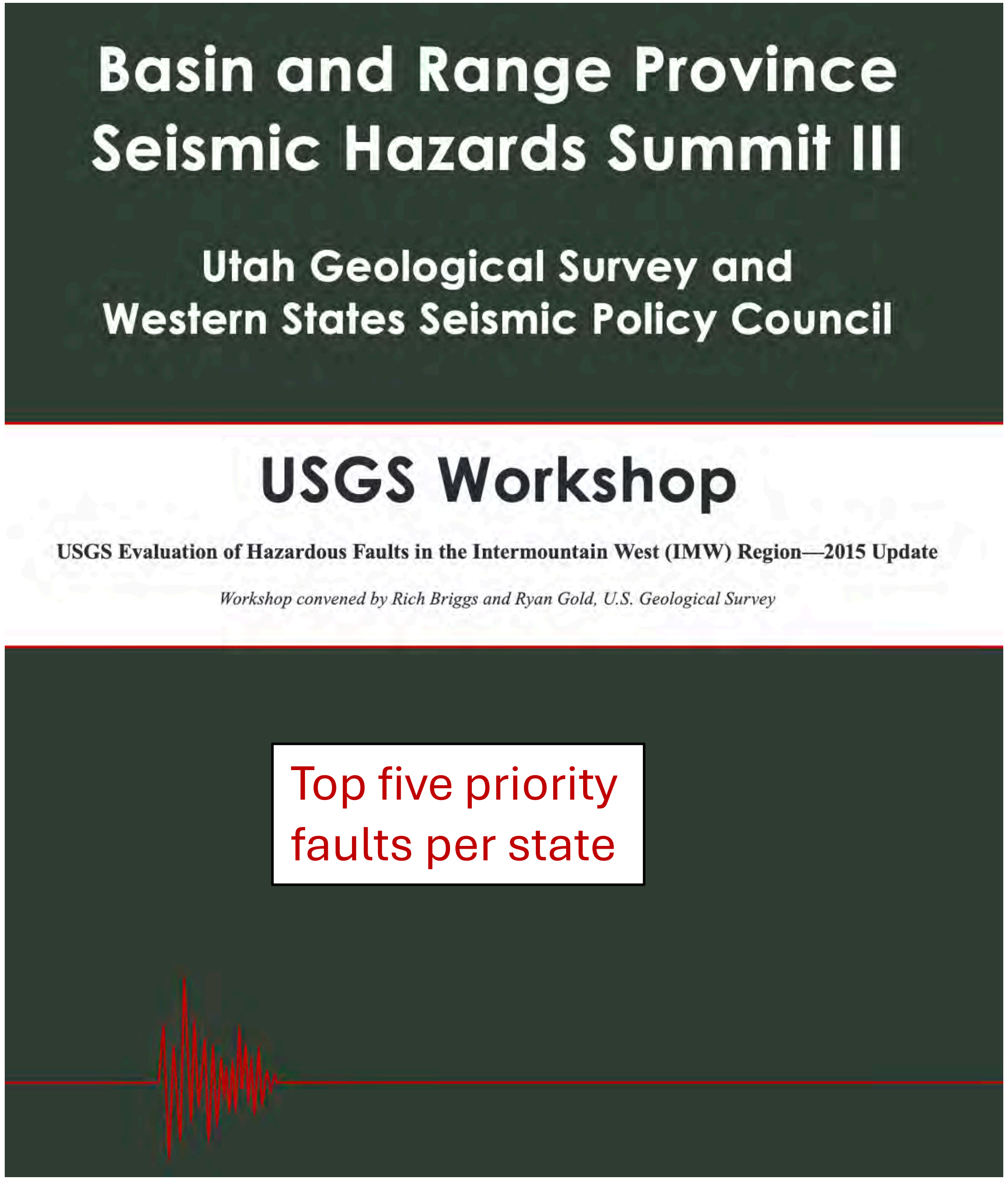
IMW region



Top Five Faults of Concern

- **Arizona**: Lake Mary, Big/Little Chino, Mead Slope, Hurricane, and Needles faults
- **Colorado**: Golden, Rampart Range, Ute Pass, Williams Fork Mountains, and Frontal faults
- **Idaho**: Lost River, Squaw Creek, Sawtooth, Beaverhead, and Lemhi faults
- **Montana**: Swan, Centennial/Madison, Continental, Bitterroot, and Brockton-Froid fault zones
- **Nevada** (not included)
- **New Mexico**: Rincon Ridge, Northern Alamogordo, Mesilla Basin, Albuquerque Basin, and Southern San Andres Mountains faults
- **Oregon** (IMW portion): Goose Lake Graben, West Klamath fault zone, La Pine Graben, Sisters-Metolius fault zone, Grande Ronde Valley faults
- **Utah** (not included)
- **Washington** (not included)
- **Wyoming**: Teton, Grand Valley, Rock Creek, Greys River, and East Gros Ventre faults
- **Texas** (not included)

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Nevada

Earthquake Research Priorities for Nevada, EHP FY22

Nevada Bureau of Mines and Geology and Nevada Seismological Laboratory

The earthquake research priorities outlined in this synopsis are defined by the Nevada Bureau of Mines and Geology (NBMG) and the Nevada Seismological Laboratory (NSL) and are intended to be included in the U.S. Geological Survey Earthquake Hazards Program (EHP) Request for Proposals for the Intermountain West region. The priorities reflect updates of consensus views of research needs developed at workshops in 2007 and 2009 (summarized in Briggs and Hammond, 2011), as well as comments from participants at the 2018 Working Group on Nevada Seismic Hazards held in Reno, Nevada (http://www.nbmg.unr.edu/Ge[illegible]sWorkshop.html). The priorities are based on the quality and detail [illegible] investigations, implications of previous loss-estimation modeli[illegible]ata needs for future updates of the National Seismic Hazard Map.

Detailed discussion of high priority faults, regions, and topics

The areas of the state that have [illegible]he greatest need for future earthquake research are the ma[illegible]and southern Nevada including the Reno-Carson City corridor and t[illegible]ly. The NBMG and NSL strongly support the efforts by the U.S. G[illegible]gic, geologic, and geodetic information about earthquake h[illegible]

The 2018 workshop recognized [illegible]h that will benefit planned updates of the National Seismic Hazards Map including:

1) Develop an organized, updateable, on-line database of active faults that summarizes and synthesizes existing knowledge of fault trace location and paleoseismic parameters.
2) Better characterize poorly understood faults including their paleoseismic histories, slip rates, geometry, and potential interconnectivity (See priority fault lists below).
3) Use of existing lidar datasets (i.e. Washoe County, Lake Tahoe basin, Pahrump Valley) and development of collaborative efforts to acquire new lidar along Quaternary faults (USGS 3DEP program).
4) Continued maintenance, monitoring, and expansion of geodetic and seismic networks.
5) Continued expansion of working group efforts including formal organization of sub-disciplines, encouragement of participation from active researchers, and written syntheses of geology, geodesy, earthquake seismology, and exploration geophysics research.
6) Prompt peer review and publication of earthquake research studies.

- **Quaternary faults in the Reno basin and Washoe Valley.**
  - Mount Rose Fault zone
  - East Reno fault zone (range front along eastern side of Truckee Meadows)
  - Little Valley fault
  - Washoe Valley range front
- **Quaternary faults in the Carson Valley and Carson City area**
  - Carson range front (Genoa and Kings Canyon faults)
  - Little Valley fault
  - Eastern Carson Valley fault zone
  - Carson City fault
  - Carson lineament
  - New Empire fault
  - Indian Hills fault
  - Eastern Prison Hill fault
  - Kings Canyon fault
- **Quaternary faults in the Lake Tahoe area.**
  - Incline Village fault
  - North Tahoe fault
  - West Tahoe – Dollar Point fault
- **Quaternary faults in the North Valleys area.**
  - Peterson Mountain fault
  - Fred's Mountain fault
  - North Peavine Mountain fault zone
  - Last Chance/Long Valley fault zone
  - Un-named faults in Lemmon Valley
  - Spanish Springs Valley fault
  - Spanish Springs Peak fault
- **Quaternary faults in the Northern Walker Lane.** Based on the number of paleoseismic studie following faults, they are considered a lesser priority than the faults listed above. However, qu remain related to the spatial and temporal patterns of strain release and the influence of past behavior on future rupture potential on these closely spaced faults.
  - Mohawk Valley fault zone
  - Honey Lake fault
  - Warm Springs Valley fault
  - Pyramid Lake fault

IMW Priorities

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Utah

UQFPWG 2025 FAULT INVESTIGATION PRIORITIES FOR USGS IMW EXTERNAL GRANTS

The Working Group's list of highest priority fault investigations is largely the same from 2023, which was carried over from 2022 due to the UQFPWG not meeting in 2023.

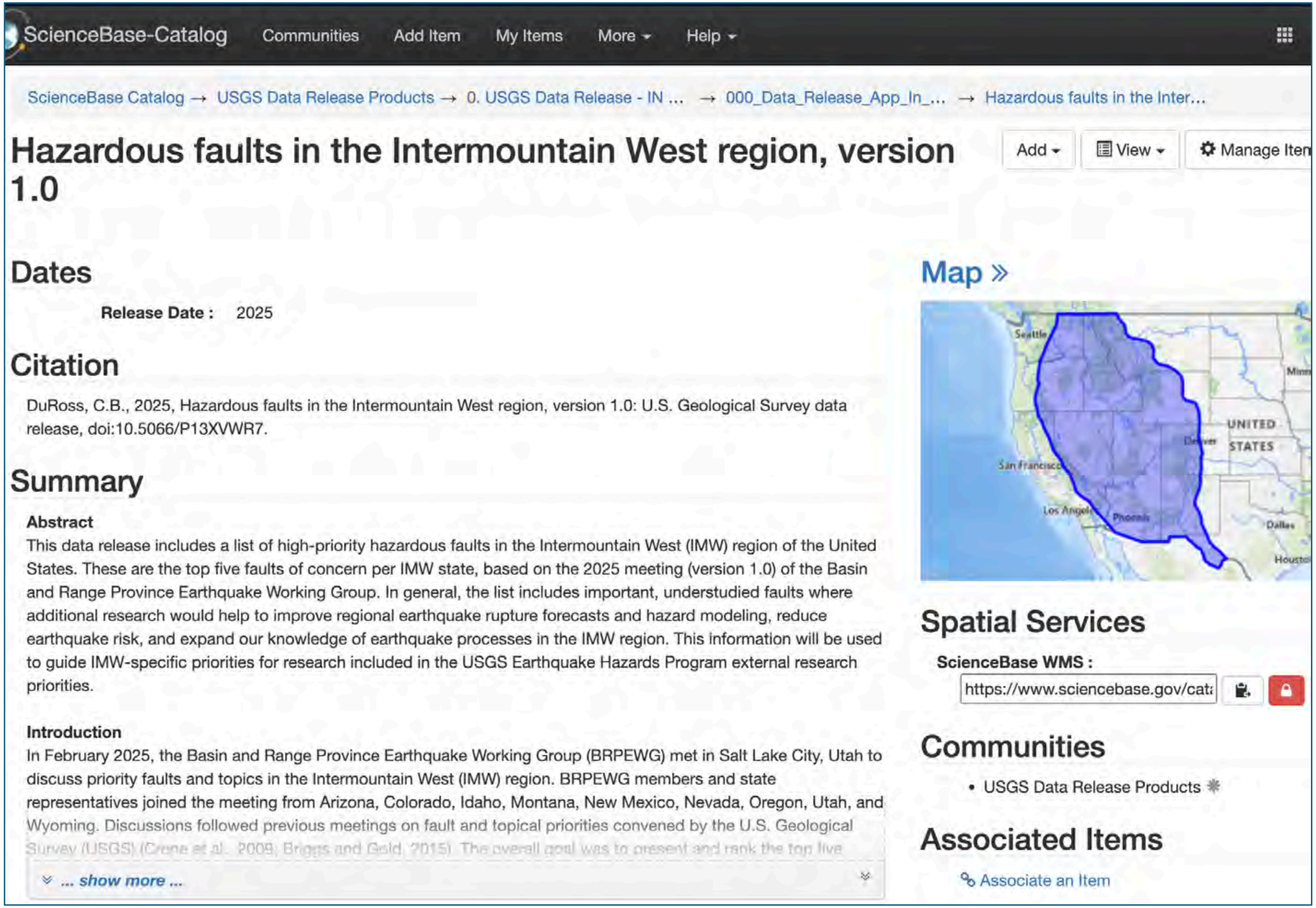
- Acquire new paleoseismic information for areas with ongoing or completed lidar fault mapping projects:
  - Cache Valley faults – East Cache fault zone and West Cache fault zone
  - Five central segments of the Wasatch fault zone – Brigham City, Weber, Salt Lake City, Provo, and Nephi
  - Oquirrh fault zone
  - Washington, Hurricane, and Sevier fault zones
  - Thousand Lake fault
- "Salvage paleoseismology" (i.e., earthquake timing investigations as rapid development is encroaching on unmodified paleoseismic trenching sites:
  - West Valley fault zone – Granger and Taylorsville faults
  - Cache Valley faults – East and West Cache fault zones

Short discussion (bullets) of high priority faults, regions, and topics (updated annually: Utah Quaternary Fault Parameters working group)

- Use recently acquired lidar data to more accurately map fault traces. Specifically:
  - Basin and Range – Colorado Plateau Transition faults (Thousand Lake fault, Paunsaugunt fault, Joes Valley faults, etc.)
  - Faults in rural areas of western Utah (Escalante Desert, Sevier Desert, Pilot Valley, Tintic Valley, Skull Valley, Hansel Valley, Beaver Basin, Scipio Valley)
  - Faults that cross zones of critical infrastructure across Utah
- Opportunistic trenching sites – Funding for dating samples left over from other projects that have been stored and would be useful:
  - Joes Valley – U.S. Bureau of Reclamation Work?
  - Various research trenches on the Wasatch and West Valley fault zones
- Post-Magna earthquake research – Use geophysical methods to collect more data about the subsurface of the Salt Lake Valley:
  - 3D Basin structural model of the Salt Lake Valley using new gravity, existing well data, and seismic data
  - Community velocity model input improvements
  - Collect, compile, and analyze new geological and geophysical data to improve subsurface models of the Salt Lake basin. Improved basin models will enable more accurate numerical ground motion modeling and may provide insight into subsurface fault geometries.
- Utah Lake faults – Improve upon previous work to better map/characterize these faults. Use new methods and techniques to improve upon previous work on these faults.
- Quaternary faults in Utah not included in 2023 NSHM Update – Paleoseismic data and lidar-based fault geometry mapping needed for including these faults in the next update to the NSHM.

This list does not include other priorities that have carried over from previous years, which are identified in Table 2.

ScienceBase: Hazardous faults in the IMW, version 1.0


ScienceBase-Catalog Communities Add Item My Items More Help

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Hazardous faults in the Intermountain West region, version 1.0

Add View Manage Item

Dates

Release Date : 2025

Citation

DuRoss, C.B., 2025, Hazardous faults in the Intermountain West region, version 1.0: U.S. Geological Survey data release, doi:10.5066/P13XVWR7.

Summary

Abstract

This data release includes a list of high-priority hazardous faults in the Intermountain West (IMW) region of the United States. These are the top five faults of concern per IMW state, based on the 2025 meeting (version 1.0) of the Basin and Range Province Earthquake Working Group. In general, the list includes important, understudied faults where additional research would help to improve regional earthquake rupture forecasts and hazard modeling, reduce earthquake risk, and expand our knowledge of earthquake processes in the IMW region. This information will be used to guide IMW-specific priorities for research included in the USGS Earthquake Hazards Program external research priorities.

Introduction

In February 2025, the Basin and Range Province Earthquake Working Group (BRPEWG) met in Salt Lake City, Utah to discuss priority faults and topics in the Intermountain West (IMW) region. BRPEWG members and state representatives joined the meeting from Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, and Wyoming. Discussions followed previous meetings on fault and topical priorities convened by the U.S. Geological Survey (USGS) (Crone et al., 2009; Briggs and Gold, 2015). The overall goal was to present and rank the top five

... show more ...

Map »

Spatial Services

ScienceBase WMS : https://www.sciencebase.gov/cat

Communities

- USGS Data Release Products

Associated Items

Associate an Item

Short discussion (bullets) of high priority faults and regions

+ Spatial data
+ Versioning

– Priority topics excluded

Top Five faults – Update February 2025

Colorado

- Uncompahgre Plateau faults [region]
- Gore Range Frontal fault
- Williams Fork Mountains fault
- Sawatch fault (southern section)
- Poncha fault

Utah

- East and West Cache Valley faults (Cache Valley regional faults)
- Washington and Hurricane faults (Southern Utah regional faults)
- Wasatch fault zone data gaps
- Quaternary faults not in the 2023 USGS National Seismic Hazard Model
- Great Salt Lake and Utah Lake faults
- For additional information, refer to https://geology.utah.gov/hazards/info/workshops/working-groups/q-faults/

Nevada

- Carson Range front (Genoa, Kings Canyon, Washoe Valley, and Mount Rose faults)
- Distributed faults in the North Valleys area of Reno
- Frenchman Mountain fault
- Intra-basin faults in Las Vegas Valley,
- Northern Walker Lane faults (Pyramid, Warm Springs, and Honey Lake faults).
- For additional information, refer to http://www.nbmg.unr.edu/_docs/Earthquakes/NBMG_priorities_NEHRP.pdf

Wyoming

- Rock Creek fault
- Grand Valley fault
- Southeast Yellowstone faults (region of interest)
- Jackson Hole faults (region of interest)
- Stagner Creek fault

New Mexico

- San Andres fault system (including Organ Mountain fault)
- Alamogordo fault
- Sandia-Rincon fault system
- Southern Sangre de Cristo fault
- Caballo fault

Arizona

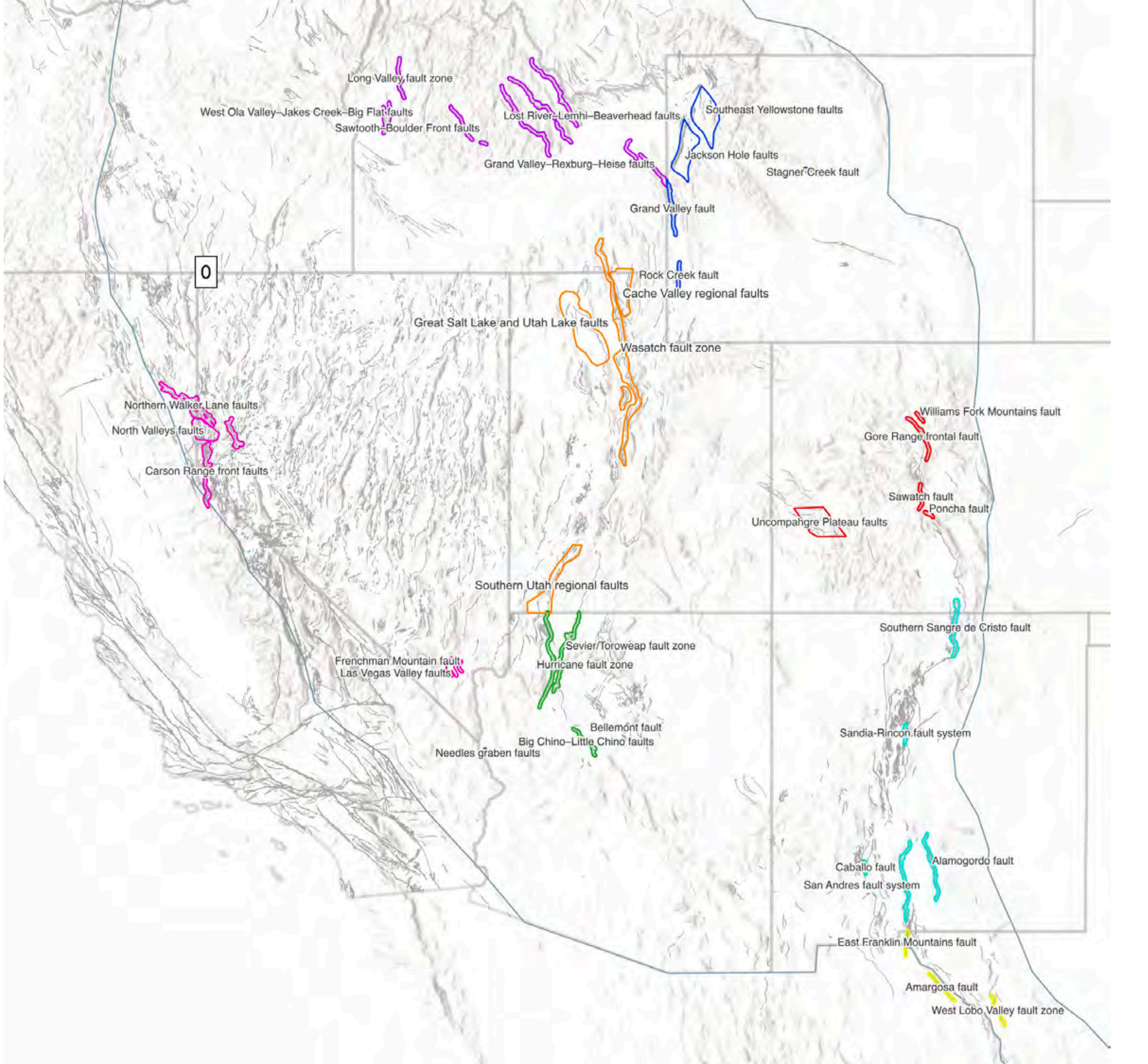
- Big Chino–Little Chino faults
- Needles Graben faults
- Toroweap fault
- Hurricane fault
- Bellemont fault

Idaho

- Long Valley fault
- West Ola Valley–Jakes Creek–Big Flat faults
- Sawtooth–Boulder Front faults
- Lost River–Lemhi–Beaverhead faults
- Grand Valley–Rexburg–Heise faults

Spatial Data

- Faults, grouped faults, regions
  - 2.5-km-wide buffer around Qfaults traces
  - Regions as provided by state reps
- Fields
  - **Name** – Name of IMW fault, grouped faults, or region.
  - **Type** –Fault, grouped fault, region
  - **Fault** – Faults included region or grouped faults.
  - **ID** – Unique identifier from USGS Qfaults.
  - **State** – IMW state.
  - **Source** – Source of spatial data. E.g., Qfaults – fault trace with 2.5-km-wide buffer added.
  - **Notes** –justification, remaining questions, data gaps, risk reduction, etc.



Discussion

1. Criteria for selecting priority faults?
   - Should IMW states use a common set of guidelines?
   - How should we prioritize research on well-known (high hazard) vs unstudied (~lower hazard) faults?

2. Should the USGS IMW priorities include just the IMW list or also NV/UT lists?

3. How can we improve the format, availability, versioning, etc. of this priority document?

4. What spatial data, fields, and formats should be included?
   - Faults, grouped faults, regions
   - Other fields?

5. Should a revised IMW-wide fault/region list also include topics?

Paleoseismic and Geologic Constraints on the Location and Timing of Surface Faulting along the Provo Segment of the Wasatch Fault Zone in Orem, Utah

Robert Givler, Christopher Bloszies, and John Baldwin
Lettis Consultants International, Inc.

February 10, 2025

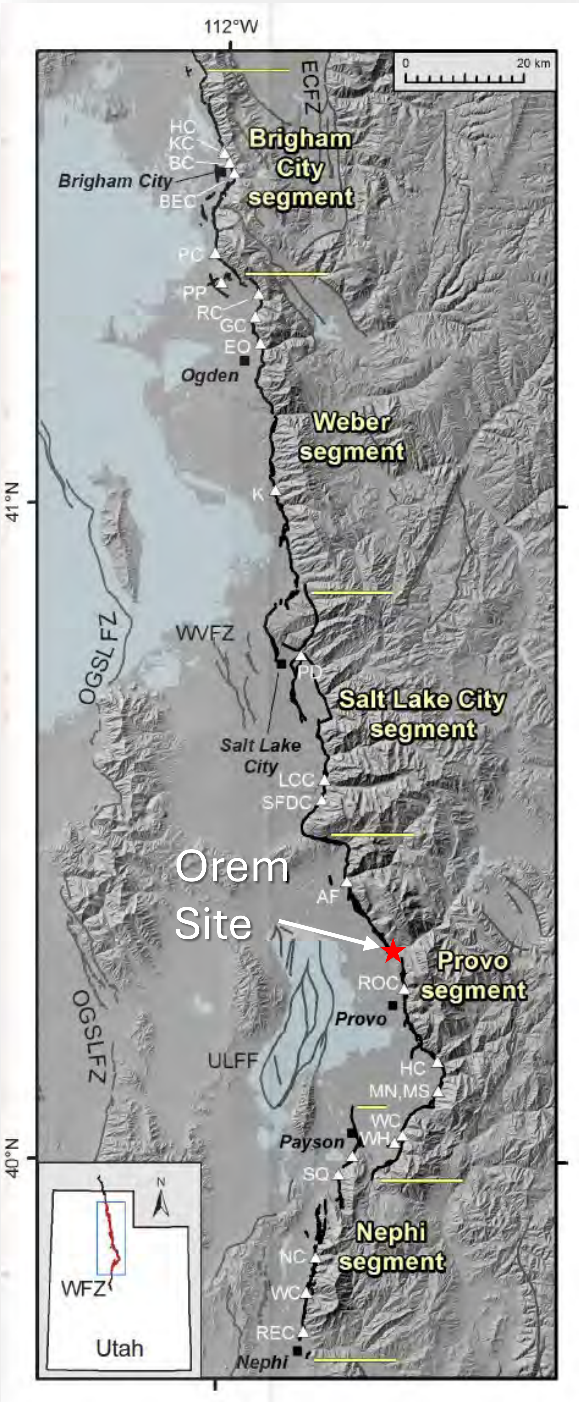
2025 Utah Quaternary Fault Parameters Working Group meeting

Partially Funded by U. S. Geological Survey National Earthquake Hazards Reduction Program Award Number G22AP00037

Lettis Consultants International, Inc.
EARTH SCIENCE CONSULTANTS

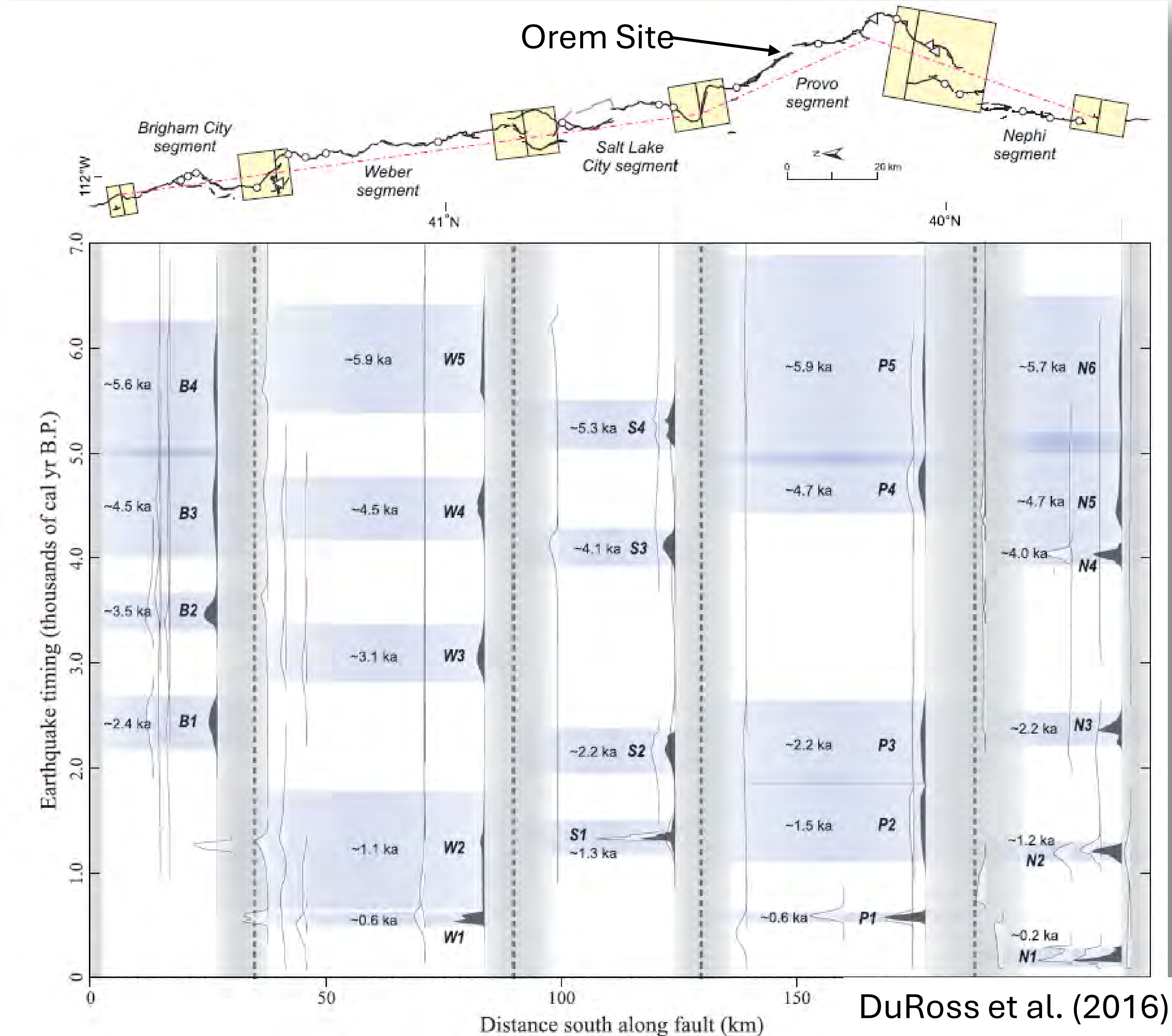
Introduction

- Orem Site located along the Prov Segment of the Wasatch Fault zone
- Fault investigation for a seismic resiliency study for a water conveyance pipeline
- Purpose was to evaluate the location and width of faulting
- Focus of presentation
  - Trench results – Luminescence dating
  - Discuss constraints on event timing
  - Borehole/CPT transect results

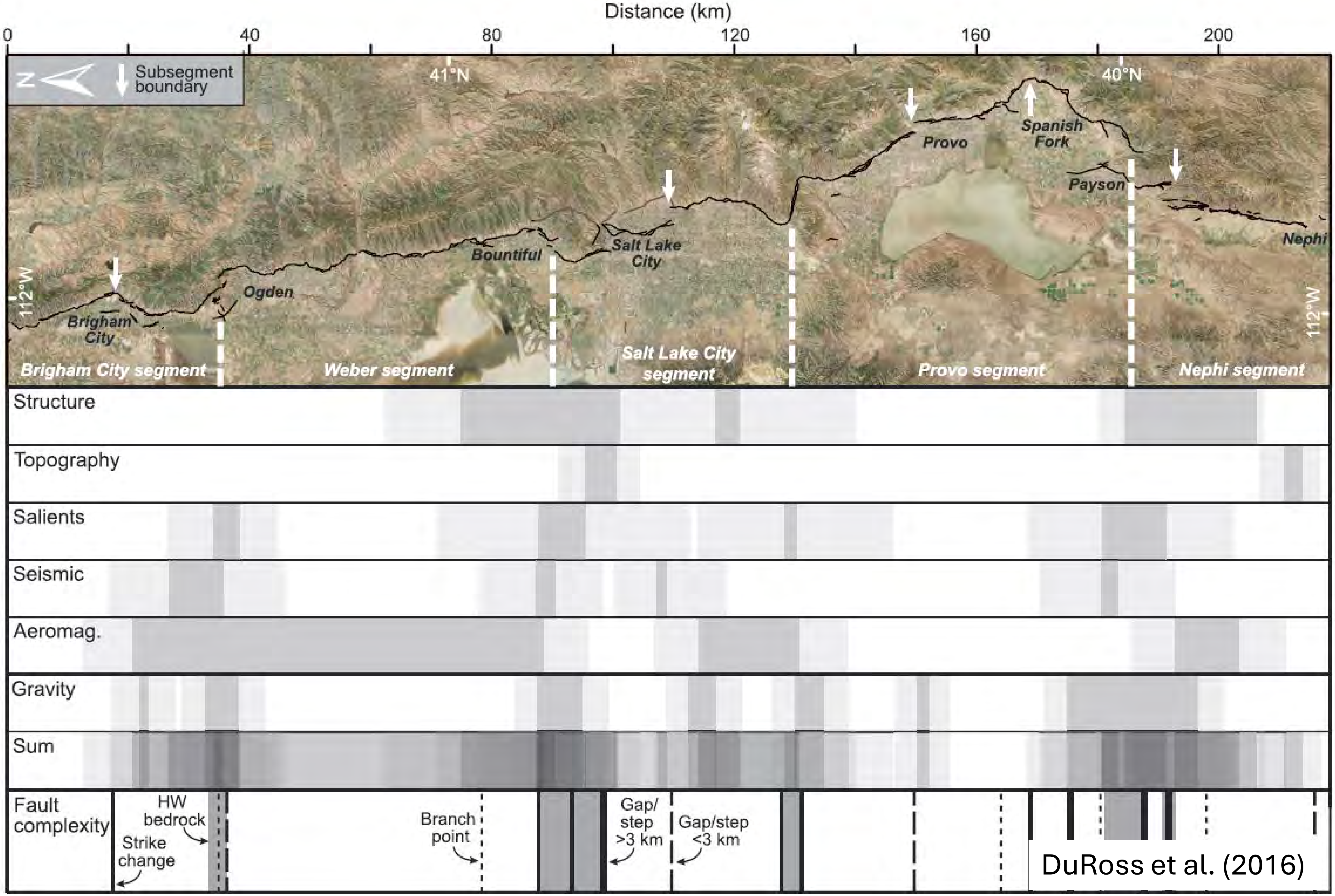


Existing Provo Segment Event Chronology

- 5 events in 6 ka



DuRoss et al. (2016)



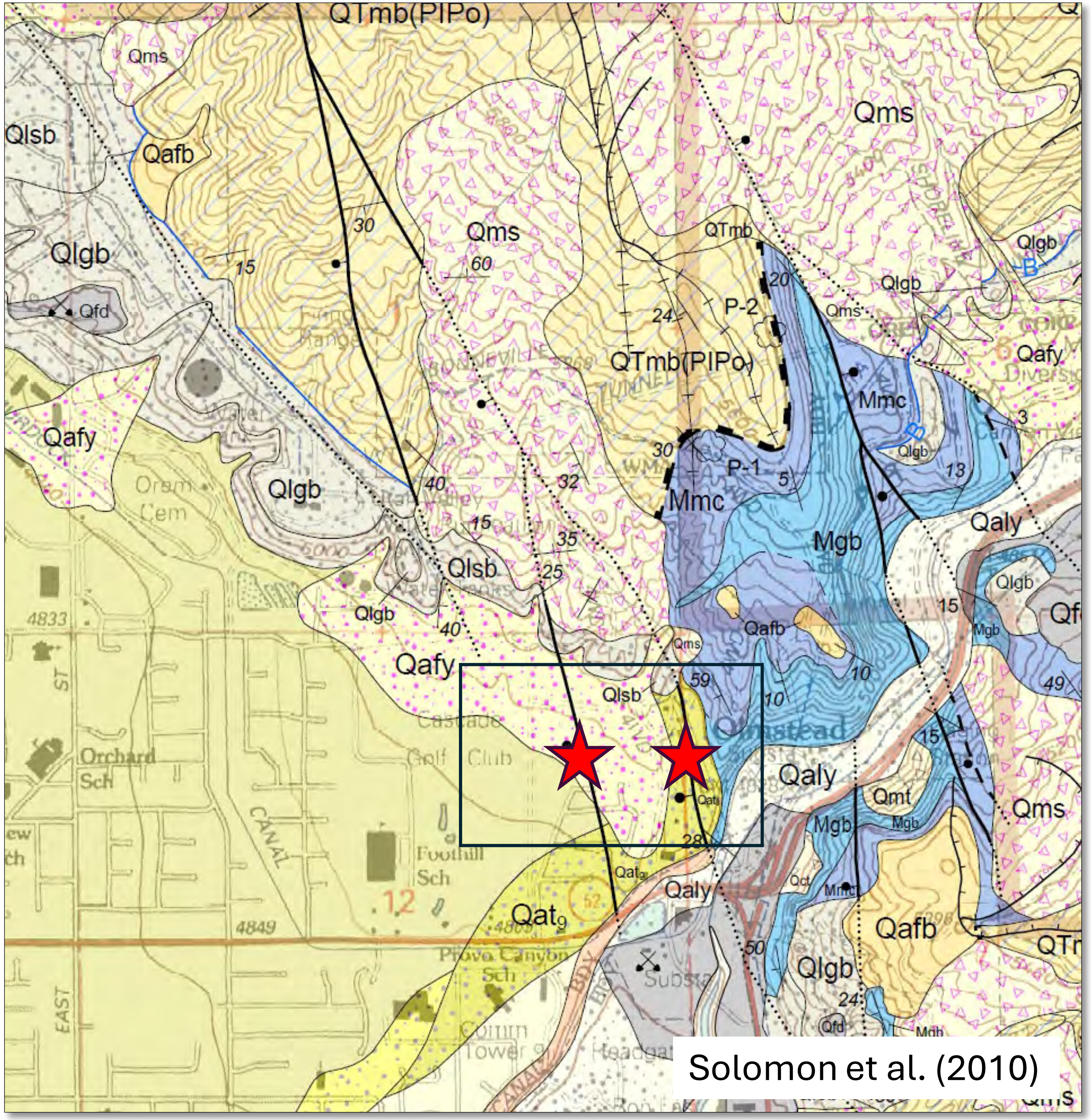
DuRoss et al. (2016)

Regional Geology

Primary Geologic Units

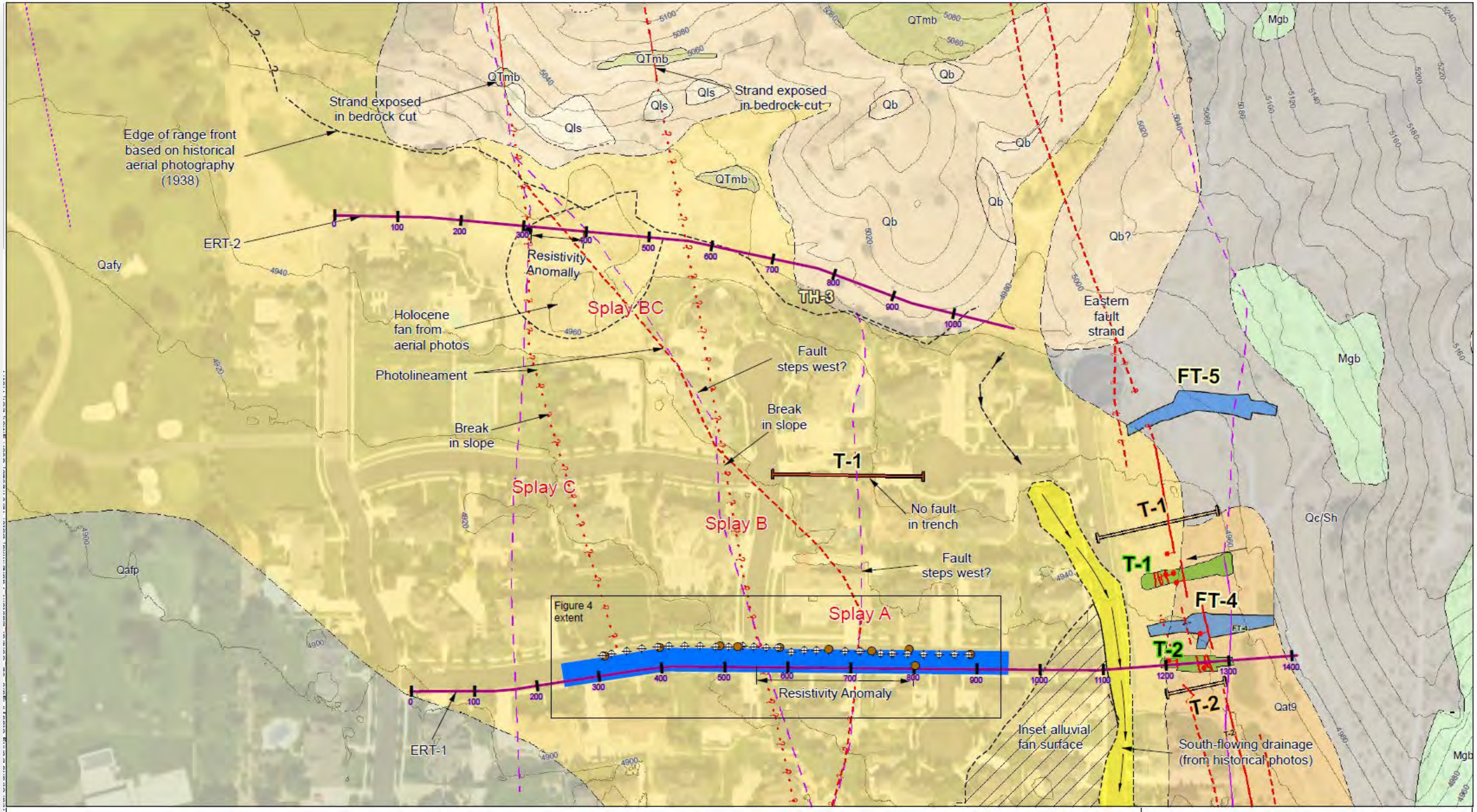
- Bedrock (Mesozoic)
  - Manning Canyon Shale
  - Great Blue Limestone
- Megabreccia (Tertiary-Quaternary)
- Lake Bonneville and alluvial fan deposits (Quaternary)

- Three mapped Wasatch fault strands

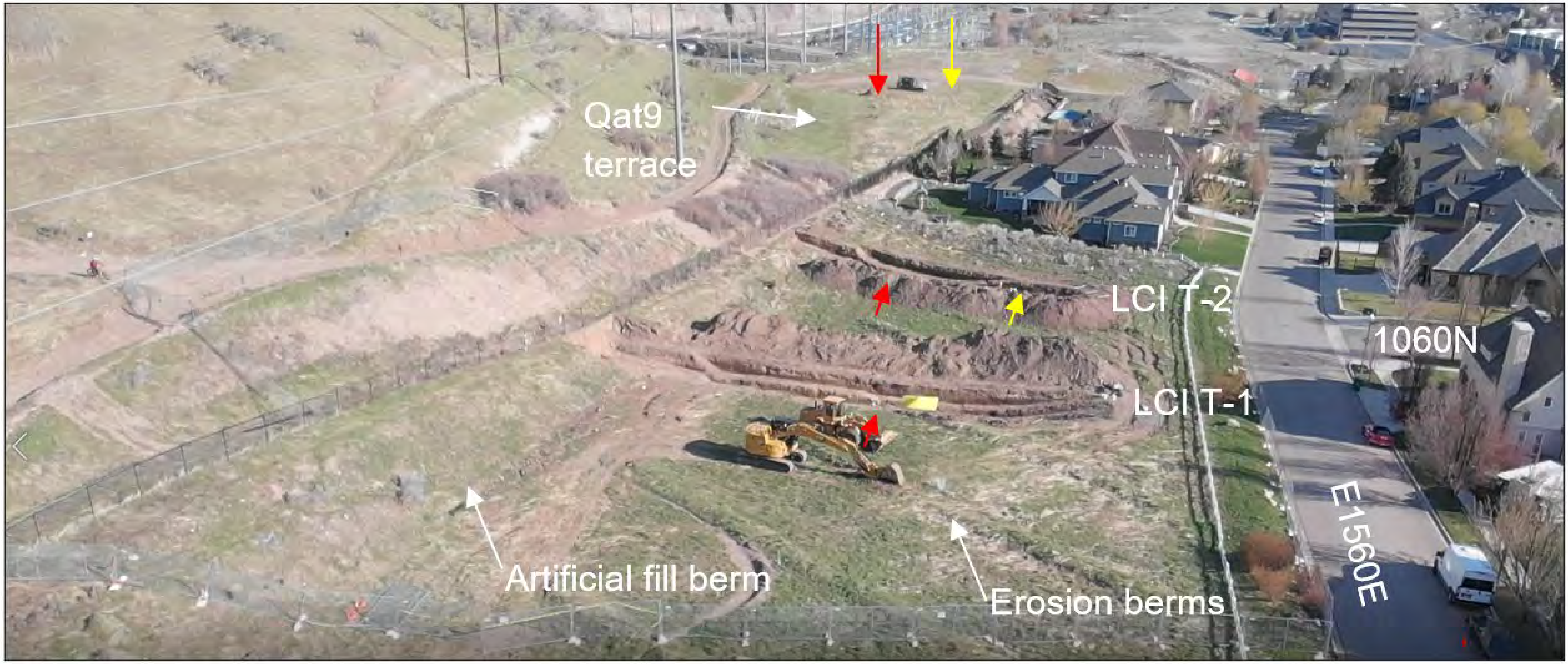


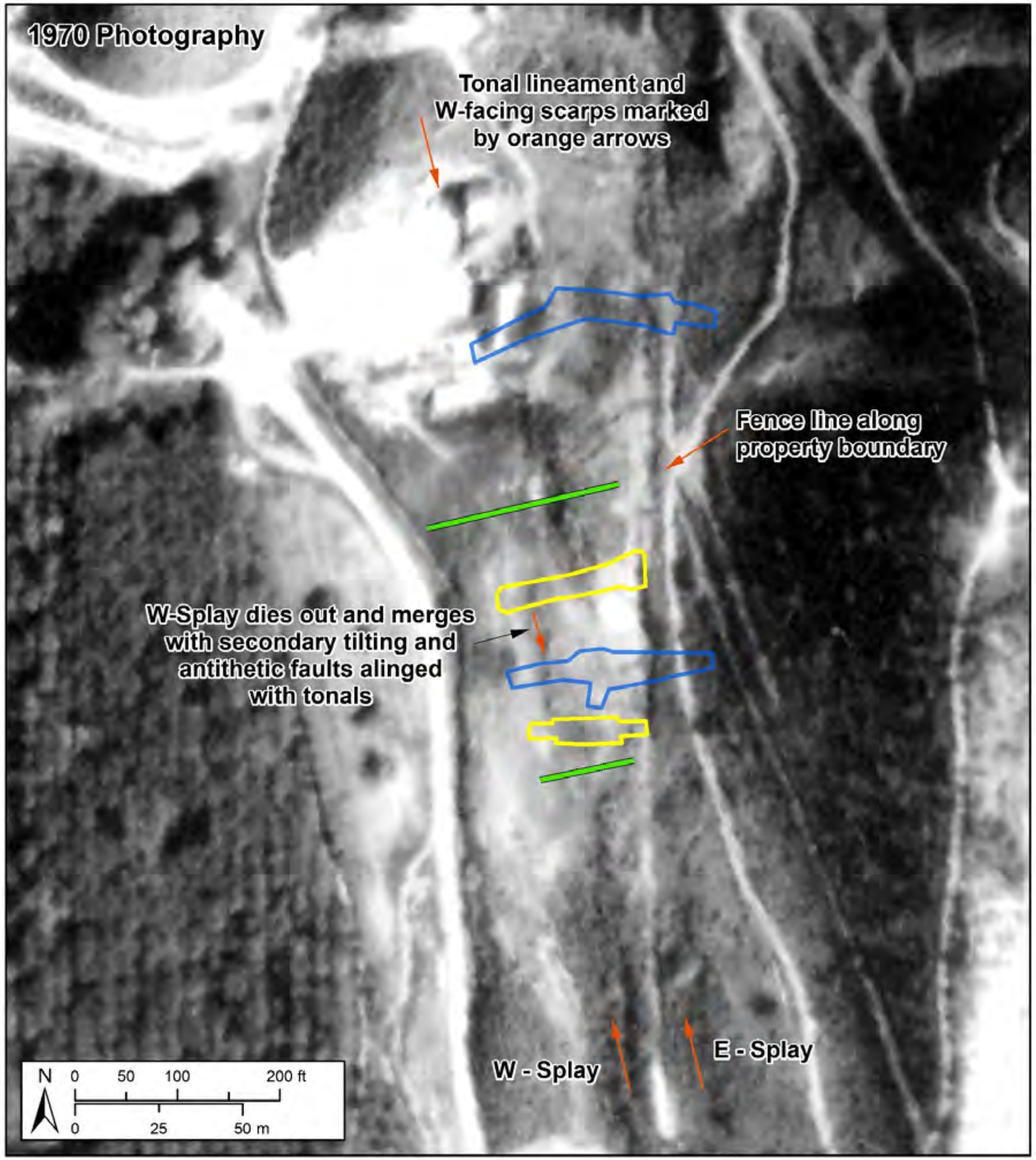
Solomon et al. (2010)

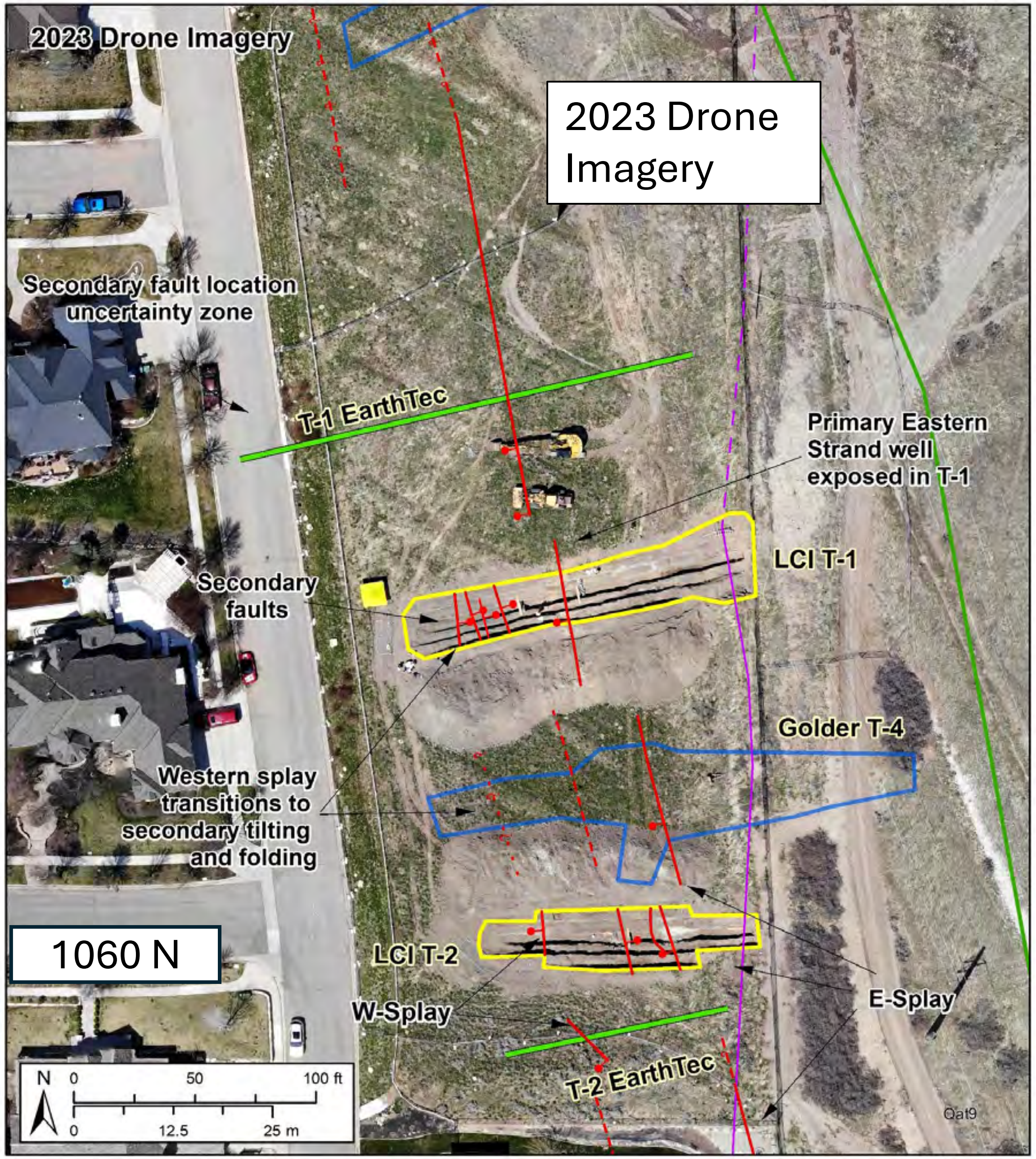
Orem Site Geologic Mapping



Drone Photo Looking south along Western Strand



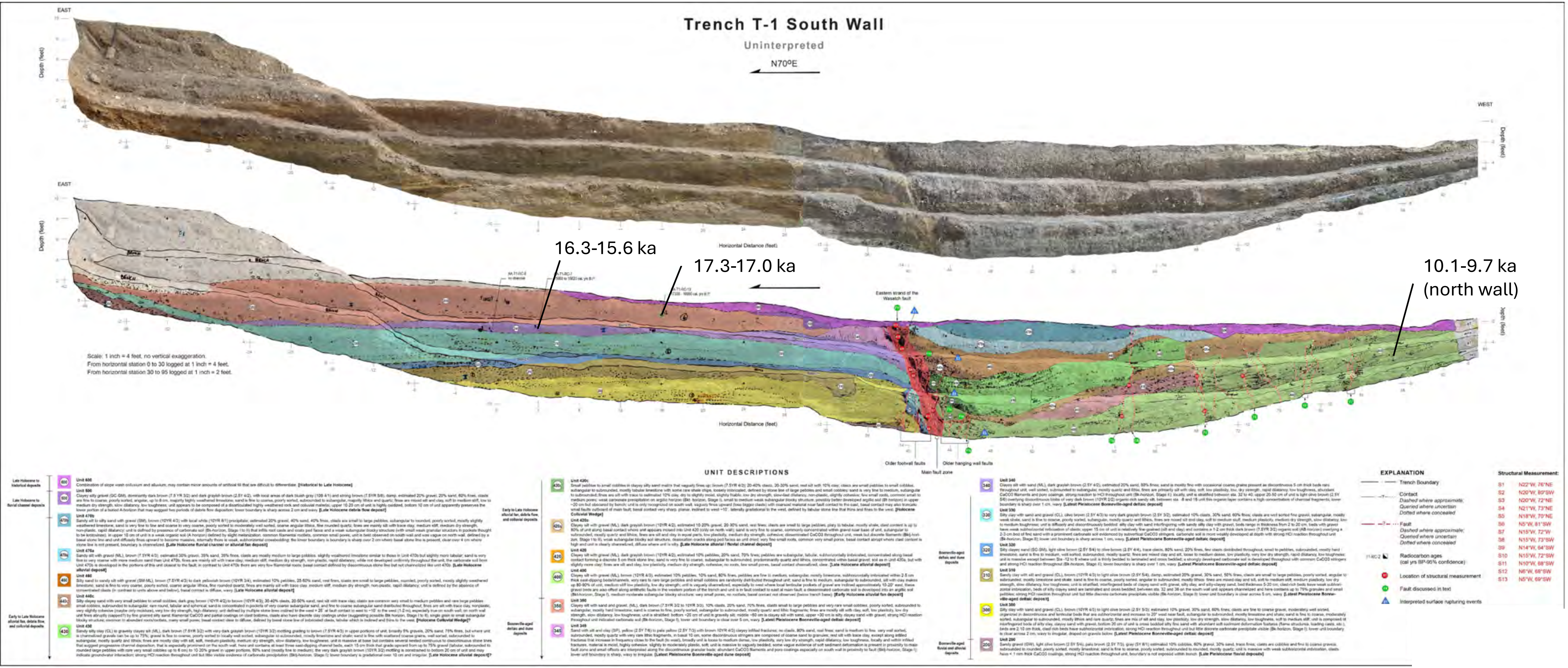

1970 Photography
Tonal lineament and W-facing scarps marked by orange arrows
Fence line along property boundary
W-Splay dies out and merges with secondary tilting and antithetic faults alinged with tonals
W - Splay
E - Splay
N
0 50 100 200 ft
0 25 50 m


2023 Drone Imagery
2023 Drone Imagery
Secondary fault location uncertainty zone
T-1 EarthTec
Primary Eastern Strand well exposed in T-1
LCI T-1
Secondary faults
Golder T-4
Western splay transitions to secondary tilting and folding
1060 N
LCI T-2
W-Splay
E-Splay
T-2 EarthTec
Qat9
N
0 50 100 ft
0 12.5 25 m

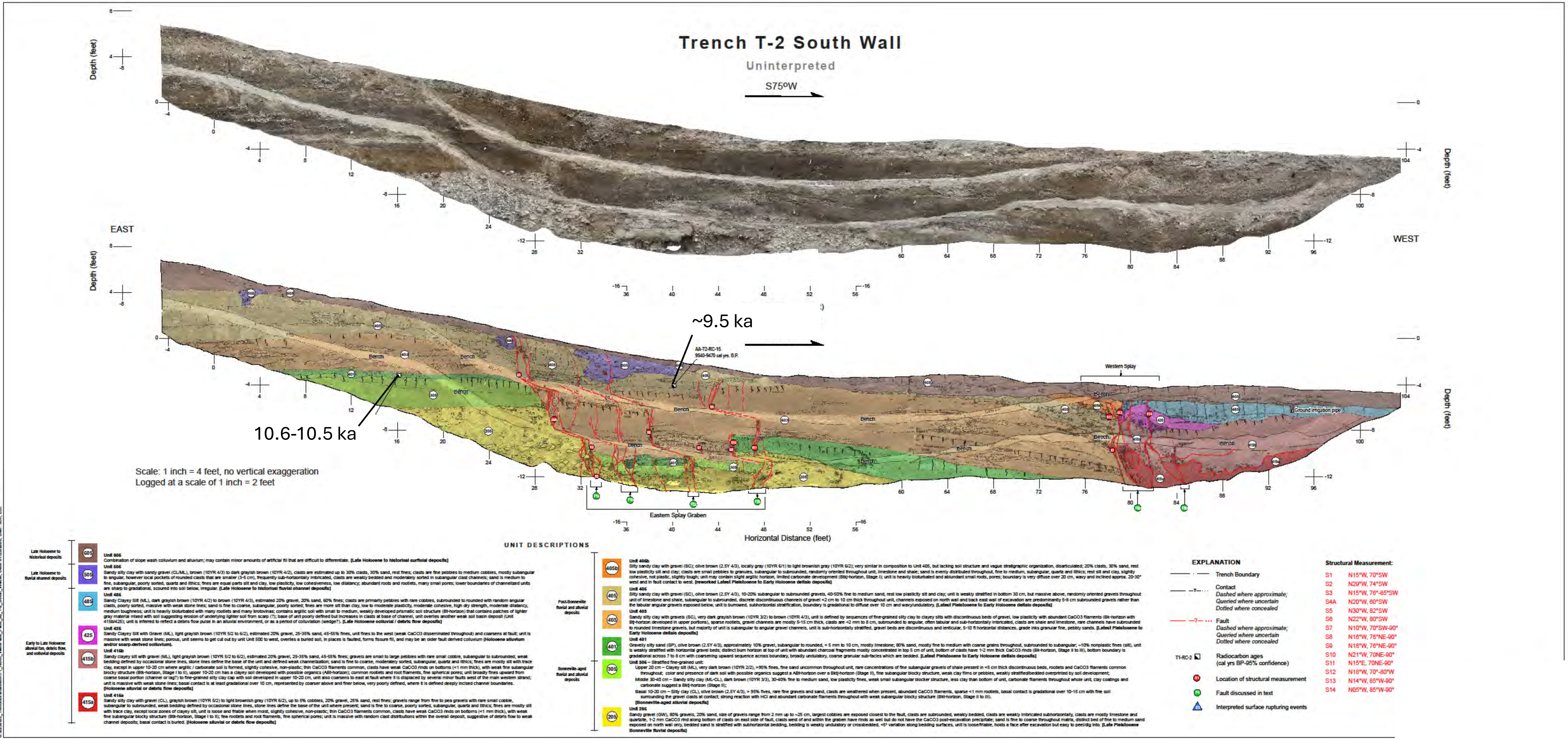
Trench Details

- Excavated in April and May 2023
- T-1 - 150 feet long and 11 to 14 ft. deep
- T-2 - 115 feet long and ≤12 ft deep
- Trench Review April 26th and 27th (UGS and USGS)

Trench T-1 Eastern Fault Strand

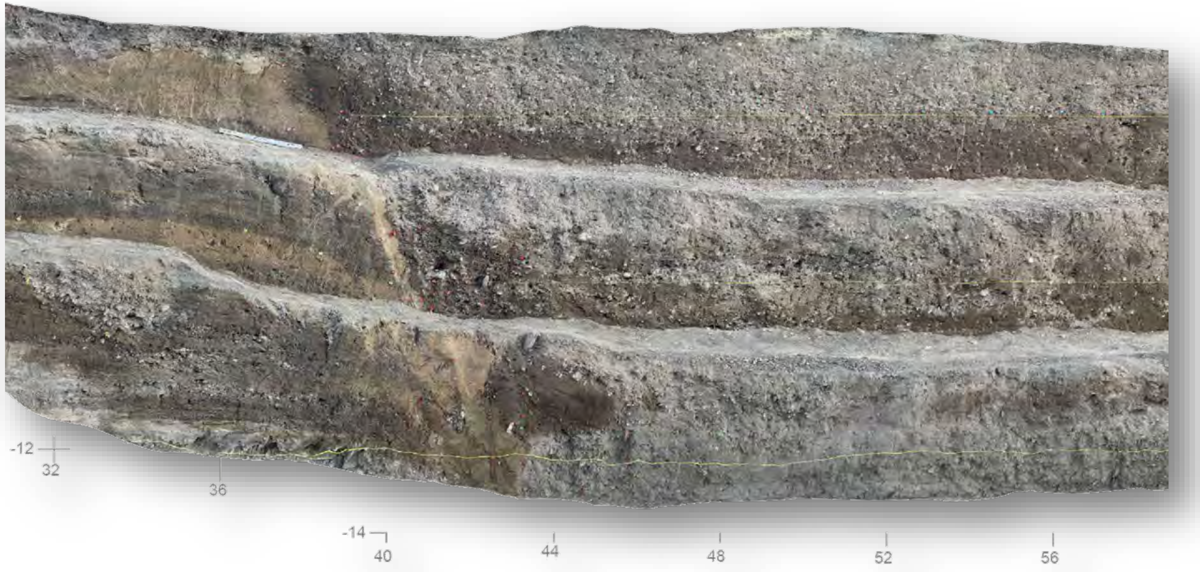


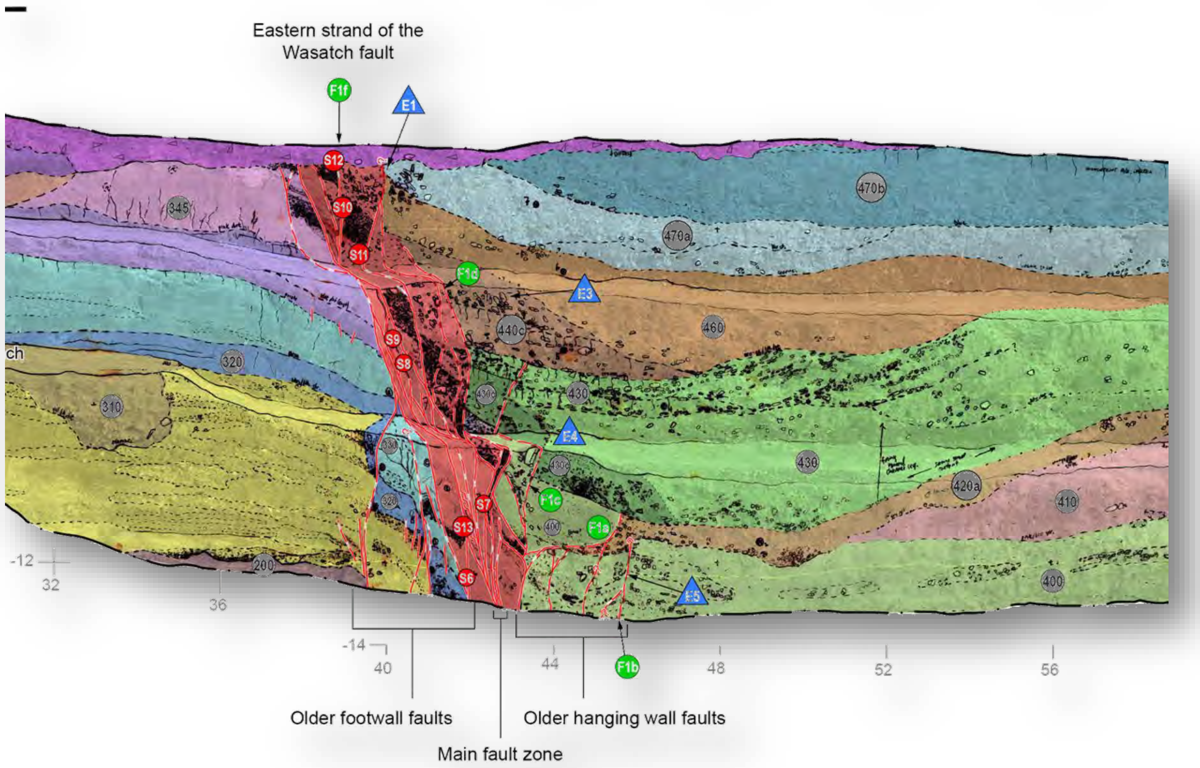
Trench T-2 Eastern Fault Strand



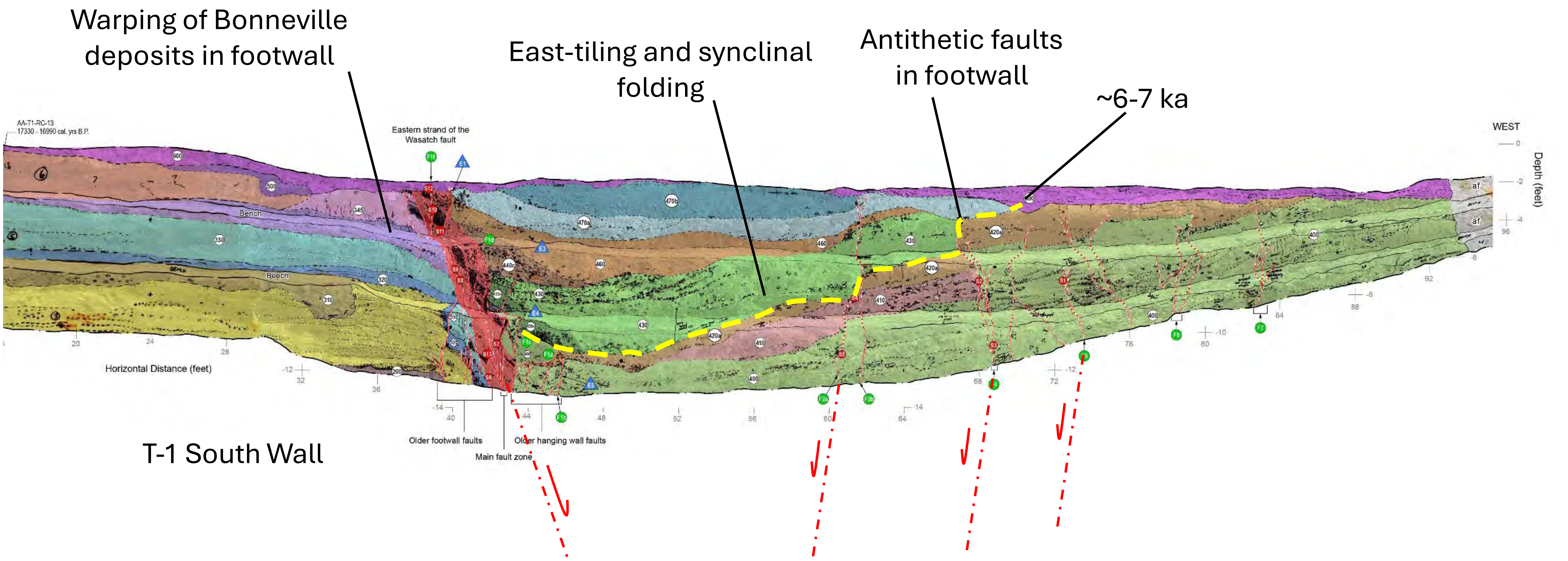
Eastern Fault Strand: Trench Results

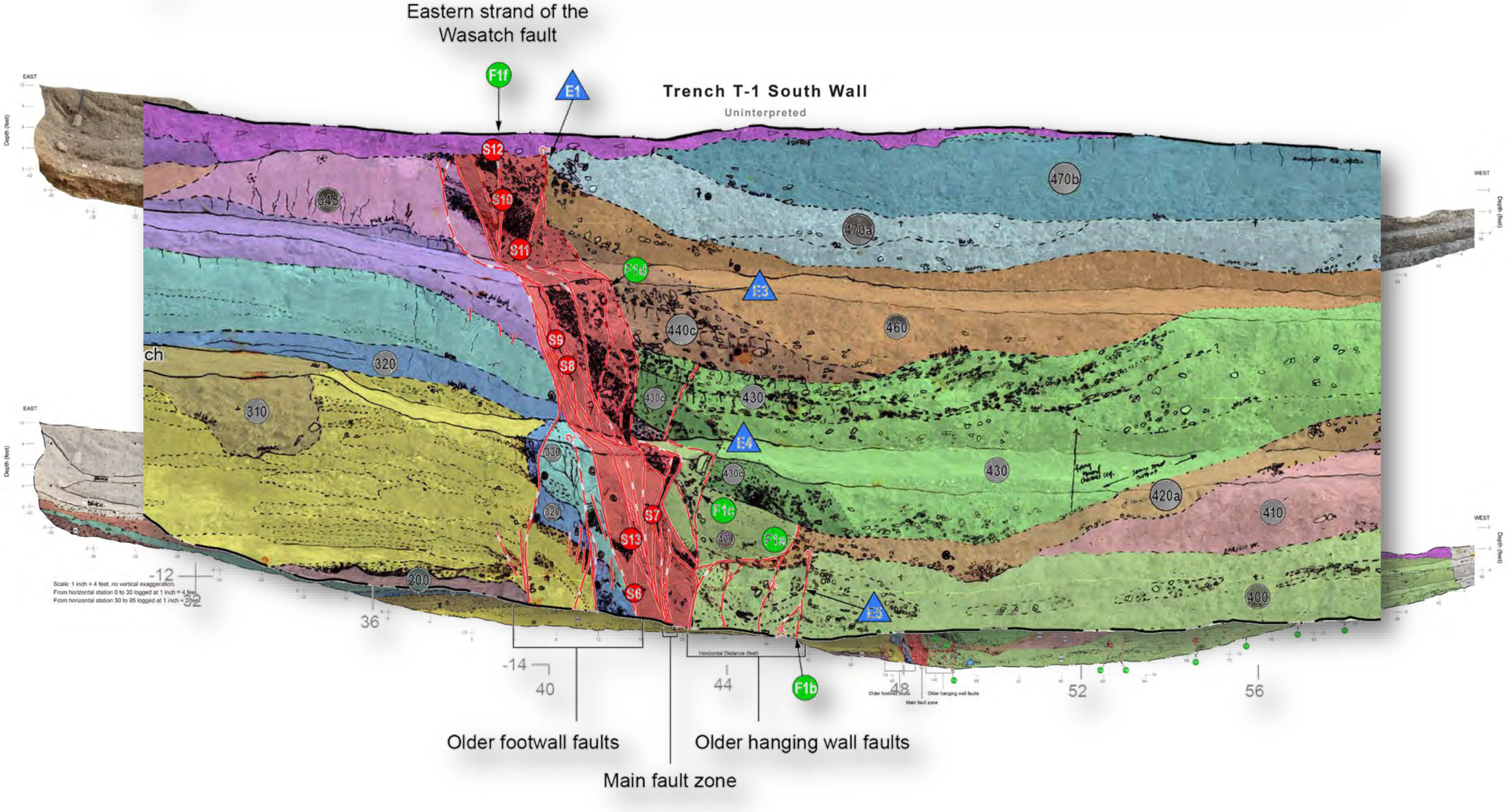
- Lake Bonneville deposits overlain by late Pleistocene-Holocene alluvial, colluvial and fluvial deposits
- About 1m' wide zone primary faulting and broad zone of antithetic faulting define graben structure
- Dips of 60-70 degrees west along primary fault and 70-85 degrees (E and W) along antithetic faults
- A least four paleo-events (E1 to E4) interpreted as colluvial wedges of variable thickness
- MRE (E1) approaches ground surface and capped by fill (surface modified)





Eastern Fault Strand: Graben





Eastern strand of the Wasatch fault
Trench T-1 South Wall
Uninterpreted
F1f
E1
S12
S10
S11
F1d
E3
345
470b
470a
440c
460
320
310
S9
S8
430c
430
E4
330
430c
430
420a
410
320
F1c
S7
S13
F1a
400
200
S6
E5
400
Scale: 1 inch = 4 feet, no vertical exaggeration.
From horizontal station 0 to 30 logged at 1 inch = 4 feet.
From horizontal station 30 to 95 logged at 1 inch = 2 feet.
-12
36
-14
40
44
F1b
48
52
56
Horizontal Distance (feet)
Older footwall faults
Older hanging wall faults
Main fault zone
EAST
WEST
Depth (feet)

Orem Site - OSL Results

- Collected 6 OSL samples
- Samples run at DRI (Dr. Rodrigues)
- SAR
- One sigma ages

Event Timing

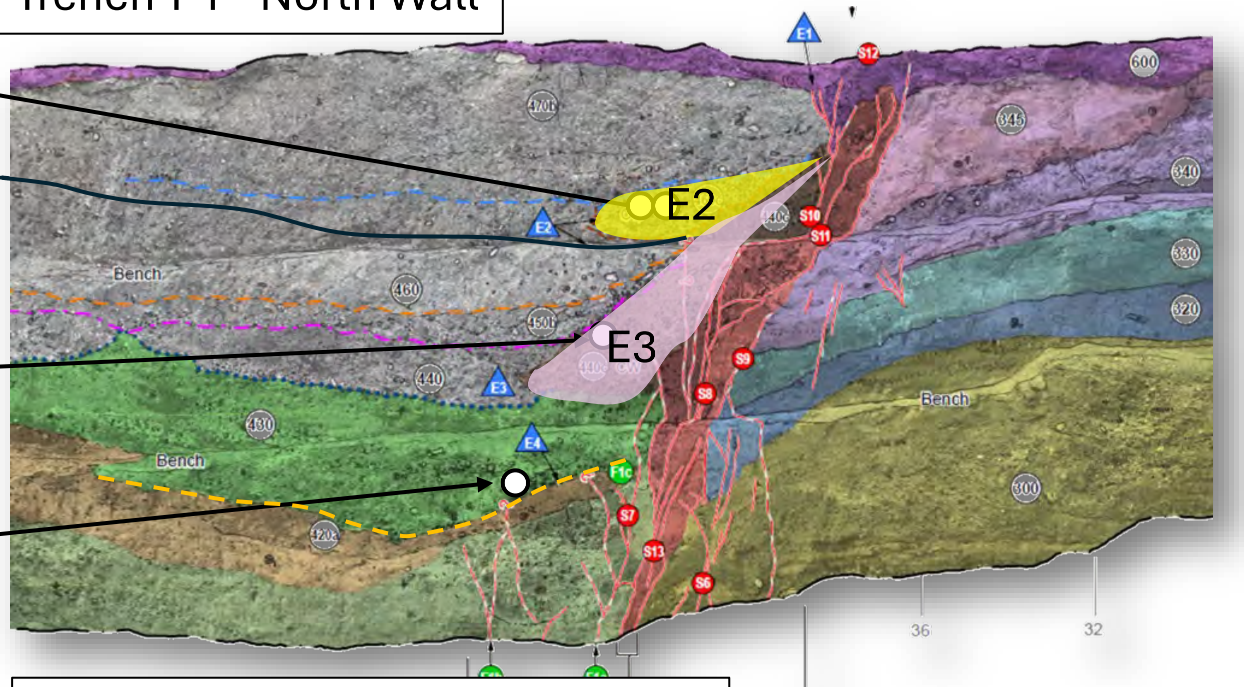
- 4 Events in 6.0-7.2 ka

Trench T-1 - North Wall

2.1 – 2.6 ka

4.3– 5.0 ka

6.0 – 7.2 ka



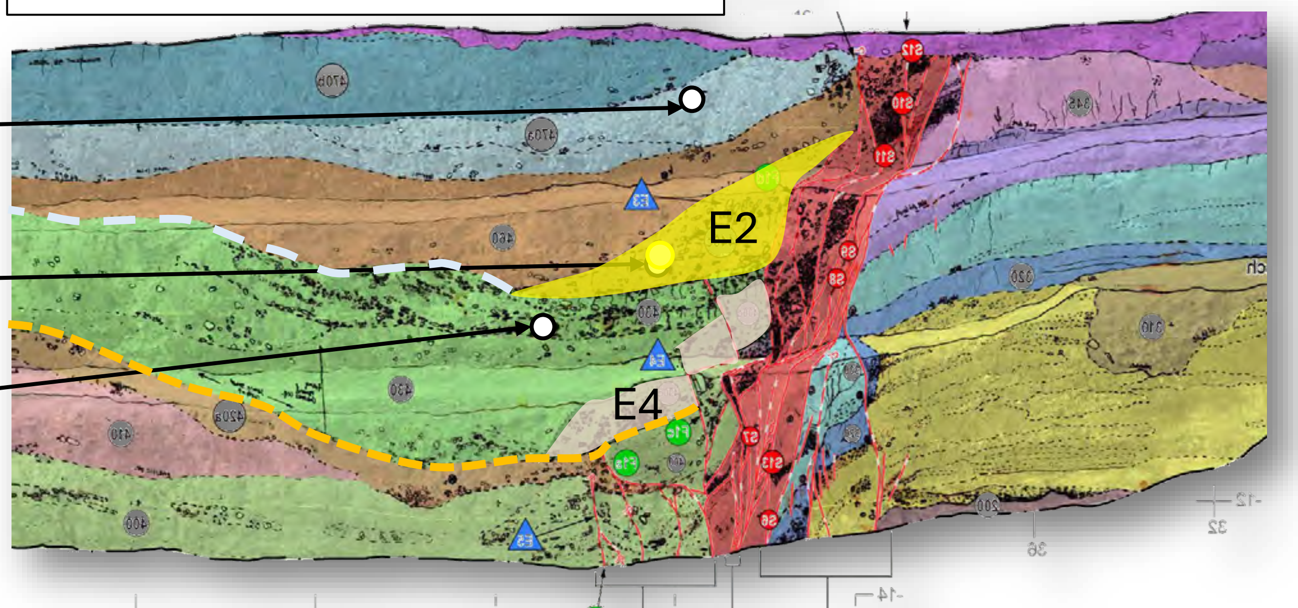
Trench T-1 - South Wall (inverted)

Too Old?

3.1– 3.9 ka

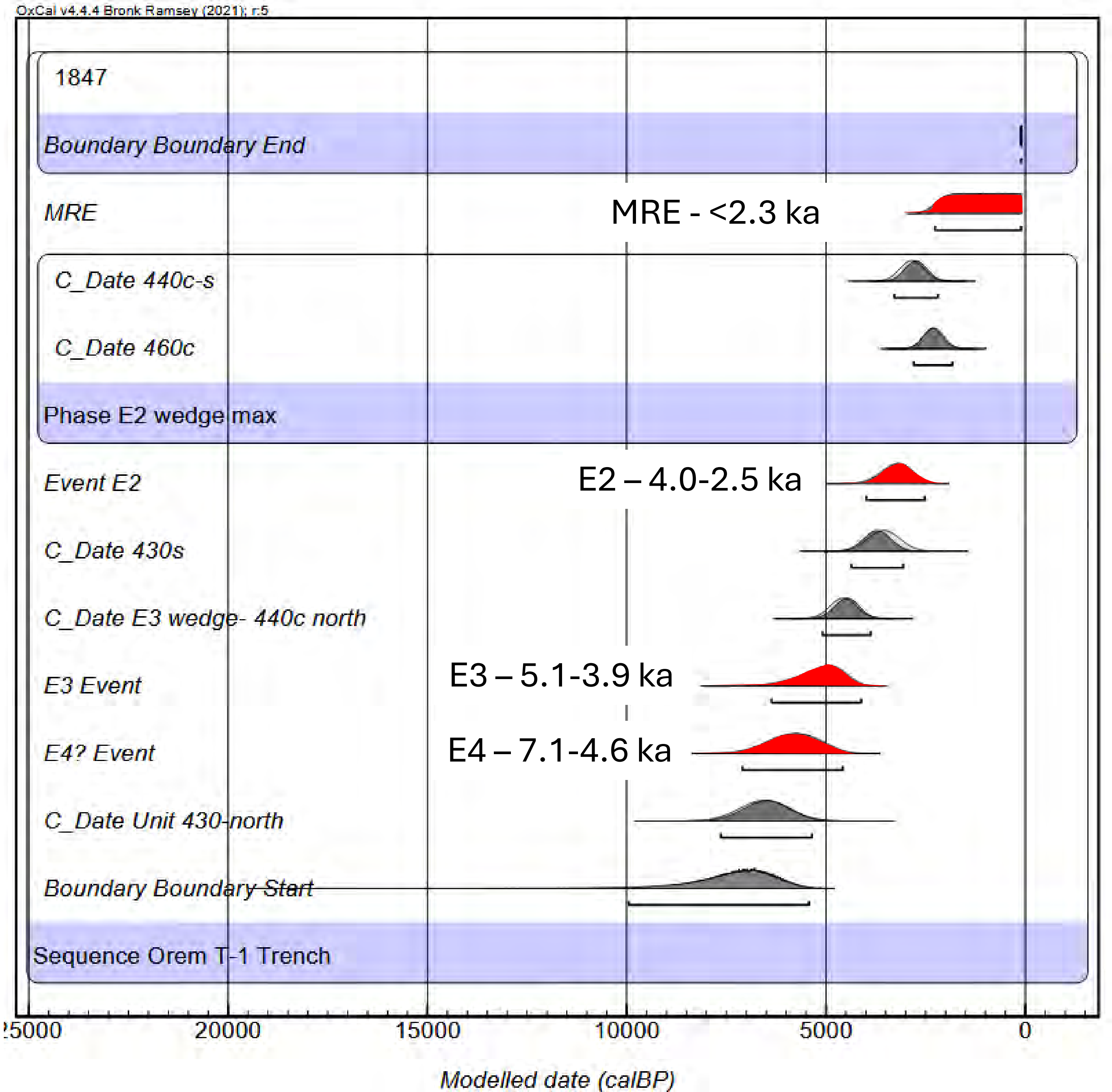
2.6 – 3.2 ka

3.2 – 4.0 ka



Orem Site – Event Timing

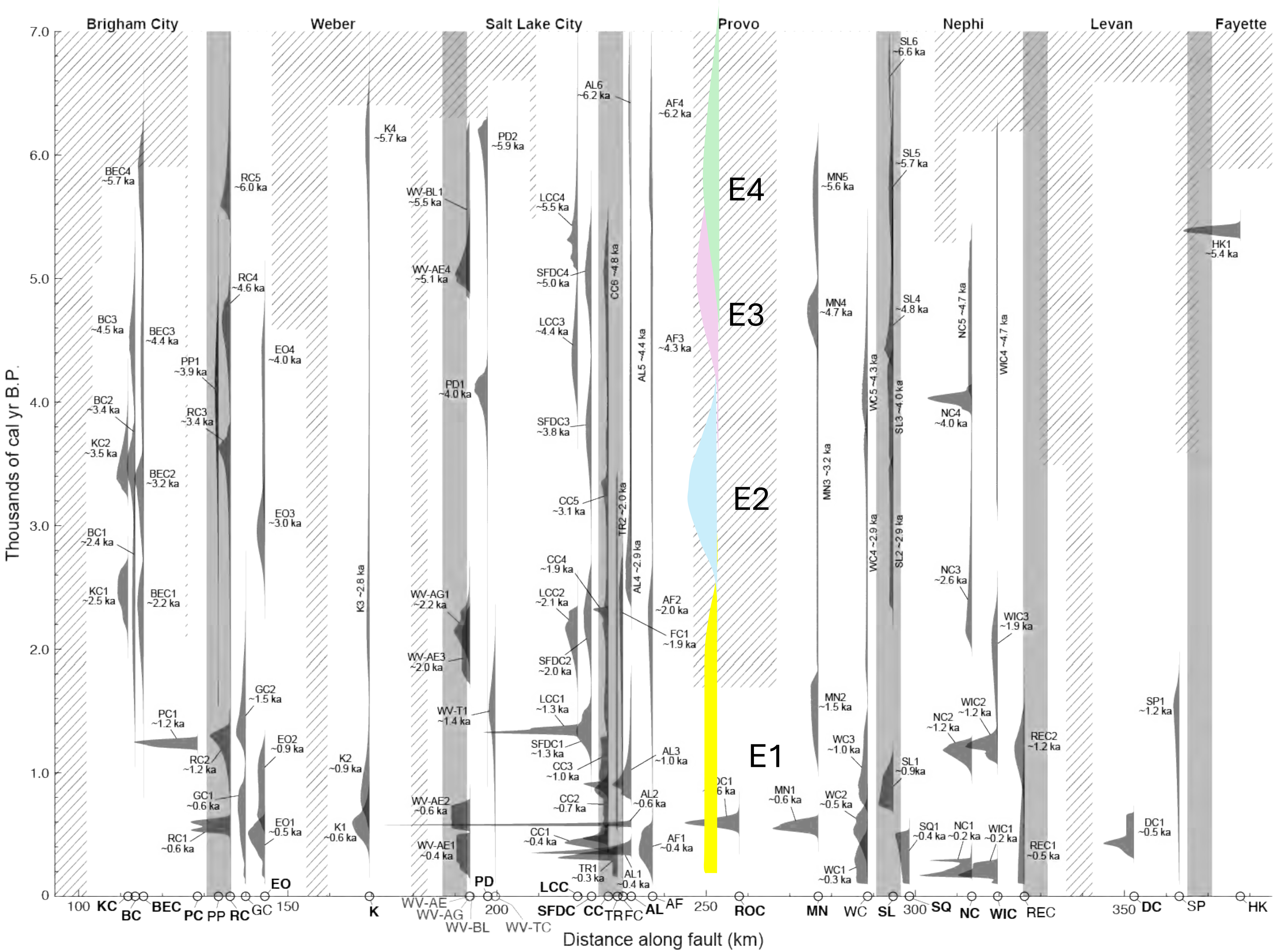
- Oxcal Model (OSL)
  - Grouping E2 wedge OSL dates in phase
  - Assume wedge ages are minimums
  - 95% confidence limits shown
- Event Summary
  - MRE < 2.3 ka – One or two events
  - E2 - 2.5-4.0 ka – Best constrained
  - E3 – 5.1-3.9 ka – well constrained minimum
  - E4? – 7.1-4.6 ka - poorly constrain minimum



Wasatch Fault Zone Event Timing (DuRoss, 2025 Feb Draft)

Comparison with Orem Site

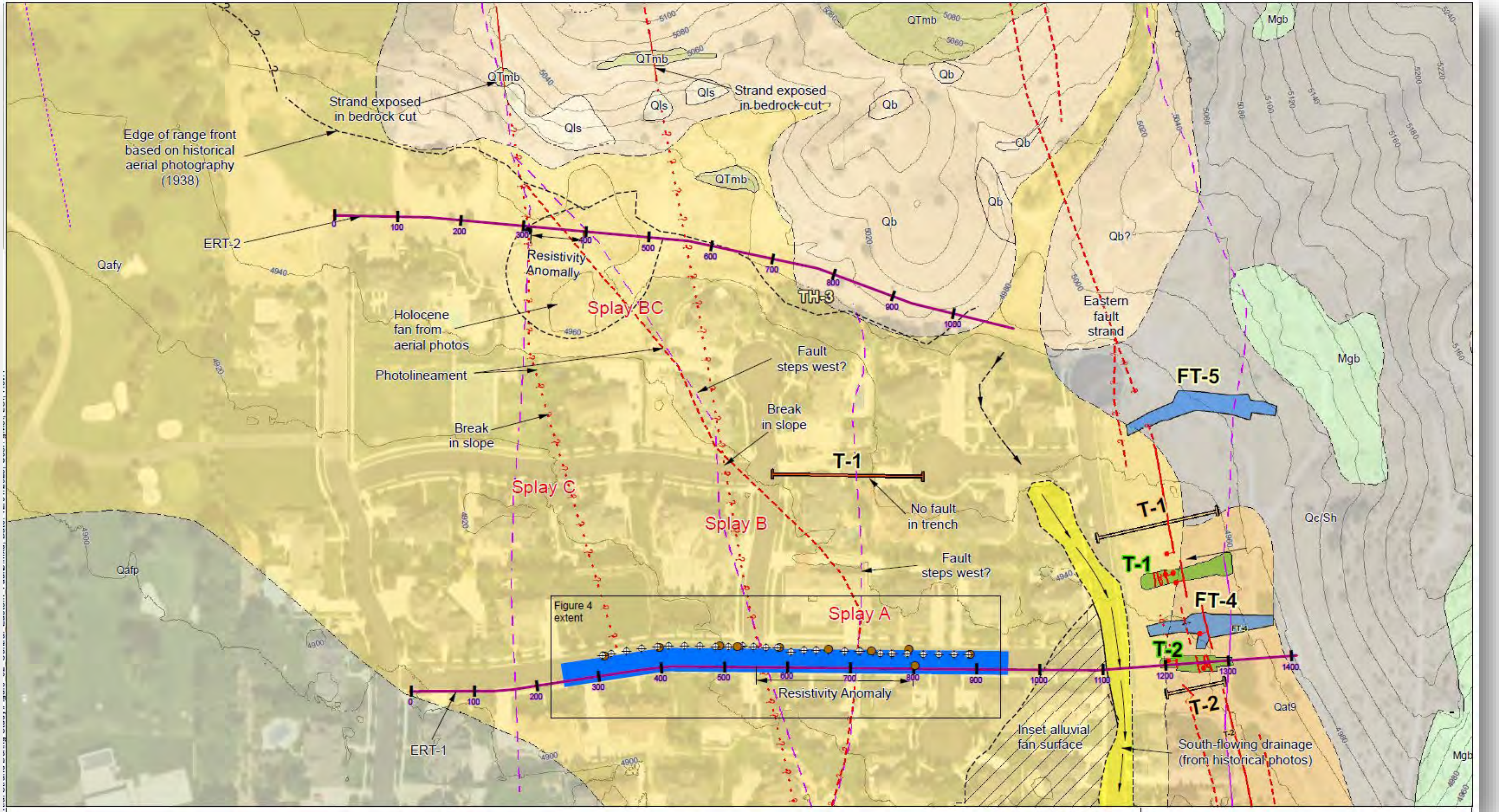
- Event Timing
  - MRE < 2.3 ka – One or two events
  - E2 - 2.5-4.0 ka – Best constrained
  - E3 – 5.1-3.9 ka – well constrained minimum
  - E4? – 7.1-4.6 ka - poorly constrain minimum
- New event Timing Info for older part of the paleoseismic record
- Overlaps with events at AF and MN to the north and south
  - E4 = P5
  - E3 = P4
  - E2 = MN3 (?)



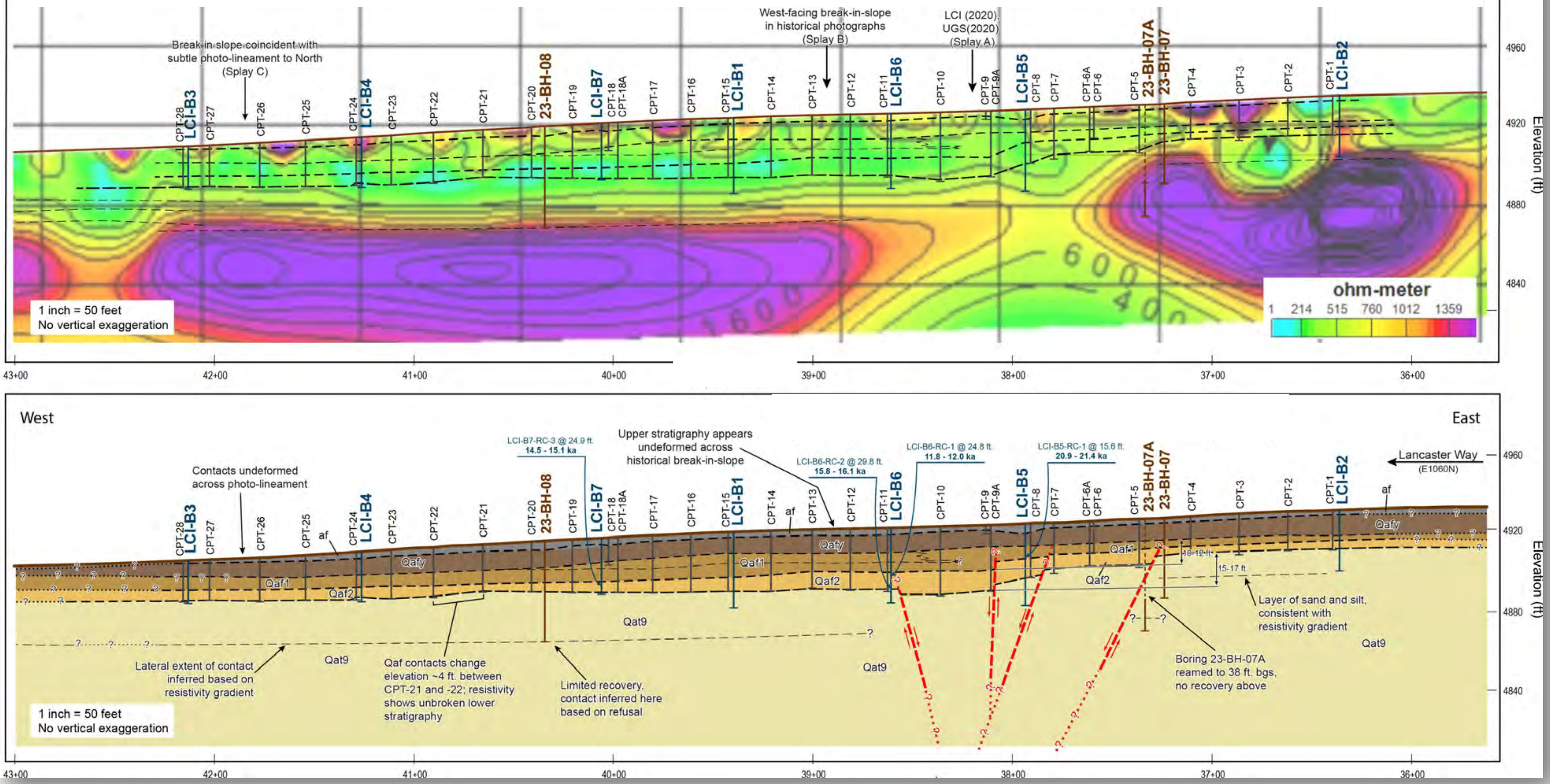
Borehole and CPT Investigation

- Roughly 600 ft long E-W transect across Central fault strand
- 39 CPTs and 7 boreholes to maximum depth of 41.5’ with spacings of 20-25 ft for CPT
- Drilling methods include hollow stem auger (<30 ft) and mud rotary (>30 ft) with CPT’s typically extending to refusal <30 ft bgs

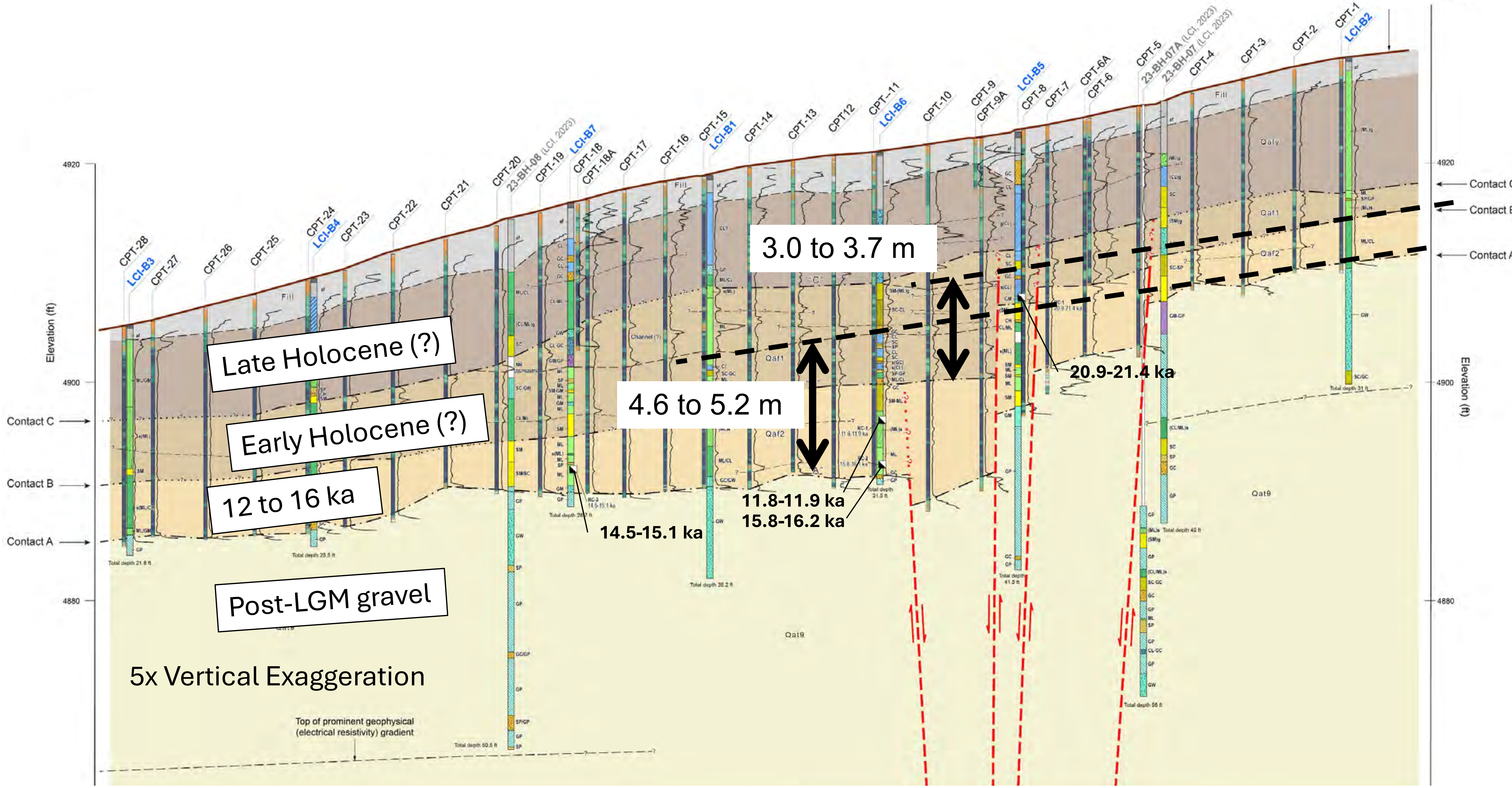
Borehole and CPT Investigation



Electrical Resistivity Profile and CPT/Borehole Transect



Electrical Resistivity Profile and CPT/Borehole Transect



Orem Site – Summary and Conclusions

Trench Investigation:

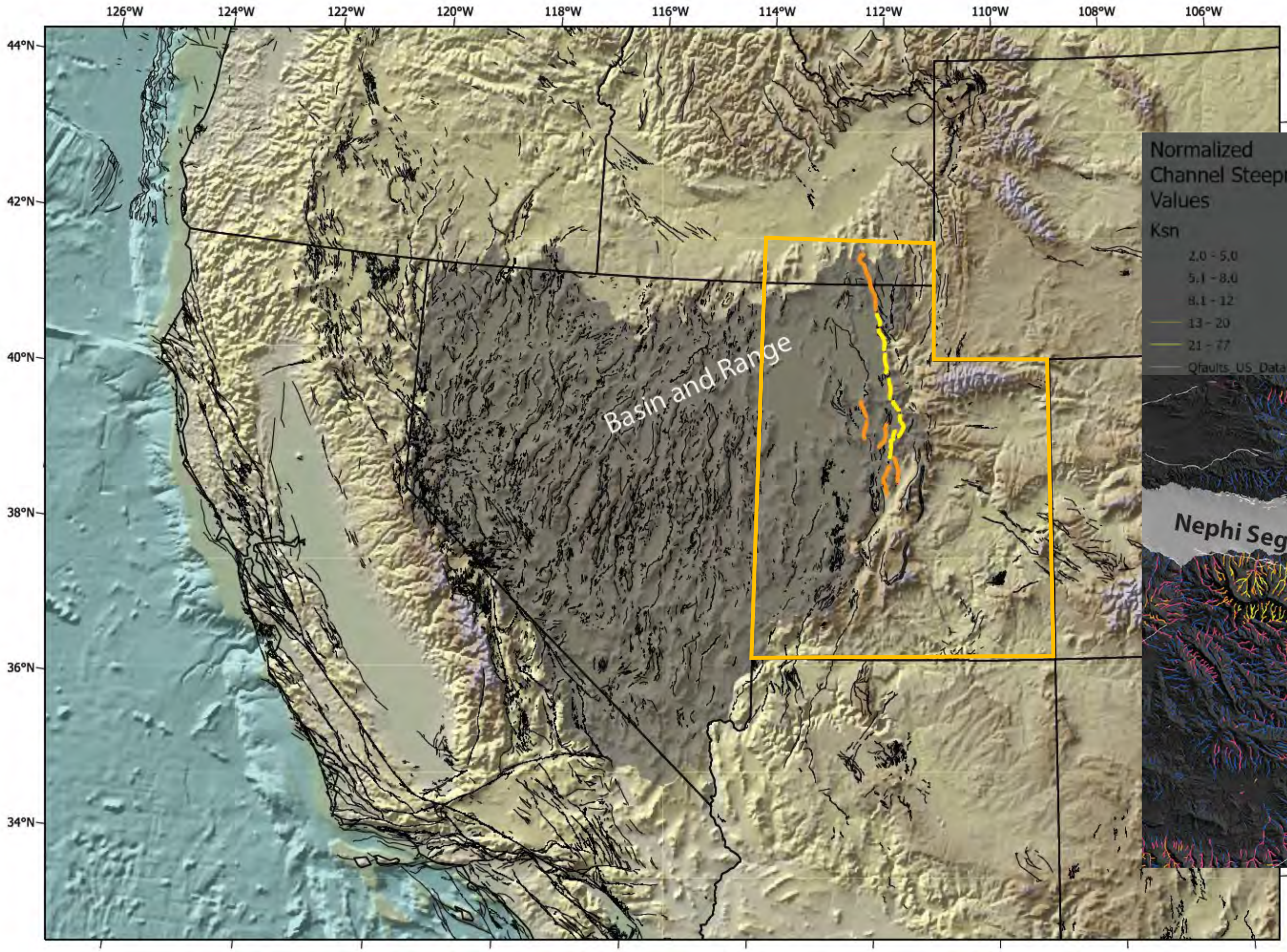
- Eastern Strand includes multiple splays and forms a broad hanging wall graben separating Bonneville deposits (footwall) from early to late Holocene deposits in the hanging wall.
- A least four paleo-events (E1 to E4) interpreted as colluvial wedges of variable thickness
    - MRE (E1) approaches ground surface and capped by fill (surface modified)
- Luminescence Dating (SAR, n=6) establish events stratigraphy between 7.0-2.0 ka
    - Constrain event timing: MRE (E1; <2.3 ka); E2 (2.5-4.0 ka), E3 (5.1-3.9 ka), E4(7.1-4.6 ka)
- Orem Site events generally agree with middle Holocene events, on a poorly section of the fault

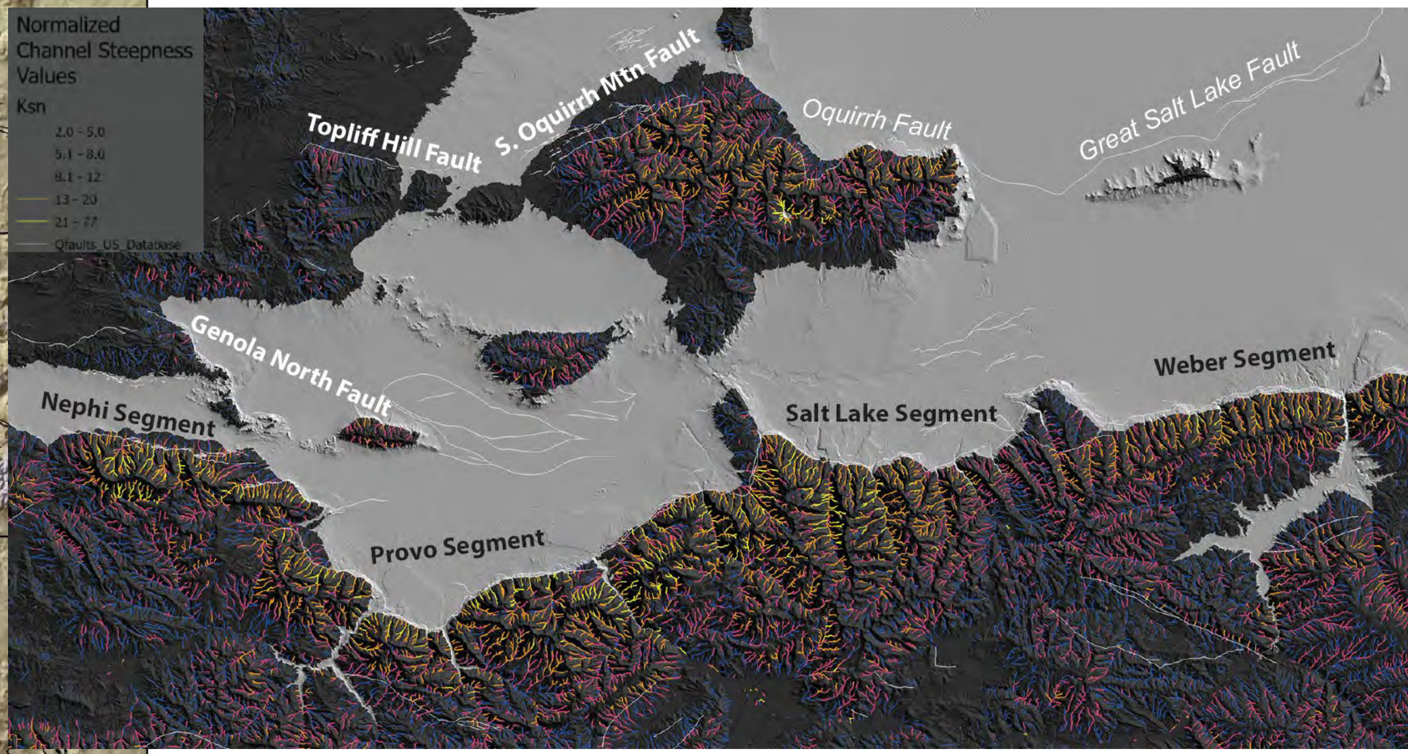
CPT-Borehole Transect:

- Central fault Strand is coincident interpreted faulting in resistivity profile
- Stratigraphy includes: Late Holocene alluvial fan deposits (Qafy), Holocene to latest Pleistocene alluvial deposits (Qaf1/2), Late Pleistocene stream-terrace deposits (Qat9)
- 4.6 to 5.2 m of vertical displacement across the Central Strand (Contact A)
- Central fault strand accommodate west-side-down late Pleistocene and Holocene displacement consistent with a north- to north-northwest striking, west-dipping normal faulting.

Questions?

Examining what can be learned about active faulting in Utah through geomorphic metrics including normalized channel steepness (Ksn) and mountain front sinuosity (Smf)





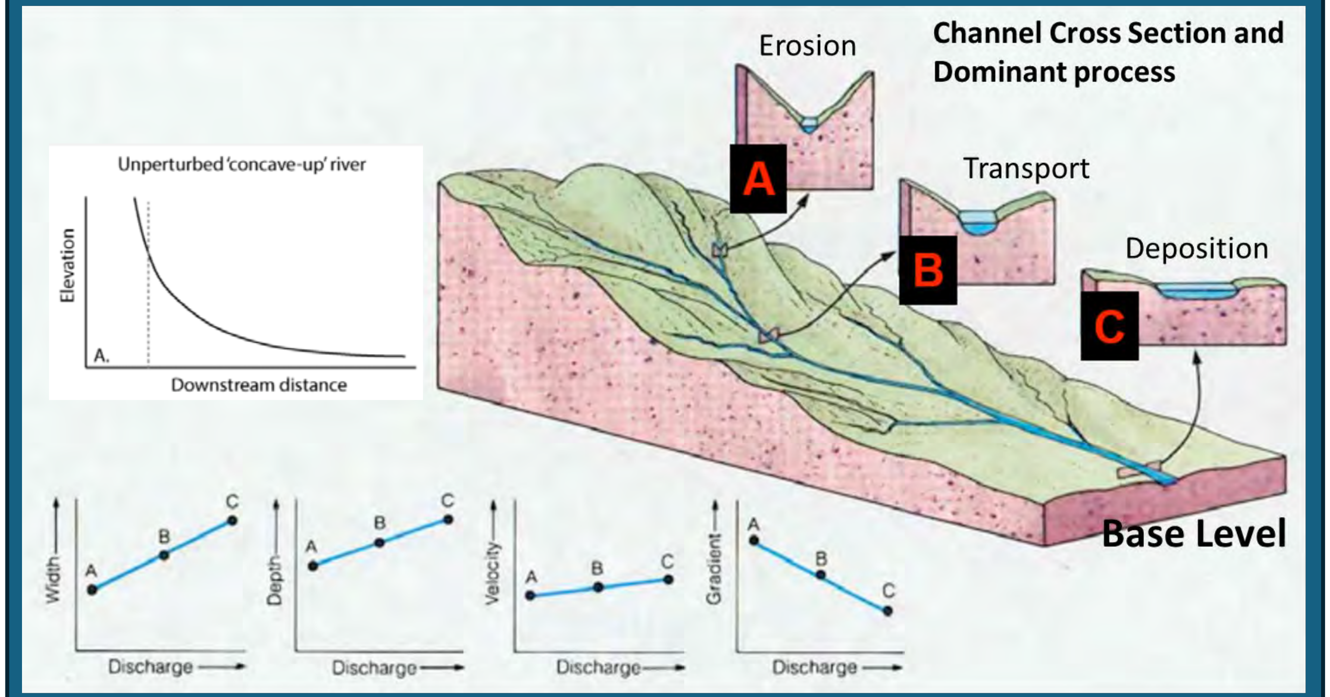
2025 Utah Fault Parameters Working Group Meeting

Prof. **Nathan Toké (UVU)** and

Parker Farnworth (IGES) and Veronica Richards (IGES)

River Downstream Changes

Linear log – log relationships with parameters and Discharge or Area… Power Law



width increases

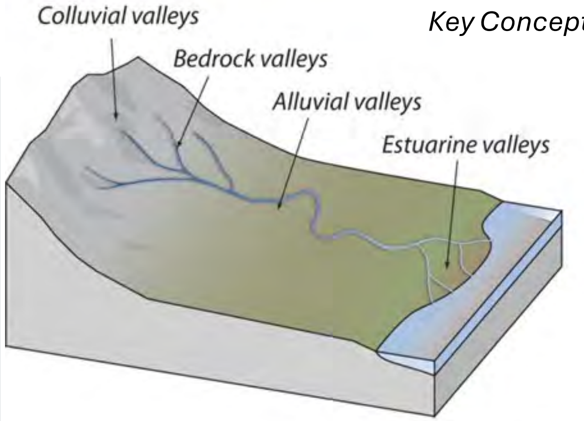
depth increases

velocity increases

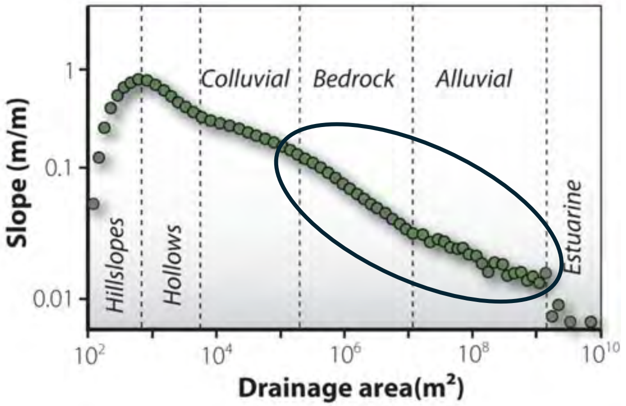
Slope decreases

Colluvial valleys. Found in the headwaters of drainage networks, where hillslope processes deliver sediment to valley bottoms by soil creep and rare episodic processes like **debris flows** and **landslides**. In upland colluvial valleys, sediment is delivered more rapidly than day-to-day fluvial processes can remove it.

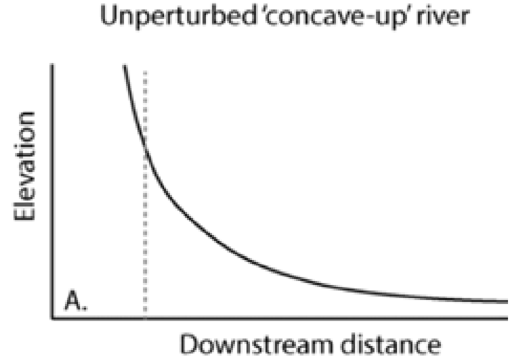
Bedrock valleys. Narrow, steep valley bottoms with little sediment storage and a high capacity for sediment transport. Here the fluvial system can efficiently move the sediment supplied from hillslopes and from upstream.



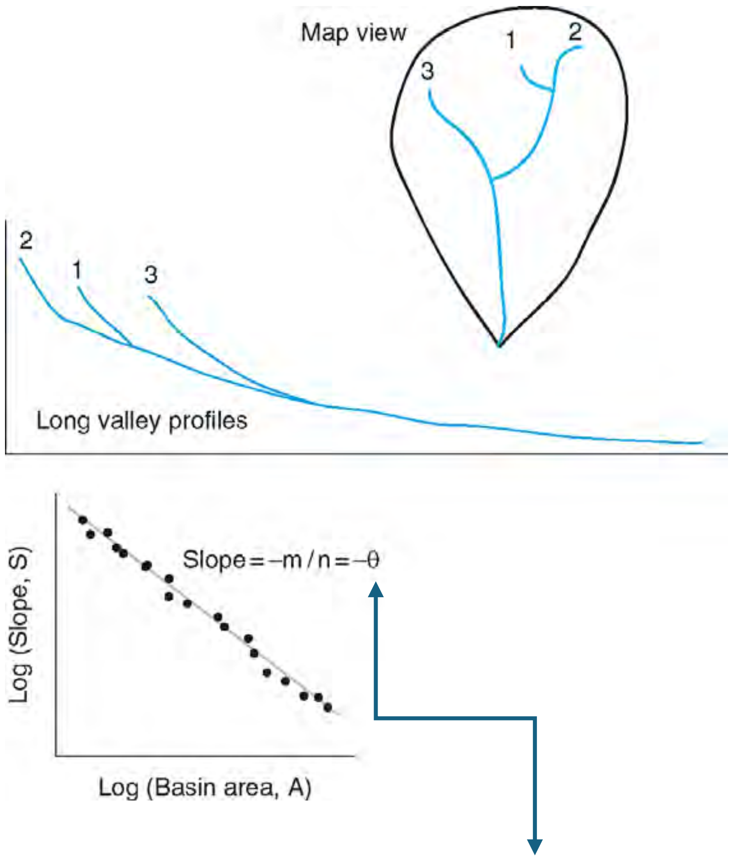
Key Concepts in Geomorphology, Bierman and Montgomery



Alluvial valleys. Low gradient and filled with sediment, streams are usually unable to scour to bedrock. **Floodplains** and **terraces** are common and can store significant amounts of sediment.



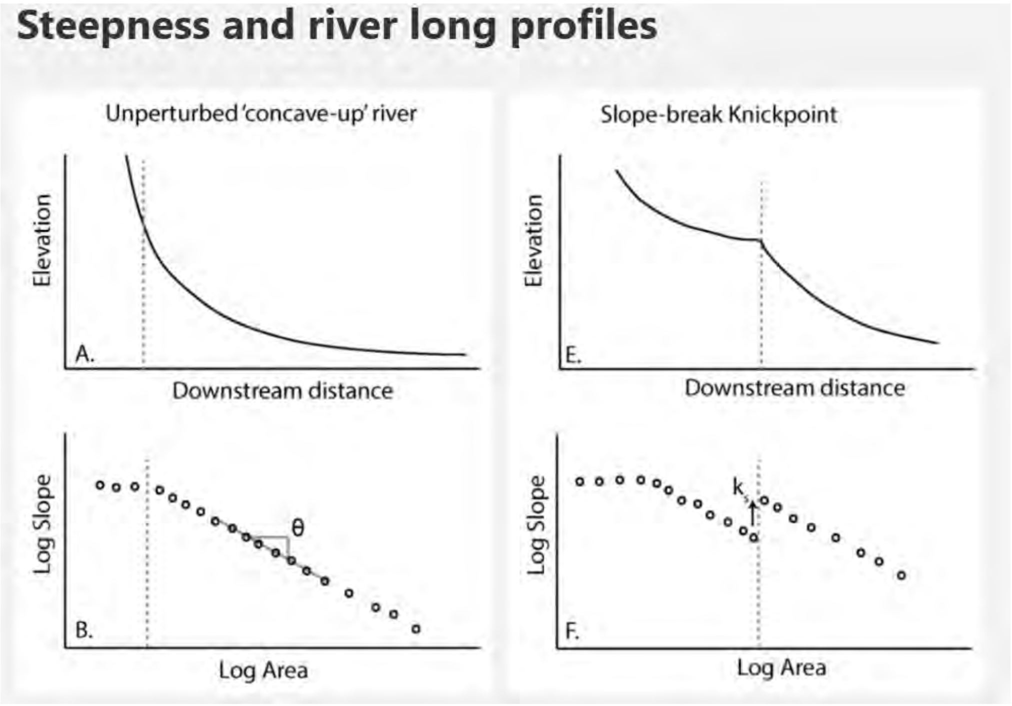
Ksn and Concavity



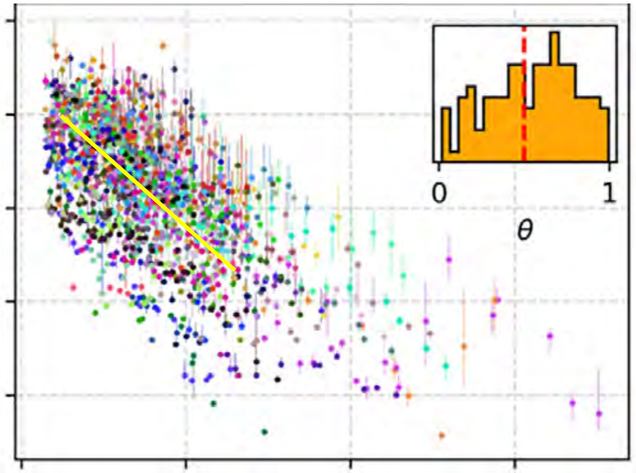
$$S = K_{sn} A^{-\theta}$$

K_{sn} = steepness index

θ = concavity



https://geomorphonline.github.io/fluvial/concavity_steepness/



Reference Concavity 0.45

Calculating Normalized Channel Steepness: SRTM, TopoToolbox, TAK, and Subsetting

We used TopoToolbox following the approach outlined in the Ksn User Guide and Topographic Analysis Kit (e.g., Forte and Whipple, 2019) to calculate Ksn values using a regional ~30m Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM).

We elected not to use high resolution (1-meter) lidar data because it did not yield significantly different results in our pilot analyses and using SRTM allowed us to examine the whole region.

We only processed the Ksn values within the mountains, and we subsetted the data to examine Ksn in areas of varying rock strength (Figure 11) and glacial history (Table 1).

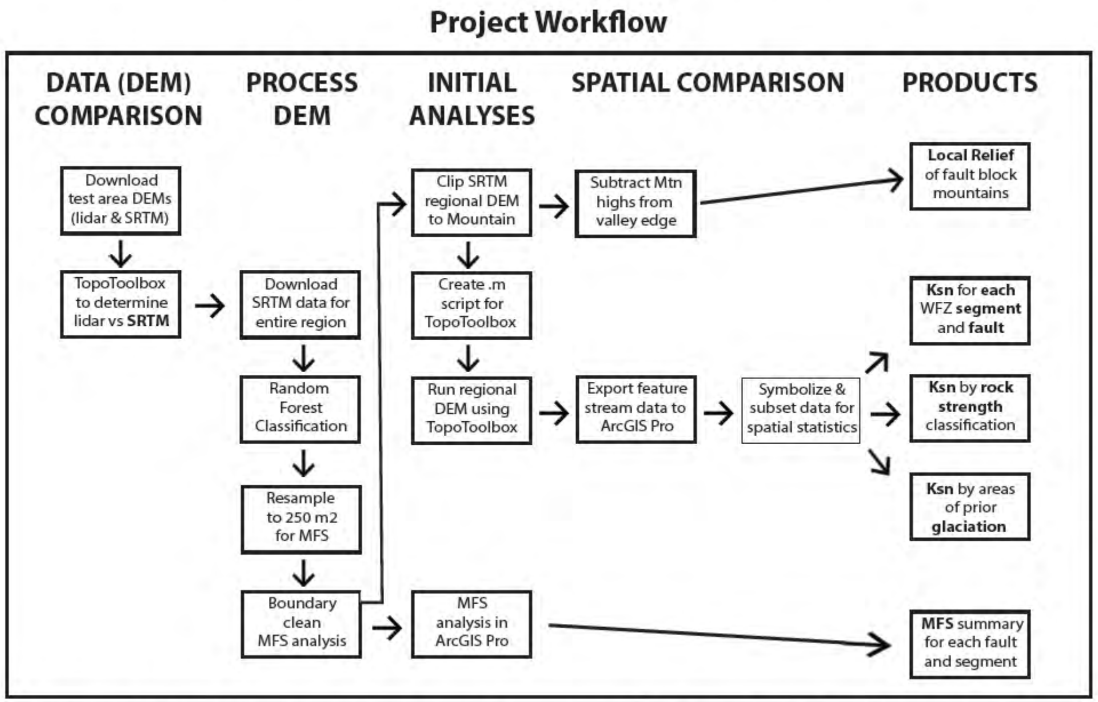
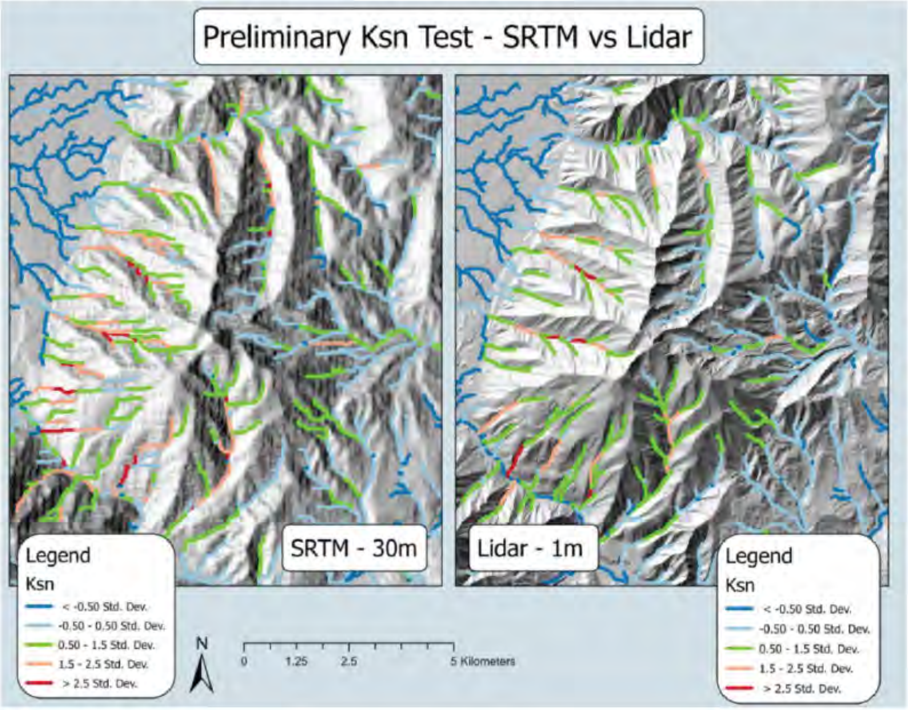


Figure 5. Workflow for calculating Ksn values, MFS, and relief within fault-bounded ranges of the eastern Basin and Range in Utah. We clipped out valley floor areas using the RF classification for the mountain front sinuosity analysis and used this to clip the DEM for both analyses of local relief (Figure 2) and Ksn analyses (Figure 7). We then subset areas of Ksn analysis within the ranges faulted by the Wasatch and other faults (Figure 8). We also subsetted the data to examine the role of rock strength (Figure 9) and history of glaciation (Table 1) within the Wasatch Range.

Figure 6. We explored utilizing high resolution lidar to run the Ksn analyses. However, while we found small differences in the values of Ksn from the SRTM and Lidar data sets, they were quite similar. Symbolizing the Ksn values by standard deviation nicely shows that the SRTM results are consistent with using a higher resolution lidar DEM. We elected to use the SRTM data across the region for computational efficiency and so we could examine areas without lidar coverage.



Calculating Mountain Front Sinuosity using Random Forest Classification

Random Forest (RF) classification was used to classify the parts of the landscape that were valley lowlands and mountain uplands and objectively establish the position of the mountain front.

For the RF classification we created a multi-band (n=6) terrain raster consisting of the DEM and derivative rasters of slope, curvature, aspect, hillshade, and a simple unsupervised classification raster of geomorphic landforms.

An accuracy assessment of the RF classification along the Wasatch fault yielded Kappa values from 0.93 to 0.97, having better accuracy on segments that ultimately had straighter mountain fronts (Figure 3).

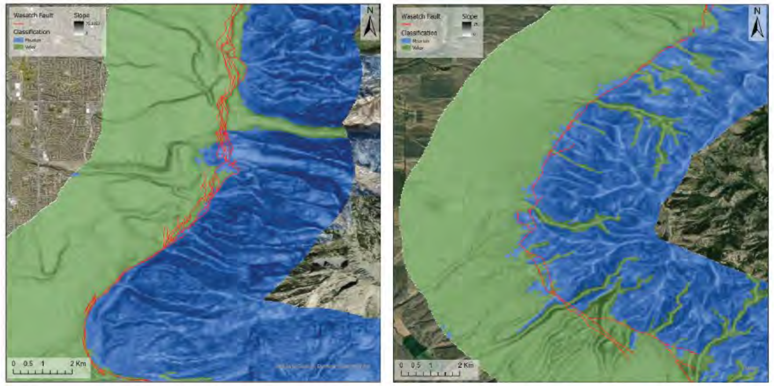


Figure 3. The Random Forest classification of mountain (blue) vs valley (green) was more accurate on straighter mountain fronts with higher fault activity than on mountain fronts with higher sinuosity and lower activity. For example, a section of the Salt Lake City mountain front classification is shown above (0.97 Kappa and MFS = 1.2) in comparison with the Malad City mountain front (0.93 Kappa and MFS = 1.4; Table 1) which was estimated to be 20% more sinuous.

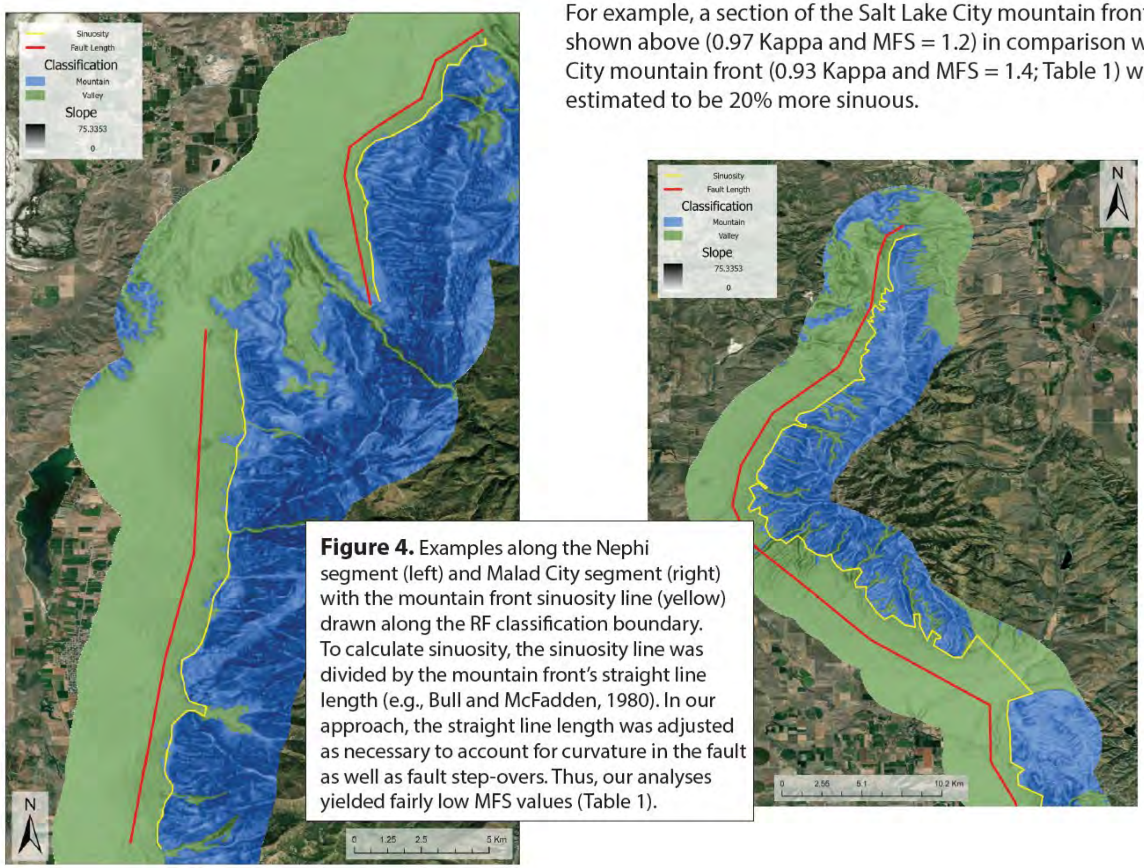
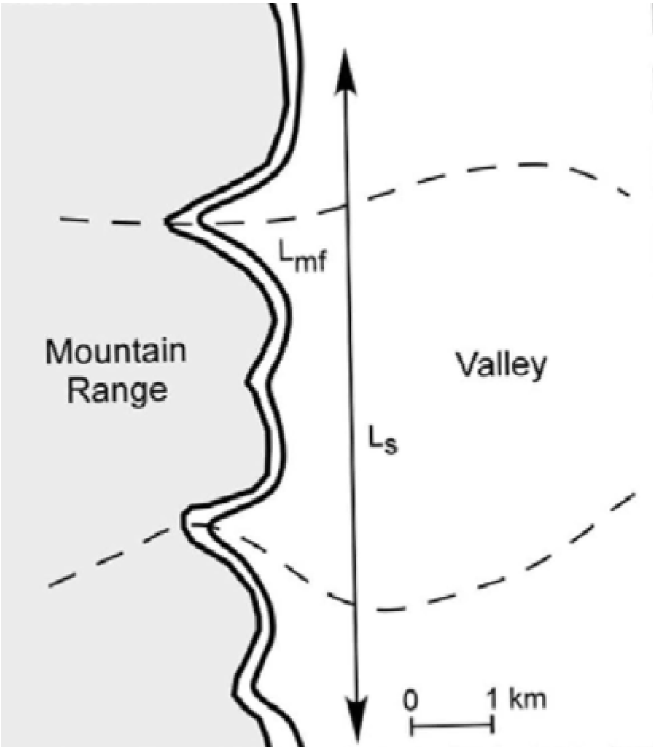


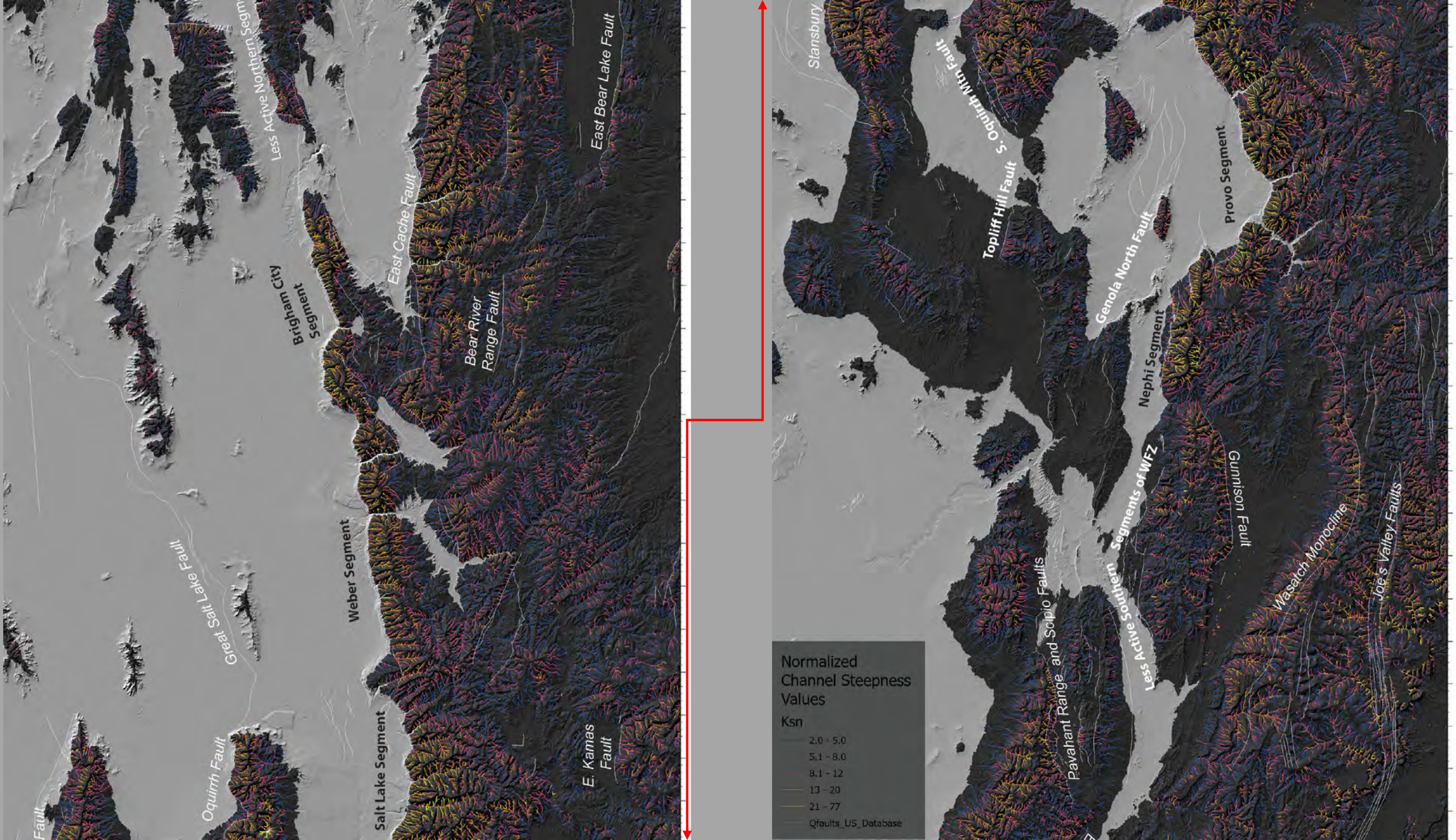
Figure 4. Examples along the Nephi segment (left) and Malad City segment (right) with the mountain front sinuosity line (yellow) drawn along the RF classification boundary. To calculate sinuosity, the sinuosity line was divided by the mountain front's straight line length (e.g., Bull and McFadden, 1980). In our approach, the straight line length was adjusted as necessary to account for curvature in the fault as well as fault step-overs. Thus, our analyses yielded fairly low MFS values (Table 1).

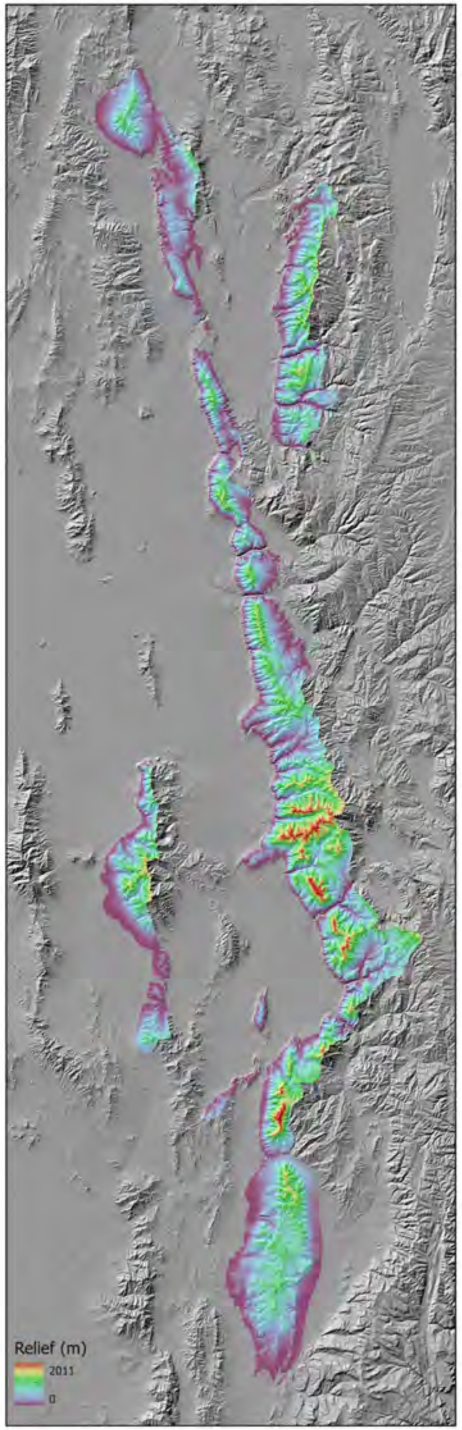


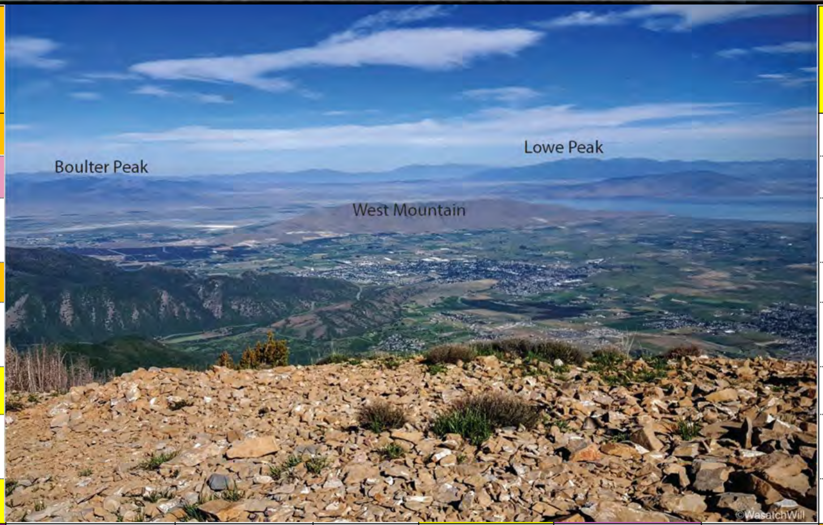
Keller et al., 1996

$$S_{mf} = L_{mf}/L_s$$

Closer to 1 = more actively uplifting


Less Active Northern
East Bear Lake Fault
East Cache Fault
Brigham City Segment
Bear River Range Fault
Weber Segment
Great Salt Lake Fault
Oquirrh Fault
Salt Lake Segment
E. Kamas Fault
Fault
Stansbury
S. Oquirrh Mtn Fault
Topliff Hill Fault
Provo Segment
Genola North Fault
Nephi Segment
Segments of WFZ
Less Active Southern
Gunnison Fault
Wasatch Monocline
Joe's Valley Faults
Pavahant Range, and Scipio Faults
Normalized Channel Steepness Values
Ksn
2.0 - 5.0
5.1 - 8.0
8.1 - 12
13 - 20
21 - 77
Qfaults_US_Database





Fault *or Segment*	Relief (m)	MFS[1]	Ksn[2] Mean	Ksn Median	Ksn Std. Dev.	Ksn Max	Ksn Strong[3]	Ksn Weak[4]	Ksn Glacial[5]	Est. Vertical Slip Rates[6]
WFZ Central Segments	**2,011**	**1.2**	**10.9**							**1-2 mm/a**
WFZ BCS	**1,342**	**1.2**	**10.6**							
WFZ WS	**1,343**	**1.2**	**9.8**							
W-SLC Seg. Boundary	*1,240*	-	*9.4*							
WFZ SLCS	**1,874**	**1.2**	**10.6**							
SLC-P Seg. Boundary	*1,819*	-	*11.1*							
WFZ PS	**1,950**	**1.2**	**11.2**							
P-N Seg. Boundary	*1,620*	-	*10.8*							
WFZ NS	**2,011**	**1.1**	**12.4**							
Less Active WFZ North	**1,237**	**1.4**	**7.1**	6.0	4.1	35.7	-	-	-	**0.1-0.4 mm/a**
Less Active WFZ South	**1,427**	**1.3**	**6.8**	6.0	4.1	77.1	-	-	-	**0.1-0.4 mm/a**
Southern Oquirrh Mtn. Fault	**1,605**	**2.1**	**7.8**	7.1	4.6	24.3	-	-	-	**0.1-0.2 mm/a**
Topliff Hills Fault	**914**	**2.8**	**4.8**	4.3	2.1	15.4	-	-	-	**0.1-0.2 mm/a**
Genola North Fault	**495**	**1.5**	**6.8**	5.8	3.0	15.1				**0.1-0.2 mm/a**

1- Mountain Front Sinuosity (measured as described in MFS panel)
2- Normalized Channel Steepness (mean) along all channels within the active range front (channels in the range back were not included unless there is evidence of active uplift high Ksn values or range symmetry).
3- Mean Ksn where channels flow over strong rocks (e.g., crystalline, basement rocks of significant age)
4- Mean Ksn where channels flow over weak rocks (e.g., shales, mudstones, Quaternary and Cenozoic non-crystalline and weakly lithified units)
5- Mean Ksn of channels which flow through previously glaciated terrain.
6- Estimated Holocene and late Pleistocene vertical slip rates from paleoseismic investigations: Genola North Fault (Smith et al., 2022); Topliff Hills Fault (Toke et al., 2021); Southern Oquirrh Mountain Fault (Olig et al.,1996 and 2001); Less Active WFZ (UGS FF Database) WFZ central segments (DuRoss et al., 2016)

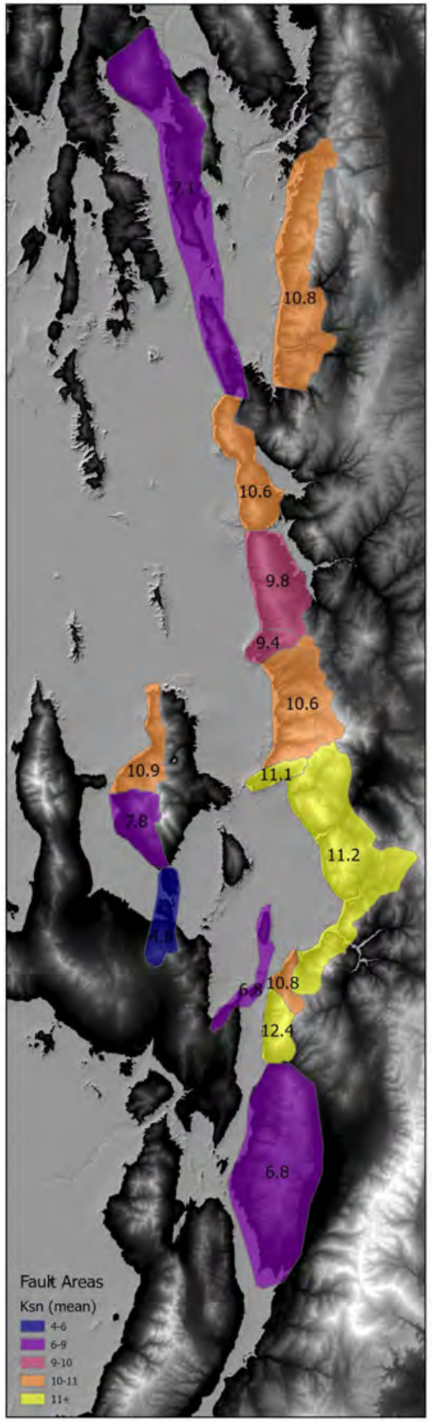
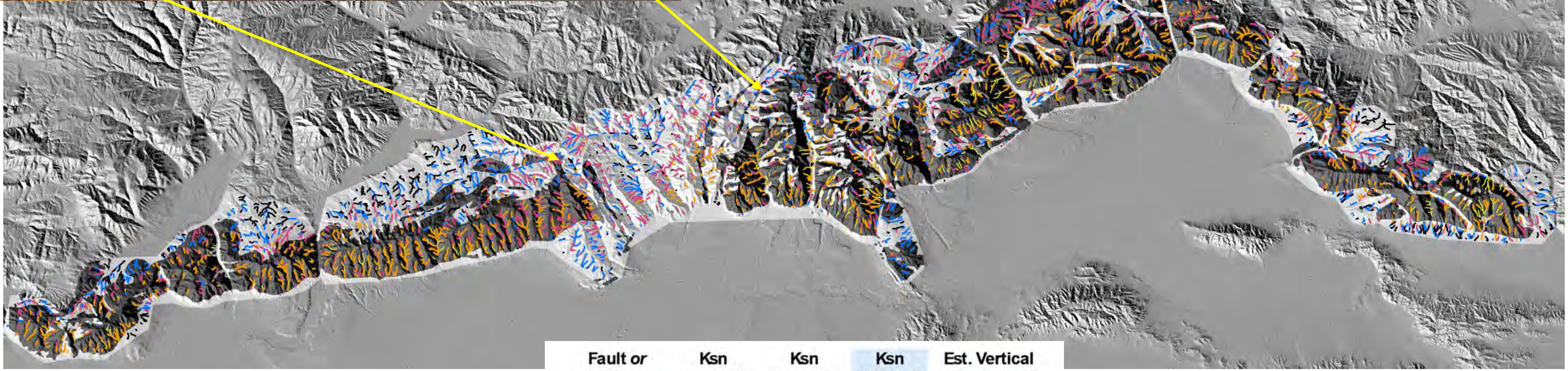
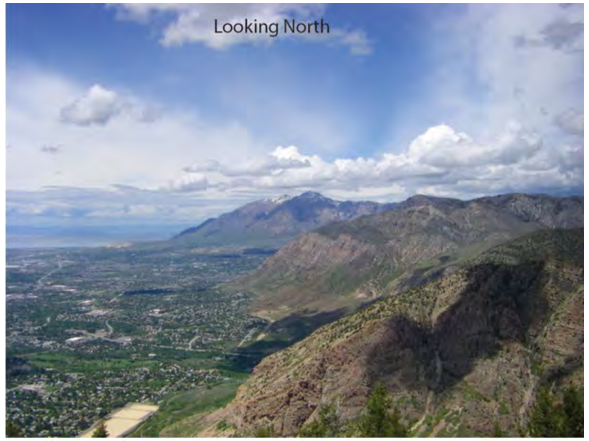


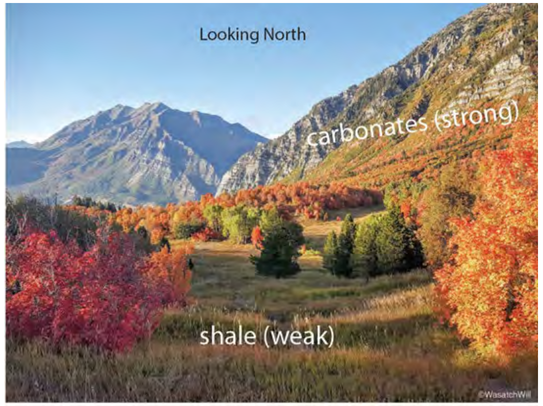
Figure 11. The Salt Lake City section of the Wasatch Front (facing ESE), note the change in relief and apparent steepness as you move from the north (left side of image) to the south (right side of image). This obvious change is associated with a shift from weaker (north) to stronger (south) rock types (see Figure 9). Image from University of Utah website.



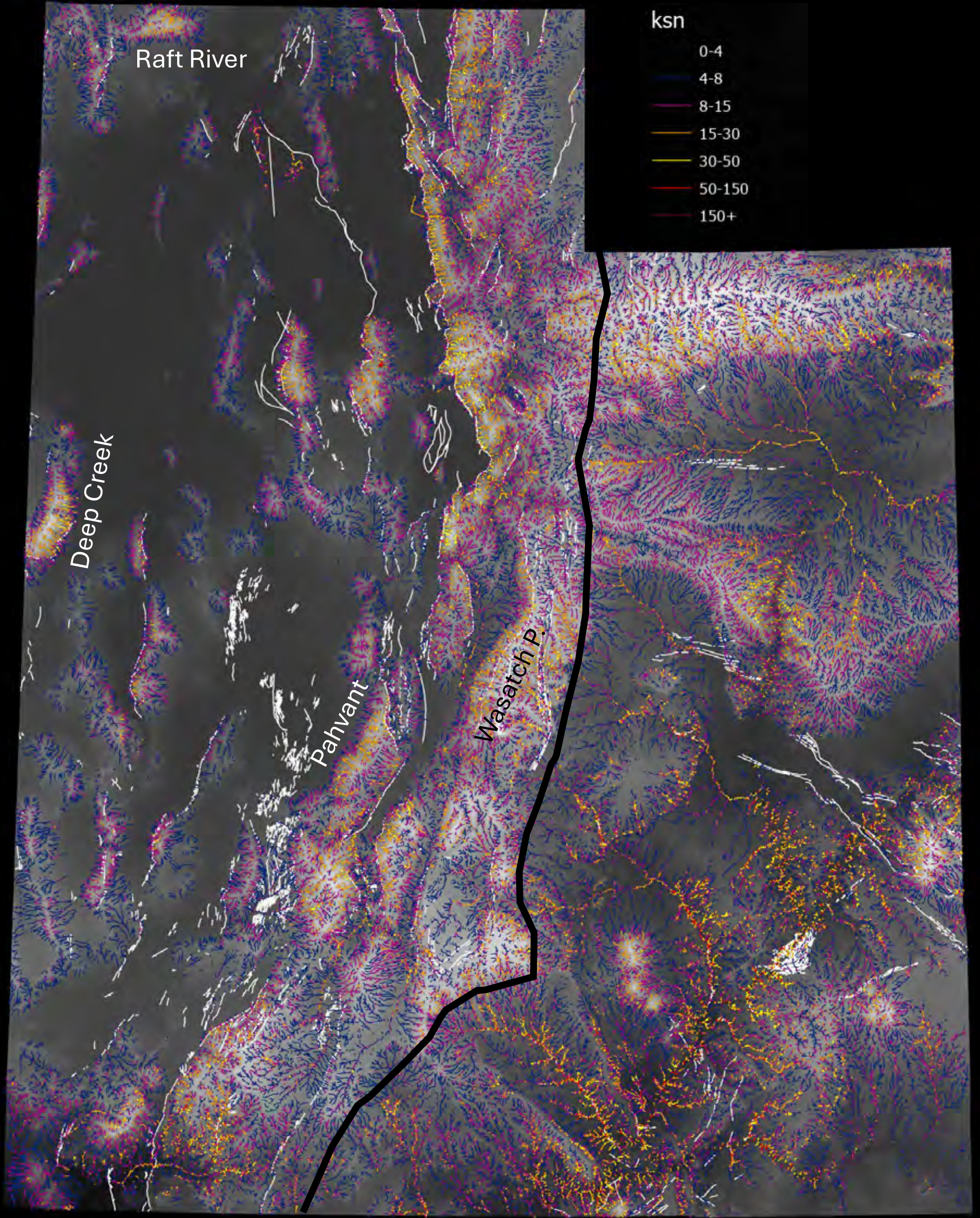


Wasatch Front, Weber Segment

Fault or Segment	Ksn Strong[3]	Ksn Weak[4]	Ksn Glacial[5]	Est. Vertical Slip Rates[6]
WFZ Central Segments	13.6	7.5	12.8	1-2 mm/a
WFZ BCS	12.4	6.9	-	Red = Associated with Highest Activity Yellow = High Activity Orange = Moderate Activity Tan = Lower Activity Blue = Ksn in areas of Glaciation
WFZ WS	13.0	6.5	-	
W-SLC Seg. Boundary	-	-	-	
WFZ SLCS	13.6	8.8	11.7	
SLC-P Seg. Boundary	-	-	14.5	
WFZ PS	12.8	8.3	12.3	
P-N Seg. Boundary	-	-	-	
WFZ NS	16.3	7.2	-	



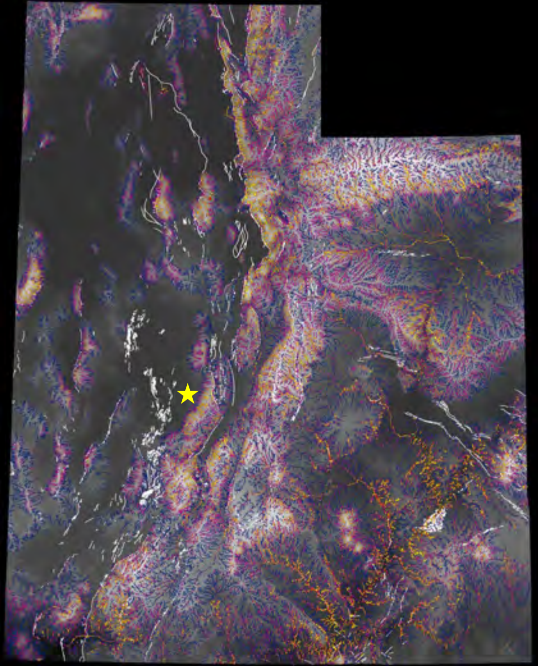
Contrast between weak and strong rock topography along the Provo Segment of the Wasatch fault.



- Highest Ksn values are related to incision into Colorado Plateau, including S. Uintahs, Book Cliffs, Canyonlands, etc.

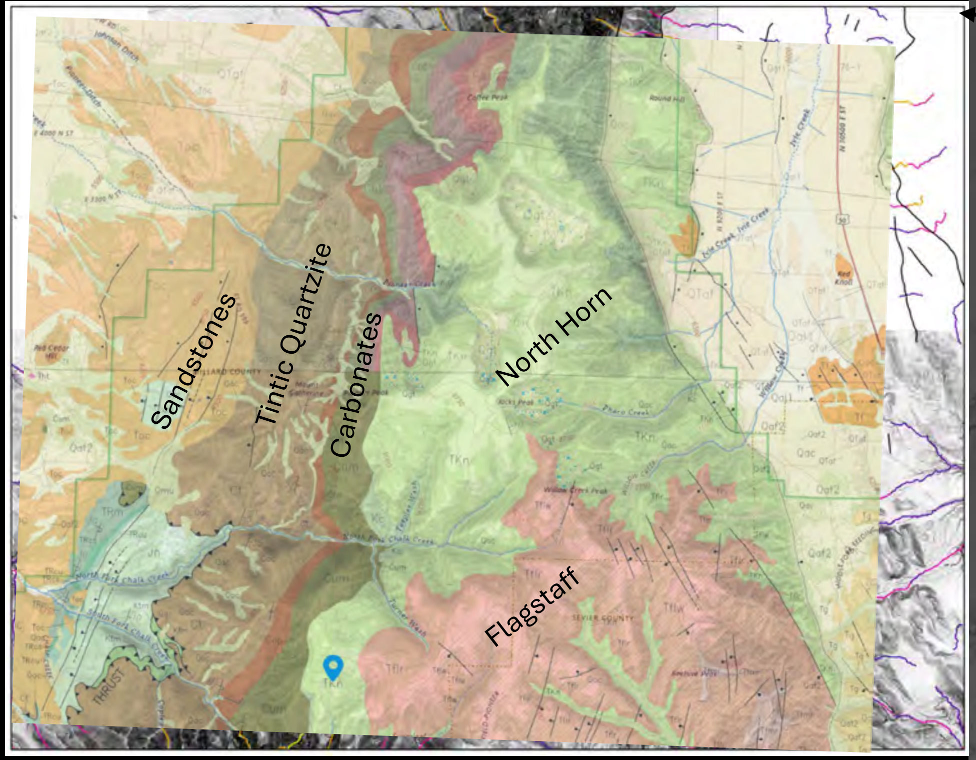
- Within the Basin and Range:
  - Wasatch fault
  - East Cache fault
  - Oquirrh fault
  - Stansbury faults

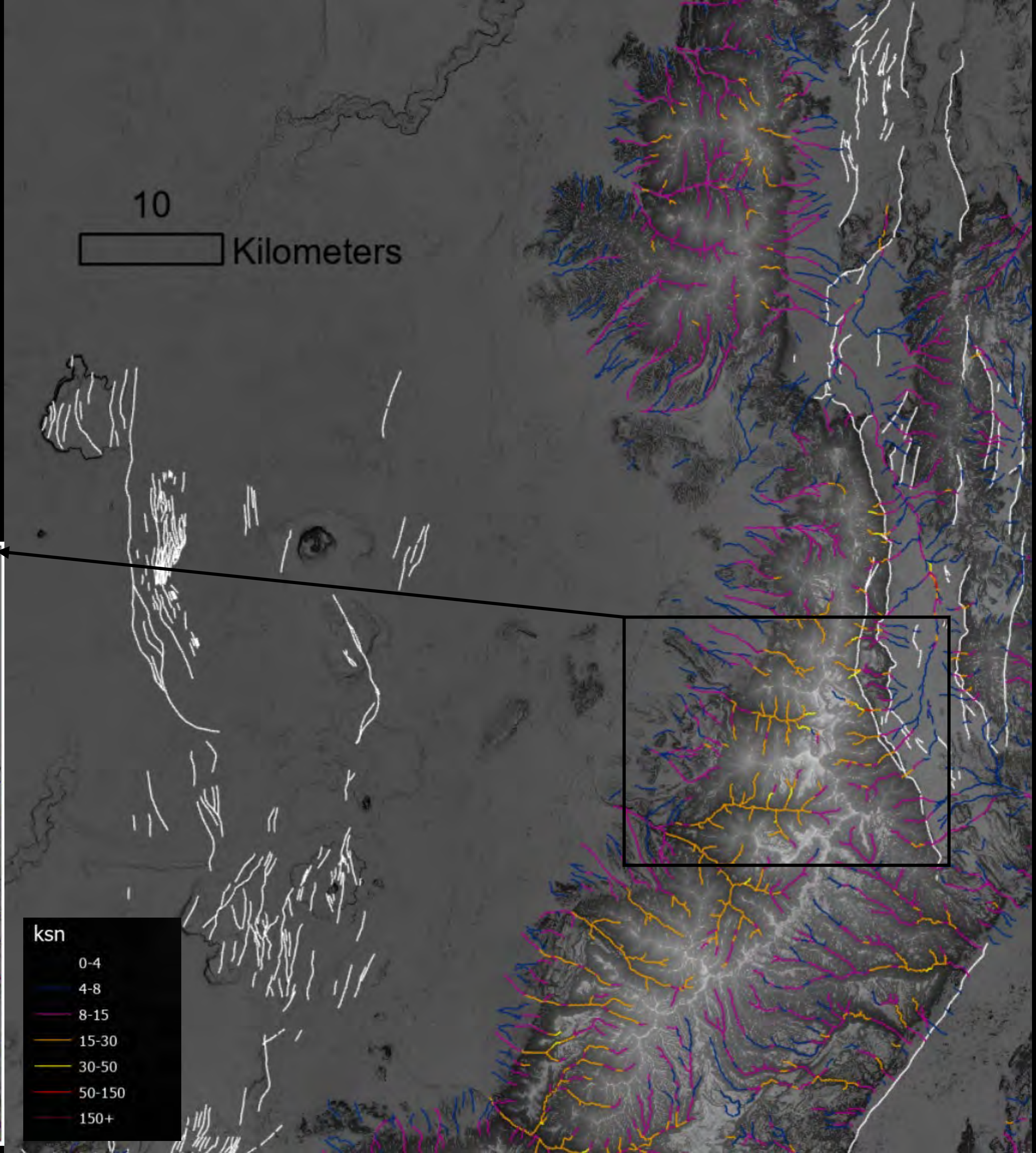
- Surprisingly high Ksn
  - Pahvant Range
  - Raft River Range
  - Deep Creek Range
  - Wasatch Plateau

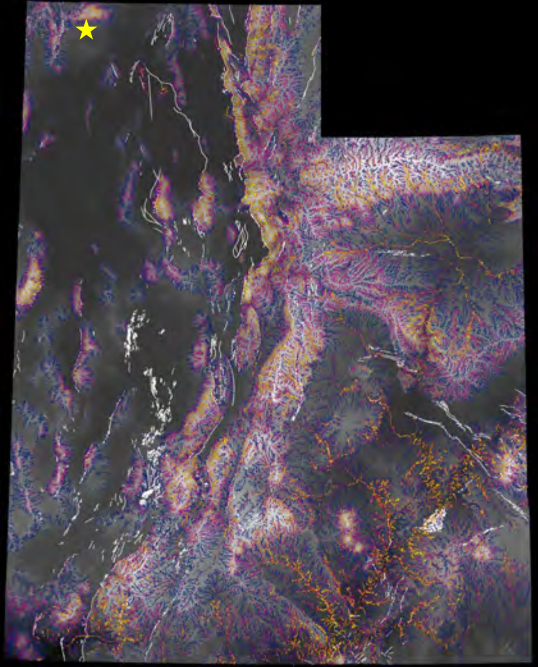


Pahvant Range

Nearby Maple Grove Fault
< 15 ka
< 0.2 mm/a

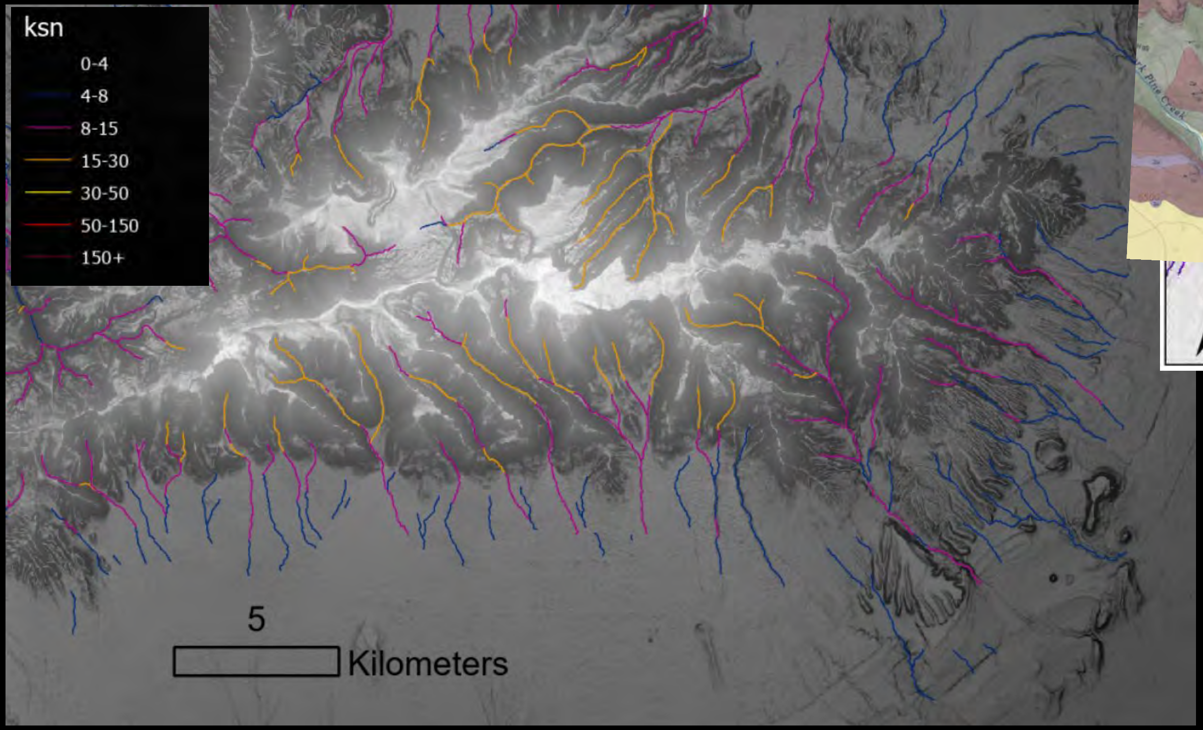


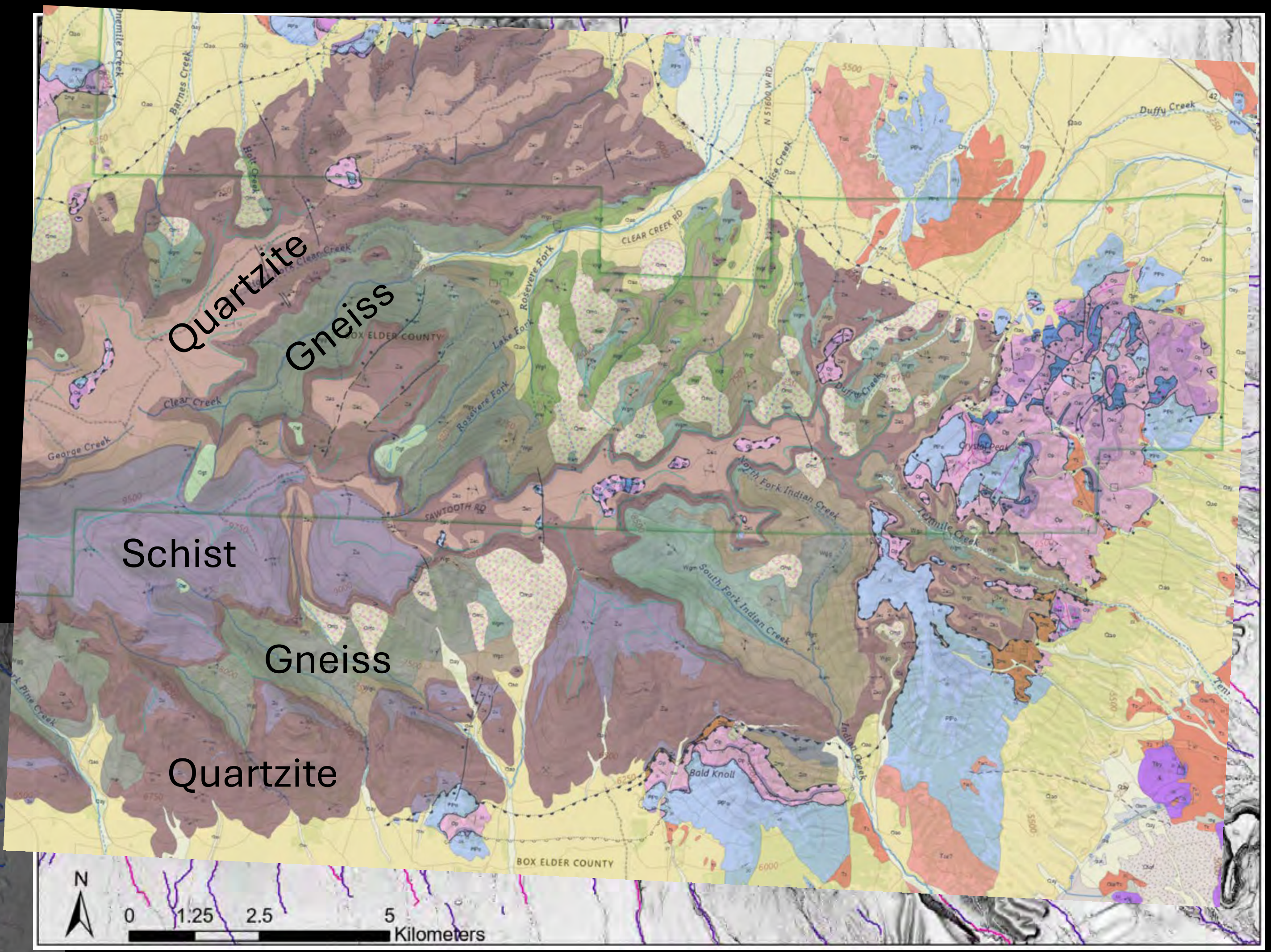




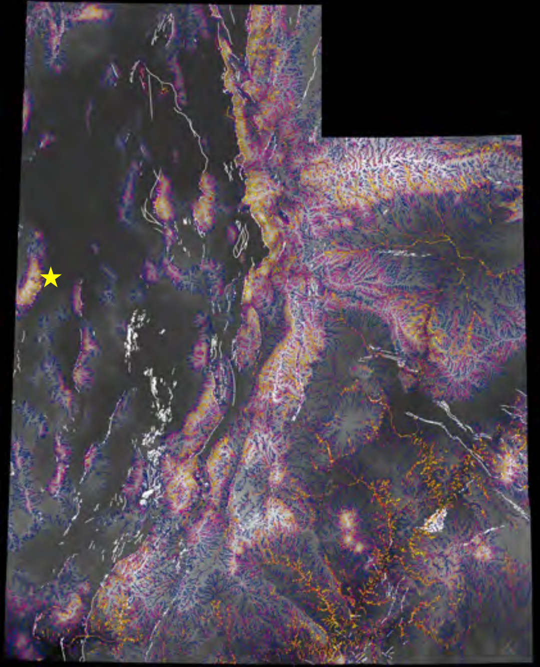
Raft River Range

< 0.2 mm/a
< 750 ka?





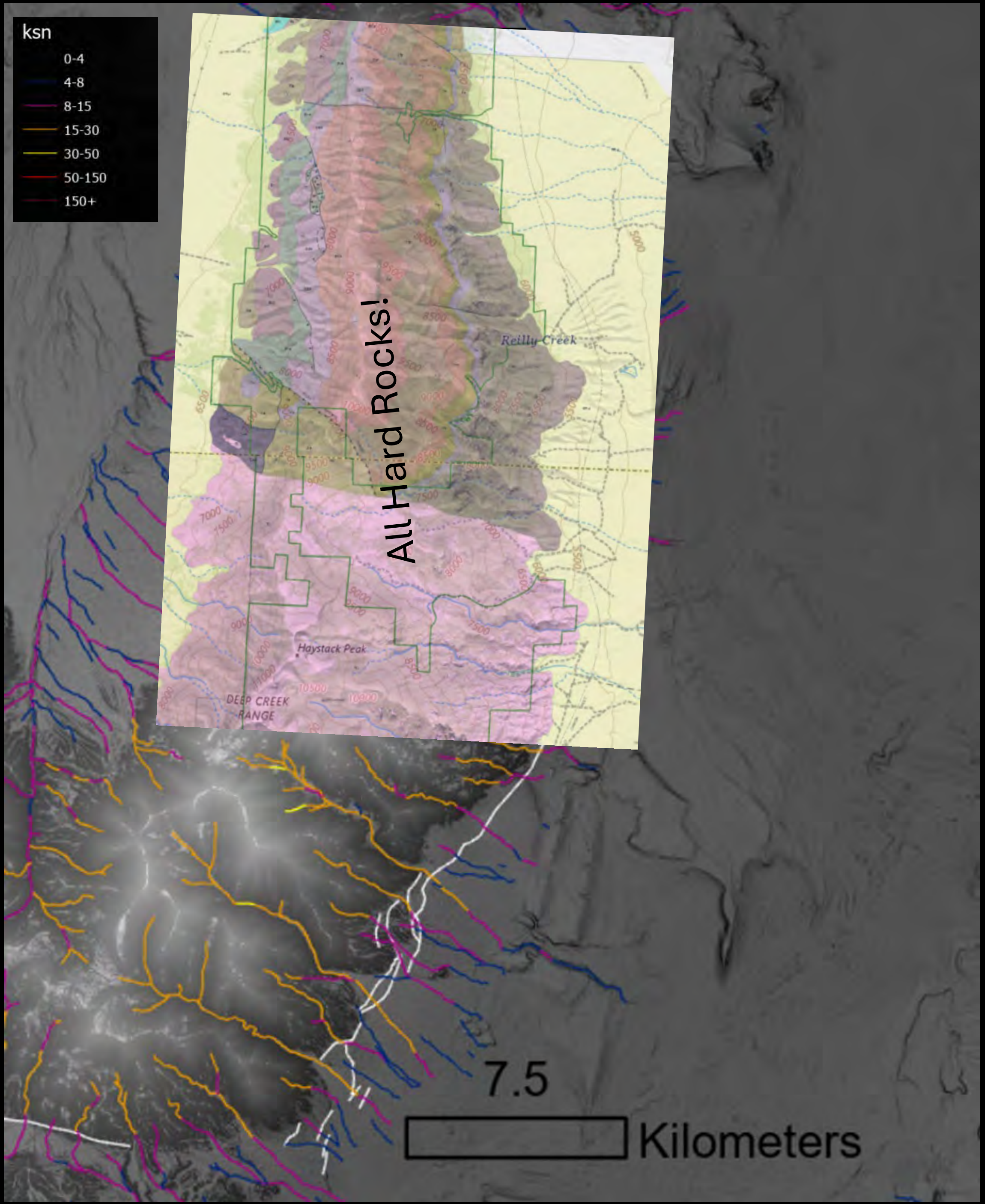
Metamorphic and Intrusive Igneous Rocks (hard and steep)

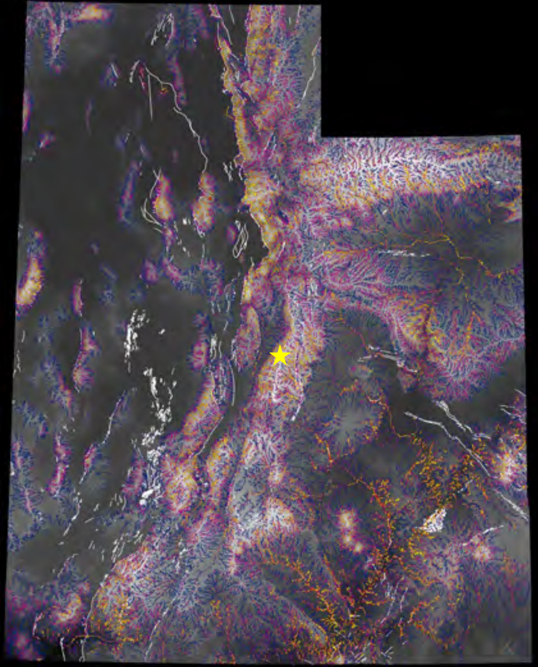


Deep Creek Range

< 0.2 mm/a
< 750 ka?

Scarps not on
Younger fans
Lidar incomplete

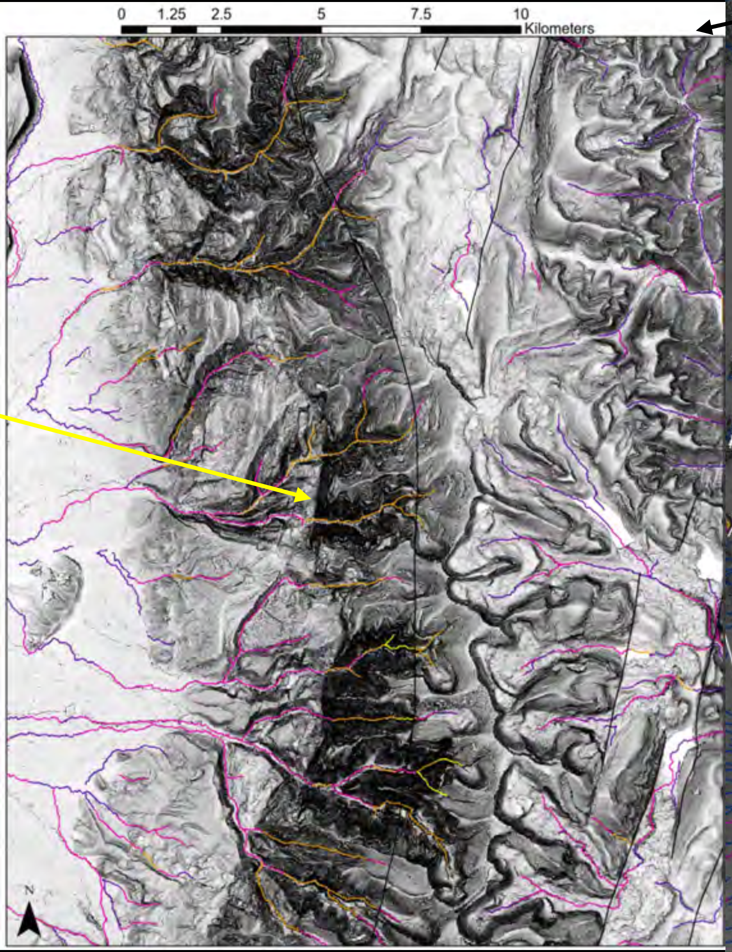


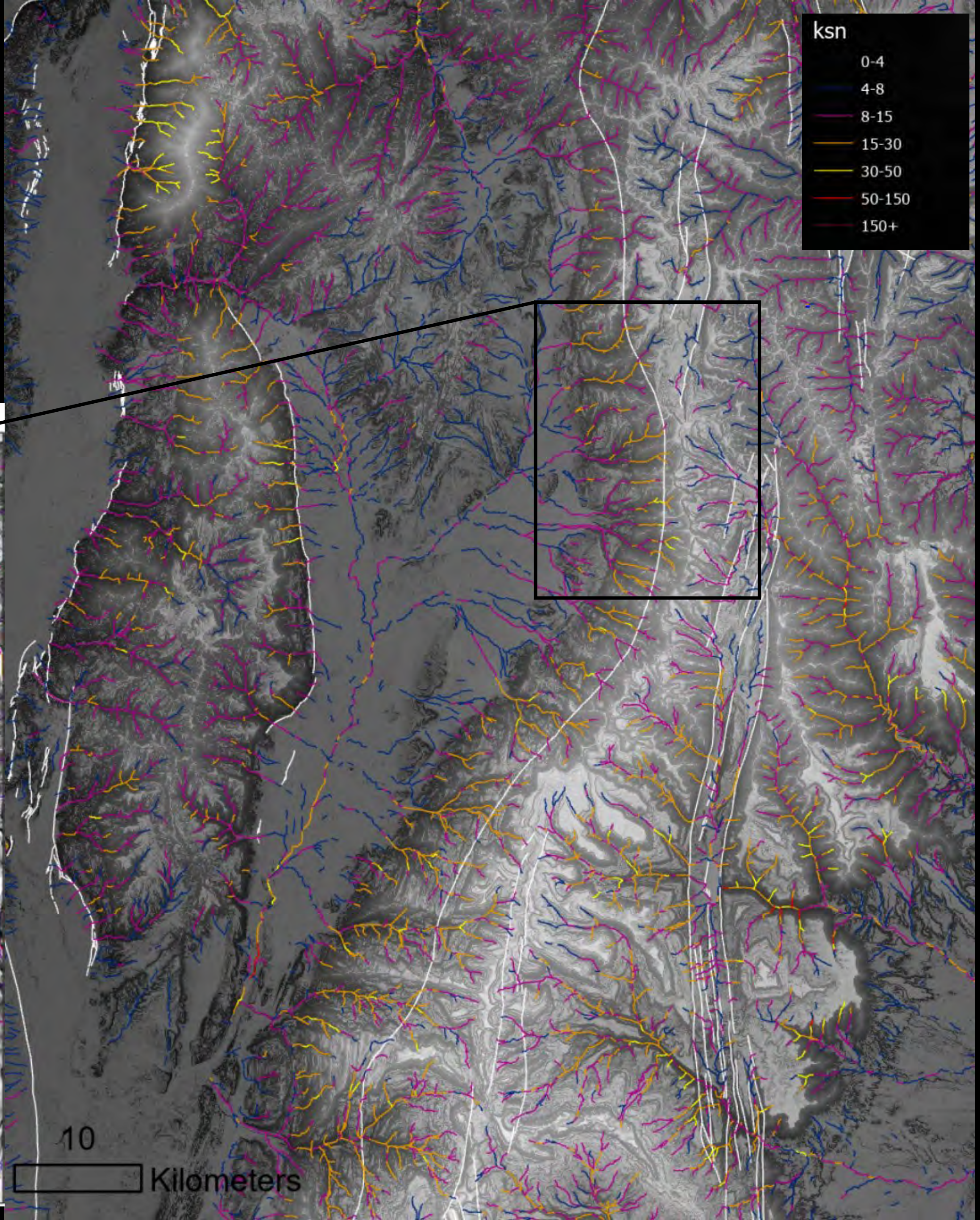


Wasatch Plateau Monocline + Faults

Range Front Structures Probably Worth Investigating.

No Major Lithologic Contrast Across Structures/Ksn Jump.





Towards an Improved Salt Lake Valley Community Velocity Model Through Seismic and Gravity Joint Inversion

HyeJeong Kim[1], Fan-Chi Lin[1], James Pechmann[1],
Adam McKean[2], Christian Hardwick[2]

[1] University of Utah
[2] Utah Geological Survey

This work is supported by the USGS Earthquake Hazard Program G23AP00021 & G23AP00051

Towards an Improved Salt Lake Valley Community Velocity Model Through Seismic and Gravity Joint Inversion
Final Results & Future

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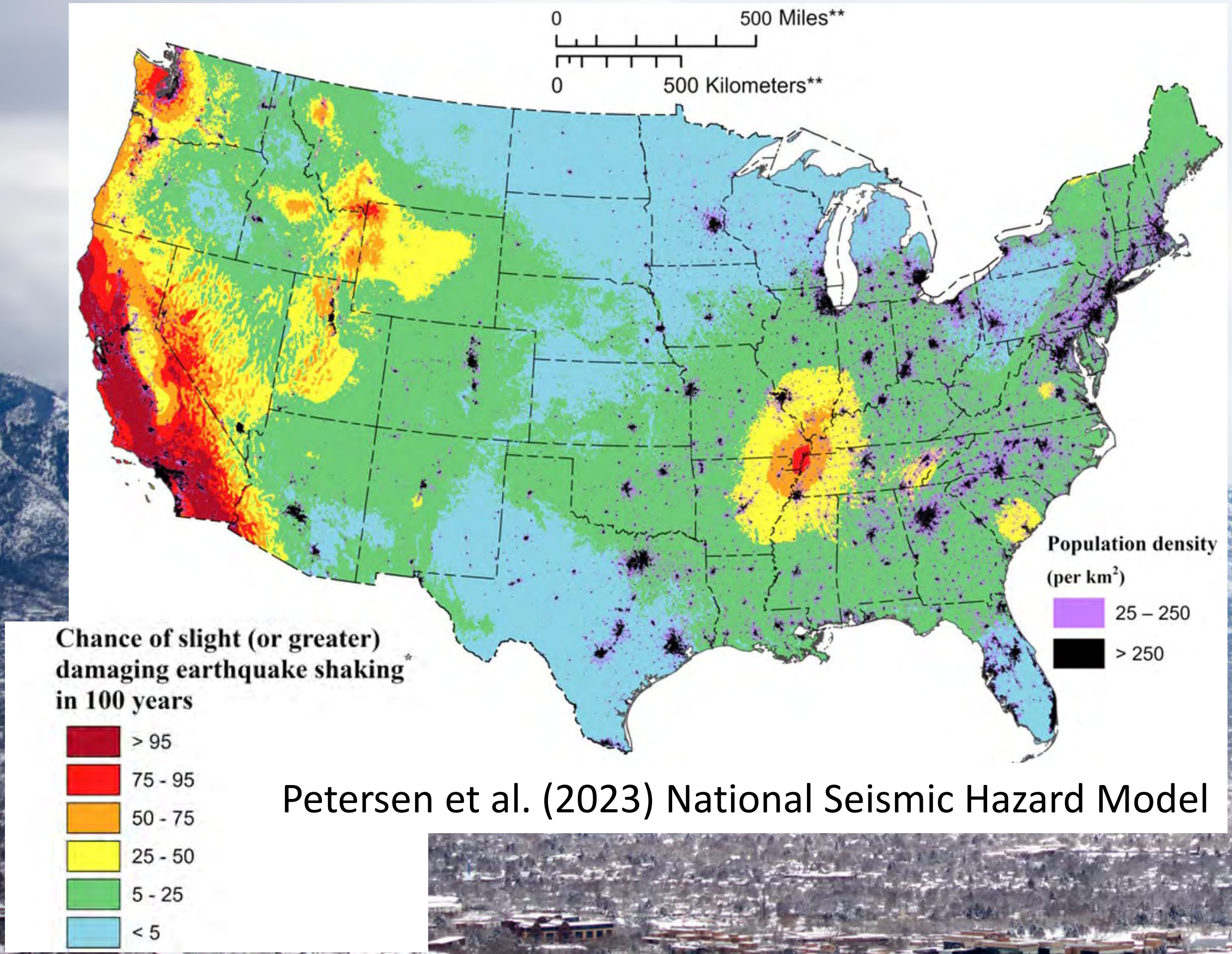
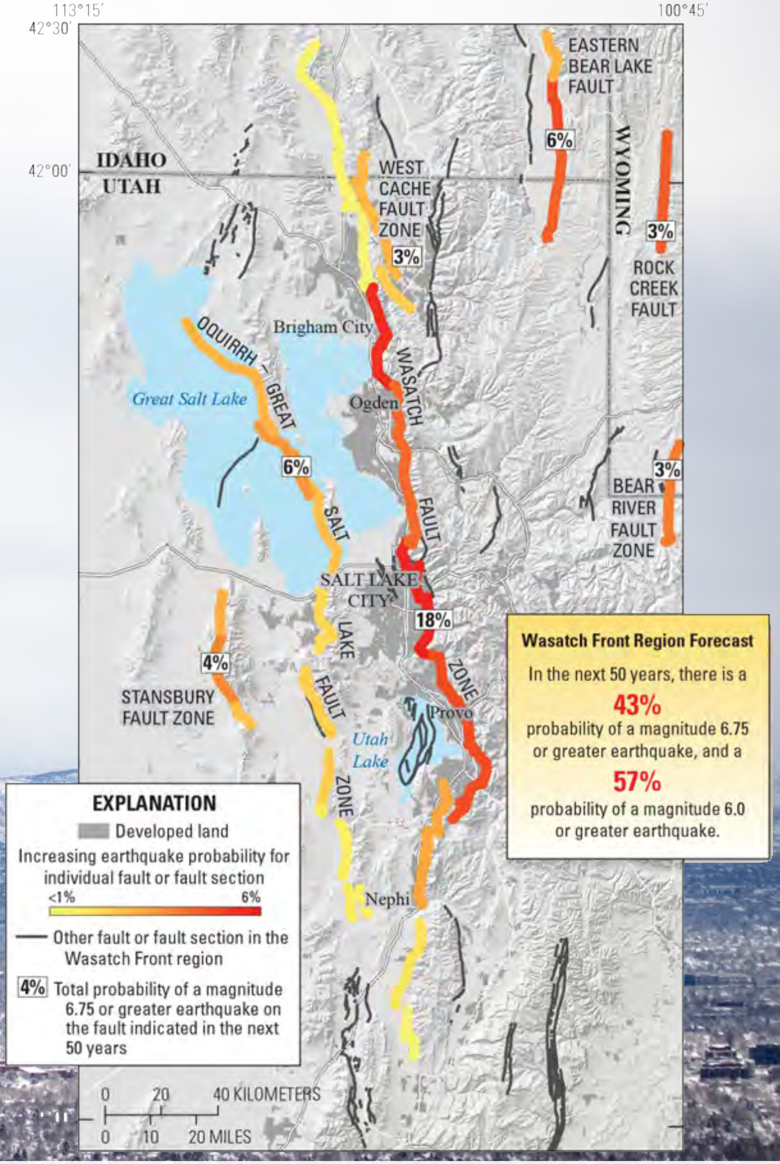
This work is supported by the USGS Earthquake Hazard Program G23AP00021 & G23AP00051

Ground shaking hazard in the Salt Lake Valley

- Example: 18 March 2020 M_W 5.7 Magna earthquake



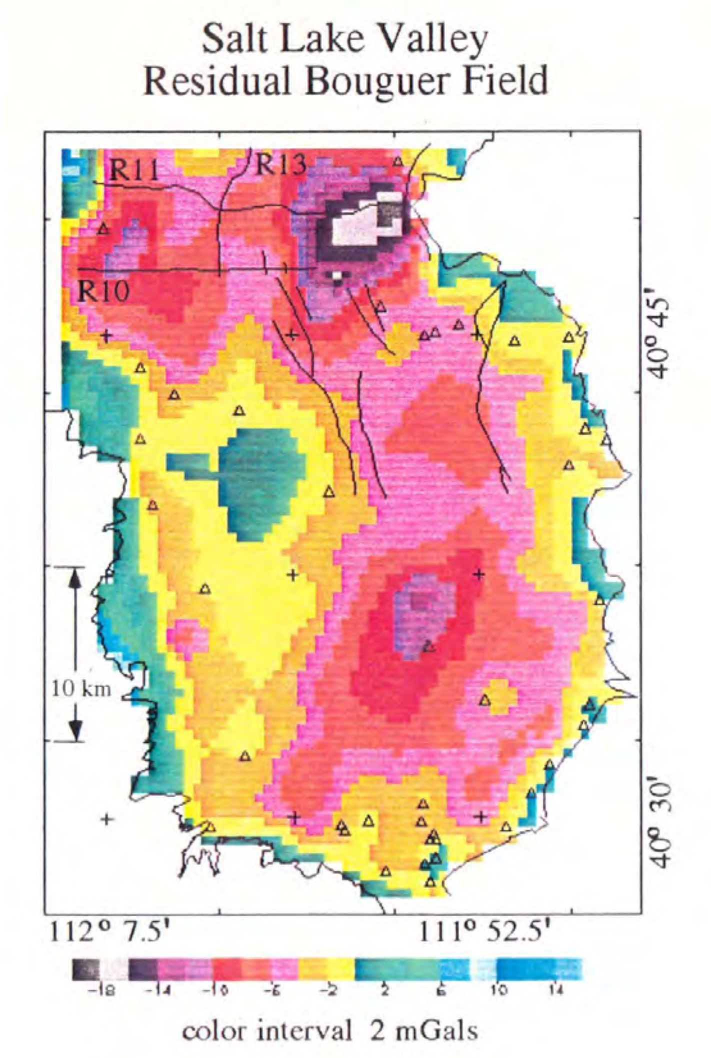
Petersen et al. (2023) National Seismic Hazard Model



Modified from Working Group on Utah Earthquake Probabilities (2016)

Salt Lake Valley — *the Wasatch Front Community Velocity Model*

- Constructed based on legacy gravity measurements, supplemented by sparsely distributed well logs and legacy active-source seismic profiles.



Radkins (1990)

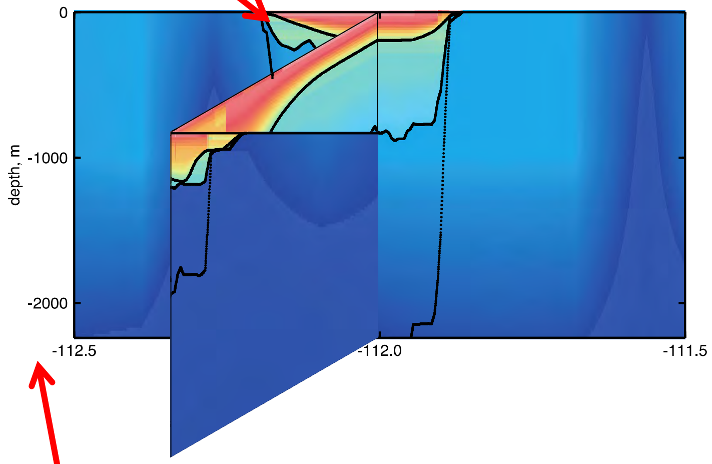
Hill et al. (1990)

Salt Lake Valley — ***the Wasatch Front Community Velocity Model***

- R1: unconsolidated/semi-consolidated sediments
- R2: semi-consolidated/consolidated sediments
- R3: depth to basement

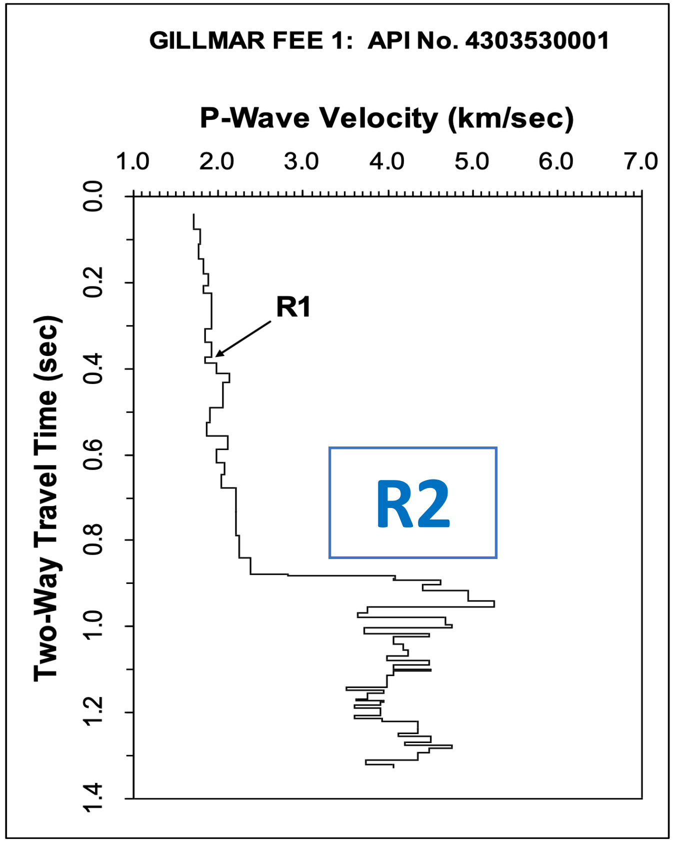
R1 boundary

R2 boundary



R3 boundary

Magistrale et al. (2008)



Pechmann et al. (2010)

Evaluation of the Wasatch Front CVM with Magna earthquake data

Hutchings (2023)

- Mw 5.7 Magna Earthquake in March 2020 provided an opportunity to evaluate the model's ability to predict strong motion in Salt Lake City

Observed

Synthetic

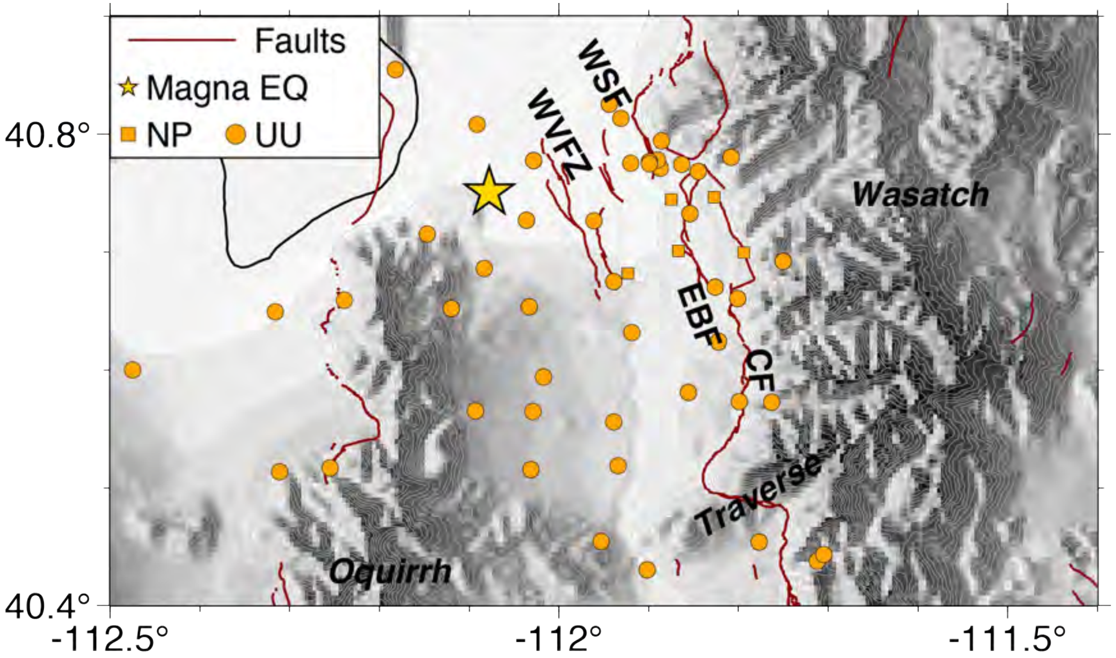
Observed PGA (%g)

Synthetic PGA (%g)

Horizontal peak ground acceleration low-pass filtered 3 Hz

Improved seismic data coverage in Salt Lake Valley → Total: 301

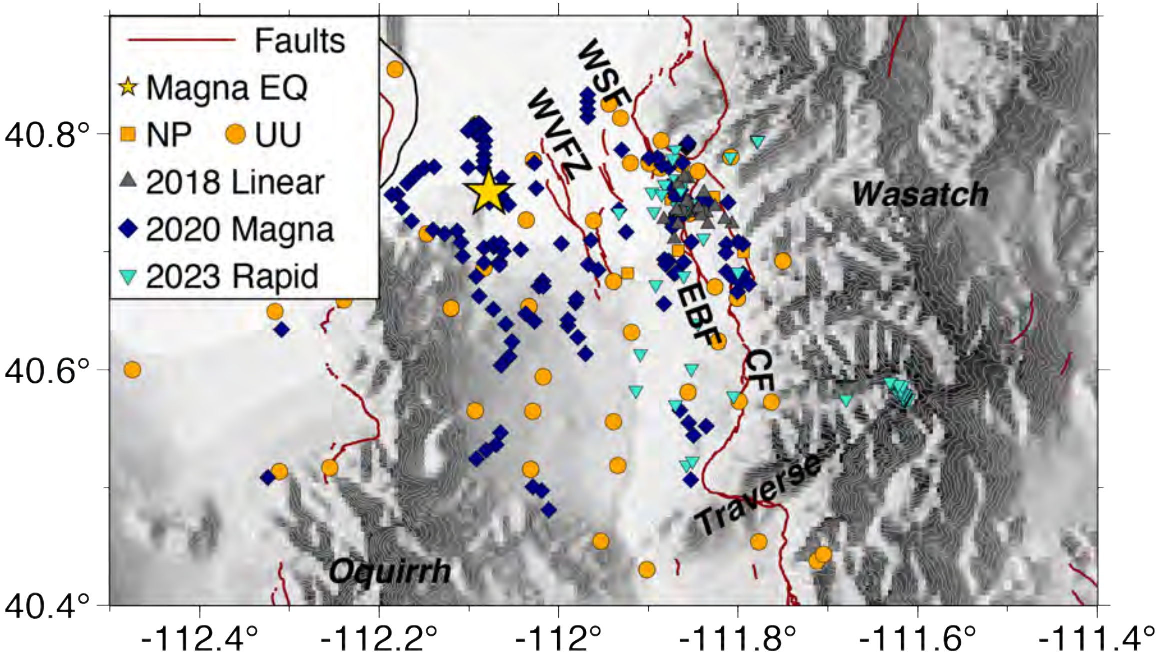
Before 2018



(1) UU: 55

(2) NP: 5

Up to 2023



(3) 2018 Linear: 32

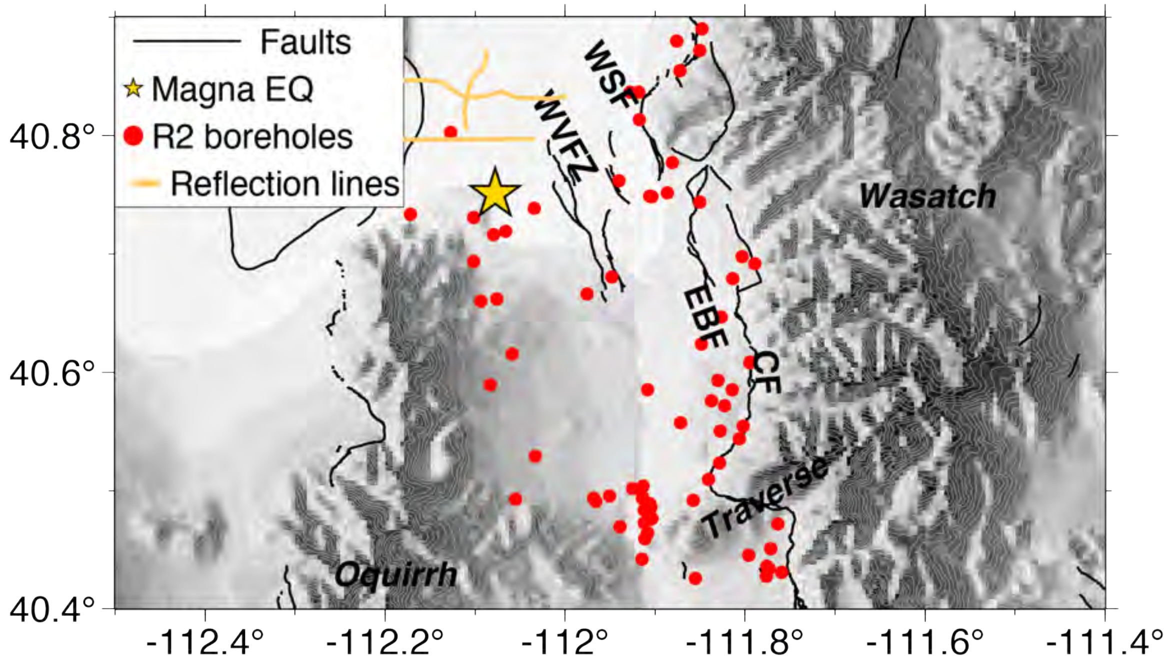
(4) 2020 Magna: 170

(5) 2023 Rapid: 39

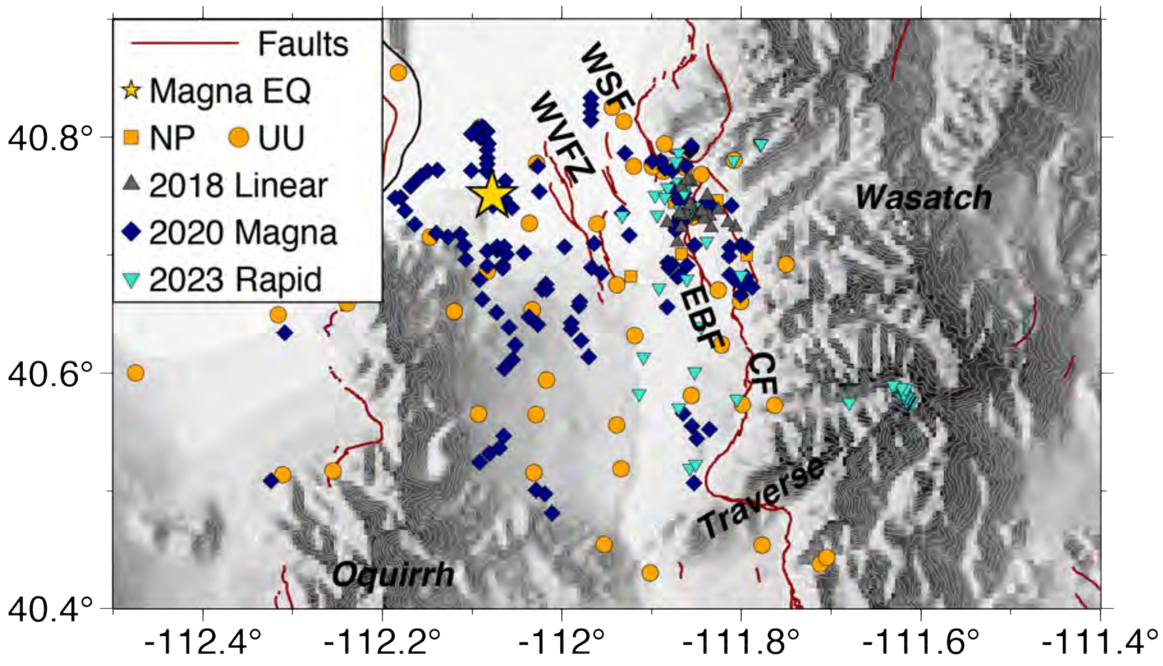
Kim et al. (2024) Under review

Seismic stations filling gaps of sparsely distributed R2 constraints

Location of known R2s



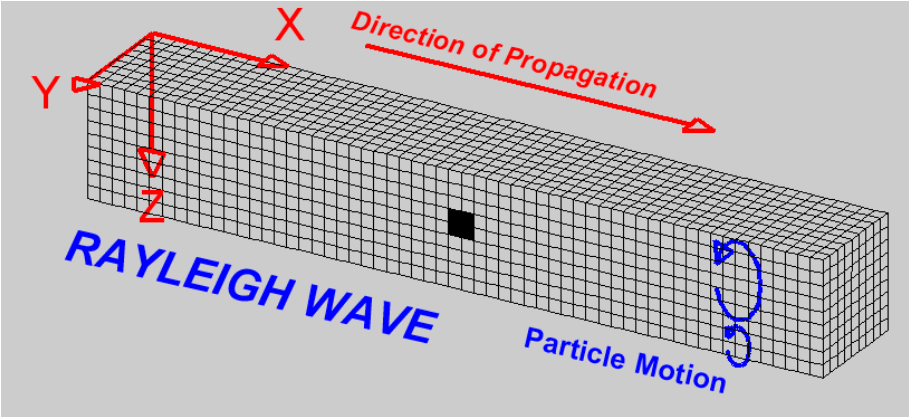
Up to 2023



Seismic stations to unveil the R2 depths in urbanized regions?

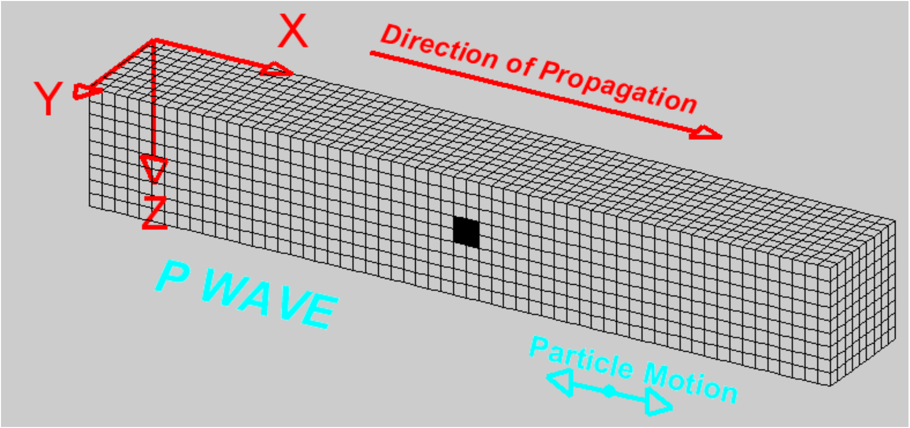
Passive Seismic Methods for sedimentary basin imaging

Rayleigh wave



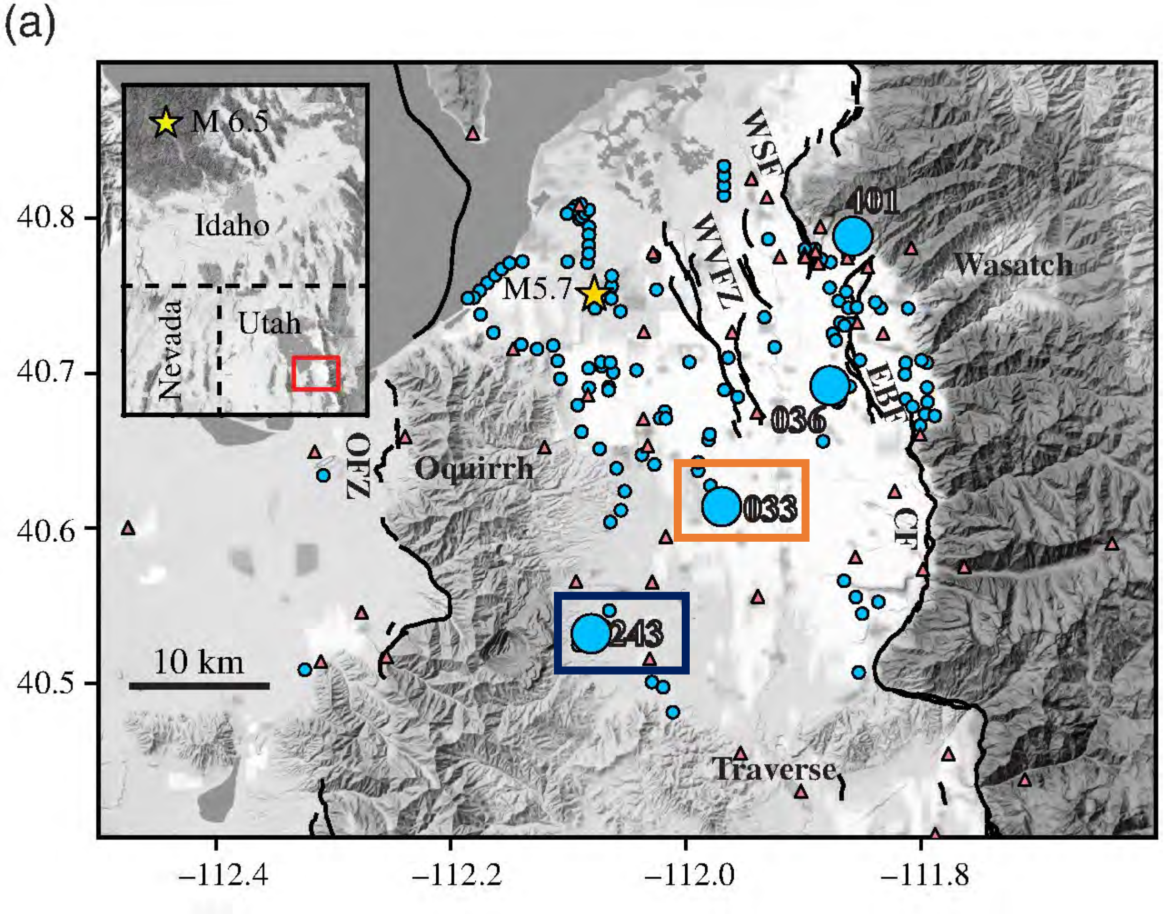
https://web.ics.purdue.edu/~braile/edumod/waves/Rwave.htm

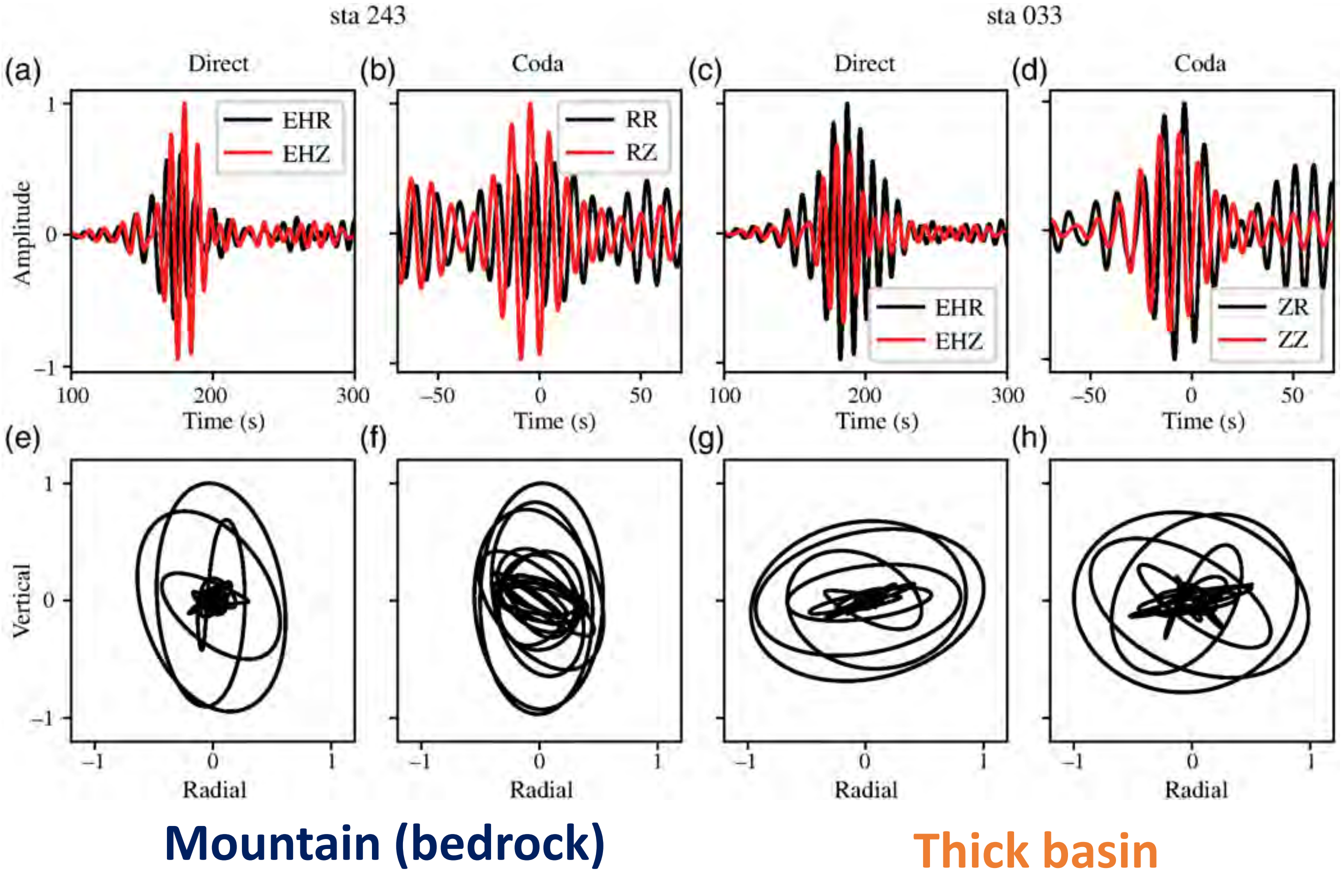
Body waves — P, S wave



Rayleigh wave data for sedimentary basin imaging

- **Phase velocity:** slower velocity in basins
- **Ellipticity** (Rayleigh wave H/V)



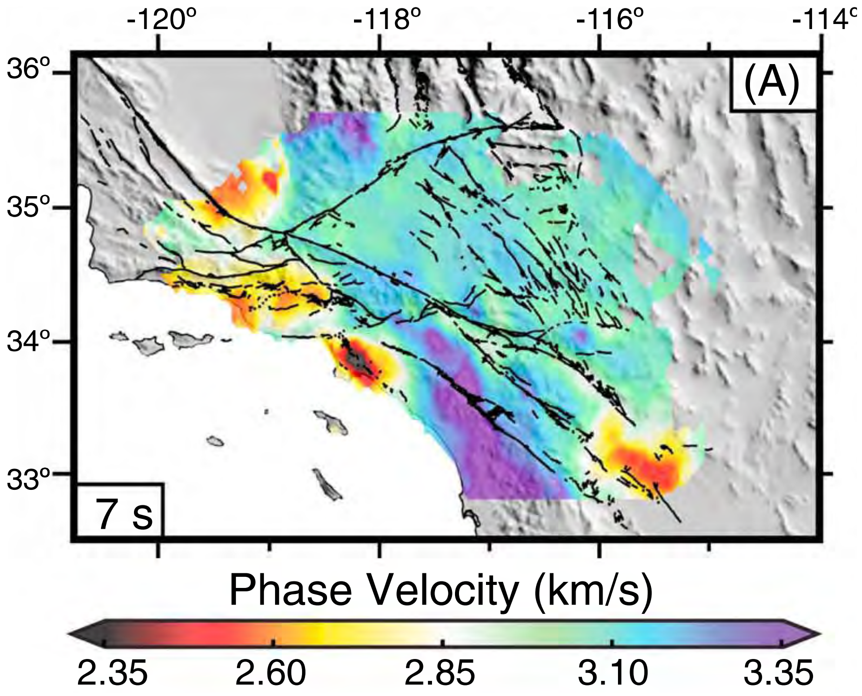


Zeng et al. (2022)

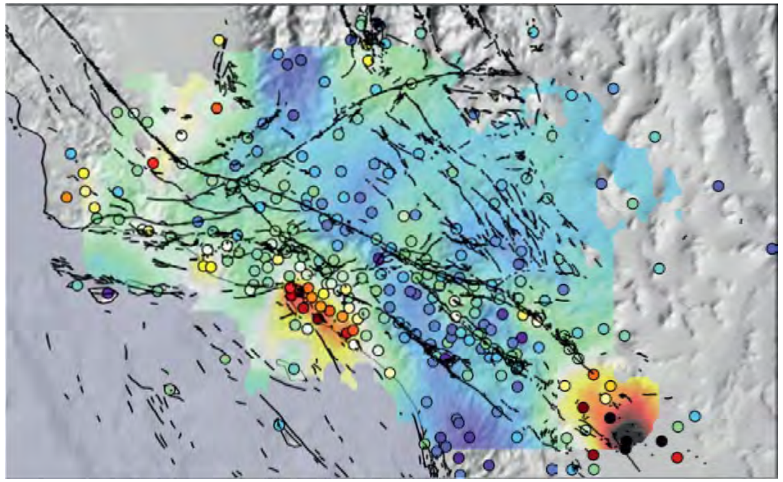
Rayleigh wave data for sedimentary basin imaging: example

- In LA: Observations of phase velocity and ellipticity correlates well with Vs30

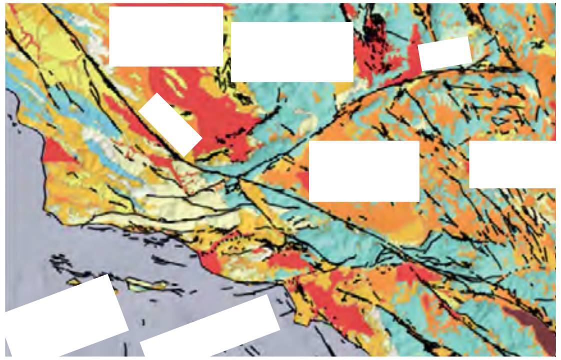
Phase velocity (7 s)



Ellipticity (7 s)



Vs30



Berg et al. (2018; 2021)

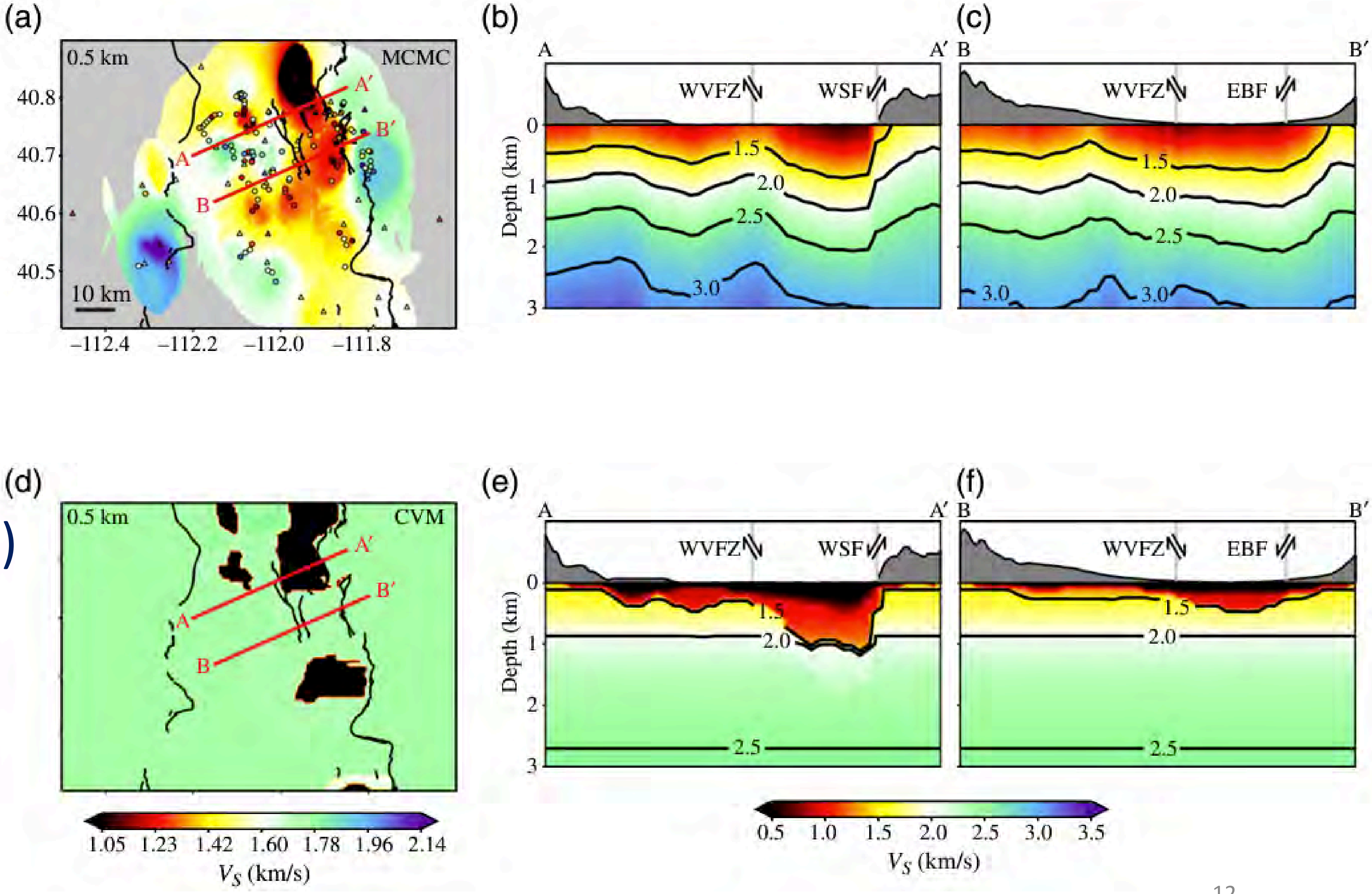
Existing 3D velocity models to present

Zeng et al. (2022)

Using Rayleigh wave

- Phase velocity
- Ellipticity (H/V)

WFCVM (Magistrale et al., 2008)

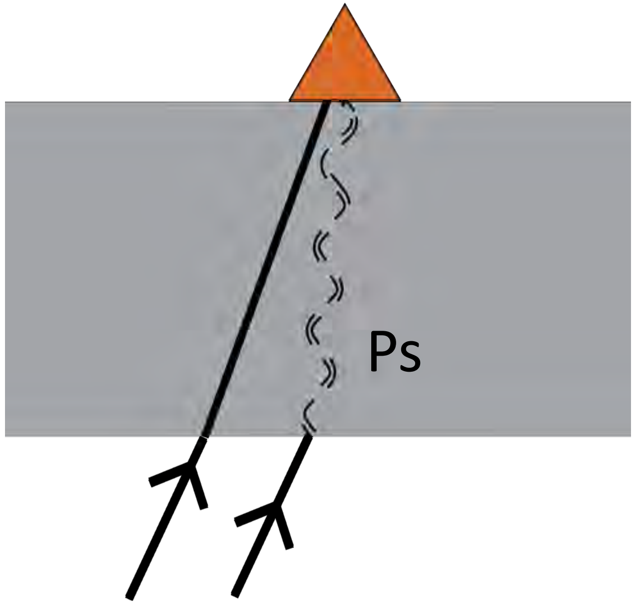


Zeng et al. (2022)

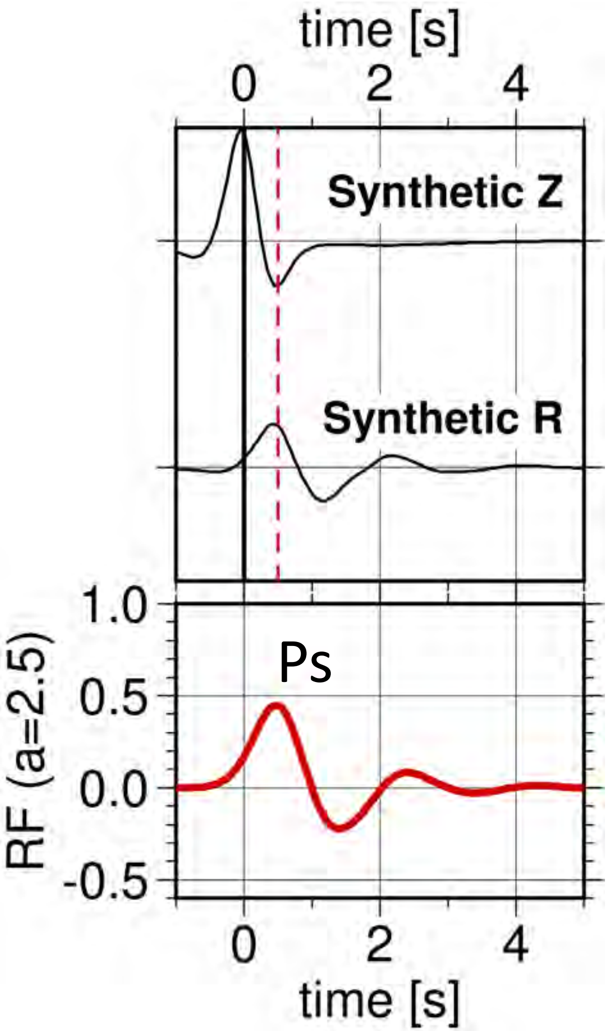
Adding the sharpness of the sedimentary boundaries with body waves

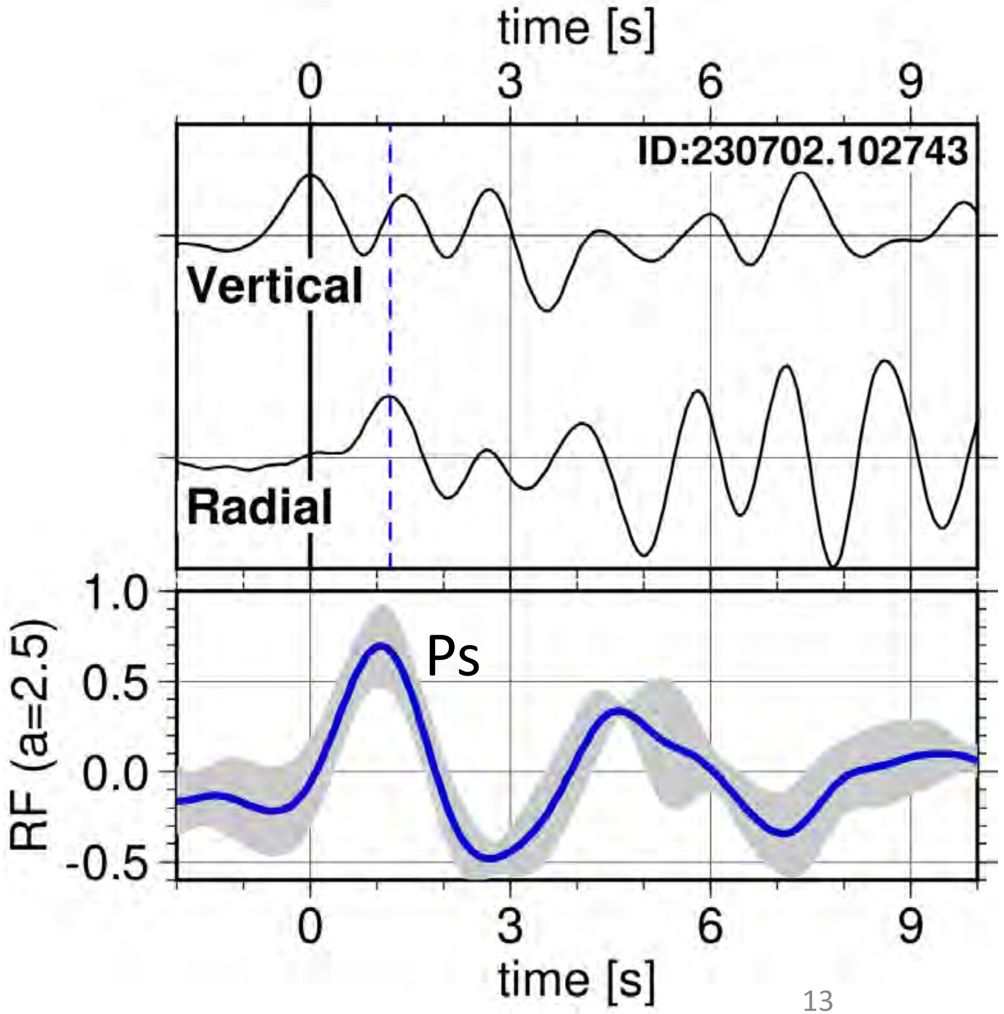
- Receiver Functions show the Ps phase converted at the sedimentary boundaries
- Thicker and slower Vs layer produces larger Receiver Function peak delays

Converts to
S-wave upon a boundary



Incoming teleseismic P-wave

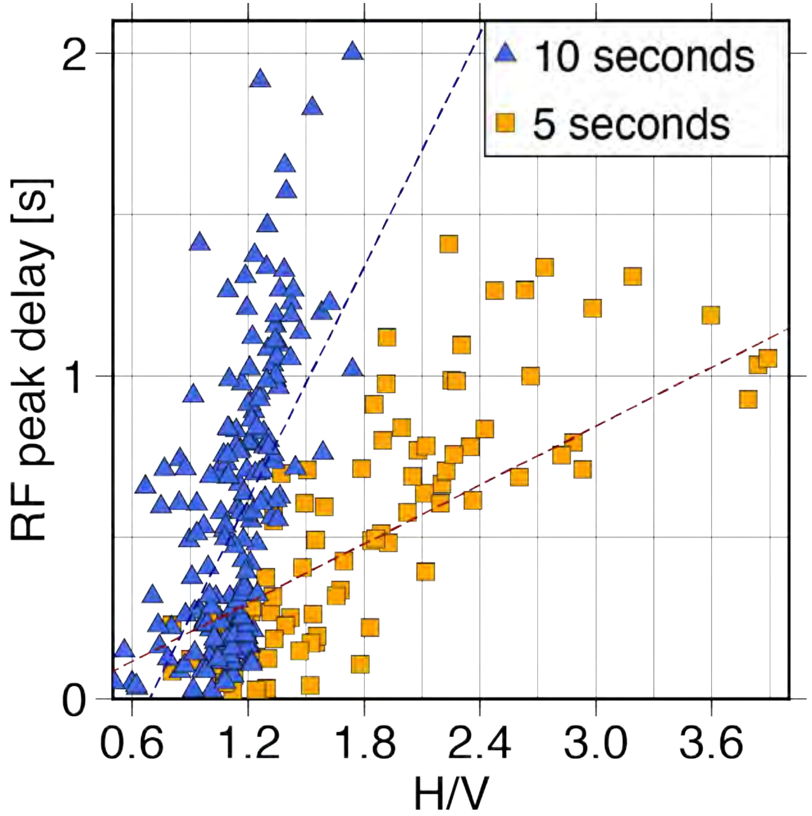


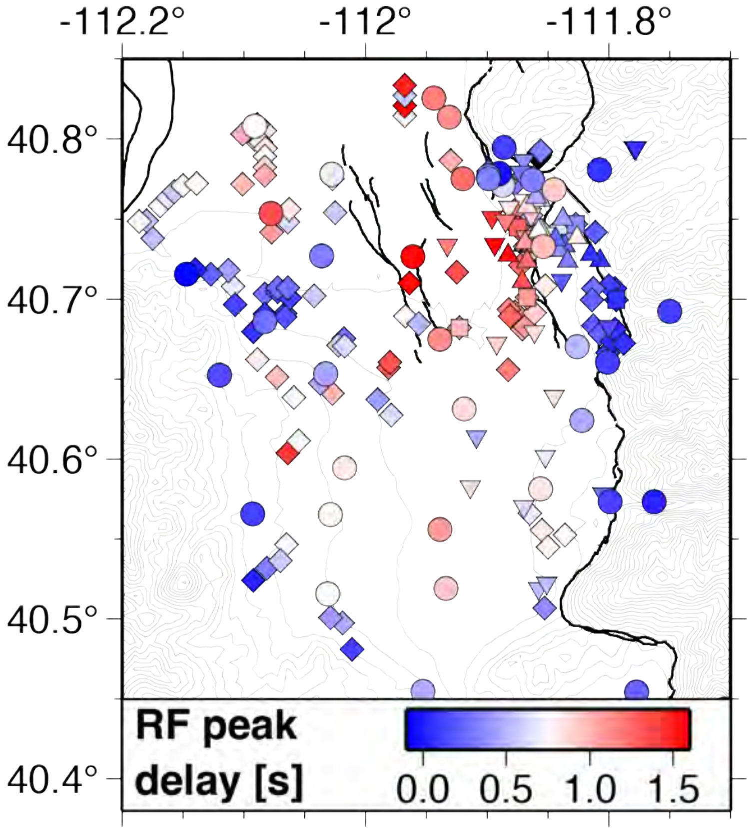


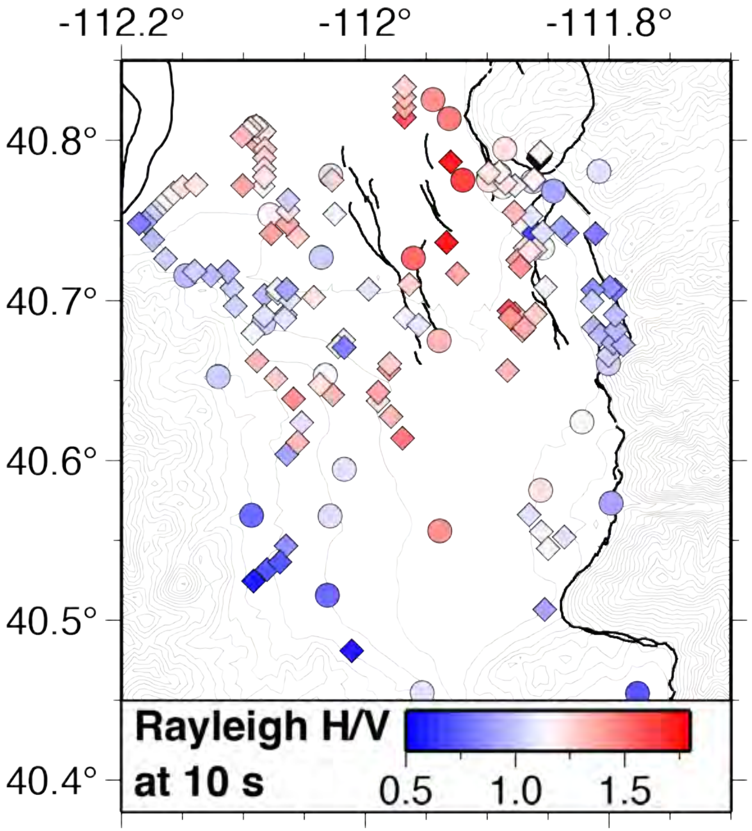
Kim et al. (2024) Under review

Joint inversion of Rayleigh wave ellipticity (H/V) and the RFs

- Thicker sediment → Larger RF delay time
- Slower sediment → Larger H/V, larger RF delay time







- Rayleigh wave ellipticity (H/V) and RF peak delay have a positive correlation

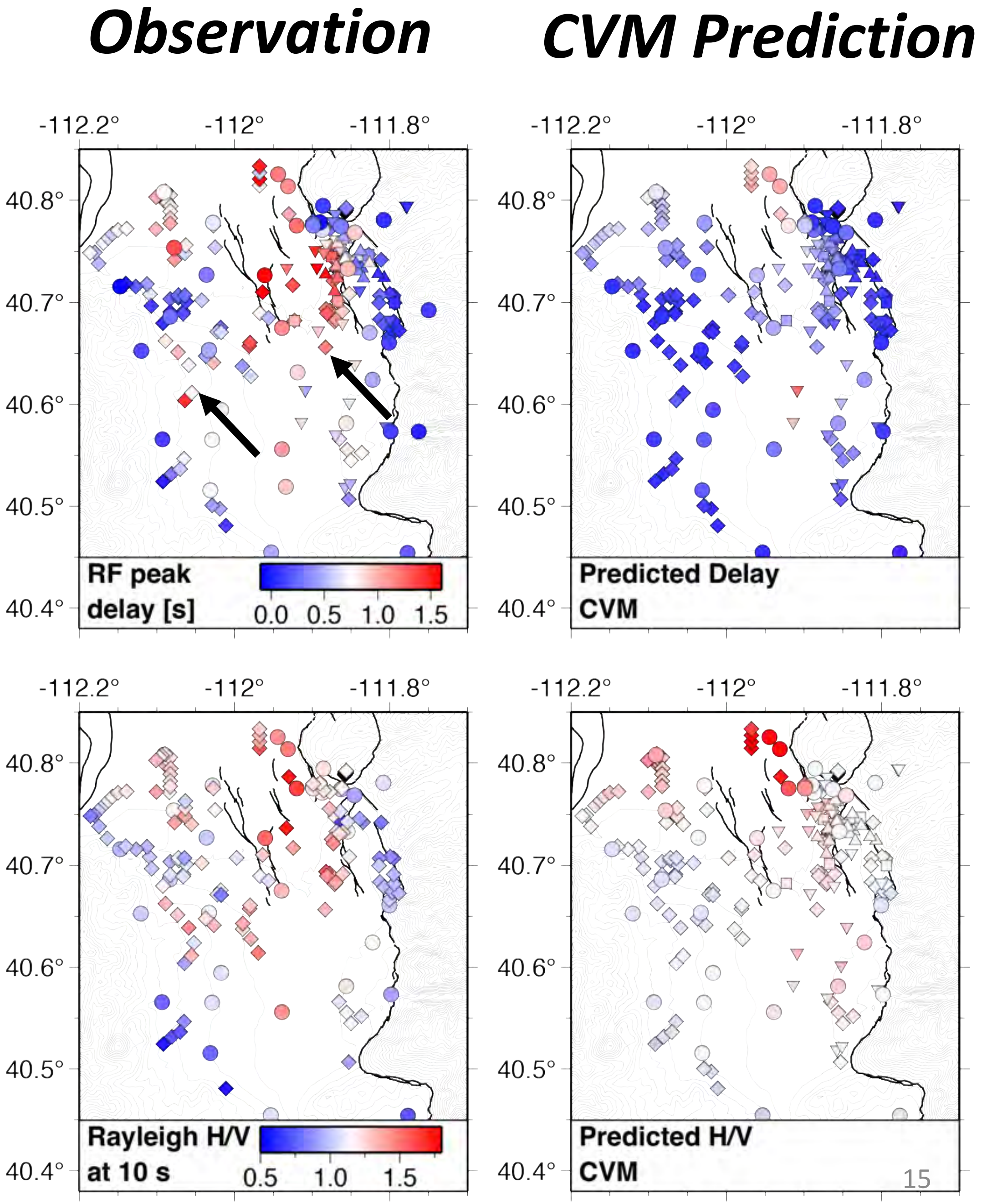
Kim et al. (2024) Under review

CVM Underpredicts Observed RF Delay Times and H/V

RF delay time ↗

H/V at 10 s ↘

- Noticeable differences exist between the East Bench Fault and the West Valley Fault Zone



Kim et al. (2024) Under review

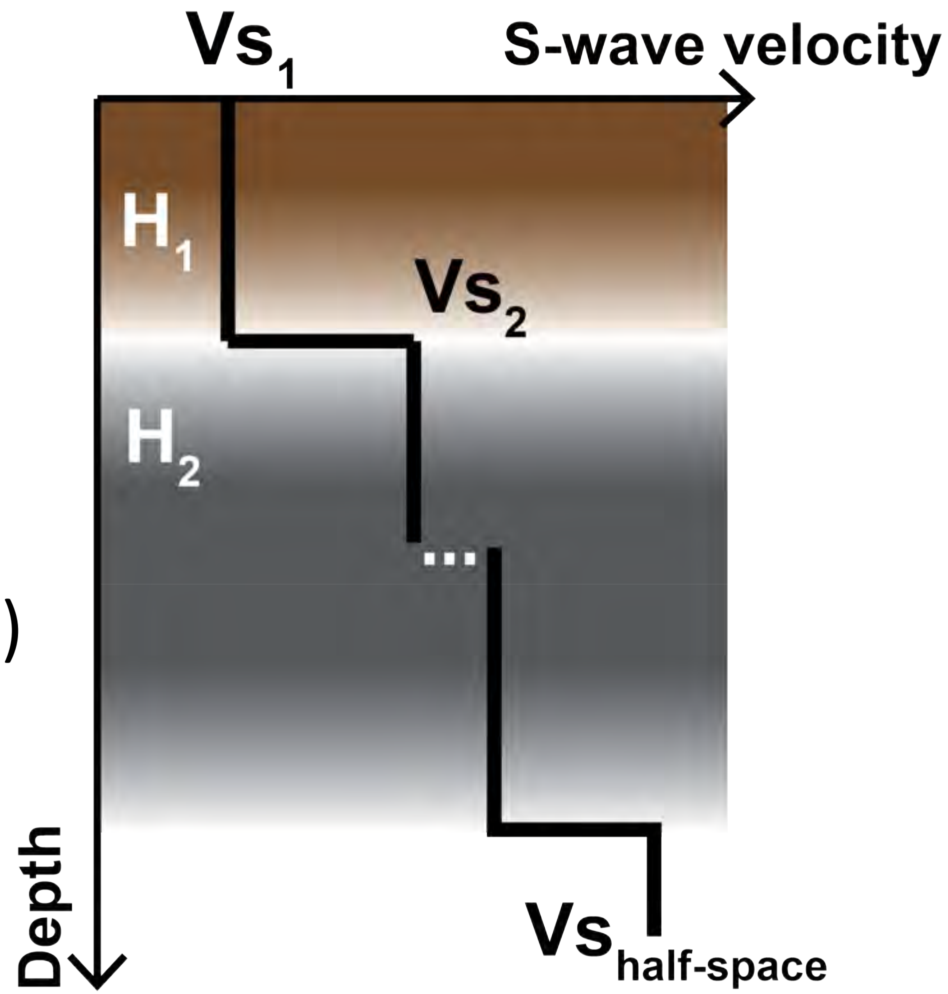
Parameterization in the Joint Inversion

We solve for:

Vs_1, H_1
Vs_2, H_2
Vs_3 fixed, $H_3 = 8$ km – H_1 – H_2
$Vs_{4,\text{half-space}}$ fixed

Vp & density are determined by Vs (Brocher, 2005)

Solving layered structure via
Markov chain Monte Carlo with Parallel Tempering



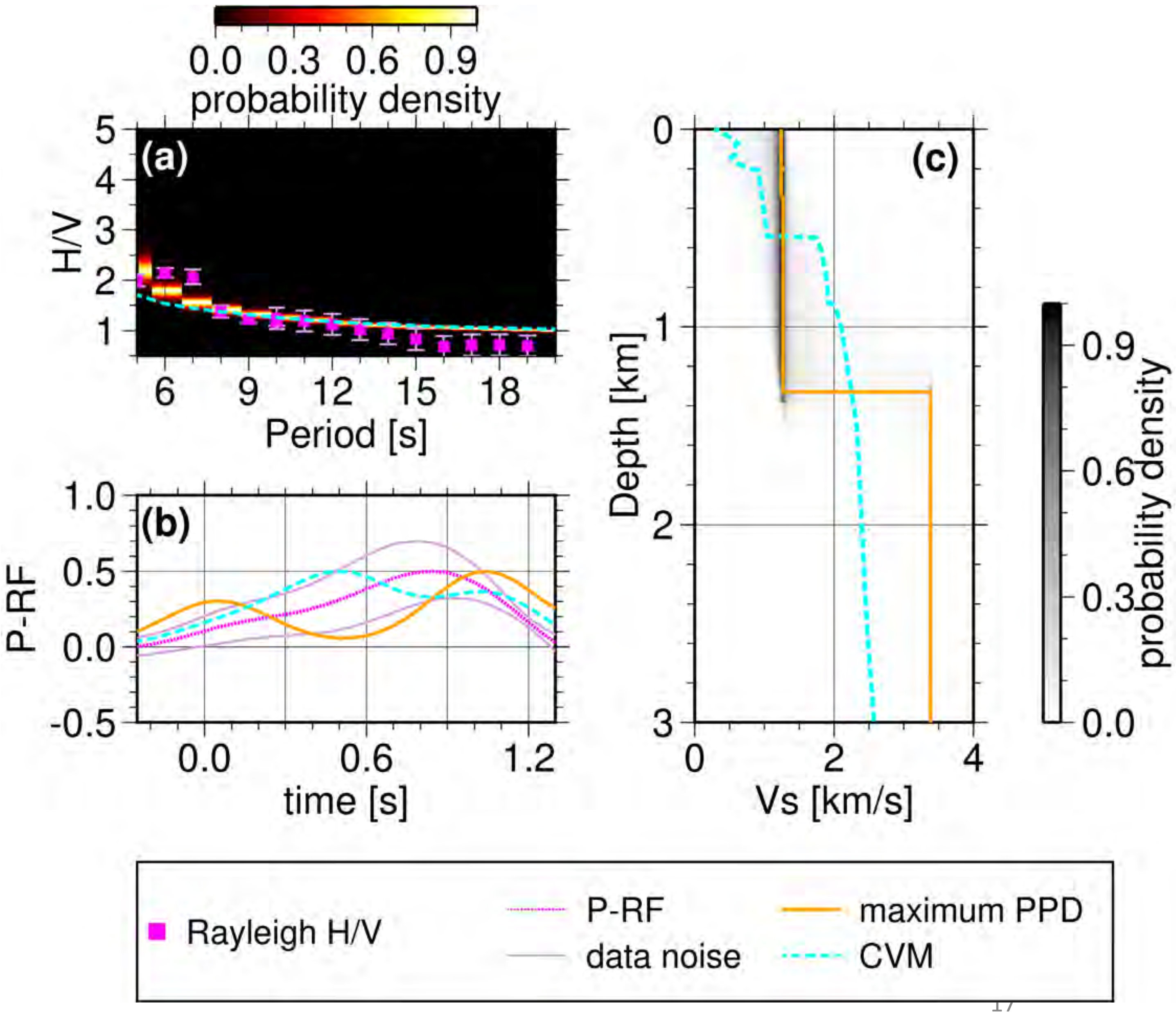
3-step Joint Inversion of Rayleigh wave ellipticity & Receiver Functions

Iterative 1D McMC inversion

1st Iteration: Basin-wide 1D Rayleigh wave phase velocity inversion

2nd Iteration: Rayleigh wave H/V

3rd Iteration: Rayleigh wave H/V + RF



Kim et al. (2024) Under review

3-step Joint Inversion of Rayleigh wave ellipticity & Receiver Functions

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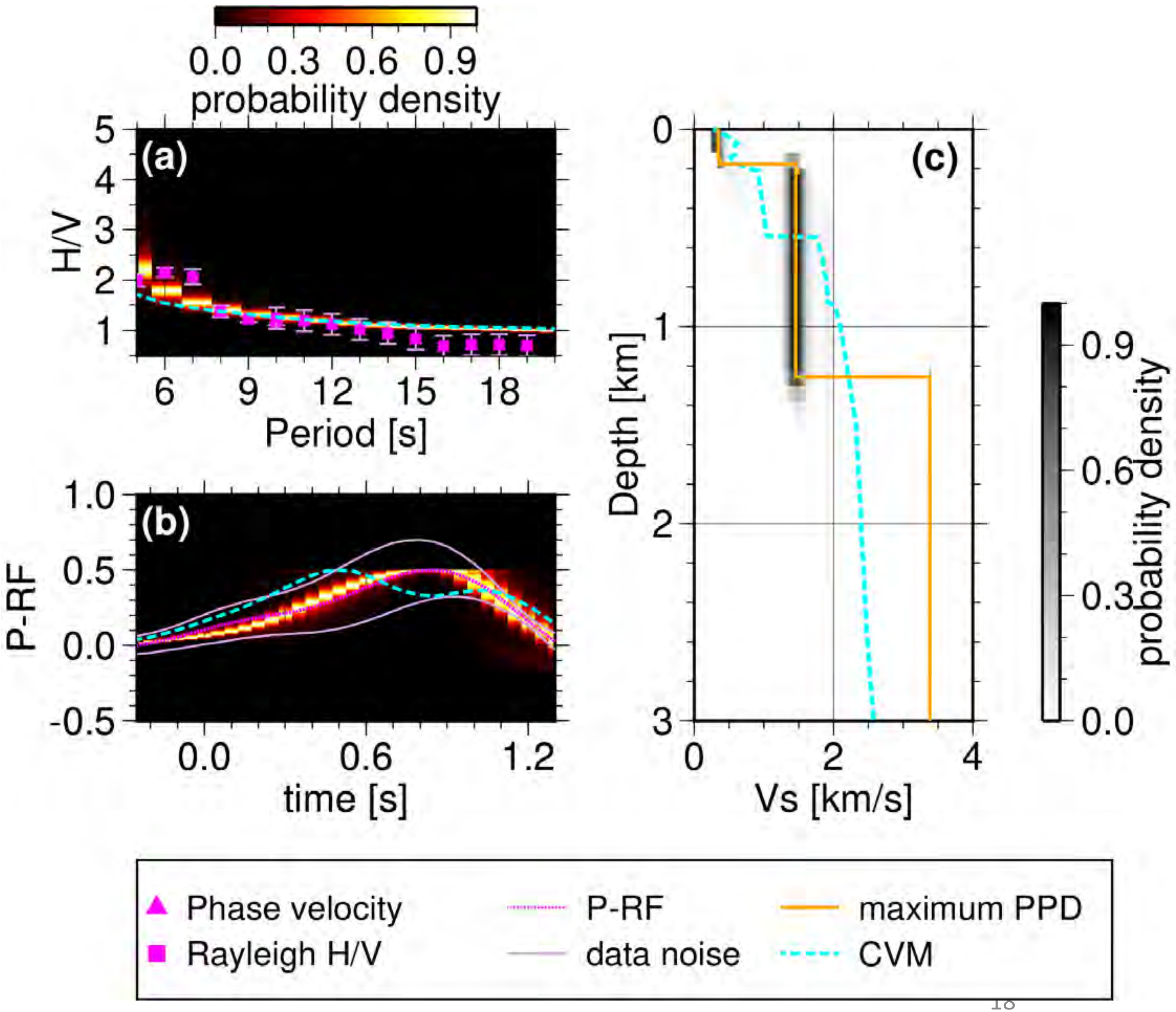
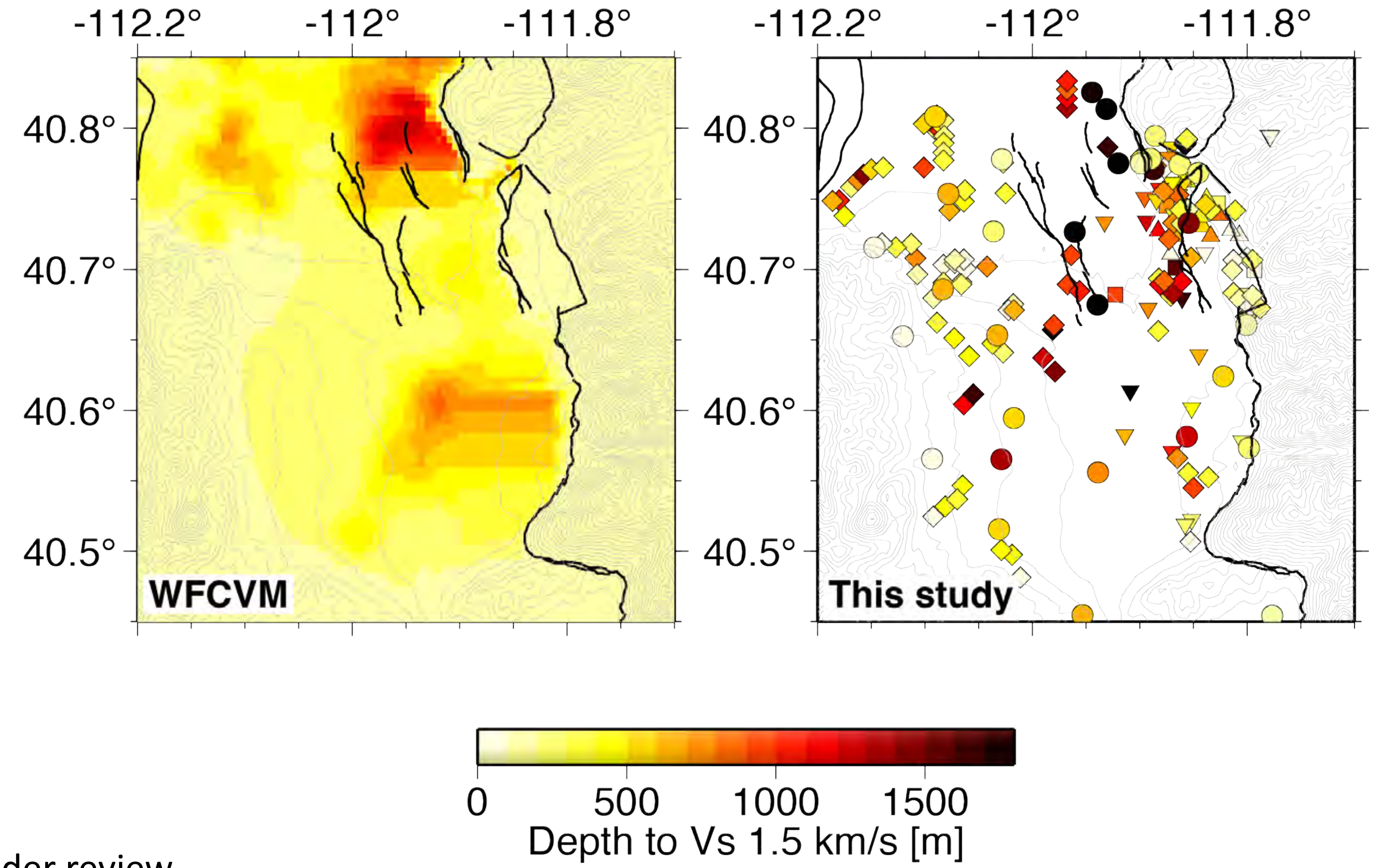


Kim et al. (2024) Under review

Results: Inverted R2 depths in map view

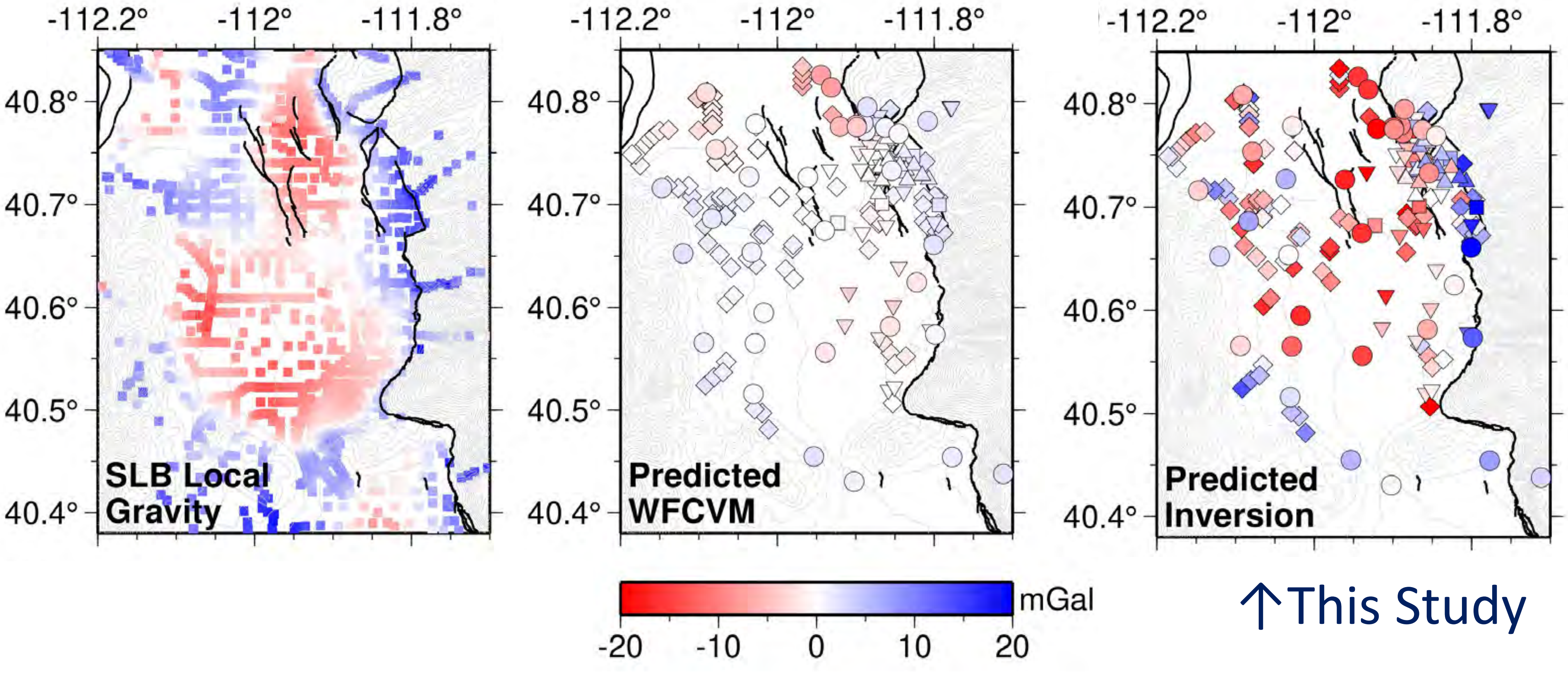
- Inverted R2 Depths (depths of Vs = 1.5 km/s) are larger than in WFCVM.
- The greatest R2 depths are between the WVFZ and the Wasatch fault (EBF+WSF)



Kim et al. (2024) Under review

Comparison between observed and predicted gravity values

- The pattern of gravity predicted from our new seismic model agrees with the local gravity map.
- Predicted gravity from WFCVM shows smaller amplitudes.

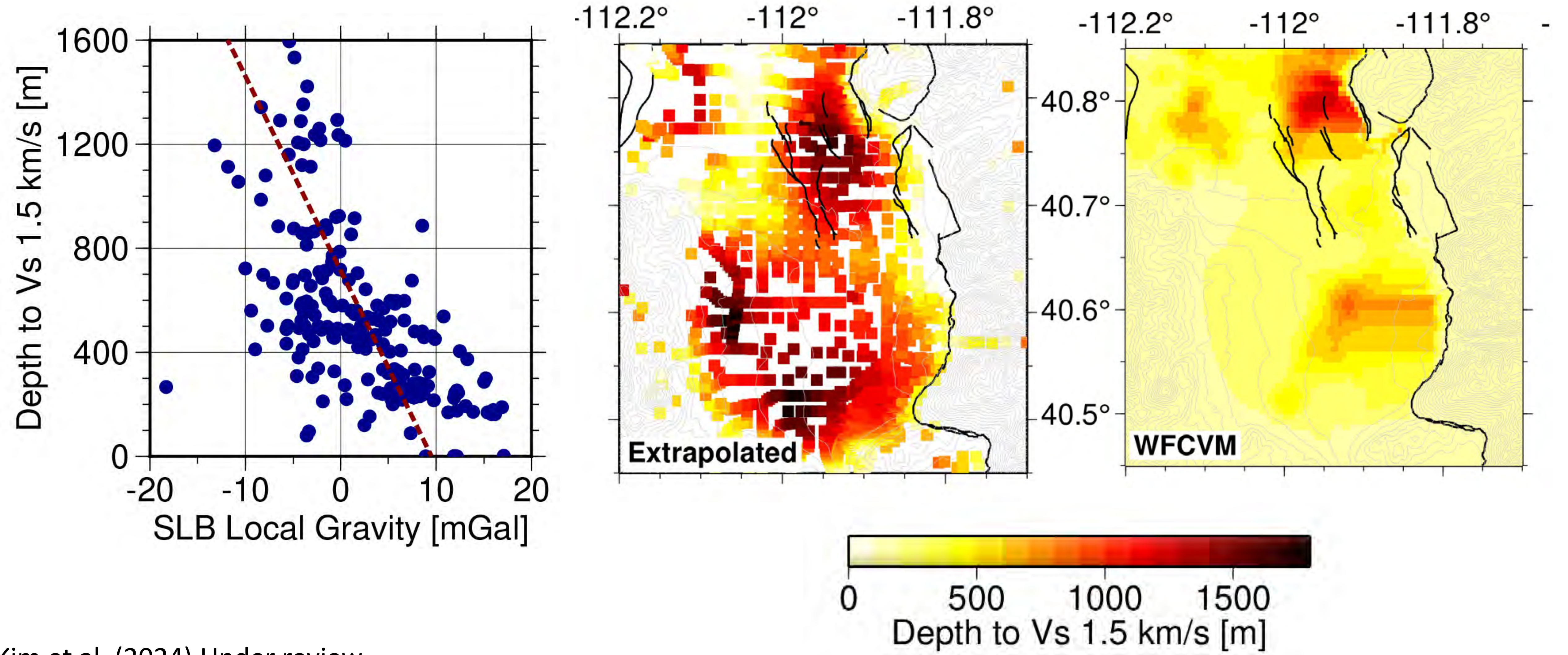


↑This Study

Kim et al. (2024) Under review

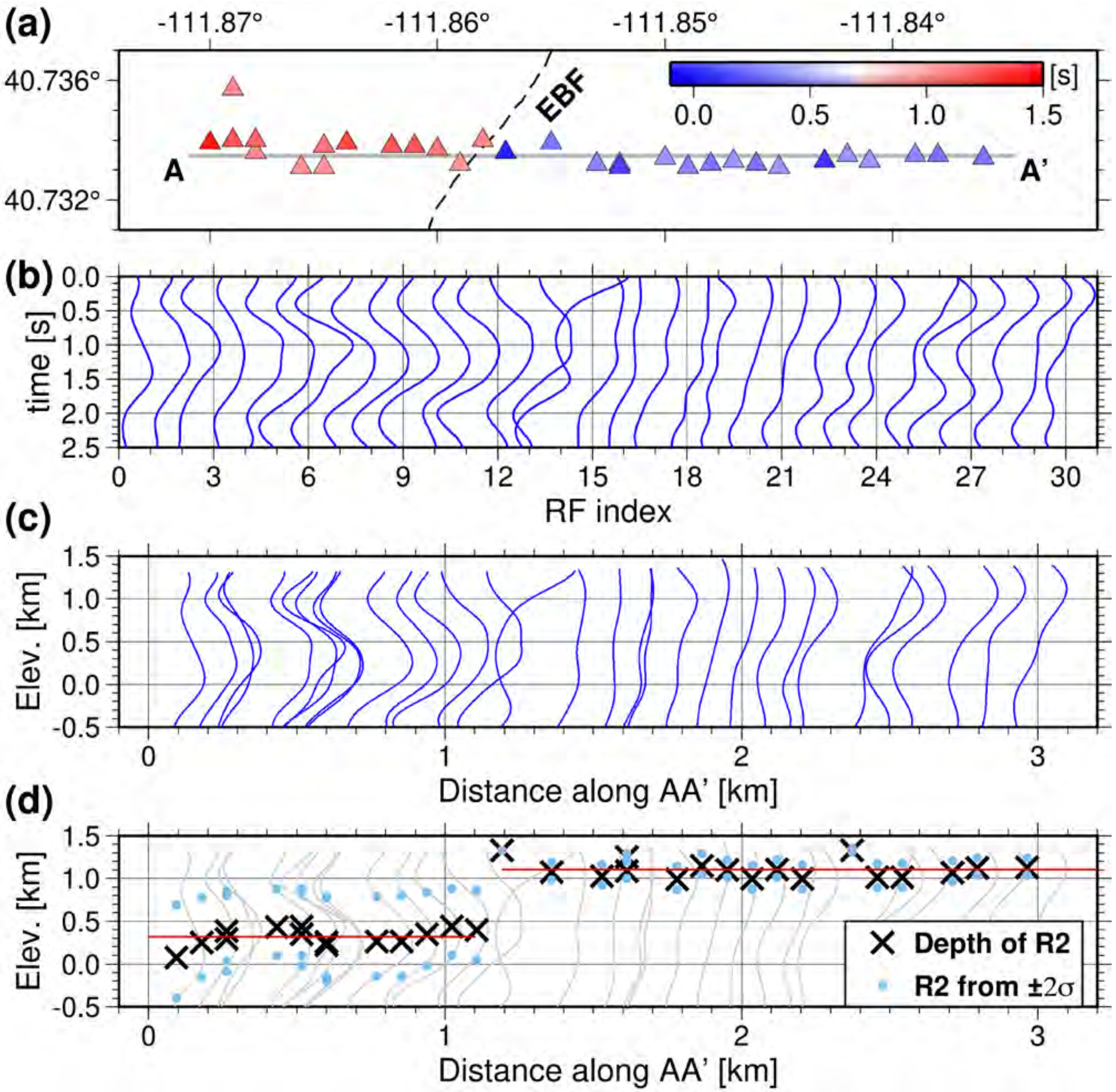
Valley wide depth to the bedrock from the new inversion

- Extrapolate R2 using a linear relationship between the inverted R2 and local gravity.

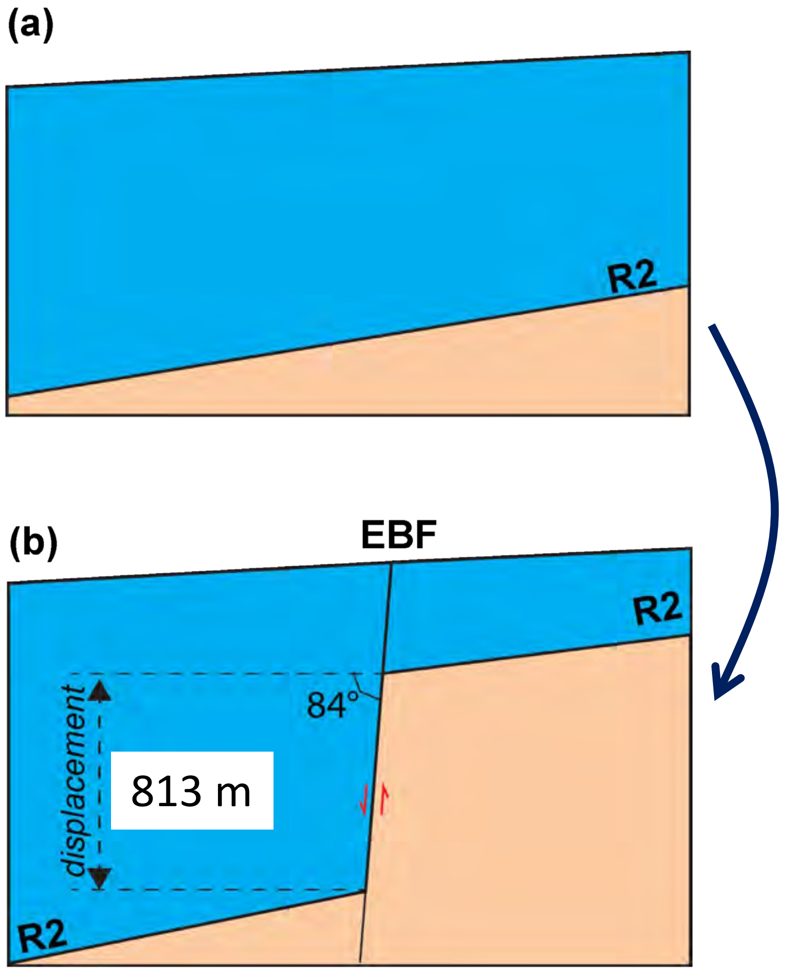


Kim et al. (2024) Under review

Sharp change of Receiver Function peak time across EBF



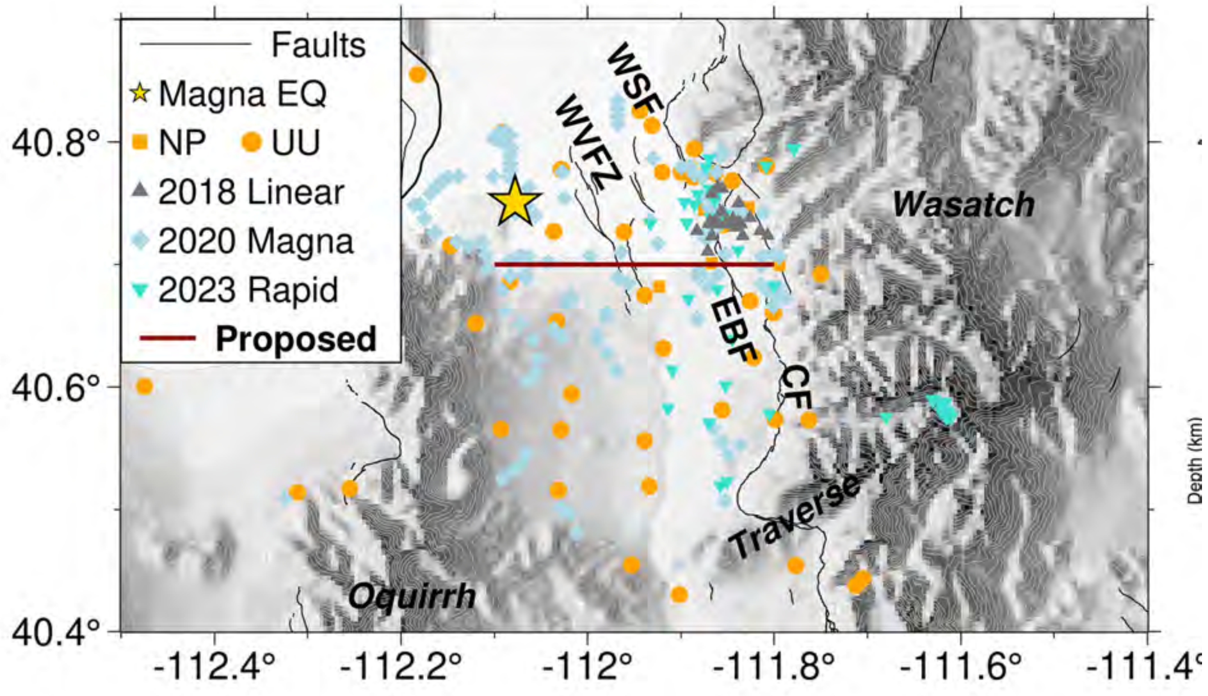
- Change in delay time → Indicates a change of depth to the bedrock



1.1 mm/yr (Hatem et al., 2025)
→ Slip during 740 ka?

Kim et al. (2025) In prep.

Potential of using Receiver Functions for understanding the geometry



Petersen et al. (2014)

Summary

- Receiver functions can detect R2, the boundary between semi-consolidated sediments and sedimentary rocks, in the Salt Lake Valley.

- We performed a 1D joint inversion of Rayleigh wave phase velocity, Rayleigh wave ellipticity, and receiver functions for all available stations in the Salt Lake Valley.

- Our results show a thicker layer of unconsolidated and semi-consolidated sediments compared to the CVM.

- The predicted gravity field from the new model agrees better with a new residual Bouguer gravity anomaly map from this study.

Questions & Comments?

Reach us further through hkim.geo@gmail.com

Acknowledgements

This work is supported by USGS Earthquake Hazard Program: "Towards an Improved Salt Lake Valley Community Velocity Mod
Through Seismic and Gravity Joint Inversion: Collaborative Proposal with University of Utah and Utah Geological Survey"

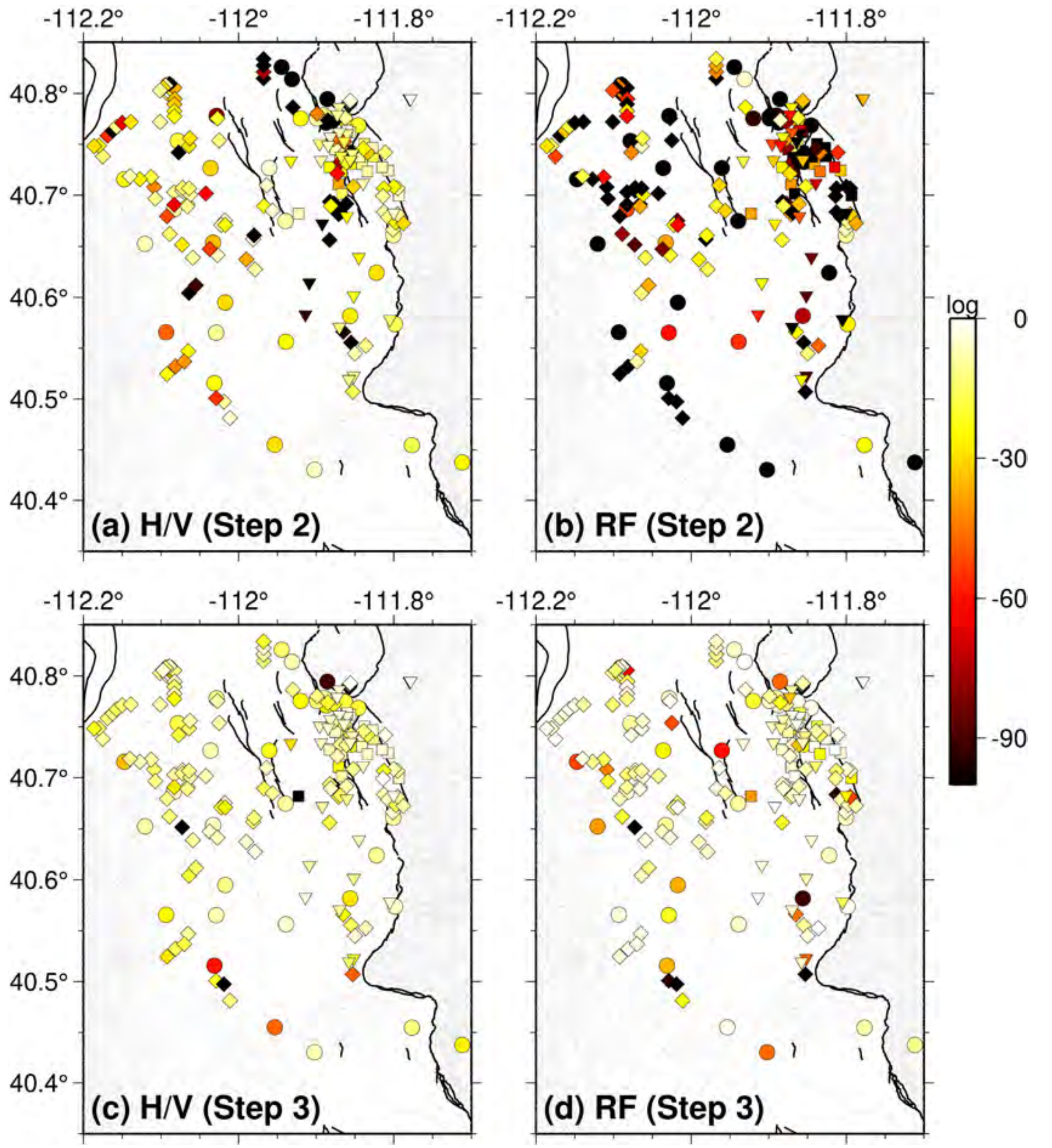
3-step Joint Inversion of Rayleigh wave ellipticity & Receiver Functions

Iterative 1D McMC inversion

1st Iteration: Basin-wide 1D Rayleigh wave phase velocity inversion

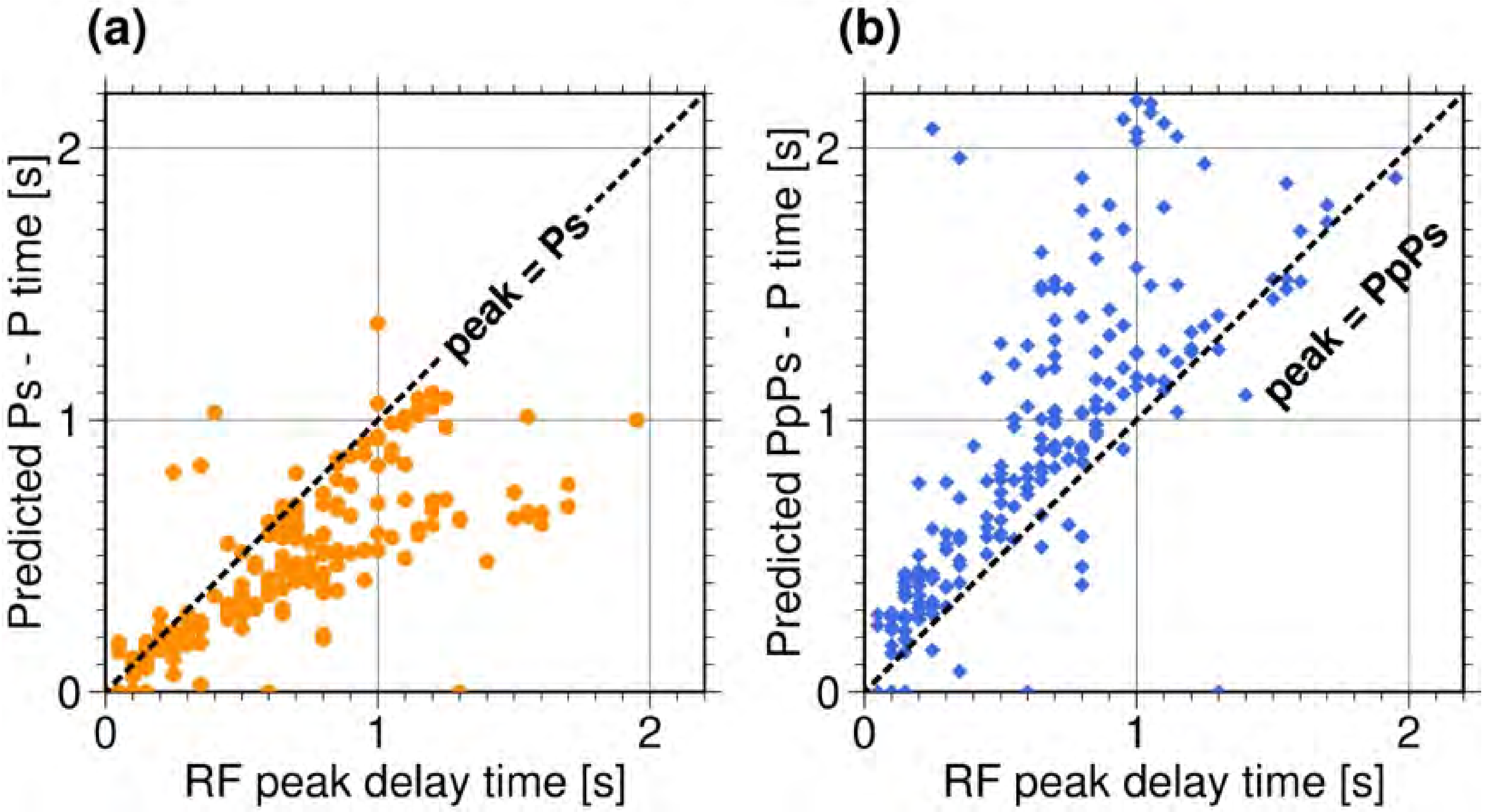
2nd Iteration: Rayleigh wave ellipticity (H/V)

3rd Iteration: Rayleigh wave ellipticity (H/V) + Receiver Function



Ambiguity of delay time interpretation

- It could be Ps phase or PpPs phase.



Modeling evolving shear tractions on the Wasatch fault since 5 ka

Grasshopper Anderson-Merritt, Michele Cooke, & Chris DuRoss

2025 UQFPWG Meeting

2/10/25

Public domain image from https://en.wikipedia.org/wiki/File:Jan_14_06_eastern_Salt_Lake_County_UT_USA.JPG

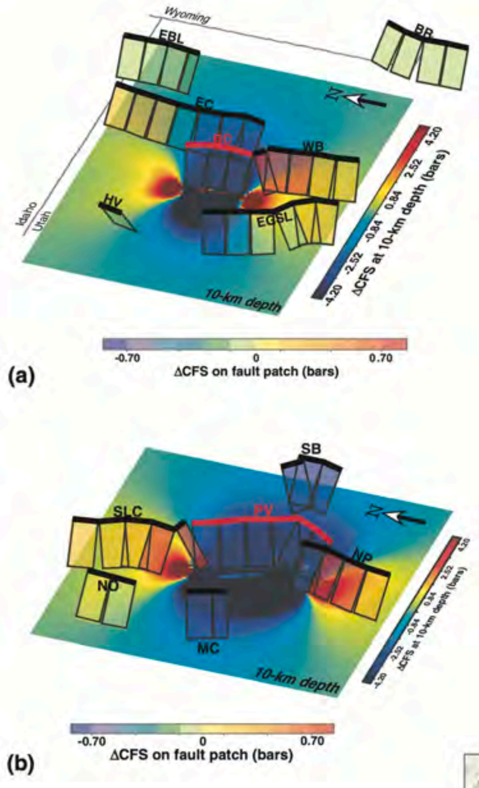
Why model fault tractions?

- Traction estimates can inform the conditions that produce large earthquakes & can provide context for interpreting the paleoseismic record
- Measuring tractions in the crust is difficult in the present day & even more so for past earthquakes
- Dynamic rupture model results depend on initial tractions, which are typically simple estimates using the remote stress field

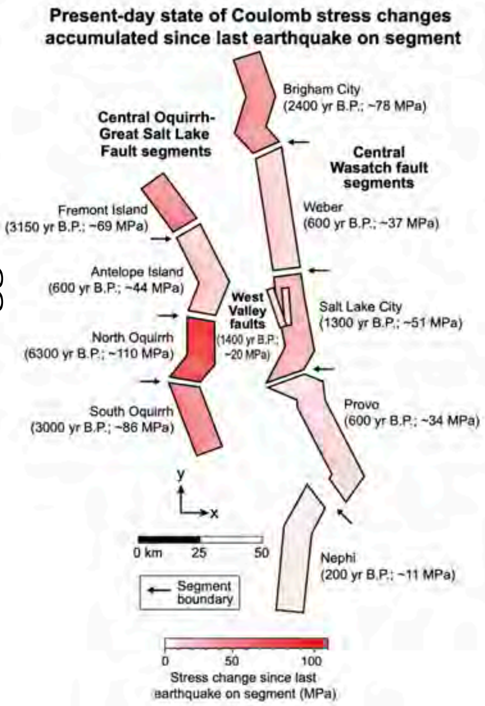
Previous modeling efforts

- Explore Coulomb stress changes on the Wasatch fault
- Each has some of the following limitations:
  - Limit analysis to period since most recent earthquake on each section
  - Use simplified fault geometries
  - Don't explicitly consider uncertainty in earthquake timing or upper crustal rheology

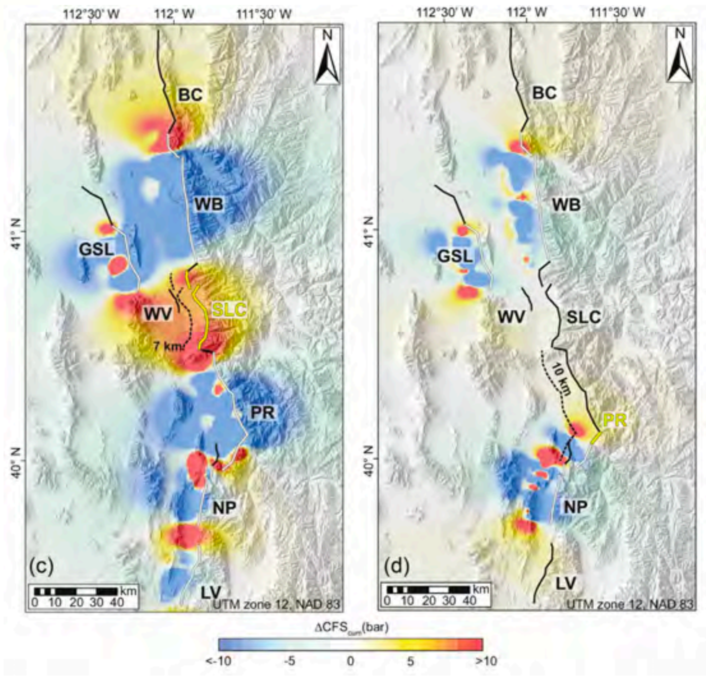
Chang & Smith 2002



Bagge et al. 2019

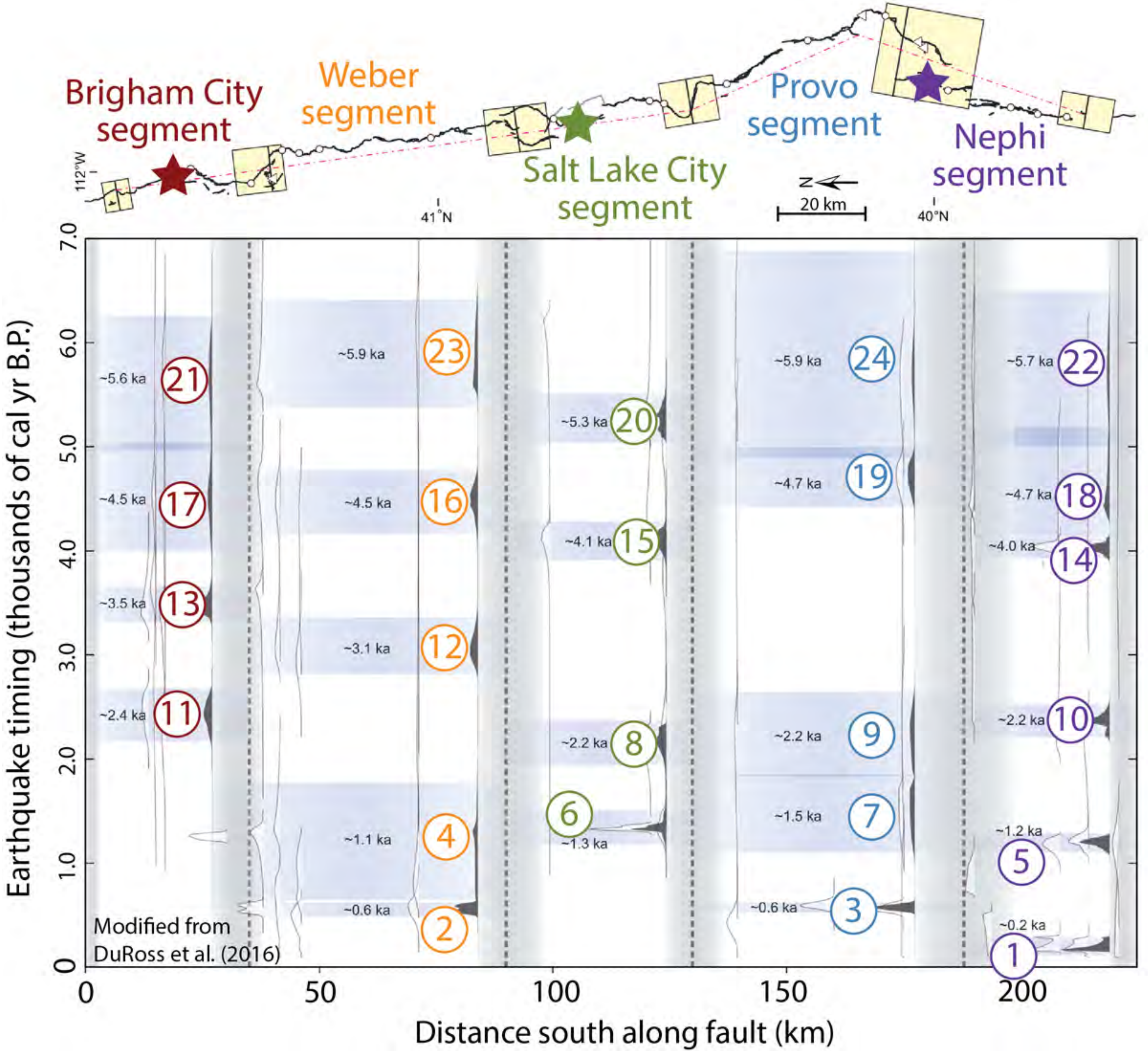


Verdecchia et al. 2019



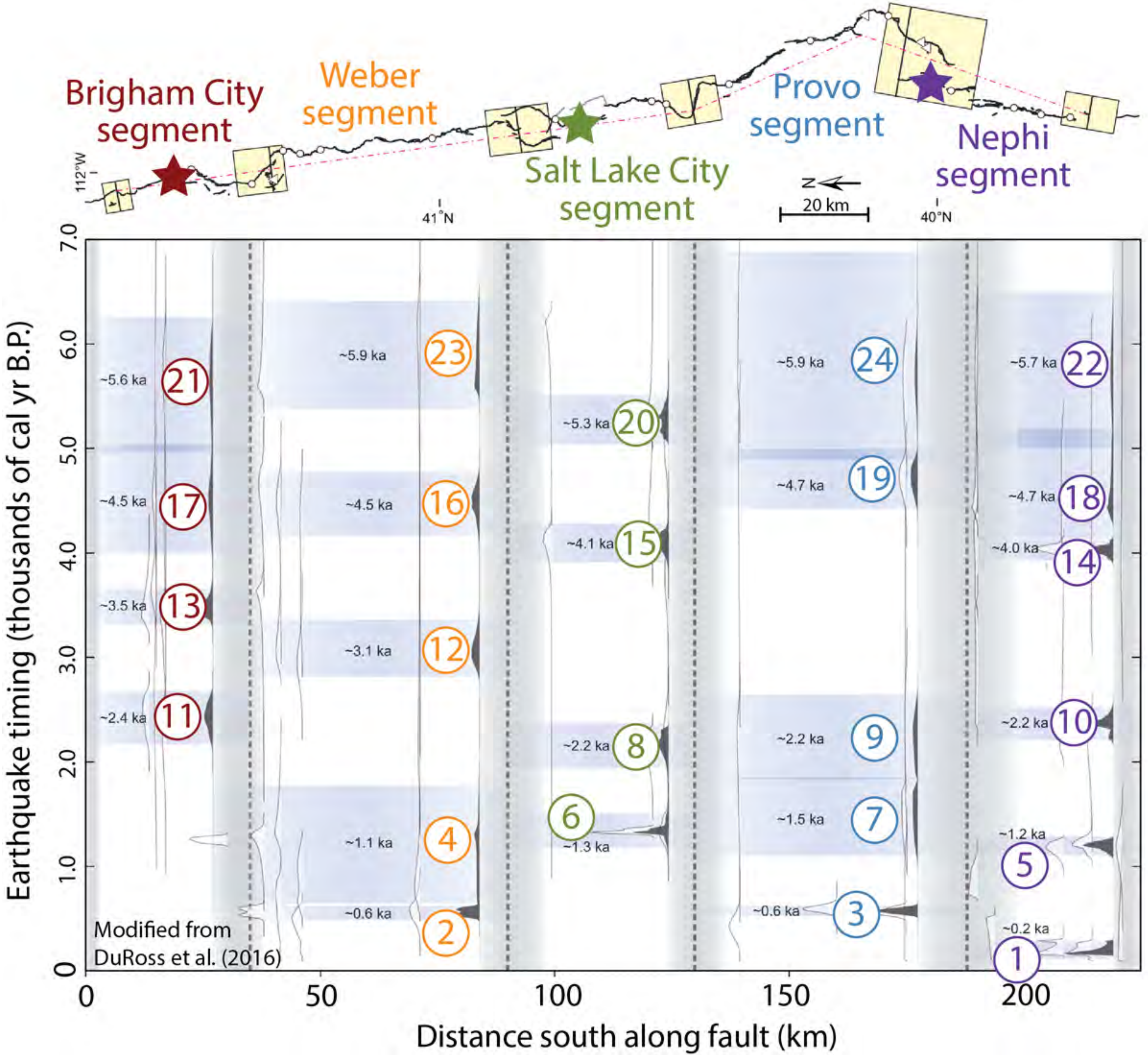
Where we're going

- Simulate segmented rupture history from DuRoss et al. (2016)
- Incorporate complex, 3D fault geometry using Poly3d
- Explore uncertainties in earthquake timing and upper crustal rheology that previous models have not been able to address

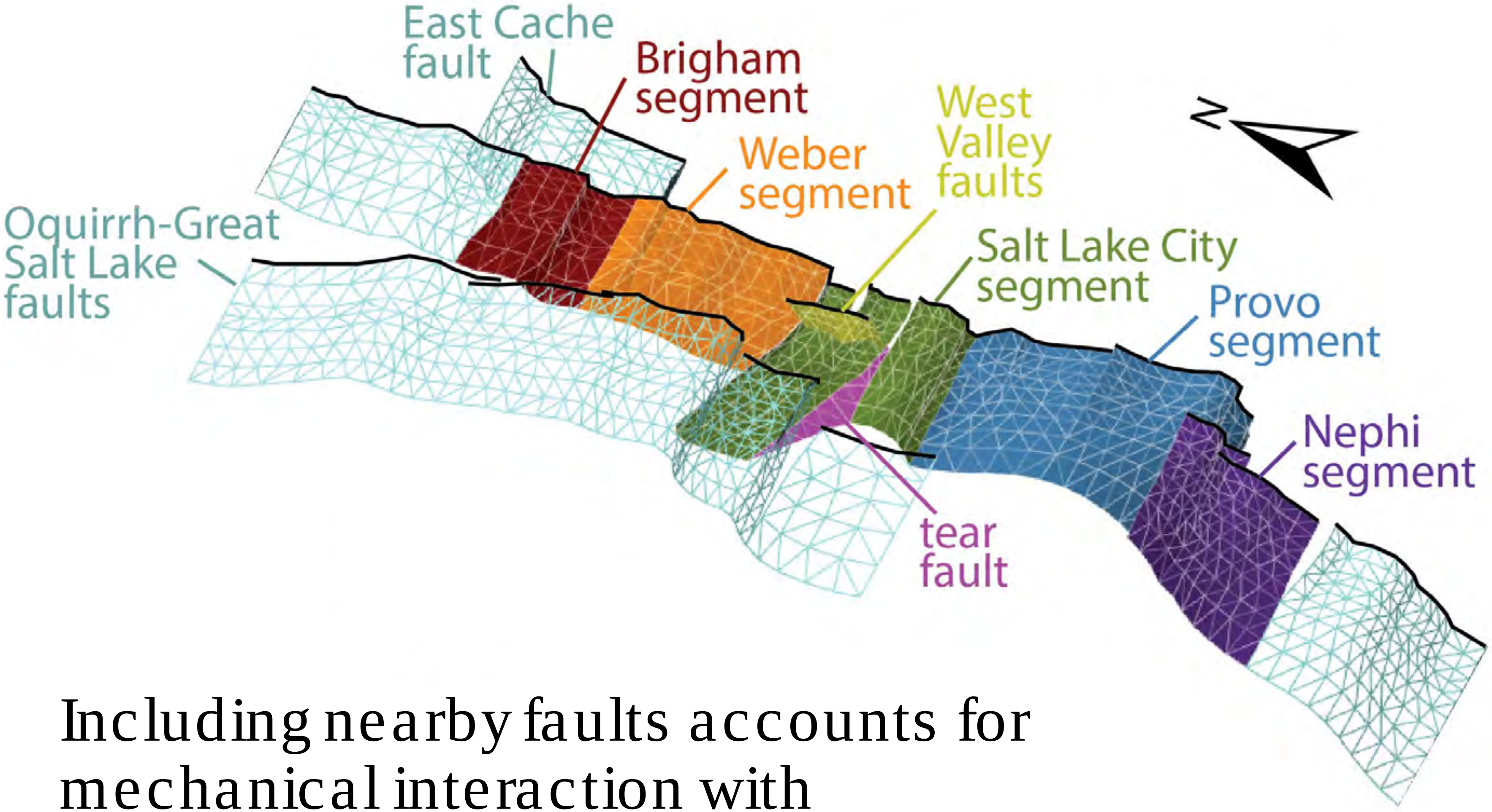


Where we're going

- Fault mesh geometry
- Methods (&validation along the way)
- Tractions through time at sites of interest
- Spatial traction patterns
- Pre-quake tractions
- Conclusions &what's next



Model mesh geometry



Including nearby faults accounts for mechanical interaction with segments of interest

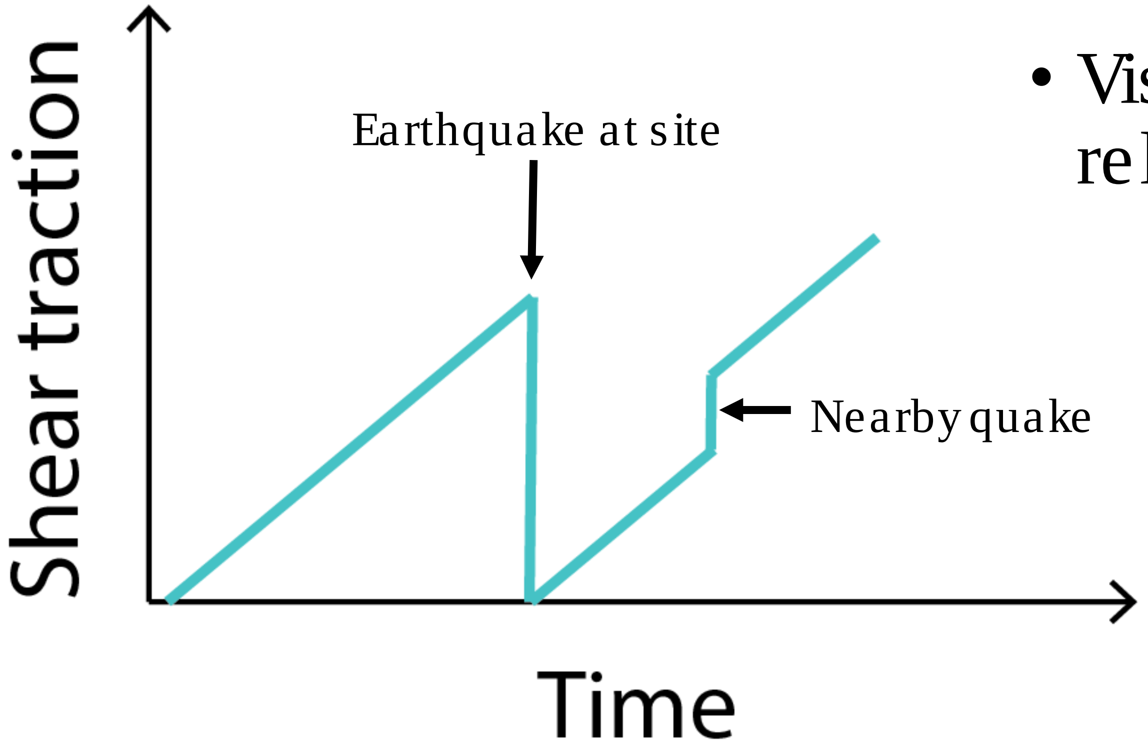
- NSHM v2 fault traces projected to depth
- 50° westward dip except for listric sections near SLC
- Tear faults connect listric and non-listric sections
- Basal crack at 40 km depth simulates distributed deformation

How do we model fault stress through time?

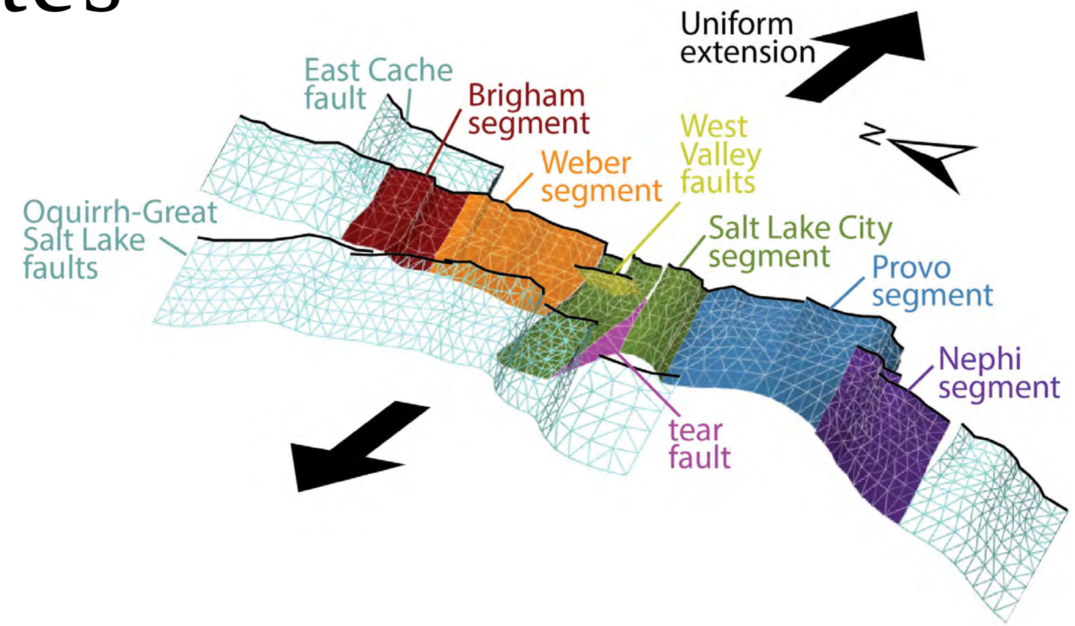
Dip shear traction = interseismic stressing + earthquake effects

- Tectonic loading
- Viscoelastic stress relaxation (or not)

- Earthquakes at site
- Nearby earthquakes

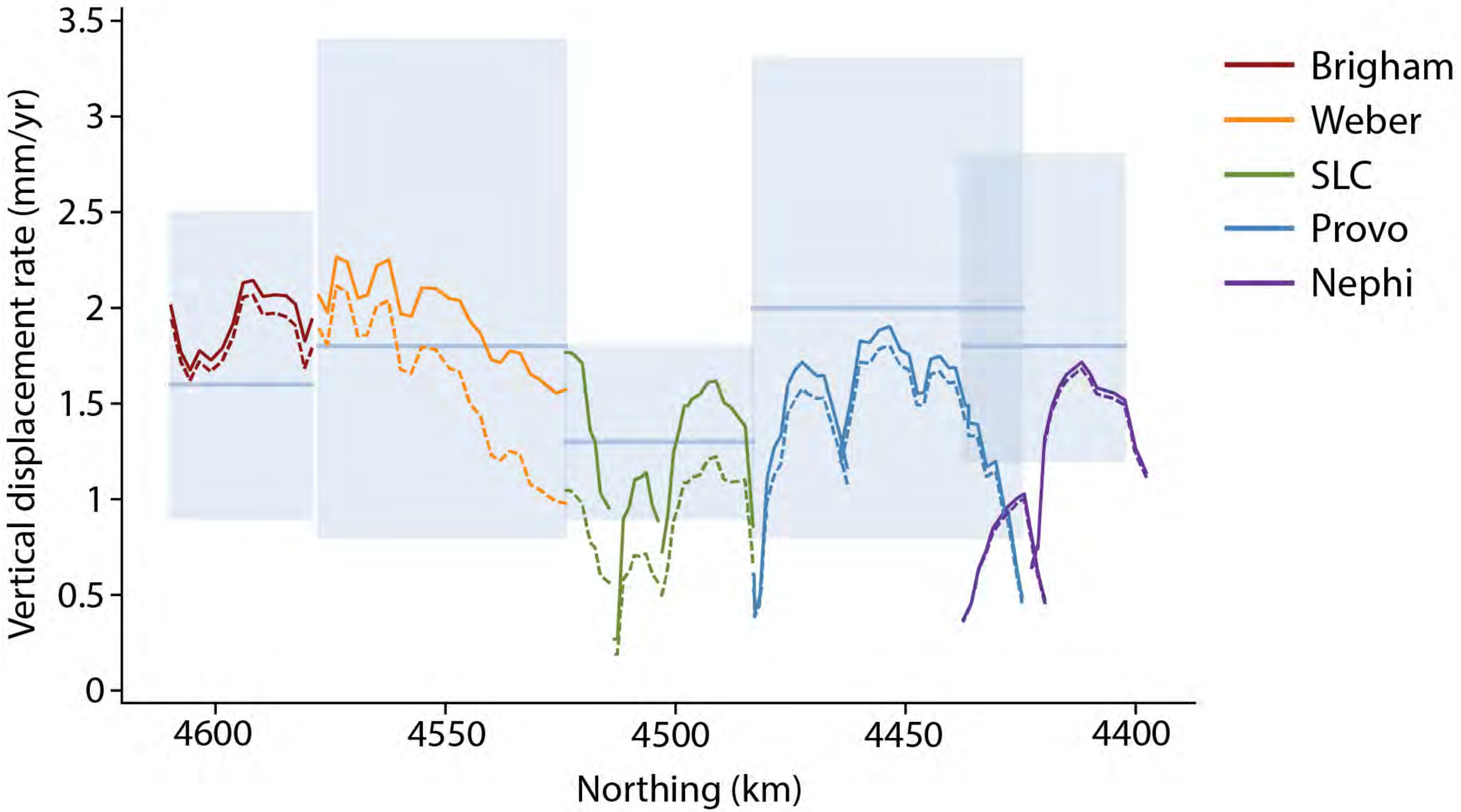


Tectonic loading ➔ stressing rates



Step 1: apply tectonic loading while faults slip freely to get slip rates

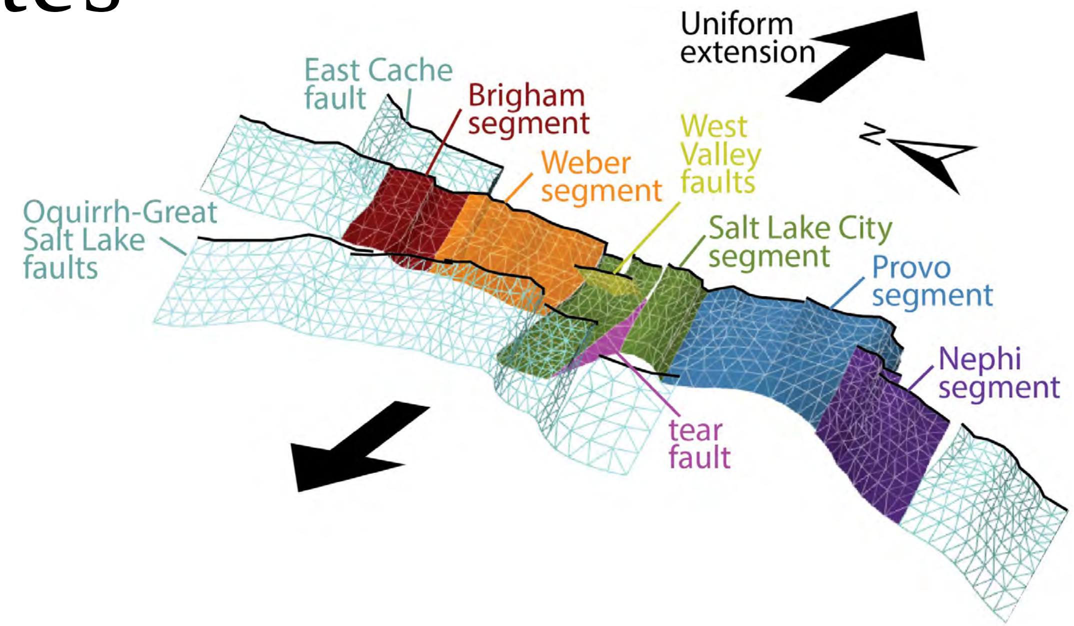
Validation part 1: vertical displacement rates



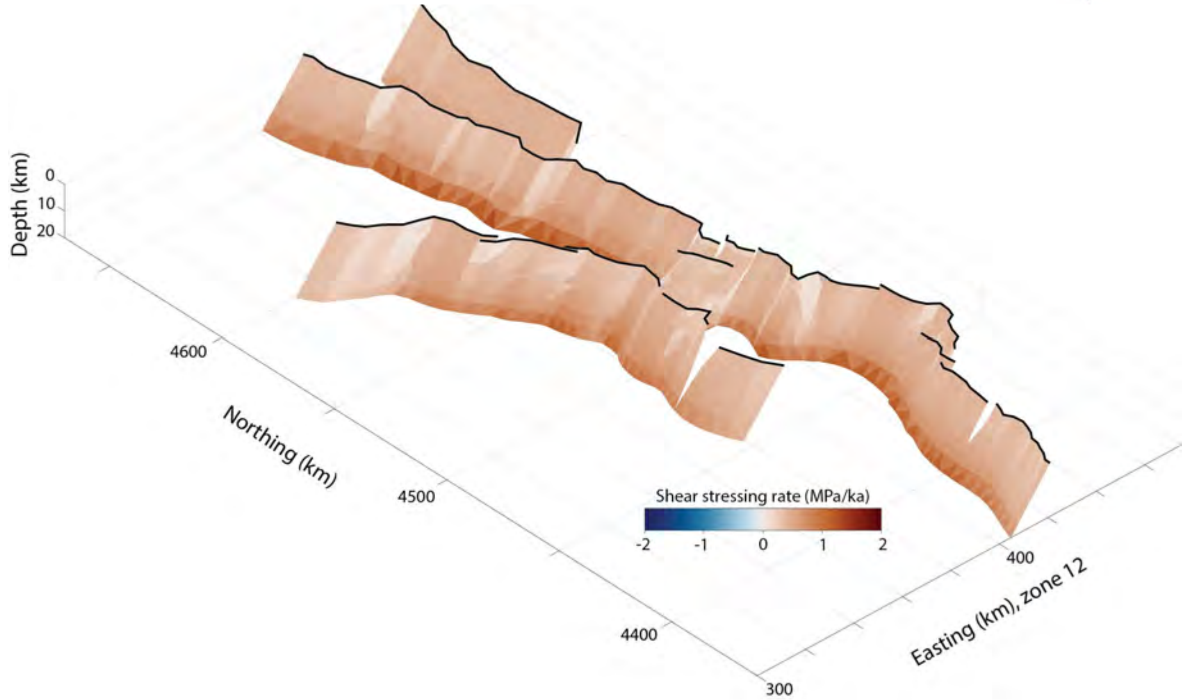
- Model displacement rates generally within error of preferred geologic rates
- Including tear faults increases displacement rates nearby

Tectonic loading → stressing rates

Step 1: apply tectonic loading while faults slip freely to get slip rates



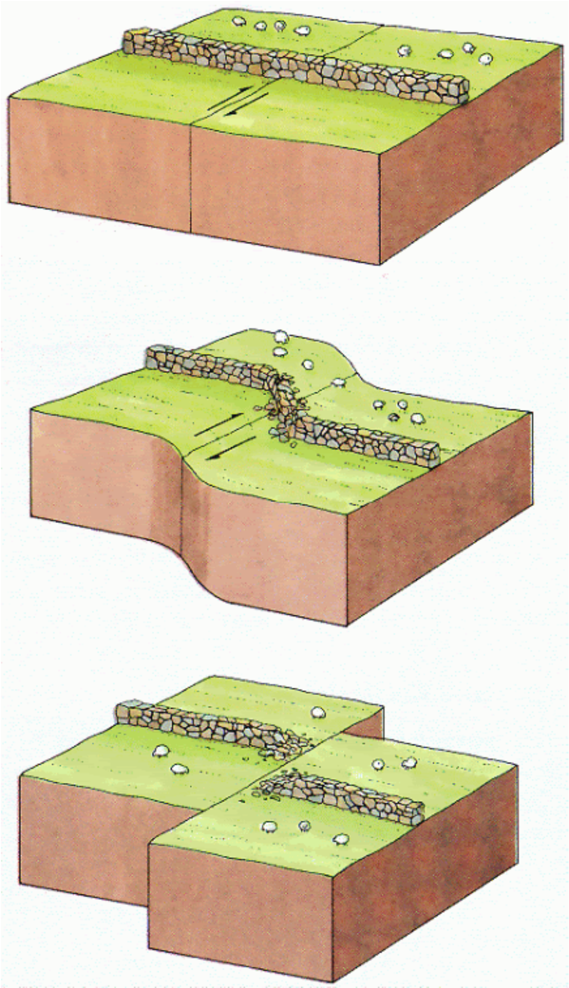
Step 2: apply slip rate below 25 km locking depth to get interseismic stressing rates

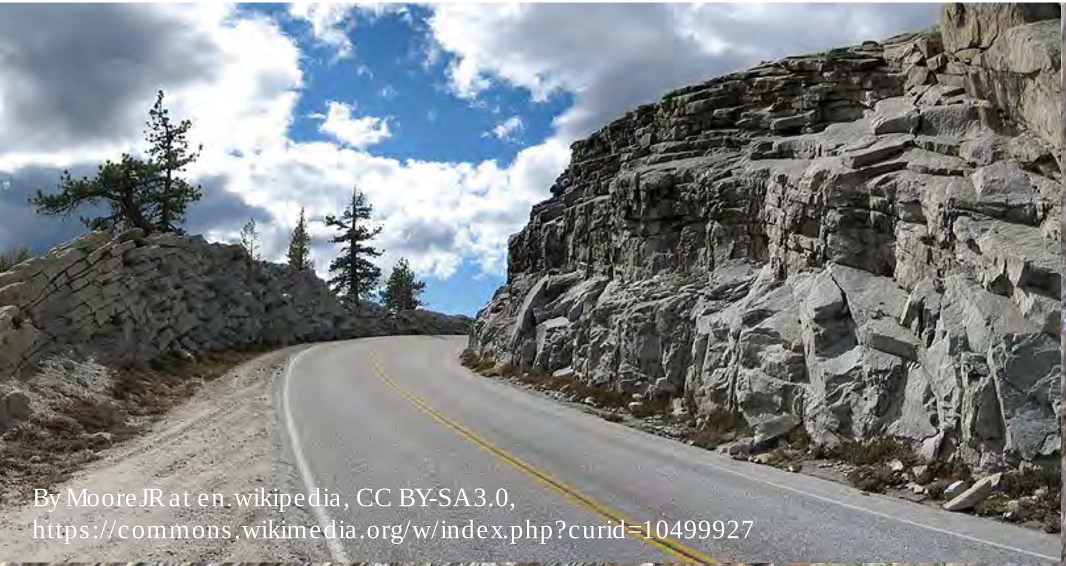


Interseismic stressing: accumulating traction

Linear elastic: all deformation is recoverable and can be released in earthquakes

$$\sigma(t) = \dot{\sigma} t$$




By MooreJR at en.wikipedia, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=10499927


Marli Miller


Joints
National Park Service

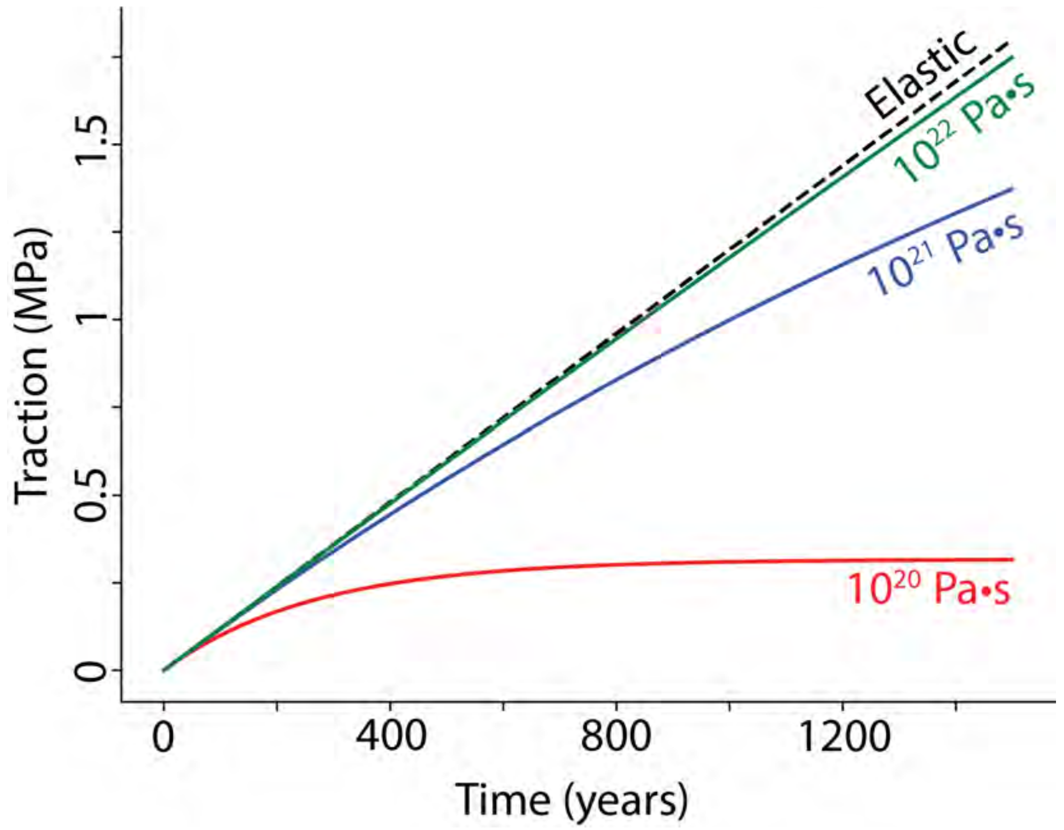
Interseismic stressing: accumulating traction

Linear elastic: all deformation is recoverable and can be released in earthquakes

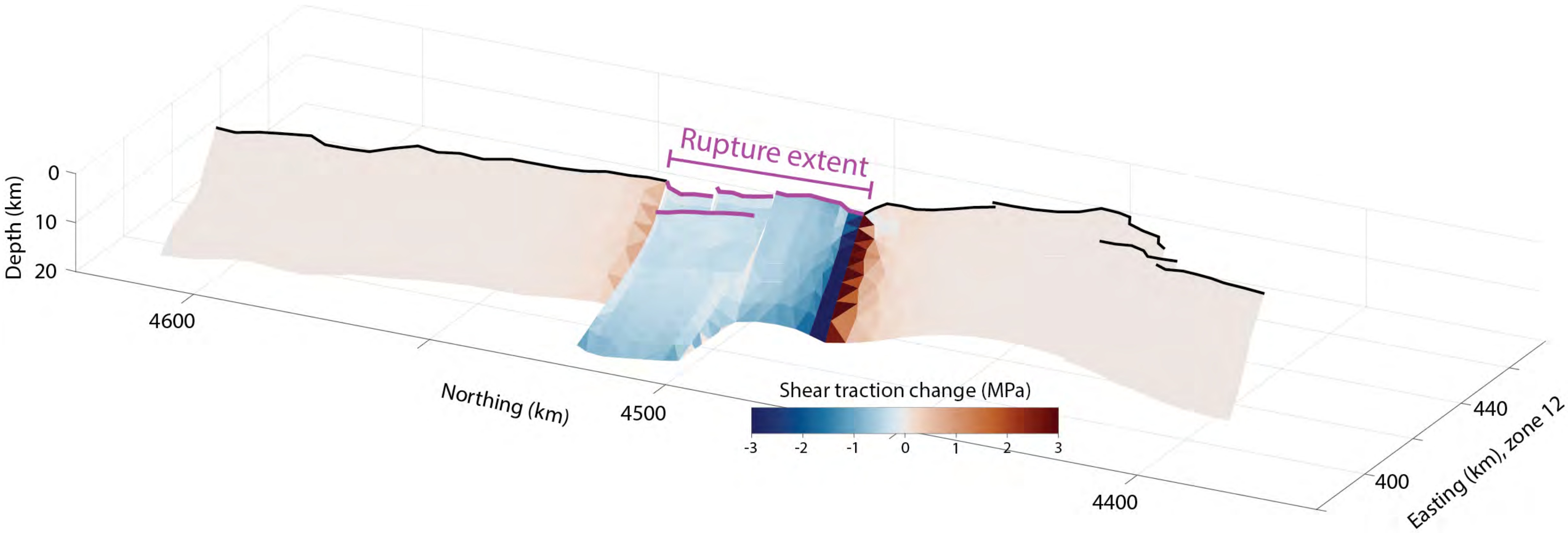
$$\sigma(t) = \dot{\sigma} t$$

Viscoelastic: permanent deformation in the crust relieves some traction on faults

$$\sigma(t) = (\sigma_0 - \eta\dot{\varepsilon}) * \exp\left(-\frac{\mu}{\eta} t\right) + \eta\dot{\varepsilon}$$



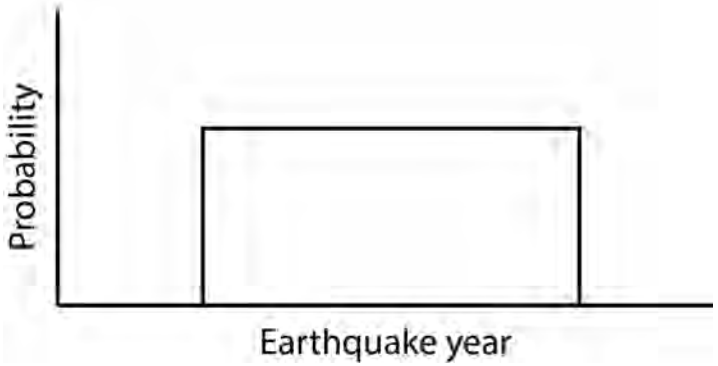
Release accumulated tractions to simulate earthquakes



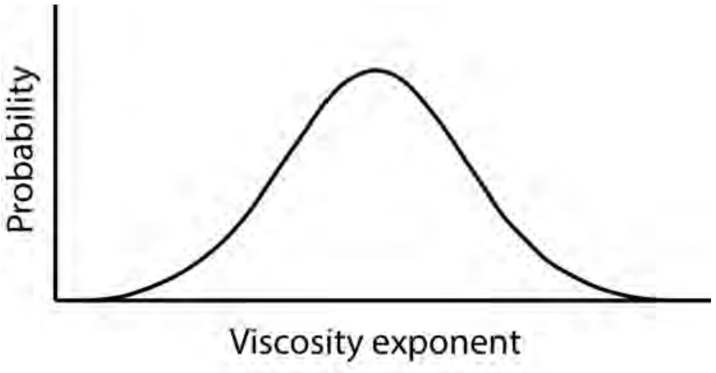
- Apply a shear traction change to the rupture patch (complete stress drop)
- Surrounding faults experience a change in shear traction as a result

Monte Carlo simulations address uncertainties

- Earthquake timing: boxcar distribution from DuRoss et al. (2016)

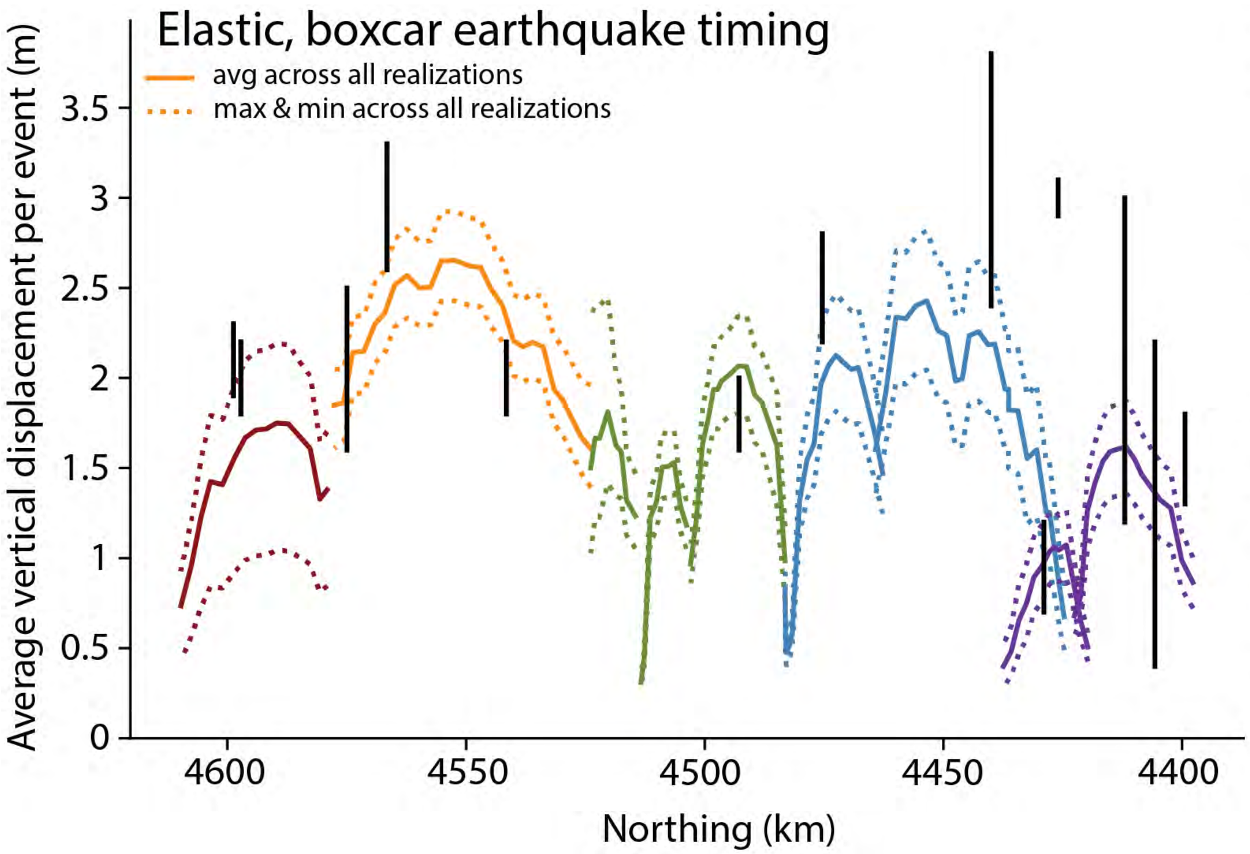


- Crustal viscosity: $10^{20} – 10^{22}$ Pa·s; Gaussian distribution of exponent (mean = 21, std dev = 0.5)

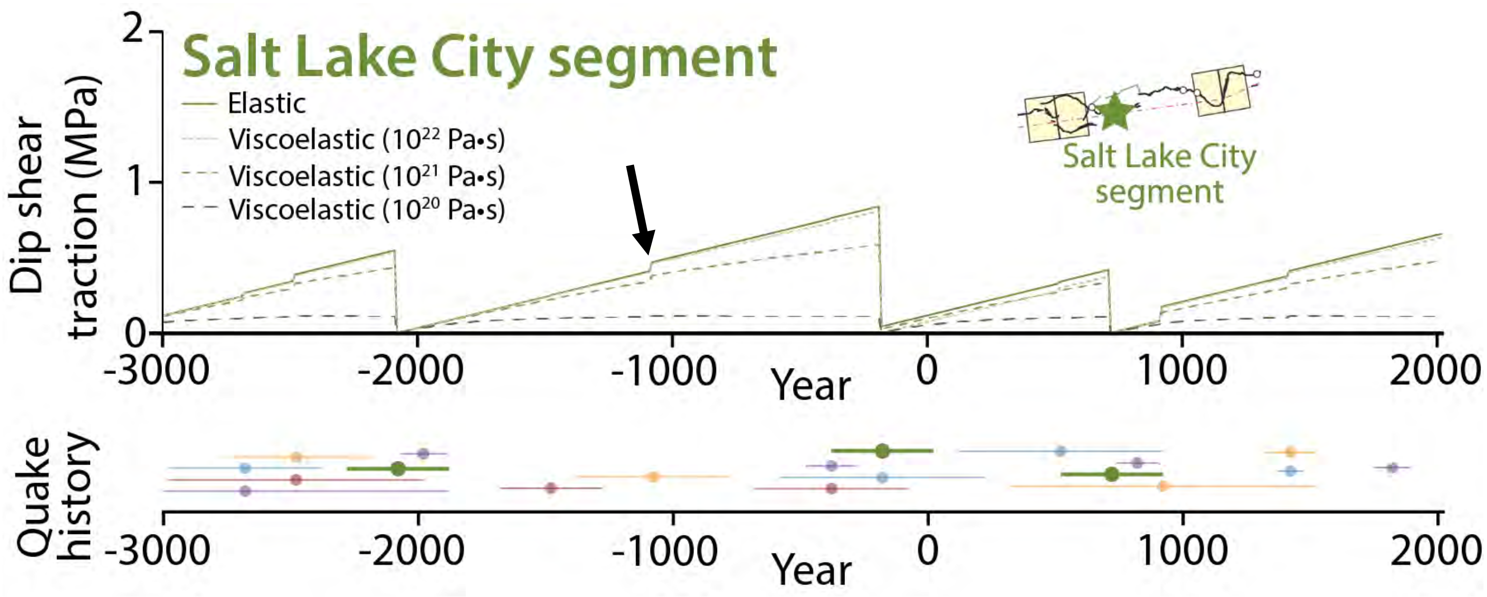


Validation part 2: average vertical displacement per event

- Elastic and high viscosity simulations are generally consistent with the geologic record
- Low viscosity simulations underestimate slip by a lot!

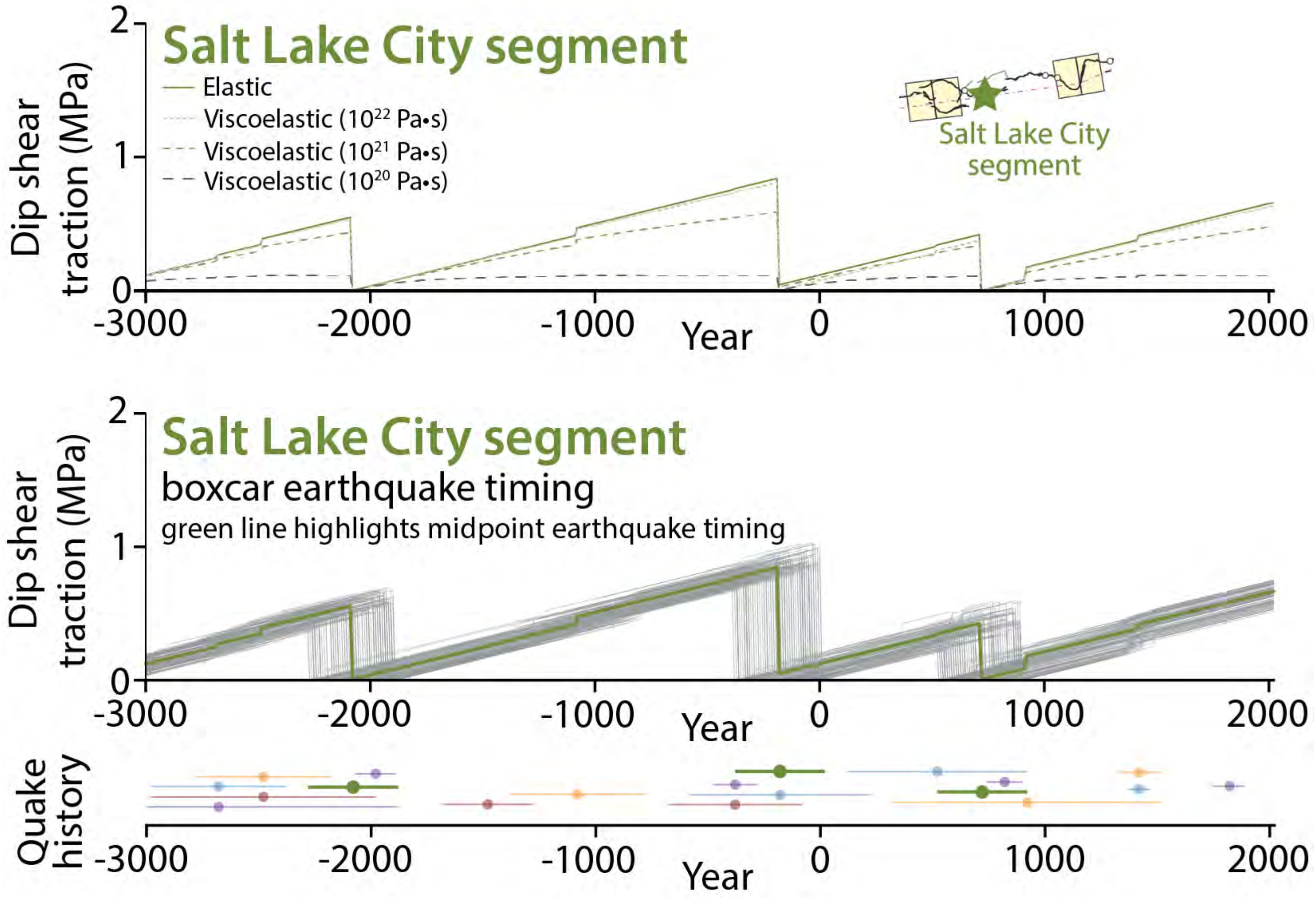


Traction through time: Salt Lake City



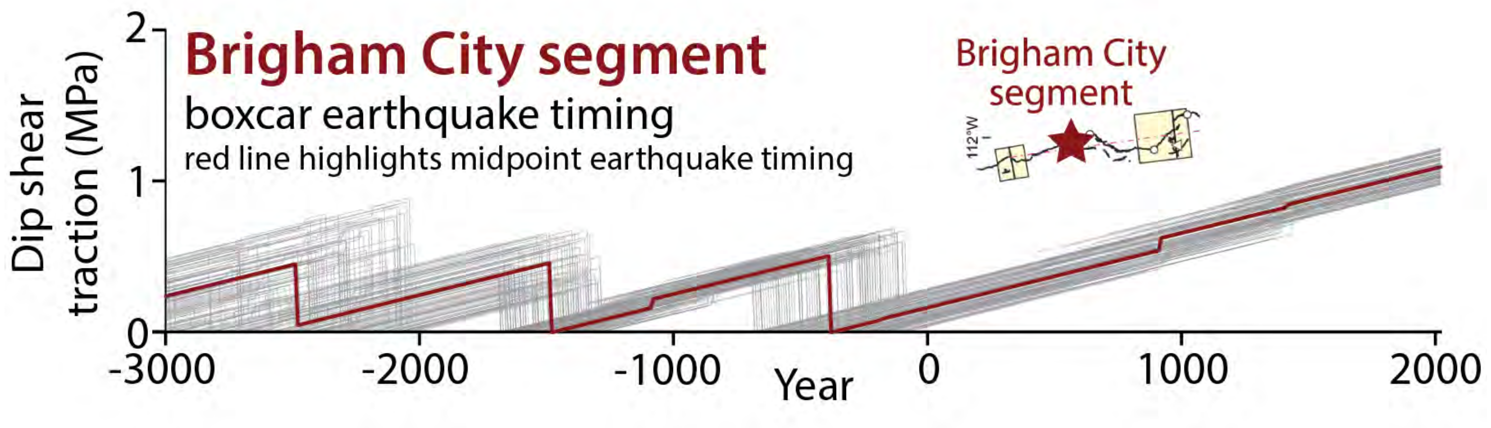
- Most accumulated traction is from interseismic loading
- Choice of viscosity greatly changes accumulated tractions
- In the middle of the segment, nearby quakes have small effects

Traction through time: Salt Lake City



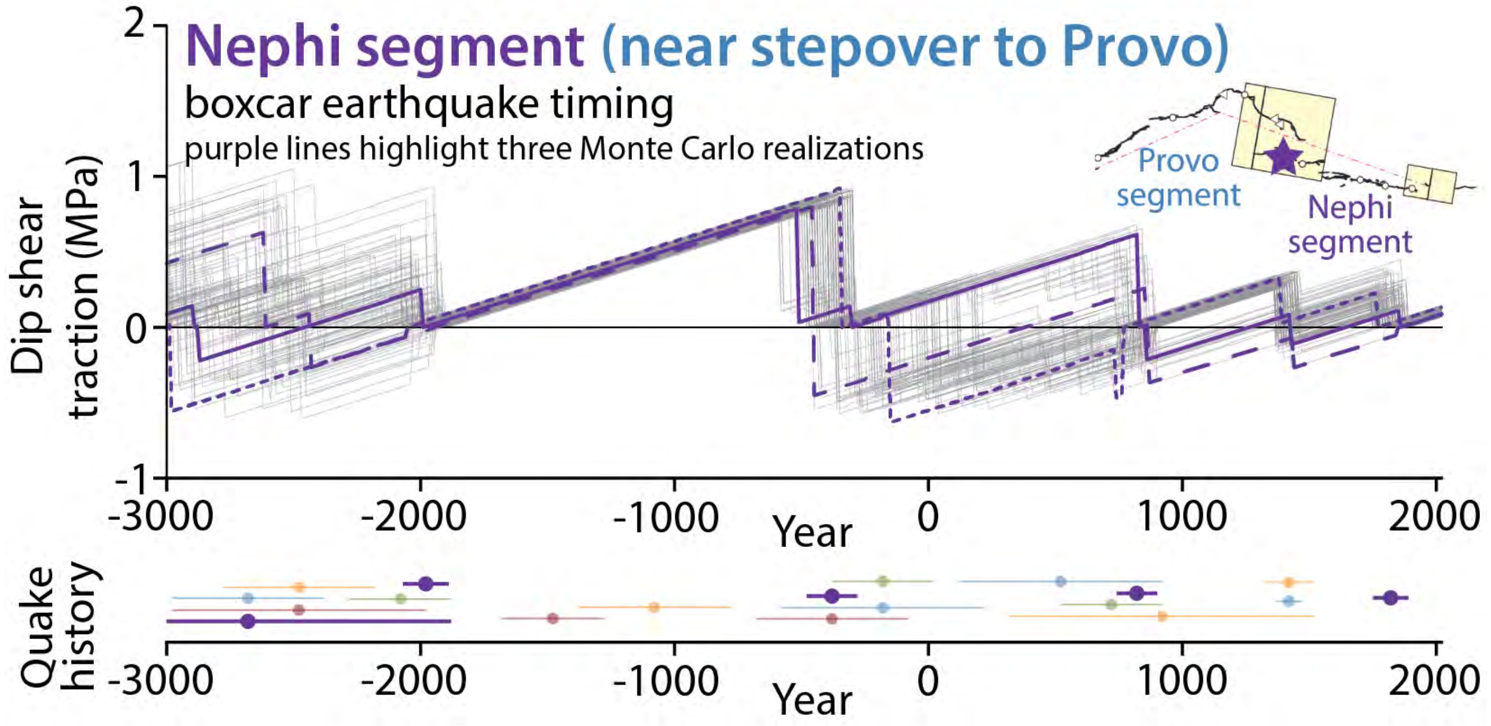
- Present-day traction is comparable to past pre-earthquake traction at this location

Traction through time: Brigham City



- Current open interval is longer than recurrence interval
- Present-day traction estimates exceed past pre-quake tractions for the elastic models…

Traction through time: Nephi/Provo stepover

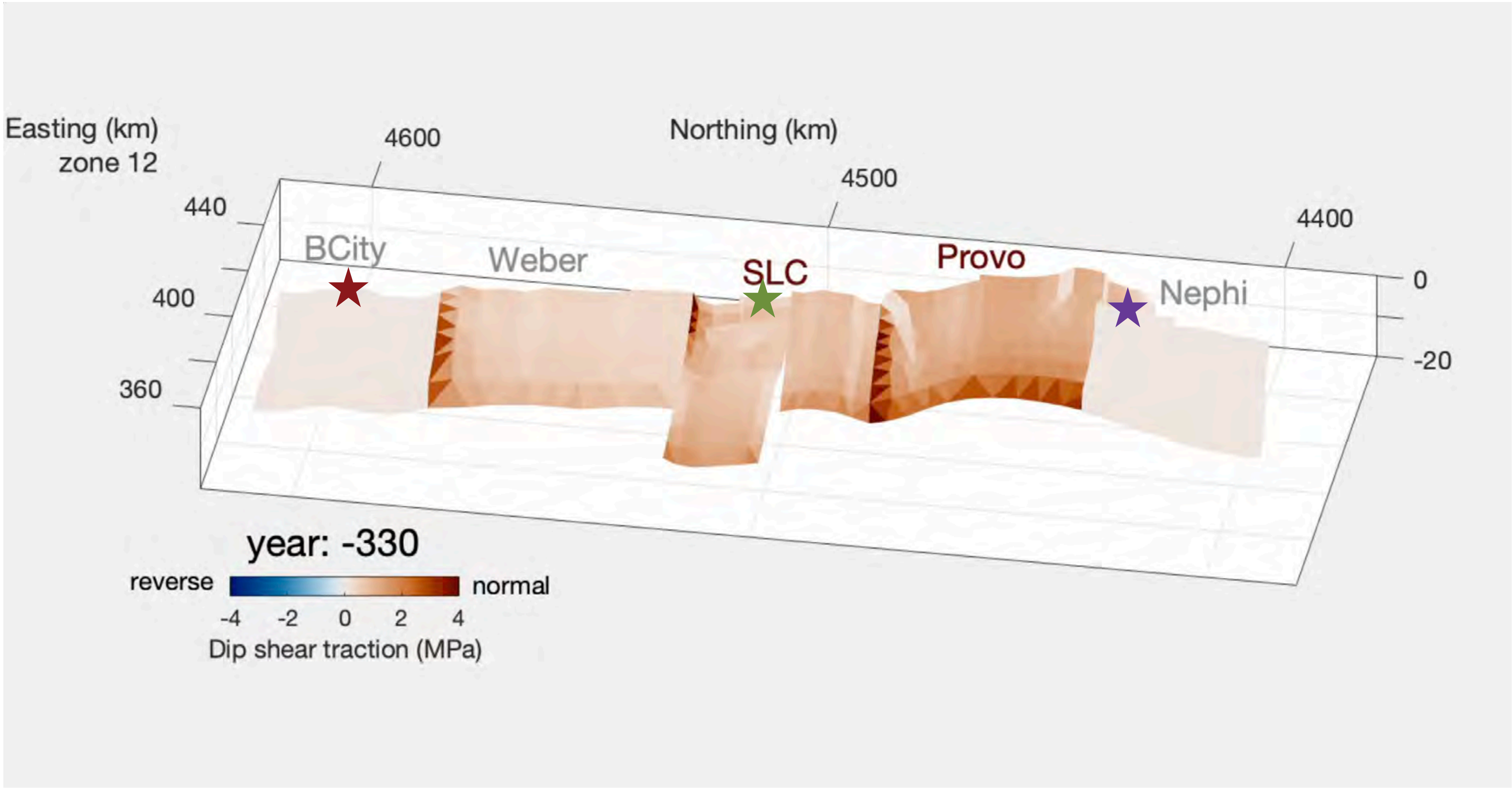


- Nearby earthquakes have significant effects on tractions near segment boundaries

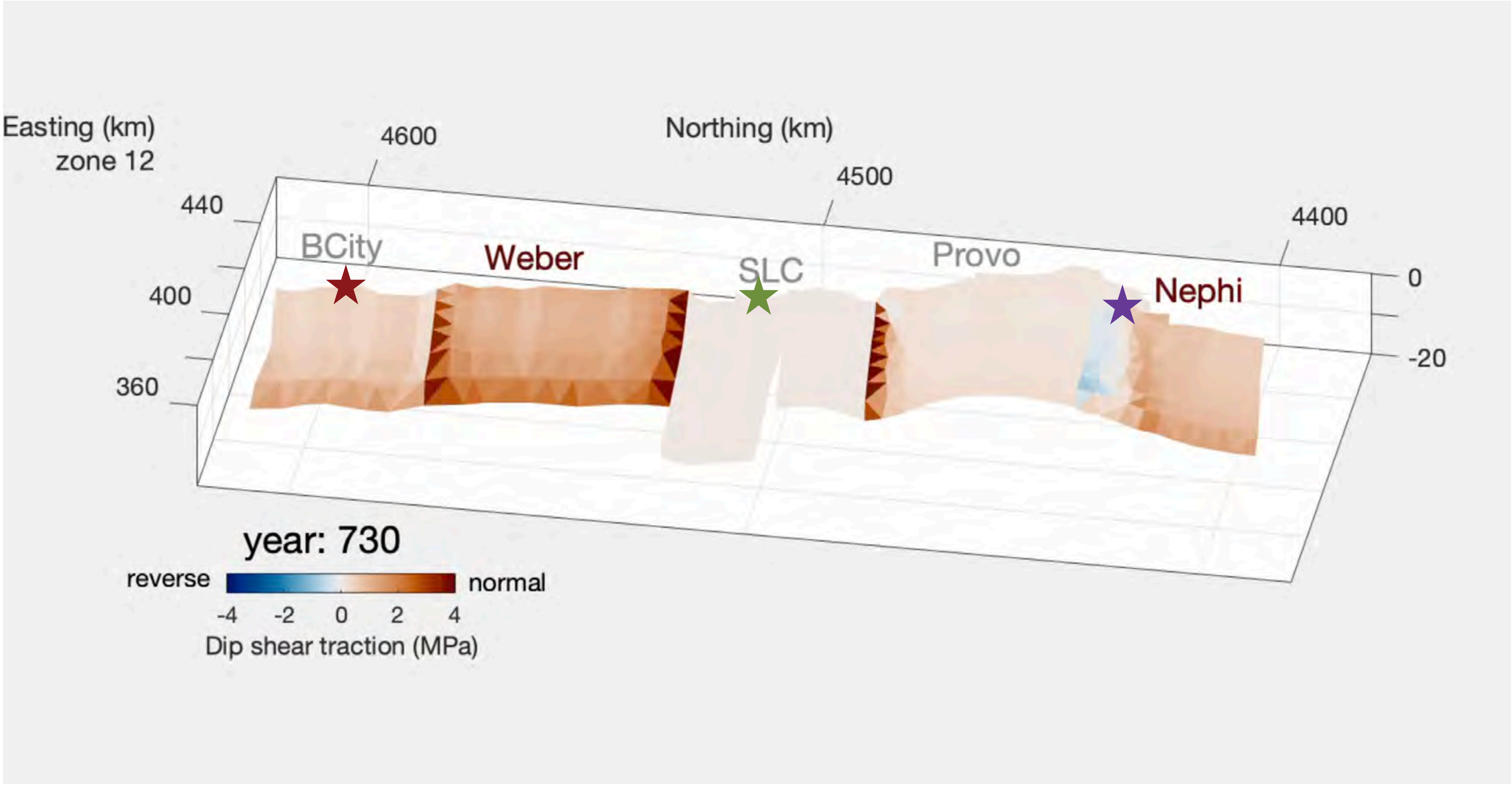
- Uncertainty in relative timing of earthquakes on neighboring segments amplifies this effect

Tractions in space and time

Traction changes near segment boundaries

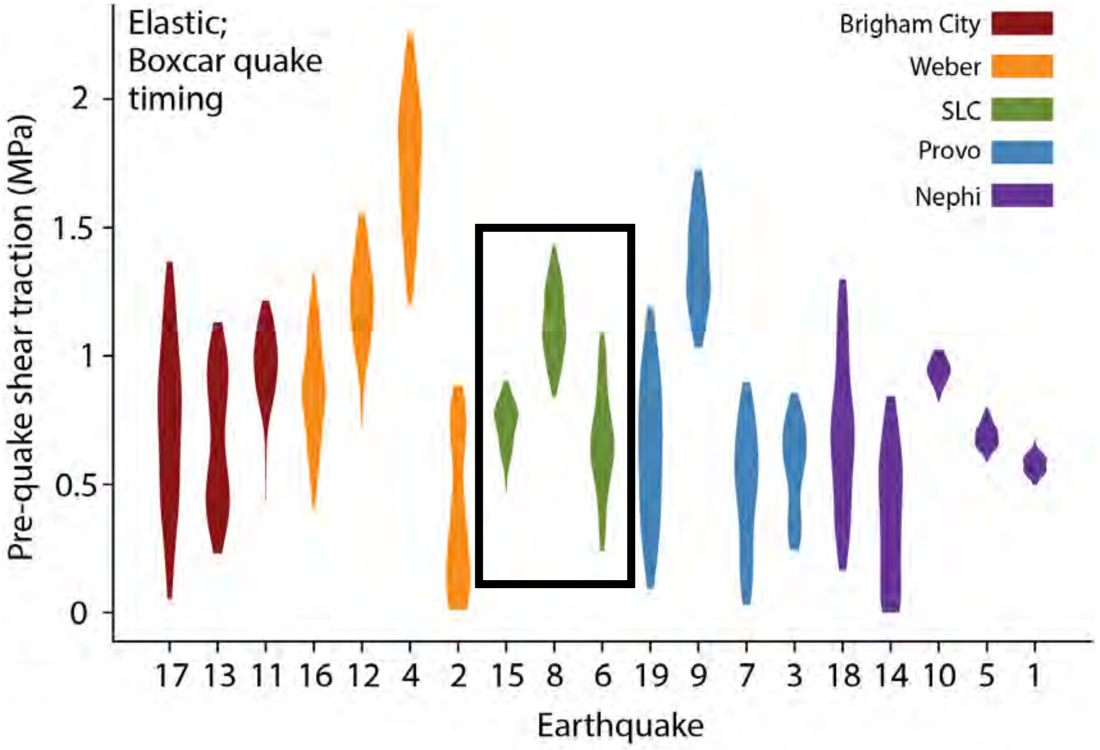


Traction changes near segment boundaries



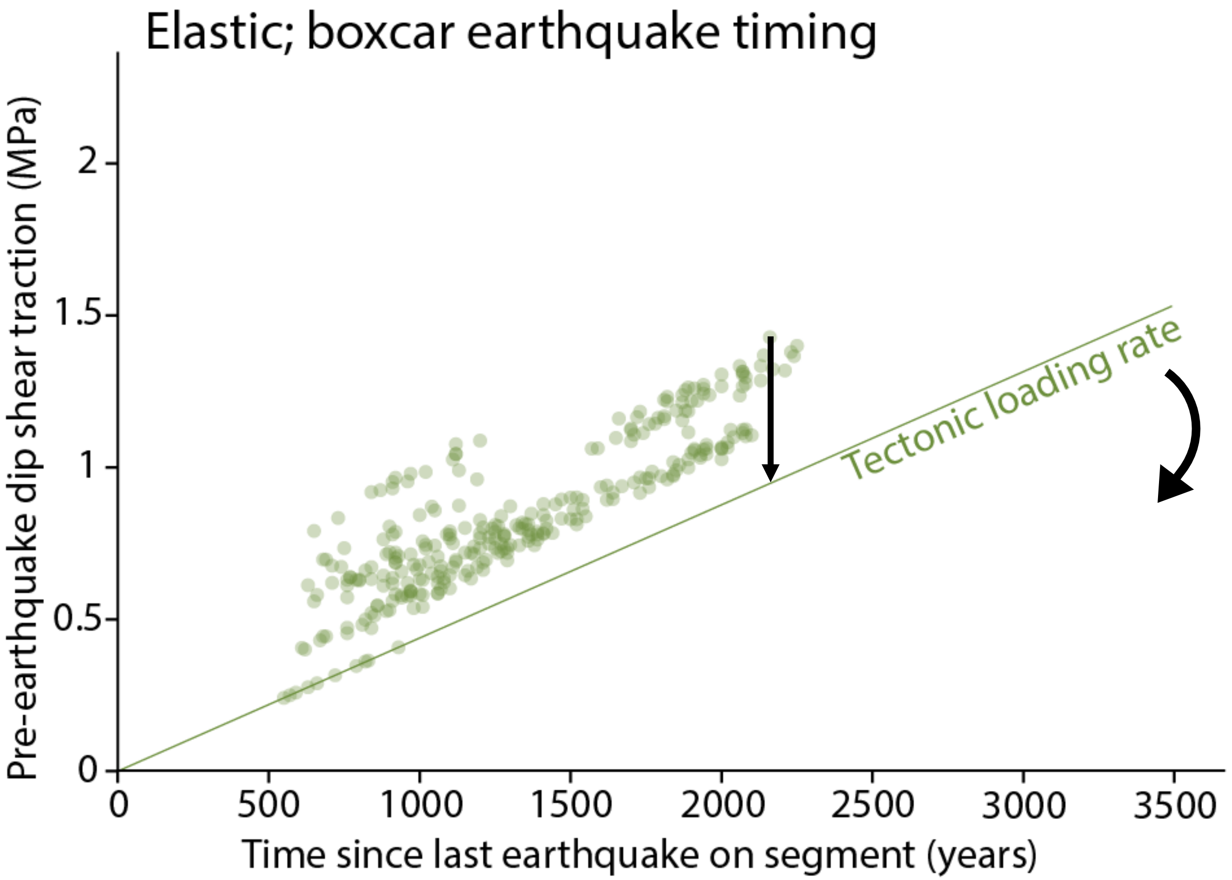
Pre-earthquake traction estimates

- Pre-quake tractions are typically > 2 MPa



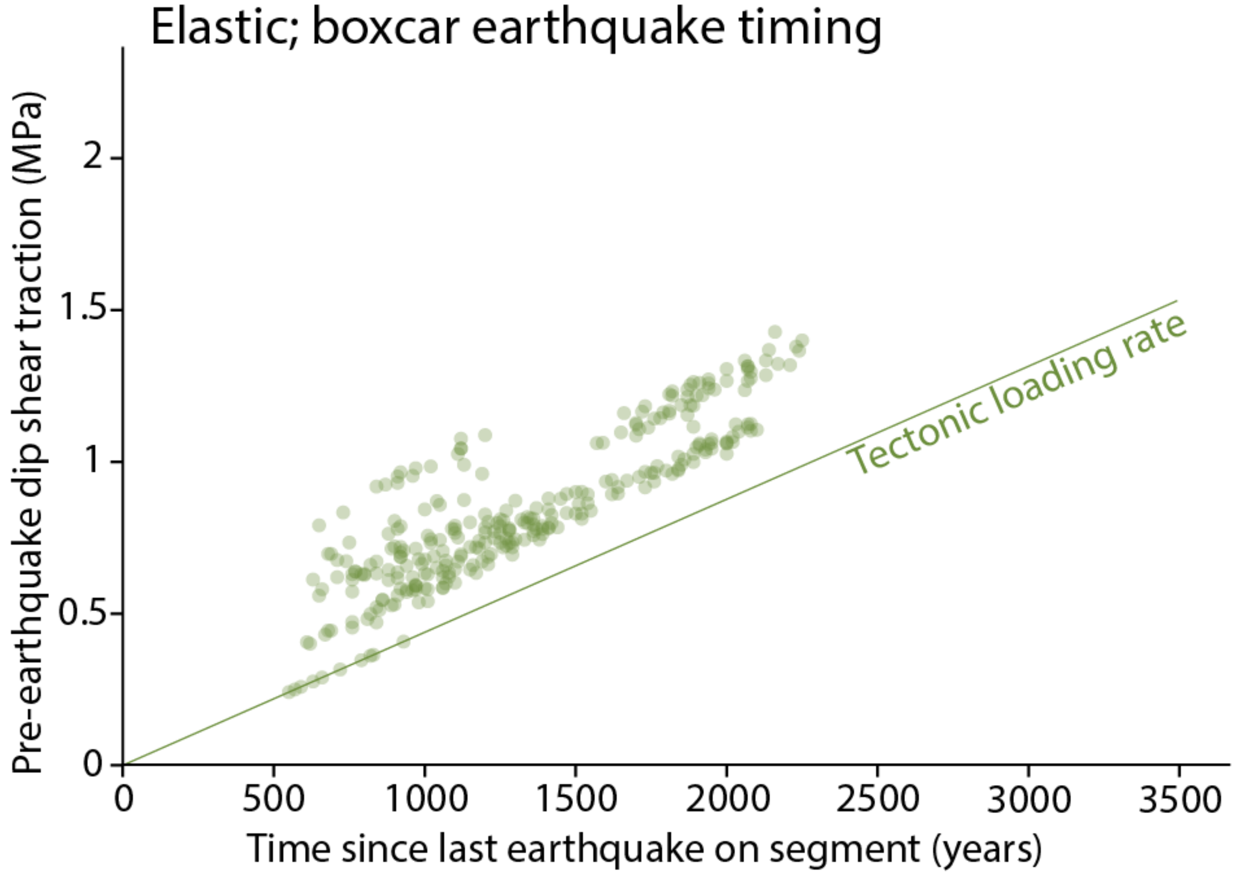
Contribution of nearby earthquakes

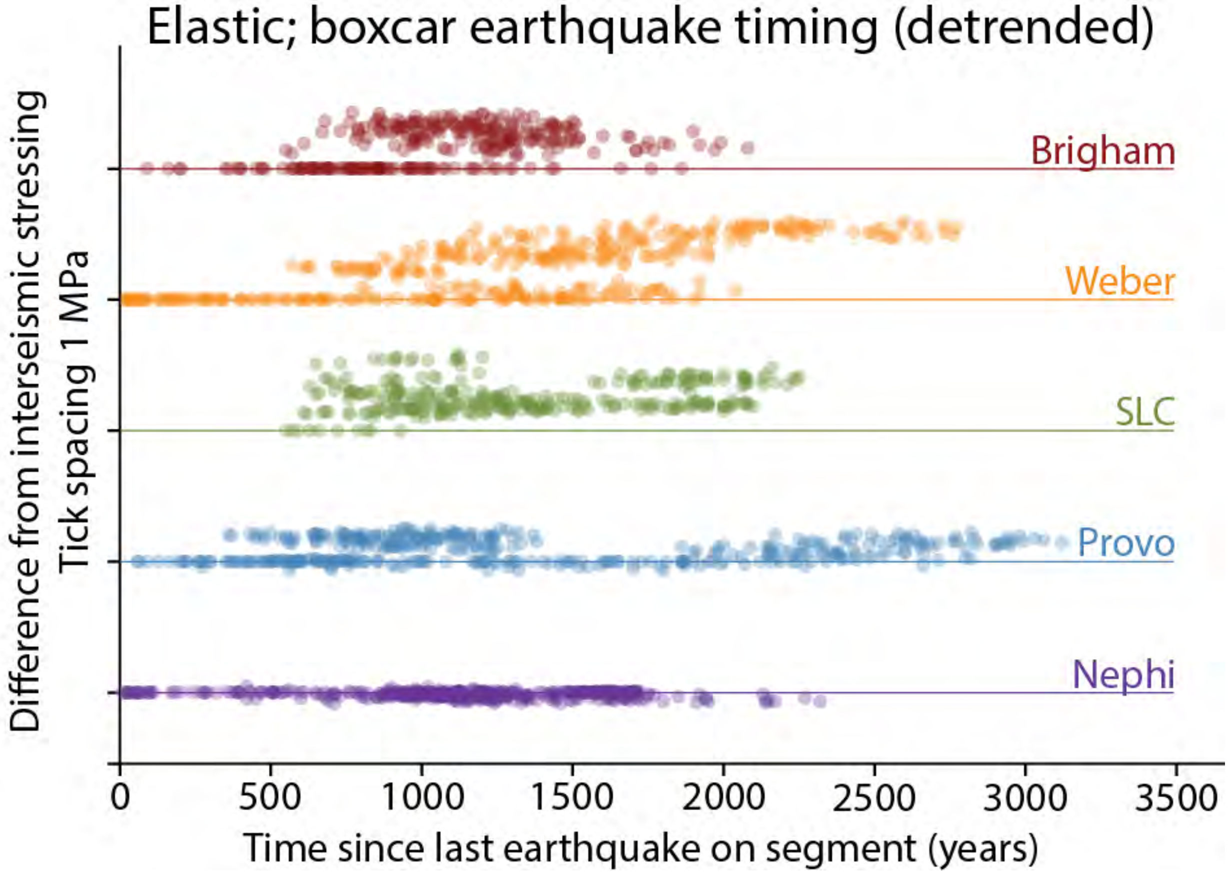
- How different are pre-quake tractions compared to estimates based on linear elastic stressing alone?



Contribution of nearby earthquakes

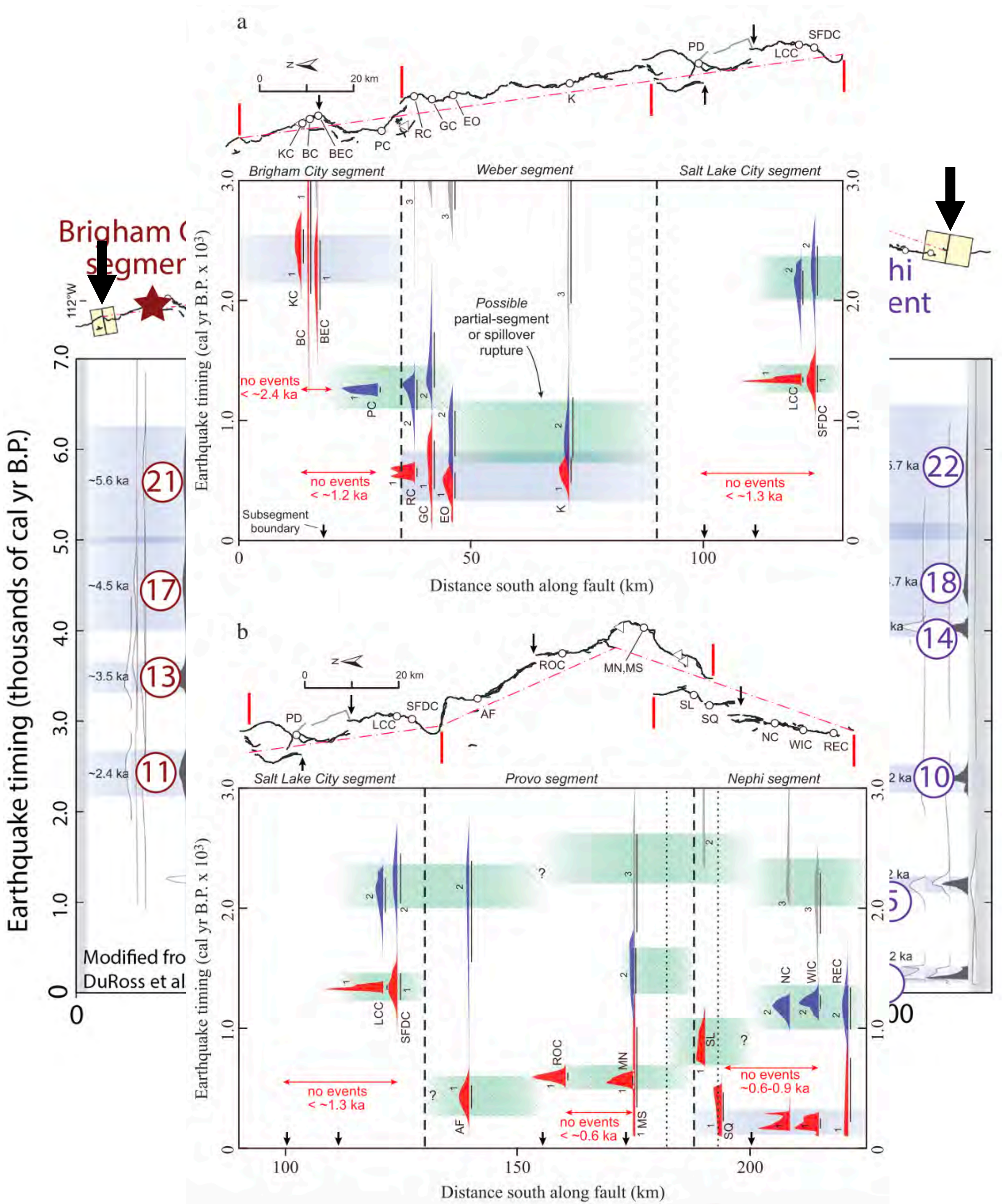
- Nearby earthquakes often increase tractions, but not always
  - Decreases are relatively small
- Caveat: non-segmented rupture models may produce different traction accumulation patterns





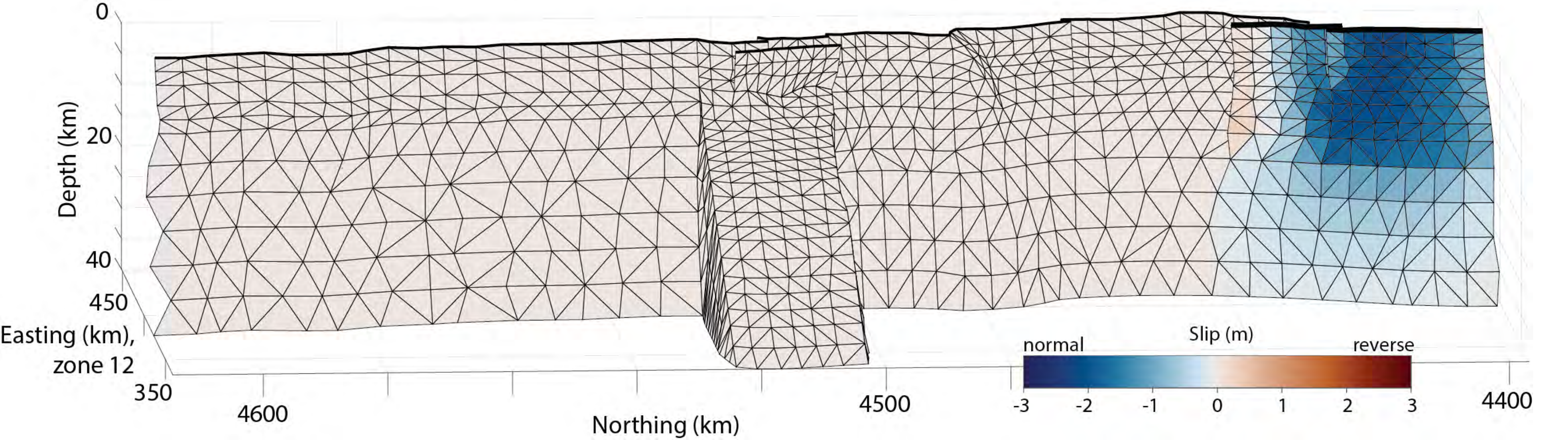
What's next?

- Variations on segmented model
  - Vary rupture endpoints within segment boundary uncertainty
  - Allow multisegment ruptures if ruptures on adjacent segments occur within a small time range
- Simulate alternate rupture models that include spillover ruptures
- Test incomplete stress drops

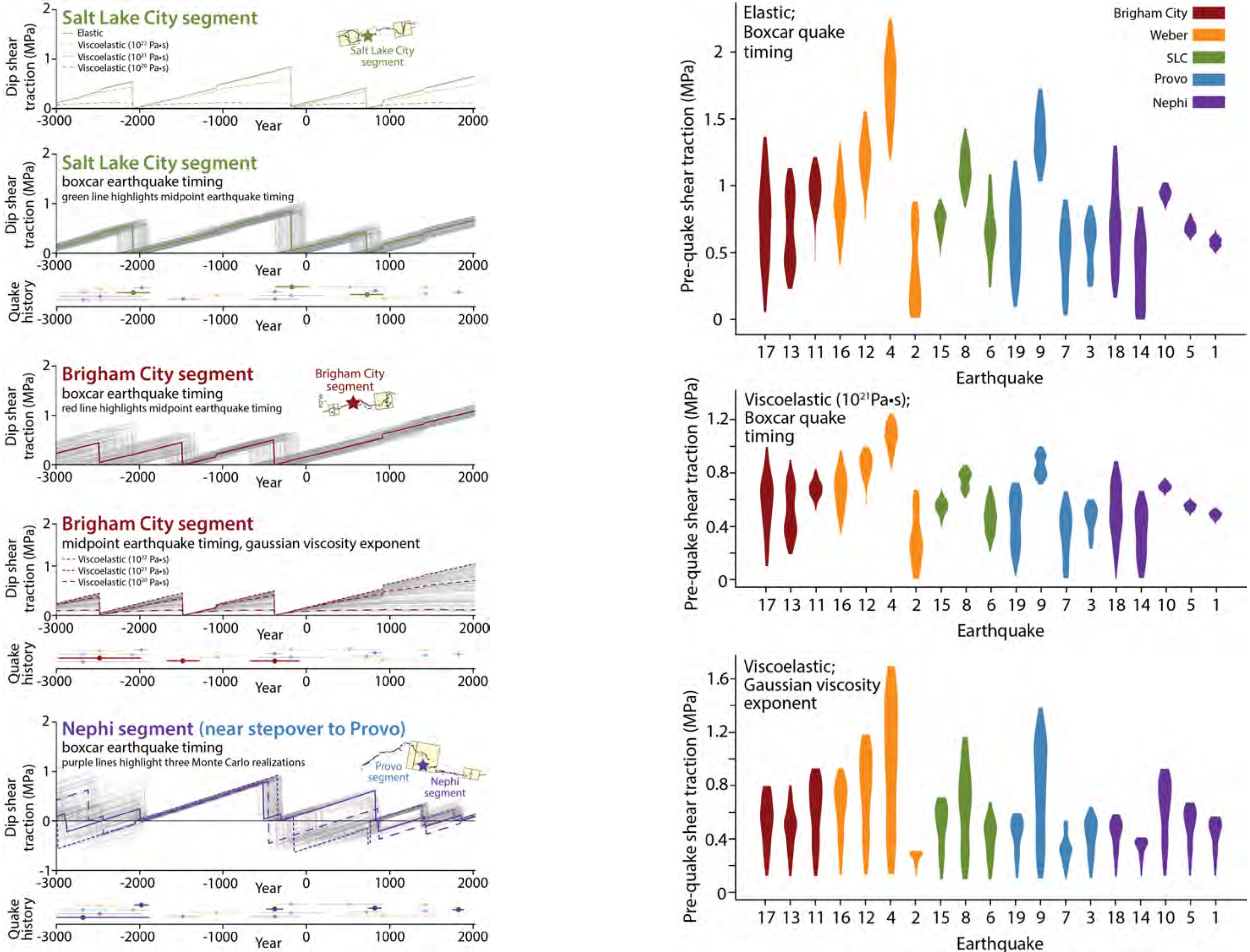


Conclusions

- Pre-quake dip shear tractions are typically ~2 MPa or less
- Viscosity uncertainty has the biggest impact on traction estimates
- Nearby earthquakes generally increase pre-earthquake tractions; this effect is greatest near segment boundaries
- Earthquake timing uncertainty matters most near segment boundaries



0
20
40
Depth (km)
450
Easting (km),
zone 12
350
4600
4500
4400
Northing (km)
normal
Slip (m)
reverse
-3
-2
-1
0
1
2
3


Salt Lake City segment
Elastic
Viscoelastic (10²² Pa•s)
Viscoelastic (10²¹ Pa•s)
Viscoelastic (10²⁰ Pa•s)
Salt Lake City segment
Dip shear traction (MPa)
Year
Salt Lake City segment
boxcar earthquake timing
green line highlights midpoint earthquake timing
Quake history
Brigham City segment
boxcar earthquake timing
red line highlights midpoint earthquake timing
Brigham City segment
Brigham City segment
midpoint earthquake timing, gaussian viscosity exponent
Nephi segment (near stepover to Provo)
boxcar earthquake timing
purple lines highlight three Monte Carlo realizations
Provo segment
Nephi segment
Elastic;
Boxcar quake timing
Brigham City
Weber
SLC
Provo
Nephi
Pre-quake shear traction (MPa)
Earthquake
Viscoelastic (10²¹Pa•s);
Boxcar quake timing
Viscoelastic;
Gaussian viscosity exponent

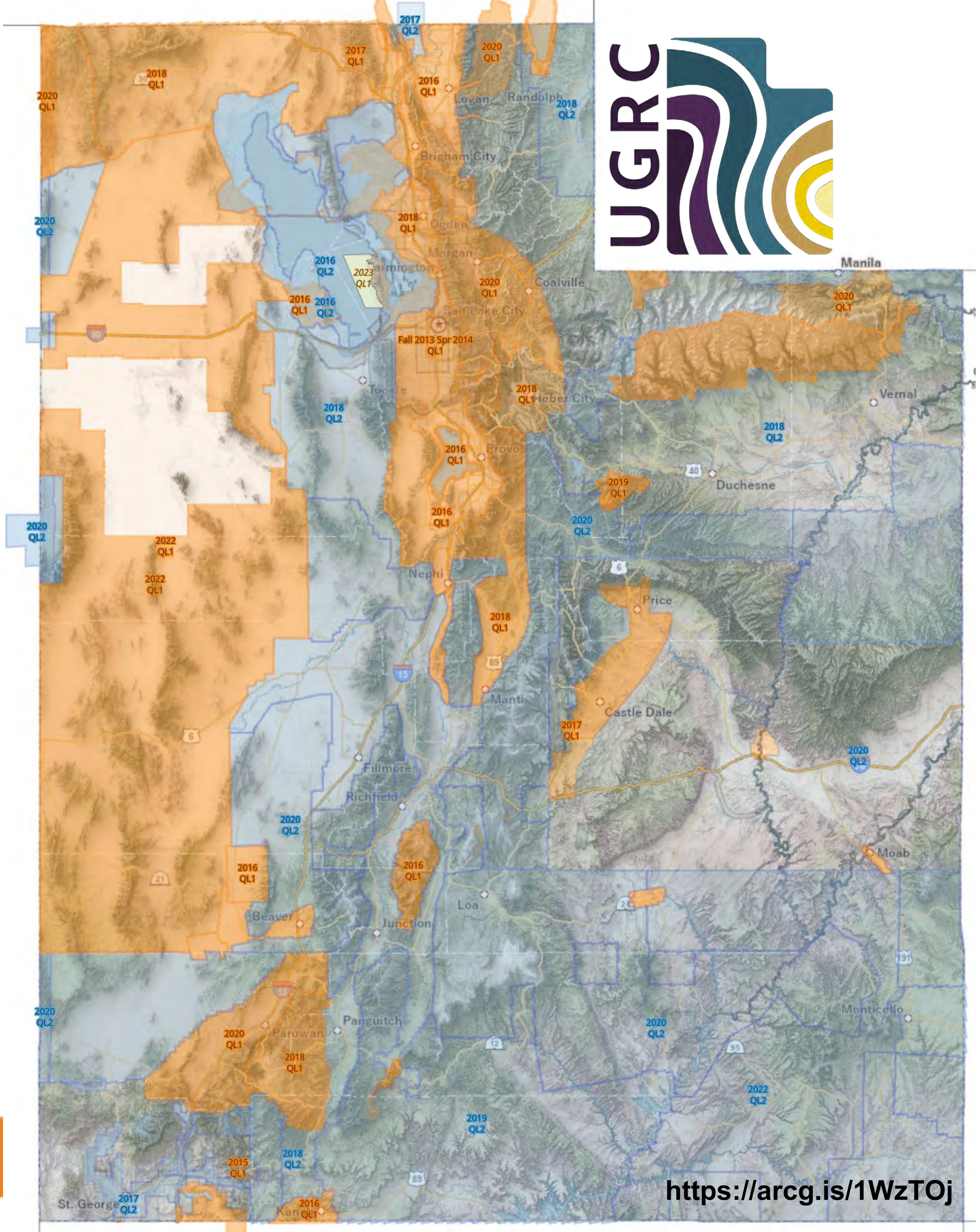
UTAH QUATERNARY FAULT MAPPING UPDATES

Rachel N. Adam & Adam I. Hiscock
Utah Geological Survey Hazards Program

UTAH DNR GEOLOGICAL SURVEY

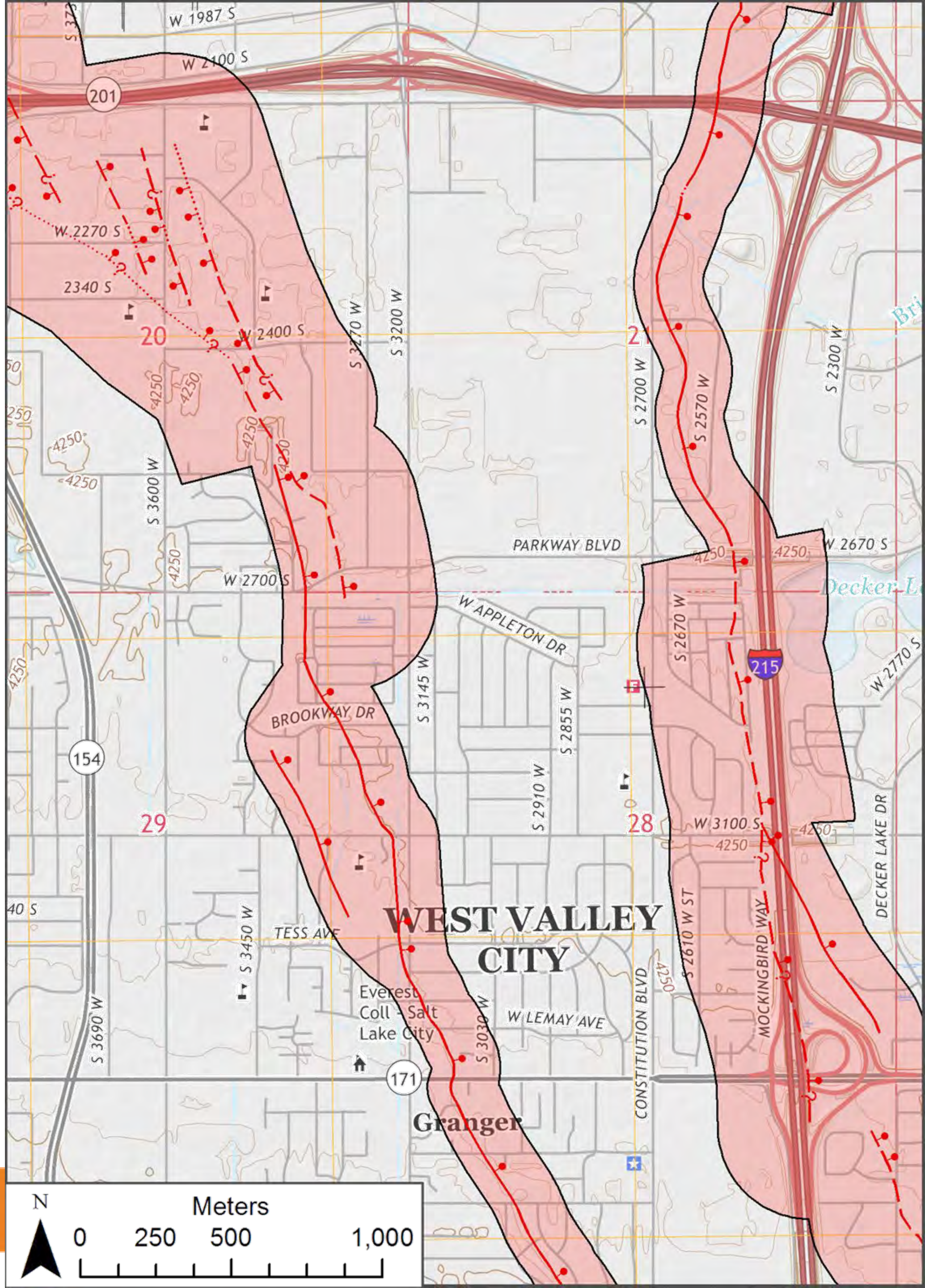
Objectives

- 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 EHP funded fault mapping projects since 2014
- New mapping available through the UGS's *Utah Geologic Hazards Portal,* and used for updates to the USGS National Seismic Hazard Maps.
- Necessary to help characterize and identify active faults in rapidly growing and urbanizing parts of Utah
- Identify potential paleoseismic trenching sites



Surface Fault Rupture Special-Study-Zones (SSZ)

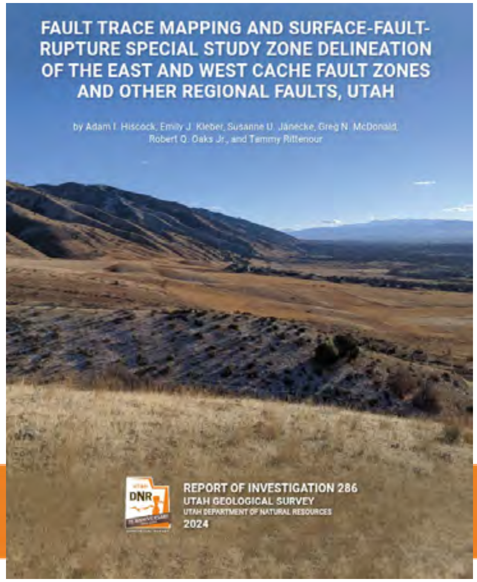
- Special-study-zones are delineated around each mapped trace
- Assist local governments with urban planning and developing hazard ordinances
- Help facilitate understanding of the hazard by triggering additional surface faulting studies
- Based on UGS Circular 128 – *Guidelines for evaluating surface-fault-rupture hazards in Utah*. https://doi.org/10.34191/C-128.

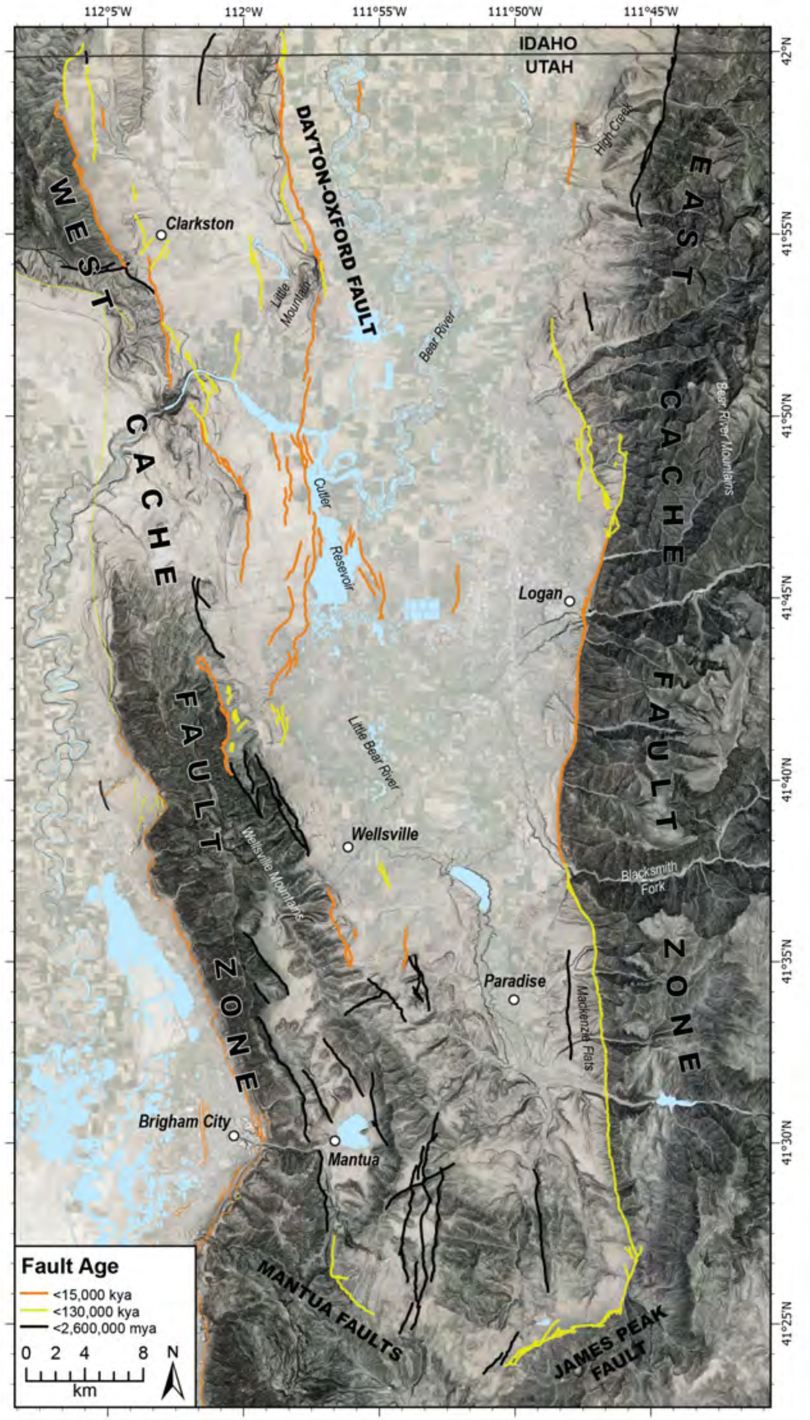


Cache Valley Fault Mapping

- Adam I. Hiscock, Emily J. Kleber, Greg N. McDonald (UGS); Susanne Jänecke, Bob Oaks, Tammy Rittenour (USU). Additional guidance, reviews from others at USU.
- Funded by USGS External Grants in 2017 - Final Technical Report submitted in 2020 (14 7.5-minute plates).
- Re-mapped at 1:10,000 scale (or better)
- Added substantial length and much better detail to all regional faults.
  - 188 km added length of faults compared to UQFFD.

- **UGS Report of Investigation 286**





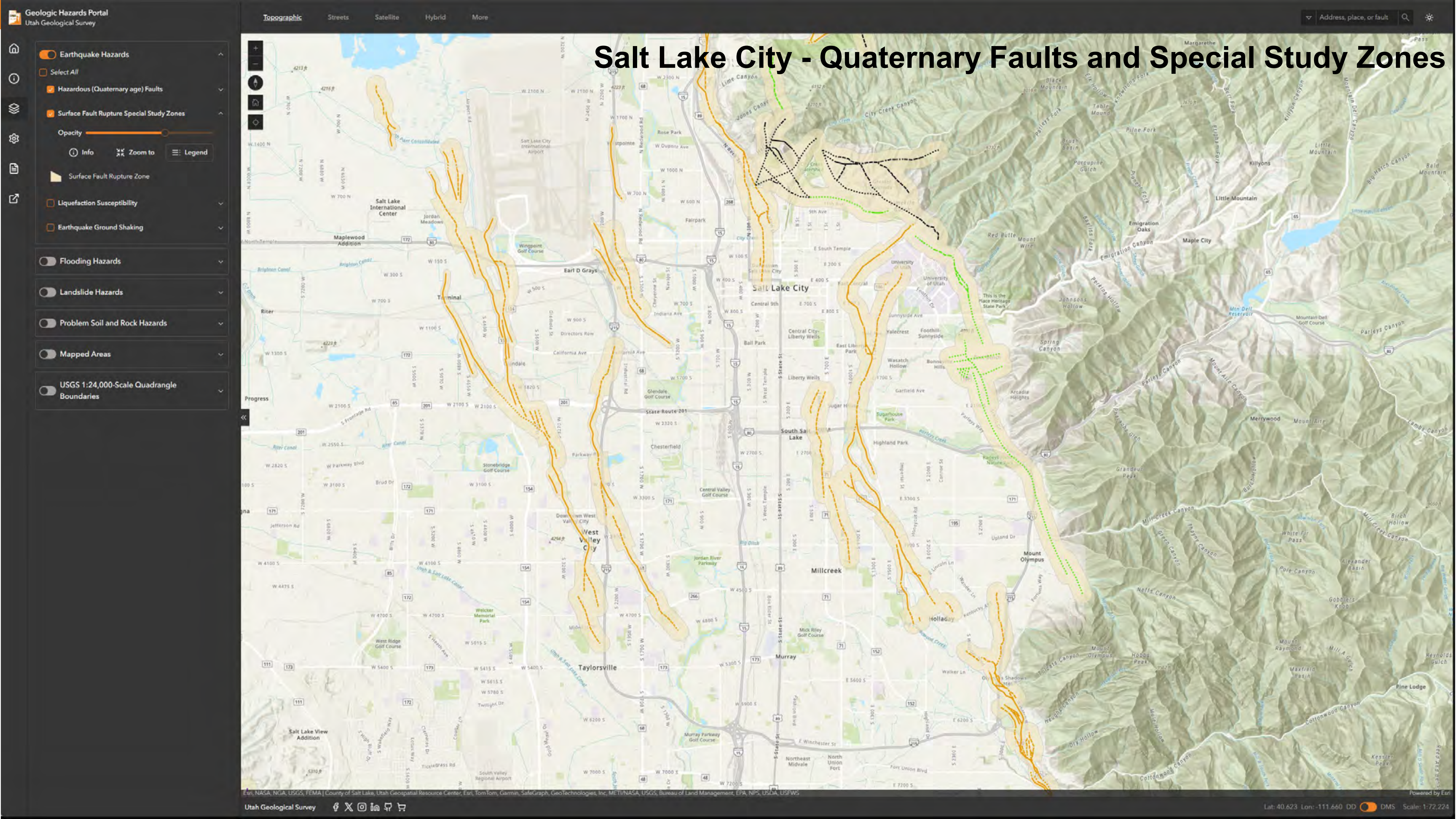
Utah Geological Survey

UTAH GEOLOGIC HAZARDS PORTAL

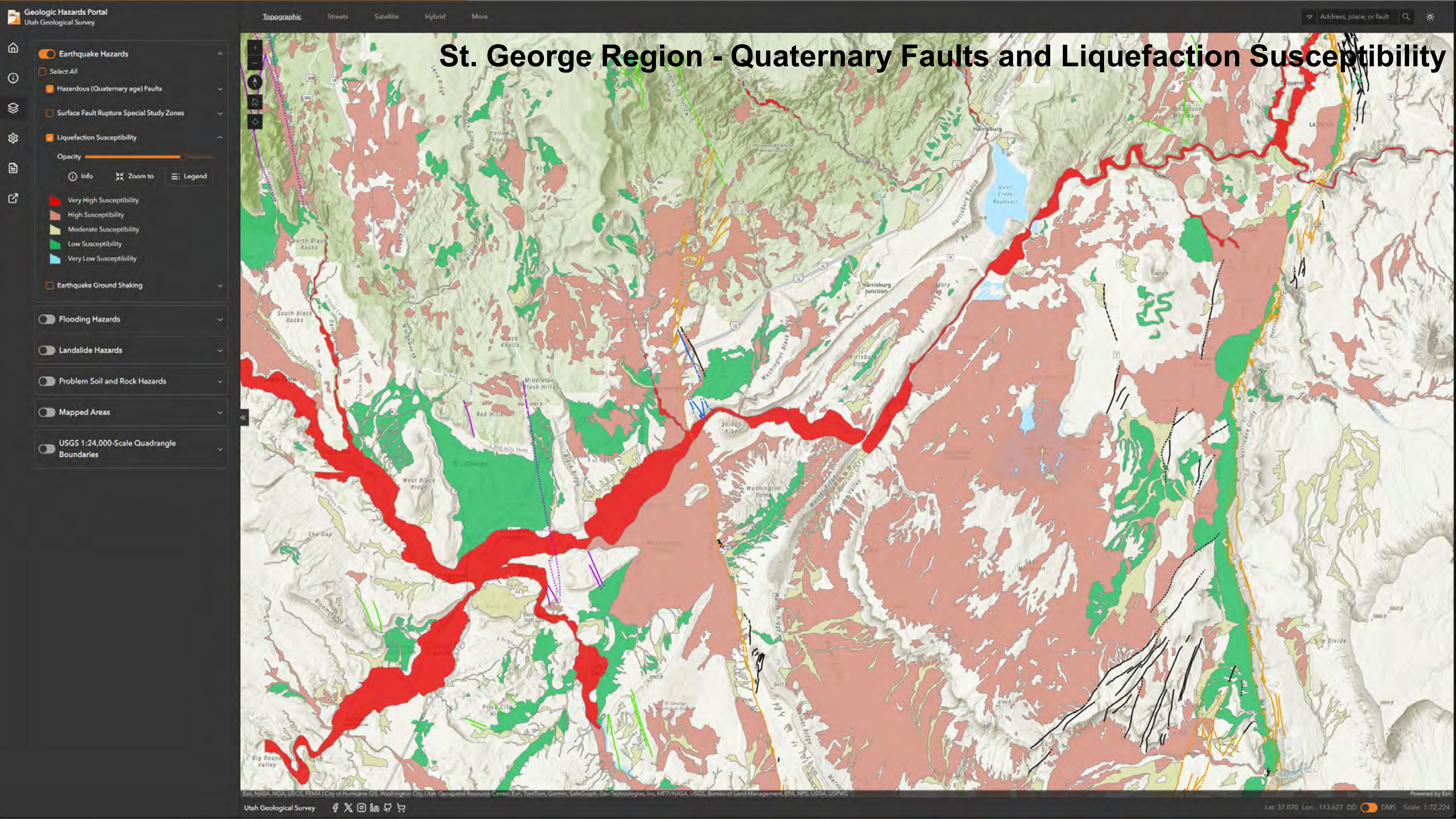
- One-stop-shop for all UGS Geologic Hazards Mapping products (fault mapping, special-study-zones, landslide susceptibility, flooding, problem soils, etc.)
- Replaced the Utah Quaternary Fault and Fold Database (UQFFD) webmap – UQFFD now lives on the Hazards Portal.
- **COMING SOON – New Geo Haz Portal! –**
  - Live (Hopefully) end of February

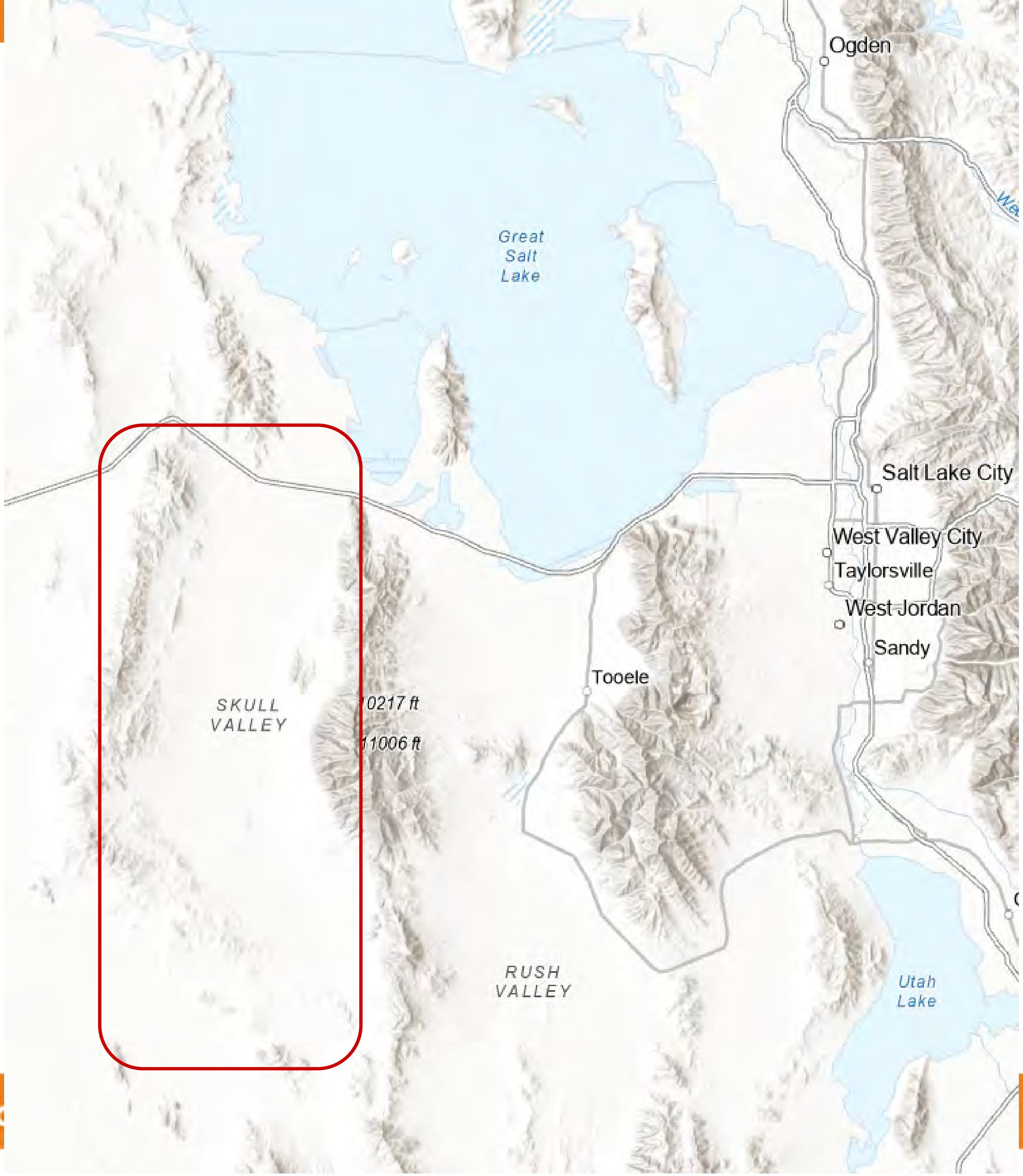
https://geology.utah.gov/apps/hazards/

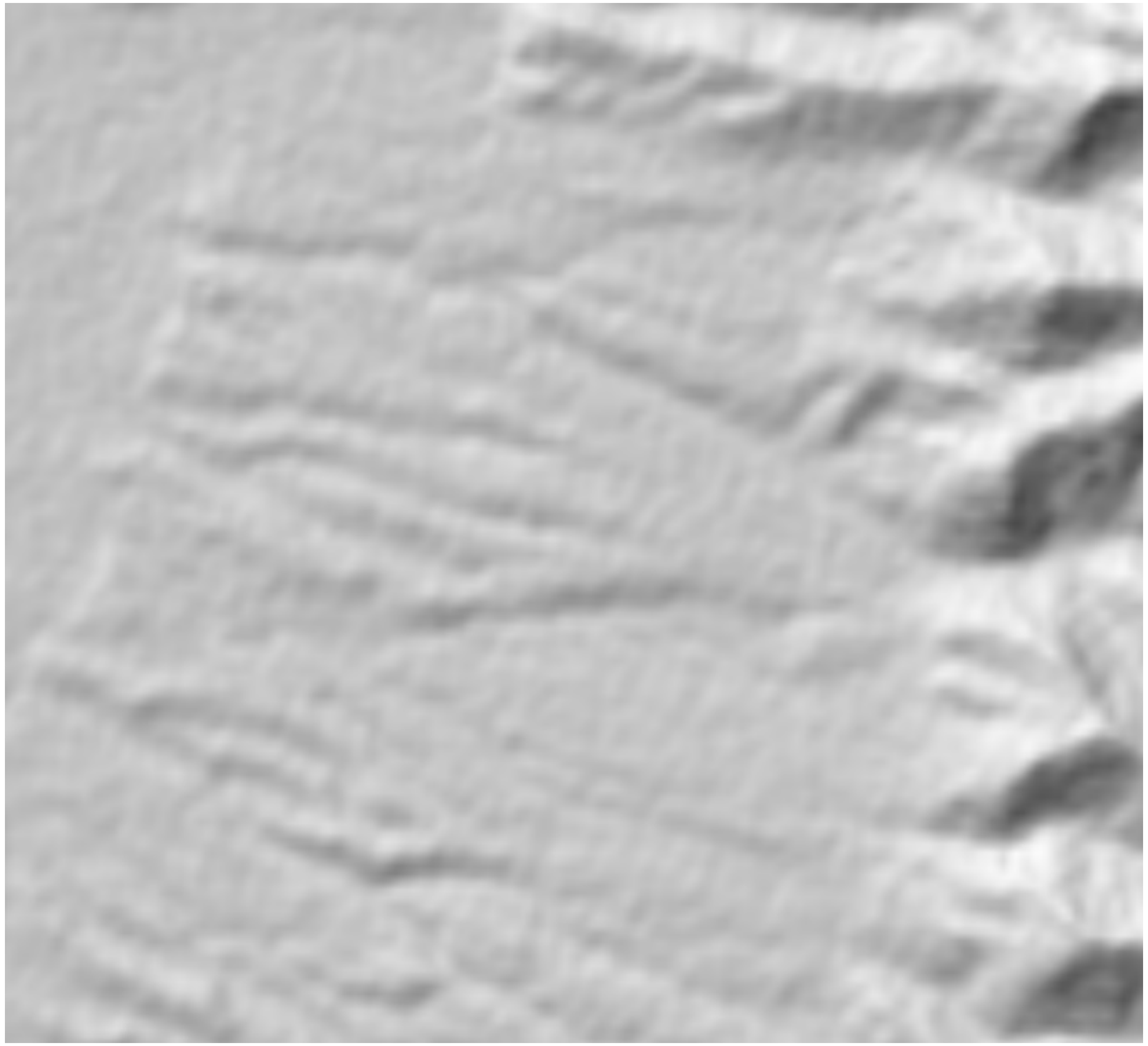
Salt Lake City - Quaternary Faults and Special Study Zones



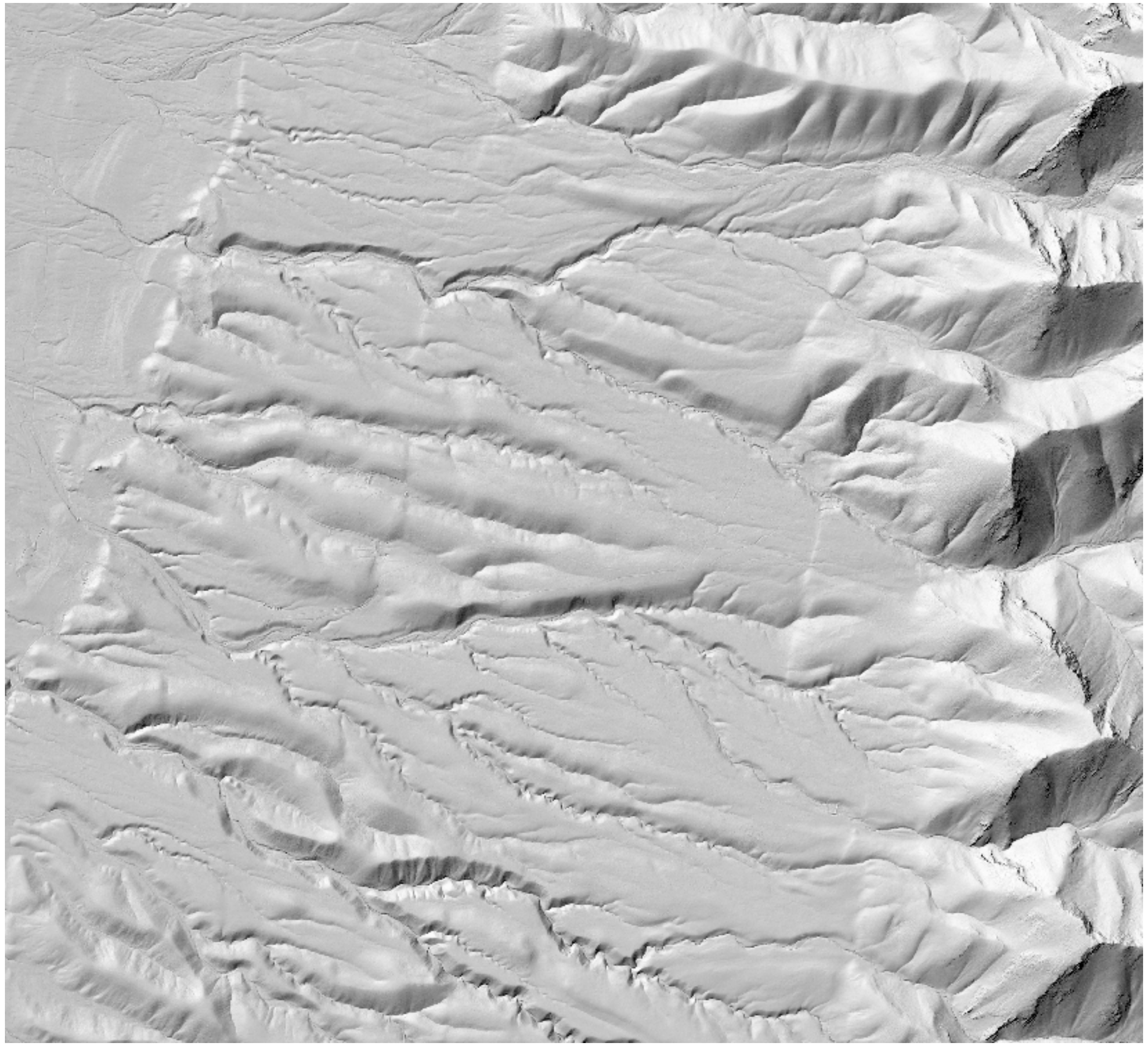
St. George Region - Quaternary Faults and Liquefaction Susceptibility




Ogden
Great Salt Lake
Salt Lake City
West Valley City
Taylorsville
West Jordan
Sandy
Tooele
SKULL VALLEY
10217 ft
11006 ft
RUSH VALLEY
Utah Lake

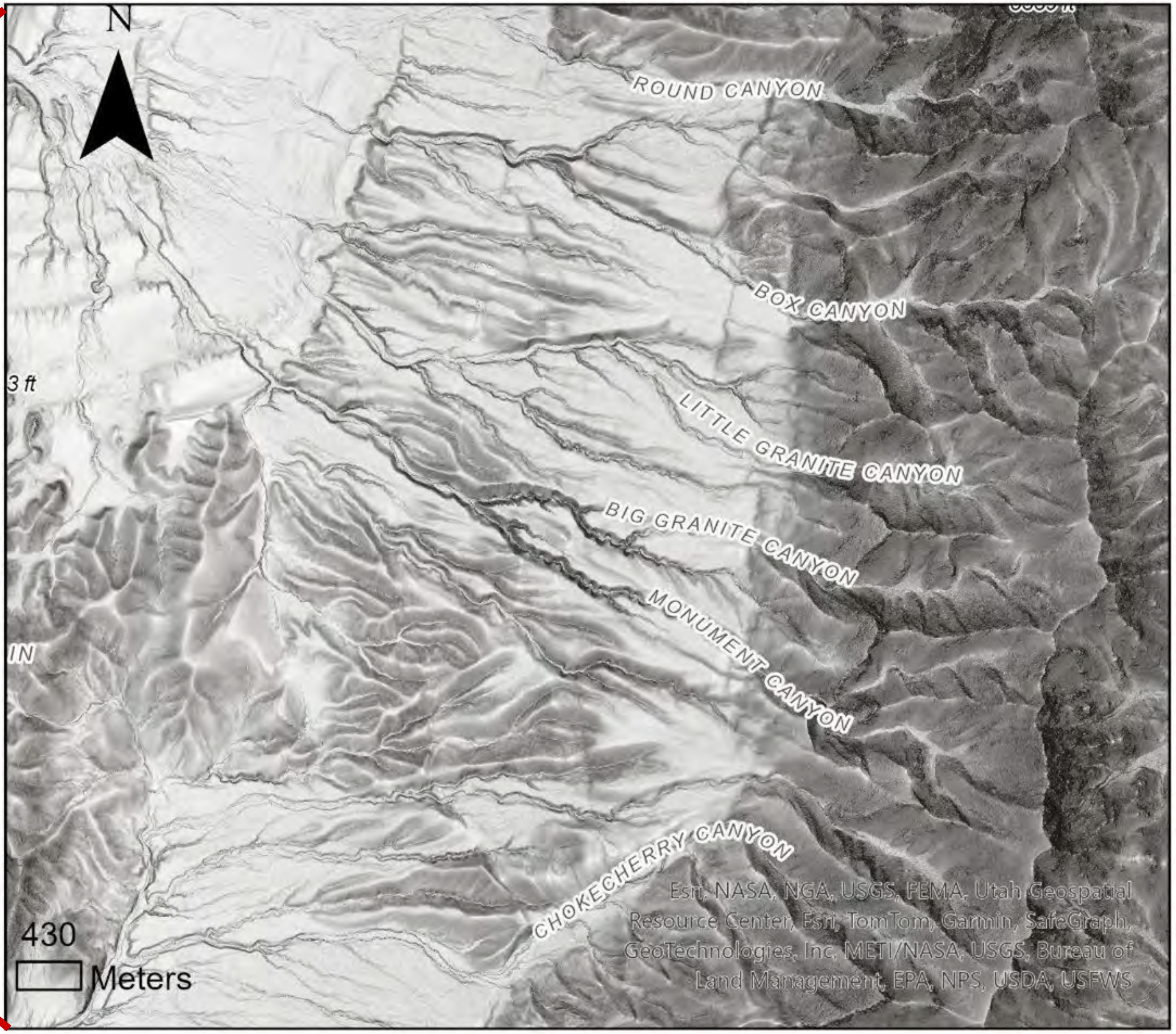


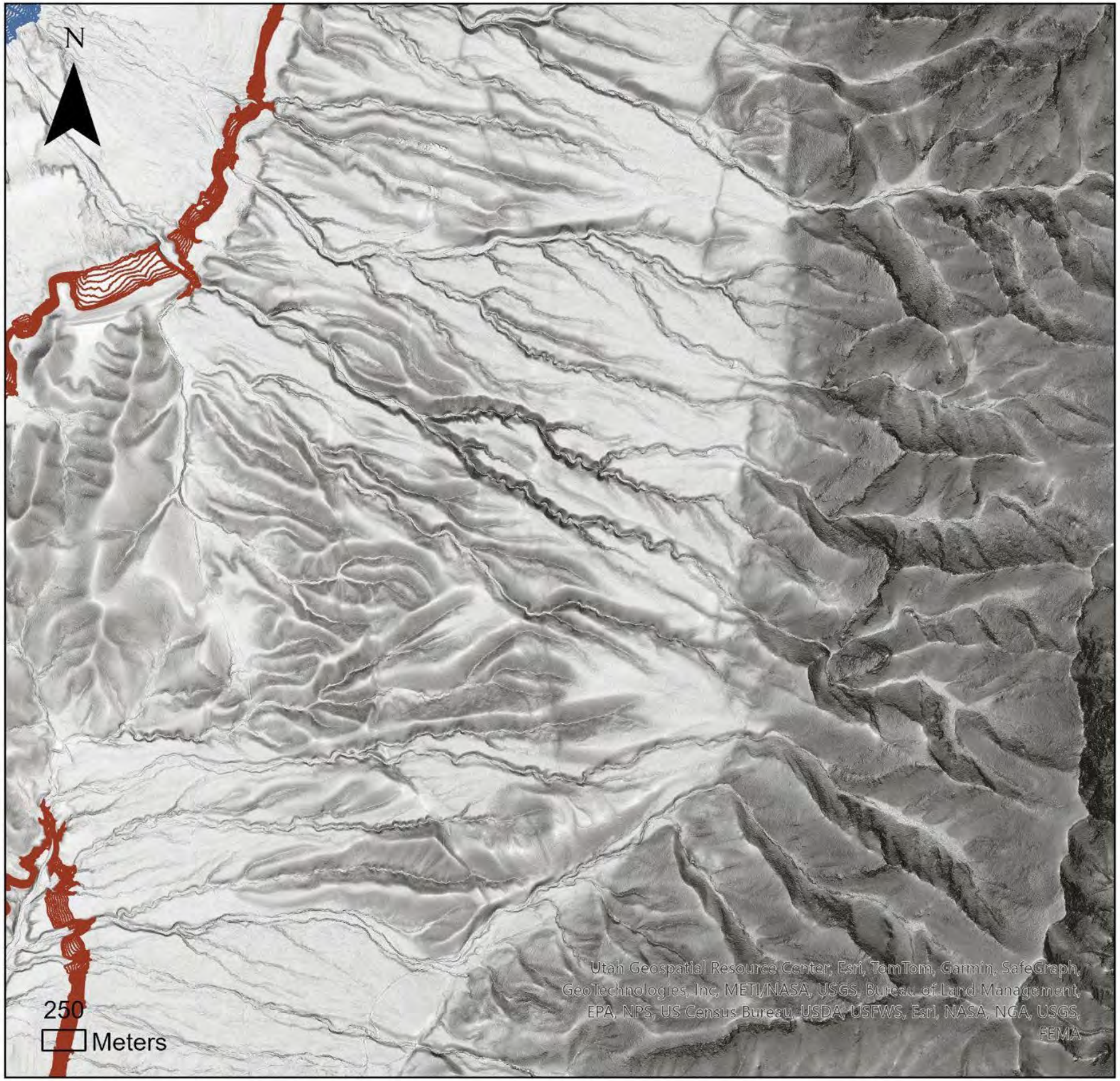
30 meter SRTM (shuttle radar topography mission)



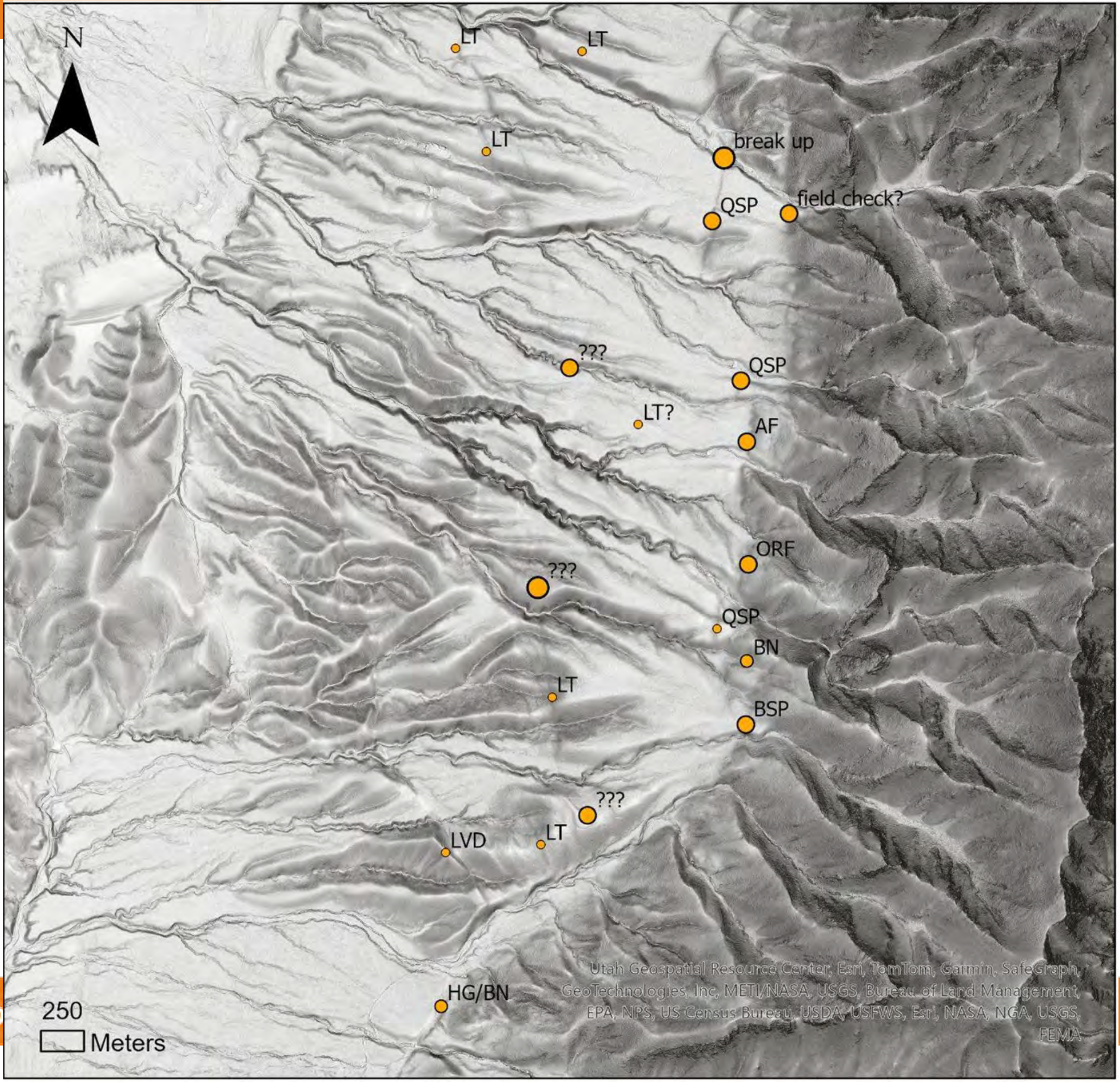
1 meter lidar


N
SKULL VALLEY
STANSBURY MOUNTAINS
11006 ft
Dugway
ONAQUI MOUNTAINS
0.75
Kilometers
Esri, NASA, NGA, USGS, Utah Geo
Center, Esri, TomTom, Garmin, SafeG
NASA, USGS, Bureau of Land Manag

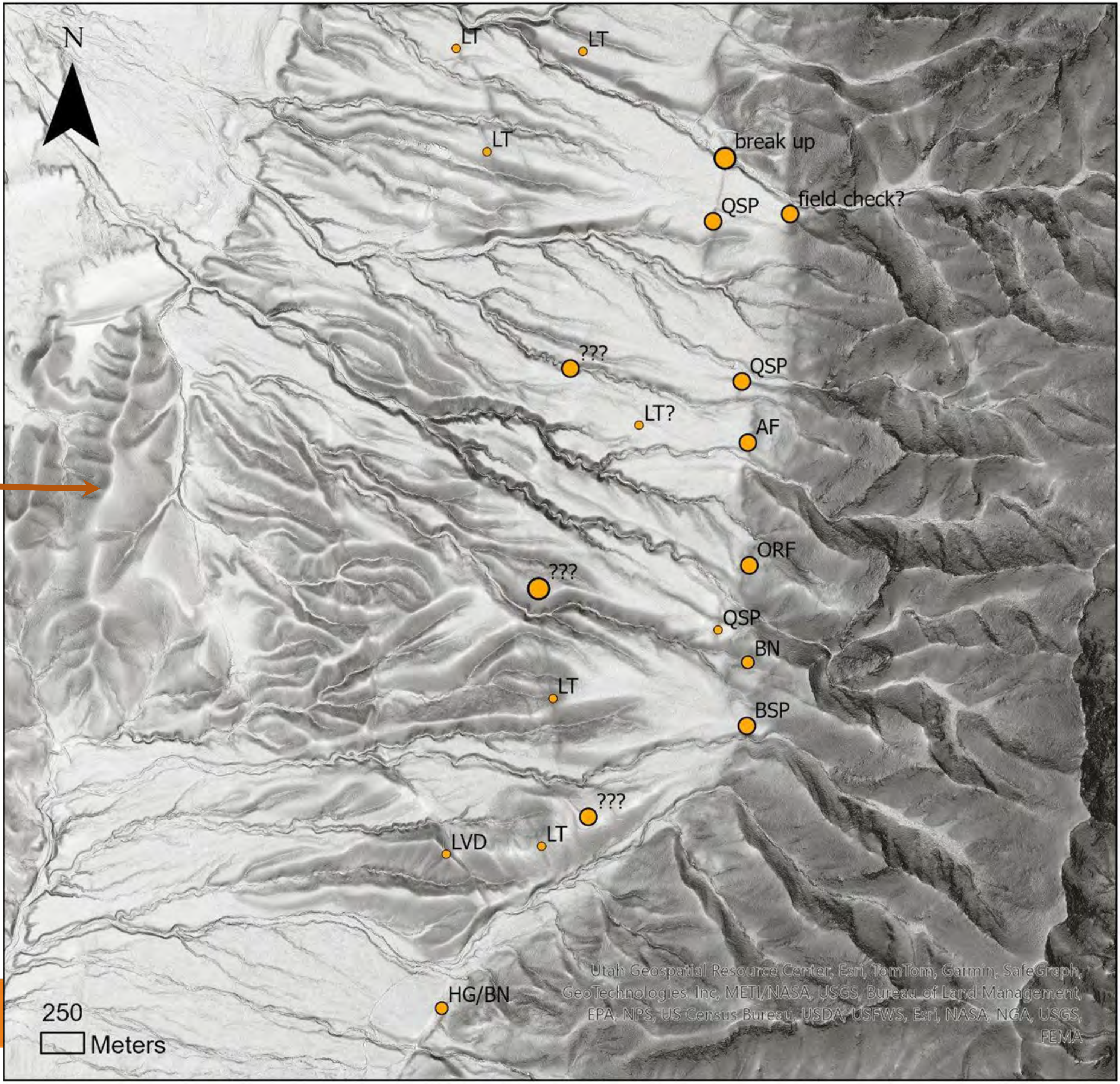

N
ROUND CANYON
BOX CANYON
LITTLE GRANITE CANYON
BIG GRANITE CANYON
MONUMENT CANYON
CHOKECHERRY CANYON
430
Meters
Esri, NASA, NGA, USGS, FEMA, Utah Geospatial Resource Center, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS

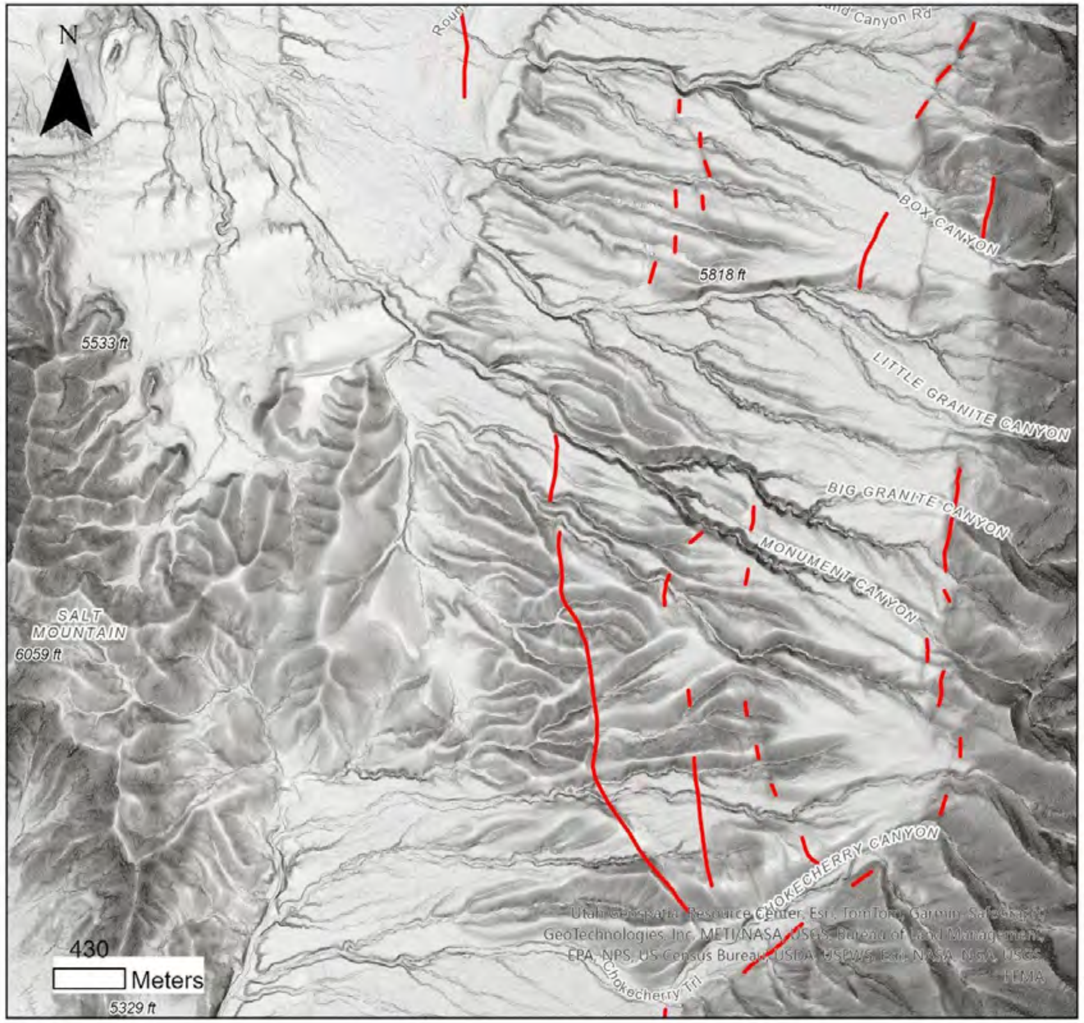


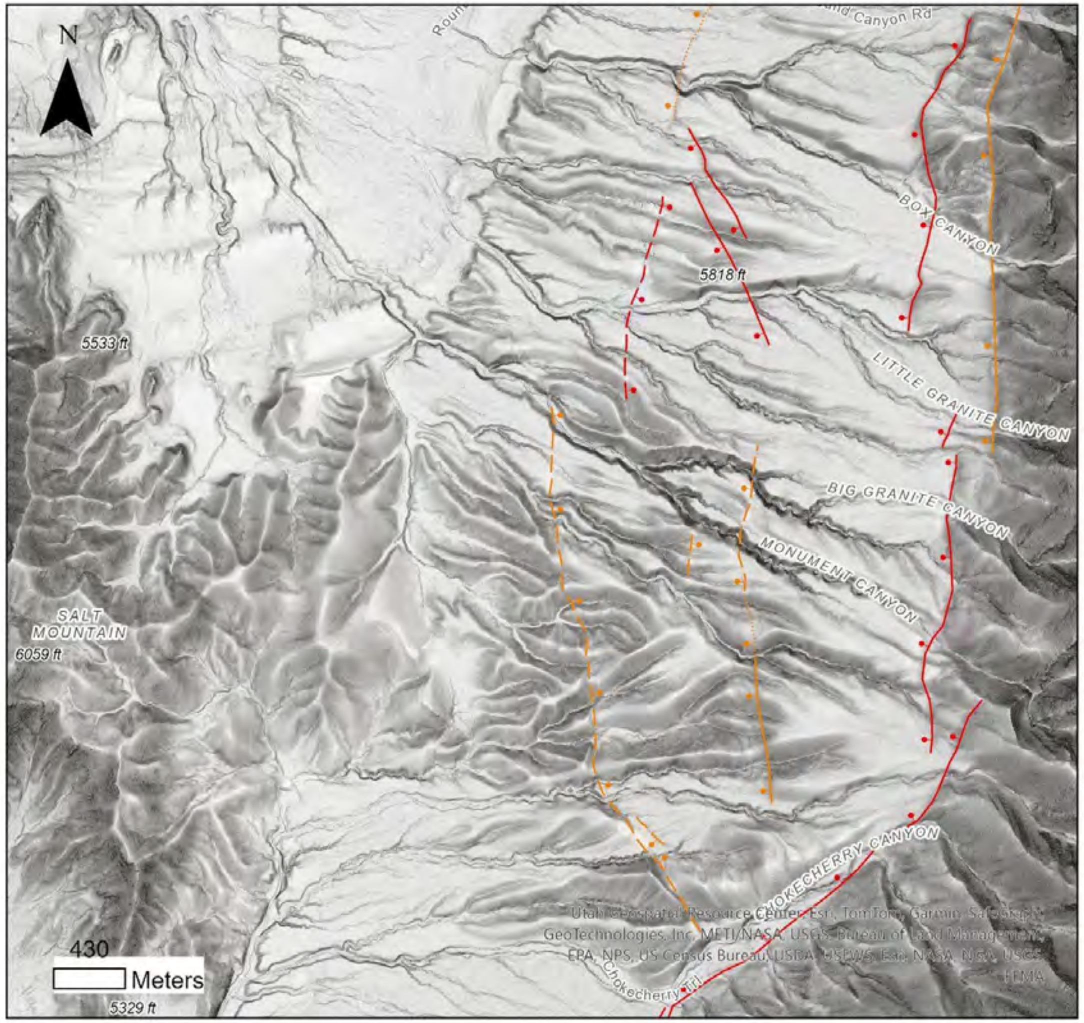
N
250
Meters
Utah Geospatial Resource Center, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS, Esri, NASA, NGA, USGS, FEMA


N
LT
LT
LT
break up
QSP
field check?
???
QSP
LT?
AF
ORF
???
QSP
BN
LT
BSP
???
LT
LVD
HG/BN
250
Meters
Utah Geospatial Resource Center, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS, Esri, NASA, NGA, USGS, FEMA

SYMBOL	FEATURE
AF	Cut offset/ alluvial fan
BN	Bench
BSP	Bedrock scarp
HG	Horst/graben
LT	Lineament in topography
LVD	Linear valley/drainage
QSP	Quaternary scarp
ORF	Oversteepened rangefront




N
Box Canyon
5818 ft
5533 ft
Little Granite Canyon
Big Granite Canyon
Monument Canyon
Salt Mountain
6059 ft
Chokecherry Canyon
Chokecherry Trl
430
Meters
5329 ft
Utah Geospatial Resource Center, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS, Esri, NASA, NGA, USGS, FEMA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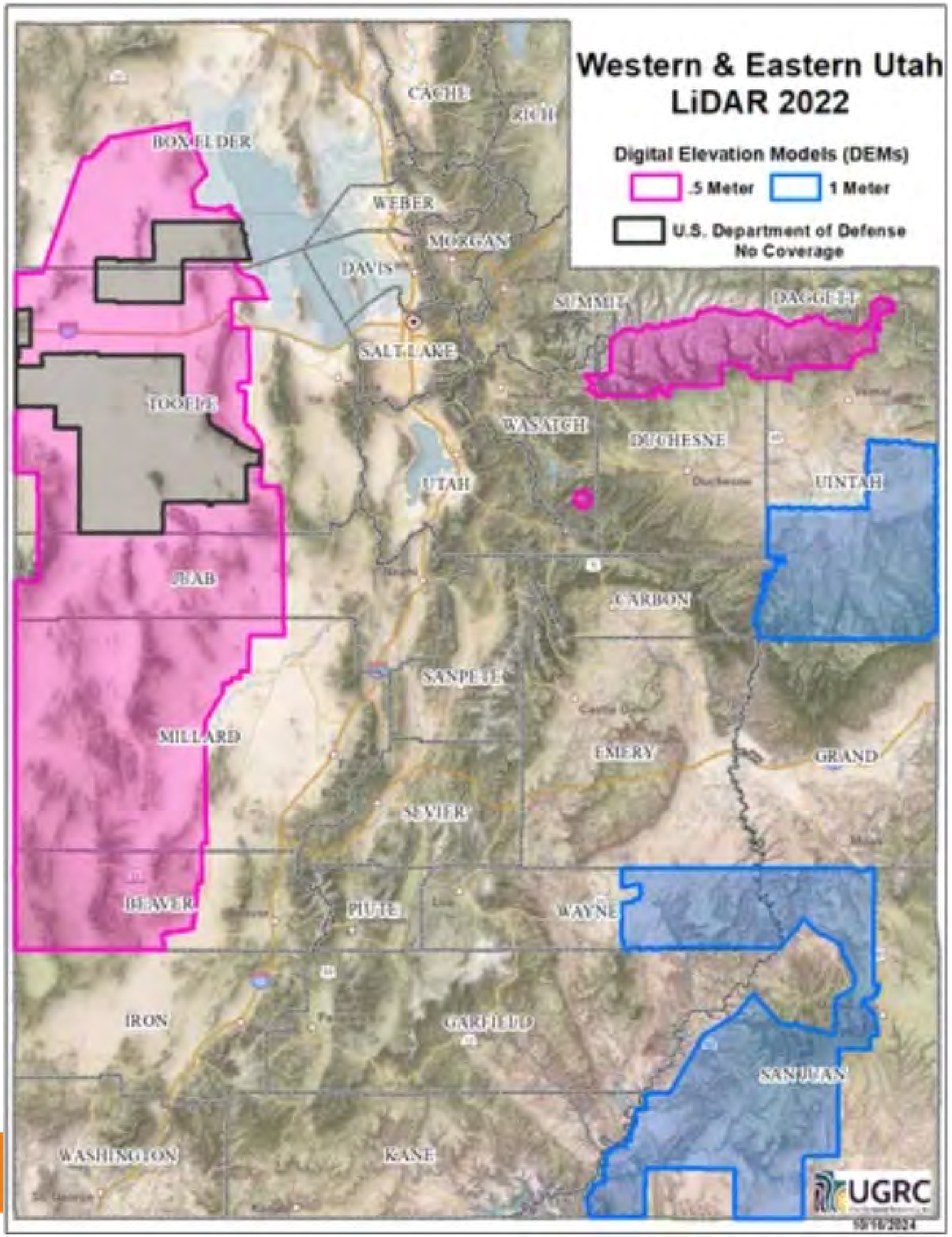
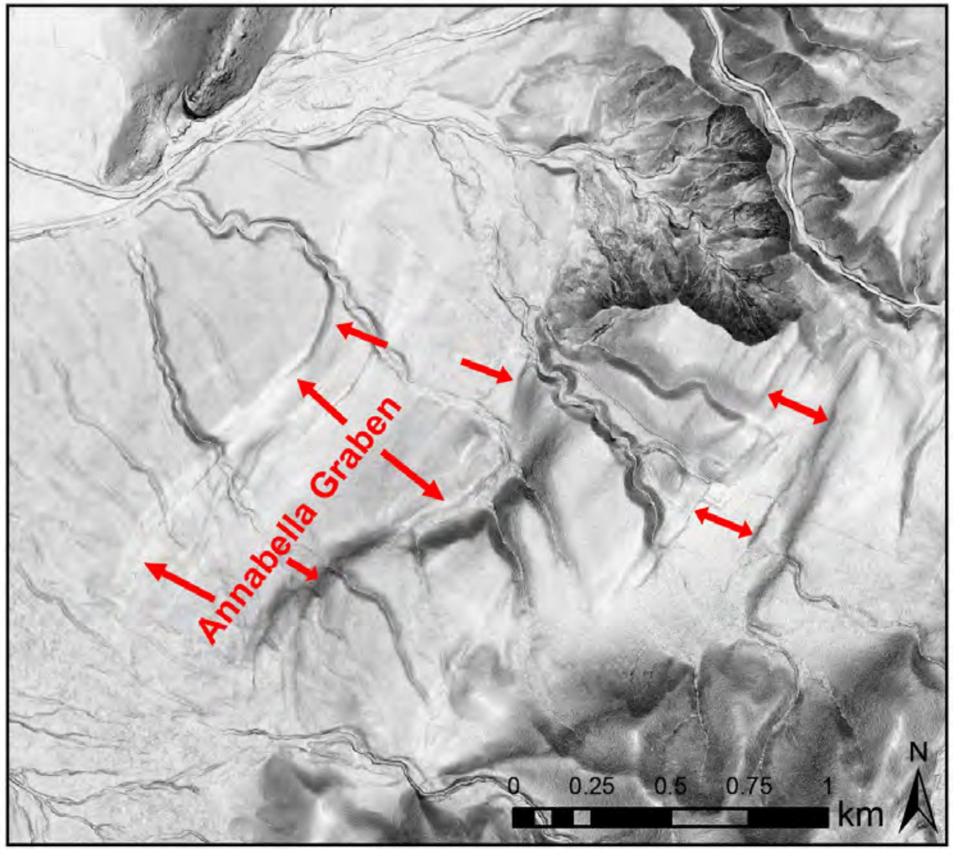
Future Work

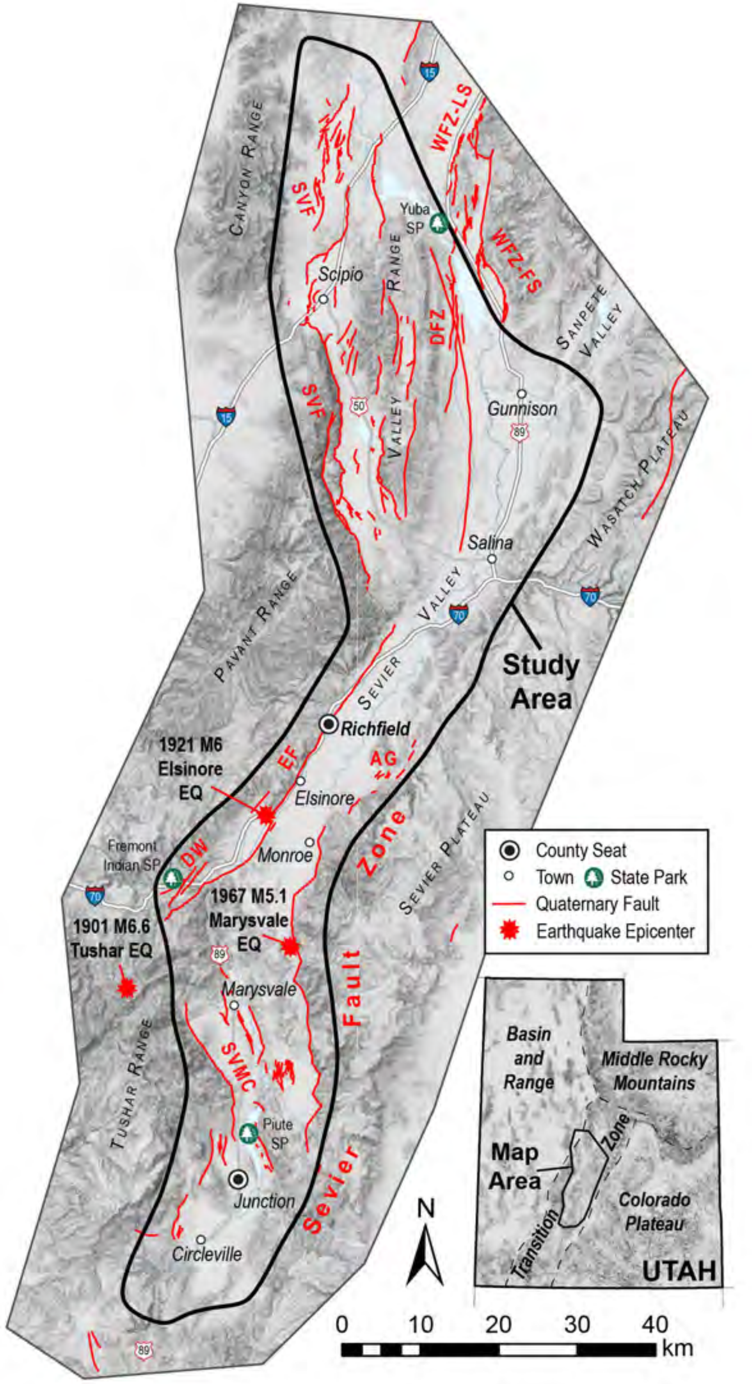
- Recently released lidar imagery from the UGRC (Collected in 2022) provides 0.5 meter data for the remaining western half of Skull Valley
- The quaternary faults for the new area will be remapped and updated in the UGS Geologic Hazards Portal



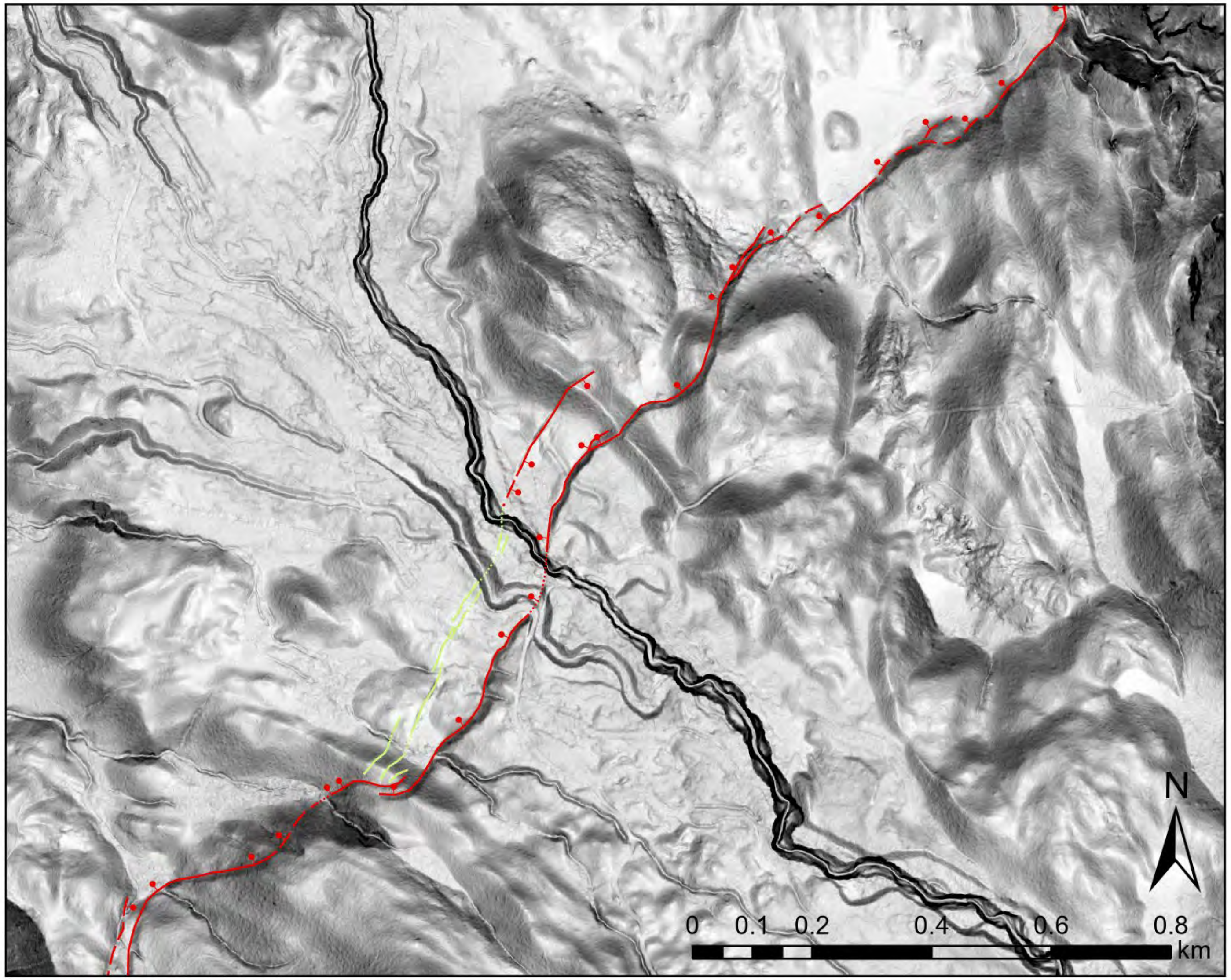
Central/Southern Utah Fault Mapping

- USGS EHP Proposal submitted 2023, funded 2024
- Continues mapping of the Sevier FZ up through Central Utah.
- Includes mapping of several other regional faults such as the Marysvale area faults, Dover fault zone, Scipio Valley faults, and the Annabella Graben.

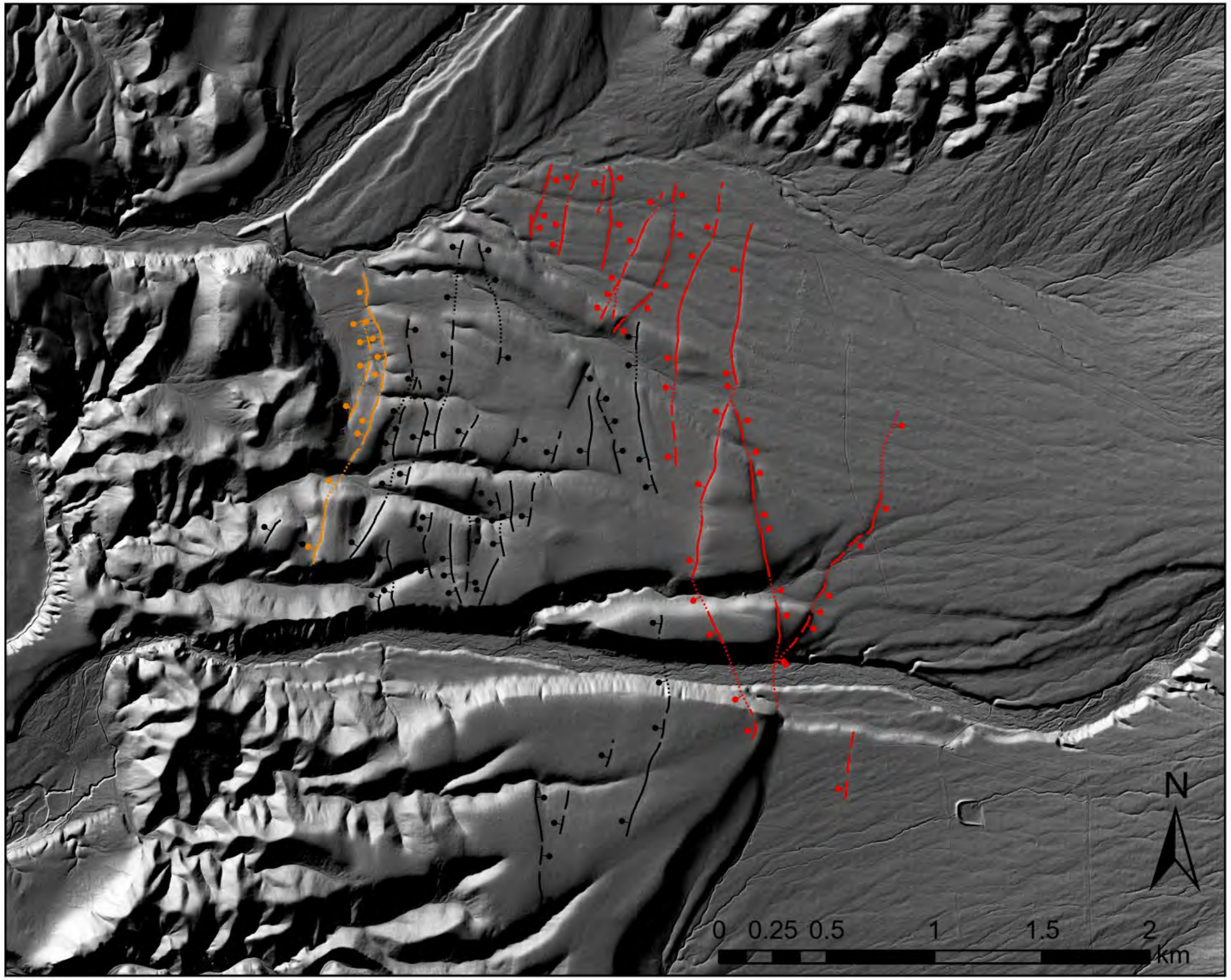




Central/Southern Utah Fault Mapping



CENTRAL/SOUTHERN UTAH FAULT MAPPING



UAV-based Lidar for Fault Mapping

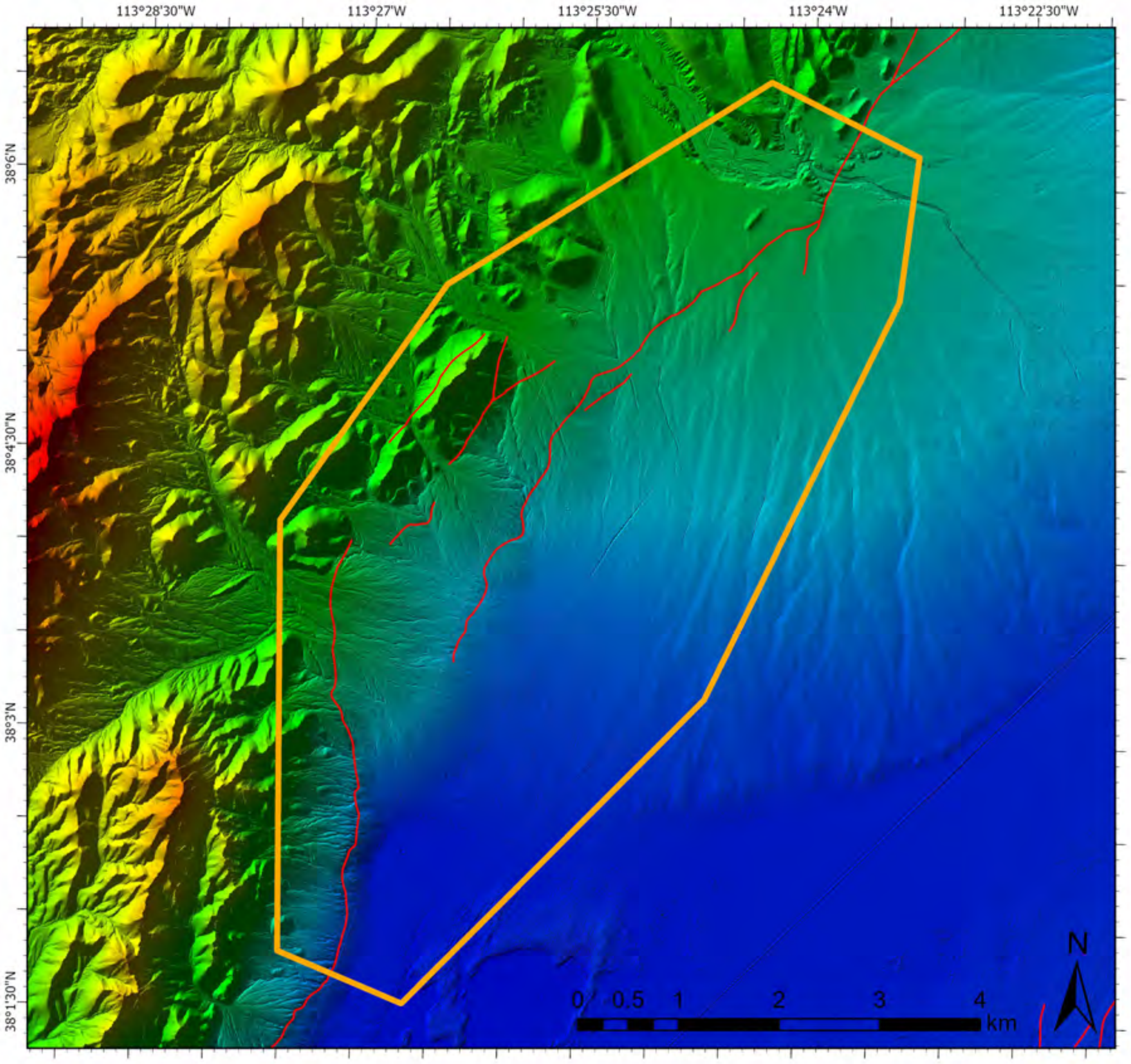
Adam I. Hiscock, Utah Geological Survey

DOE INGENIOUS Geothermal Research Project

- **IN**novative **G**eothermal **E**xploration through **N**ovel **I**nvestigations **O**f **U**ndiscovered **S**ystems (**INGENIOUS**)
- Project focused on geothermal play fairway analysis of areas to accelerate discoveries of new, commercially viable, hidden geothermal systems.
- From 2021-2023, performed reconnaissance mapping across the Utah portion of the Great Basin – only in areas with lidar data coverage (myself, Emily Kleber, & Tyler Knudsen).

Lund North Site

- Sites selected based largely on fault/structural settings
  - Accommodation zones, fault stepovers, fault terminations, etc.
- Utah – Narrowed down to a “Top 4”, further narrowed down to the Lund North Site
- QL2 (2-meter) traditional aerial lidar data covered site (collected 2020)
- May 2024 – Collected additional UAV lidar data at Lund North for more detailed fault mapping

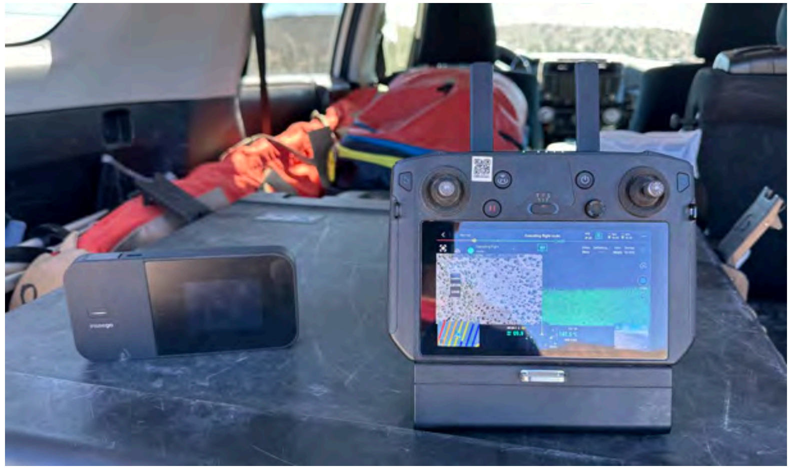


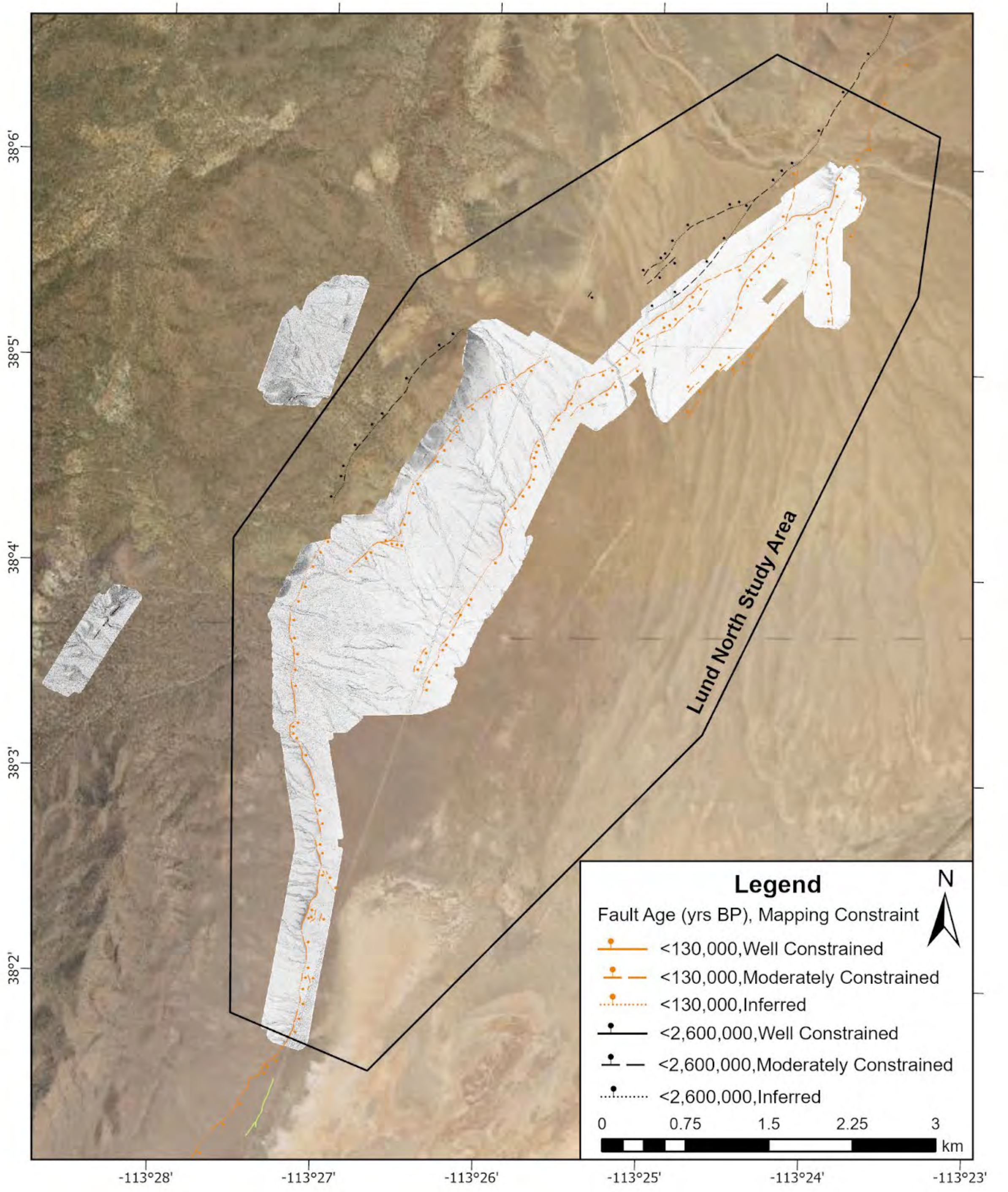
UAV-Lidar Data Collection

- DJI Matrice M300 UAV
- DJI Zenmuse L1 Lidar Scanner
- RTK GNSS/cell data connection for corrections

UAV-Lidar Data Collection

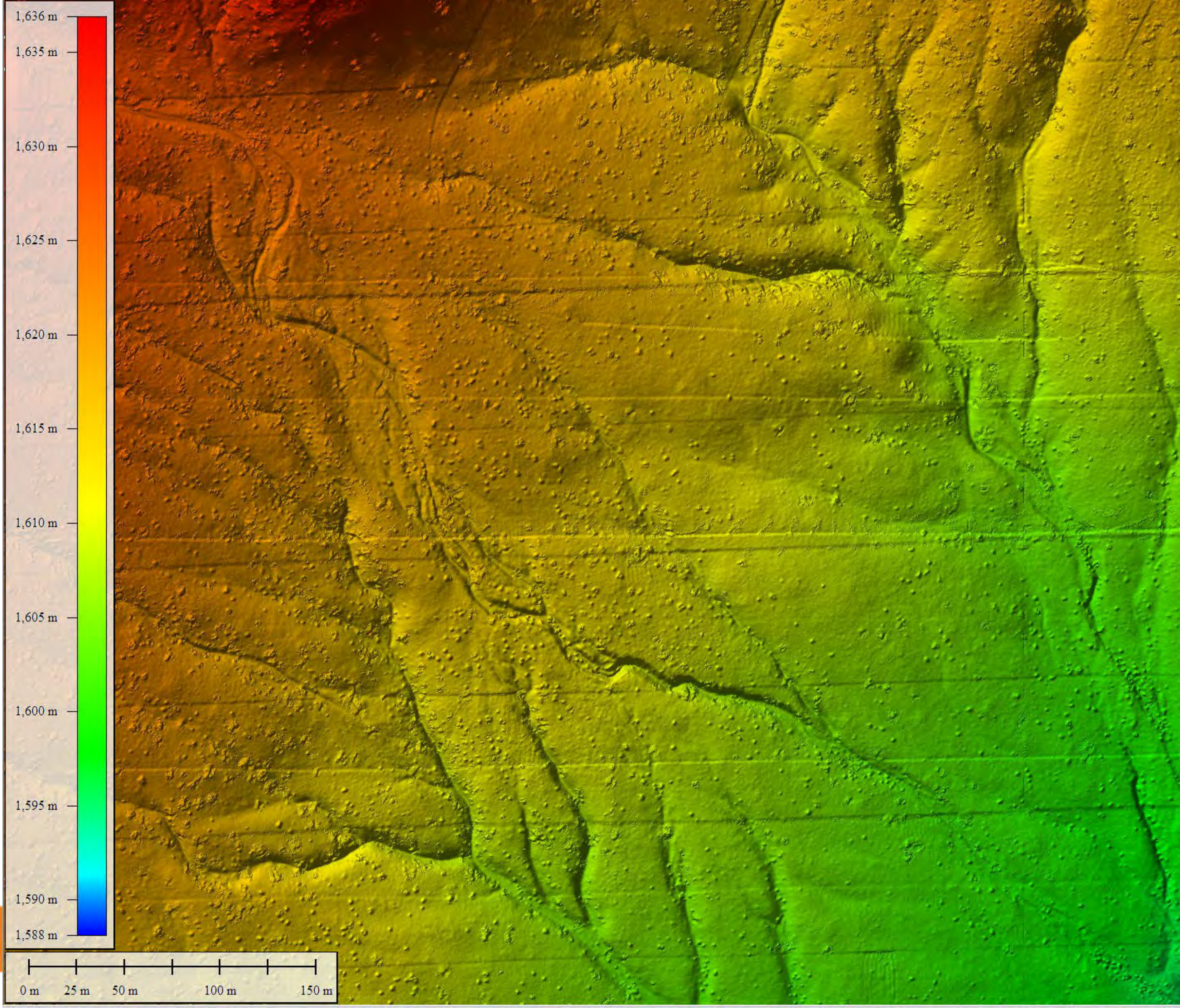
- Collected ~10.15 km^2 of lidar data in May 2024
- 1 week of field time, 1 day of office processing time
- Generated 0.22 m/pixel DEM for highly detailed fault mapping

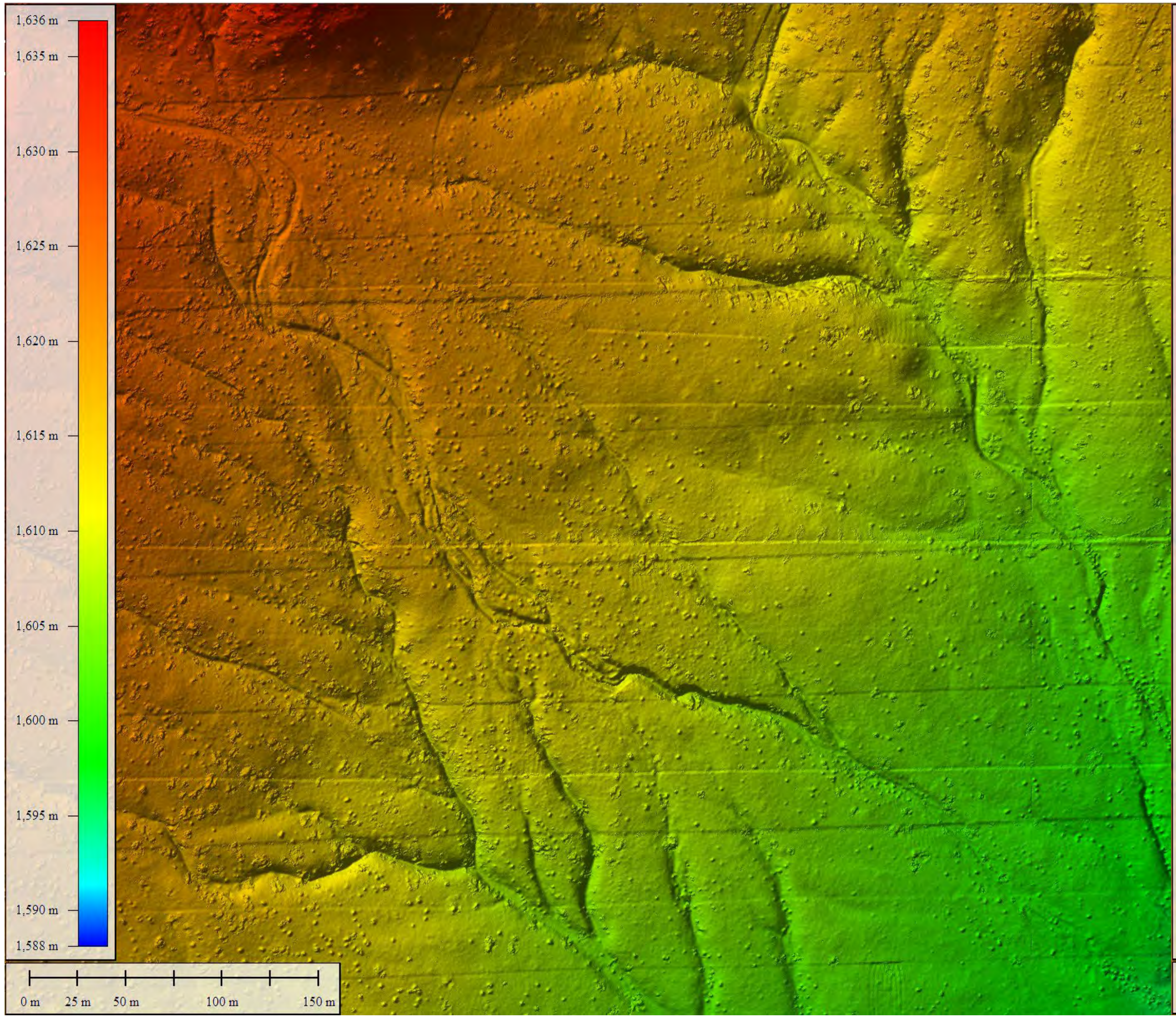




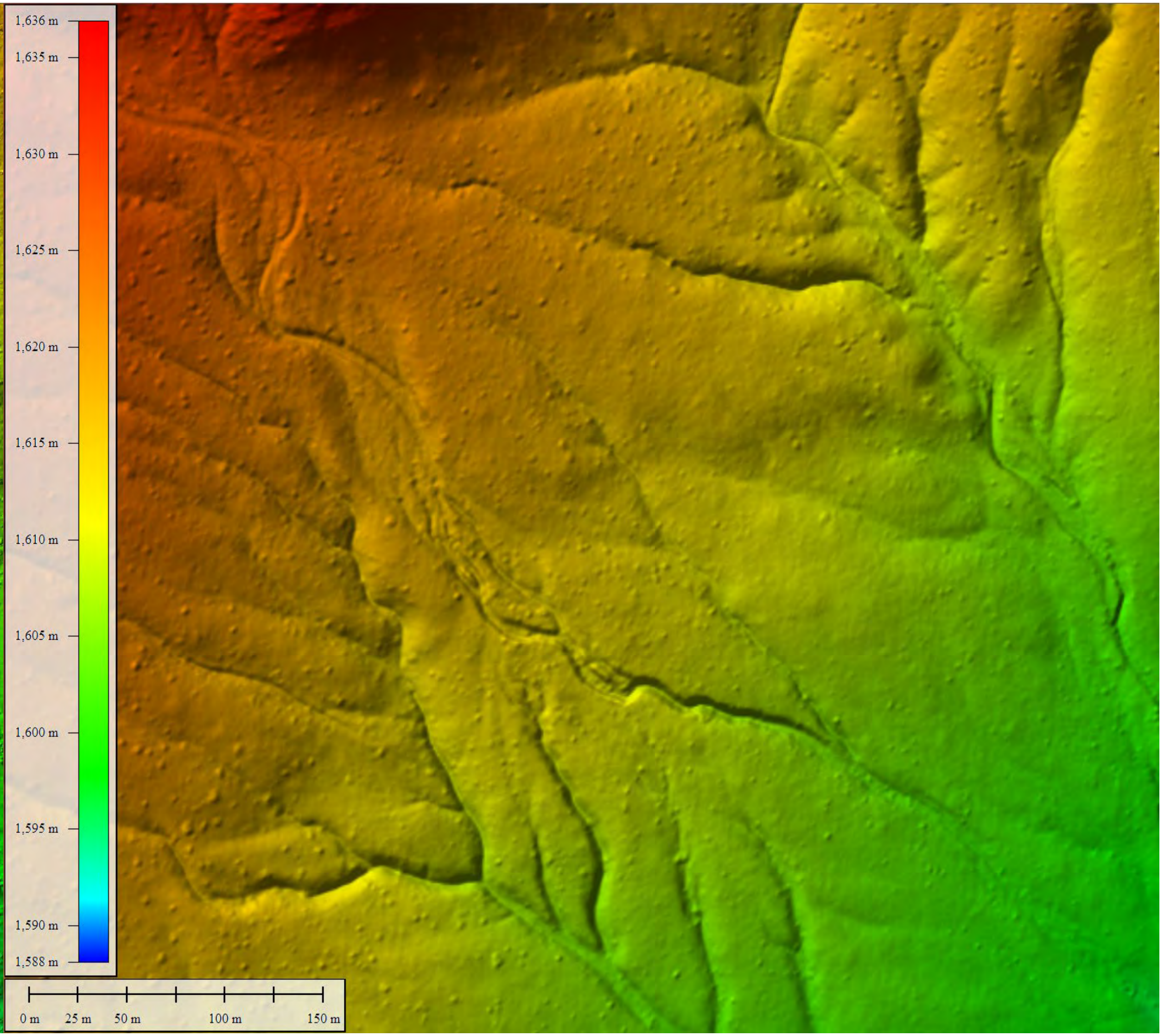
UAV-Lidar Data

- Issues with lidar swath alignment
- Can be minimized by maximizing overlap between lidar swaths
- However, more overlap = longer flight times = more batteries/charging needed = longer time in the field
- UGS has developed a workflow to minimize this issue inherent with the Zenmuse L1





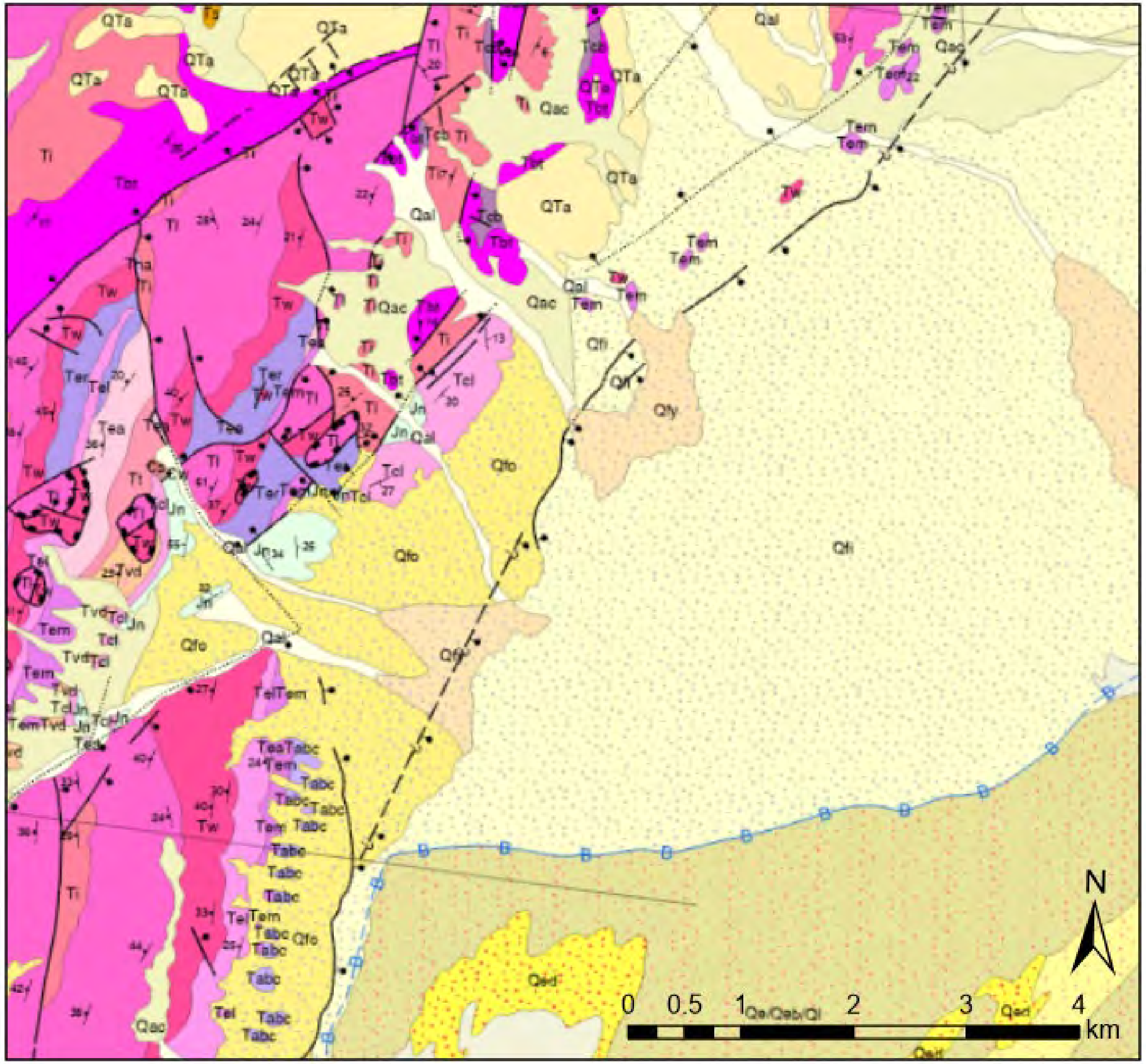
UAV 0.22m/pixel DEM

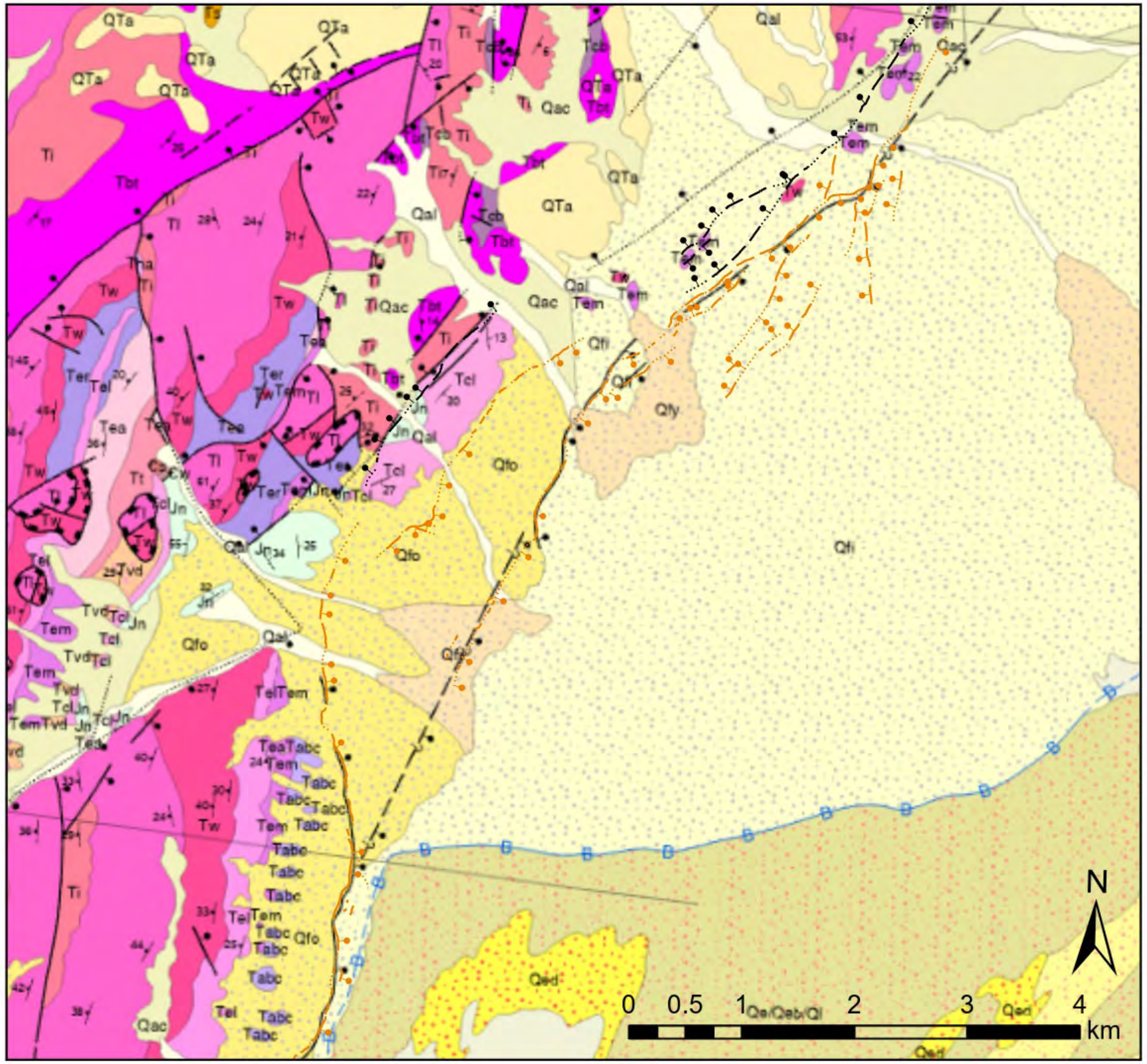


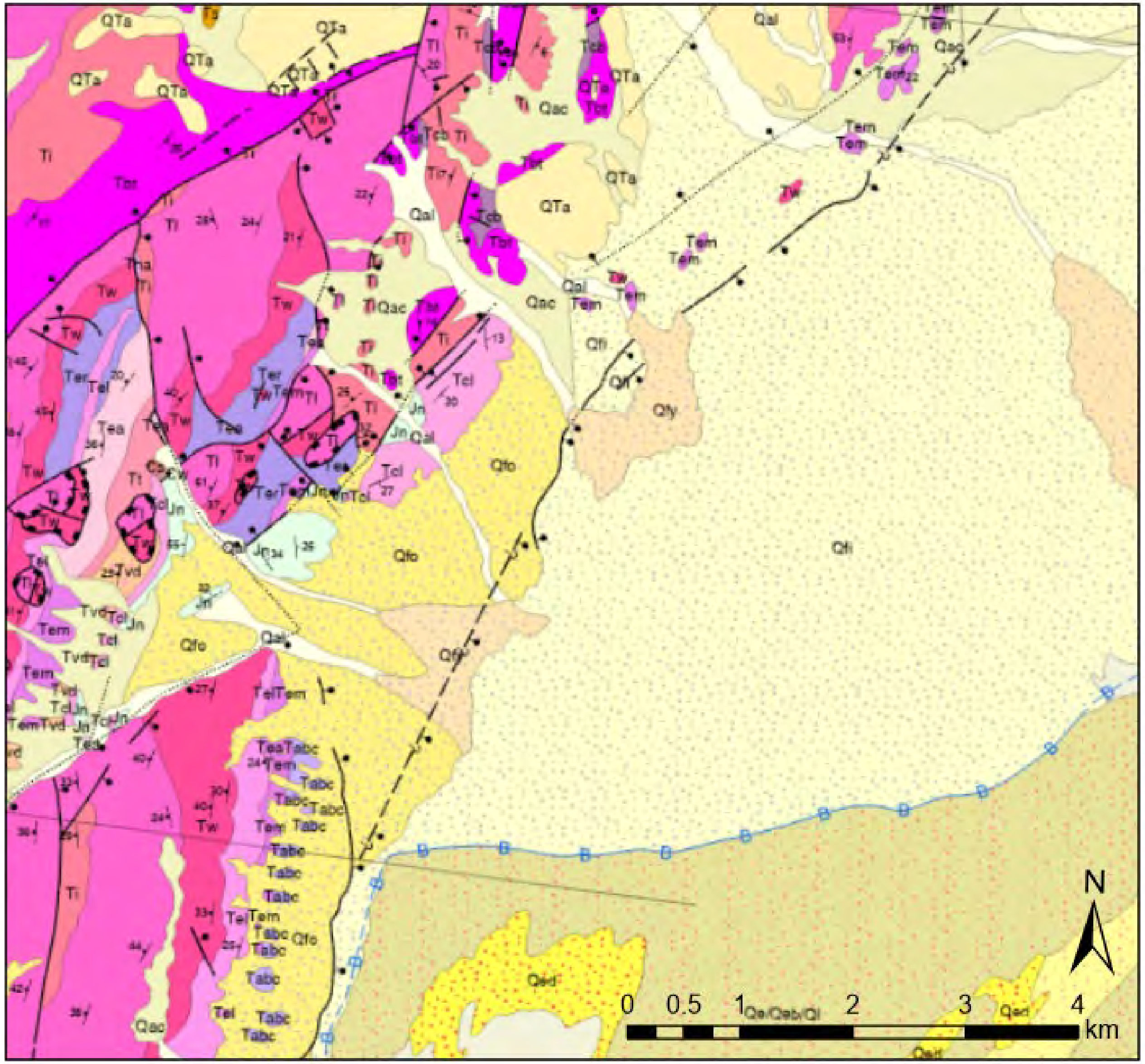
USGS 1m/pixel DEM

AREA FAULTS

- UQFFD – Wah Wah Mountains (south end near Lund) fault
- First mapped by Lehi Hintze (Geologic Map of the Blue Mountain-Lund area, Hintze et al. 2017, USGS OFR-678DM)
- ~37-km long, follows the southern margin of the Wah Wah Mountains
- Cuts late-Pleistocene alluvial fans (<130ka and <2.6mya age categories in QFFD)




N
0 0.5 1 2 3 4
km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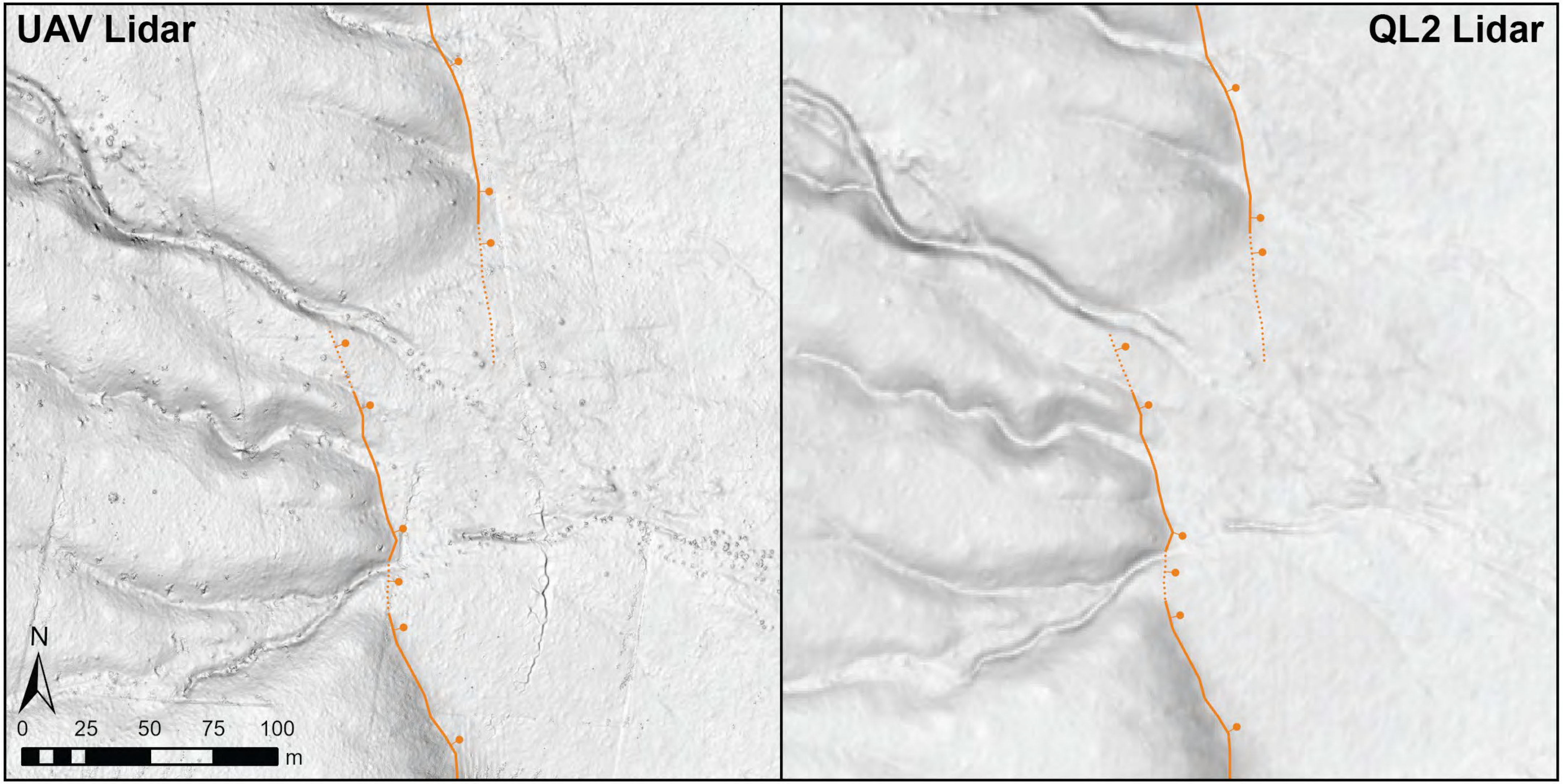
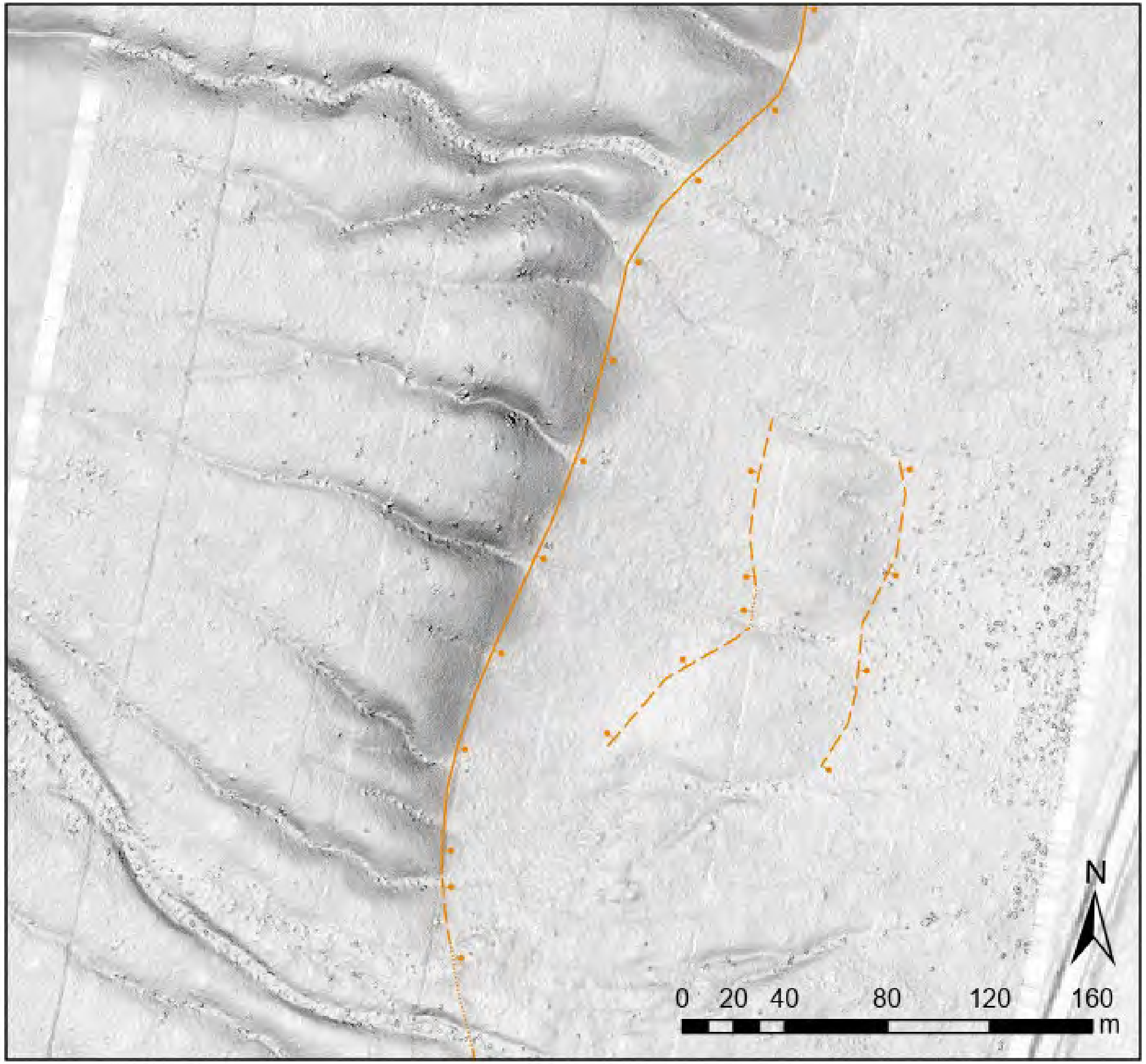


UAV 0.22m/pixel DEM

USGS 1m/pixel DEM

Fault Mapping

- Higher-resolution data allowed us to tease out more complexity in scarps
  - Step-overs, small grabens & horst blocks
- Mapped numerous very small scarps



Lessons Learned

- In most cases, QL1 or QL2 lidar is sufficient for fault mapping
- Best used to collect super high-resolution data for small areas
  - Time consuming for large areas – unless you have a way to recharge batteries on site
- Good quality data with some caveats – mainly associated with the Zenmuse L1 sensor
  - If using this sensor, suggest maximizing flight swath overlap and filtering out extreme lidar scan angles to minimize lines in DEM between swaths
  - Currently exploring other, higher quality UAV-based lidar sensors
- Good workflow for processing data is important

Thank you.

Utah Geologic Survey
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Salt Lake City, UT 84116-6201
(801) 537-3300

UTAH DNR GEOLOGICAL SURVEY

FUTURE OF THE UTAH SEISMIC SAFETY COMMISSION

USSC UTAH SEISMIC SAFETY COMMISSION

Adam I. Hiscock
Utah Geological Survey

NON-GOVERNMENTAL ORGANIZATIONS

ENVISION UTAH

Non-profit organization which brings business, government, and community organizations together for future growth and planning

UTAH SECTION CIVIL & GEOTECHNICAL ENGINEERING

ASCE members design and build the public and private infrastructure, including roads, bridges and utilities which will be critical to the State and local governments, as well as citizens, after a damaging earthquake.

STRUCTURAL ENGINEERS ASSOCIATION OF UTAH

SEAU promotes technical expertise, professional development, and ethics within the profession. They advocate for legislation and codes to support best practices in building design and construction to improve the safety of the built environment.

AMERICAN PUBLIC WORKS ASSOCIATION

APWA helps maintain and develope safe and effective Public Works services, and provides public works professionals an opportunity of leadership and professional education

THE AMERICAN INSTITUTE OF ARCHITECTS

AIA's Disaster Assistance Program trains architects to help communities mitigate, prepare for, respond to, and recover from disasters, aligning their disaster-response processes, protocols, and training with federal frameworks.

UTAH LEAGUE OF CITIES AND TOWNS

ULCT is a nonpartisan, interlocal cooperative working to strengthen the quality of municipal government and administration in Utah's cities and towns

SCIENTIFIC ORGANIZATIONS

UTAH GEOLOGICAL SURVEY

Provides technical scientific information regarding Utah's earthquake hazard. Supports the USSC through staff input and technical services.

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS

Operates a large network of seismograph stations throughout the state of Utah and helps reduce the risk from earthquakes in Utah through research, education, and public service.

USU EARTHQUAKE ENGINEERING RESEARCH CENTER

Conducts cutting edge earthquake engineering research and implements findings into practice with a goal of increasing Utah's earthquake resiliency.

Utah Seismic Safety Commission

SEISMIC POLICY AND PUBLIC OUTREACH

STAFF SUPPORTING USSC

FEDERAL EX-OFFICIO ORGANIZATIONS

FEMA · USGS (science for a changing world)

GOVERNMENTAL ORGANIZATIONS

UTAH DEPARTMENT OF TRANSPORTATION

Operates Utah's transportation networks, and is tasked with keeping networks opearating after a damaging earthquake

GOVERNORS OFFICE OF PLANNING AND BUDGET

The Governor's Office of Planning and Budget brings a unique perspective, providing a focus on long-term and strategic planning, interagency and local government coordination, and a consideration of budgetary and policy implications.

UTAH DIVISION OF FACILITIES AND CONSTRUCTION MANAGEMENT

DFCM manages the design and construction of public buildings which are critical to state and local governments, as well as citizens, after a damaging earthquake.

UTAH INSURANCE DEPARTMENT

Seeks to provide Utah consumers with education and information about the insurance products that can assist with financial recovery from an earthquake.

UTAH DIVISION OF EMERGENCY MANAGEMENT

DEM coordinates emergency management efforts among state, local, and federal government entities.

UTAH STATE BOARD OF EDUCATION

USBE oversees Utah's public school system, providing licensing and policy for educators in Utah.

A volunteer, multidisciplinary state commission focused on reducing Utah earthquake risk

USSC's Mission

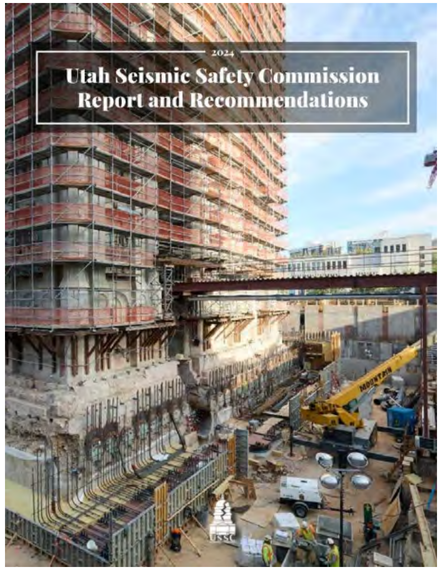
- Review earthquake-related hazards and risks to the State of Utah and its inhabitants.
- Prepare recommendations to identify and mitigate those hazards and risks.
- Prioritize recommendations and present and promote them to state and local governments for adoption as policy or loss reduction measures.
- Act as a source of information with those concerned with earthquake safety.
- Act as a promoter of earthquake loss reduction measures and legislation.
- Periodically update a strategic seismic planning document that helps monitor the progress toward achieving the goal of seismic risk reduction in the state of Utah.

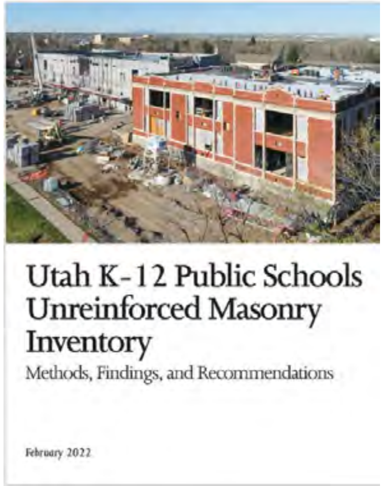
USSC Utah Seismic Safety Commission

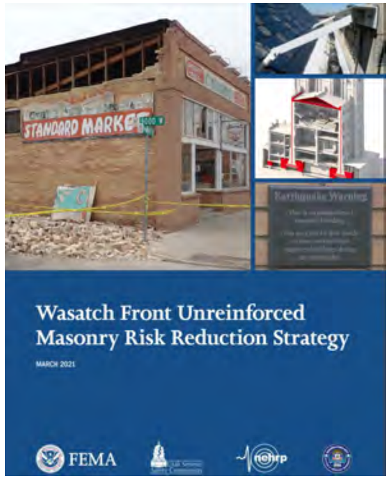
USSC Projects/Reports

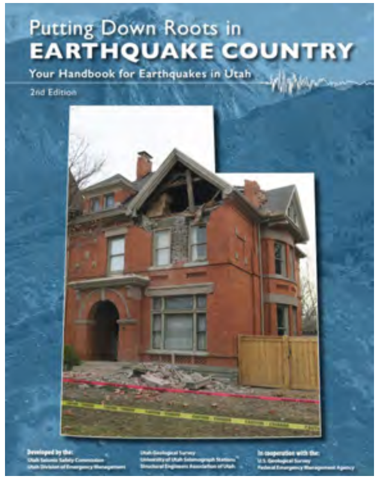
USSC's Projects/Reports:

- Yearly Report and Recommendations to the Utah Legislature
- Utah K-12 Public Schools URM Inventory
- Mitigation Endorsement Report for Utah's URM Schools
- Putting Down Roots in Earthquake Country, 2nd Edition (English & Spanish)
- Wasatch Front URM Risk Reduction Strategy
- earthquakes.utah.gov Website









EARTHQUAKES.UTAH.GOV

USSC SUNSETTING

- Utah State Legislature voted to sunset the USSC in the 2024 session – effective January 1, 2025
- Ongoing work on identifying seismically unsafe schools was not received well by the Utah Legislature – political hot button issue
- HB47 in 2024 Legislative session attempted to re-establish commission, but died on the senate floor 18 (nay) – 10 (yay)

The Salt Lake Tribune SUBSCRIBE LOG IN

This group is tasked with preparing Utah for the "Big One." Utah leaders voted to get rid of it.

Were lawmakers irritated over reports on seismic safety needs for school buildings?

(Trent Nelson | The Salt Lake Tribune) Damage in Magna from the March 18, 2020, earthquake. With Utah due for a major temblor, state lawmakers have done away with the 30-year-old Utah Seismic Safety Commission.

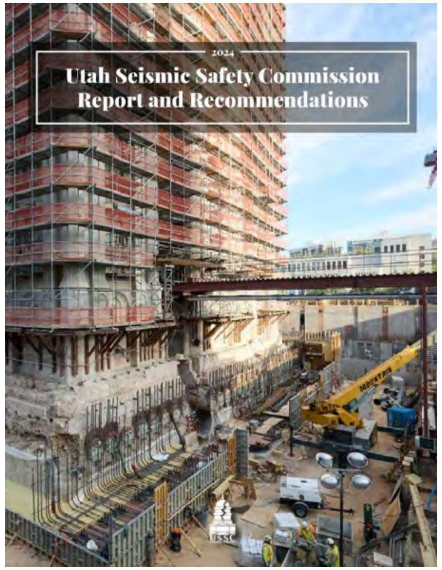
By Sofia Jeremias | Aug. 15, 2024, 6:00 a.m. | Updated: 12:54 p.m.

New Commission - Future

- Potential new name: **UCEP – Utah Commission for Earthquake Preparedness**
  - Focused on economic and infrastructure preparedness
  - UCEP will provide coordination, education and planning between agencies, infrastructure entities, and members of the business community and associations
- Similar member organizations and commissioners
- Will continue to be staffed by the UGS/DNR and Utah DEM
- New state code drafted to create UCEP

NEW COMMISSION - FUTURE

- As of February 7, 2025:
  - Bill is sponsored by Rep. Thomas W. Peterson
  - Still waiting on a numbered bill in the 2025 session (runs through March 7)
- Event tomorrow (February 12, 2025) at the Capital rotunda to hand out 2025 Recommendations Report to representatives
- As of February 25, 2025:
  - Bill has passed committee with a vote of 7-3 (yay-nay)
  - Next step – full chambers



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