Update on Quaternary Fault Mapping in Utah

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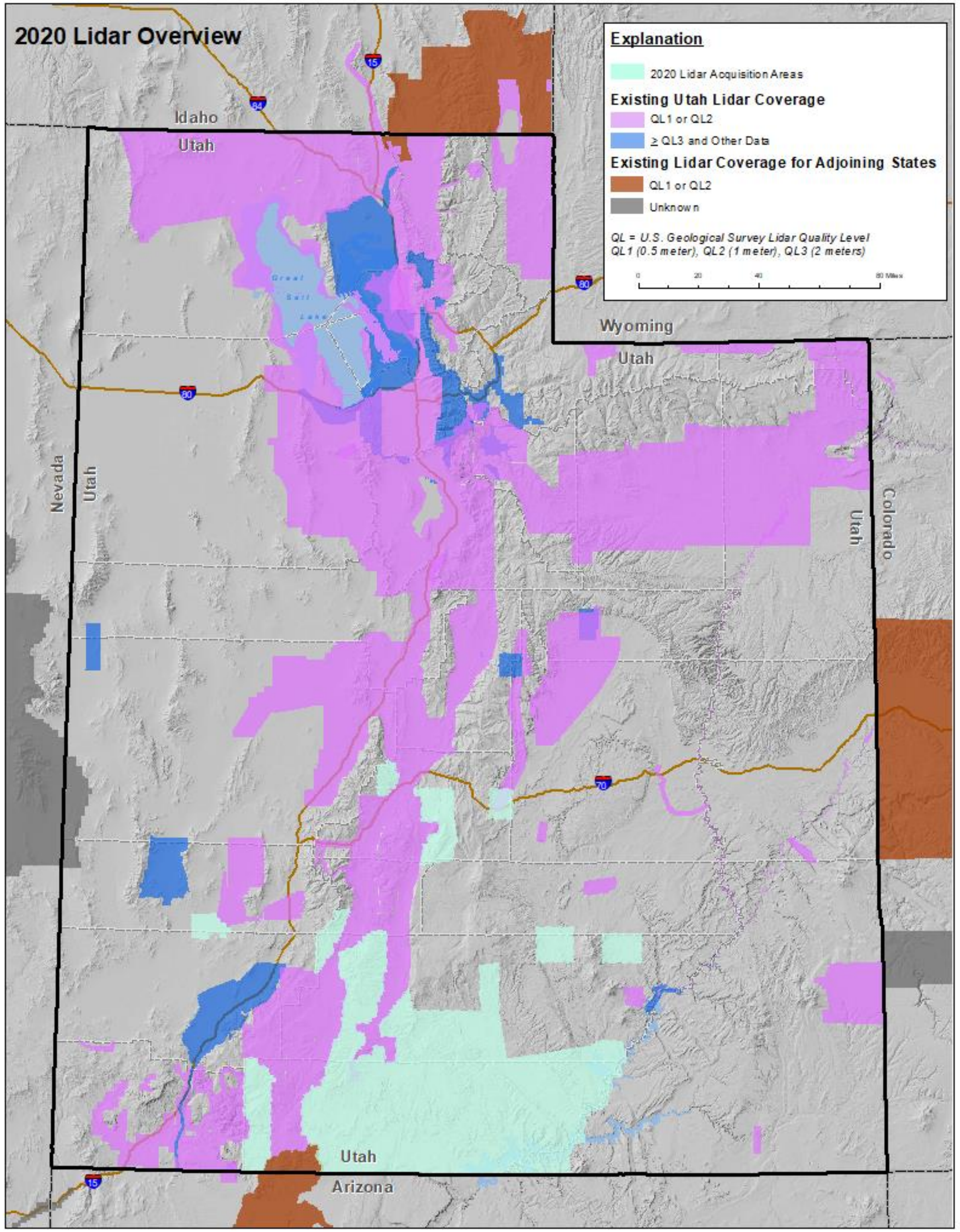
Utah Geological Survey Hazards Program

Collaborators:
UGS – Adam McKean, Zach Anderson, Mike Hylland, Kimm Harty, Mike Lowe, Jessica Castleton
USGS – Scott Bennett
UVU – Nathan Toke
USU – Susanne Janecke
IGS - Zach Lifton
AGS - Phil Peartree

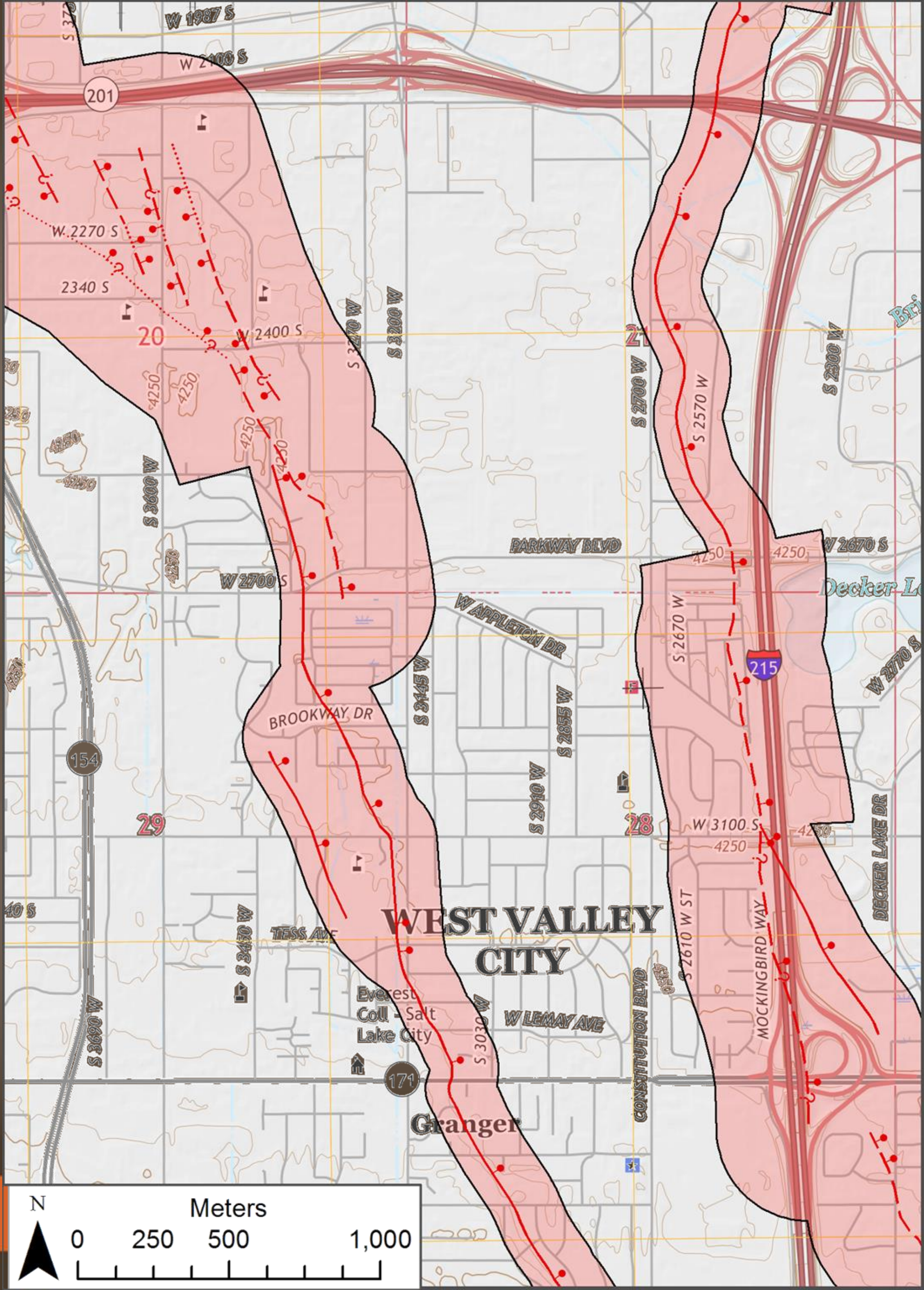
Objectives

- Availability of high resolution lidar data has expanded greatly in the past decade - great tool for characterizing and identifying active faults
- The UGS has been involved in multiple NEHRP funded fault mapping projects since 2014
- New mapping made publically available through the UGS's *Quaternary Fault and Fold Database of Utah* and the USGS's *Quaternary Fault and Fold Database of the United States,* and will be used for updates to the USGS National Sesimic Hazard Maps (2023?)
- Necessary to help characterize and identify active faults in rapidly growing and urbanizing parts of Utah



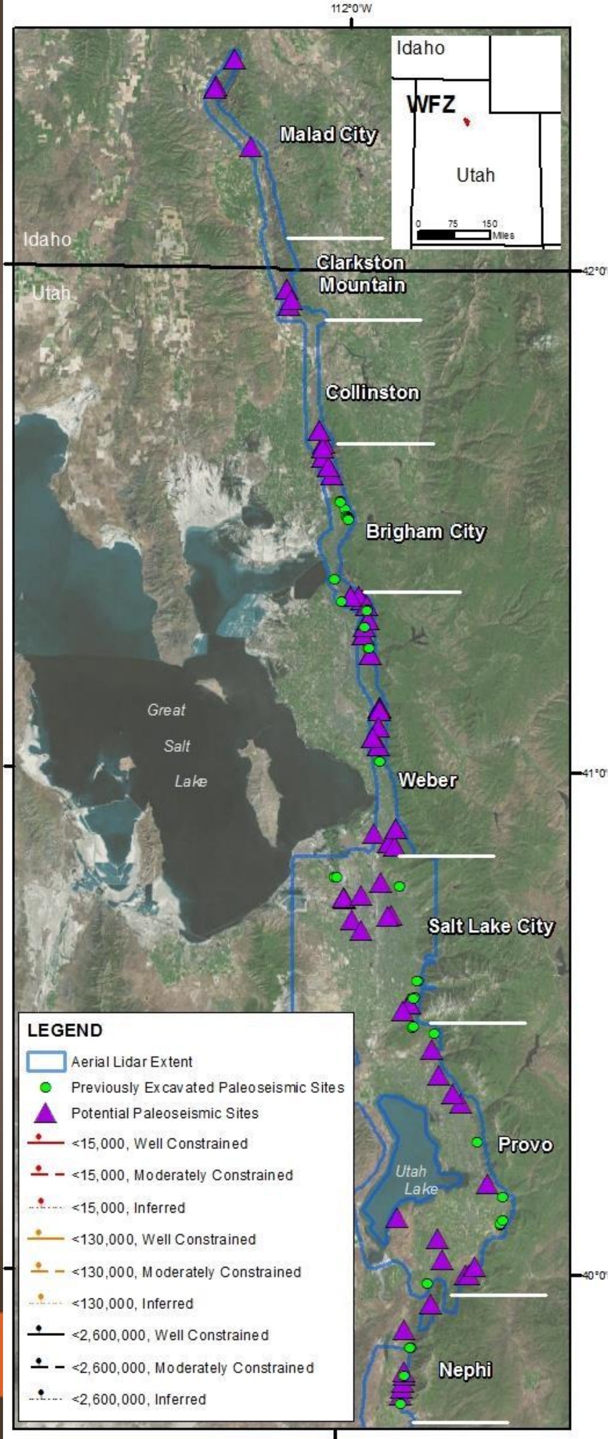
Special-Study-Zones

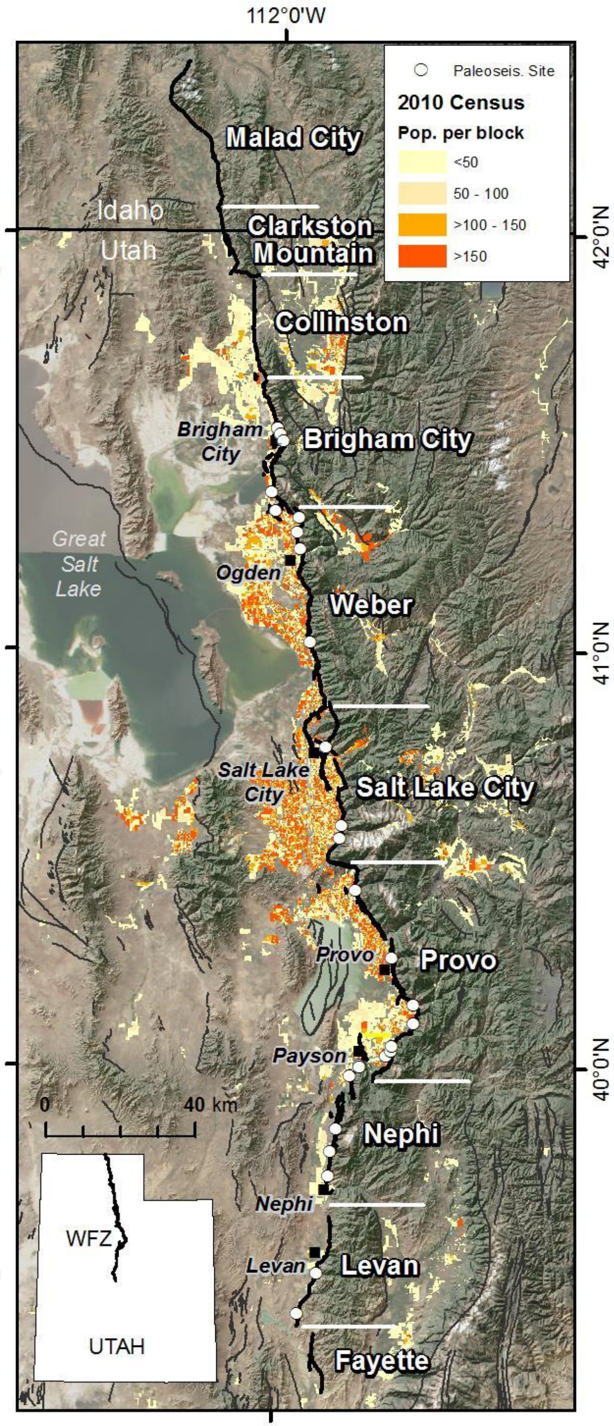
- Special-study-zones are delineated around each mapped trace
- Assist local governments with urban planning and developing hazard ordinances
- Help facilitate understanding of the hazard by triggering additional surface faulting studies
- Discussion later today!



Wasatch Fault Zone (WFZ) Mapping

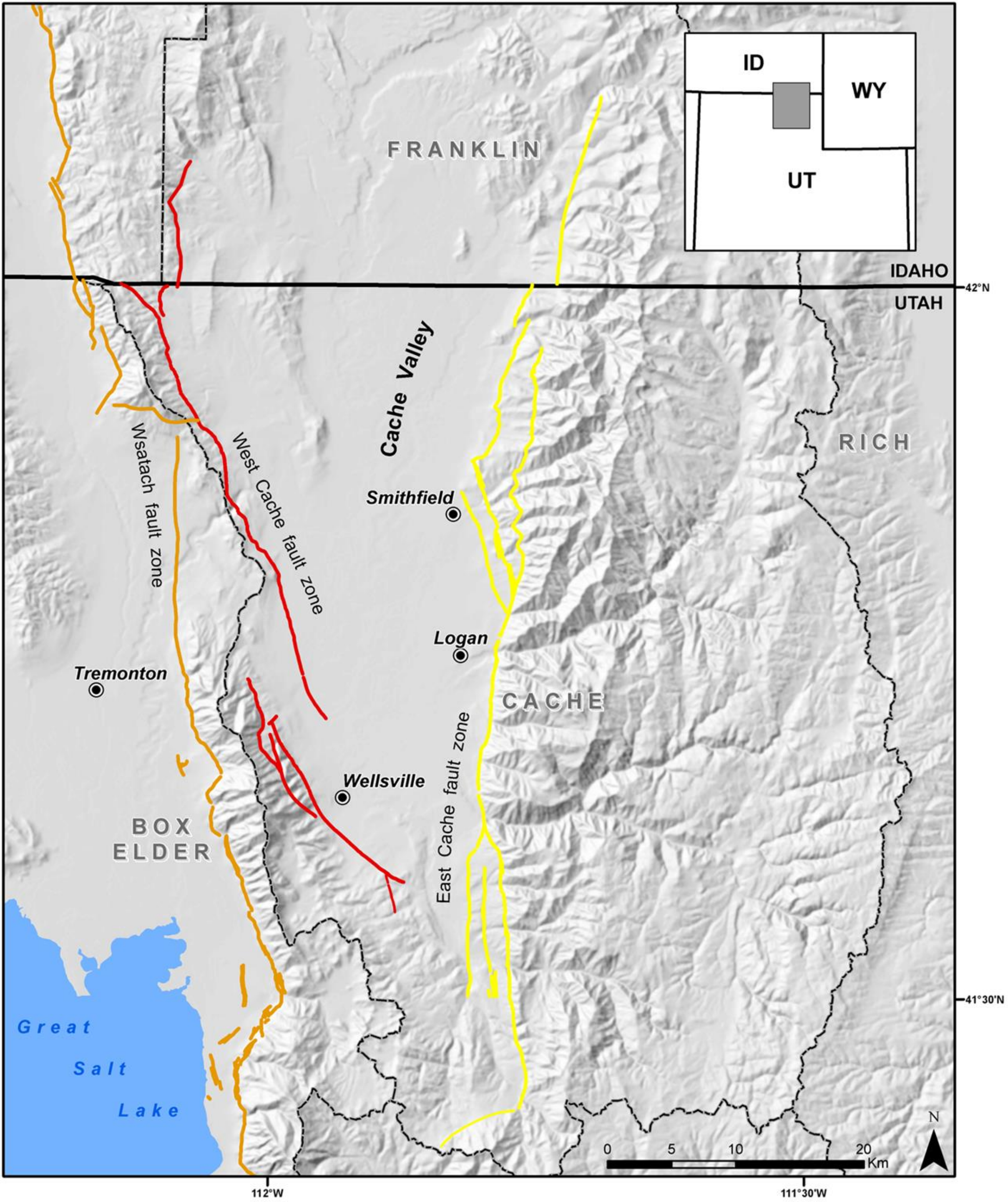
- Recently completed (in press) – UGS Report of Investigation 280 (RI-280)
- Incorporated (early 2020) into the Utah Quaternary Fault and Fold Database w/SSZ's
- 10 segments mapped at 1:24,000 scale (or better) - 39 7.5 minute quadrangles
- Identified 60 potential paleoseismic sites





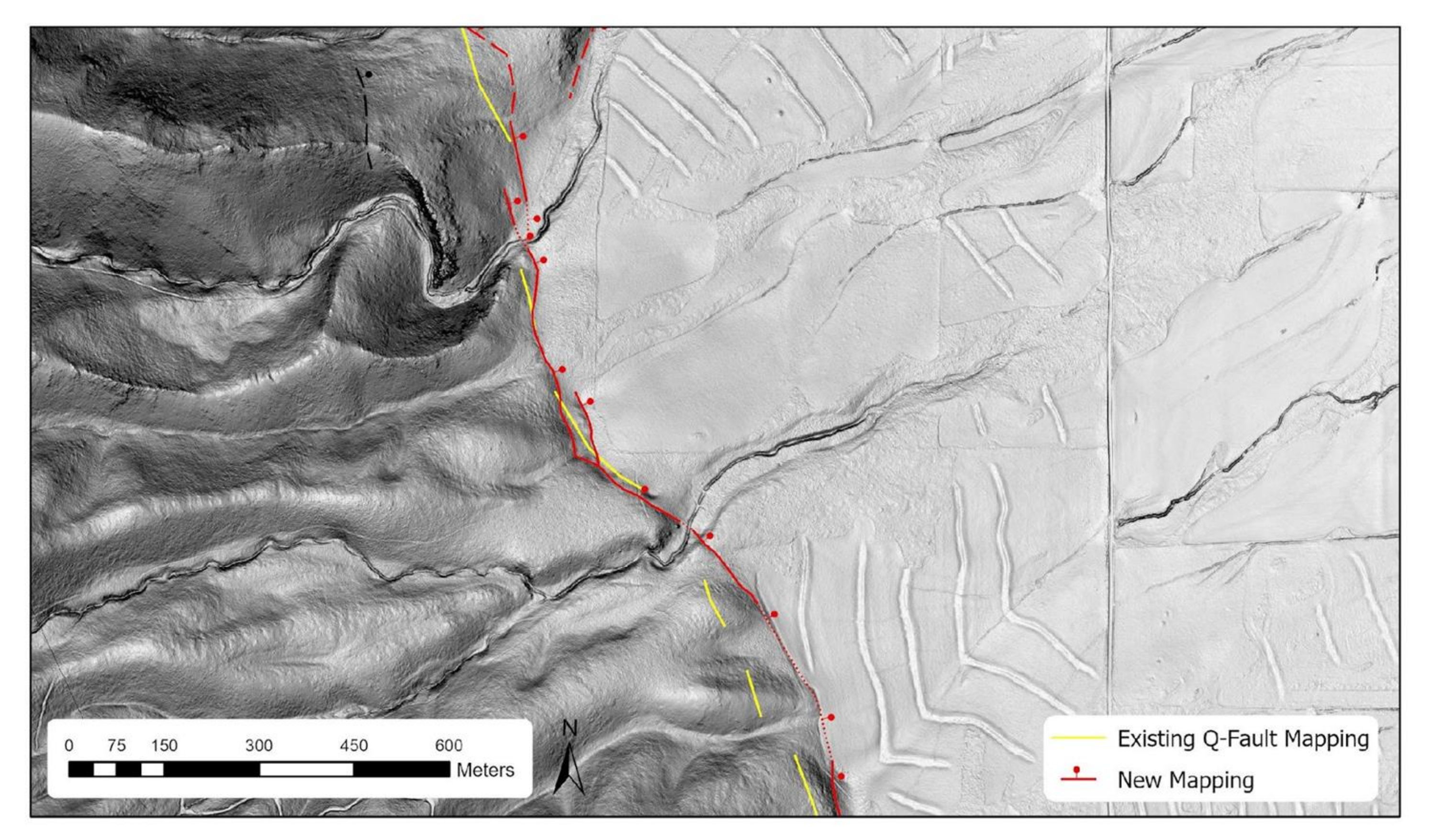
Cache Valley Fault Mapping

- Mapping at 1:10,000 scale where possible (GIS Data) – PDF Plates at 1:24,000 scale
- Generate special-study-areas
- Incorporate into the Utah Quaternary Fault and Fold Database w/SSZ's
- 13-14 7.5 minute quadrangles



Cache Valley Fault Mapping

- Refining and identifiying new fault scarps
- Multiple new possibly Holocene-age scarps and potential paleoseismic sites



Cache Valley Fault Mapping

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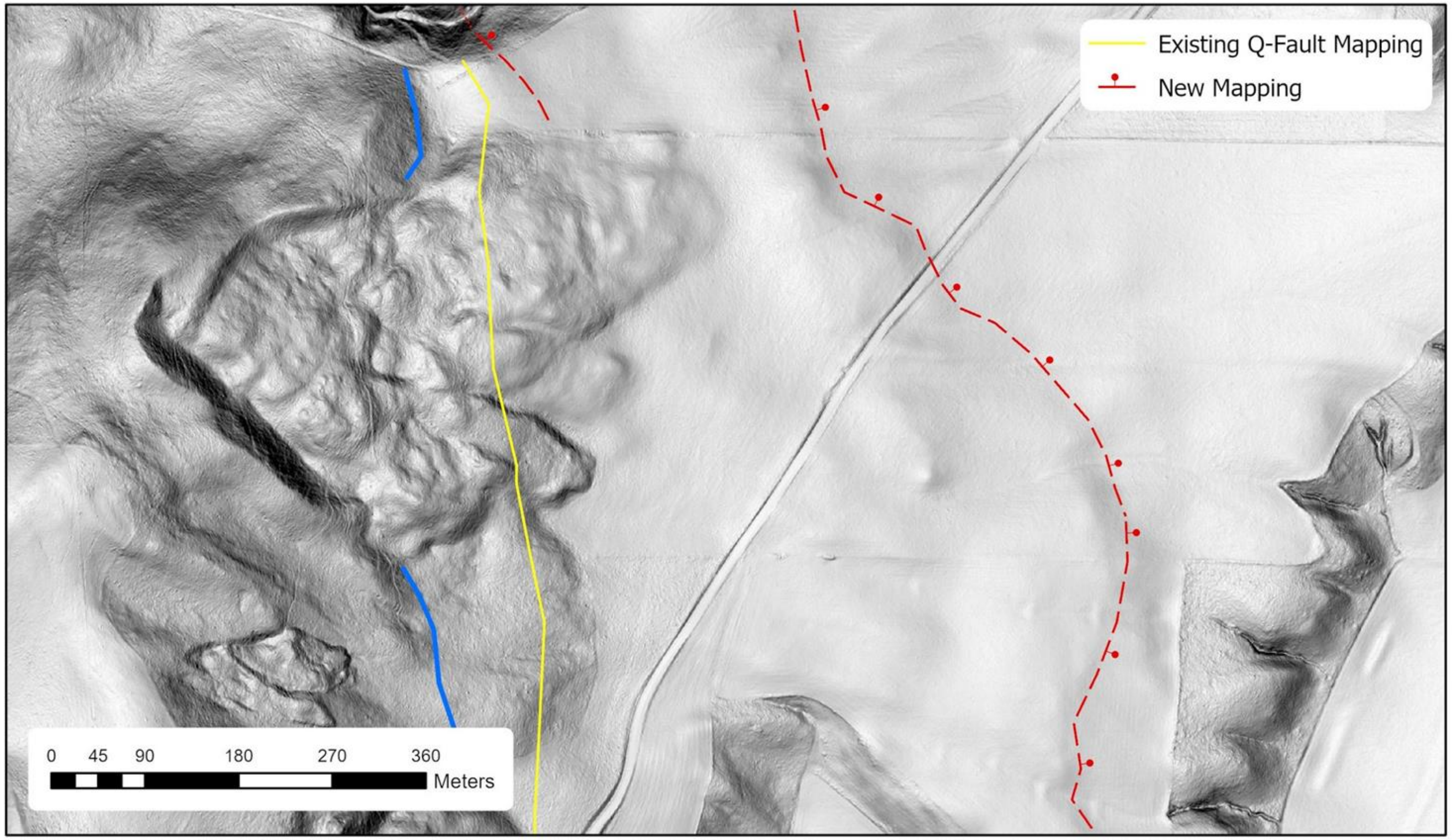
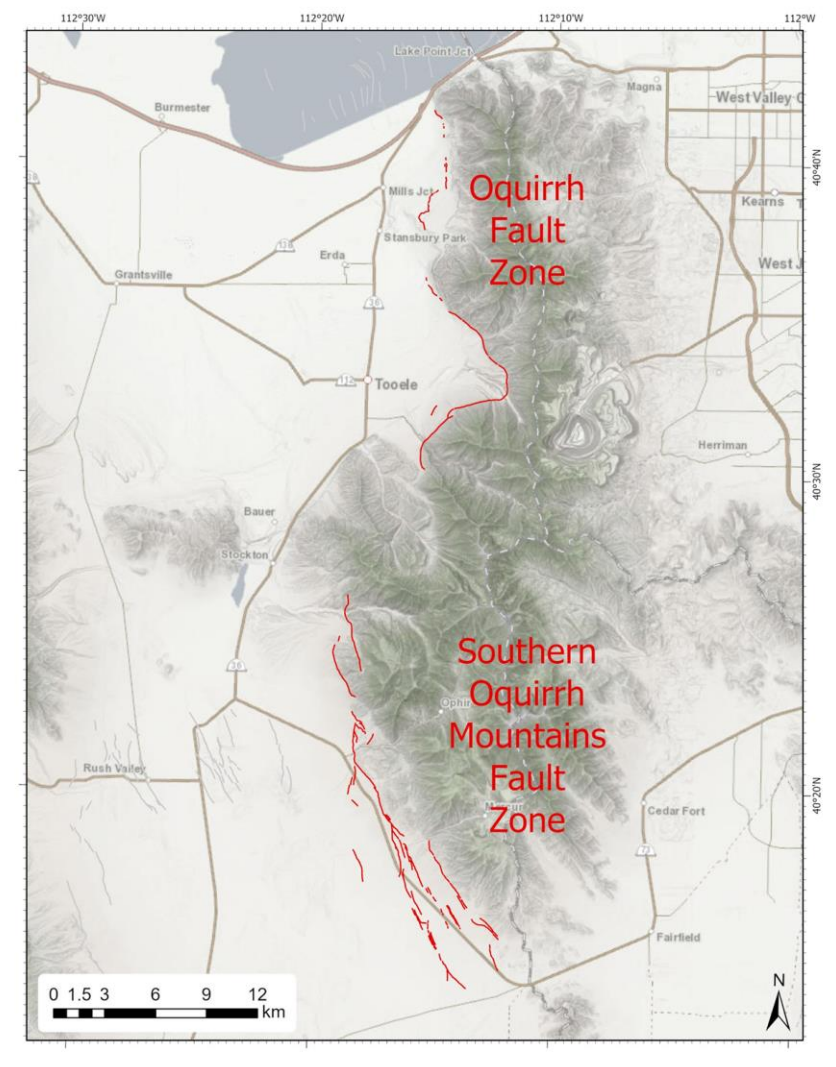


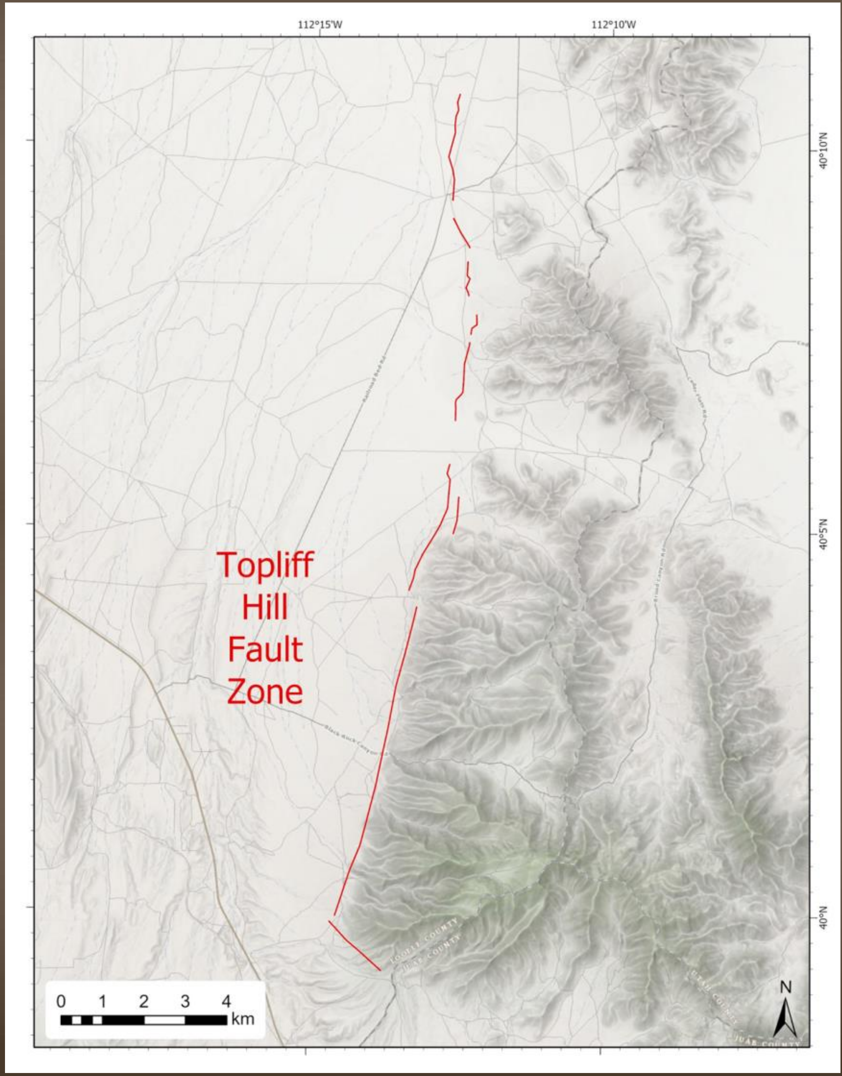
East and West Bear Lake Fault Mapping

- Collaborative project with Idaho Geological Survey (Z. Lifton)
- One of the few places in the Intermountain West (IMW) with consistent cross-border fault geometry & attributes (important topic in tomorrow's Basin and Range Province EWG meeting)

Oquirrh - Topliff Hills Fault Zones

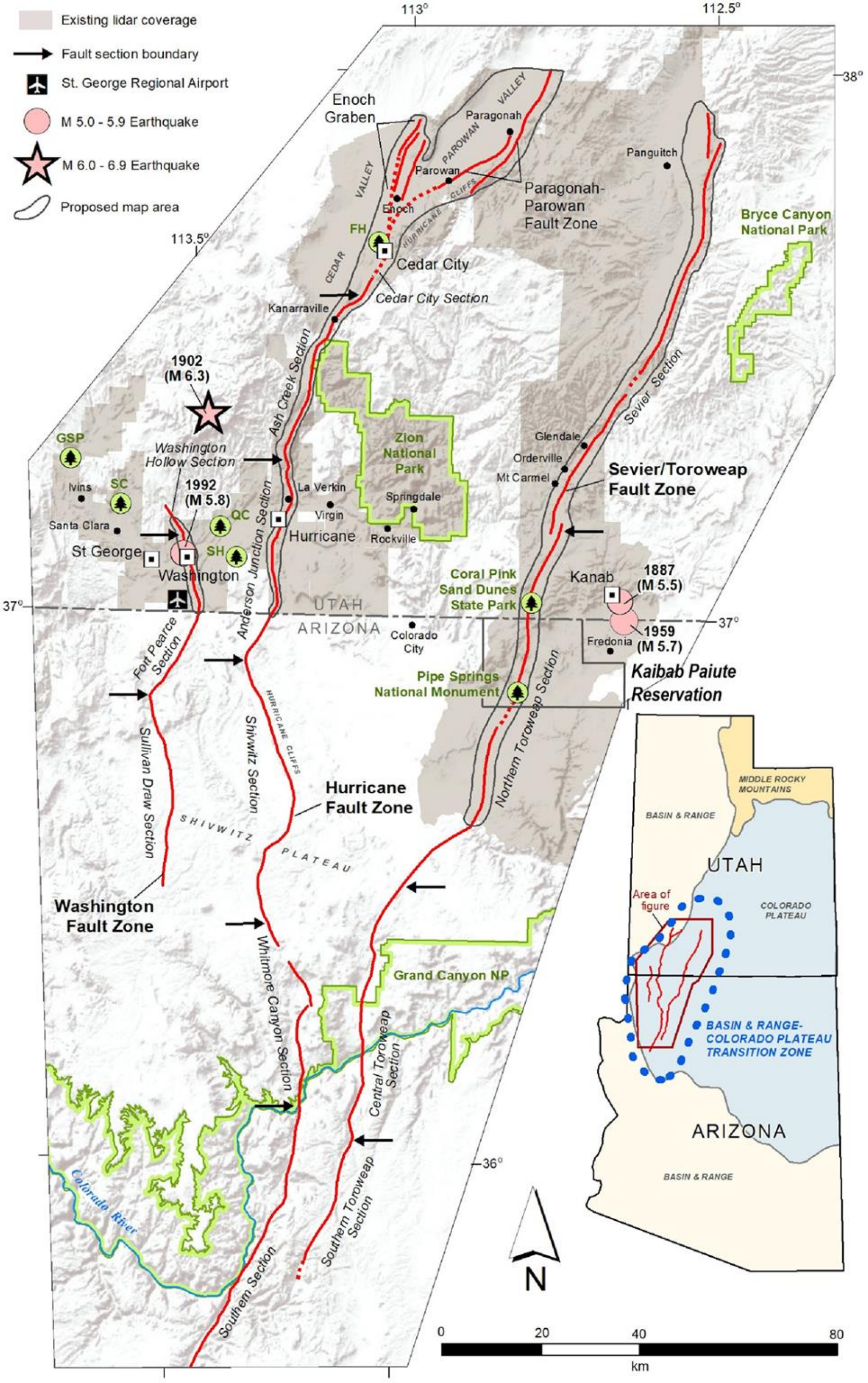
- 13 7.5 minute quads
- Very fast growing urban area
- Utah Valley University - mapping/trenching - Topliff Hills (next talk)



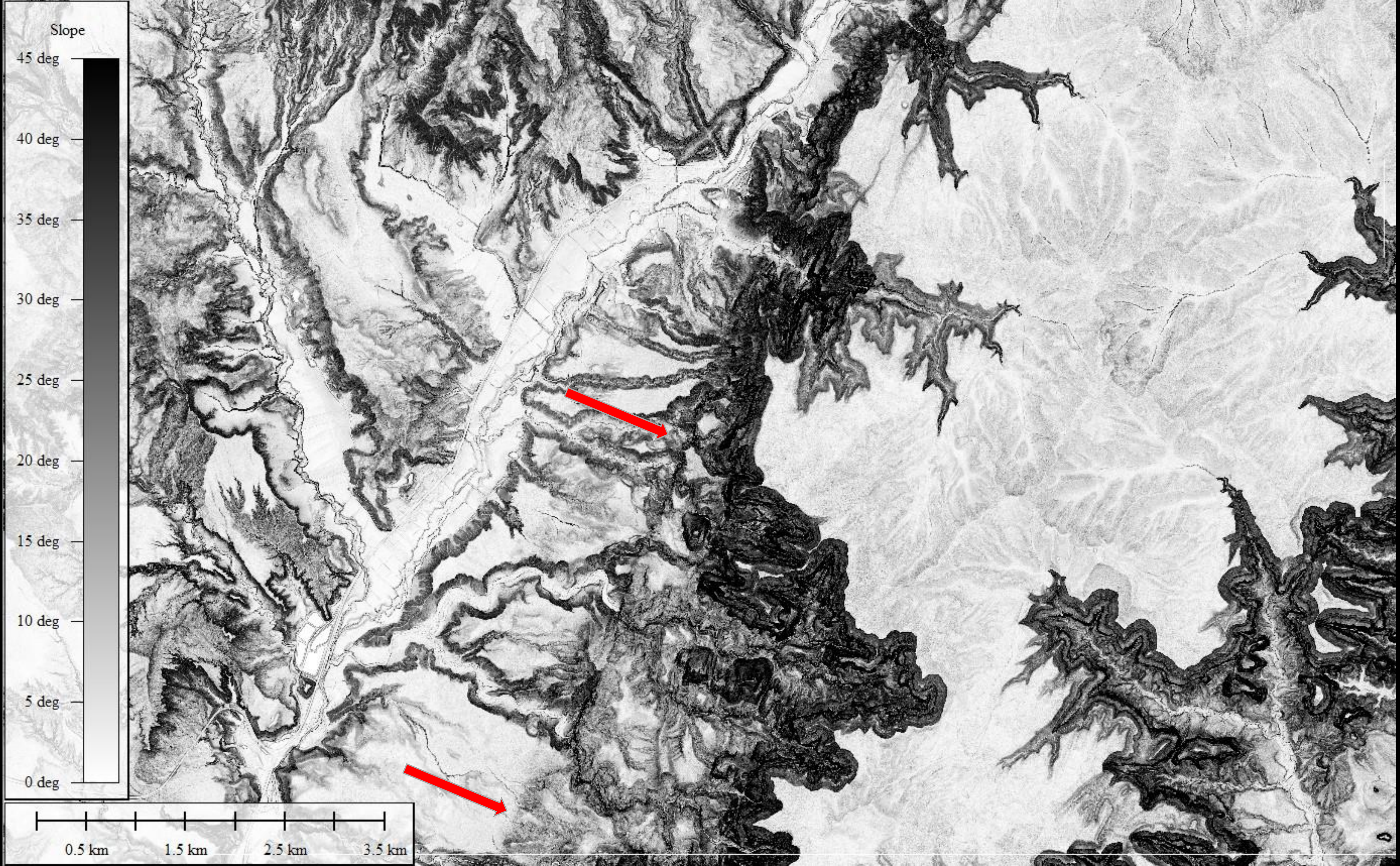


Southern Utah Fault Mapping

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




Slope
45 deg
40 deg
35 deg
30 deg
25 deg
20 deg
15 deg
10 deg
5 deg
0 deg
0 m
250 m
500 m
750 m
1000 m


Slope
45 deg
40 deg
35 deg
30 deg
25 deg
20 deg
15 deg
10 deg
5 deg
0 deg
0.5 km
1.5 km
2.5 km
3.5 km

Additional Mapping

- UGS Mapping Program - Geologic mapping around the state of Utah, specifically along the Wasatch Front
  - Identifying new faults, integrating with UGS QFFDB when published
- UGS Hazard Mapping - working on other various quads (Moab, etc.)
- Adam McKean's talk - new traces in Cedar Valley

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

Utah Quaternary Fault Parameters Working Group

February 4, 2020

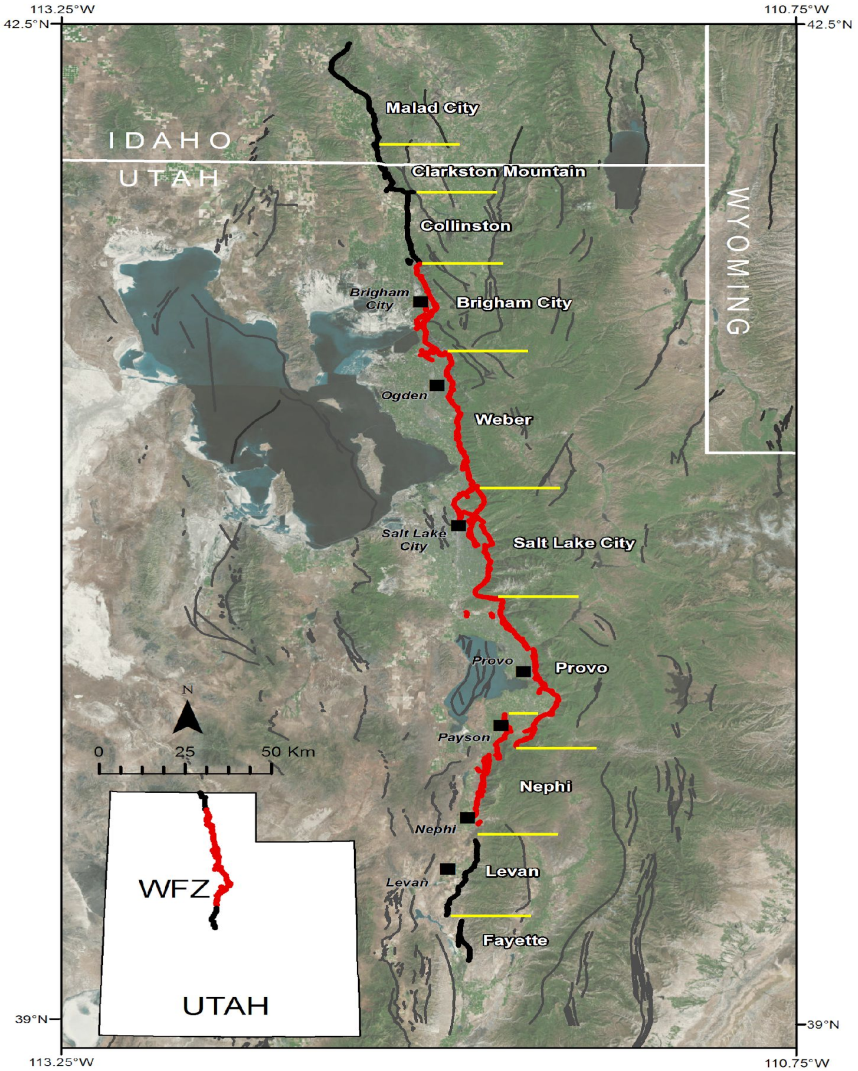
Utah Geological Survey:
Greg McDonald
Adam Hiscock
Mike Hylland
Emily Kleber
Tyler Knudsen
Rich Giraud
Adam McKean
Ben Erickson

U.S. Geological Survey:
Chris DuRoss
Ryan Gold
Jamie Delano
Shannon Mahan

Kelsey Zabrusky - BLM Richfield Field Office
Madsen Family Trust
Skyline Excavators – Todd Nielson
Yuba Reservoir State Park

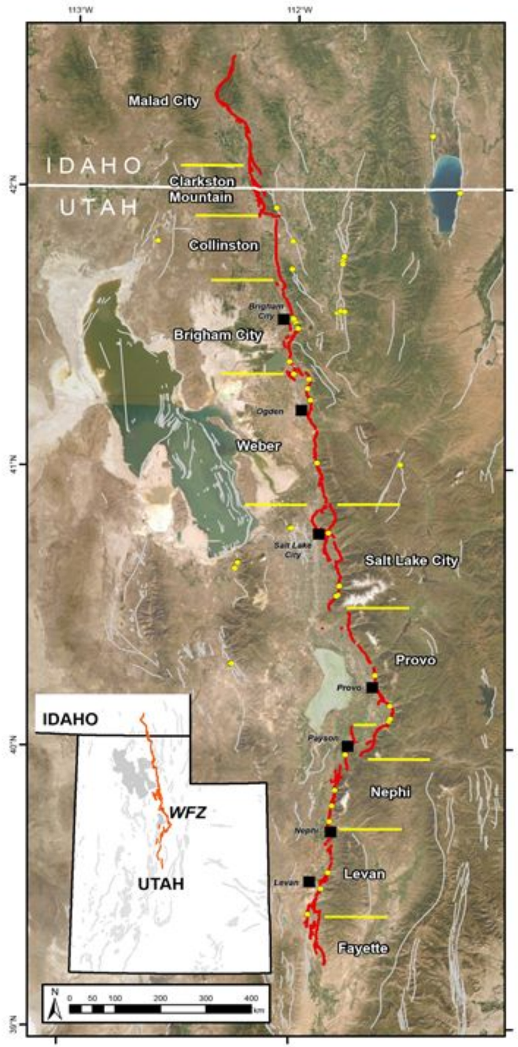
Purpose

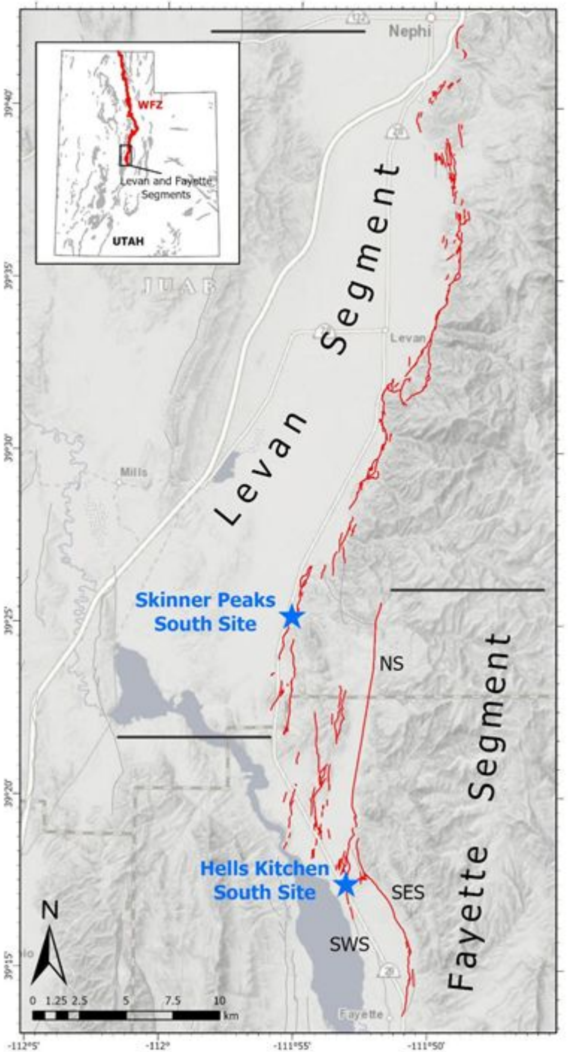
- Little paleoseismic data – earthquake timing poorly constrained for LS, non existent on FS
- Both segments show evidence of Holocene rupture
- LS/FS segment boundary spillover
- Large discrepancy between geodetic and geologic strain rates for southern WFZ
- Potential role of salt tectonics



Previous Work

- Jackson (1991) – single trench excavated near Skinner Peaks
  - Evidence for 2 surface-faulting EQ's
  - MRE 1.0 to 1.5 ka, PE prior to 3.1-3.9 ka
  - Shallow bedrock encountered in footwall –
  - Jackson logged/sampled Deep Creek exposure; MRE 0.9 to 1.1 ka
- Hylland and Machette (2008) – 31 fault-scarp profiles on the LS, 21 profiles on the FS; collected C-14 samples from Deep Creek exposure as well as faulted fan alluvium near Skinner Peaks. Ages corroborate MRE timing at about 1 ka
- Hiscock and Hylland (2015) – performed detailed fault-trace mapping for the LS and FS using 0.5-m LIDAR data



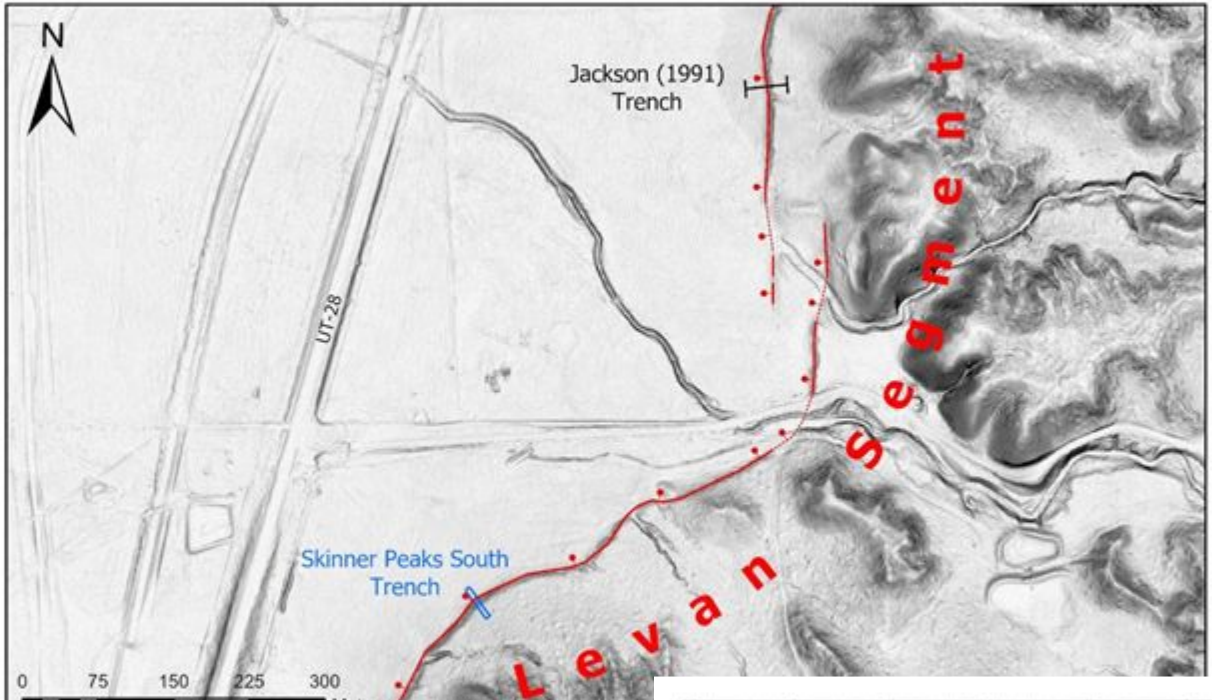


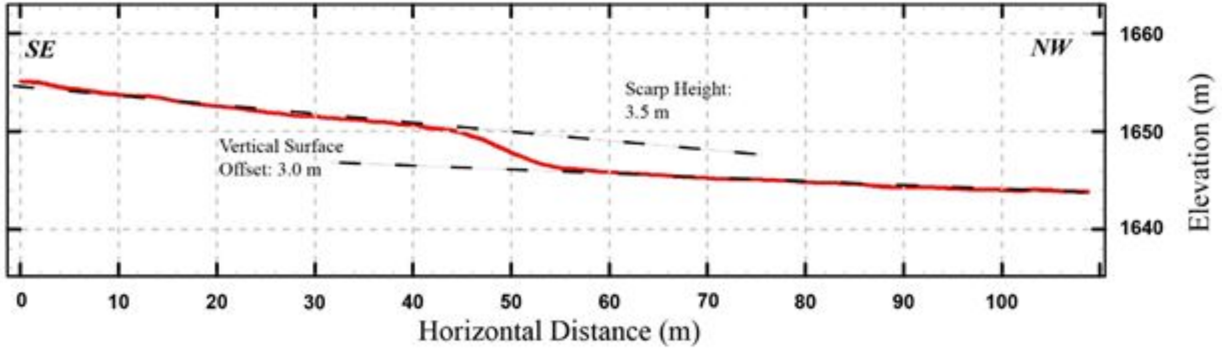
- LS - Skinner Peaks South
  Just south of Jackson's trench
  Near southern end of segment, left-lateral step over boundary

- FS - Hells Kitchen South
  South central part of segment
  Several km from range front
  QTaf footwall block

Skinner Peaks South Site

- 3-4 meter scarp
- Coarse, volcanic derived fan material
- Local bedrock: Tertiary volcaniclastics/tuffs





Skinner Peaks South Site

- Mapped 5 stratigraphic units
- Unit 1: Highly weathered tuffaceous bedrock exposed in FW.
- Units 2-5: Sandy fan gravels, several prominent buried soil horizons.

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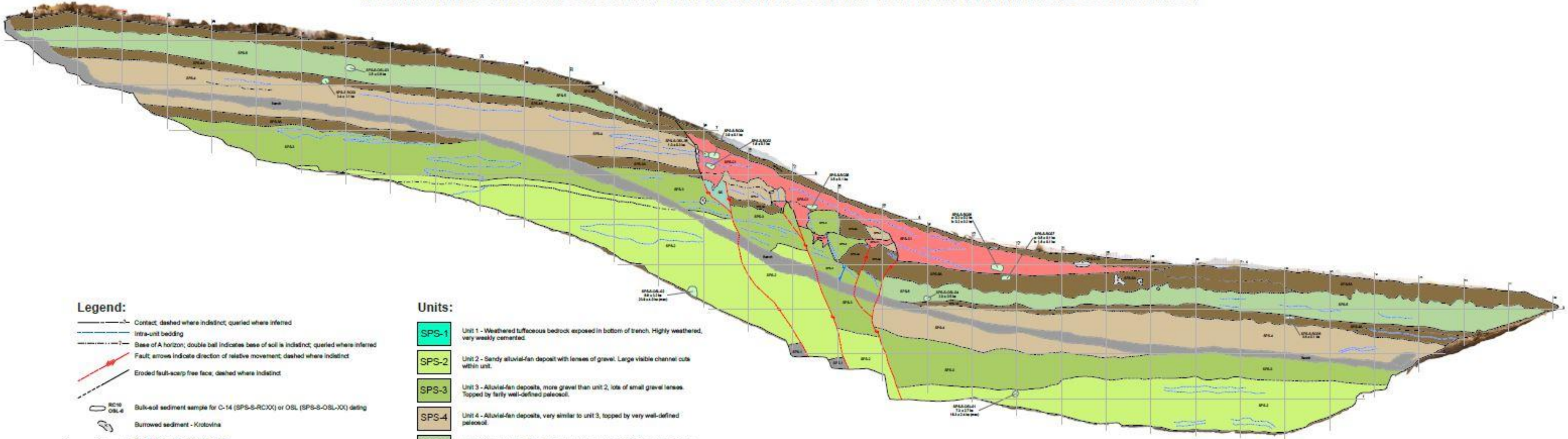
Plate 1
Utah Geological Survey Contract Deliverable
Paleoseismic Investigation of the Levan and Fayette Segments of the Wasatch Fault Zone, Juab and Sanpete Counties, Utah

STRATIGRAPHIC AND STRUCTURAL RELATIONS IN THE SOUTH WALL OF THE SKINNER PEAKS SOUTH TRENCH



Legend:

- Contact; dashed where indistinct; queried where inferred
- Intra-unit bedding
- Base of A horizon; double ball indicates base of soil is indistinct; queried where inferred
- Fault; arrows indicate direction of relative movement; dashed where indistinct
- Eroded fault-scarp free face; dashed where indistinct
- RC10 OSL-6 Bulk-soil sediment sample for C-14 (SPS-S-RCXX) or OSL (SPS-S-OSL-XX) dating
- Burrowed sediment - Krotovina
- 0 0.5 m 1 m Trench log scale - 1x1-meter grid

Units:

SPS-1	Unit 1 - Weathered tuffaceous bedrock exposed in bottom of trench. Highly weathered, very weakly cemented.
SPS-2	Unit 2 - Sandy alluvial-fan deposit with lenses of gravel. Large visible channel cuts within unit.
SPS-3	Unit 3 - Alluvial-fan deposits, more gravel than unit 2, lots of small gravel lenses. Topped by farily well-defined paleosoil.
SPS-4	Unit 4 - Alluvial-fan deposits, very similar to unit 3, topped by very well-defined paleosoil.
SPS-5	Unit 5 - Youngest alluvial-fan deposit, topped by modern soil. Strong soil pediments from modern soil.
SPS-C1	Colluvial Wedge 1 - Deposit associated with event P1, bottom contact overlies block deformation zone in trench.
A	Soil Horizons
SS	Sheared Sediment

us bedrock exposed in bottom of trench. Highly weathered,

leposit with lenses of gravel. Large visible channel cuts

s, more gravel than unit 2, lots of small gravel lenses.
d paleosoil.

s, very similar to unit 3, topped by very well-defined

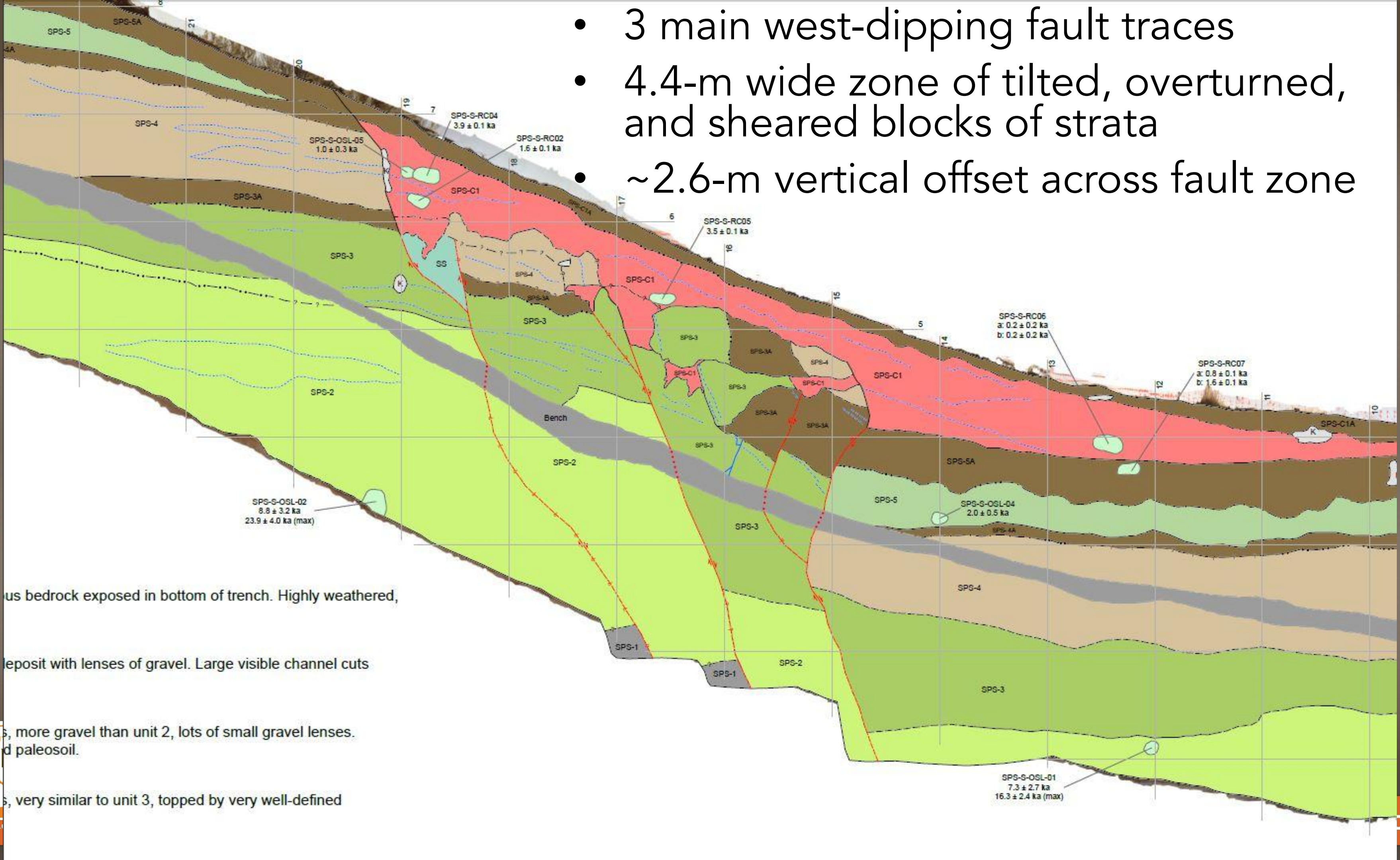
Units:

SPS-1

SPS-2

SPS-3

- 3 main west-dipping fault traces
- 4.4-m wide zone of tilted, overturned, and sheared blocks of strata
- ~2.6-m vertical offset across fault zone



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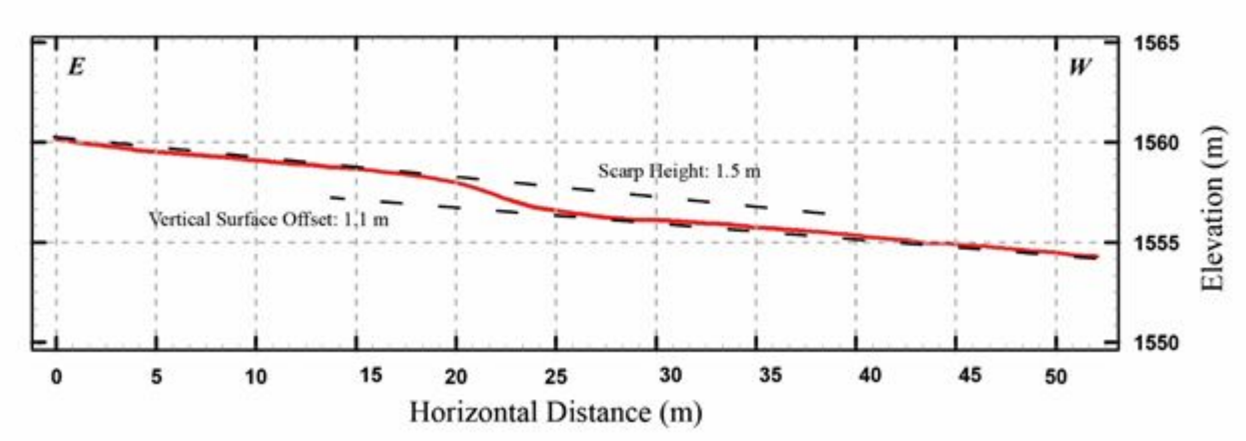
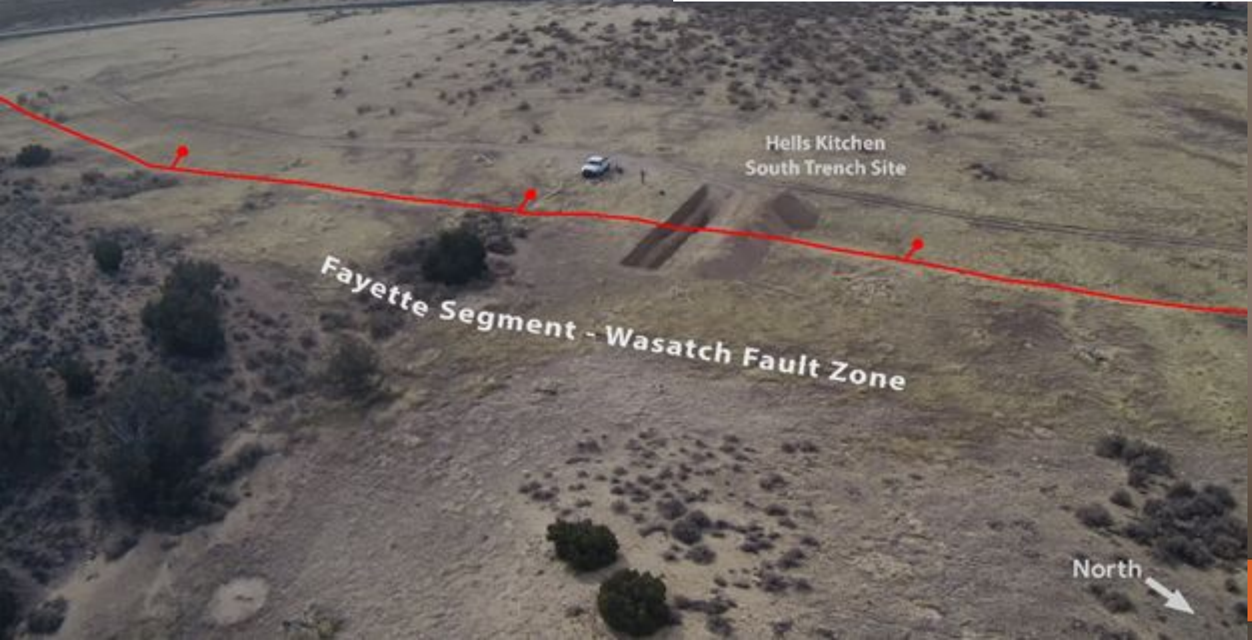
s, more gravel than unit 2, lots of small gravel lenses.
d paleosoil.

s, very similar to unit 3, topped by very well-defined

Hells Kitchen South Site

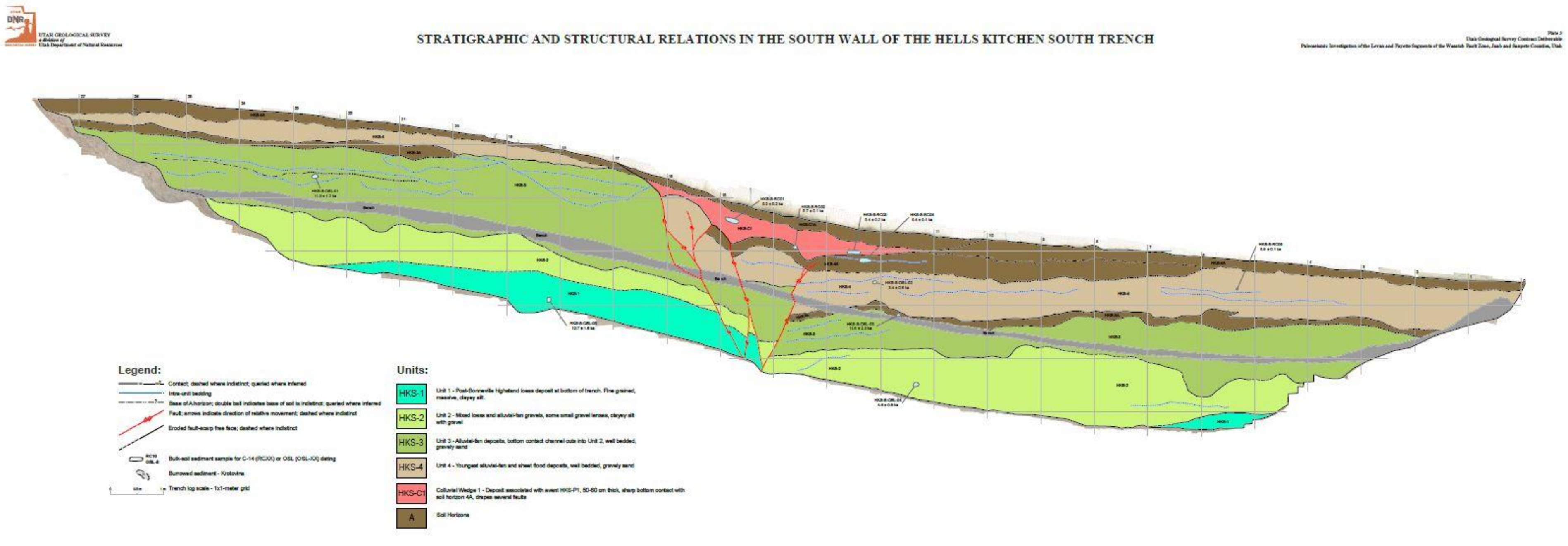
- Mapped 4 stratigraphic units
- Unit 1: post-Bonneville highstand loess
- Units 2-4: Coarse fan deposits





Hells Kitchen South Site

- 1-2 meter scarp
- Carbonate-derived fan material
- Tertiary bedrock (North Horn, Flagstaff, Colton, Green River formations), Cretaceous Indianola Group



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STRATIGRAPHIC AND STRUCTURAL RELATIONS IN THE SOUTH WALL OF THE HELLS KITCHEN SOUTH TRENCH

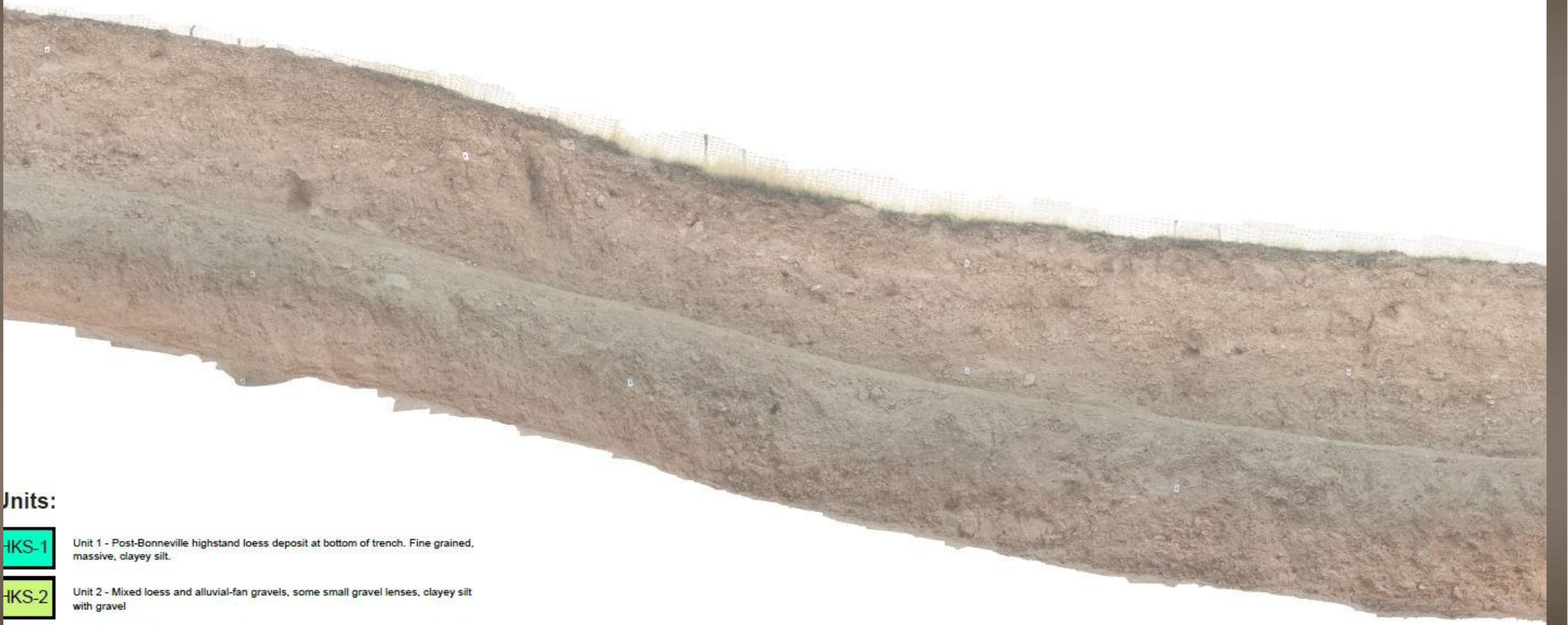
Plate 3
Utah Geological Survey Contract Deliverable
Paleoseismic Investigation of the Levan and Fayette Segments of the Wasatch Fault Zone, Juab and Sanpete Counties, Utah

Legend:

Contact; dashed where indistinct; queried where inferred
Intra-unit bedding
Base of A horizon; double ball indicates base of soil is indistinct; queried where inferred
Fault; arrows indicate direction of relative movement; dashed where indistinct
Eroded fault-scarp free face; dashed where indistinct
RC10 OSL-6 Bulk-soil sediment sample for C-14 (RCXX) or OSL (OSL-XX) dating
Burrowed sediment - Krotovina
Trench log scale - 1x1-meter grid

Units:

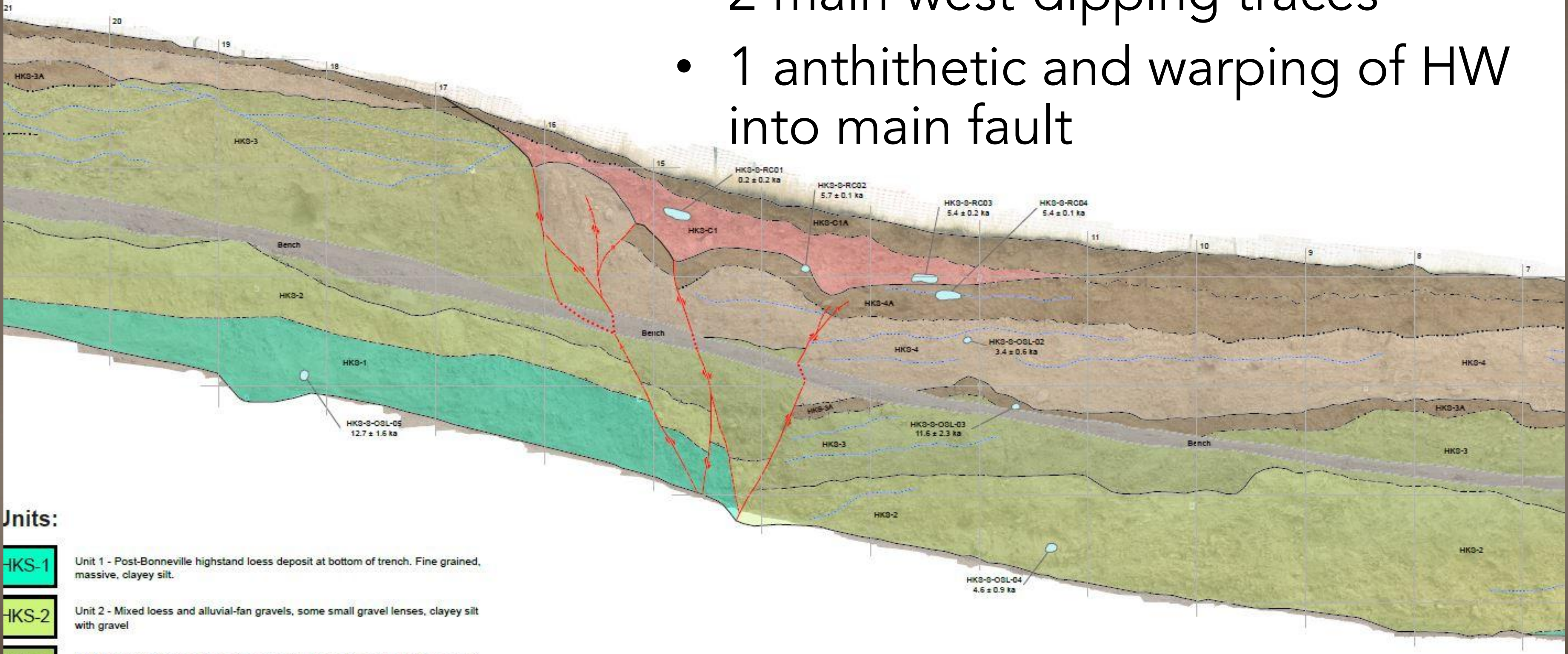
HKS-1	Unit 1 - Post-Bonneville highstand loess deposit at bottom of trench. Fine grained, massive, clayey silt.
HKS-2	Unit 2 - Mixed loess and alluvial-fan gravels, some small gravel lenses, clayey silt with gravel
HKS-3	Unit 3 - Alluvial-fan deposits, bottom contact channel cuts into Unit 2, well bedded, gravely sand
HKS-4	Unit 4 - Youngest alluvial-fan and sheet flood deposits, well bedded, gravely sand
HKS-C1	Colluvial Wedge 1 - Deposit associated with event HKS-P1, 50-60 cm thick, sharp bottom contact with soil horizon 4A, drapes several faults
A	Soil Horizons



Units:

HKS-1	Unit 1 - Post-Bonneville highstand loess deposit at bottom of trench. Fine grained, massive, clayey silt.
HKS-2	Unit 2 - Mixed loess and alluvial-fan gravels, some small gravel lenses, clayey silt with gravel
HKS-3	Unit 3 - Alluvial-fan deposits, bottom contact channel cuts into Unit 2, well bedded, gravely sand
HKS-4	Unit 4 - Youngest alluvial-fan and sheet flood deposits, well bedded, gravely sand
HKS C1	Colluvial Wedge 1 - Deposit associated with event HKS-P1, 50-60 cm thick, sharp bottom contact with

- 1-2-m wide zone of deformation
- 2 main west-dipping traces
- 1 anthithetic and warping of HW into main fault



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HKS-C1	Colluvial Wedge 1 - Deposit associated with event HKS-P1, 50-60 cm thick, sharp bottom contact with soil horizon 4A, drapes several faults

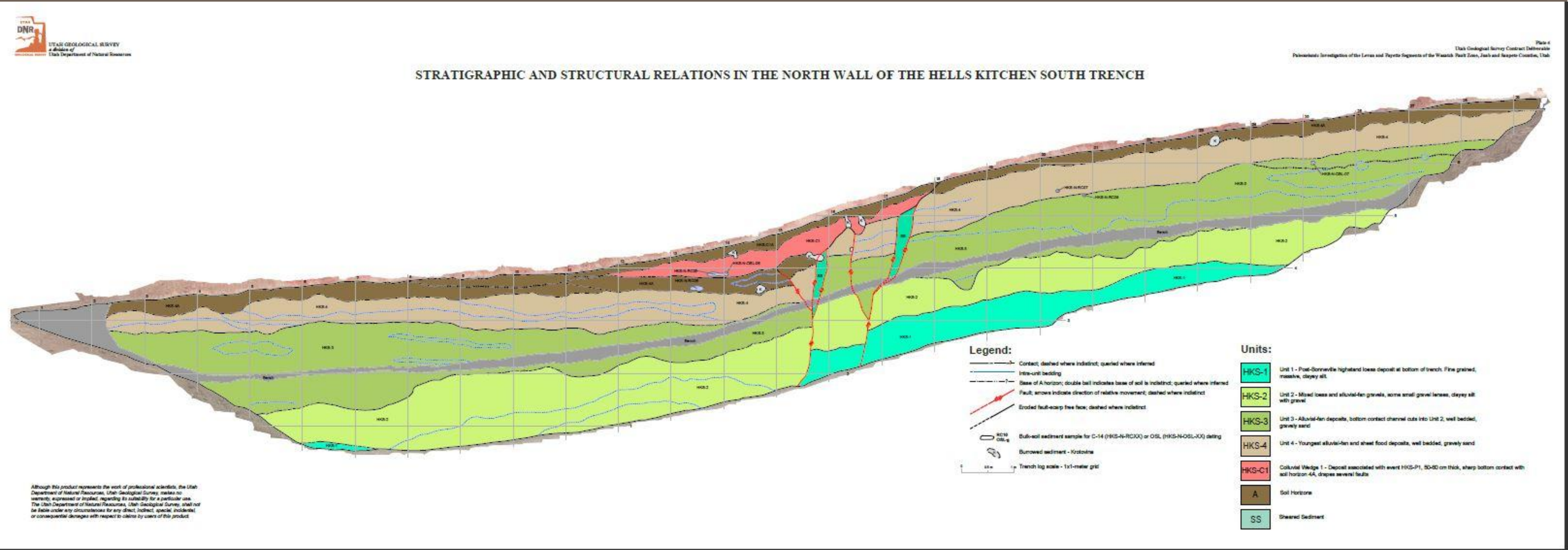

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Plate 4
Utah Geological Survey Contract Deliverable
Paleoseismic Investigation of the Levan and Fayette Segments of the Wasatch Fault Zone, Juab and Sanpete Counties, Utah

STRATIGRAPHIC AND STRUCTURAL RELATIONS IN THE NORTH WALL OF THE HELLS KITCHEN SOUTH TRENCH

Legend:

Contact; dashed where indistinct; queried where inferred
Intra-unit bedding
Base of A horizon; double ball indicates base of soil is indistinct; queried where inferred
Fault; arrows indicate direction of relative movement; dashed where indistinct
Eroded fault-scarp free face; dashed where indistinct
RC10 OSL-9 Bulk-soil sediment sample for C-14 (HKS-N-RCXX) or OSL (HKS-N-OSL-XX) dating
Burrowed sediment - Krotovina
Trench log scale - 1x1-meter grid

Units:

HKS-1	Unit 1 - Post-Bonneville highstand loess deposit at bottom of trench. Fine grained, massive, clayey silt.
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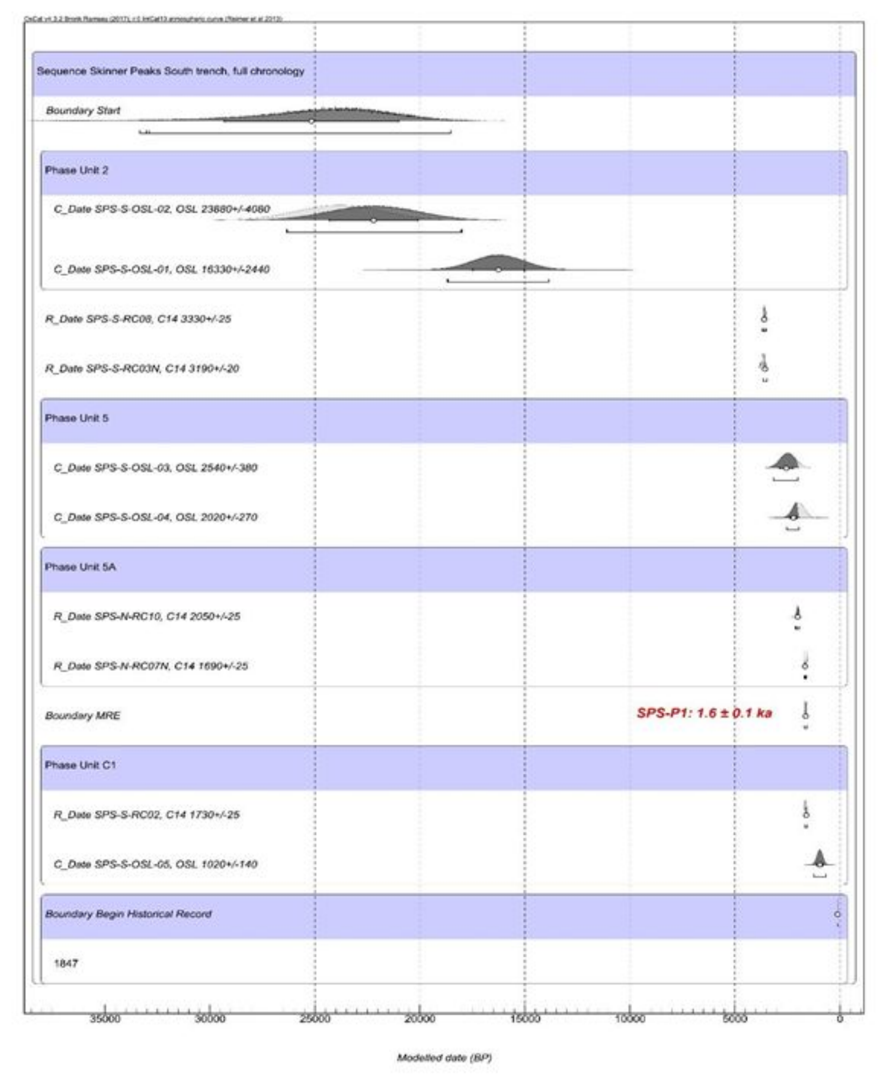
HKS-3	Unit 3 - Alluvial-fan deposits, bottom contact channel cuts into Unit 2, well bedded, gravely sand
HKS-4	Unit 4 - Youngest alluvial-fan and sheet flood deposits, well bedded, gravely sand
HKS-C1	Colluvial Wedge 1 - Deposit associated with event HKS-P1, 50-60 cm thick, sharp bottom contact with soil horizon 4A, drapes several faults
A	Soil Horizons
SS	Sheared Sediment

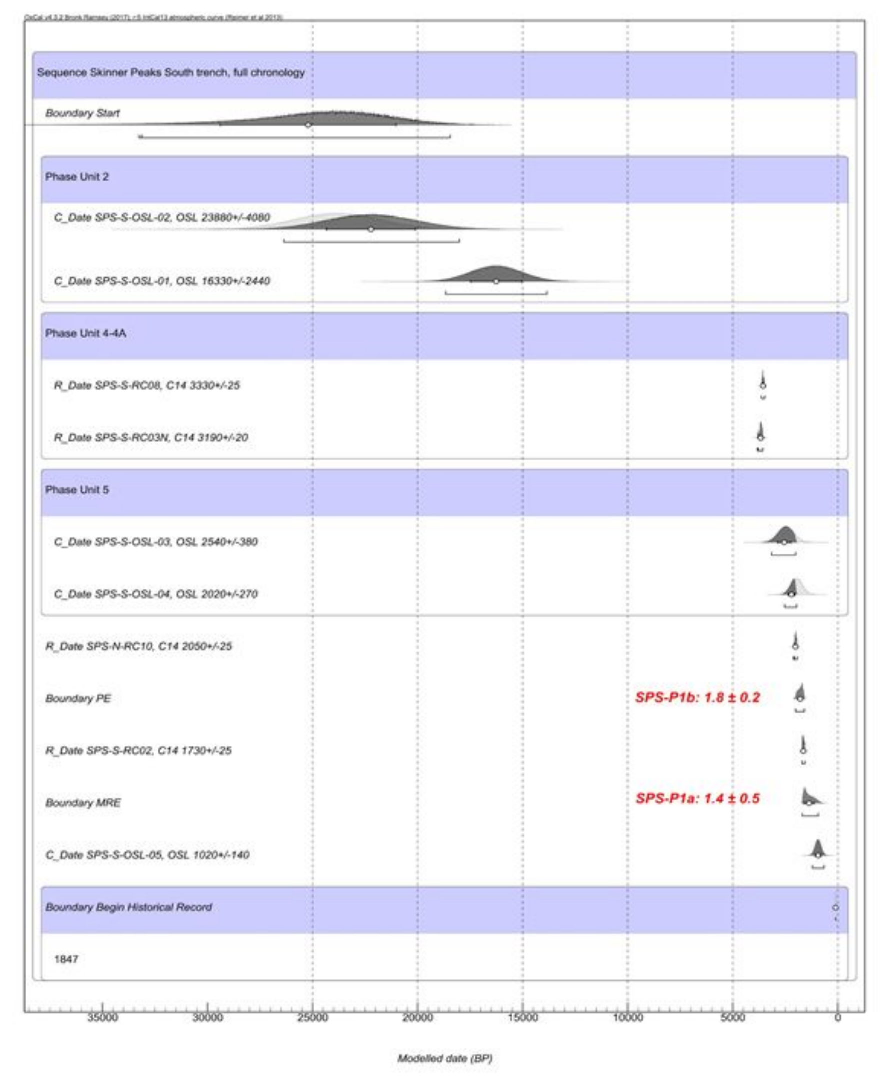
Sampling Strategy

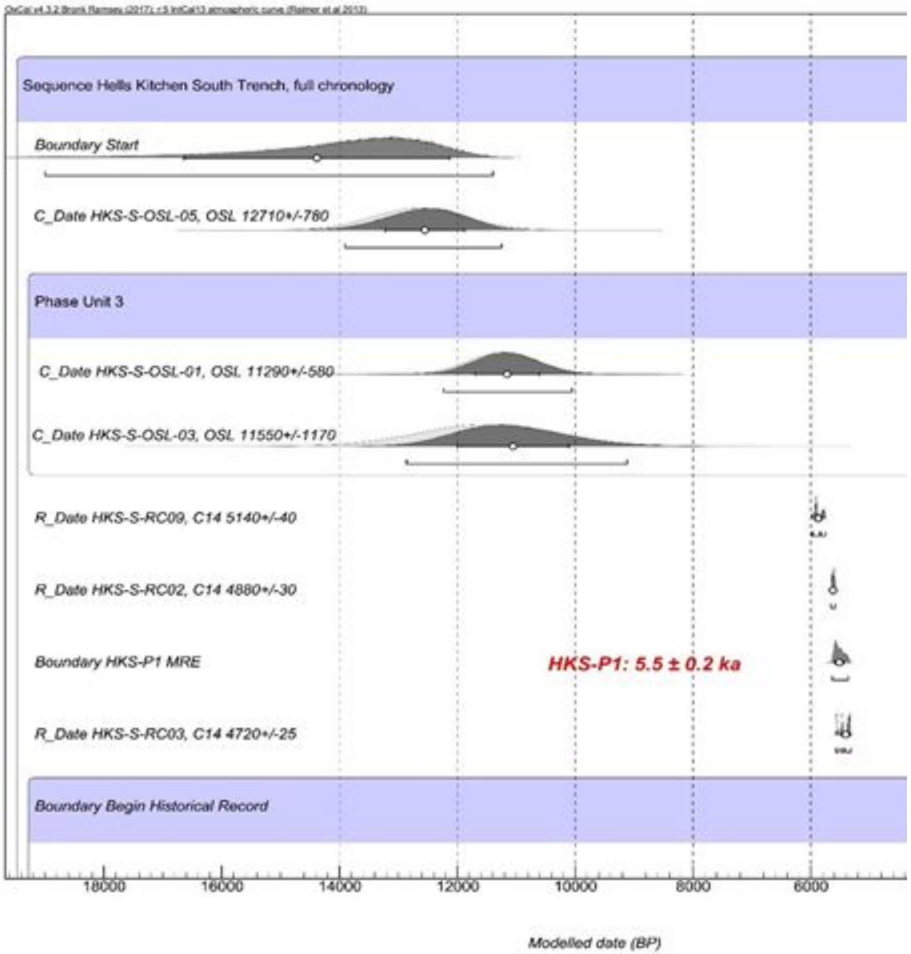
- SPS - 12 RC, 7 OSL
- HKS - 5 RC, 5 OSL

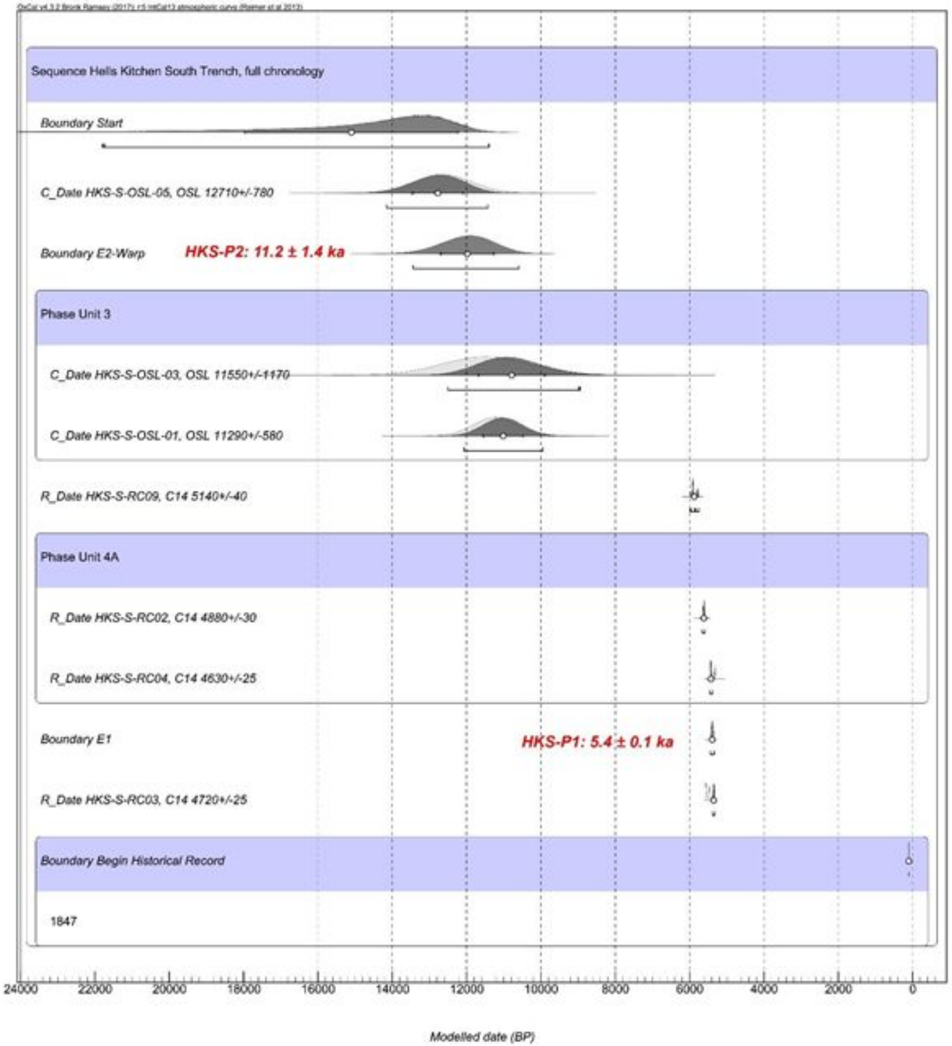
RC samples processed by PaleoResearch Inst., Golden, CO and analyzed by NOSAMS Lab, Woods Hole, MA

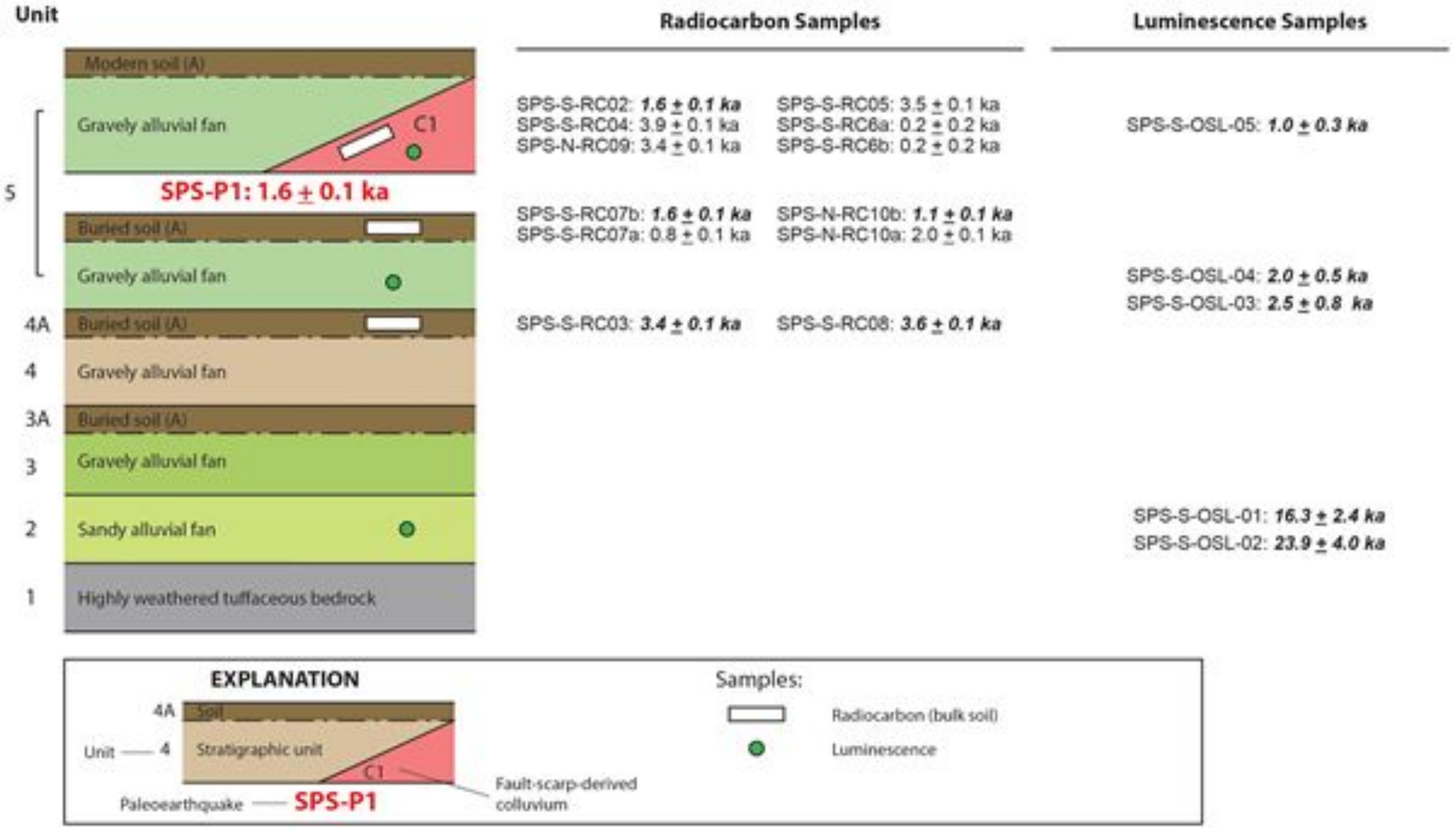
OSL samples processed/analyzed by USGS lab, Denver, CO


OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
Sequence Skinner Peaks South trench, full chronology
Boundary Start
Phase Unit 2
C_Date SPS-S-OSL-02, OSL 23880+/-4080
C_Date SPS-S-OSL-01, OSL 16330+/-2440
R_Date SPS-S-RC08, C14 3330+/-25
R_Date SPS-S-RC03N, C14 3190+/-20
Phase Unit 5
C_Date SPS-S-OSL-03, OSL 2540+/-380
C_Date SPS-S-OSL-04, OSL 2020+/-270
Phase Unit 5A
R_Date SPS-N-RC10, C14 2050+/-25
R_Date SPS-N-RC07N, C14 1690+/-25
Boundary MRE
SPS-P1: 1.6 ± 0.1 ka
Phase Unit C1
R_Date SPS-S-RC02, C14 1730+/-25
C_Date SPS-S-OSL-05, OSL 1020+/-140
Boundary Begin Historical Record
1847
35000
30000
25000
20000
15000
10000
5000
0
Modelled date (BP)


OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
Sequence Skinner Peaks South trench, full chronology
Boundary Start
Phase Unit 2
C_Date SPS-S-OSL-02, OSL 23880+/-4080
C_Date SPS-S-OSL-01, OSL 16330+/-2440
Phase Unit 4-4A
R_Date SPS-S-RC08, C14 3330+/-25
R_Date SPS-S-RC03N, C14 3190+/-20
Phase Unit 5
C_Date SPS-S-OSL-03, OSL 2540+/-380
C_Date SPS-S-OSL-04, OSL 2020+/-270
R_Date SPS-N-RC10, C14 2050+/-25
Boundary PE
SPS-P1b: 1.8 ± 0.2
R_Date SPS-S-RC02, C14 1730+/-25
Boundary MRE
SPS-P1a: 1.4 ± 0.5
C_Date SPS-S-OSL-05, OSL 1020+/-140
Boundary Begin Historical Record
1847
35000
30000
25000
20000
15000
10000
5000
0
Modelled date (BP)


OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
Sequence Hells Kitchen South Trench, full chronology
Boundary Start
C_Date HKS-S-OSL-05, OSL 12710+/-780
Phase Unit 3
C_Date HKS-S-OSL-01, OSL 11290+/-580
C_Date HKS-S-OSL-03, OSL 11550+/-1170
R_Date HKS-S-RC09, C14 5140+/-40
R_Date HKS-S-RC02, C14 4880+/-30
Boundary HKS-P1 MRE
HKS-P1: 5.5 ± 0.2 ka
R_Date HKS-S-RC03, C14 4720+/-25
Boundary Begin Historical Record
18000
16000
14000
12000
10000
8000
6000
Modelled date (BP)


OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
Sequence Hells Kitchen South Trench, full chronology
Boundary Start
C_Date HKS-S-OSL-05, OSL 12710+/-780
Boundary E2-Warp
HKS-P2: 11.2 ± 1.4 ka
Phase Unit 3
C_Date HKS-S-OSL-03, OSL 11550+/-1170
C_Date HKS-S-OSL-01, OSL 11290+/-580
R_Date HKS-S-RC09, C14 5140+/-40
Phase Unit 4A
R_Date HKS-S-RC02, C14 4880+/-30
R_Date HKS-S-RC04, C14 4630+/-25
Boundary E1
HKS-P1: 5.4 ± 0.1 ka
R_Date HKS-S-RC03, C14 4720+/-25
Boundary Begin Historical Record
1847
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Modelled date (BP)



Radiocarbon Samples

SPS-S-RC02: ***1.6 ± 0.1 ka***
SPS-S-RC04: 3.9 ± 0.1 ka
SPS-N-RC09: 3.4 ± 0.1 ka
SPS-S-RC05: 3.5 ± 0.1 ka
SPS-S-RC6a: 0.2 ± 0.2 ka
SPS-S-RC6b: 0.2 ± 0.2 ka

SPS-S-RC07b: ***1.6 ± 0.1 ka***
SPS-S-RC07a: 0.8 ± 0.1 ka
SPS-N-RC10b: ***1.1 ± 0.1 ka***
SPS-N-RC10a: 2.0 ± 0.1 ka

SPS-S-RC03: ***3.4 ± 0.1 ka***
SPS-S-RC08: ***3.6 ± 0.1 ka***

Luminescence Samples

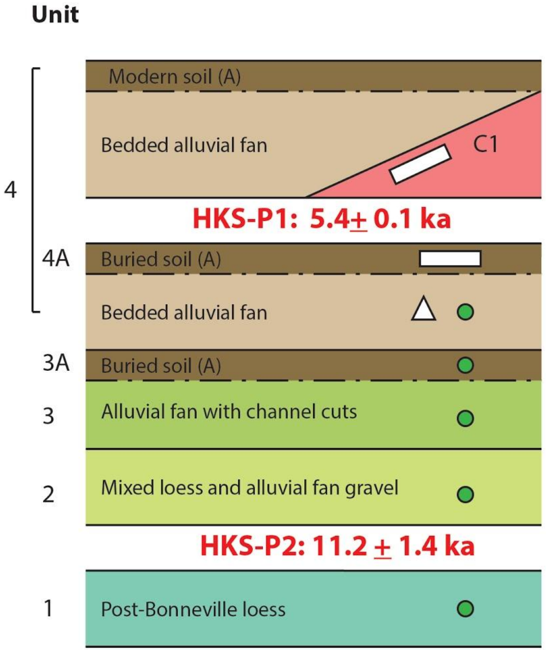
SPS-S-OSL-05: ***1.0 ± 0.3 ka***

SPS-S-OSL-04: ***2.0 ± 0.5 ka***
SPS-S-OSL-03: ***2.5 ± 0.8 ka***

SPS-S-OSL-01: ***16.3 ± 2.4 ka***
SPS-S-OSL-02: ***23.9 ± 4.0 ka***

EXPLANATION

Samples:
▭ Radiocarbon (bulk soil)
● Luminescence



Radiocarbon Samples

HKS-S-RC03: ***5.4 ± 0.2 ka*** HKS-S-RC01: 0.2 ± 0.2 ka

HKS-S-RC04: ***5.4 ± 0.1 ka*** HKS-S-RC02: ***5.7 ± 0.1 ka***

HKS-S-RC09: ***5.9 ± 0.1 ka***

Luminescence Samples

HKS-S-OSL-02: 3.4 ± 0.6 ka

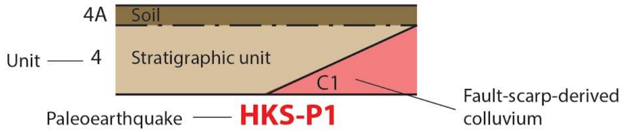
HKS-S-OSL-03: ***11.6 ± 2.3 ka***

HKS-S-OSL-01: ***11.3 ± 1.2 ka***

HKS-S-OSL-04: 4.6 ± 0.9 ka

HKS-S-OSL-05: ***12.7 ± 1.6 ka***

EXPLANATION



Samples:

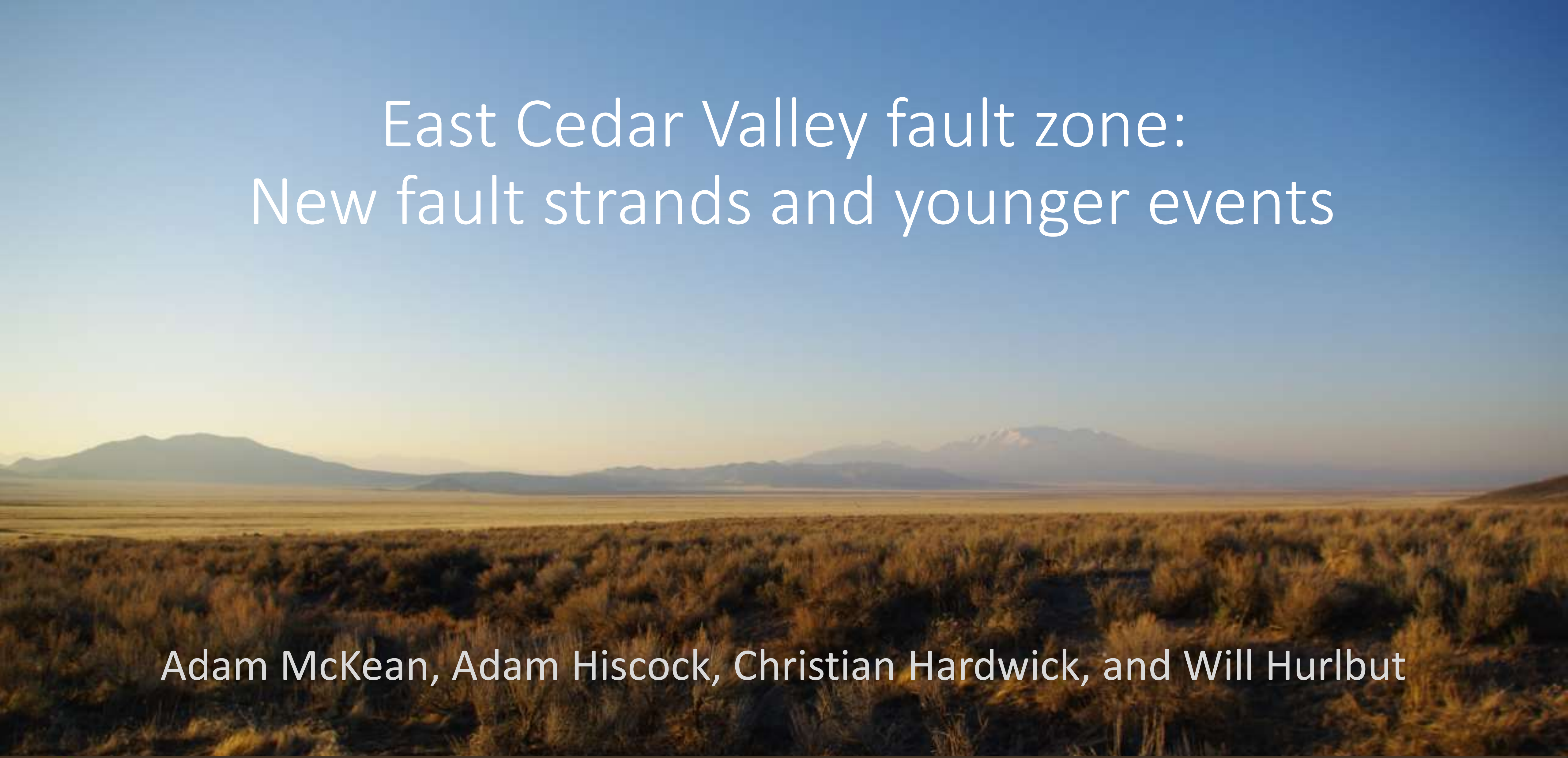
▭ Radiocarbon (bulk soil)

△ Radiocarbon (macrocharcoal)

● Luminescence

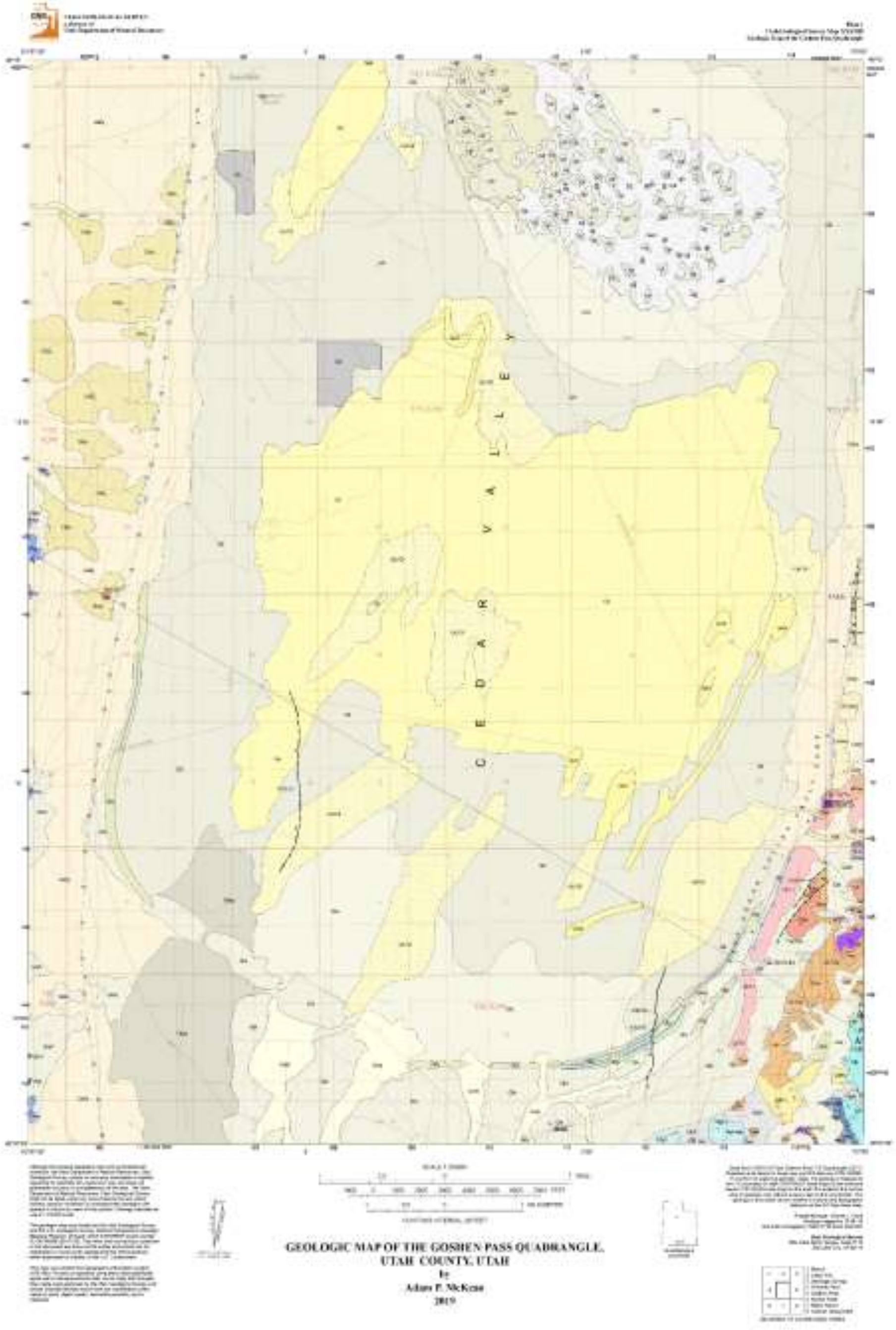
Summary & Conclusions

- LS single-event scarp
  - MRE 1.6 ± 0.1 ka; PE >16.3 ± 2.4 ka
  - Recurrence 14.7 ± 2.5 ky
  - Slip Rate 0.20-0.28 mm/yr
- FS HKS single-event scarp; secondary evidence for scarp forming PE
  - MRE 5.4 ± 0.1 ka; PE 11.2 ± 1.4 ka
  - Recurrence 4.6 to 7.3 ky
  - Slip Rate 0.17-0.33 mm/yr
- Trenched scarps likely Basin and Range extension rather than salt tectonics
  - Moab area faults (Guerrero and others, 2015)
  - High slip rates, short recurrence times
  - High per event displacements for fault length

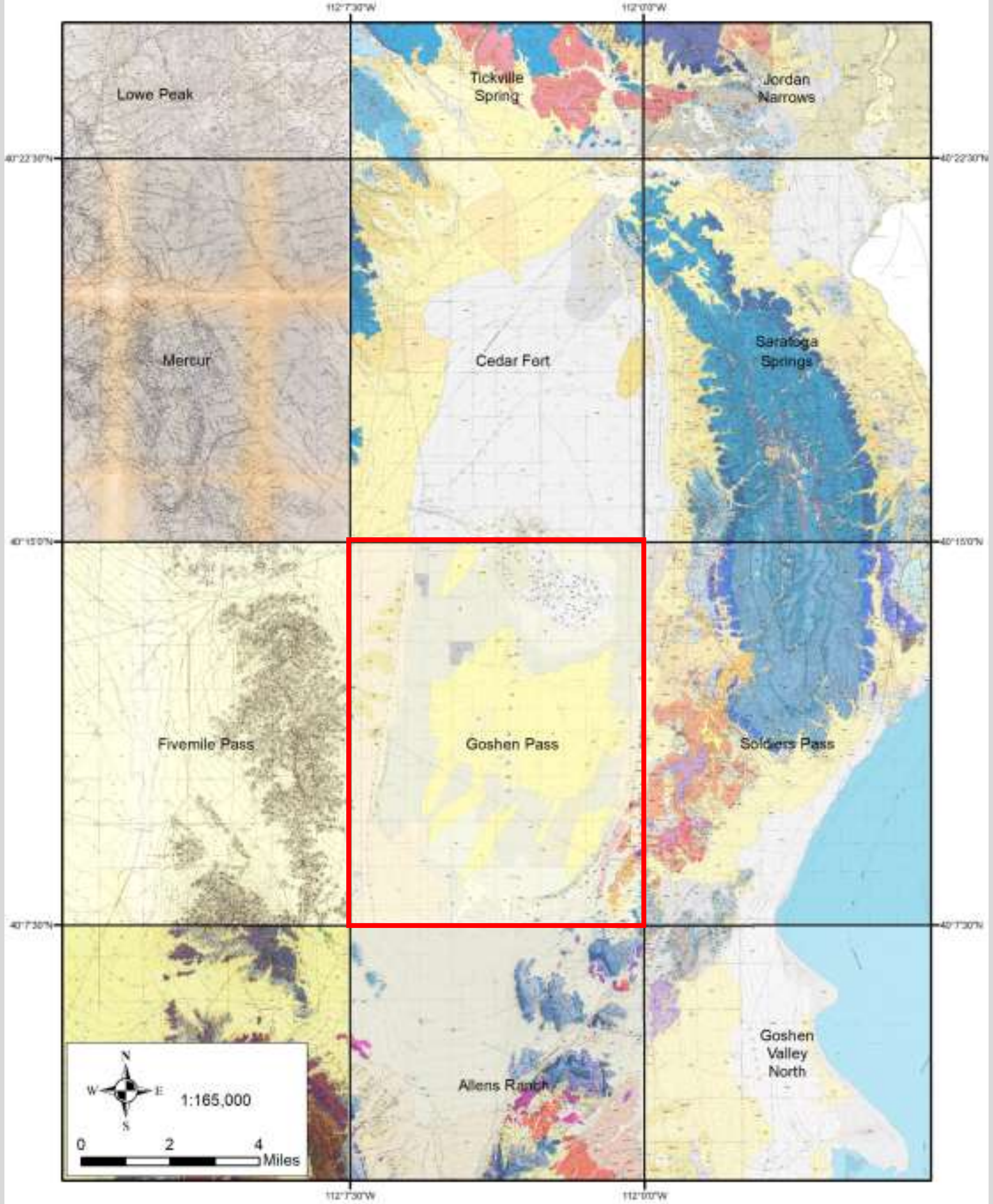


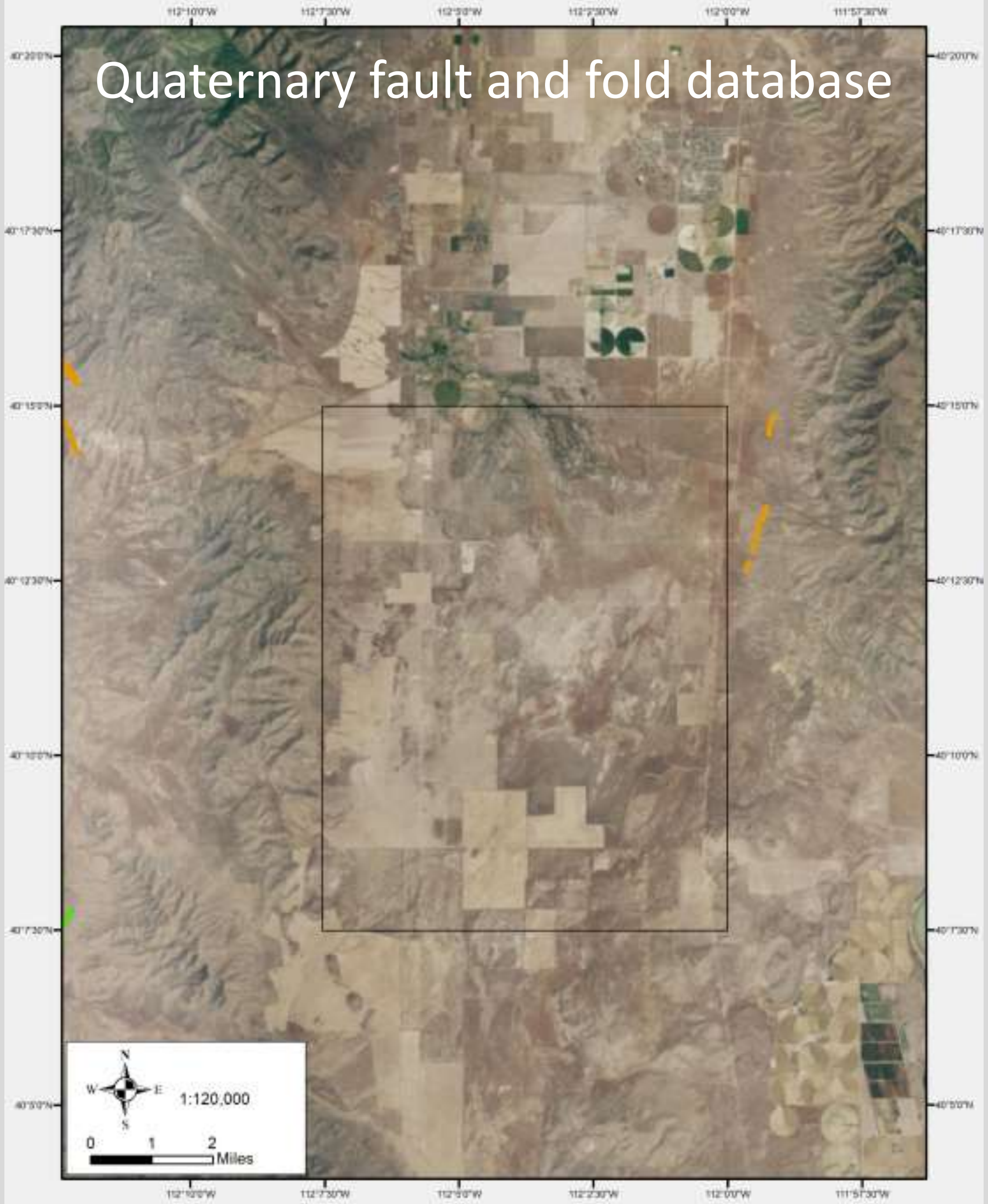
East Cedar Valley fault zone: New fault strands and younger events

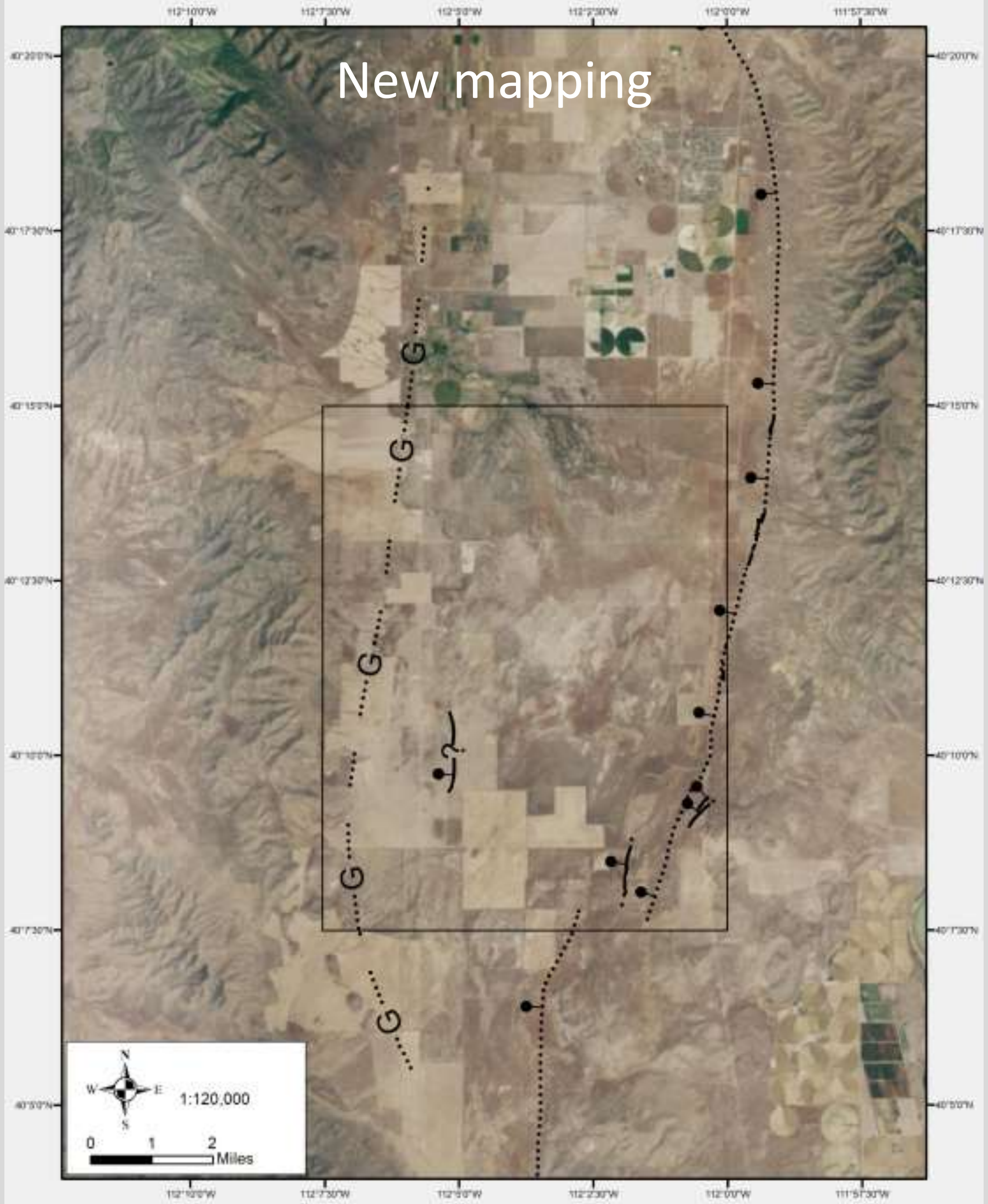
Adam McKean, Adam Hiscock, Christian Hardwick, and Will Hurlbut



GEOLOGIC MAP OF THE GOSHEN PASS QUADRANGLE,
UTAH COUNTY, UTAH
by
Adam P. McKean
2019

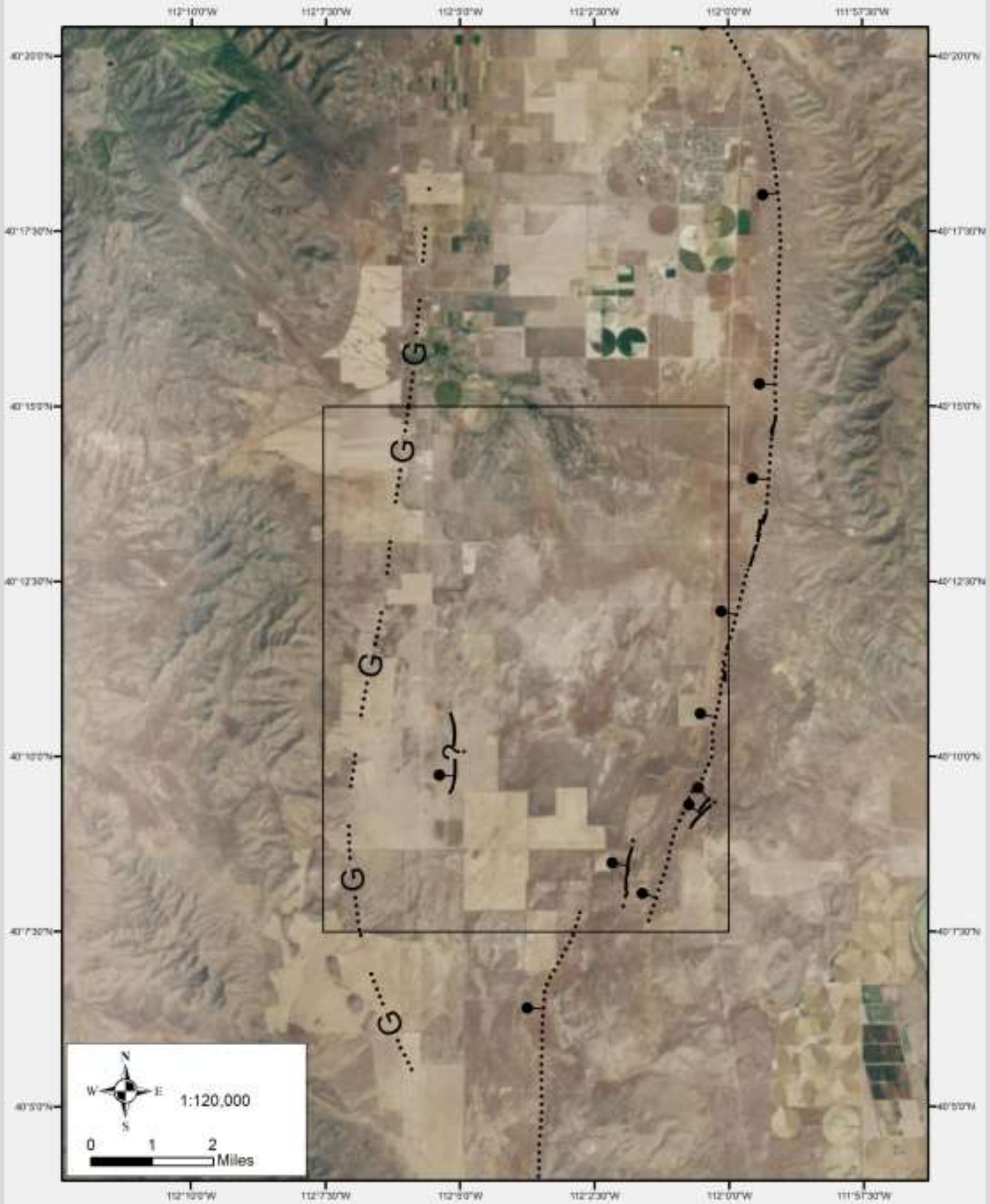



Quaternary fault and fold database

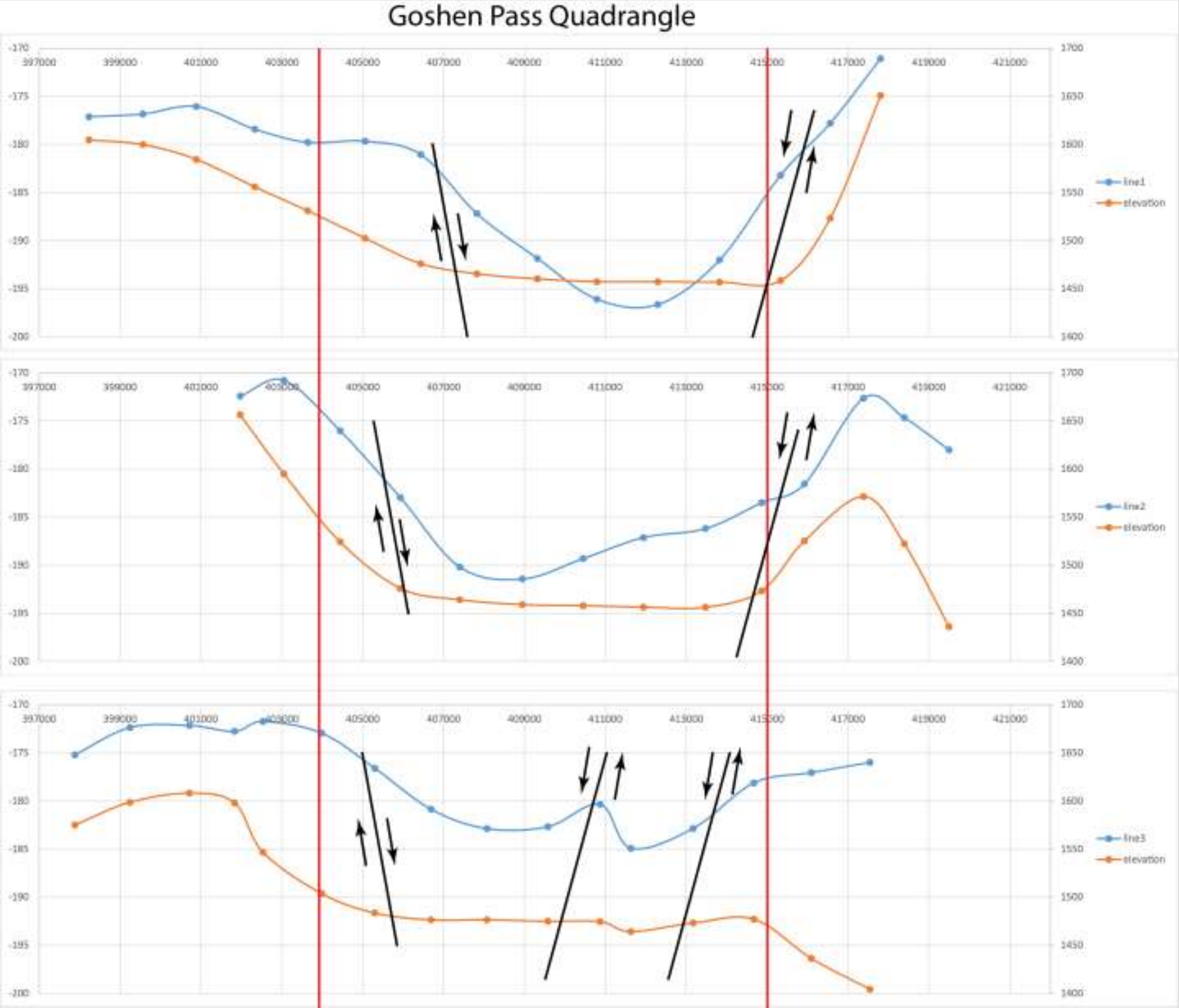

New mapping

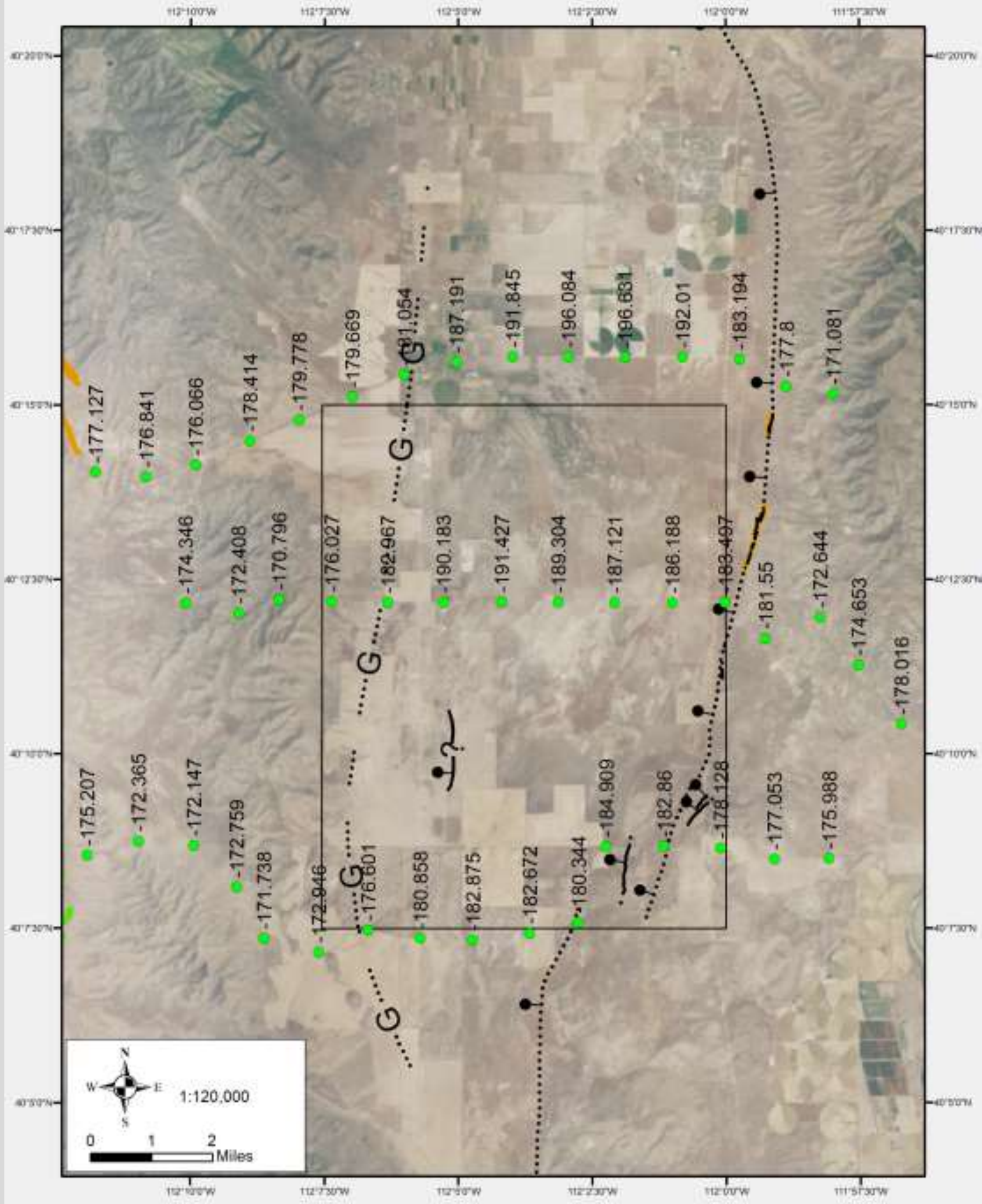
Outline

- Review evidence for East Cedar Valley fault zone and western fault
- Introduce Cedar Valley Lake
- Review new fault strands
- Conclusions

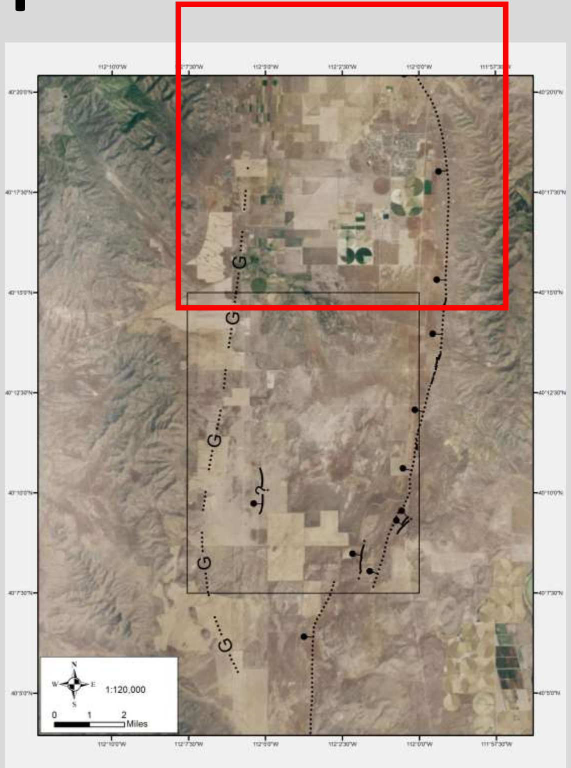


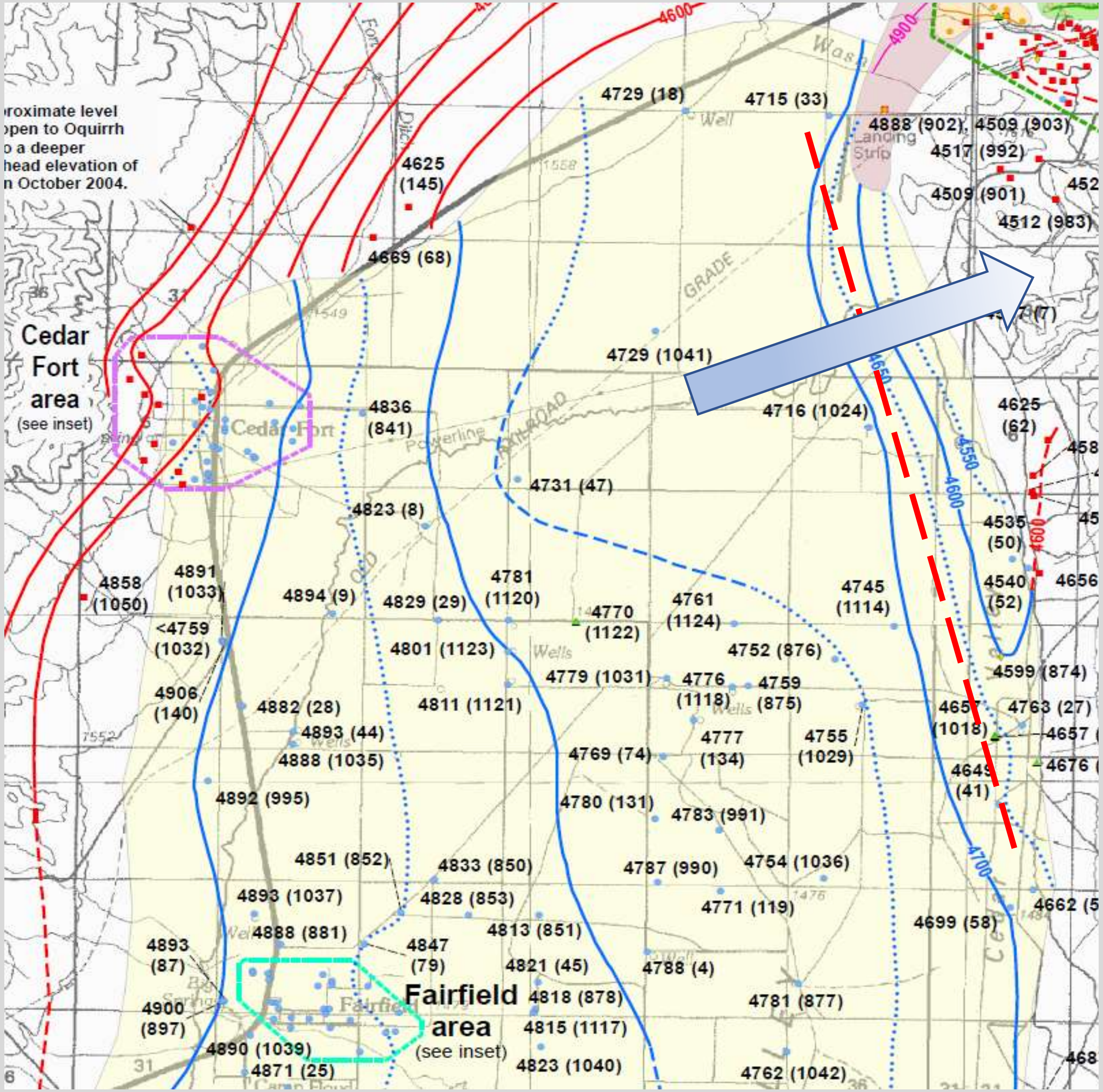
New Gravity Data





Groundwater Evidence For Faulting





Potentiometric Surface Map of Cedar Valley Study Area, March 2005 (Jordan and Sabbah, 2012)

North-south trending normal fault on the eastern margin of the valley is a conduit for fault-parallel groundwater flow and a barrier to groundwater flow across the fault.

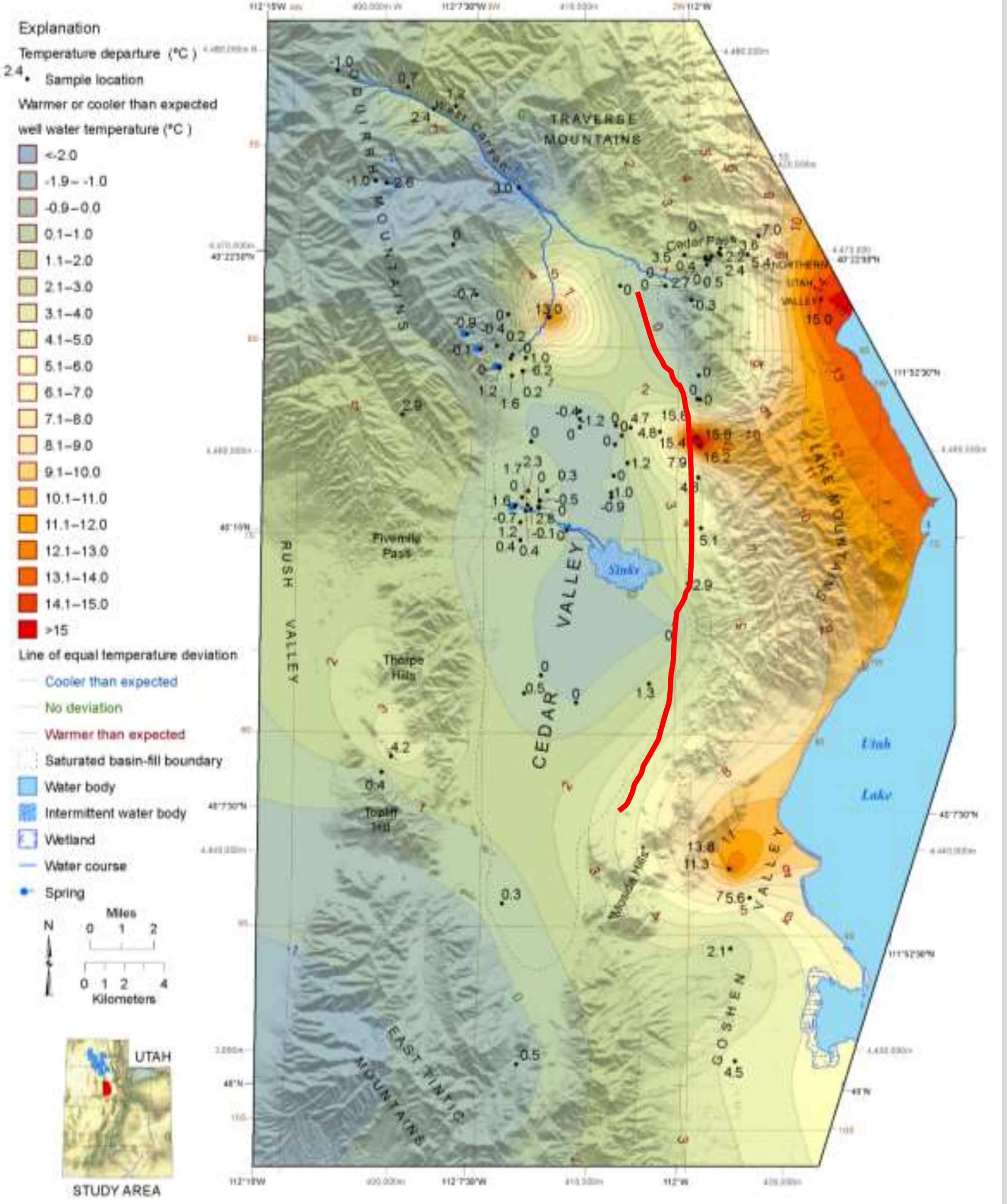
Jordan and Sabbah, 2012

Groundwater Evidence For Faulting

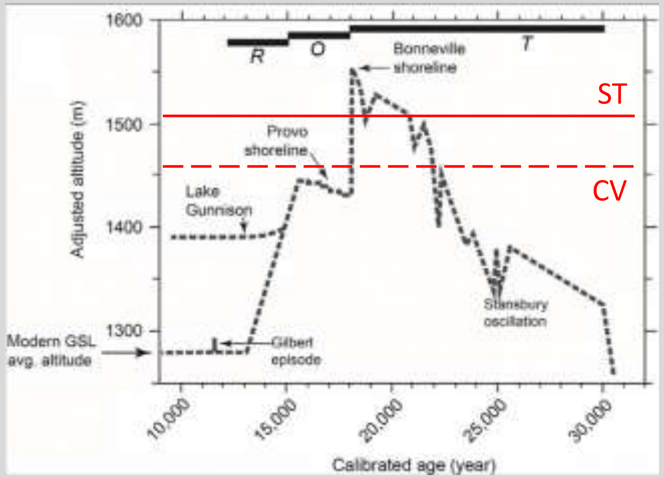
Warm groundwater found along concealed East Cedar Valley fault zone, likely circulating up from depth along the fault damage zone.

“The area east of Eagle Mountain town center has the most elevated groundwater temperature, having four wells less than 540 feet (165 m) deep in which water temperatures range from 23.5 to 29.1°C (74.3–84.4°F).”

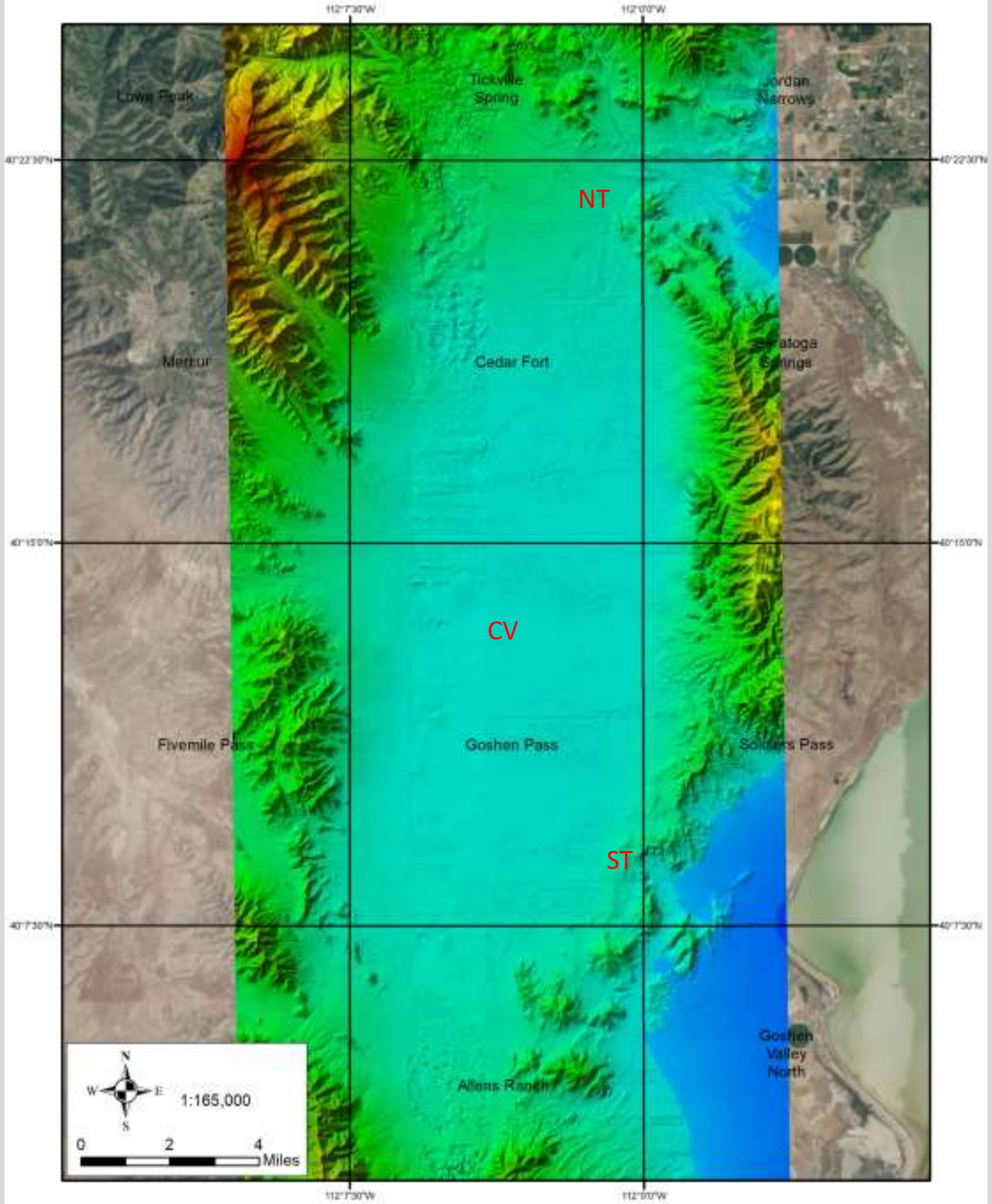
Jordan and Sabbah, 2012



Cedar Valley Lake



Oviatt and Jewell, 2016



5140 ft. (1567 m) Lake Bonneville Highstand

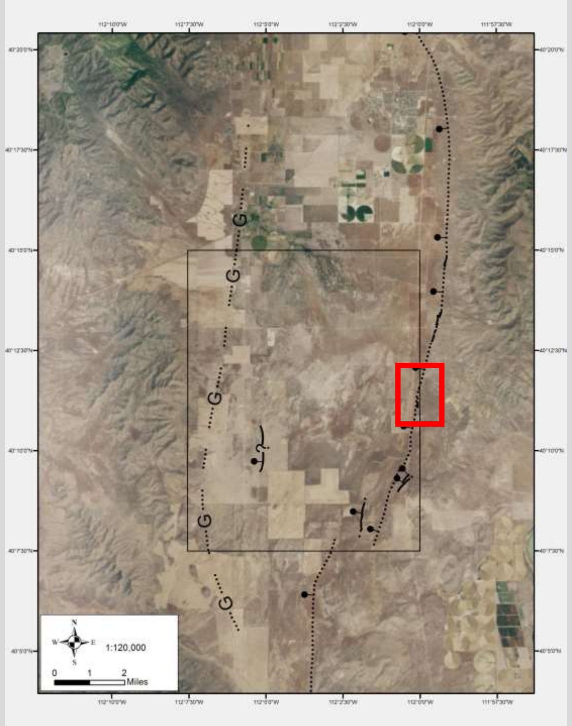
Bonneville Flood

- 4985 ft. (1519 m) Cedar Valley North Threshold (NT) (Cedar Pass)
- 4950 ft. (1509 m) Cedar Valley South Threshold (ST) (near Goshen Pass)
- 4940 ft. (1506 m) Cedar Valley South Threshold (ST) (near Goshen Pass)

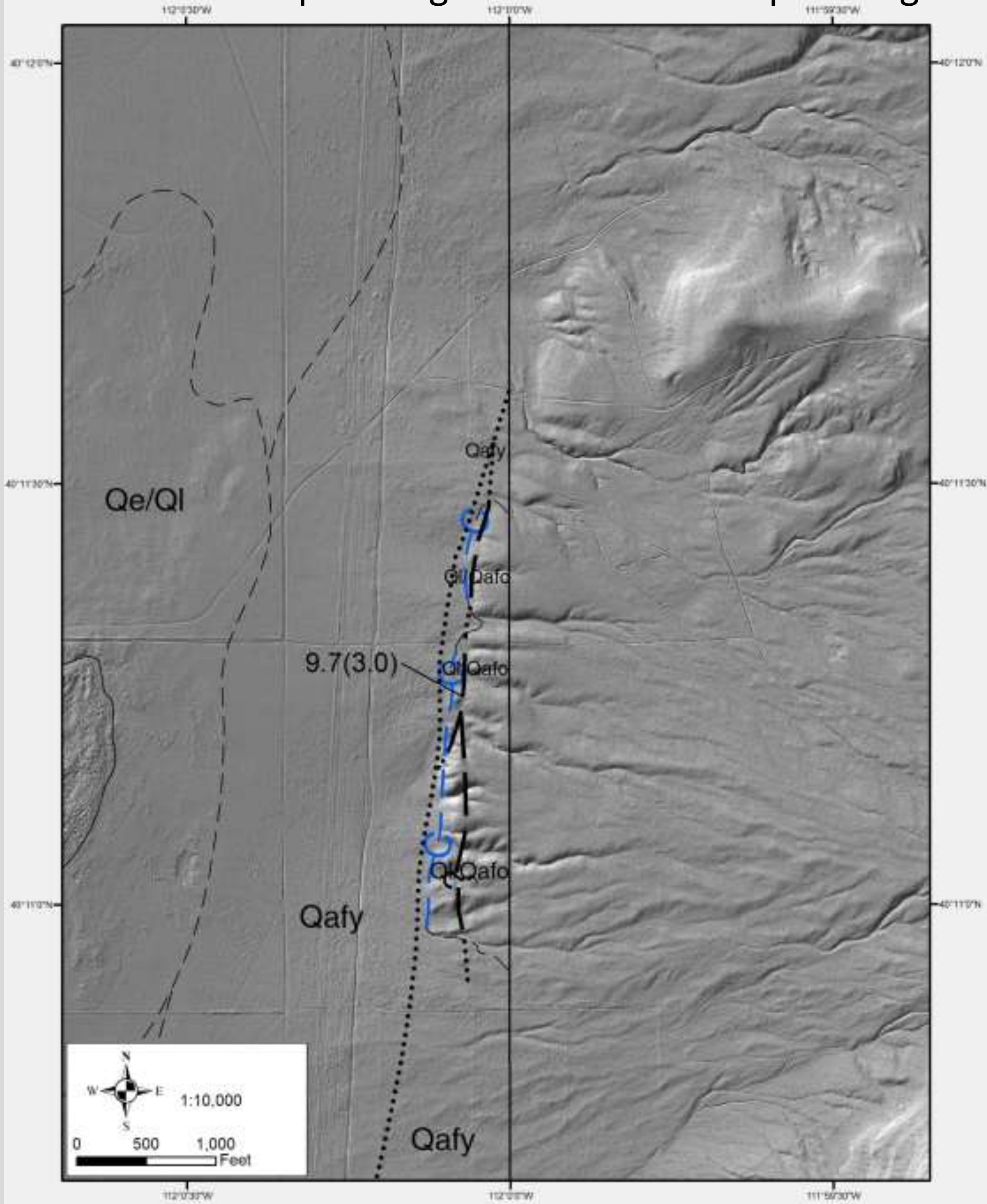
4900 ft. (1494 m) Cedar Valley Lake (CV)

4775 ft. (1455 m) Provo Shoreline

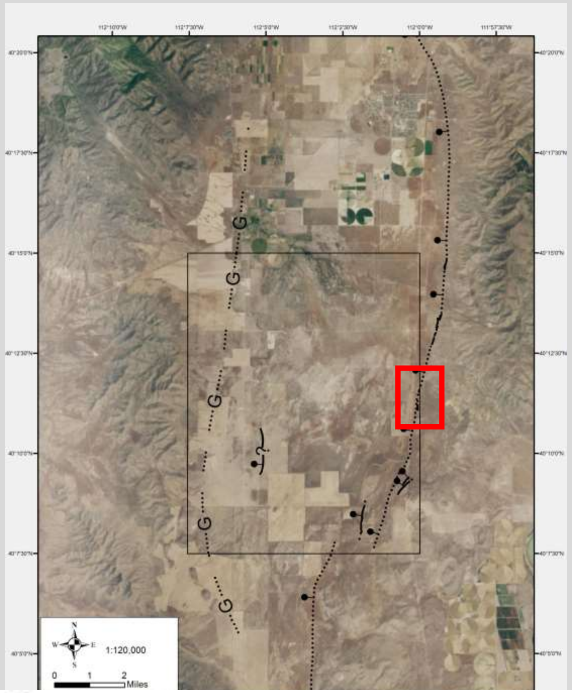
Offset of pre-Bonneville Deposits

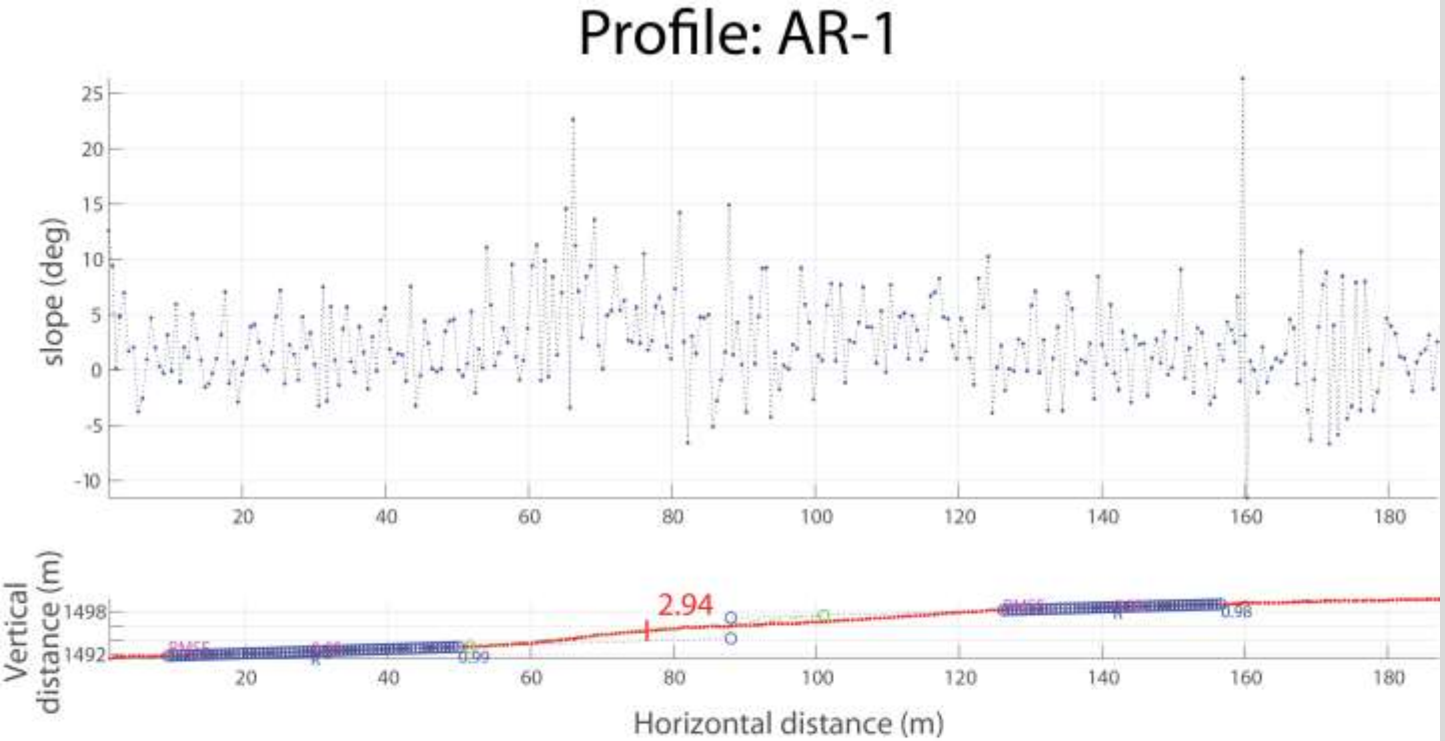


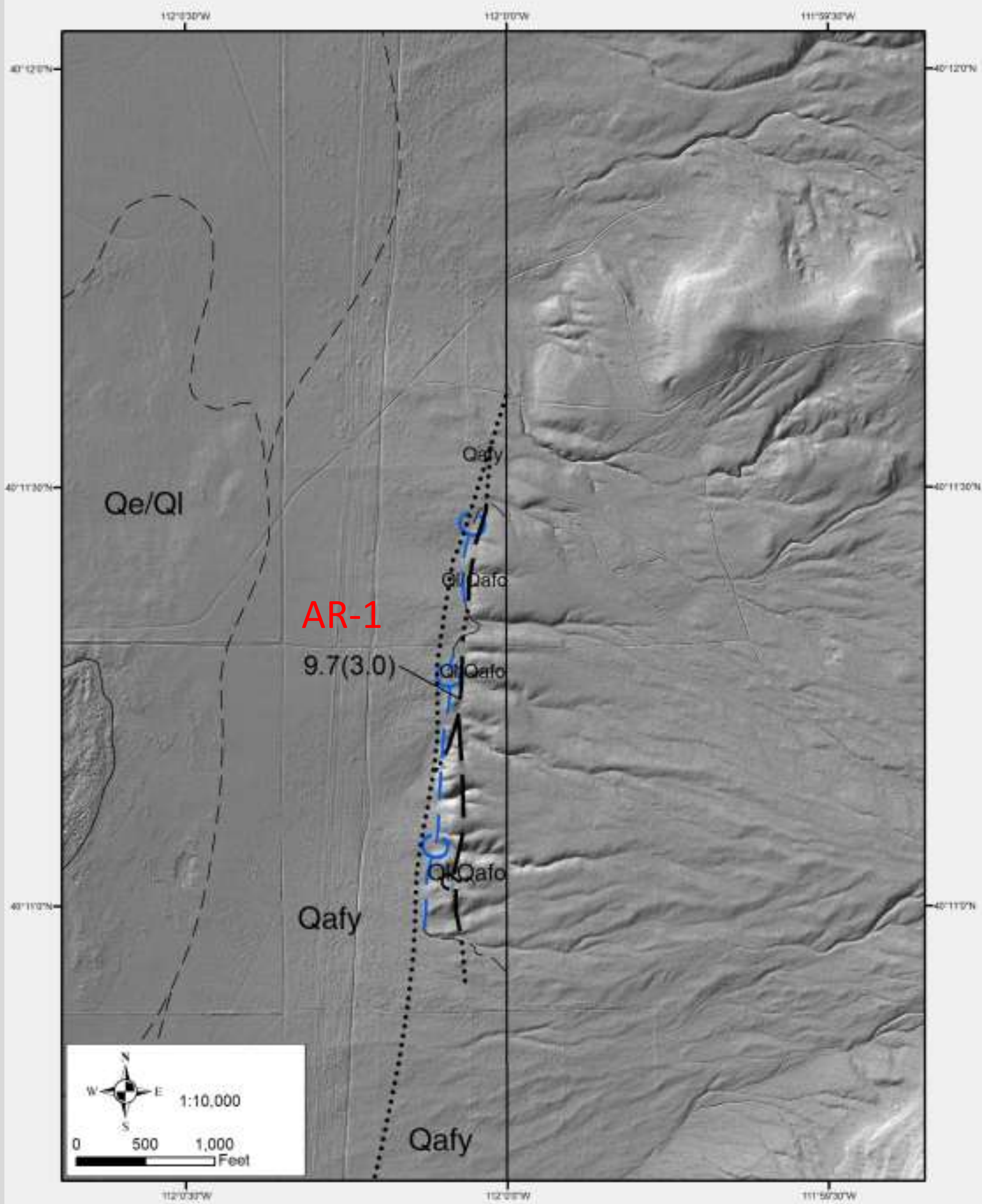
Goshen Pass quadrangle Soldiers Pass quadrangle



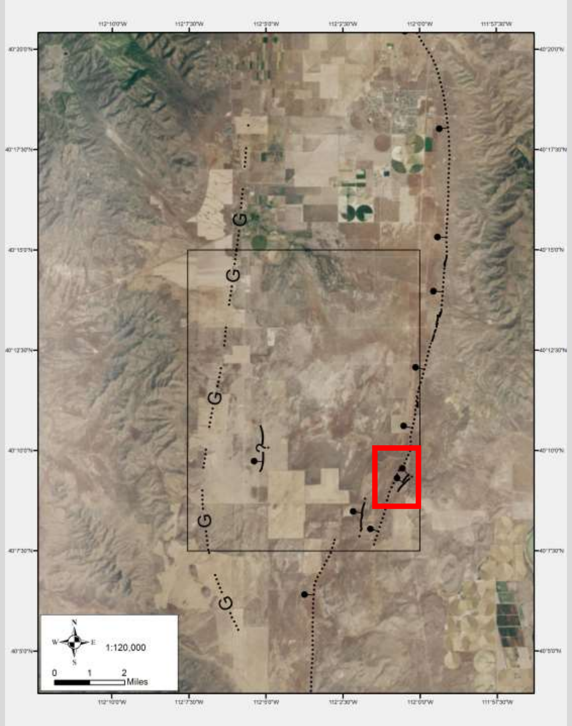
Offset of pre-Bonneville Deposits

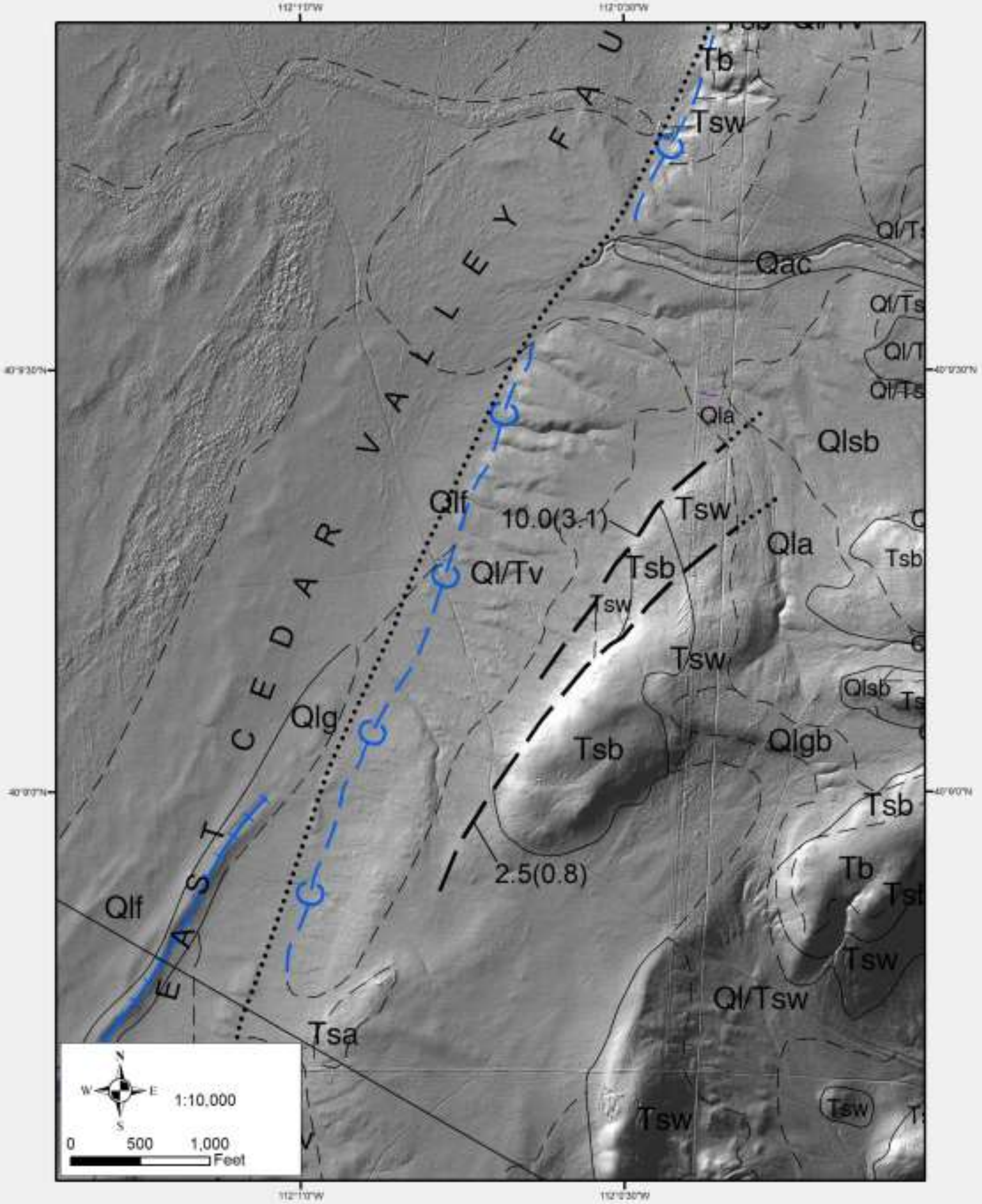




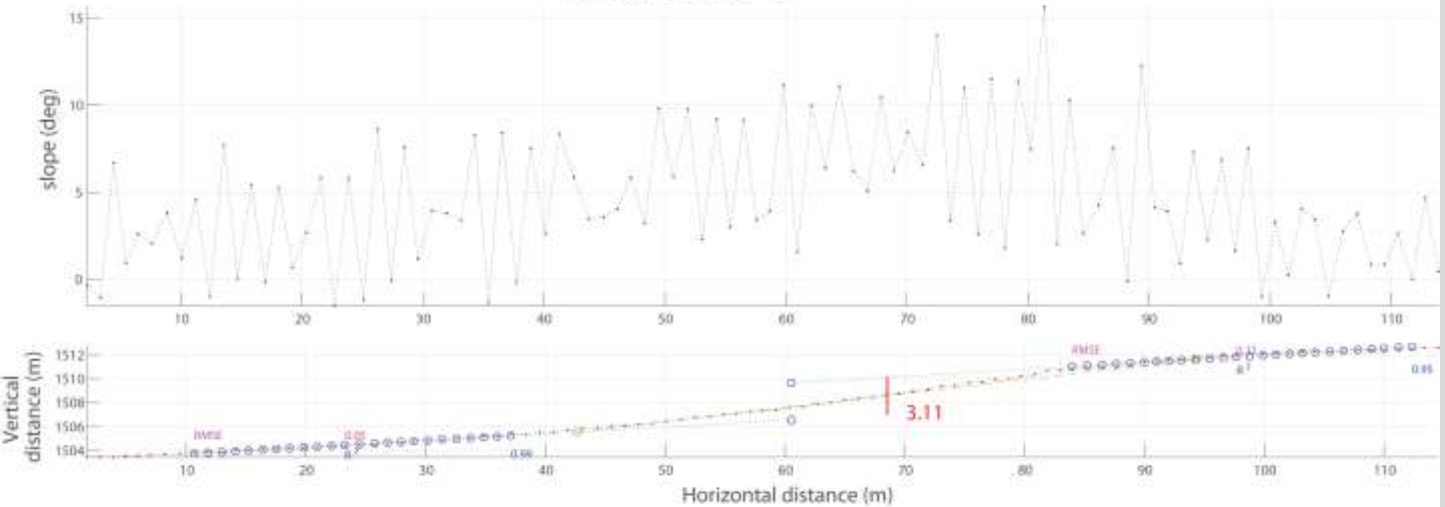


Offset of Oligocene-Eocene Volcanic and Bonneville Deposits

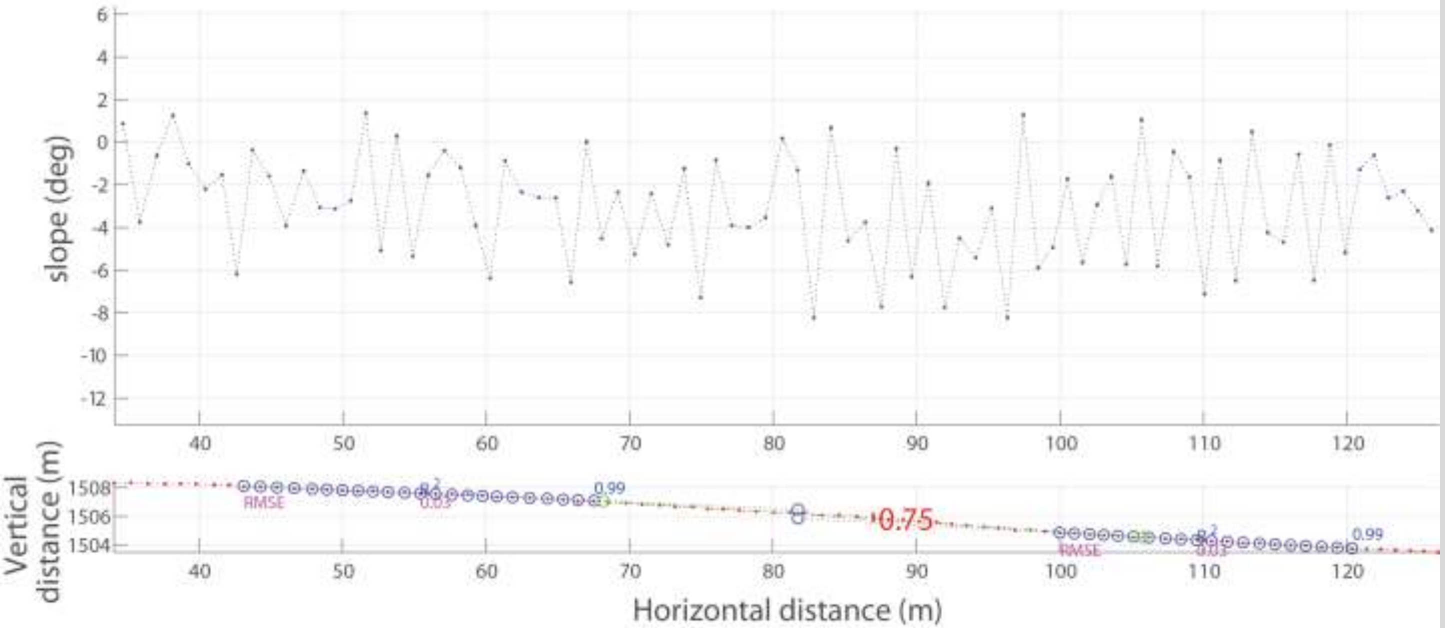


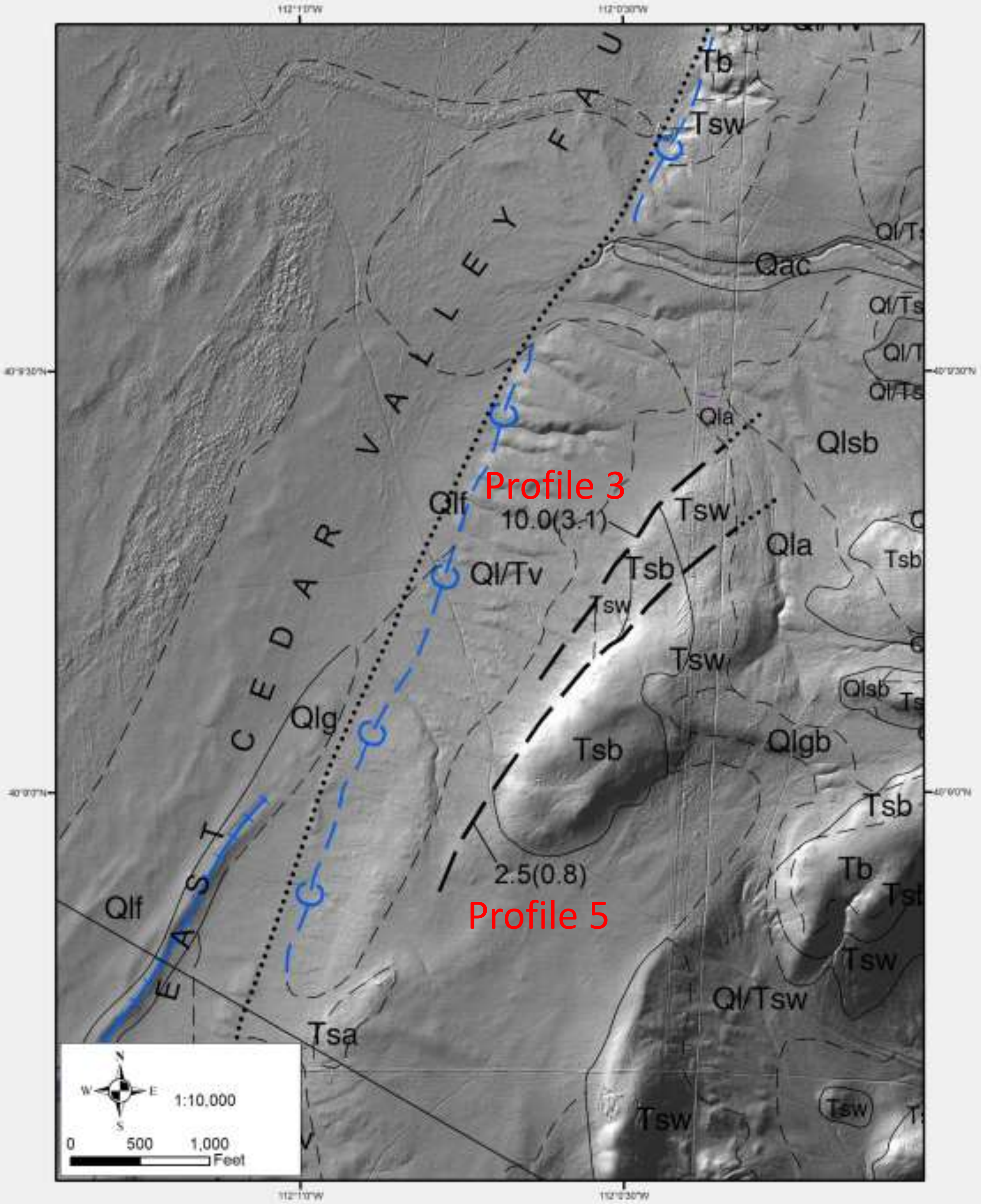


Profile: CV-3

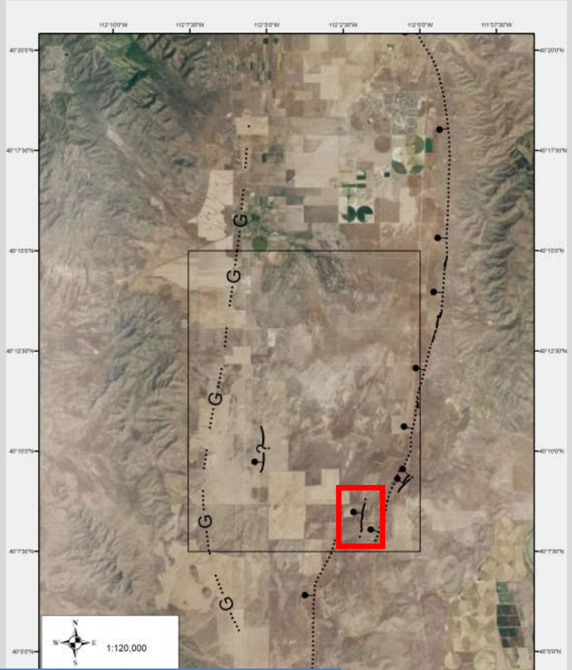


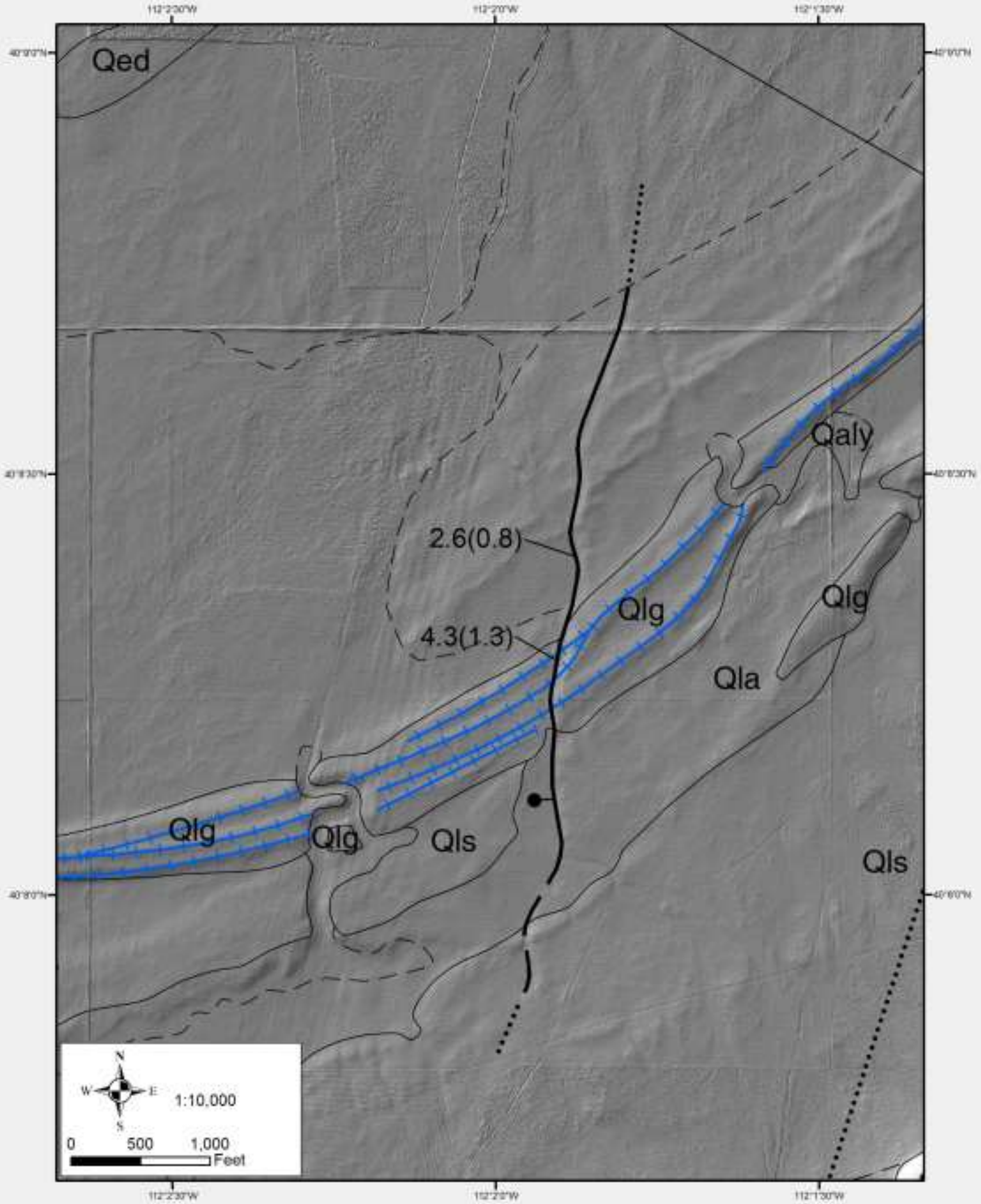
Profile: CV-5



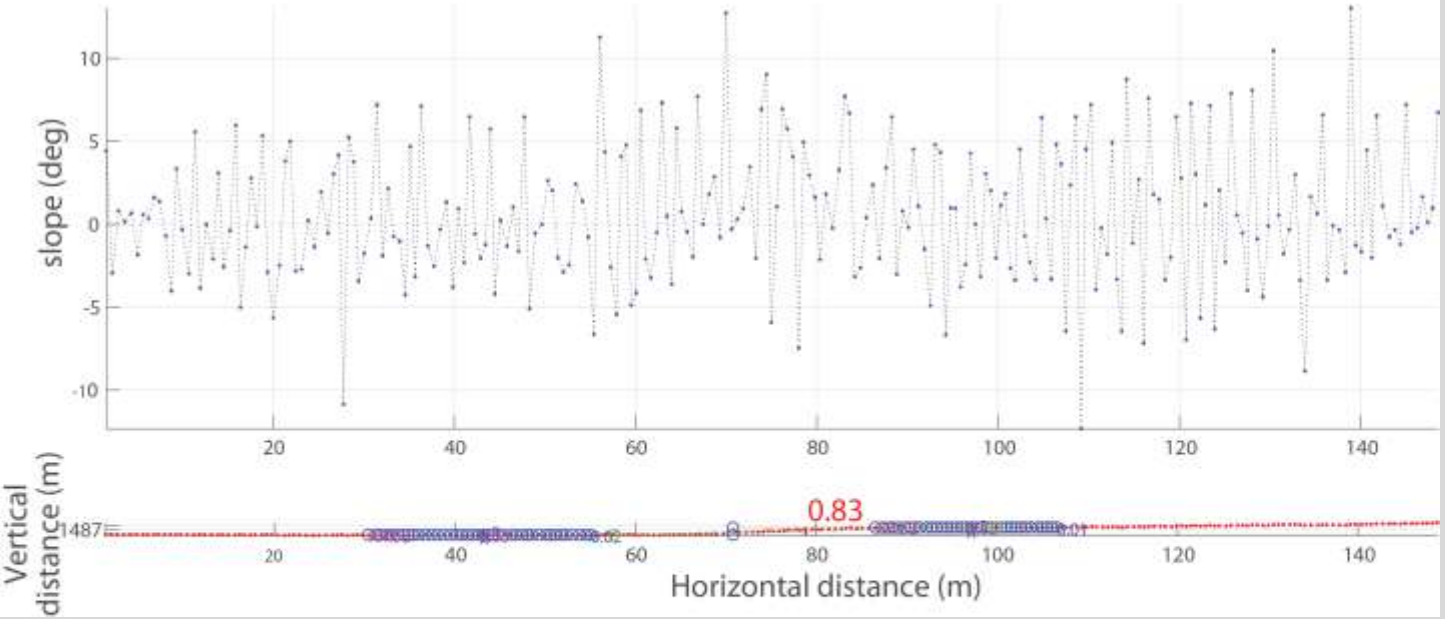


Offset of Cedar Valley Lake Gravel Bar

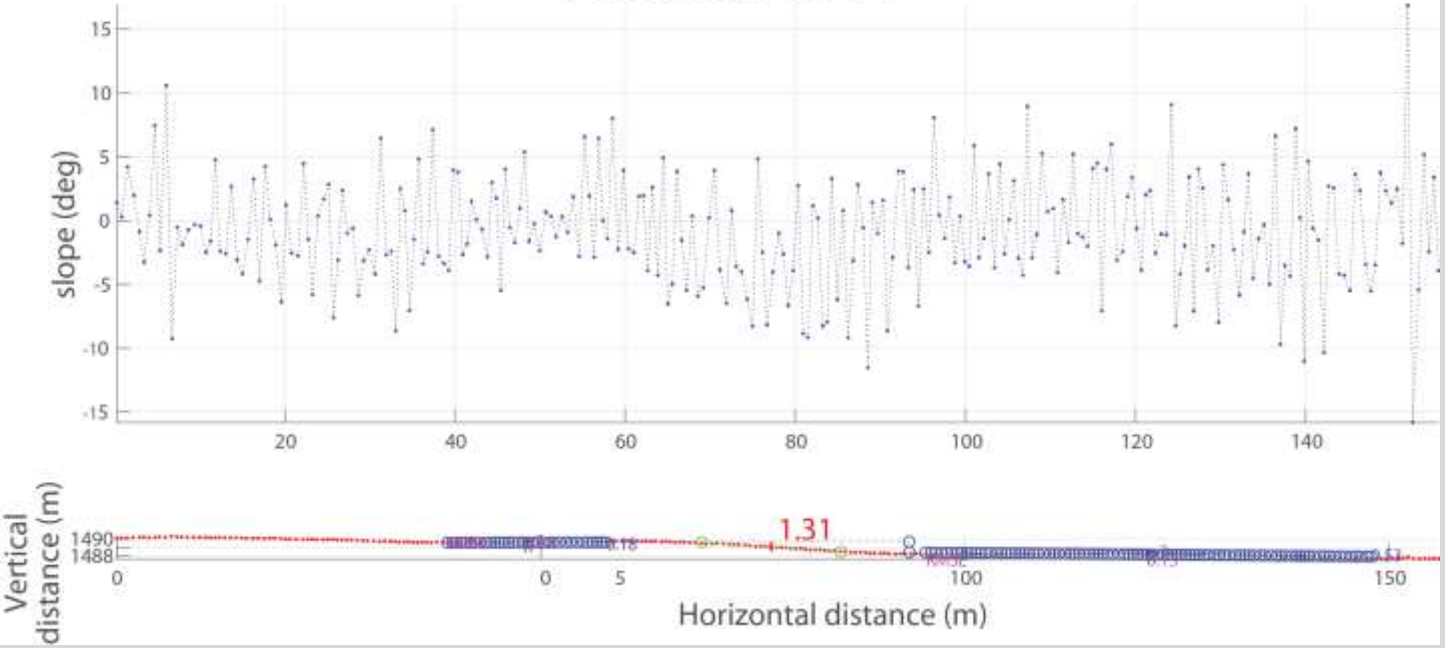


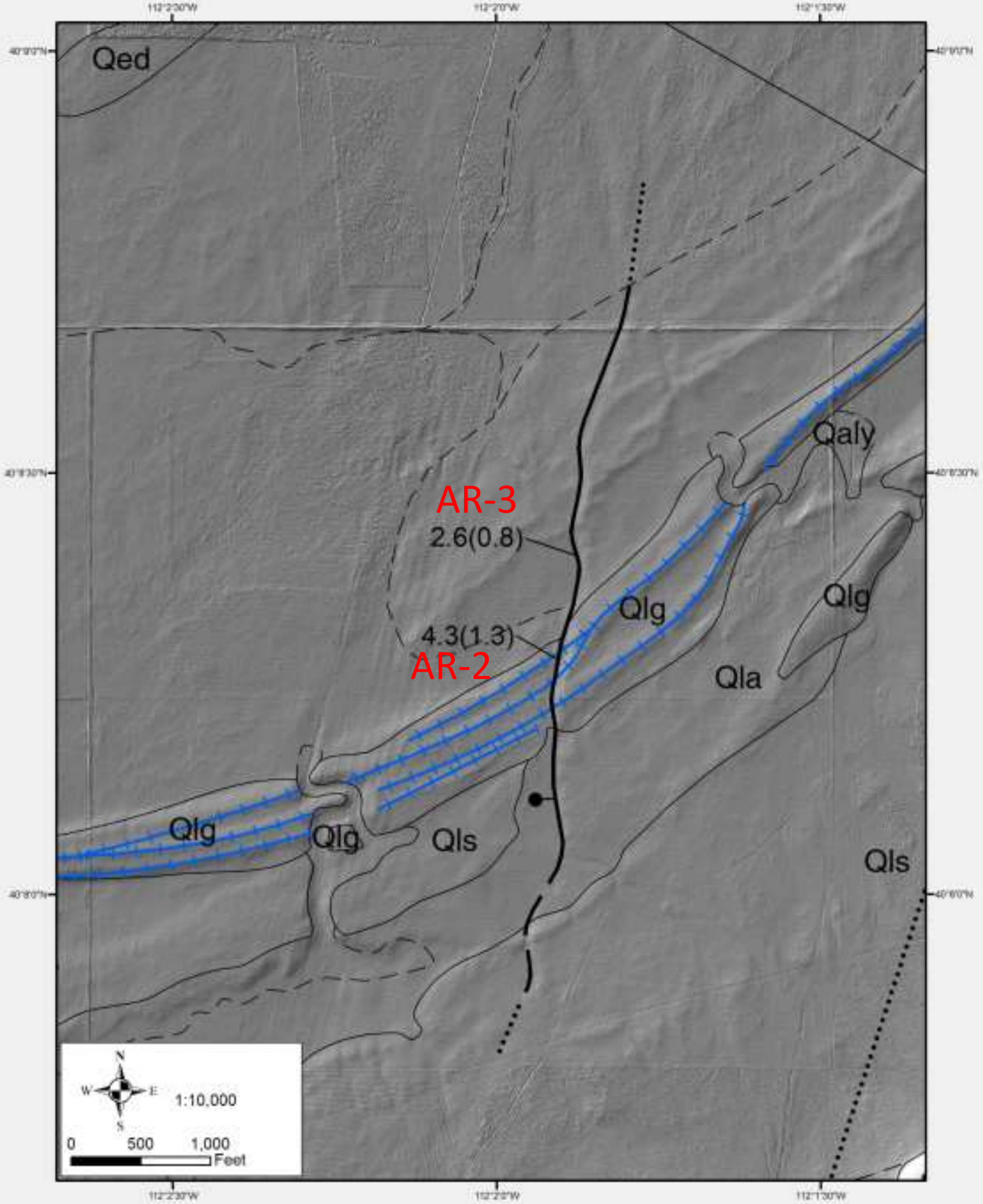


Profile: AR-3

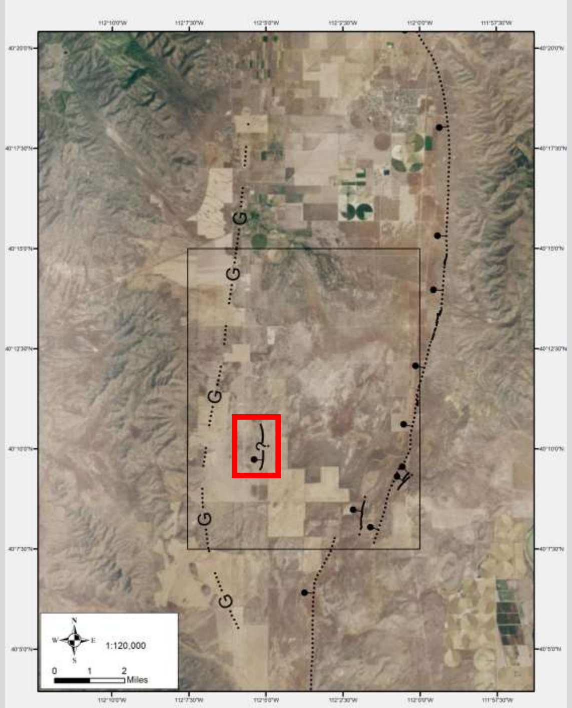


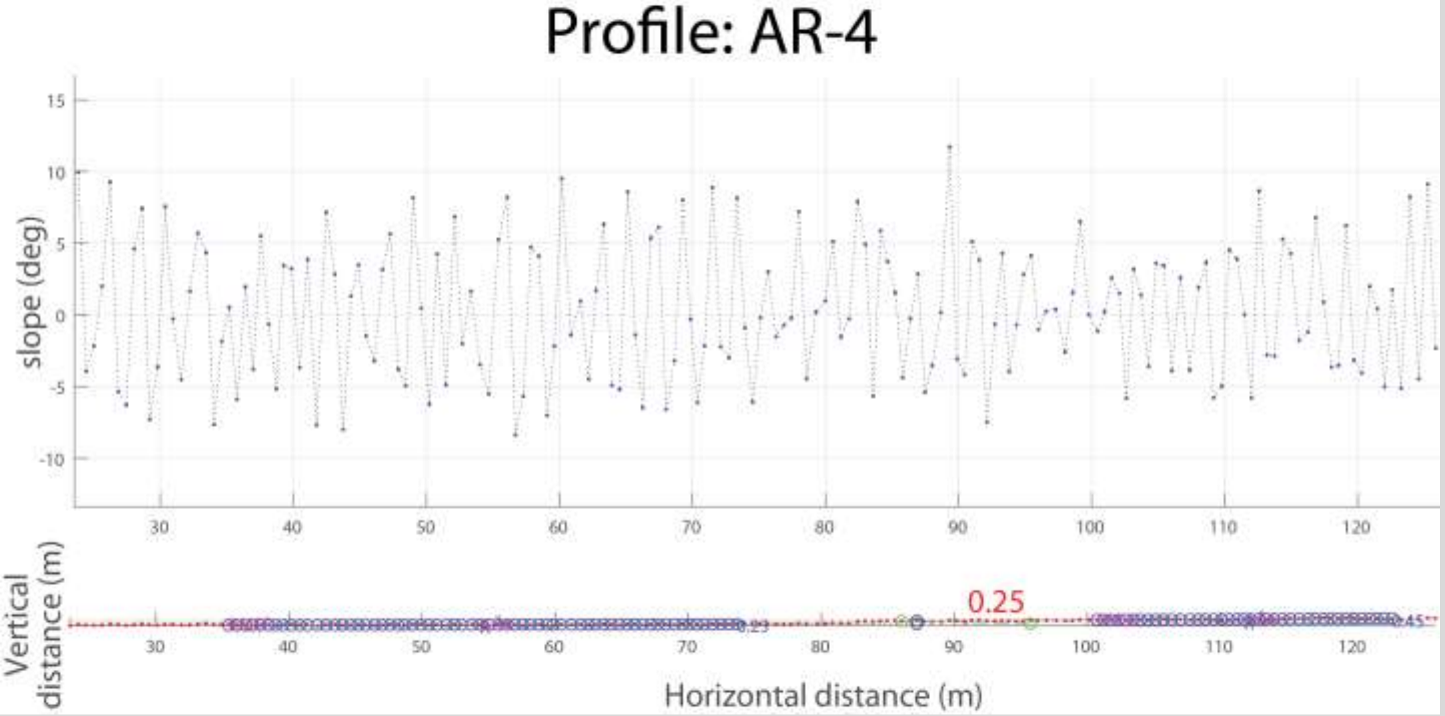
Profile: AR-2

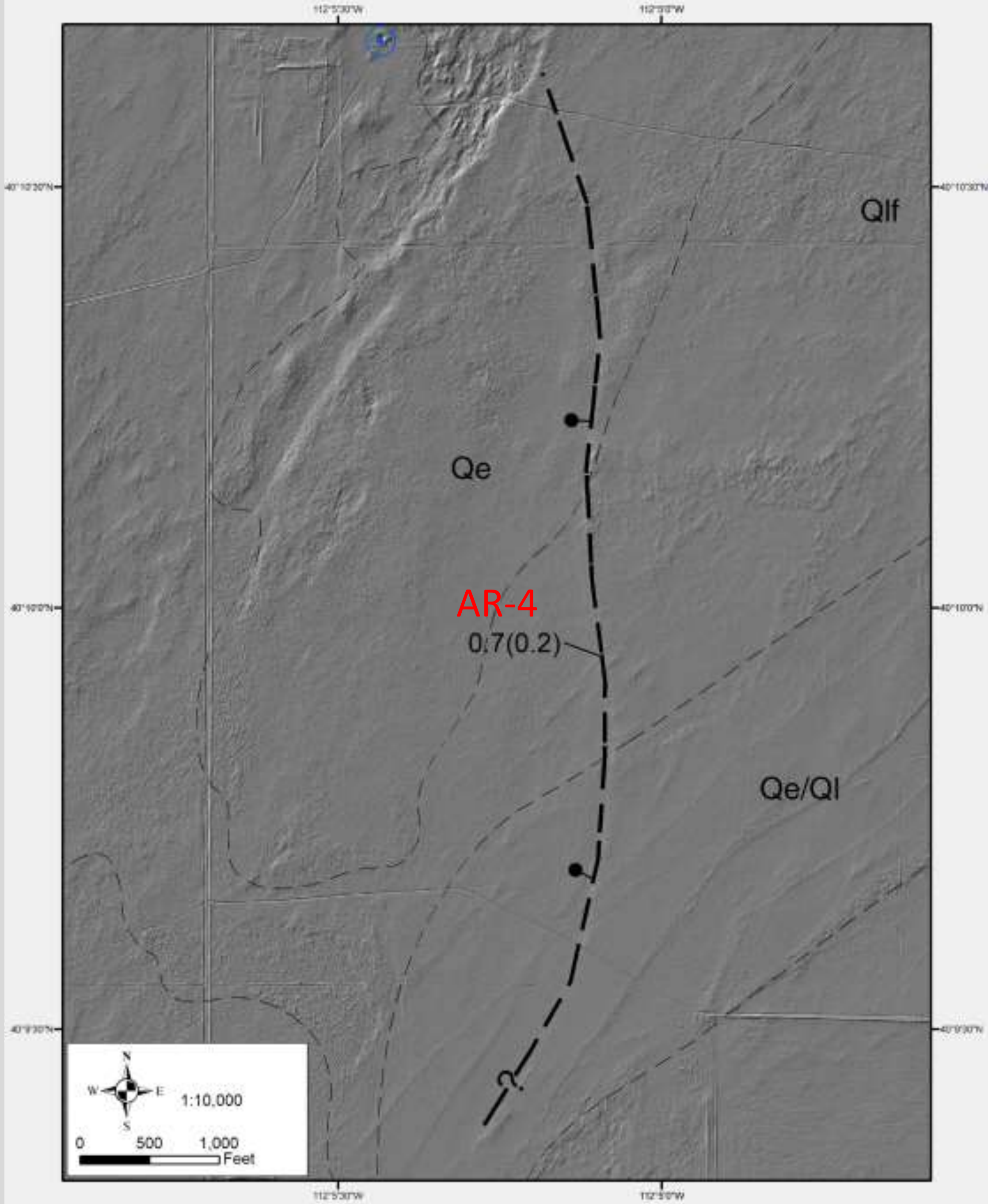




Offset of Cedar Valley Lake and Younger Eolian Deposits







Fault scarp 3 miles NE of Kosmo, photograph by Smith, R.B.

Dr. Pack looking at scarp, photograph by Smith, R.B.

Potentially similar to the surface rupture caused by the 1934 Hansel Valley Earthquake?

Conclusions

- Another example of lidar's value for fault mapping and for identifying pre-historic small offset earthquake surface fault ruptures

<u>East Cedar Valley fault zone</u>

Northern

  - Multiple lines of evidence for a concealed fault

Central

  - Confirmation of scarps in pre-Bonneville deposits

South

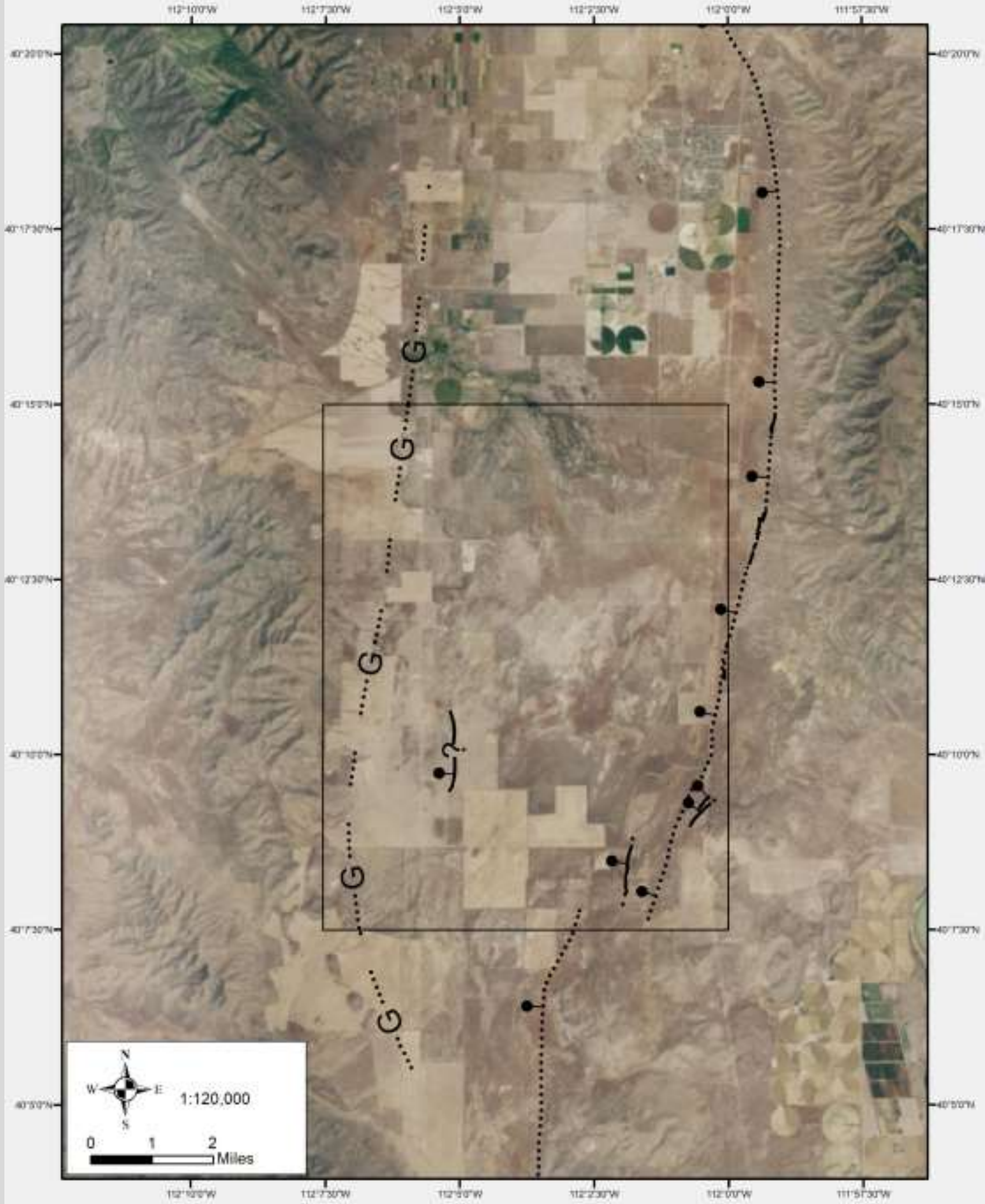
  - New mapping shows scarps in both pre-Bonneville and Bonneville age deposits

<u>Queried intrabasin fault</u>

  - New mapping shows a scarp in both Bonneville age deposits and younger eolian deposits

<u>Western fault</u>

  - Suspected concealed fault confirmed by gravity data, likely pre-Quaternary structure



Thank you

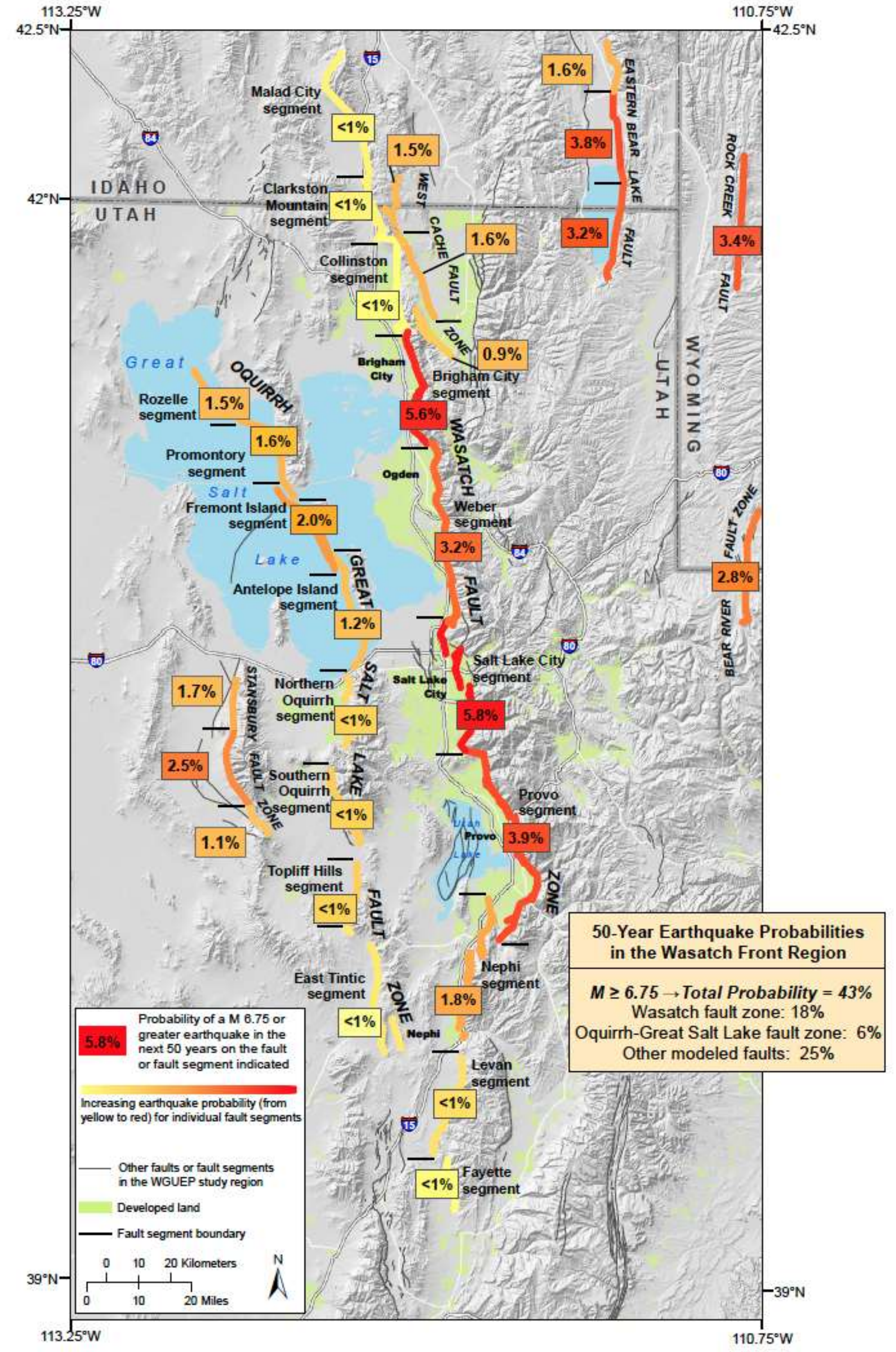
A Field Test of Portable OSL—Using 345 Samples from the Deep Creek Colluvial Wedge Exposure to Explore Earthquake-Timing Uncertainty

Christopher DuRoss, Harrison Gray, Ryan Gold, Sylvia Nicovich, Shannon Mahan, Michael Hylland, Emily Kleber, Adam Hiscock, and Greg McDonald

Utah Quaternary Fault Parameters Working Group, February 2020

Motivation

- ***Accurate models of earthquake probability and hazard rely on high-quality paleoseismic data*** (e.g., earthquake timing, recurrence, slip rate).
- However, these records can be spatially/temporally incomplete. For example, based on few paleoseismic sites, surface-rupturing earthquakes, and/or constraining ages.



Working Group on Utah Earthquake Probabilities (2016)

Principal Questions

We set out to test several aspects of normal fault colluvial sedimentation and surface burial using geochronology:

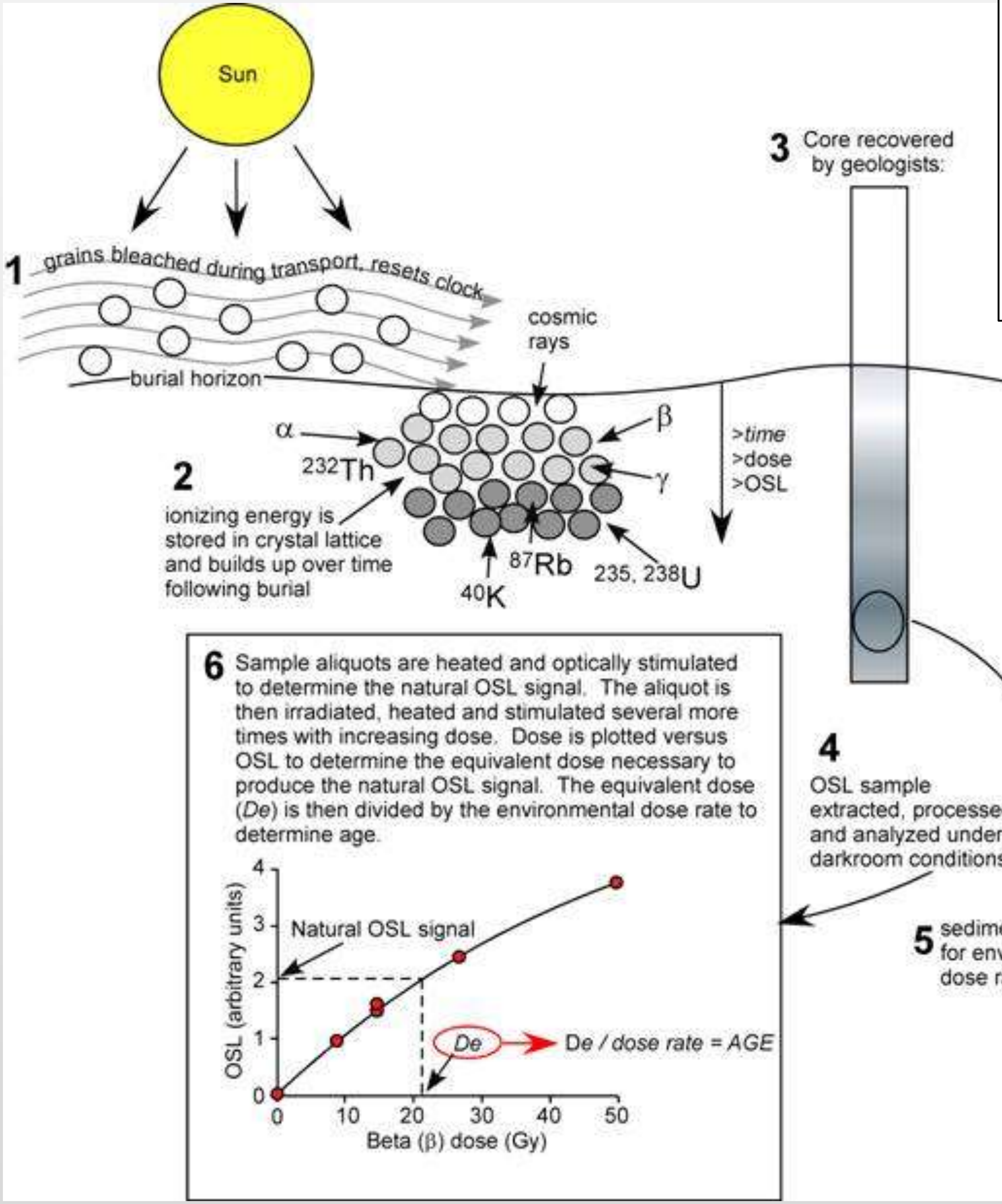
1. Are we able to separate the signal of colluvial-wedge progradation over a surface soil from the noise of age scatter?

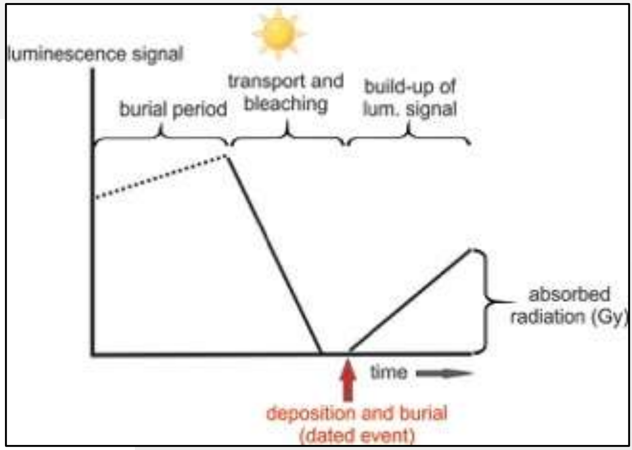
2. Does soil age from charcoal positively correlate with depth within a soil A horizon?

3. How does number of samples (and their stratigraphic context) affect earthquake-timing uncertainty?

Optically Stimulated Luminescence

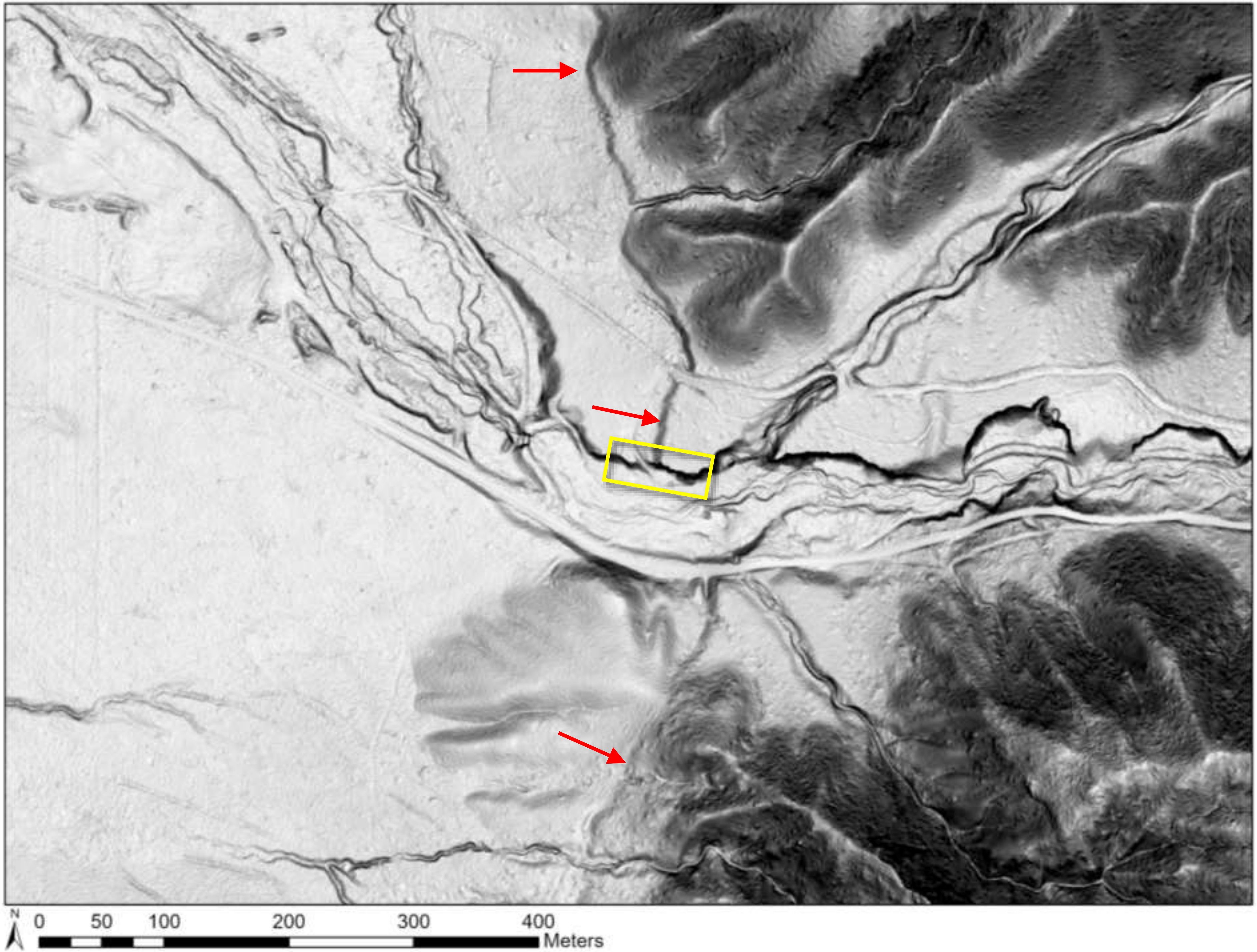
- OSL: Date the last time sediment (quartz grains) was exposed to light
  - ✓ Luminescence signal is reset during transport and exposure to sunlight
  - ✓ After burial, ionizing energy from surrounding sediment is stored (electrons trapped)
  - ✓ This energy (luminescence) can be released and measured in the laboratory
  - ✓ Age = measured energy (equivalent dose) / Dose rate





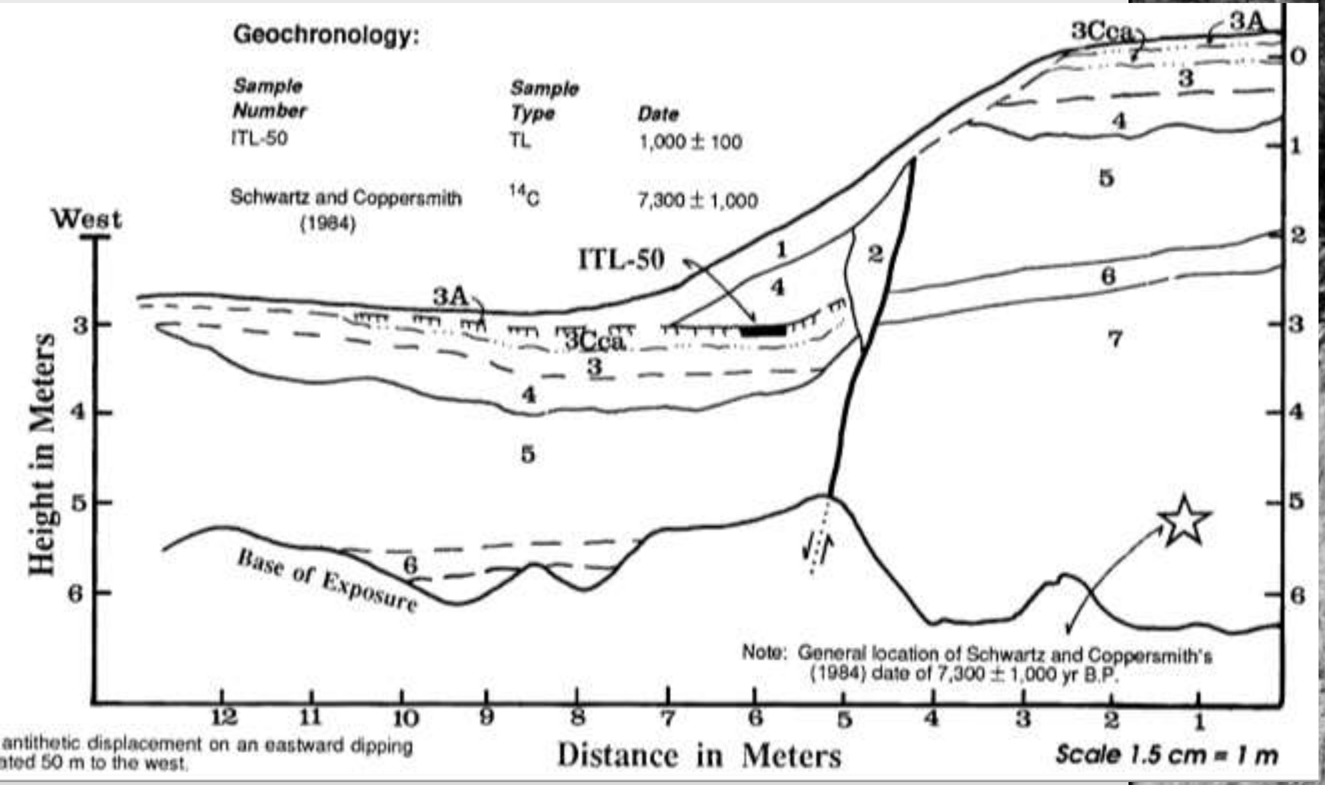
Deep Creek

- Clear expression of Holocene surface faulting
- Holocene alluvial-fan gravel and Wasatch fault exposed



Previous Work

- ➢A faulted soil A horizon buried by colluvium suggests a single surface-faulting earthquake
  - ✓Vertical displacement: 1.8 m
  - ✓Timing: < ~1000 yr

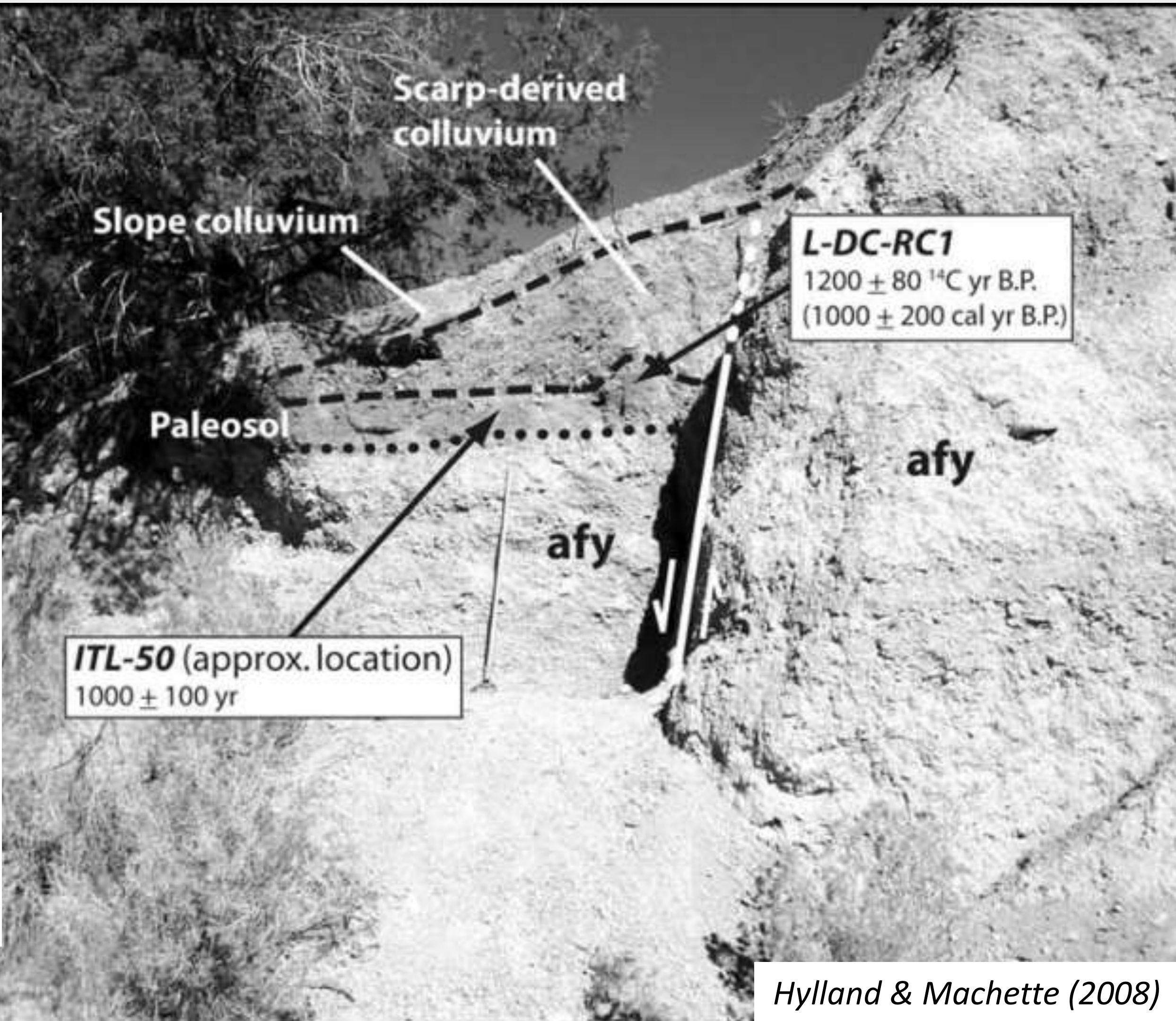


Geochronology:

Sample Number	Sample Type	Date
ITL-50	TL	1,000 ± 100
Schwartz and Coppersmith (1984)	^{14}C	7,300 ± 1,000

Note: General location of Schwartz and Coppersmith's (1984) date of 7,300 ± 1,000 yr B.P.

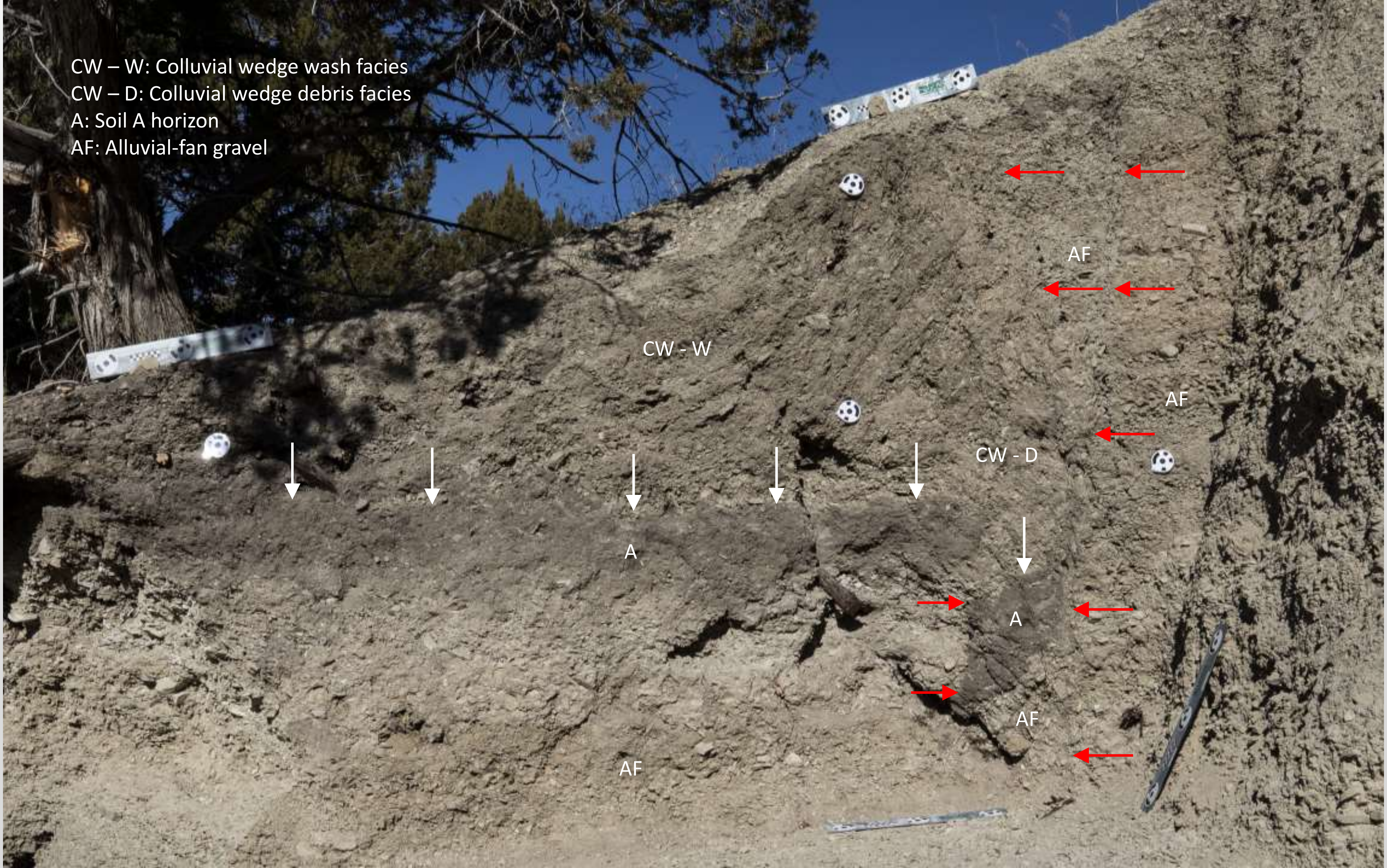
Jackson (1991)



L-DC-RC1
1200 ± 80 ^{14}C yr B.P.
(1000 ± 200 cal yr B.P.)

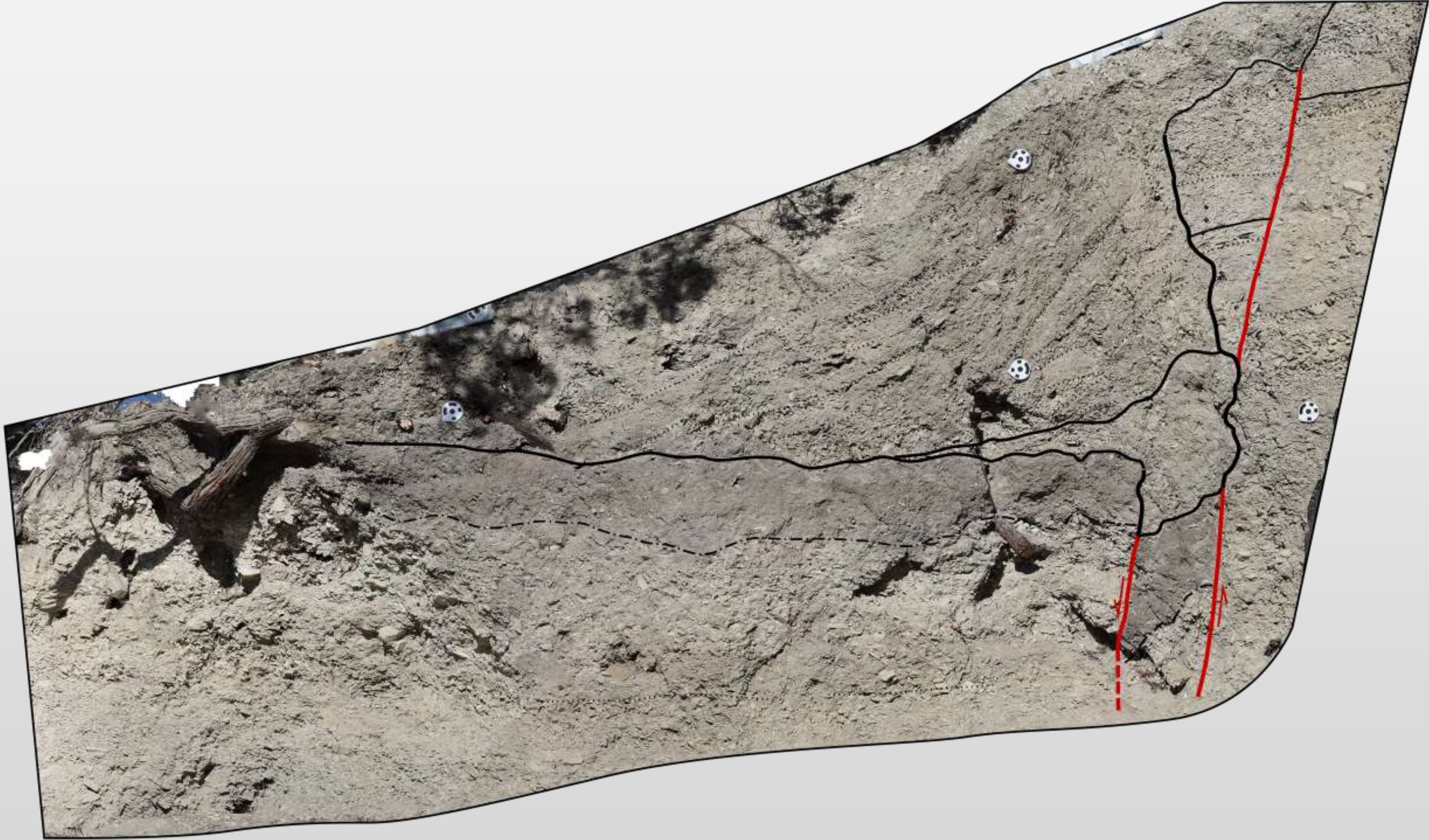
ITL-50 (approx. location)
1000 ± 100 yr

Hylland & Machette (2008)



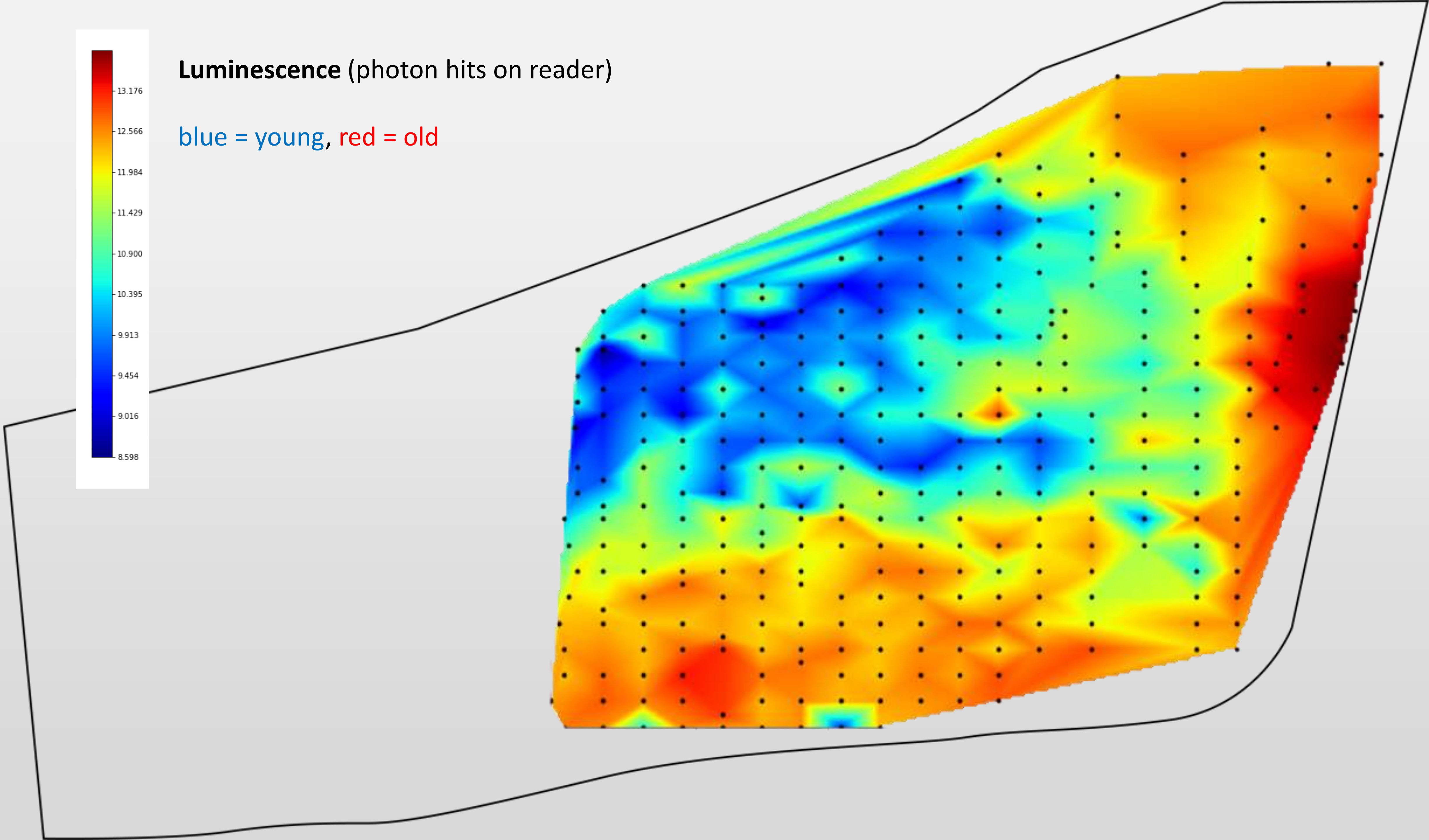
CW – W: Colluvial wedge wash facies
CW – D: Colluvial wedge debris facies
A: Soil A horizon
AF: Alluvial-fan gravel

- ➢OSL:
  - ✓ ~345 samples for portable OSL
  - ✓ 6 full OSL samples
- ➢Radiocarbon *(charcoal separation)*
  - ✓ 10 samples of buried A horizon
  - ✓ 10 samples of colluvial wedge



Luminescence (photon hits on reader)

blue = young, red = old



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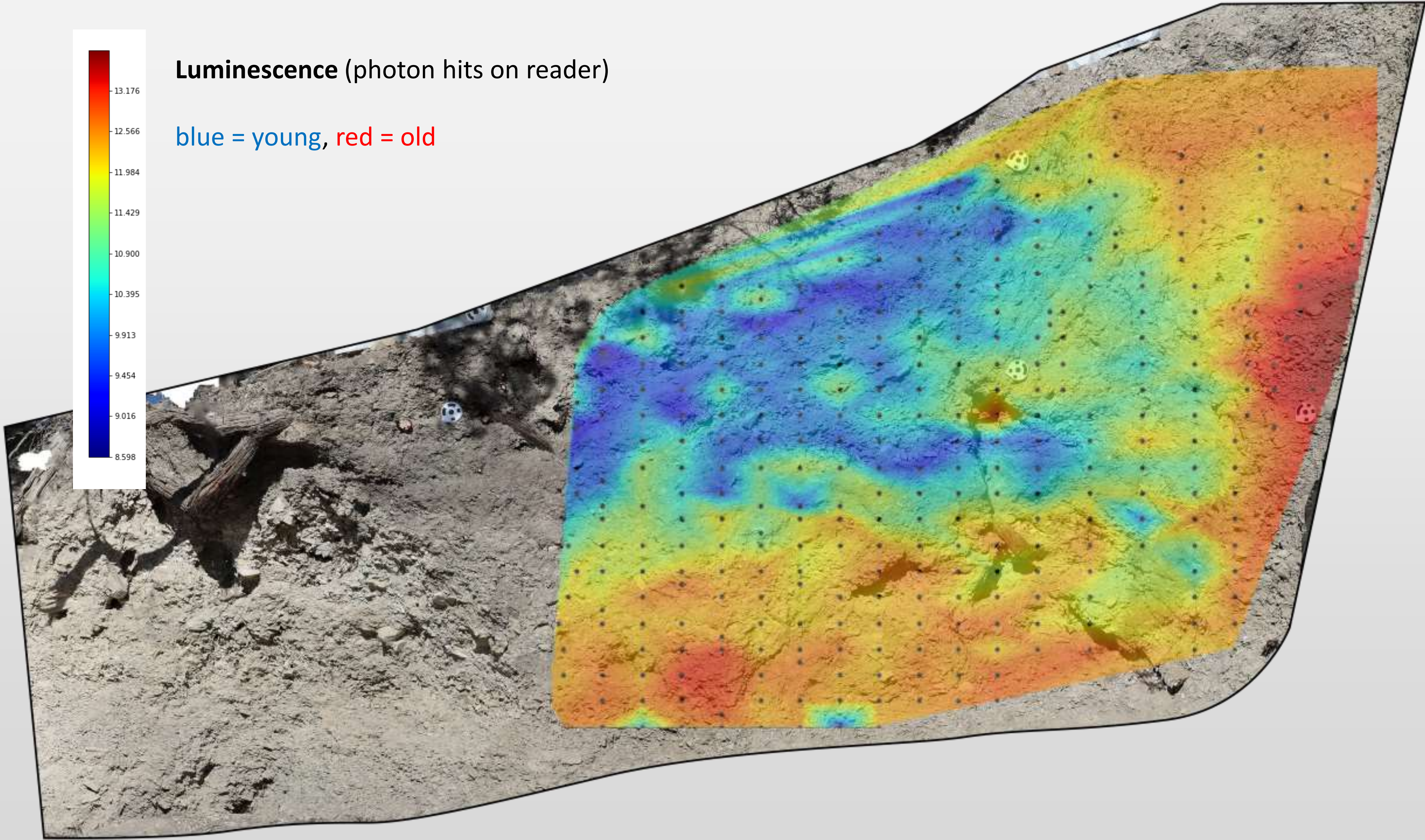

Luminescence (photon hits on reader)

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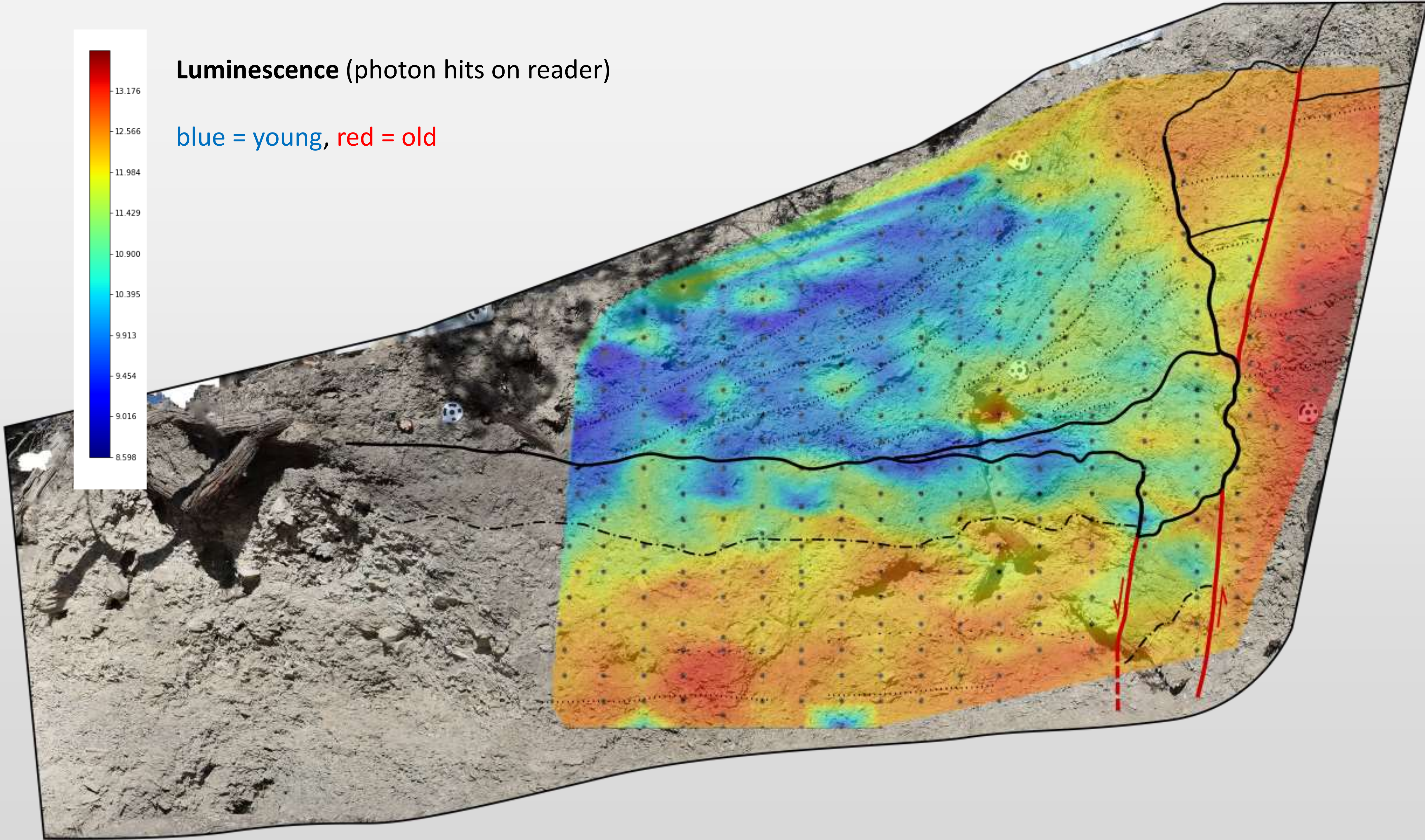

Luminescence (photon hits on reader)

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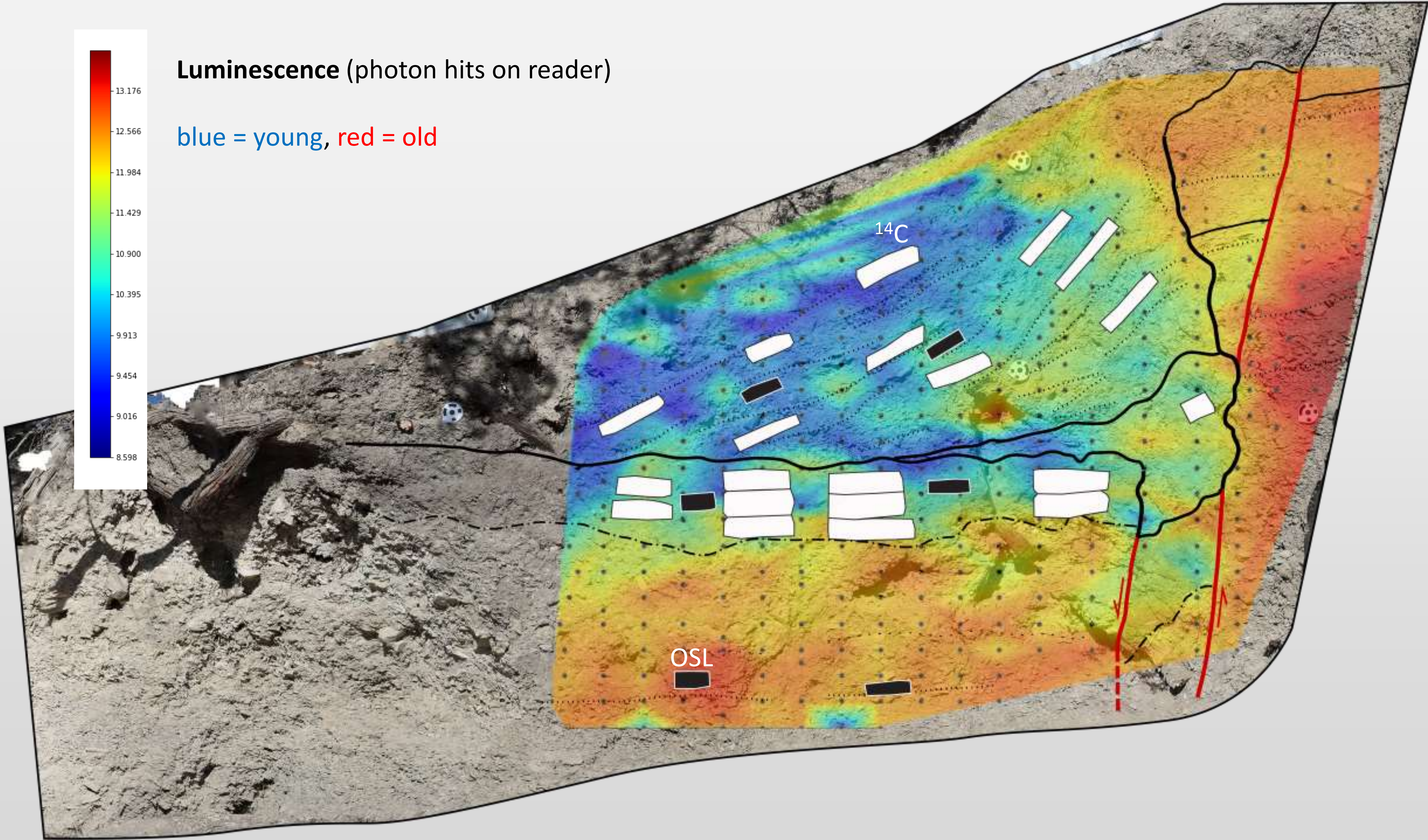
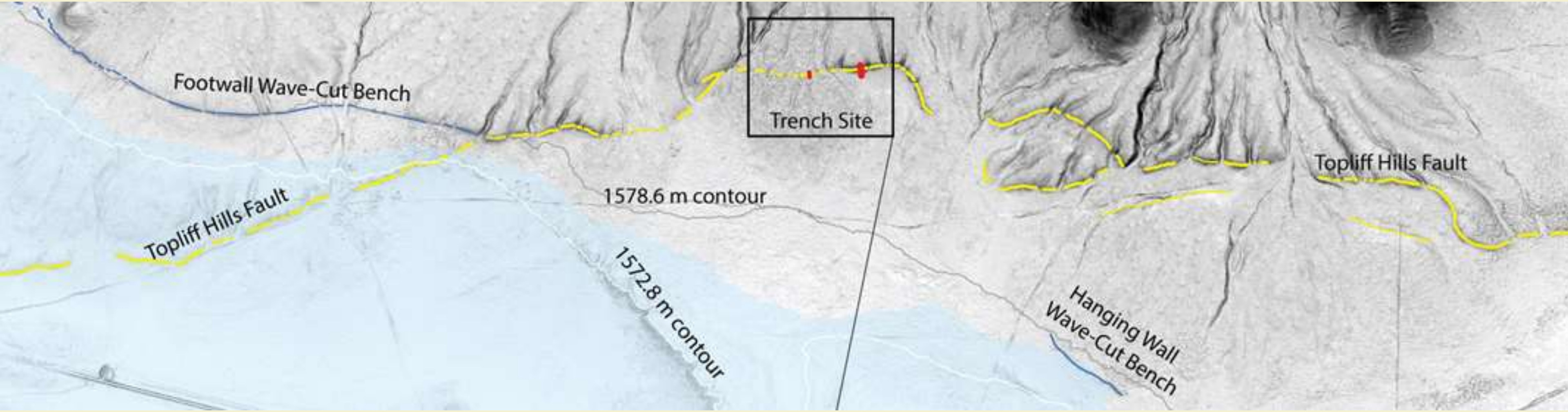


From here...

- Process full OSL and ^{14}C ages
- Calculate earthquake timing using multiple combinations of ages
- Explore implications for:
  1. the sampling and dating of paleoseismic exposures,
  2. the use of portable OSL in the field, and
  3. how sample quantity and stratigraphic context influence estimates of earthquake-timing uncertainty.

Topliff Hill Paleoseismic Site:

Six Events since 69.3 ka on the Topliff Hills Fault

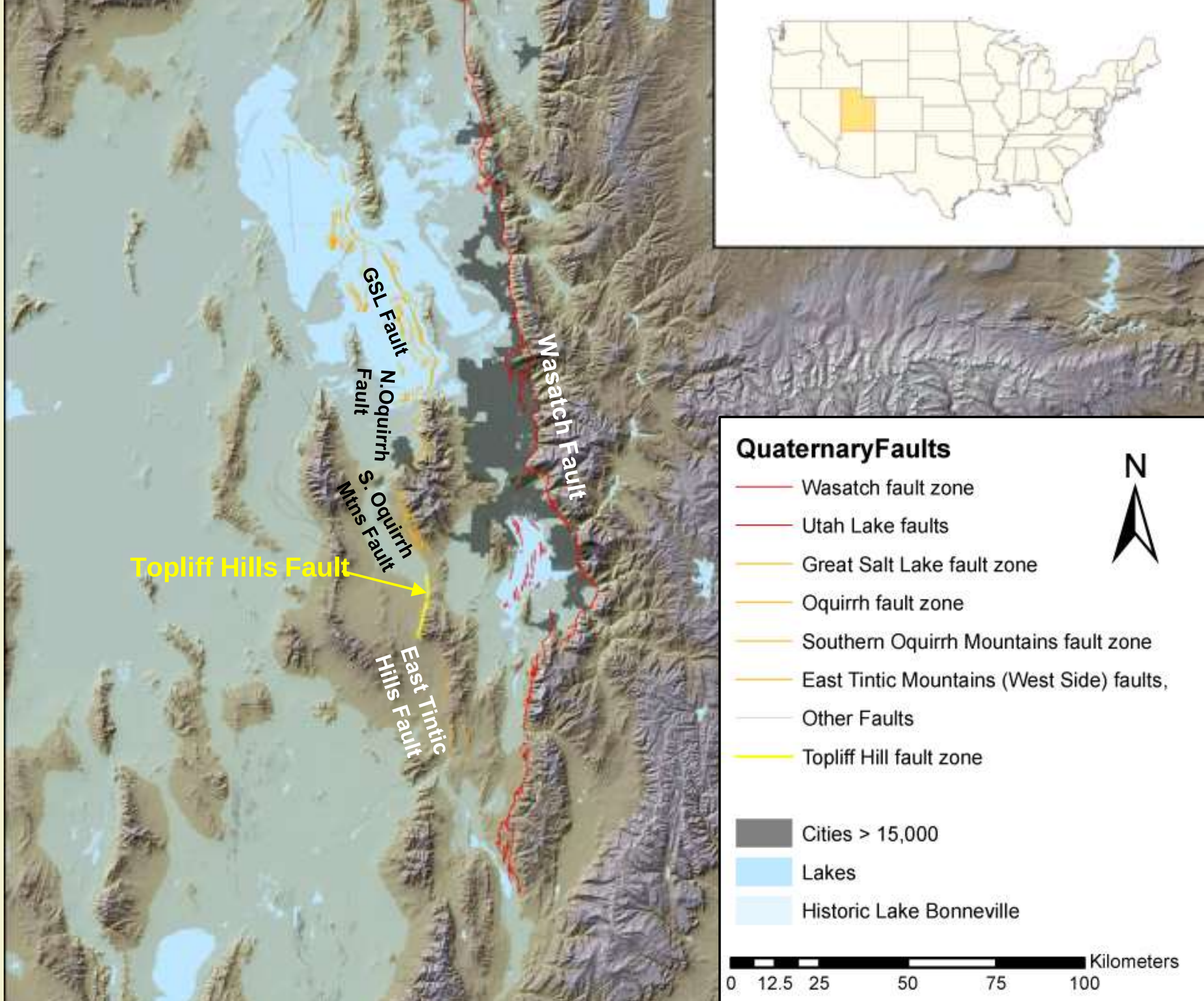


UVU Faculty: Nathan Toké[1], and Michael P. Bunds[1]
UVU Students: Rachel Richards[1], Alex Tolman[1], Brigham Whitney[1], and Sally Ward[1]
The USU Luminescence Lab: Tammy Rittenour[2] and Carlie Ideker[2]

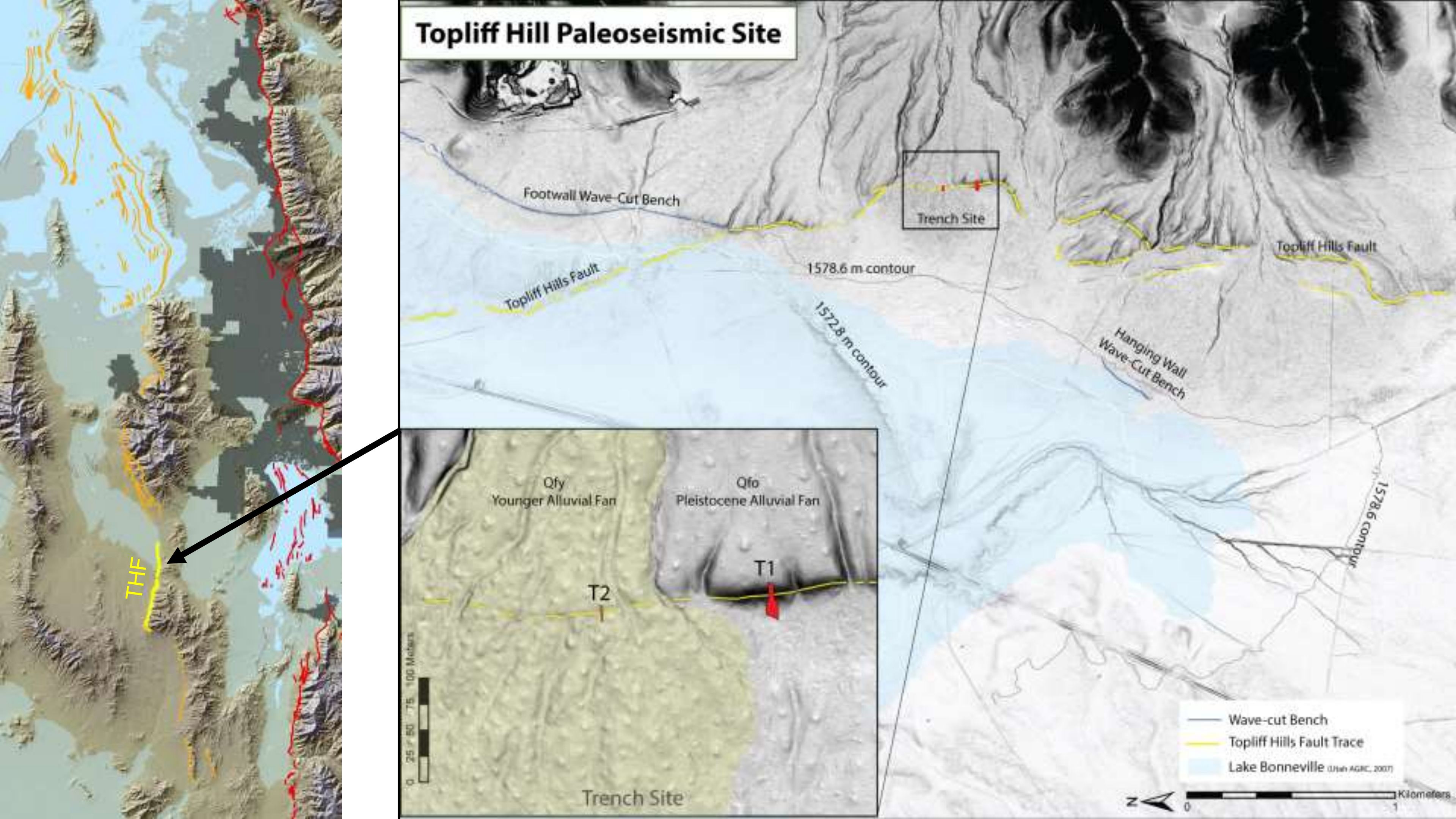
[1]Department of Earth Science, Utah Valley University
[2]Department of Geology, Utah State University

Topliff Hills Fault

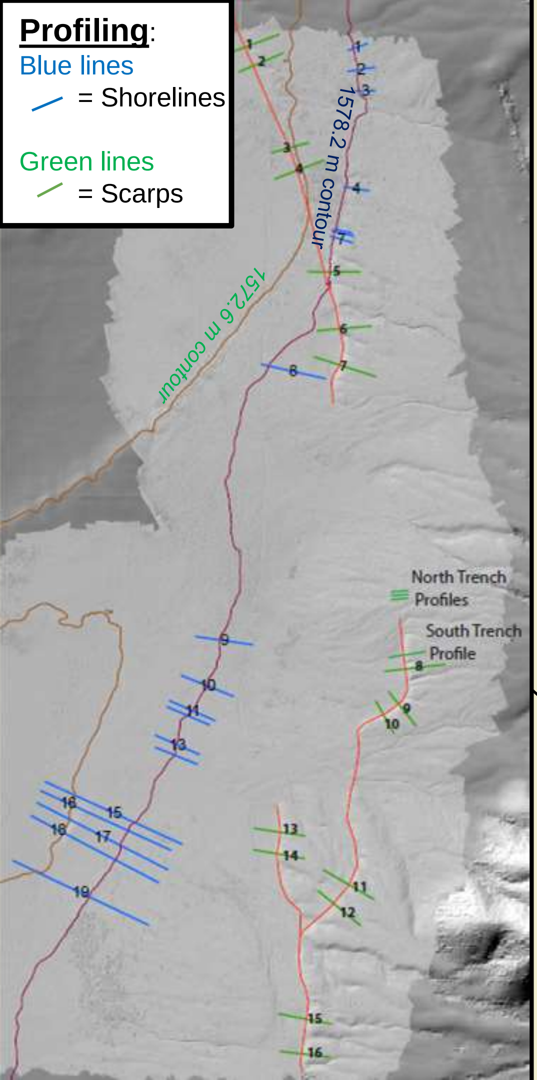
- 25 km-long, west-dipping fault
- Linked to South Oquirrh Mountains fault (SOMF)?
- Utah's second longest Fault system, >250 km length
- Within 40 km of the Wasatch front

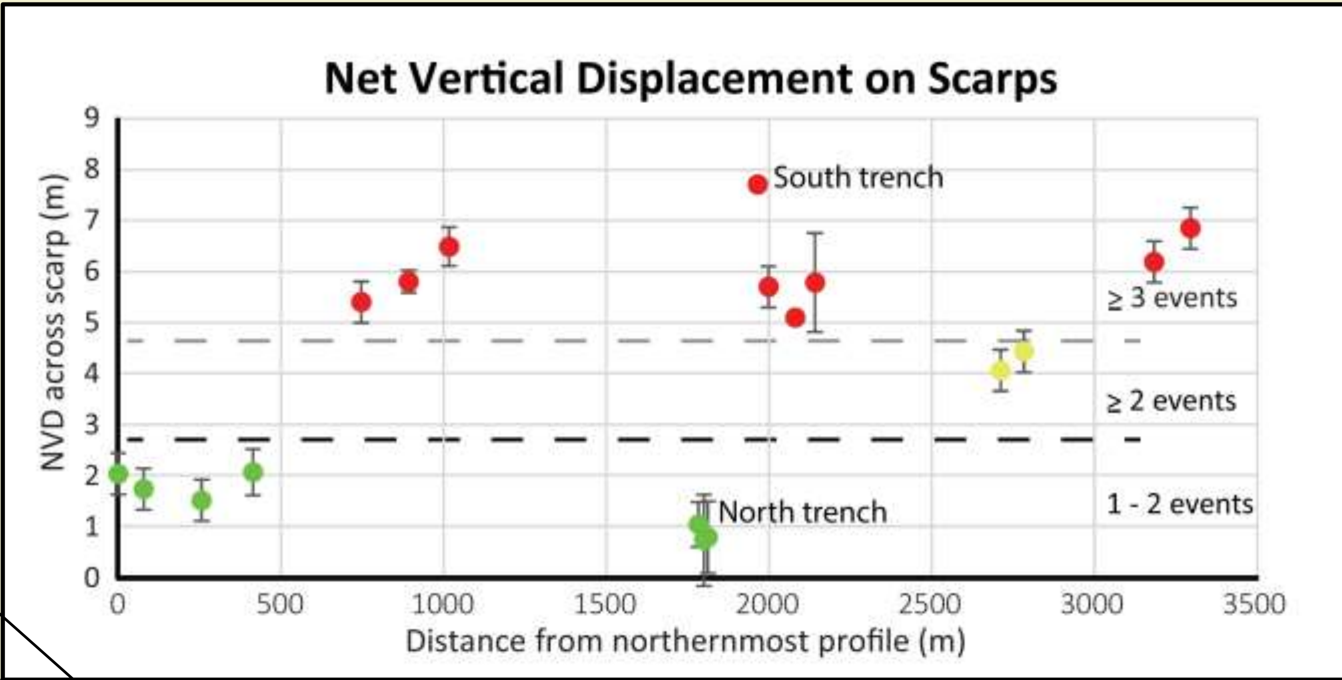


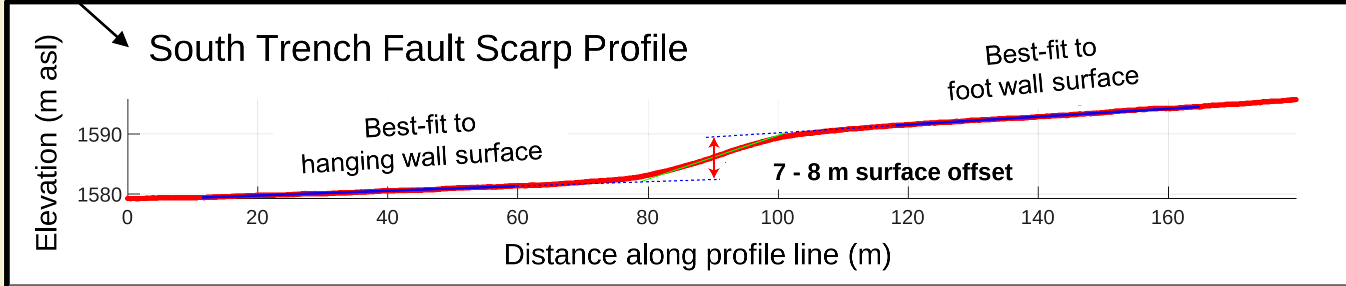
Topliff Hill Paleoseismic Site

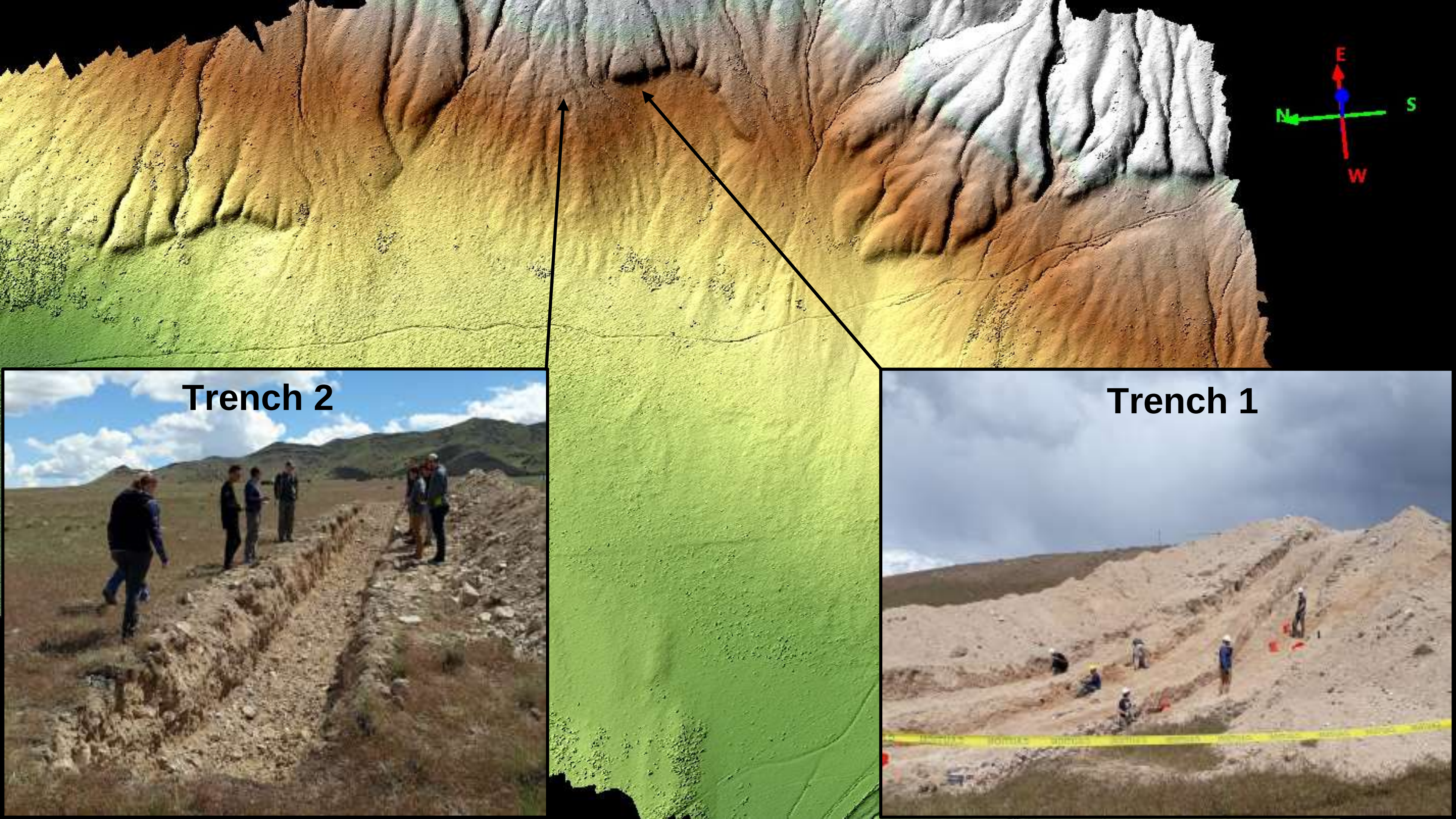


Scarp Height Profiling

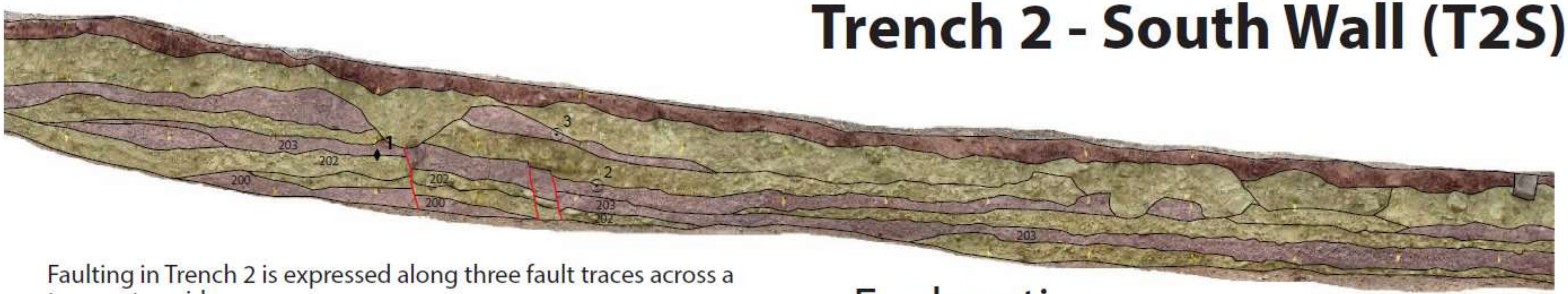







E
N
S
W
Trench 2
Trench 1

Trench 2 - South Wall (T2S)



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

Cumulative displacement is 0.5 +/ 0.05 meters.

The fault zone is overlain by several younger fan deposits.

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

Explanation

⊙ Bulk Soil Sample

♦ C14 Sample

/ Fault

0 2 m

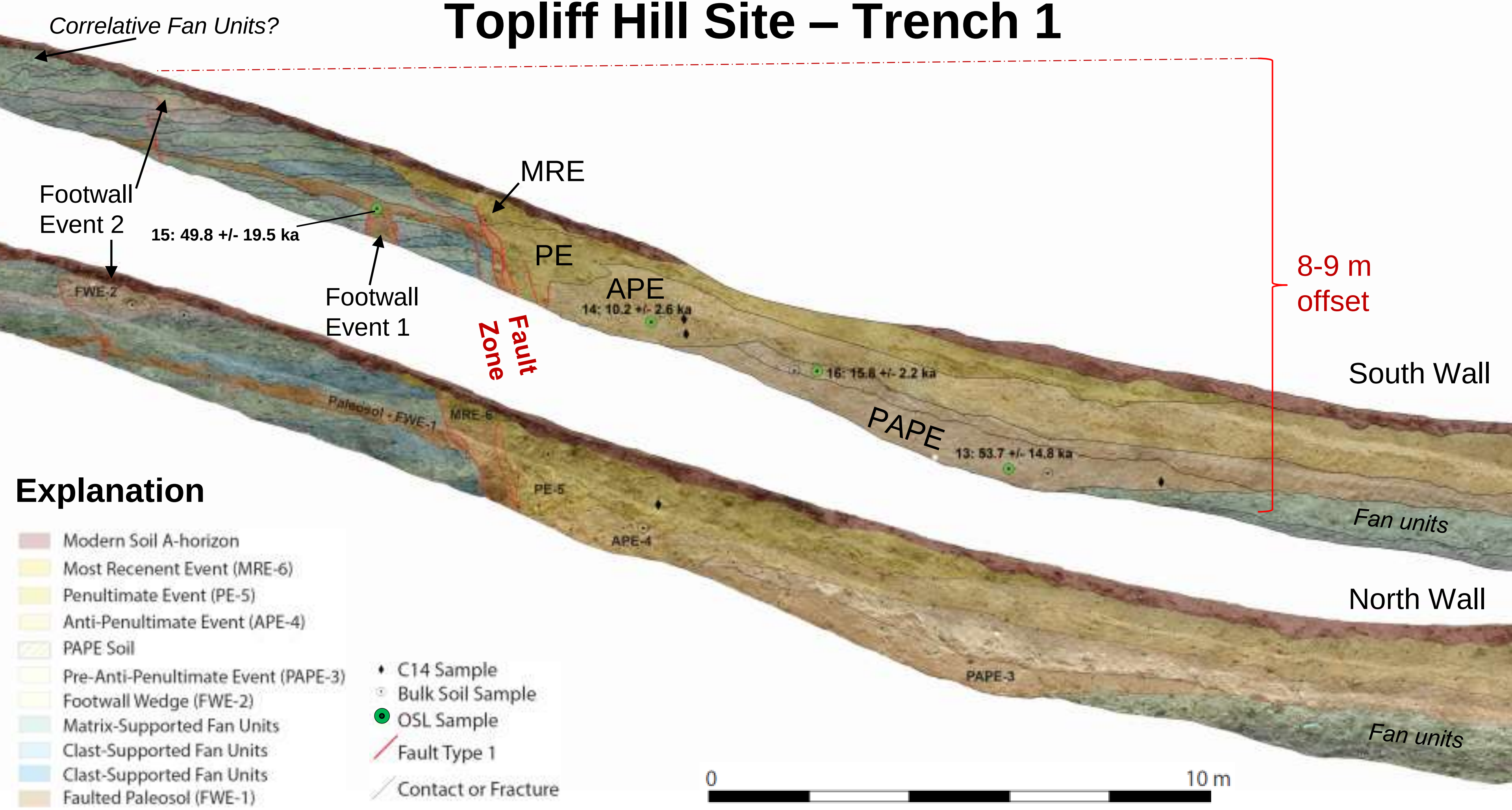
▨ Soil A-Horizon

▨ Boulder

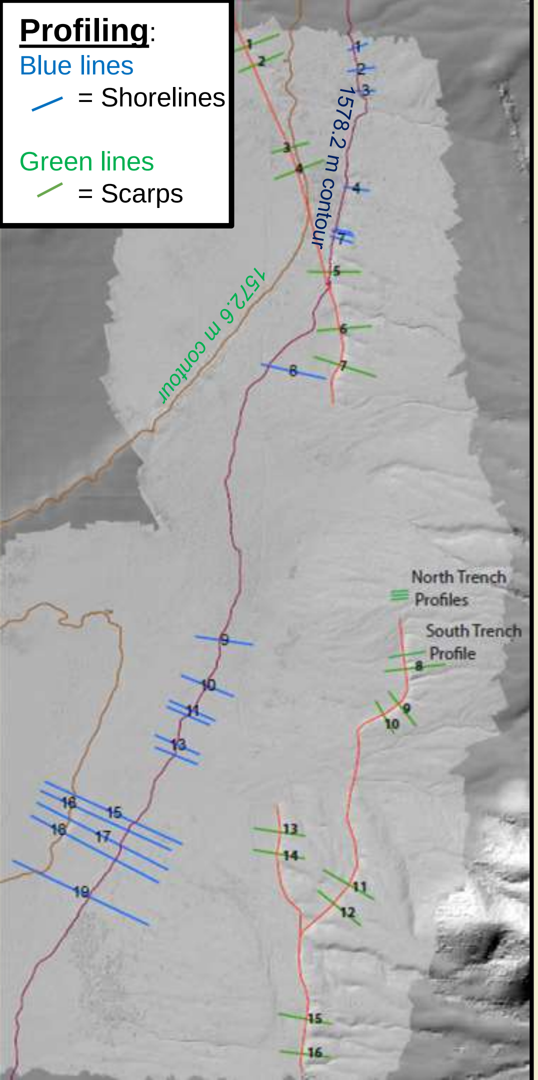
▨ Clast-Supported

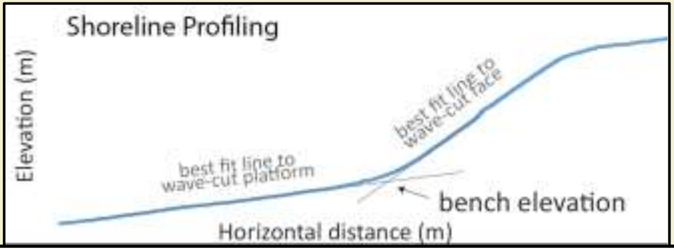
▨ Matrix-Supported

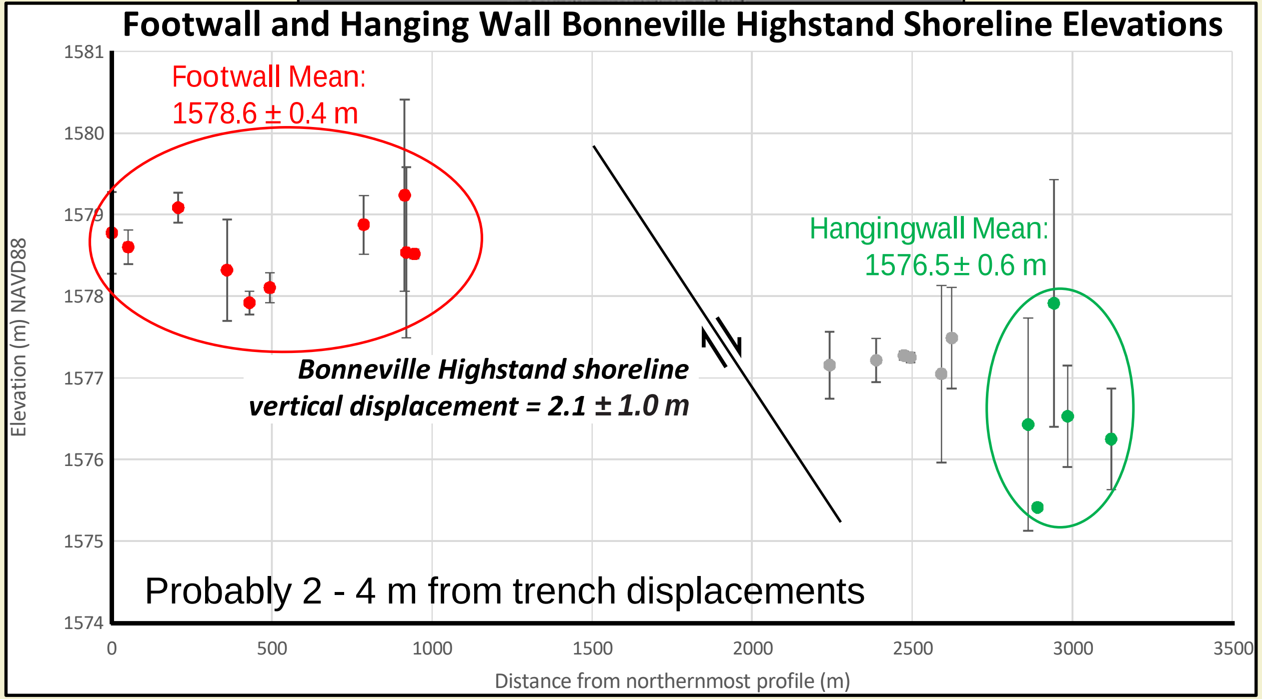
Topliff Hill Site – Trench 1



Shoreline Profiling







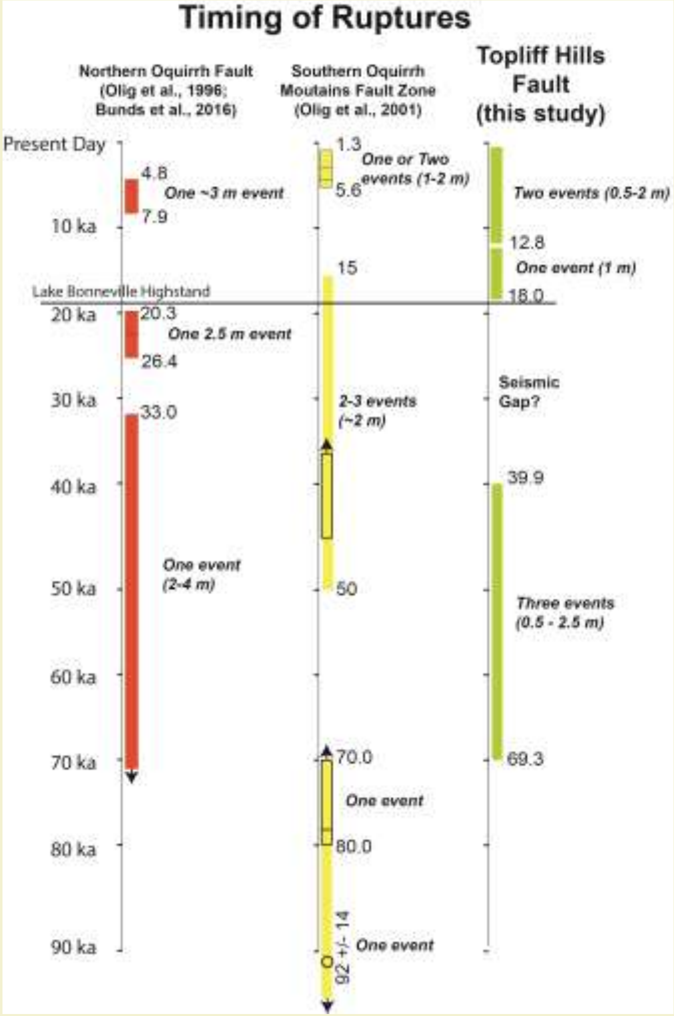
Footwall and Hanging Wall Bonneville Highstand Shoreline Elevations

Footwall Mean:
1578.6 ± 0.4 m

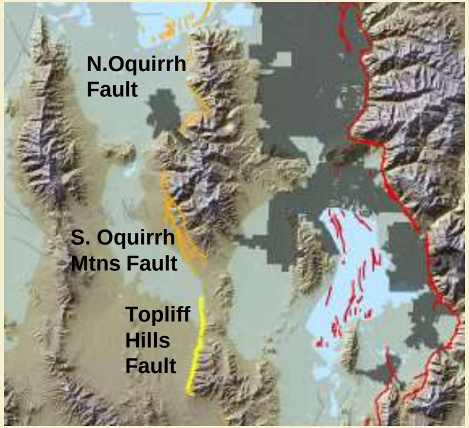
Hangingwall Mean:
1576.5 ± 0.6 m

Bonneville Highstand shoreline vertical displacement = 2.1 ± 1.0 m

Probably 2 - 4 m from trench displacements



Topliff Summary



- **Evidence for 6 events**
- **0.5 – 2.5 m event (2 m average)**
- **3 post-Bonneville events**
- **No events coincident with lake**
- **3 events from 40 - 70 ka**
- **Mean recurrence: 10 ka/event**
- **Recurrence range: 6-22 ka/event**
- **Slip rate: 0.1 - 0.2 mm/a**

Acknowledgements

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

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

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

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

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

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OSL Sampling

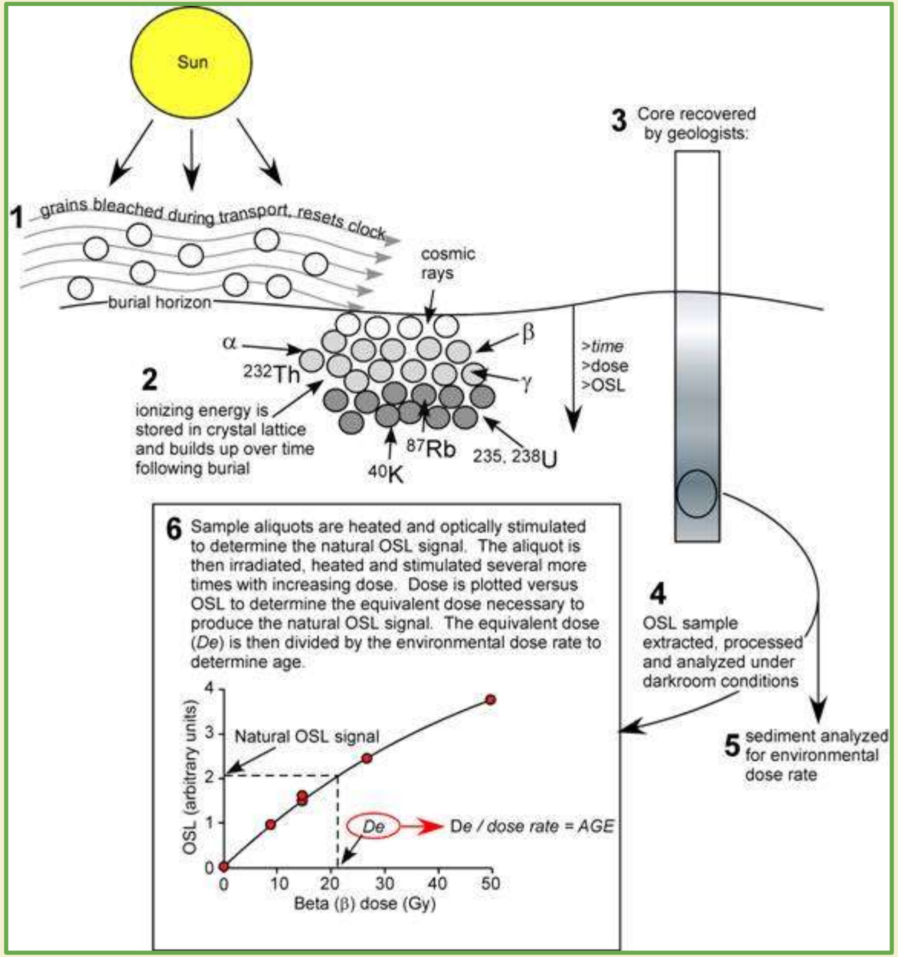
Optically Stimulated Luminescence (OSL) is used to date the last time quartz sediment was exposed to light. The collected sediments are exposed to blue-green light and trapped electrons are released and emit a photon of light. The time is calculated by dividing the equivalent dose (natural luminescence of a sample) by the environmental dose rate.

Age (kyr) = Equivalent Dose (Gy) / Dose Rate (Gy/kyr)

More information available at usu.edu/geo/luminlab

USU LUMINESCENCE LABORATORY

1770 North Research Parkway, Suite 123, North Logan, Utah 84341



1 grains bleached during transport, resets clock

2 ionizing energy is stored in crystal lattice and builds up over time following burial

3 Core recovered by geologists:

4 OSL sample extracted, processed and analyzed under darkroom conditions

5 sediment analyzed for environmental dose rate

6 Sample aliquots are heated and optically stimulated to determine the natural OSL signal. The aliquot is then irradiated, heated and stimulated several more times with increasing dose. Dose is plotted versus OSL to determine the equivalent dose necessary to produce the natural OSL signal. The equivalent dose (*De*) is then divided by the environmental dose rate to determine age.

Mallinson, D., 2008. A Brief Description of Optically Stimulated Luminescence Dating, http://core.ecu.edu/geology/mallinsond/OSL

USGS Earthquake Geology Intermountain West (IMW)

Ryan Gold, USGS Intermountain West Regional Coordinator

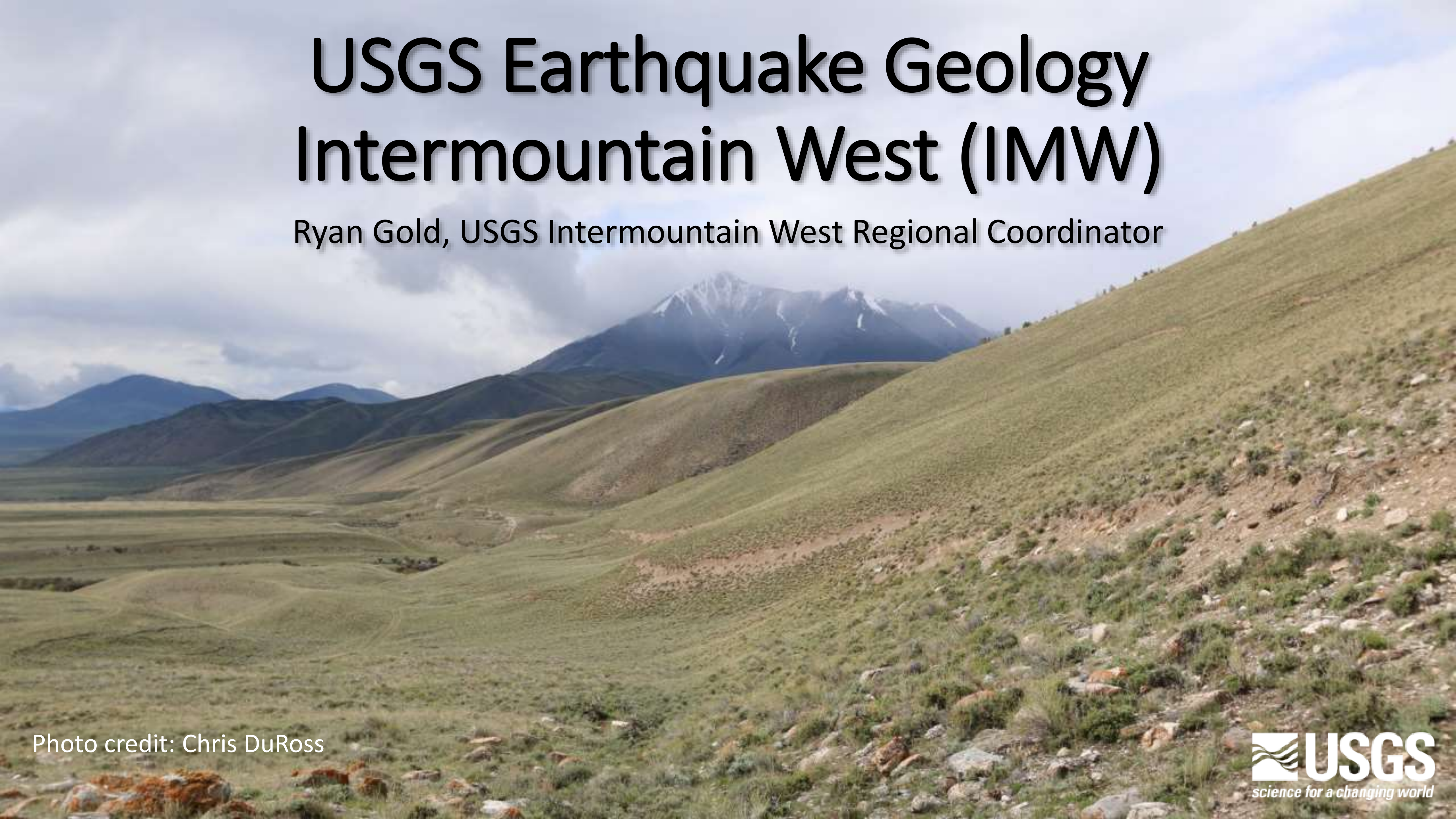
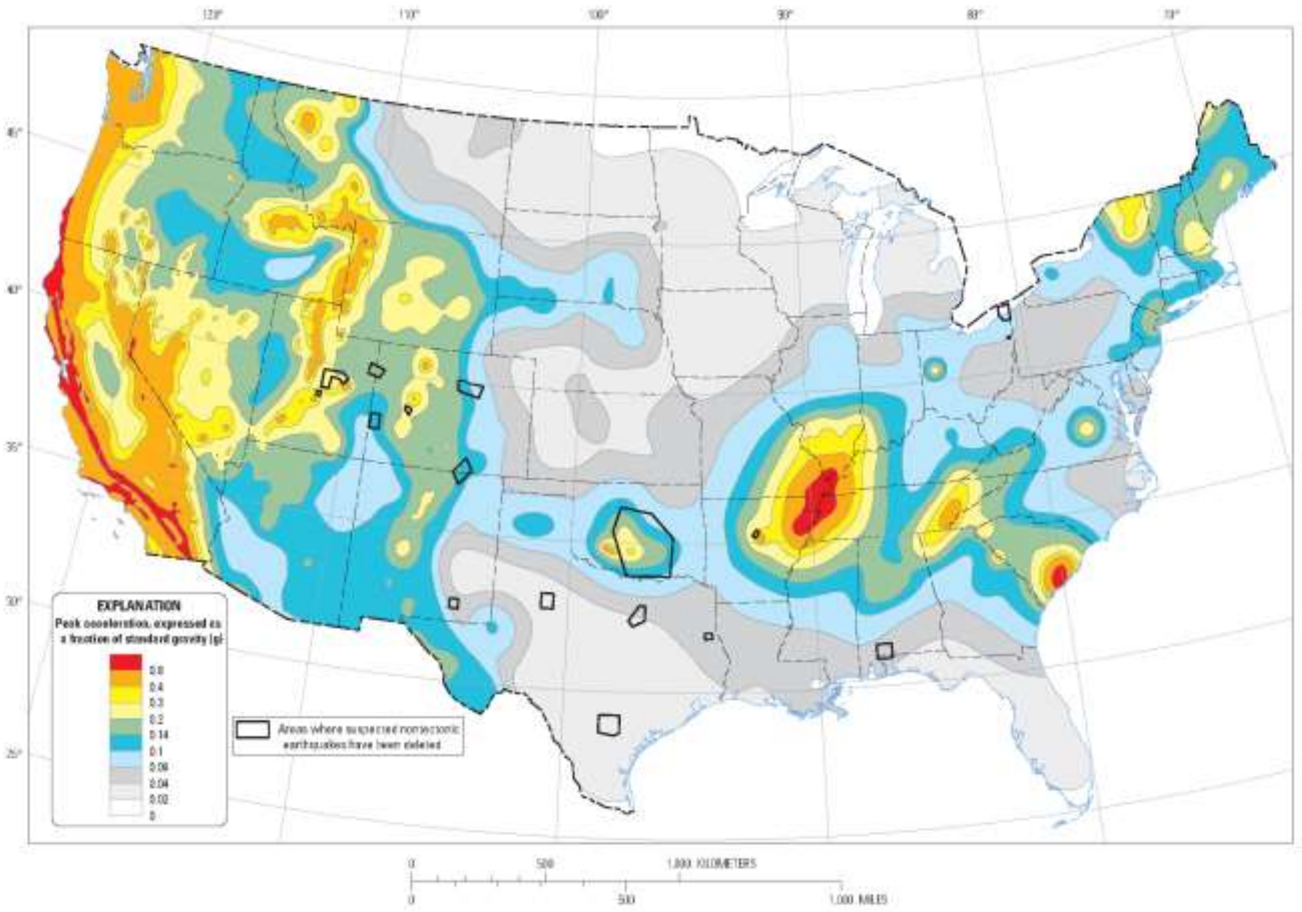


Photo credit: Chris DuRoss

USGS National Seismic Hazard Model 2023



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

- Factored into building codes and impacts billions of dollars in construction
- Impacts insurance rates
- Guide for emergency planning

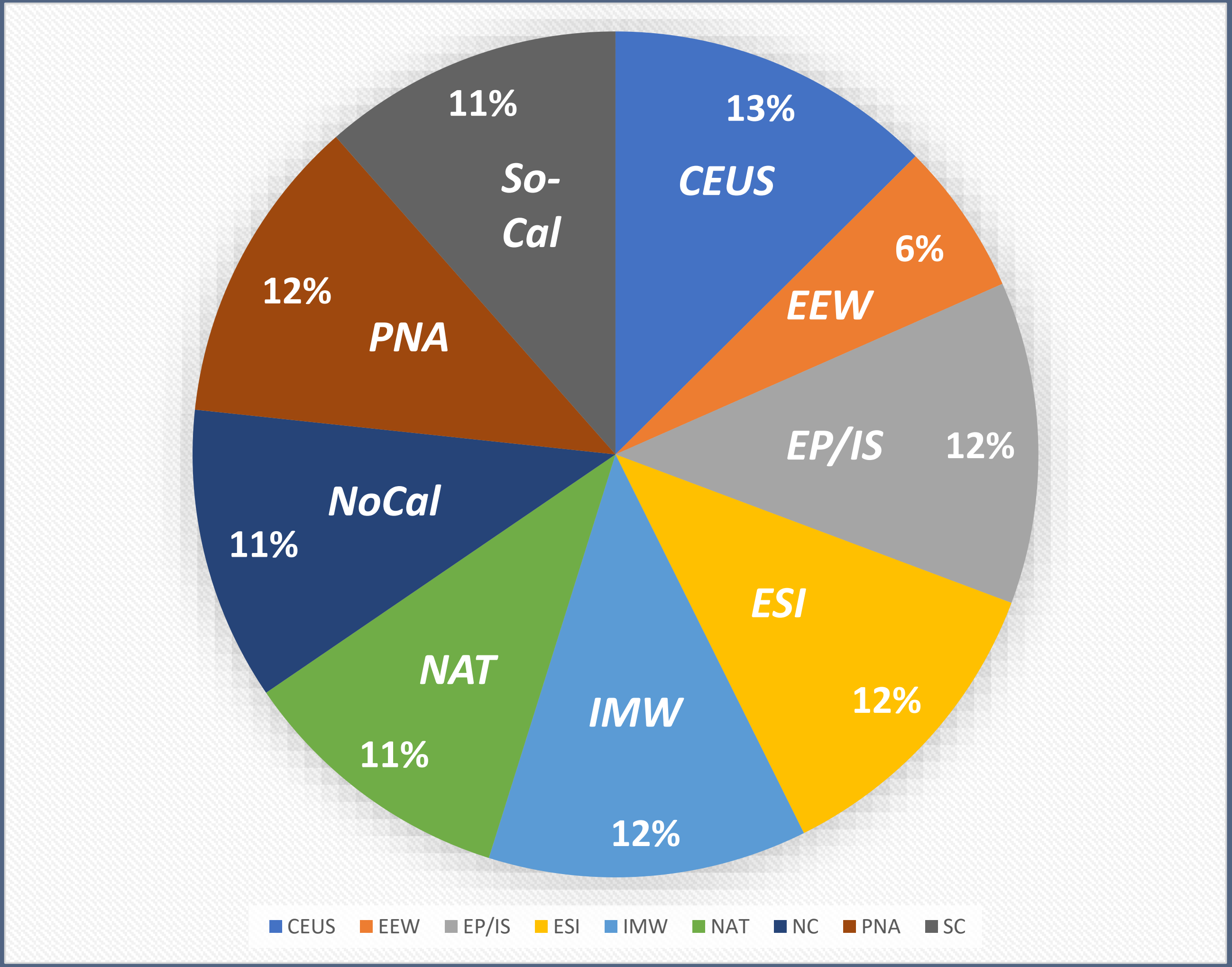
- 2023 update process underway. Current focus (2020) on source fault model. More details tomorrow.

USGS - Ongoing Research and Collaboration in IMW

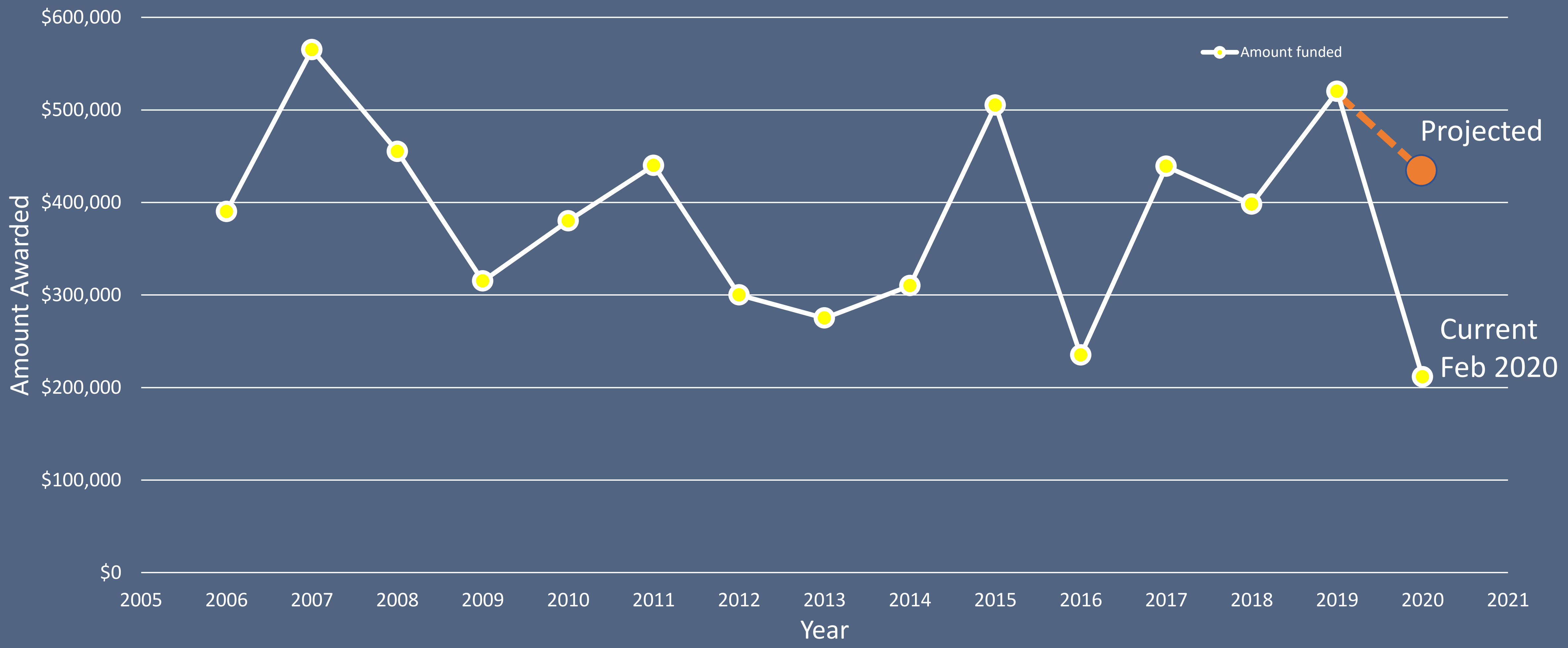
- *Wasatch Front* ***(UGS, UVU)***
- *Teton Range* ***(BoR, USFS, WGS, Univ. of ID, BGC)***
- *Las Vegas* ***(NBMG, UNR, UNLV)***
- *NE California* ***(PG&E, Univ. of Oregon)***
- *Walker Lane* ***(NBMG, UNR)***
- *Borah Peak, Idaho* ***(UVU, IGS, UGS)***
- *Ridgecrest* ***(CGS, SoCal, UNR)***

USGS External Grants Program, FY2019 (last year)

- $4.3M competitive research grants funded
- 212 Proposals received, 66 funded (31% success rate)
- IMW funded 9 proposals ($519k)



Intermountain West External Grants funding



IMW External Grants 2020 (in progress)

- IMW received 17 proposals (down from 23 proposals in FY19).
- Total request $750k. Best case scenario: $433k will be funded.
- Average proposal in fund/fund if possible category: $43.3k (FY20), down from ~$57.7k in FY19.
- FY20 Federal budget passed (Dec 2019).

Funding by state

- NV: 1 grant funded; 3 in “hold” status
- UT: 0.5 grant funded
- ID: 1 grant in “hold” status
- AZ: 0.5 grant funded grant in “hold” status
- MT: 1 grant in “hold” status
- CO: 1 grant funded
- IMW general: 1 grant funded
- Meetings/Workshops: 1 grant funded

External Grants – guidance going forward (FY21)

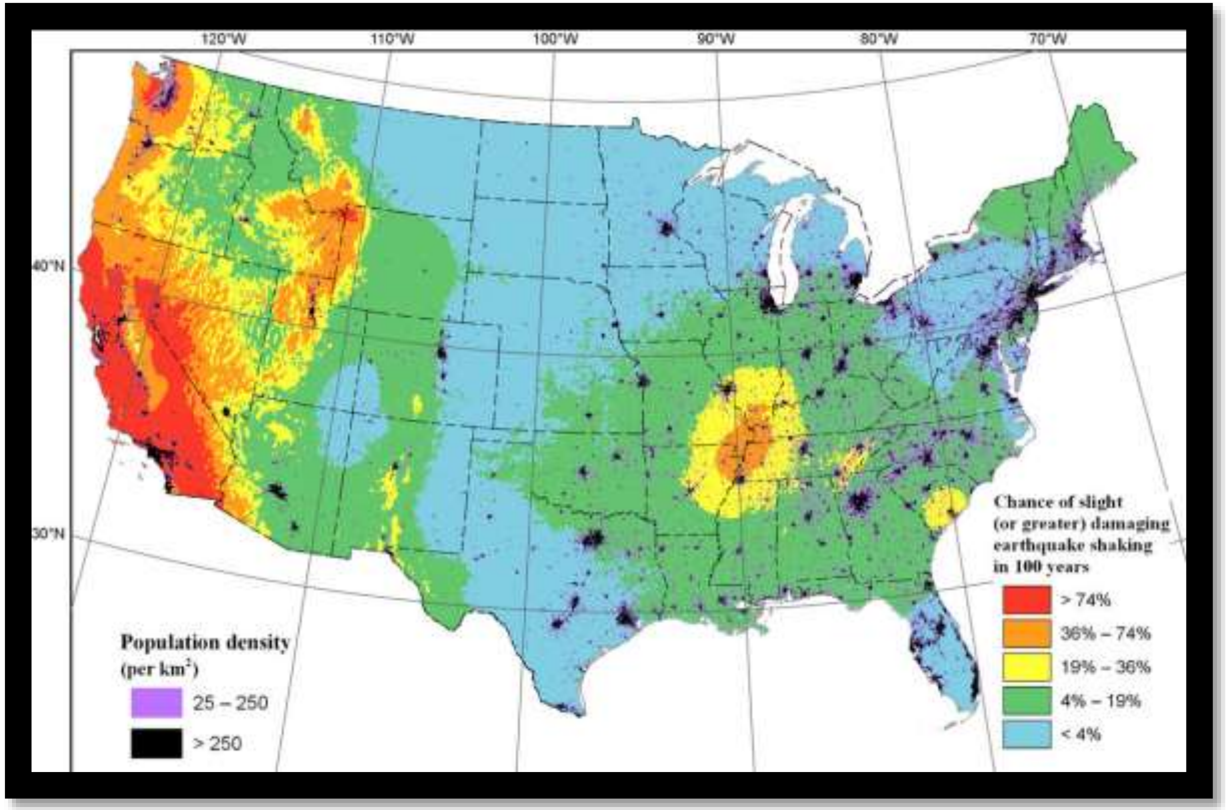
- Look for program announcement in March 2020.
- Proposal dues in ~May 2020.
- Panel meets in August – please contact me (rgold@usgs.gov) if you’d be interested in serving and won’t have conflict of interest (e.g., submitting a proposal this year or from an institution submitting proposals).
- USGS letters of commitment.
- Panels scrutinize history of publishing USGS-funded research.

Updates to Utah geology input data for 2023 USGS National Seismic Hazard Model

Alex Hatem, Ryan Gold, Rich Briggs, Ned Field, Peter Powers, Camille Collett
USGS-Golden, CO

Motivation

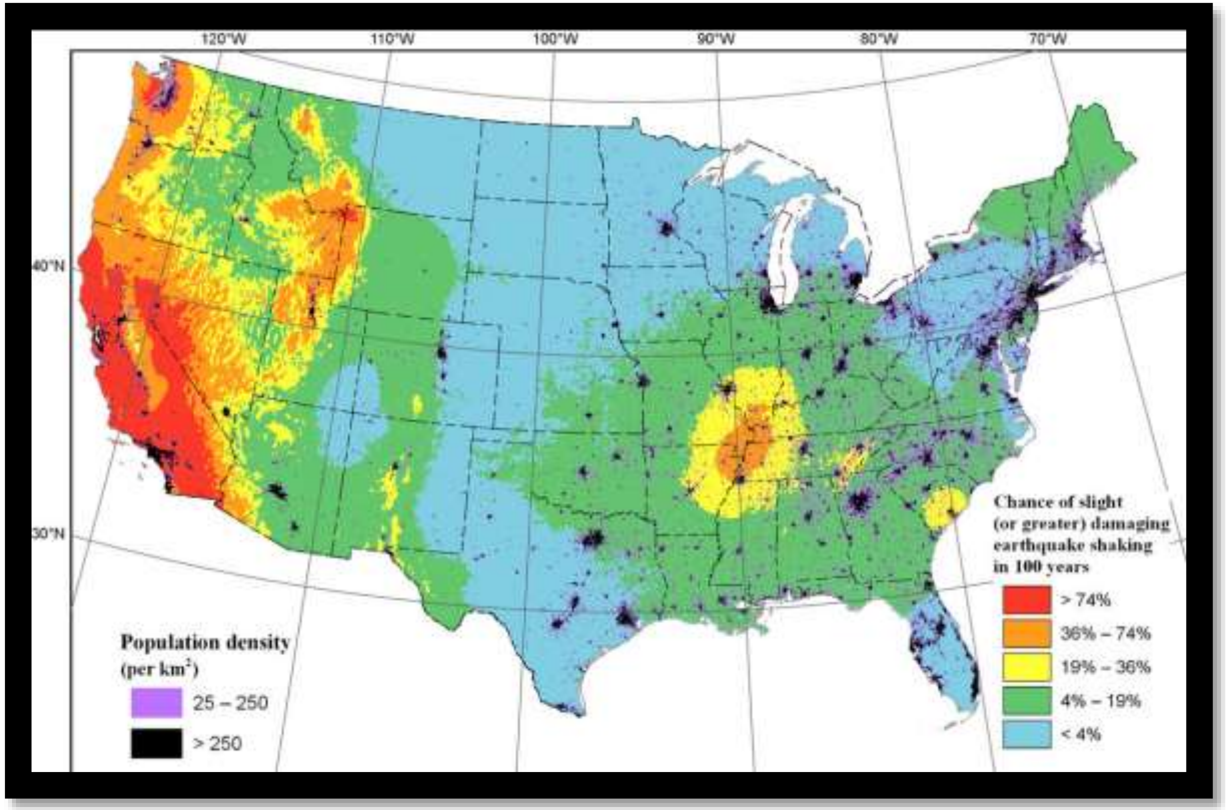
- USGS plans to release an update to U.S. National Seismic Hazard Model (NSHM) in 2023
- Geologic inputs have not been updated for NSHM since 2014, despite a map release in 2018
- Poorly organized geologic data for inputs to deformation model



Petersen et al., 2019

Goals

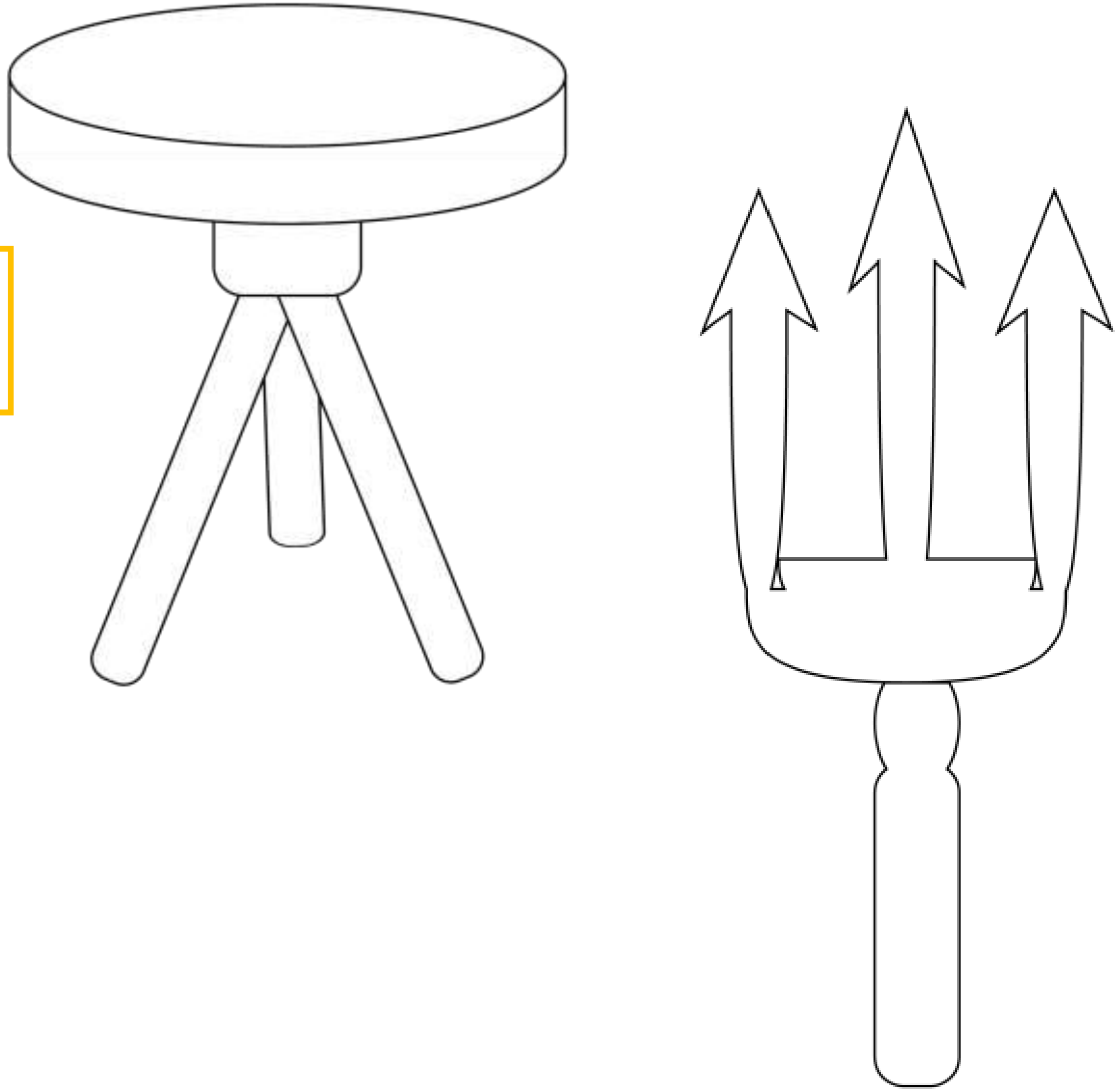
- Provide NSHM group with most up-to-date knowledge of earthquake geology across the U.S.
- Organize geologic data into a useable, shareable format
- Create a database of what is known along active faults nationwide



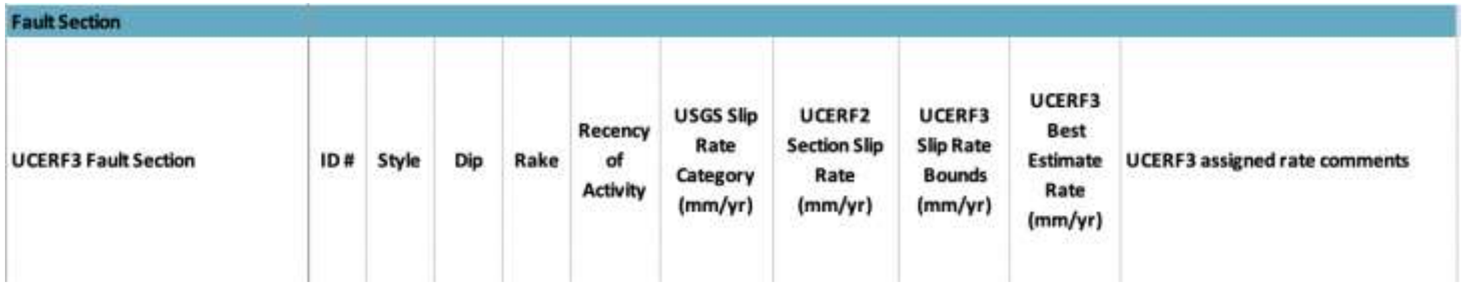
Petersen et al., 2019

Our objectives

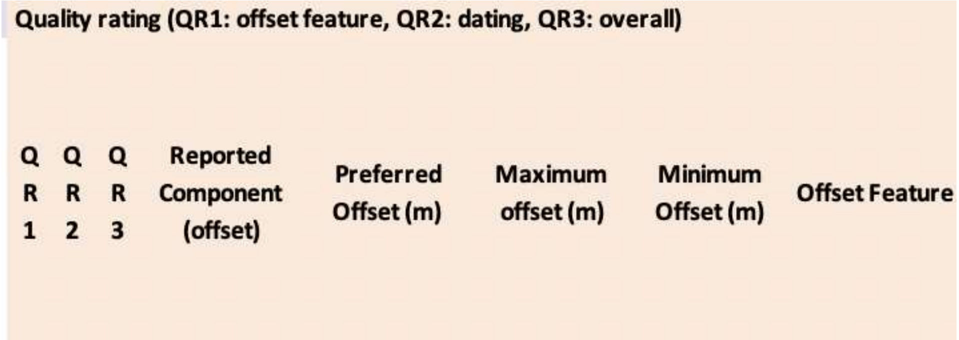
1. Bring the rest of the country up to California (UCERF3) standard
2. Add recent studies to dataset
3. Densify fault network & reassess fault geometries



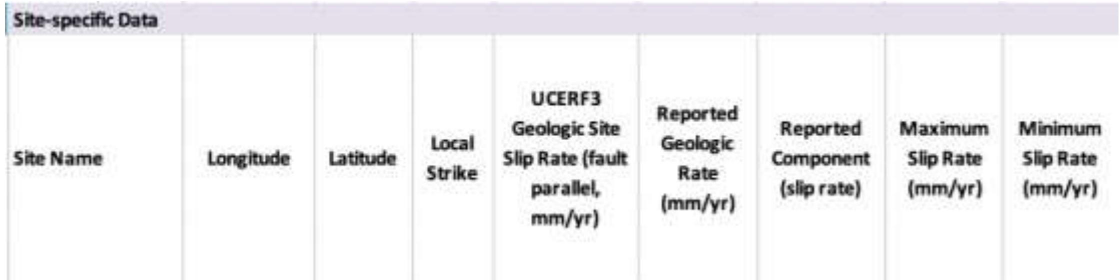
UCERF3 & WGUEP 2016 headers



Fault Section										
UCERF3 Fault Section	ID #	Style	Dip	Rake	Recency of Activity	USGS Slip Rate Category (mm/yr)	UCERF2 Section Slip Rate (mm/yr)	UCERF3 Slip Rate Bounds (mm/yr)	UCERF3 Best Estimate Rate (mm/yr)	UCERF3 assigned rate comments



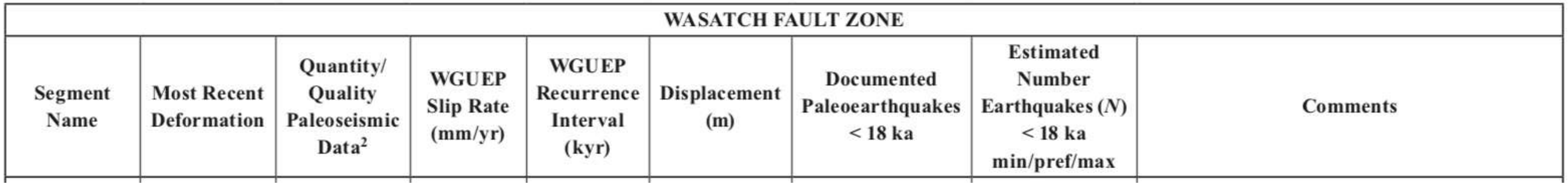
Quality rating (QR1: offset feature, QR2: dating, QR3: overall)							
QR1	QR2	QR3	Reported Component (offset)	Preferred Offset (m)	Maximum offset (m)	Minimum Offset (m)	Offset Feature



Site-specific Data								
Site Name	Longitude	Latitude	Local Strike	UCERF3 Geologic Site Slip Rate (fault parallel, mm/yr)	Reported Geologic Rate (mm/yr)	Reported Component (slip rate)	Maximum Slip Rate (mm/yr)	Minimum Slip Rate (mm/yr)

Preferred Start Age (ka)	Maximum Start Age (ka)	Minimum Start Age (ka)	Preferred End Age	Maximum End Age	Minimum End Age	Dating Method	Slip rate time frame category (ka)

Table 4.6-1. Estimated surface-faulting earthquakes < 18 ka for the WGUEP Wasatch Front region.

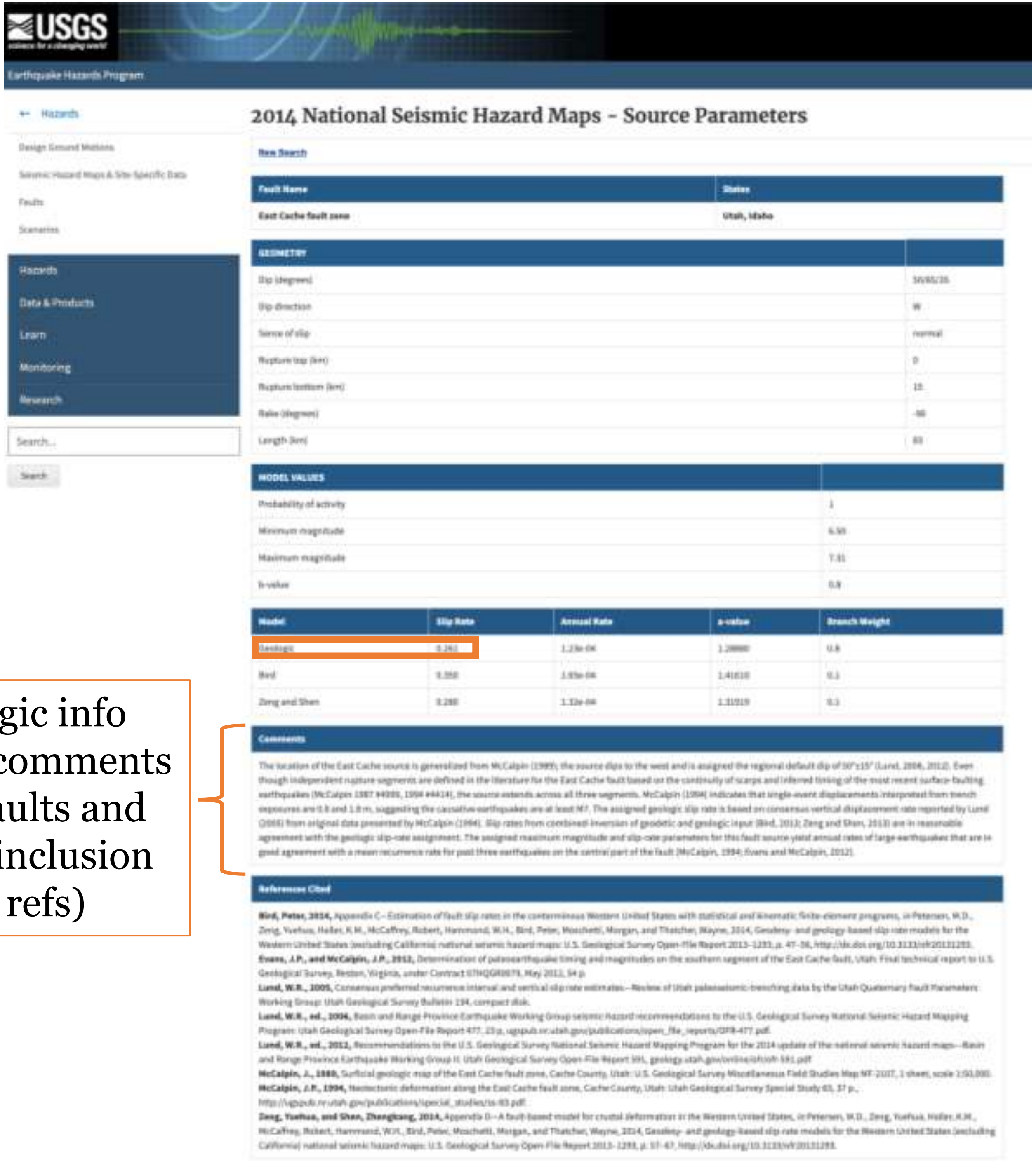


WASATCH FAULT ZONE								
Segment Name	Most Recent Deformation	Quantity/ Quality Paleoseismic Data[2]	WGUEP Slip Rate (mm/yr)	WGUEP Recurrence Interval (kyr)	Displacement (m)	Documented Paleoearthquakes < 18 ka	Estimated Number Earthquakes (N) < 18 ka min/pref/max	Comments

NSHM 2014

Example: East Cache fault zone

No metadata fields for NSHM “hazfaults” included in source parameter page



2014 National Seismic Hazard Maps - Source Parameters

Fault Name	States
East Cache fault zone	Utah, Idaho

GEOMETRY	
Dip (degrees)	50/65/35
Dip direction	W
Sense of slip	normal
Rupture top (km)	0
Rupture bottom (km)	15
Rake (degrees)	-90
Length (km)	63

MODEL VALUES	
Probability of activity	1
Minimum magnitude	6.50
Maximum magnitude	7.31
b-value	0.8

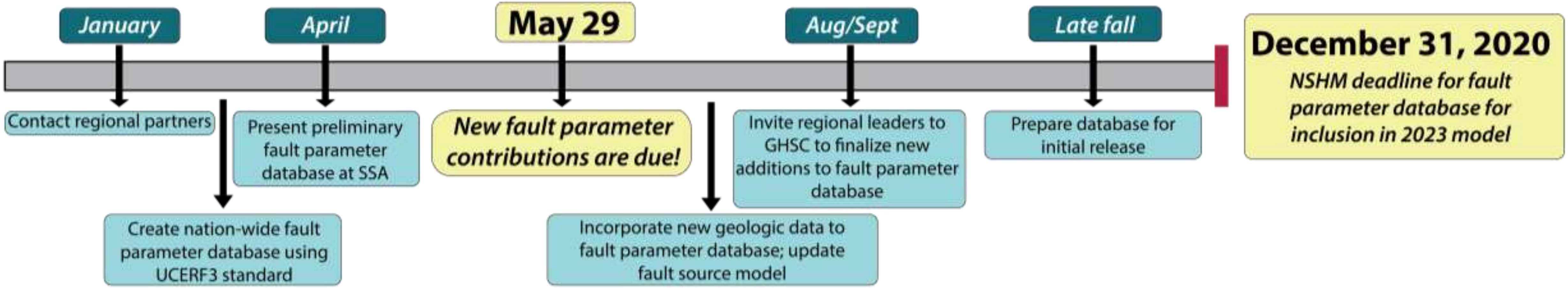
Model	Slip Rate	Annual Rate	a-value	Branch Weight
Geologic	0.262	1.23e-04	1.28880	0.8
Bird	0.350	1.65e-04	1.41610	0.1
Zeng and Shen	0.280	1.32e-04	1.31919	0.1

Comments

References Cited

Some geologic info embedded in comments (not for all faults and inconsistent inclusion of data & refs)

Our timeline



January

Contact regional partners

Create nation-wide fault parameter database using UCERF3 standard

April

Present preliminary fault parameter database at SSA

May 29

New fault parameter contributions are due!

Incorporate new geologic data to fault parameter database; update fault source model

Aug/Sept

Invite regional leaders to GHSC to finalize new additions to fault parameter database

Late fall

Prepare database for initial release

December 31, 2020

NSHM deadline for fault parameter database for inclusion in 2023 model

- Time is tight, but we will do what we can
- This will hopefully become a regularly updated database, so what is not included this time will be considered in future iterations

What data do we need to achieve these goals?

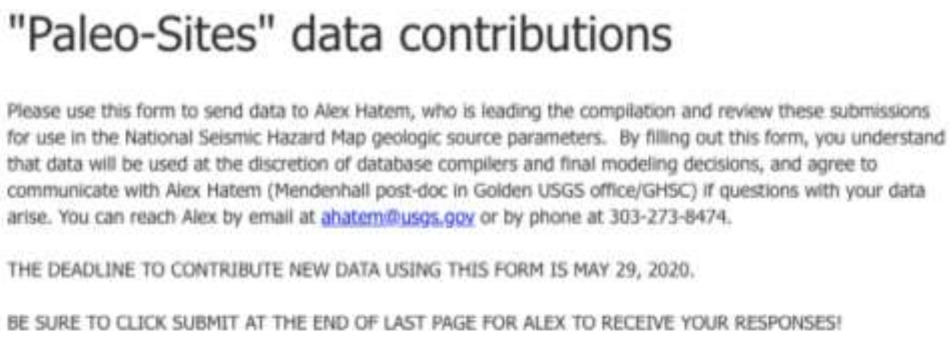
- Geologic slip rates
- Paleoearthquake data
- Slip per event estimates
- Fault geometries

….and metadata!

How can you contribute/get involved?

- Microsoft form is accessible online for all agencies
- Flexibility in how to get your data to me
  - form is not the only vehicle!

General fault info

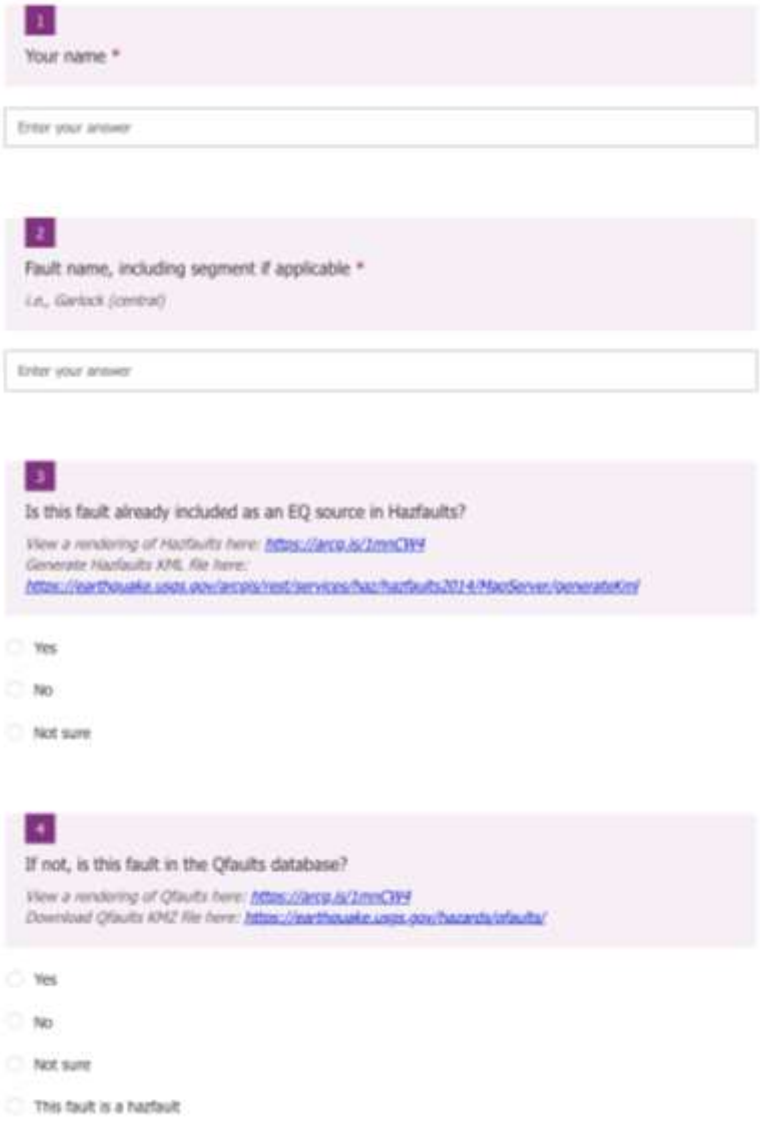


"Paleo-Sites" data contributions

Please use this form to send data to Alex Hatem, who is leading the compilation and review these submissions for use in the National Seismic Hazard Map geologic source parameters. By filling out this form, you understand that data will be used at the discretion of database compilers and final modeling decisions, and agree to communicate with Alex Hatem (Mendenhall post-doc in Golden USGS office/GHSC) if questions with your data arise. You can reach Alex by email at ahatem@usgs.gov or by phone at 303-273-8474.

THE DEADLINE TO CONTRIBUTE NEW DATA USING THIS FORM IS MAY 29, 2020.

BE SURE TO CLICK SUBMIT AT THE END OF LAST PAGE FOR ALEX TO RECEIVE YOUR RESPONSES!



1

Your name *

Enter your answer

2

Fault name, including segment if applicable *

i.e., Garlock (central)

Enter your answer

3

Is this fault already included as an EQ source in Hazfaults?

View a rendering of Hazfaults here: https://arcg.is/1mnCW4
Generate Hazfaults KML file here:
https://earthquake.usgs.gov/arcgis/rest/services/haz/hazfaults2014/MapServer/generateKml

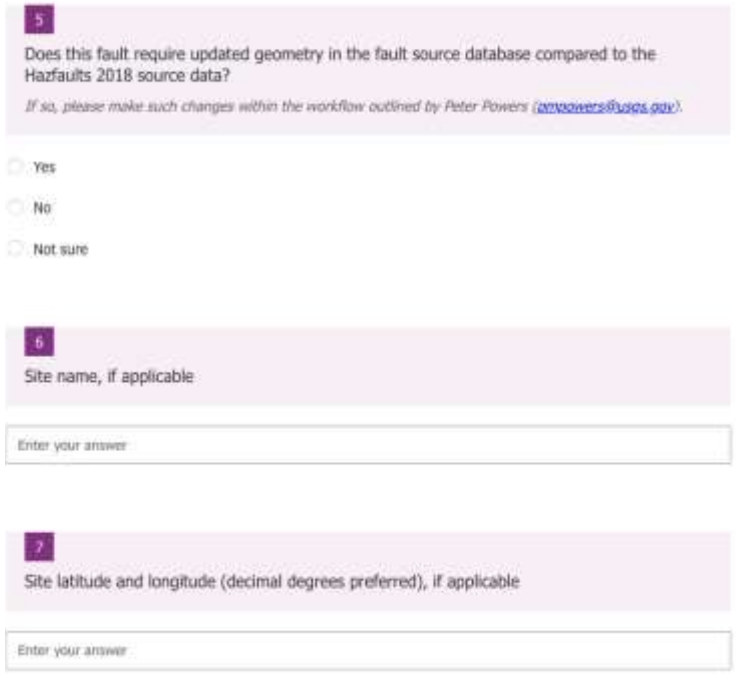
○ Yes
○ No
○ Not sure

4

If not, is this fault in the Qfaults database?

View a rendering of Qfaults here: https://arcg.is/1mnCW4
Download Qfaults KMZ file here: https://earthquake.usgs.gov/hazards/qfaults/

○ Yes
○ No
○ Not sure
○ This fault is a hazfault



5

Does this fault require updated geometry in the fault source database compared to the Hazfaults 2018 source data?

If so, please make such changes within the workflow outlined by Peter Powers (pmpowers@usgs.gov).

○ Yes
○ No
○ Not sure

6

Site name, if applicable

Enter your answer

7

Site latitude and longitude (decimal degrees preferred), if applicable

Enter your answer

Geologic data fields within form

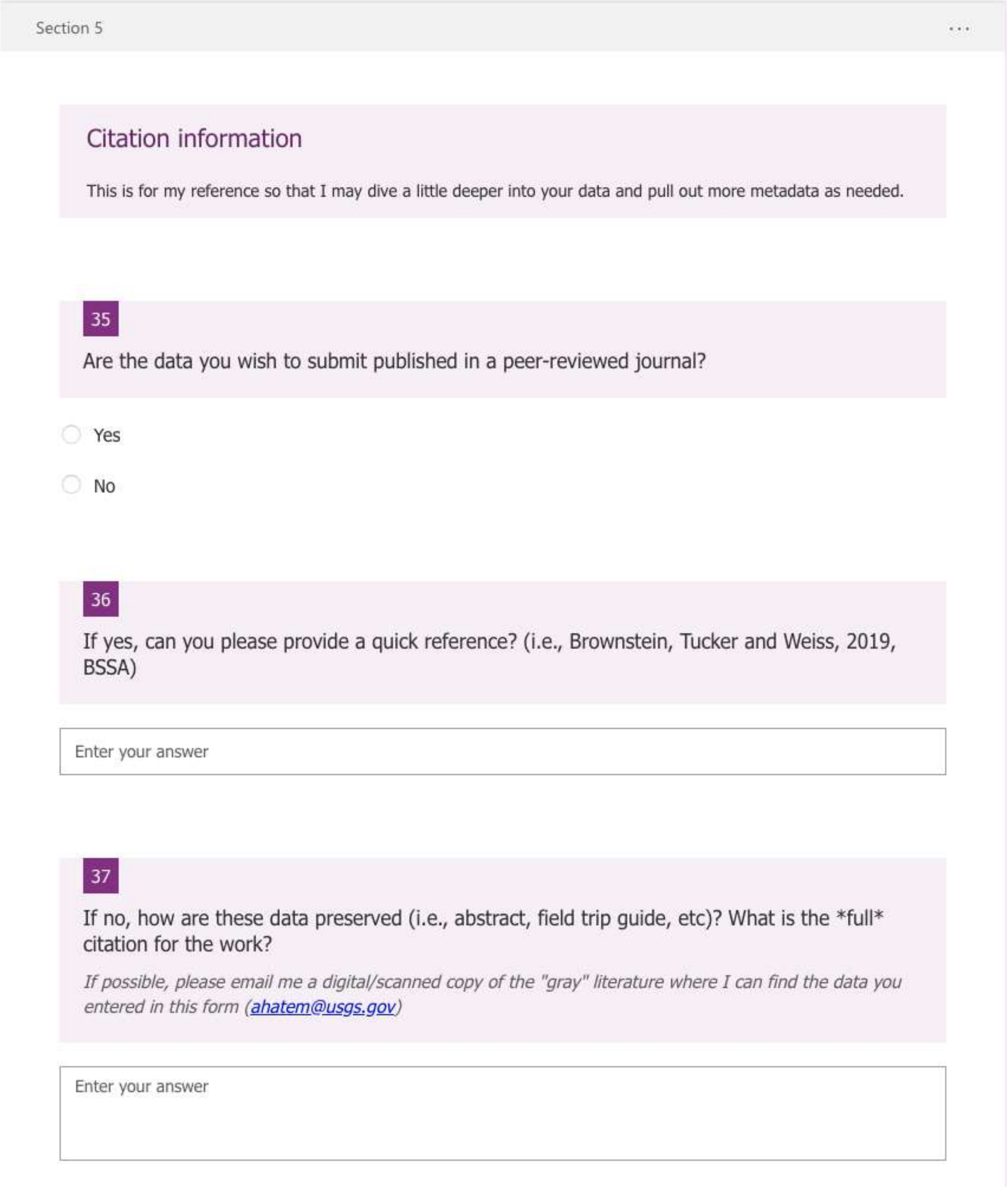
- Slip rates
  - Time interval, dating method, uncertainty in measurements, how many EQ intervals included in each rate, ratings, etc…

- Paleoearthquakes
  - Oxcal input files, number of events, depositional hiatuses, ratings, etc…

- Slip per event
  - Show your work!

Citation information

- Willing to accept anything for internal review, but unpublished/unreviewed work may not be included in the final database
- Our preference is peer-reviewed articles
- Because USGS is a public entity, all data should be available to the public



Section 5

Citation information

This is for my reference so that I may dive a little deeper into your data and pull out more metadata as needed.

35

Are the data you wish to submit published in a peer-reviewed journal?

○ Yes

○ No

36

If yes, can you please provide a quick reference? (i.e., Brownstein, Tucker and Weiss, 2019, BSSA)

Enter your answer

37

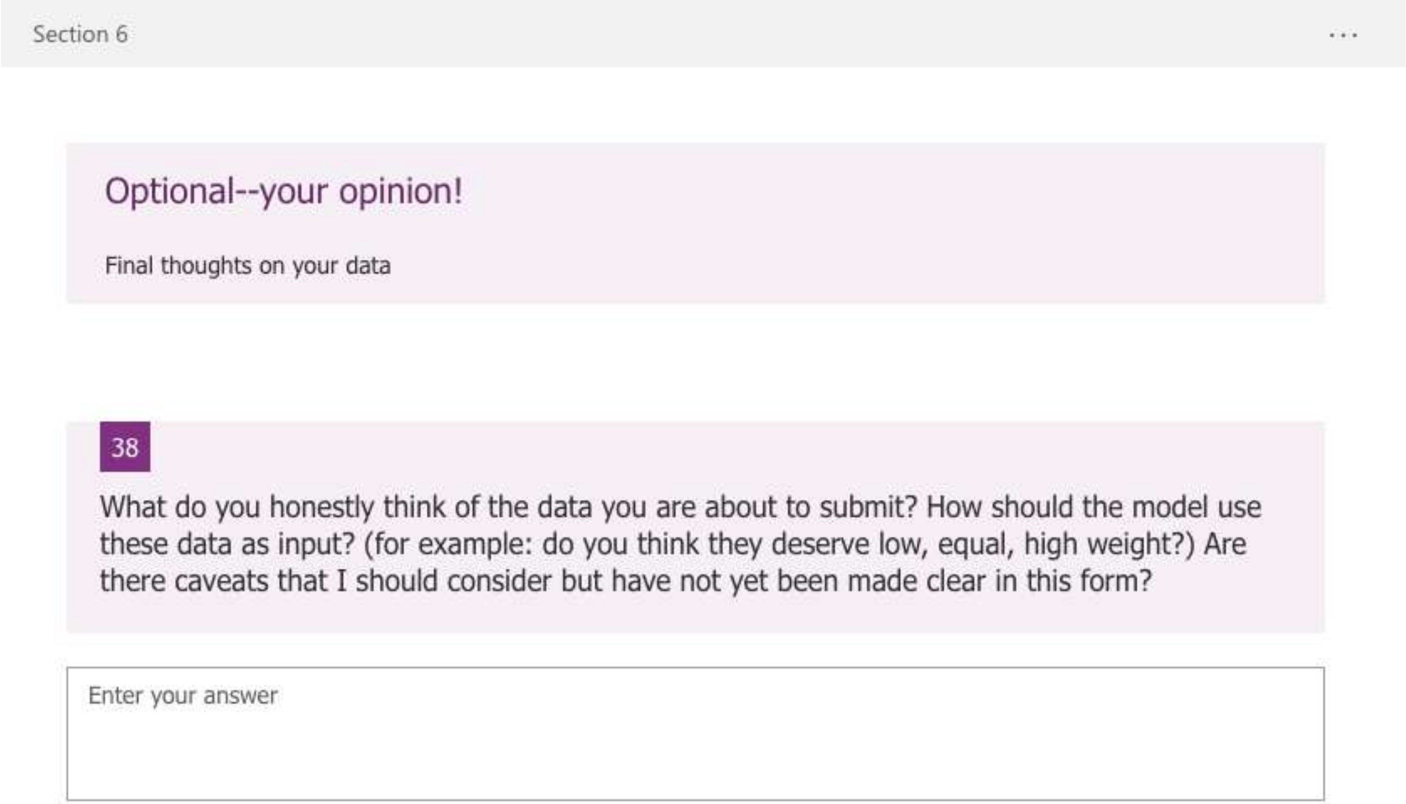
If no, how are these data preserved (i.e., abstract, field trip guide, etc)? What is the *full* citation for the work?

If possible, please email me a digital/scanned copy of the "gray" literature where I can find the data you entered in this form (ahatem@usgs.gov)

Enter your answer

Overall interpretation

- Attempt to capture the nuance in geologic data that may not be well-expressed otherwise in the form questions/publication on this site



Optional--your opinion!

Final thoughts on your data

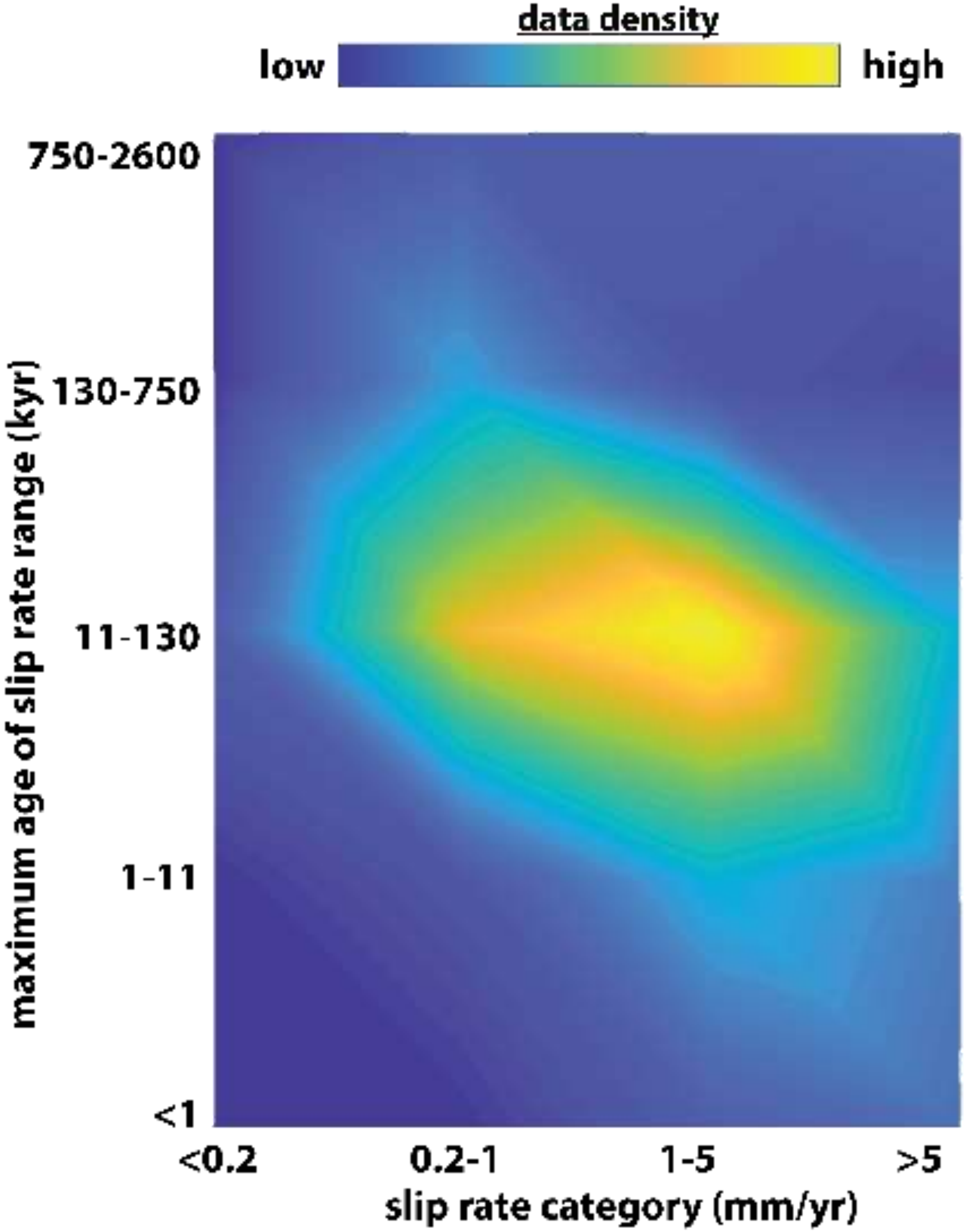
38

What do you honestly think of the data you are about to submit? How should the model use these data as input? (for example: do you think they deserve low, equal, high weight?) Are there caveats that I should consider but have not yet been made clear in this form?

Importance of database science

- Apparent sampling bias of slip rates in California as sampled by Dawson and Weldon, 2013 for UCERF3
  - *Does this bias matter for hazard calculations?*
  - *How does hazard change when using similarly aged*

  → Conduct sensitivity analyses



Importance of site-specific data

- Capture changes in geologic behavior along faults measured as points on a line

→Example for why this matters:

Potential to highlight non-geometric segmentation

(could be expressed as slip rate gradients along strike)

State of Utah data

USGS Qfaults:

thin black lines

USGS NSHM faults ('hazfaults'):

thick blue lines

USGS 'site_investigations':

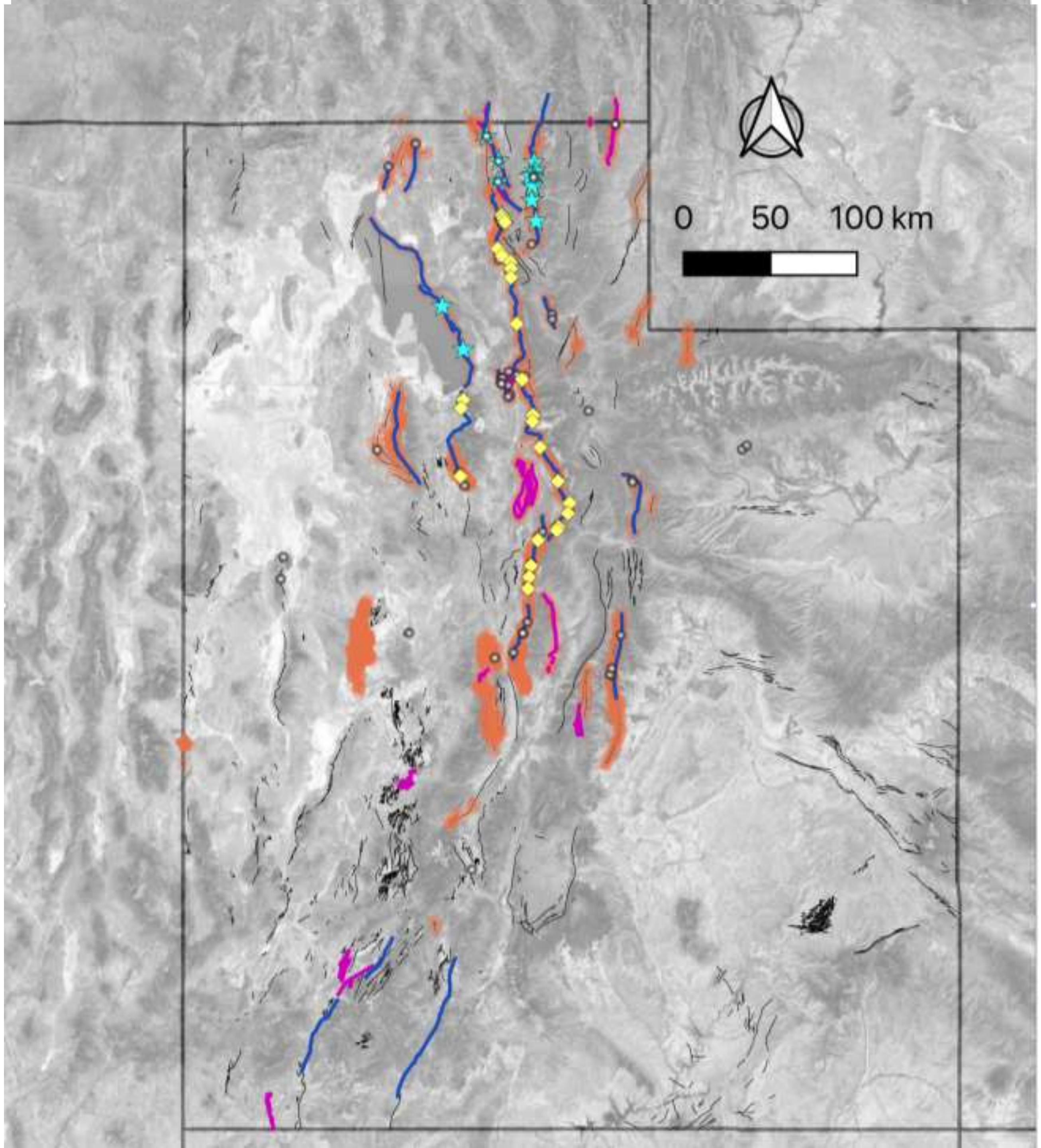
white dots

USGS reviewed 'paleo_sites':

aqua stars

USGS 'paleo_sites' ID'ed/to be reviewed:

yellow diamonds



WGEUP modeled faults incl. as Qfaults:

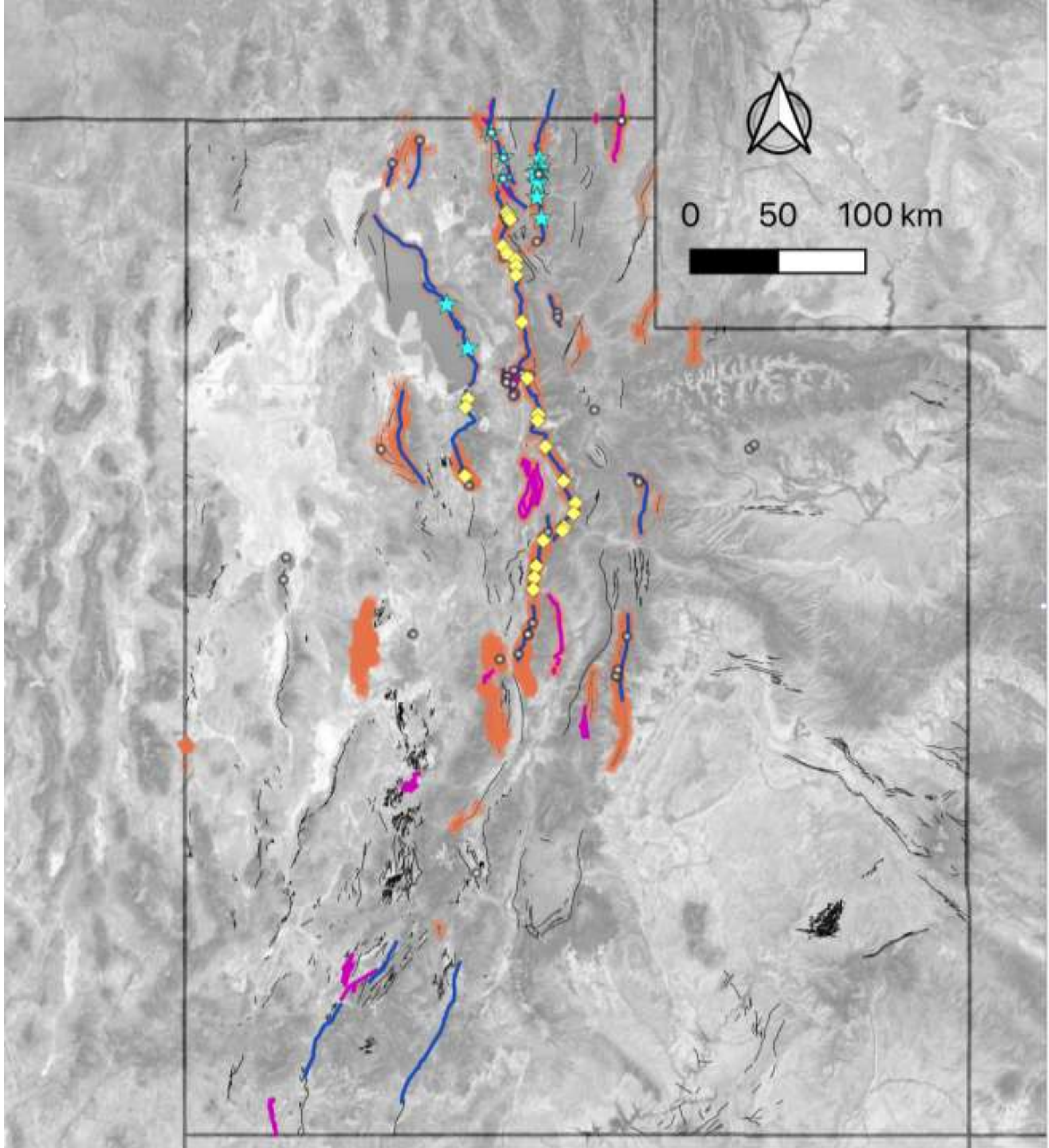
orange highlights

Faults of concern (Lund, 2005; WGUEP 2016):

pink lines

Room for improvement

- Focus on improving USGS NSHM faults to match WGUEP modelled faults
- Utilize state knowledge in national model



Contributions are welcome from now until May 29, 2020!

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