Preliminary Investigation of the Thousand Lake Fault from the Mid Miocene to Late Pleistocene:

An Approach for Characterizing Low Slip Rate Normal Faults Using Geomorphology and Paleoseismology

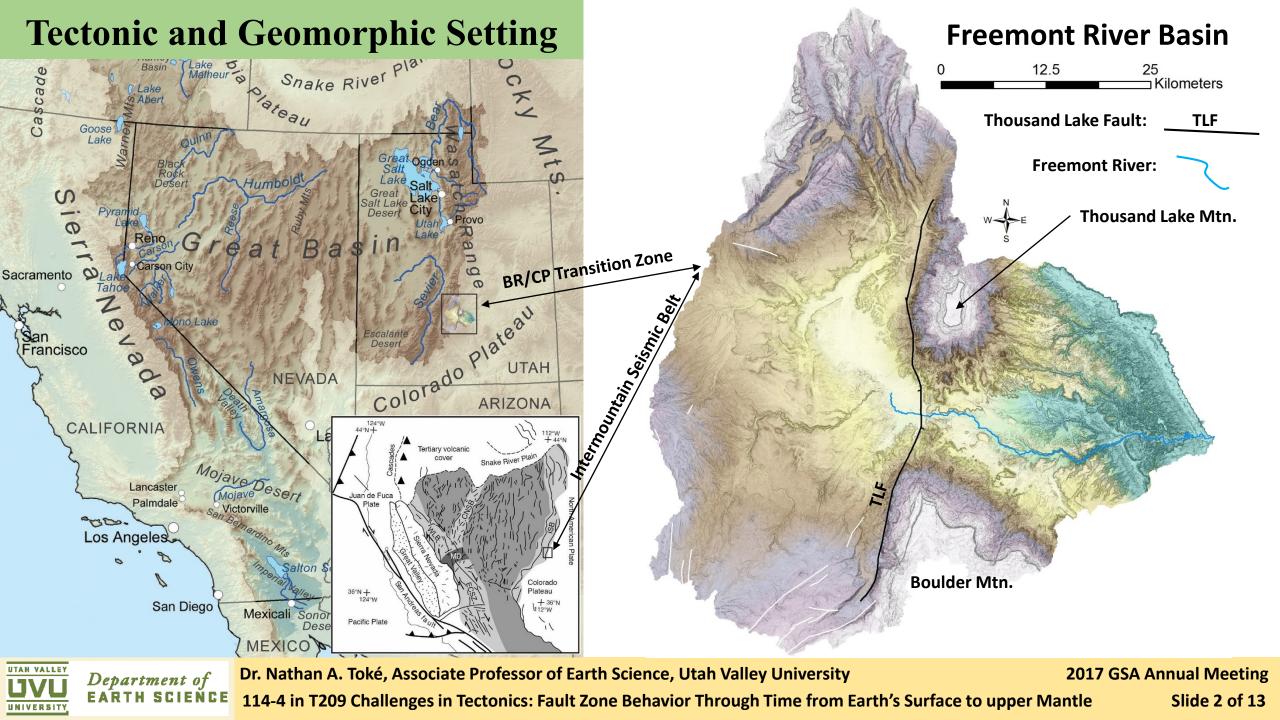




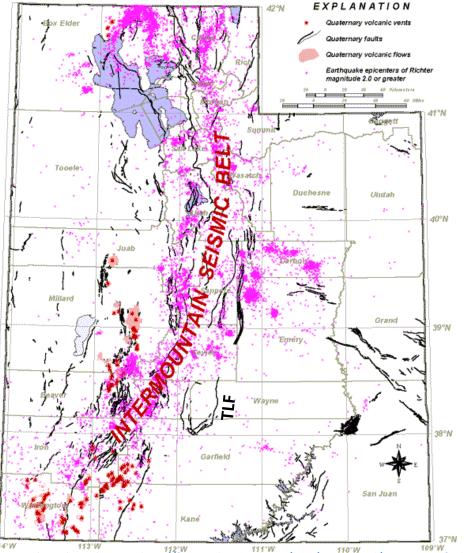
Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University
 2017
 CE 114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

2017 GSA Annual Meeting

Slide 1 of 13



Prior Information about the Thousand Lake Fault



Quaternary Activity?

- Last Activity since 750 ka (Utah Q Fault Database)
 - faulted terraces that formed since start of Mid Quaternary
- Last Active before 125 ka (Marchetti et al., 2007)
 - undisturbed landslide deposits covering TLF on Boulder Mtn.

Earthquake Size?

• Fault Length ~ 49 km

Slip Rate?

• < 0.2 mm/yr (Utah Q Fault Database)

What more can we say today?

From Utah Geological Survey: <u>http://files.geology.utah.gov/emp/geothermal/quaternary_faul</u>ts.htm

Earthquake epicenters and Quaternary tectonic features in relation to the Intermountain seismic belt (after Smith and Sbar, 1974; Hecker, 1993; and Black and others, 2000).

UTAH VALLEY UNIVERSITY UNIVERSITY Department of EARTH SCIENI Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

2017 GSA Annual Meeting

EARTH SCIENCE 114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

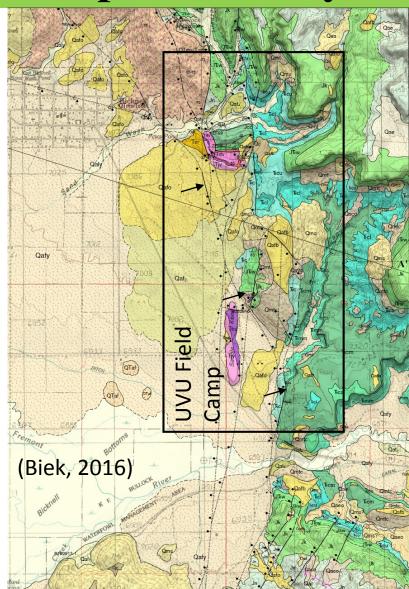
Slide 3 of 13

Methods: Mapping, Paleoseismic Recon, and Spatial Analysis



What's the character of faulting

- Fault zone width?
- Seek out Paleoseismic outcrops.
- Displacement per event?
- Most recent activity?
- Slip rate?
- -Mapped/Recon. about 5 x 2.5 km
 -Used GIS to determine LT Slip Rate
 -Documented paleoseismic outcrops
 -Measured displacement of surfaces
 -Explored Freemont R. terraces in GIS



UTAH VALLEY UNIVERSITY UNIVERSITY Department of EARTH SCIENCE Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

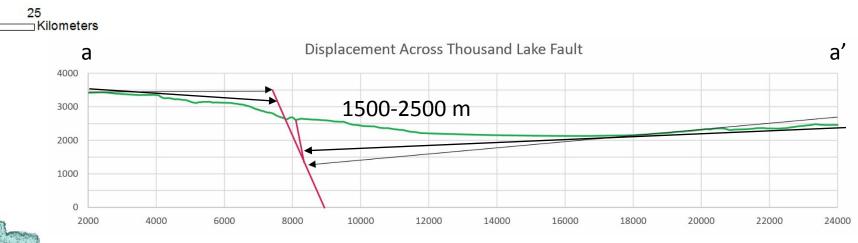
2017 GSA Annual Meeting

ICE 114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

Slide 4 of 13

Total Displacement and Long Term Slip Rate

12.5



- Age of Displaced Volcanics ~24.5 Mya (e.g., Mattox, 1991)
- Tectonic Initiation 10-16 Mya (e.g., McQuarrie and Warnicke, 2005)

Near Fault Center

Minimum Long Term Slip Rate ~ 0.1 mm/yr Maximum Long Term Slip Rate ~ 0.25 mm/yr

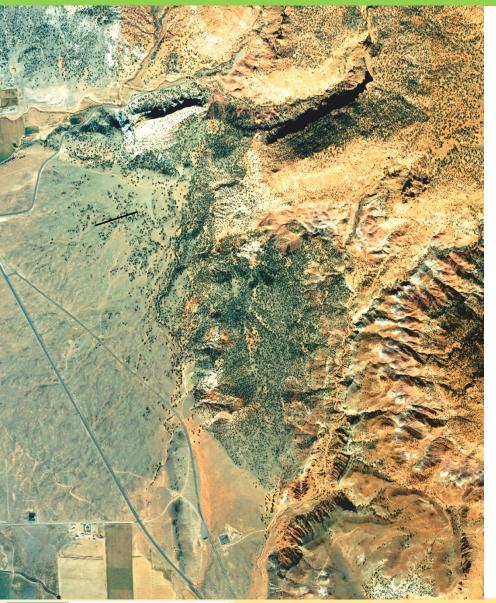
UTAH VALLEY UVU UNIVERSITY Department of EARTH SCIENCE Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

2017 GSA Annual Meeting

114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

Slide 5 of 13

Earthquake Evidence – Fault Scarps





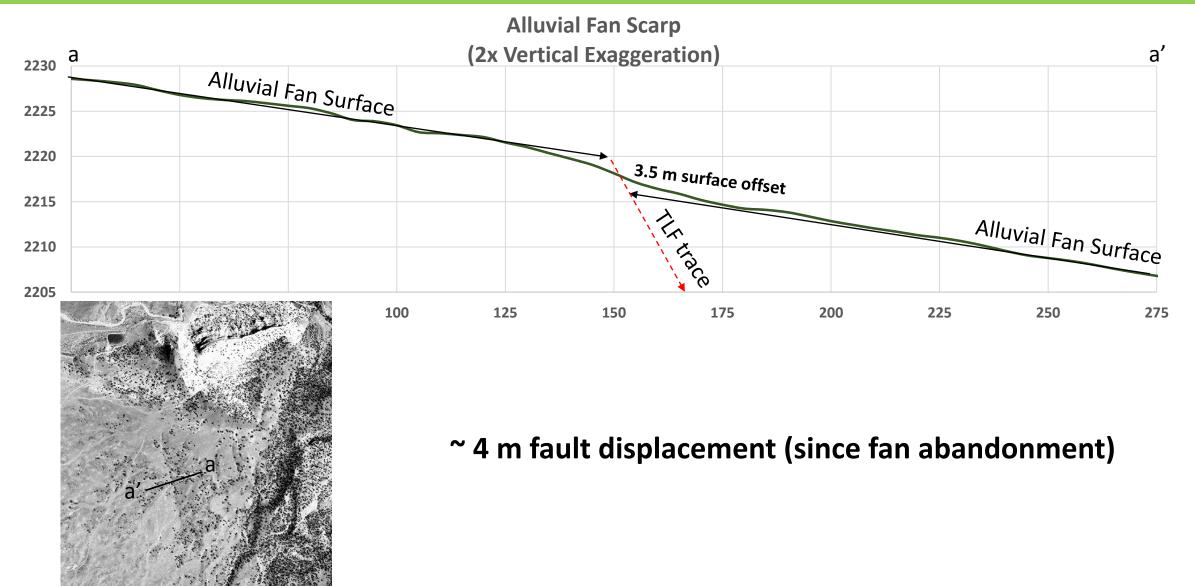


UTAH VALLEY UNIVERSITY Department of EARTH SCIENCE

Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University201202203203204204205<

2017 GSA Annual Meeting ntle Slide 6 of 13

Fault Scarp Displacement Analysis



Department of Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

UTAH VALLEY

UNIVERSITY

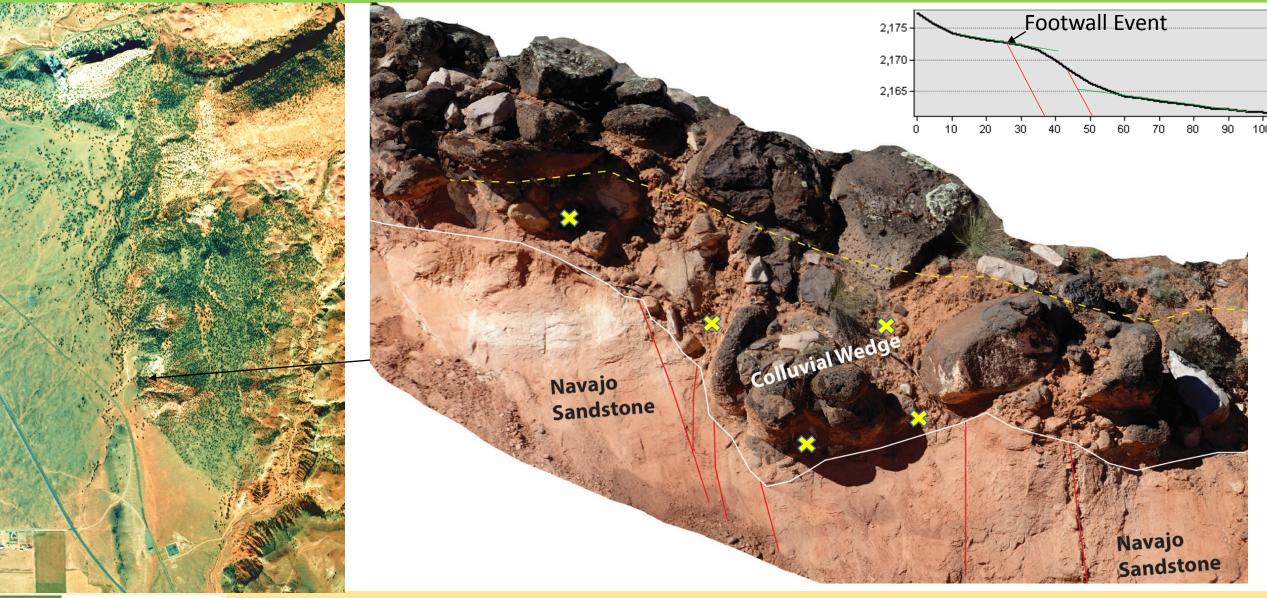
EARTH SCIENCE

2017 GSA Annual Meeting

114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

Slide 7 of 13

Earthquake Evidence – Footwall Colluvial Wedge



114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle



Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

2017 GSA Annual Meeting

Slide 8 of 13

Earthquake Evidence – Fault-derived Colluvium





Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University **2017 GSA Annual Meeting** 114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

Slide 9 of 13

Paleoseismic Reconnaissance Recap



- Footwall faulting in Terrace 10-12 m above local base level: Slip-per-event = ~ 1+ m/event Expected recurrence rate
 - 1m/0.25 mm/yr = 4,000 yrs
 - 2m/0.1 mm/yr = 20,000 yrs
- Alluvial Fan surface with 4 m displacement
 - Given slip rate, possibly a surface associated with end of Last Glacial Maximum (15-25 kya)
 - 2-4 events since surface abandonment.
- Anticipated Mw: 6.8 7.2 (30-50 km-long ruptures, 1-2 m displacement, 20 km depth)

Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

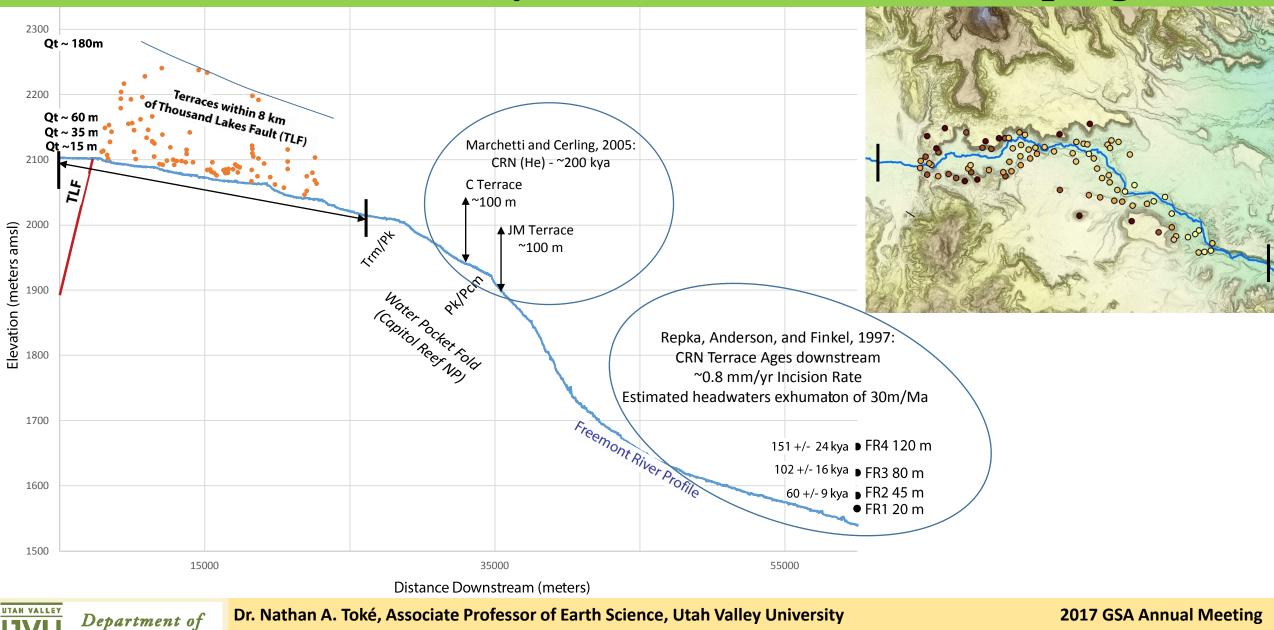
2017 GSA Annual Meeting

VALUET VERBITY VERBITY Department of EARTH SCIENC

^E 114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

Slide 10 of 13

Pleistocene Activity Evidence – Terrace Warping



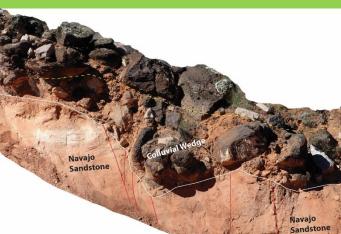
EARTH SCIENCE 114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

UNIVERSITY

Slide 11 of 13

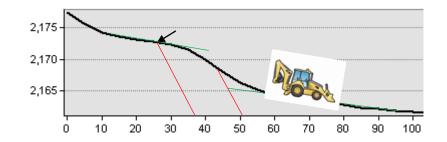
Preliminary Findings Thousand Lake Fault

- Geologic Slip Rate 0.1-0.25 mm/year
- Likely Active During the Late Pleistocene
- Recurrence Rate 4,000 20,000 years per event
- Anticipated Moment Magnitude: 6.8-7.2



Work to come:

- C-14 Ages from Footwall Colluvial Wedge Material
- Possibly trench adjacent displaced terrace or fan.







Dr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University

2017 GSA Annual Meeting per Mantle Slide 12 of 13

114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

References:

UTAH VALLEY

UNIVERSITY

- Anderson, R.E., and Barnhard, T.P., 1986, Genetic relationship between faults and folds and determination of Laramide and neotectonic paleostress, western Colorado Plateau-transition zone, central Utah: Tectonics, v. 5, p. 335-357.
- Biek, R.F., 2016, Interim Geologic Map of the Bicknell Quadrangle, Wayne County, Utah, Utah Geological Survey Open-File Report 654.
- Doelling H. and P. Kuehne, 2007, Interim Geologic Map of the East Half of the Loa 30' x 60' Quadrangle, Wayne, Garfield, and Emery Counties, Utah, Utah Geological Survey Open-File Report 489.
- Harty, K.M., 1987, Field reconnaissance of Thousand Lake fault zone: Utah Geological and Mineral Survey, memorandum, 2 p.
- Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., 6 pls., scale 1:500,000.
- Marchetti, D. and T. Cerling, 2005, Cosmogenic 3He exposure ages of Pleistocene debris flows and desert pavements in Capitol Reef National Park, Utah, Geomorphology, v. 67, 423-435.
- Marchetti, D., T. Cerling, and E. Lips, 2005, A glacial chronology for the Fish Creek drainage of Boulder Mountain, Utah, USA, Quaternary Research, v. 64, 264-271.
- Marchetti, D., T. Cerling, J. Dohrenwent, and W. Gallin, 2007, Ages and significance of glacial and mass movement deposits on the west side of Boulder Mountain, Utah, USA, PALAEO, v. 252, 503-513.
- Mattox, S.R., 1991. Petrology, age, geochemistry, and correlation of the tertiary volcanic rocks of the Awapa Plateau, Garfield, Piute, and Wayne Counties, Utah. Utah Geol. Surv. Misc. Publ. 91-5,46 pp.
- National Agricultural Imagery Program, 2014, NAIP imagery acquired from Utah AGRC: <u>https://gis.utah.gov/data/aerial-photography/</u>
- Repka, J., R. Anderson, and R. Finkel, 1997, Cosmogenic dating of fluvial terraces, Freemont River, Utah, Earth and Planetary Science Letters, V. 152, 59-73.
- Smith, J., I. Huff, K. Hinrichs, and R. Luedke, 1957, Preliminary Geologic Map of the Loa 1 SE Quadrangle, Utah, Mineral Investigations Field Studies Map MF 101.
- State of Utah, 2006, Auto-Correlated 5 meter DEM, Utah AGRC: <u>https://gis.utah.gov/data/elevation-terrain-data/</u>
- Utah Quaternary Fault and Fold Database: <u>https://geology.utah.gov/resources/data-databases/qfaults/</u>
- Utah Geological Survey Aerial Imagery Collection: 1950 DKT, 1958 EEZ, and 1966 EEZ https://geodata.geology.utah.gov/imagery/

Department ofDr. Nathan A. Toké, Associate Professor of Earth Science, Utah Valley University201EARTH SCIENCE114-4 in T209 Challenges in Tectonics: Fault Zone Behavior Through Time from Earth's Surface to upper Mantle

2017 GSA Annual Meeting

Slide 13 of 13