USGS science for a changing world
HUMBOLDT STATE UNIVERSITY
PennState College of Earth and Mineral Sciences
earthquake.usgs.gov

Active deformation along multiple strands of the northern Maacama fault, Mendocino County, California from lidar-derived topographic data

Charles C. Trexler [1], Harvey M. Kelsey [2], & Kevin P. Furlong [3]

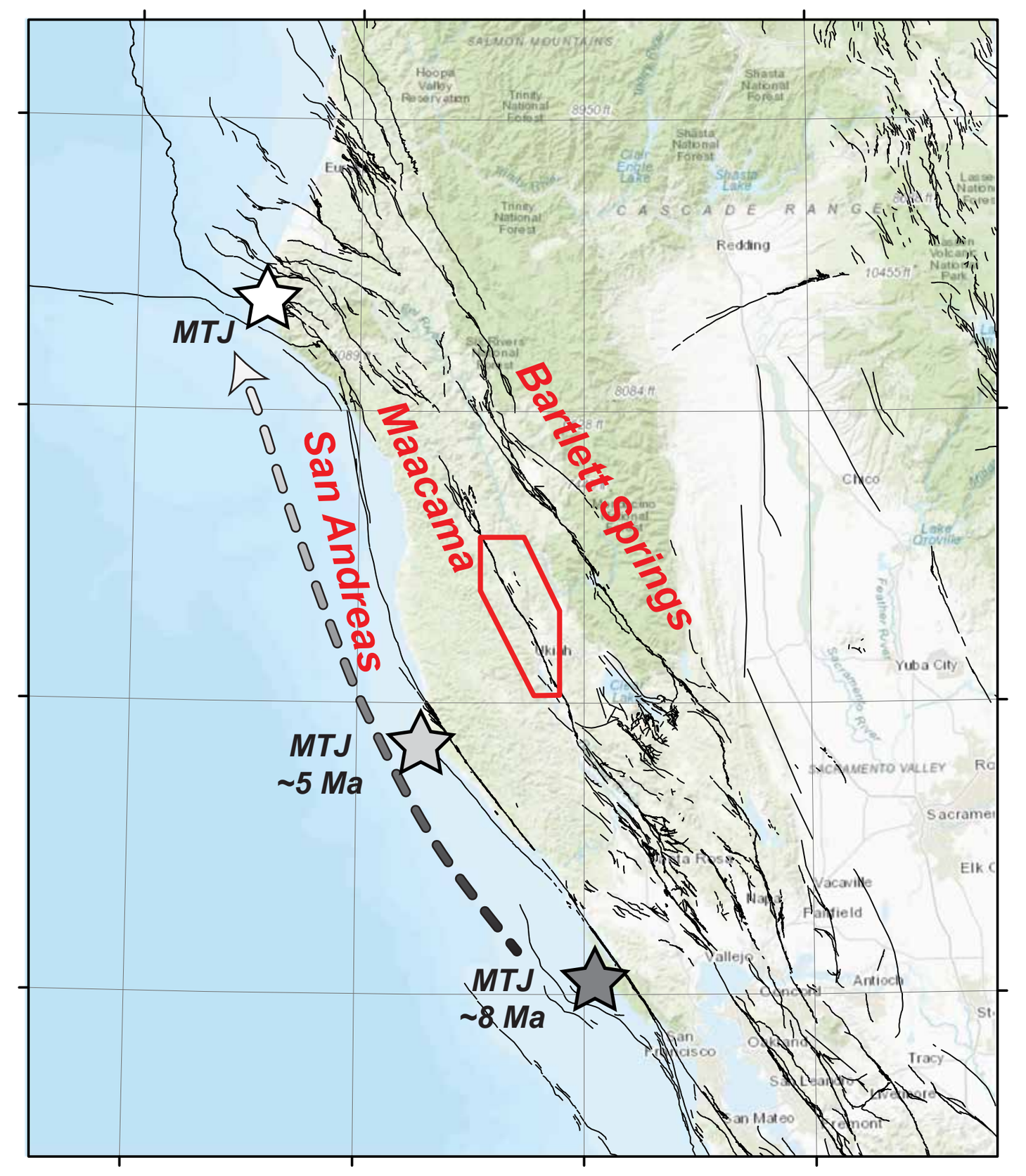
[1] U.S. Geological Survey Earthquake Science Center [2] Dept. of Geology, Humboldt State University [3] Dept. of Geosciences, Pennsylvania State University

Note from the presenting author:
While I am unable to attend the meeting in person, I'd love to talk to you about this work!

Scan the QR code at left to join me on Microsoft Teams from 12 -1 pm on Sunday, October 10th, 2021

or you can contact my by email any time at ctrexler@usgs.gov

1 Introduction: the Maacama fault and the San Andreas fault system



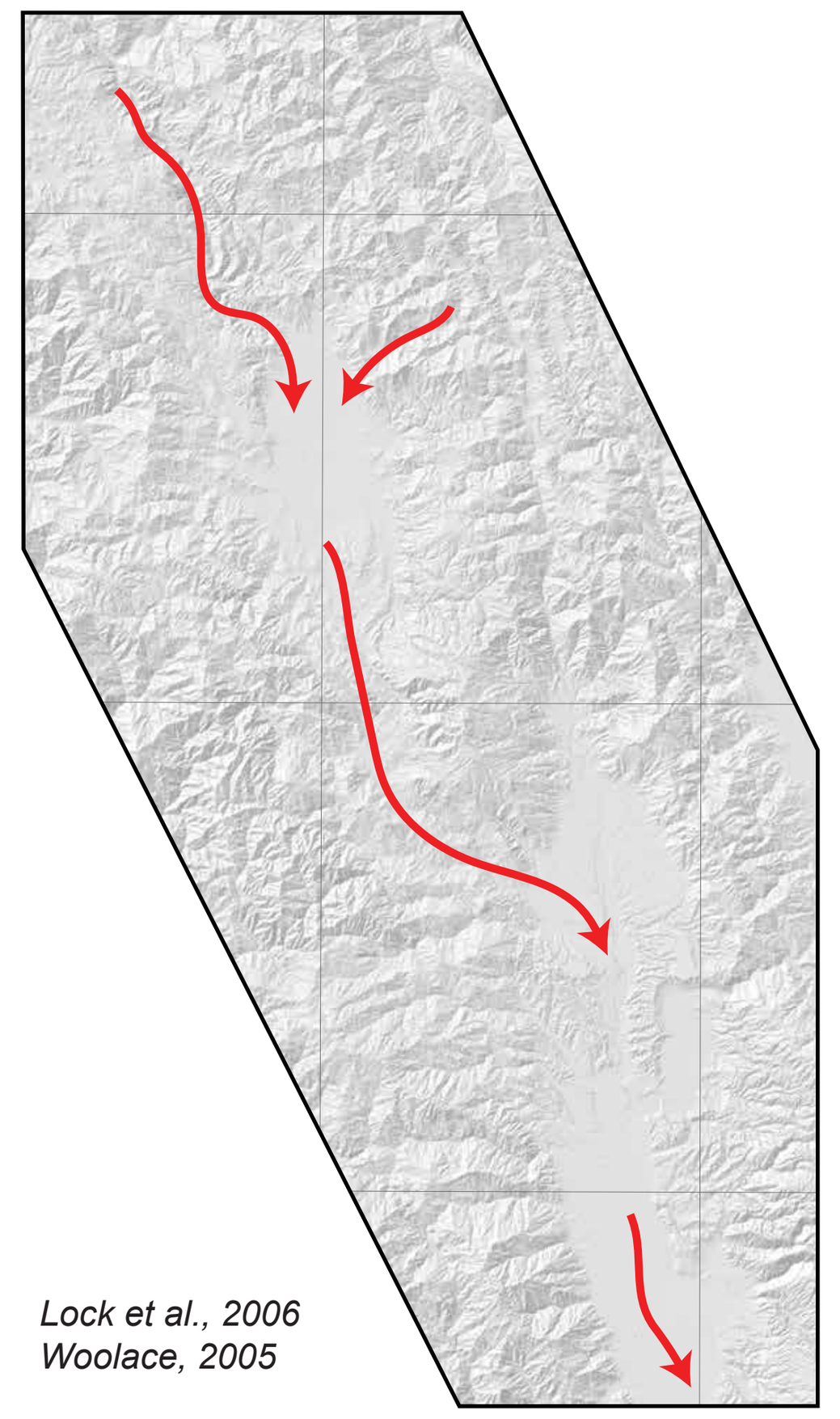
- The San Andreas transform boundary north of San Francisco Bay consists of three major strike-slip faults:
  - -- the San Andreas fault
  - -- the Maacama fault
  - -- the Bartlett Springs fault

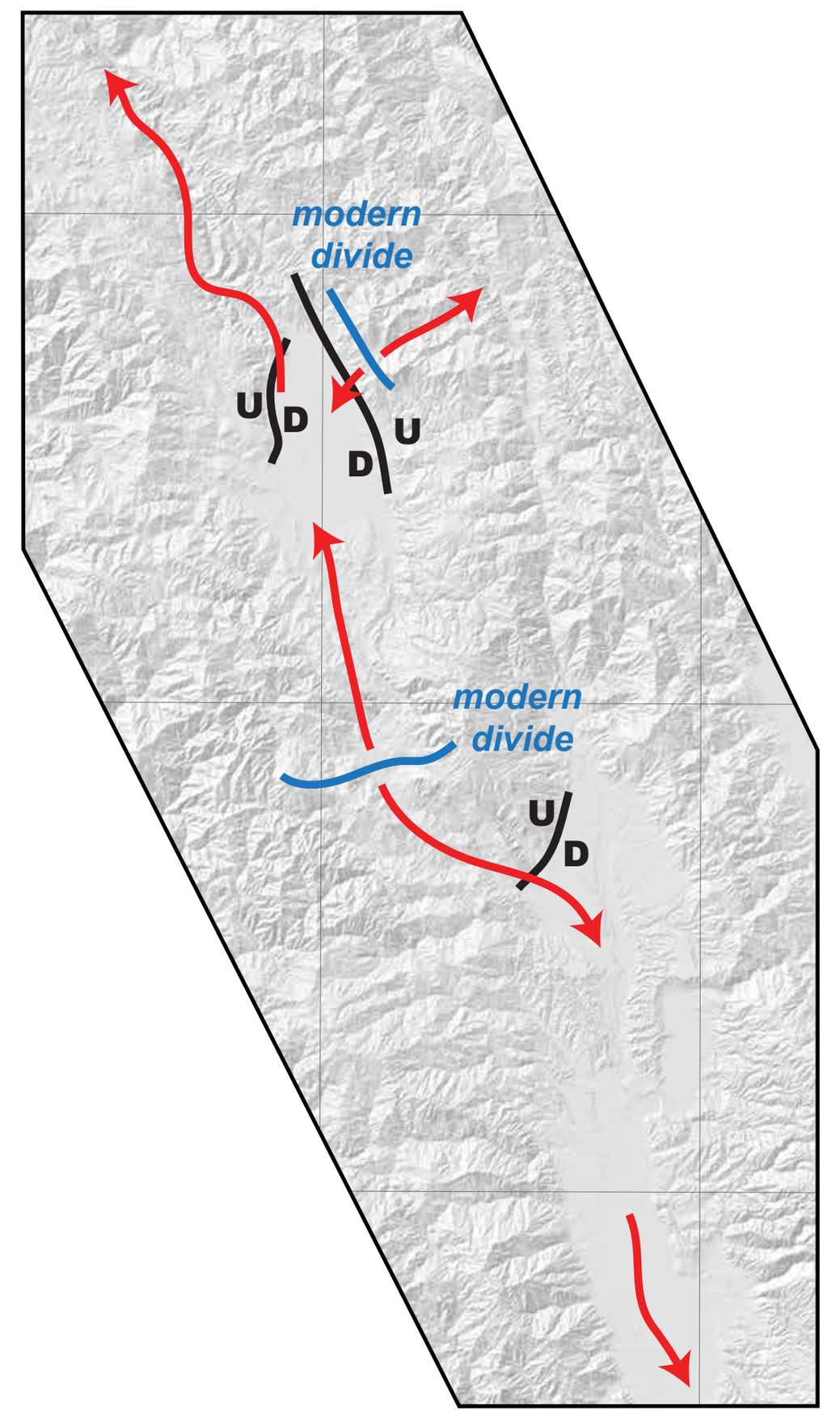
- The Maacama fault propagated northward following the migration of the Mendocino Triple Junction (MTJ), which passed the study area *(red outline)* at ~ 3 Ma

Drainage reorganization at ~1 Ma

- Faulting in Little Lake Valley & Laughlin Range triggers a partial reversal of drainage direction at ~1 Ma

- These faults play a role in the northward propagation of the Maacama fault

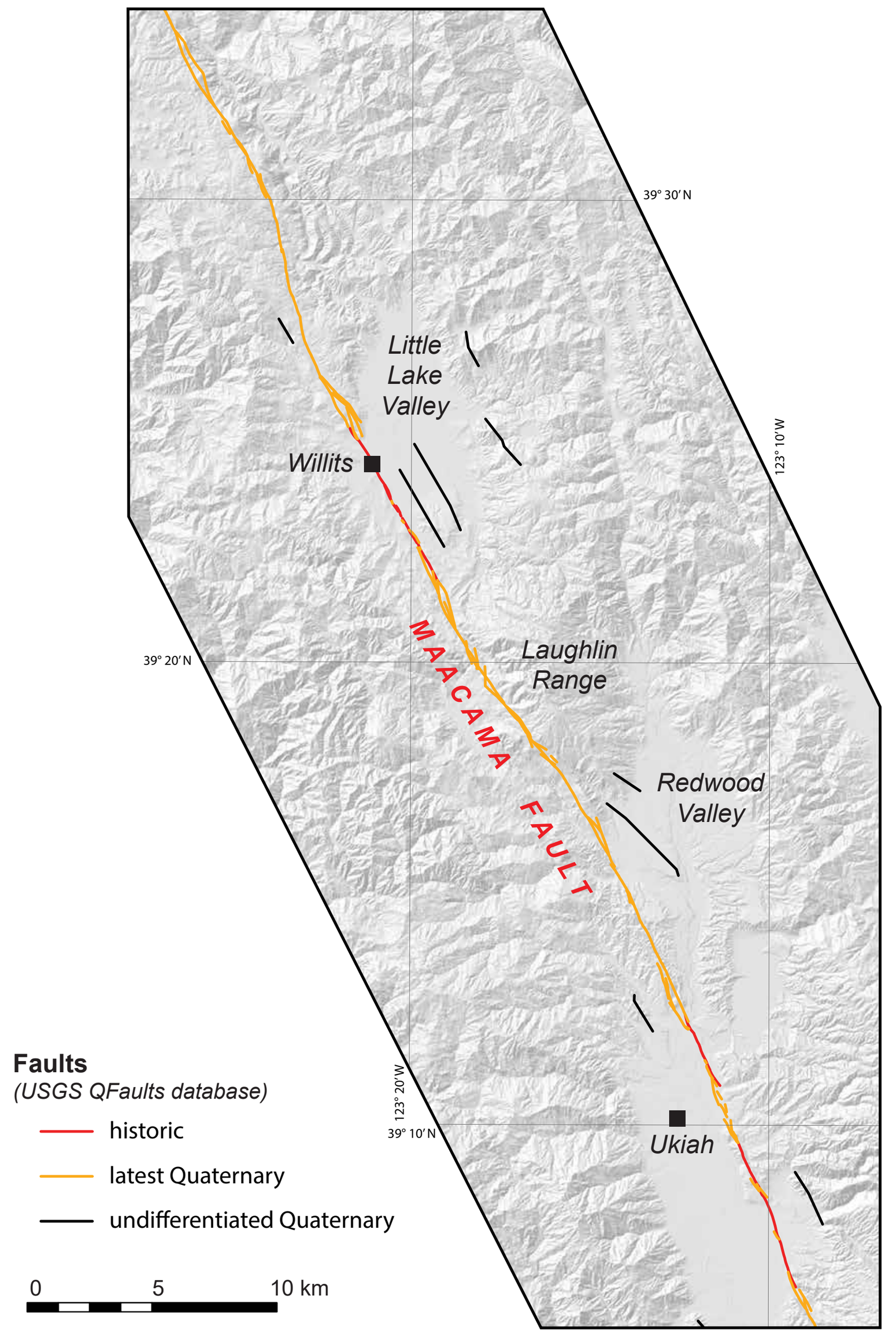




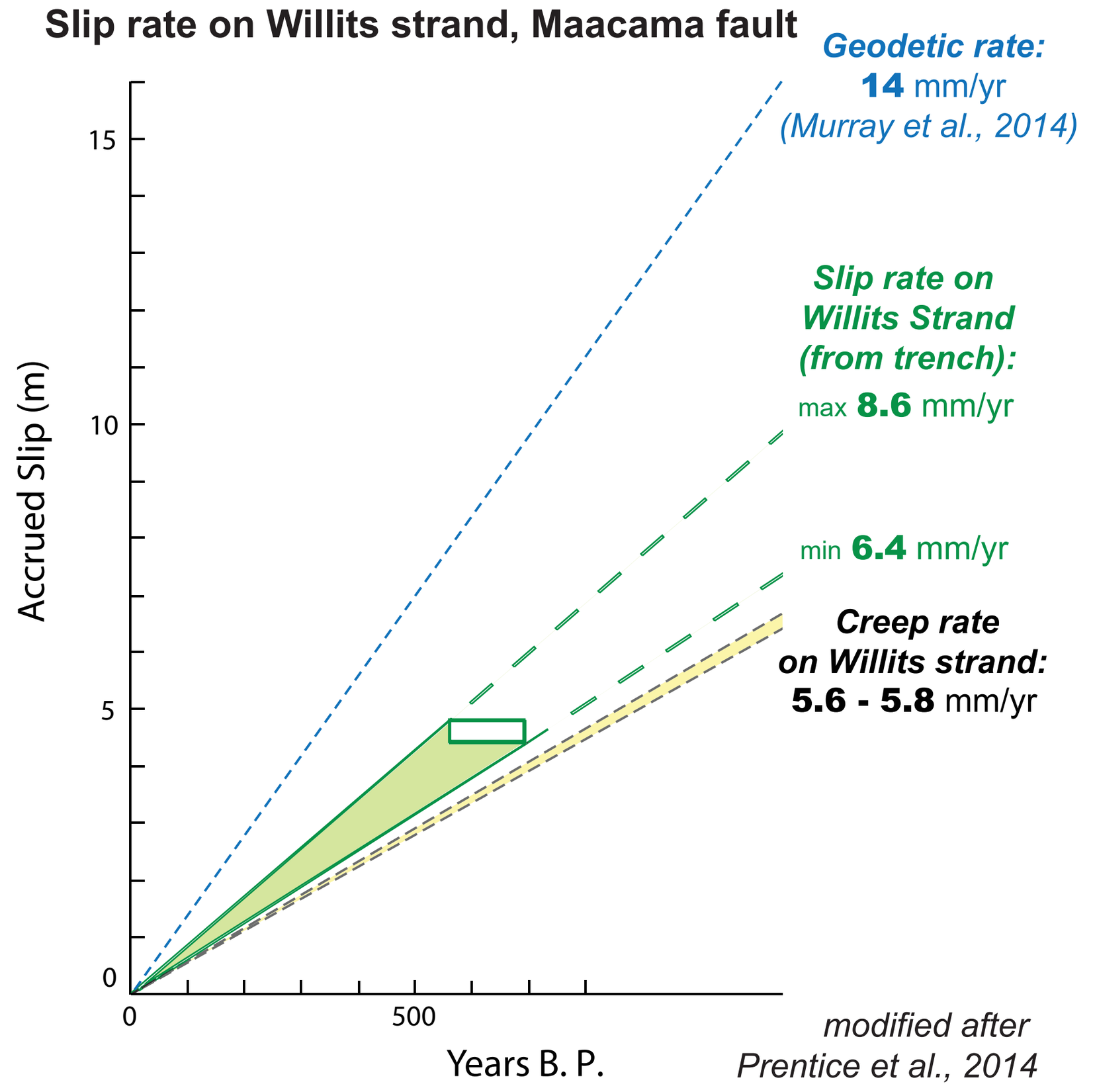
Lock et al., 2006
Woolace, 2005

2 Evidence of fault activity in lidar data

Pre-existing fault mapping (USGS QFaults database)



Discrepancy in slip rate estimates

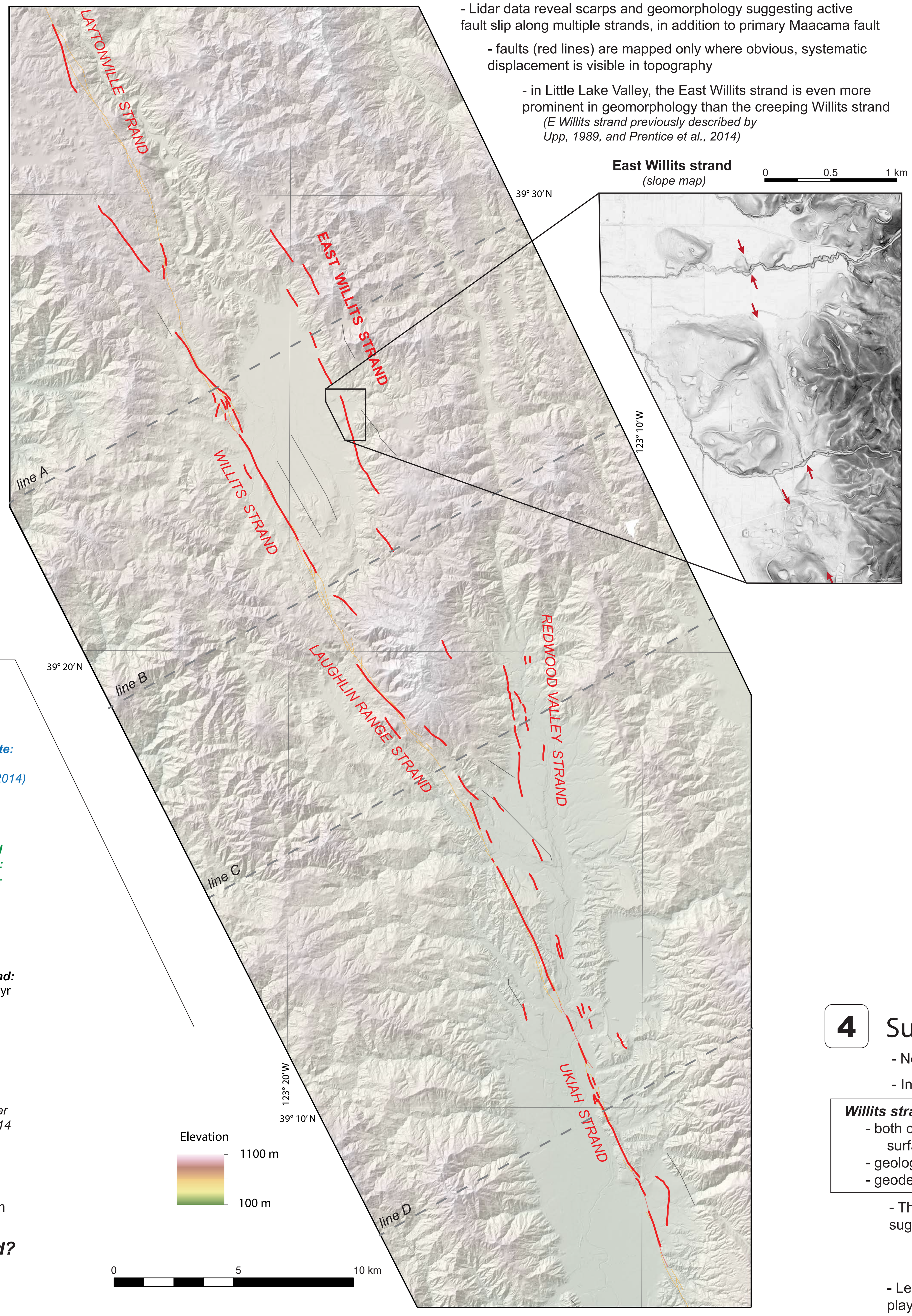


- Measured *creep rate* and *slip rate estimates from paleoseismic trenching* on the main strand of the Maacama fault near Willits are significantly lower than the *modeled geodetic rate* on the Maacama system

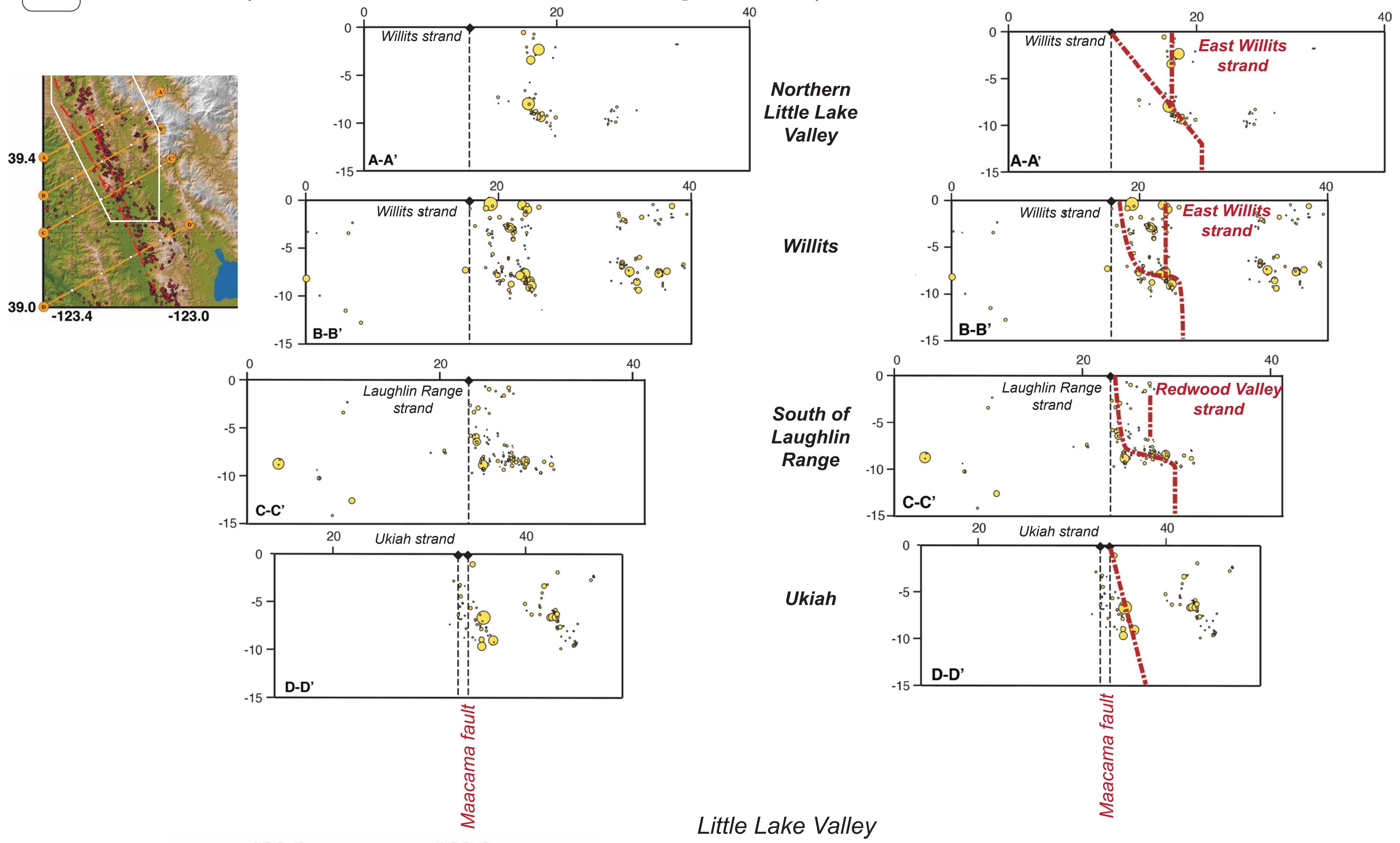
Where is the remaining slip accommodated?

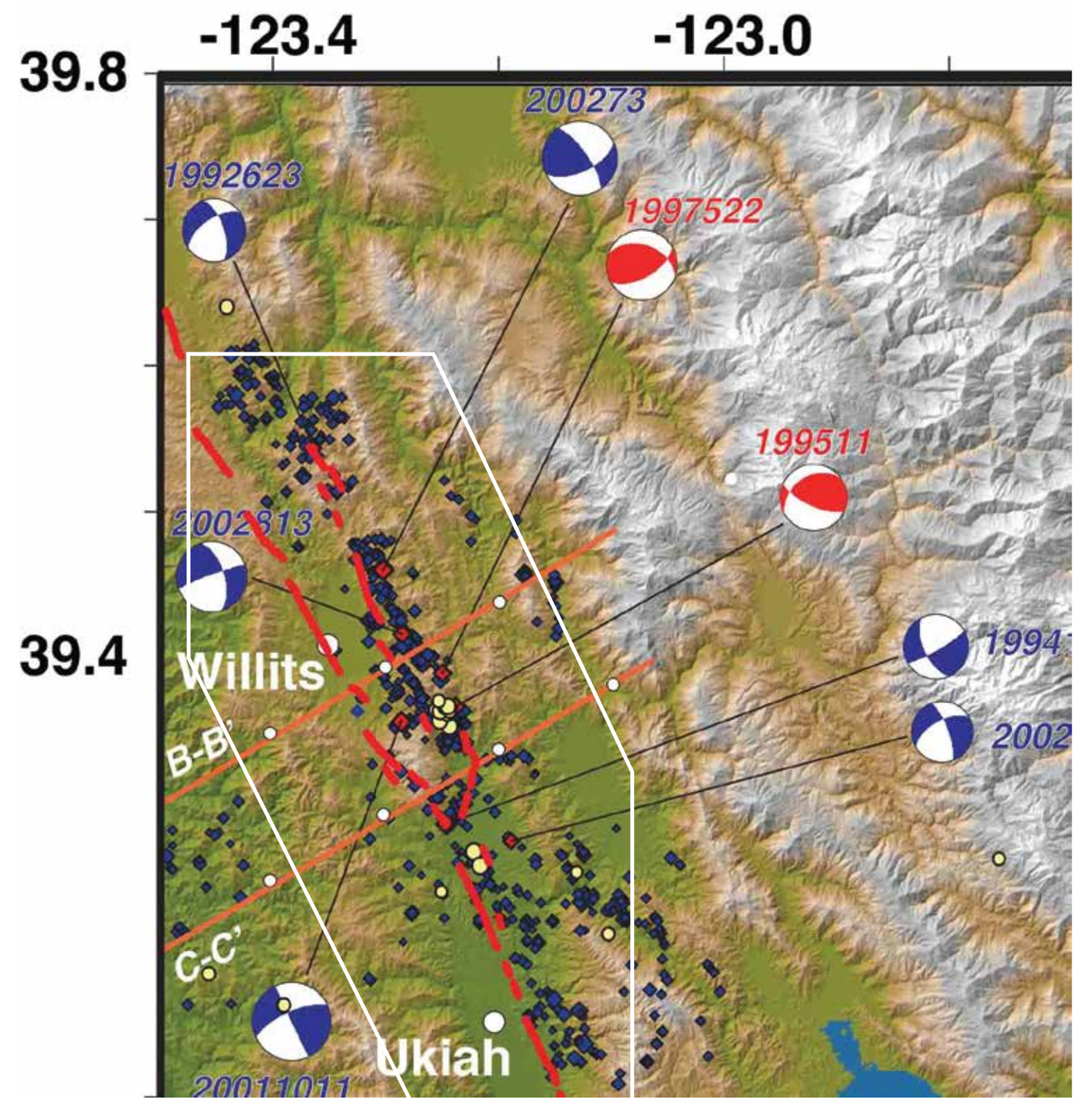
New fault mapping (using USGS 3D Elevation Program lidar, released 2018)

- Lidar data reveal scarps and geomorphology suggesting active fault slip along multiple strands, in addition to primary Maacama fault
  - faults (red lines) are mapped only where obvious, systematic displacement is visible in topography
    - in Little Lake Valley, the East Willits strand is even more prominent in geomorphology than the creeping Willits strand
      (E Willits strand previously described by Upp, 1989, and Prentice et al., 2014)



3 Seismicity and implications for fault geometry





Little Lake Valley
- In the Northern Little Lake Valley (line A-A') and WIllits (line B-B') profiles, seismicity at depth is focused distincly to the east of the creeping Willits strand

- We infer from seismicity combined with surface creep data that the Willits strand must dip eastward to the base of the seismogenic zone

- Seismicity aligns with surface trace of the East Willits strand and suggests the fault is steeply dipping

Laughlin Range & Redwood Valley
- Both the Laughlin Range and Redwood Valley strands exhibit seismicity at depth (line C-C'), and larger earthquakes have thrust mechanisms (red focal mechanisms, at left)
  - -- may be actively contributing to growth of Laughlin Range and reinforcing the new drainage divide

Ukiah Valley
- Seismicity beneath the Ukiah strand (line D-D') is aligned with the surface trace and suggests the fault is steeply dipping

4 Summary

- North of the Ukiah Strand, the Maacama fault splits into two active strands at the Laughlin Range stepover
- In Little Lake Valley, the Willits and East Willits strands together collectively define the Maacama fault zone

Willits strand	*East Willits strand*
- both creeps and has surface-rupturing earthquakes - geologic slip rate ~7.5 mm/yr - geodetic slip rate (deep slip rate) >> geologic slip rate	- long history of activity based on well, gravity, and geophysical data - clear surface expression - strain release behavior unknown! creep? earthquakes?

- The geomorphic expression of the East Willits strand is at least as well expressed as the Willits strand, suggesting that deformation rates may be similarly comparable
  - -- the East Willits strand could fully account for the 'missing' deformation suggested by the discrepancy between geodetic data and deformation rates on the Willits strand alone
- Legacy of structures developed in prior tectonic regime (convergent margin before passage of MTJ) play an important role in the evolution of the Maacama fault system

Acknowledgements
Thanks to the organizing committee for the 2021 USGS Northern California Earthquake Hazards Workshop organizing committee, whose invitation to H. Kelsey inspired this work. G. Hayes produced the original seismicity datasets and figures. C. Trexler would also like to thank B. Melosh, R. McLaughlin, and R. Rubin for helpful and productive conversations about the tectonic and geologic history of the Maacama system.

References

Lock, J., Kelsey, H., Furlong, K., Woolace, A., 2006. Late Neogene and Quaternary landscape evolution of the northern California Coast Ranges: Evidence for Mendocino triple junction tectonics. Geological Society of America Bulletin, v. 118, p. 1232-1246.
Murray, J. R., Minson, S. E., & Svarc, J. L., 2014. Slip rates and spatially variable creep on faults of the northern San Andreas system inferred through Bayesian inversion of Global Positioning System data. Journal of Geophysical Research: Solid Earth, v. 119, p. 6023-6047.
Prentice, C. S., Larsen, M. C., Kelsey, H. M., & Zachariasen, J., 2014. Late Holocene slip rate and ages of prehistoric earthquakes along the Maacama Fault near Willits, Mendocino County, northern California. Bulletin of the Seismological Society of America, v. 104, p. 2966-2984.
Upp, R. R., 1989. Holocene activity and tectonic setting of the Maacama Fault Zone, Mendocino County, Ca: in Johnson, A.M. Burnham, C.W., Allen, C.R., and Muehlberger, W. eds., Richard H. Jahns memorial volume: Engineering Geology, v.27, p. 375-412.
Woolace, A., 2005. Late Neogene and Quaternary Stratigraphy and Structure of Little Lake Valley, Northern Coast Range, California. Masters Thesis; Humboldt State University, Arcata, California; May 2005.