UC DAVIS
KECKCAVES
W.M. Keck Center for Active Visualization in the Earth Sciences

Abstract #: S33F-4950

RAPID SCIENTIFIC RESPONSE AS AN EDUCATIONAL OPPORTUNITY INTEGRATING GEOSCIENCE AND ADVANCE VISUALIZATION

Arredondo, Katrina; Barr, Mary; Banesh, Divya; Hawkins, Angela; Kellogg, Louise; Lindeman, Justin R.; Morelan, Alexander; Oskin, Michael; Prush, Veronica; Tarlow, Scott; Trexler, Chad; Wang, Yiran

UC DAVIS
DEPARTMENT of EARTH AND PLANETARY SCIENCES

24 AUGUST, 2014 M6.0 EARTHQUAKE

Abstract: Natural disasters provide important opportunities to conduct original scientific research. We present the results of a graduate course at the University of California, Davis centered on rapid scientific response to the 24 August magnitude 6.0 South Napa earthquake. Students from both geoscience and computer visualization formed collaborative teams to conduct original research, choosing from diverse research topics including mapping of the surface rupture, both in the field and remotely, production and analysis of three-dimensional scans of offset features, topographic point-cloud differencing, identification and mapping of pre-historic earthquake scarps, analysis of geodetic data for pre-earthquake fault loading rate and modeling of finite fault offset, aftershock distribution, construction and 3D visualization of earth structure and seismic velocity models, shaking intensity from empirical models, and earthquake rupture simulation.

Goals and Conclusions

1. Map surface rupture and slip distribution from field observations and LiDAR.
15 km of surface rupture, with up to 32cm dextral slip (23 cm measured on August 24).

2. Relate the 2014 South Napa earthquake with the 2000 Yountville event.
Both earthquakes probably occurred on the same steeply west-dipping fault.

3. Map northern West Napa fault, and determine a preliminary slip rate.
West Napa fault extends entire length of Napa Valley to Calistoga. Preliminary Slip rate of ~1 mm/yr.

4. Determine the West Napa fault structure at depth.
Fault dips 85° in near Napa, 70° near Yountville, and less (60°?) between St. Helena and Calistoga.

5. Model Coulomb stress changes along the West Napa fault.
The 2014 South Napa earthquake increased shear stress on adjacent strands of the West Napa fault by up to 5 bars

6. Explore the potential effects of a M7 earthquake in Napa Valley.
Strong shaking, with horizontal accelerations exceeding 1g, predicted for a M7 earthquake along the West Napa fault.

Structure from Motion

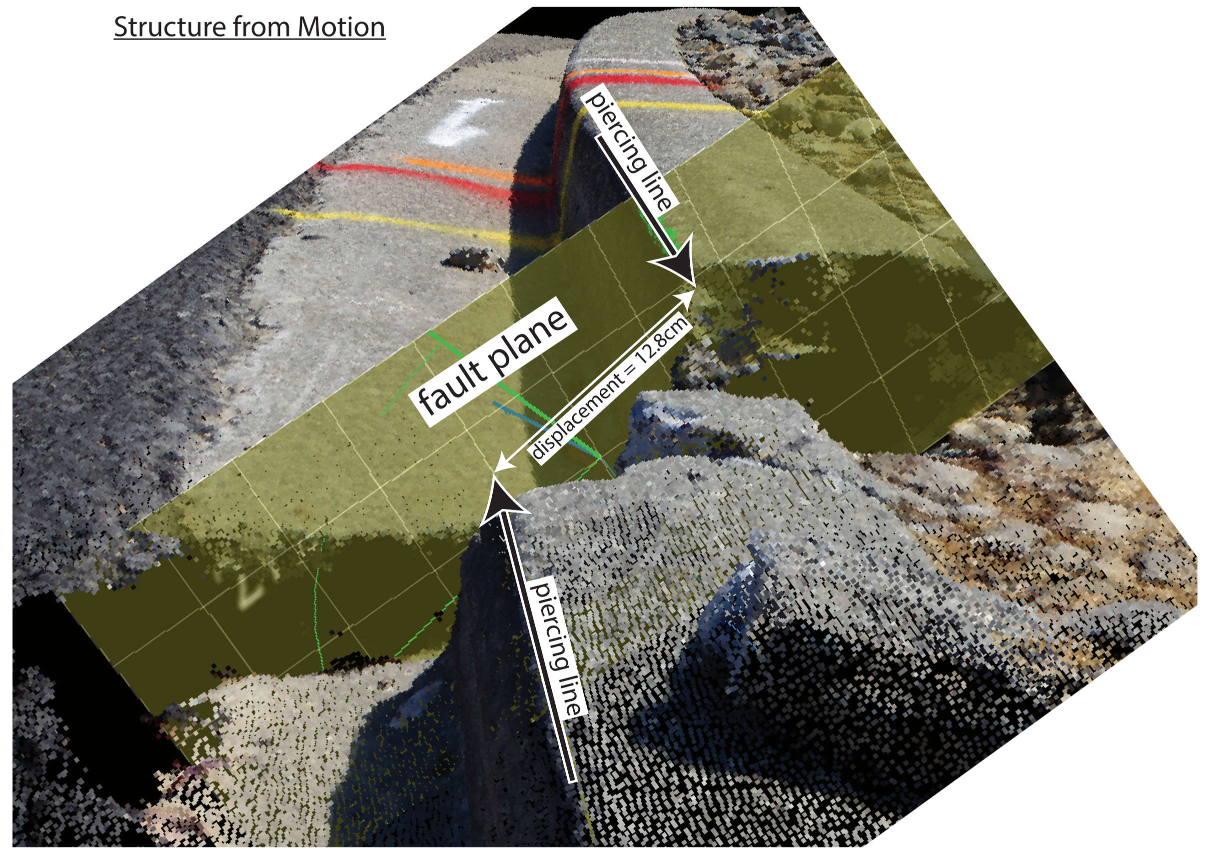
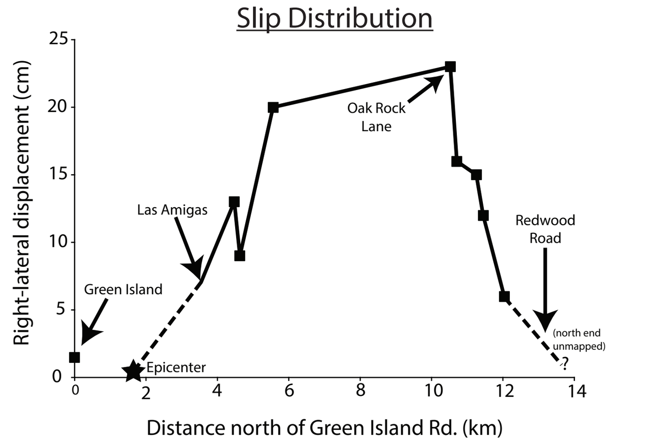


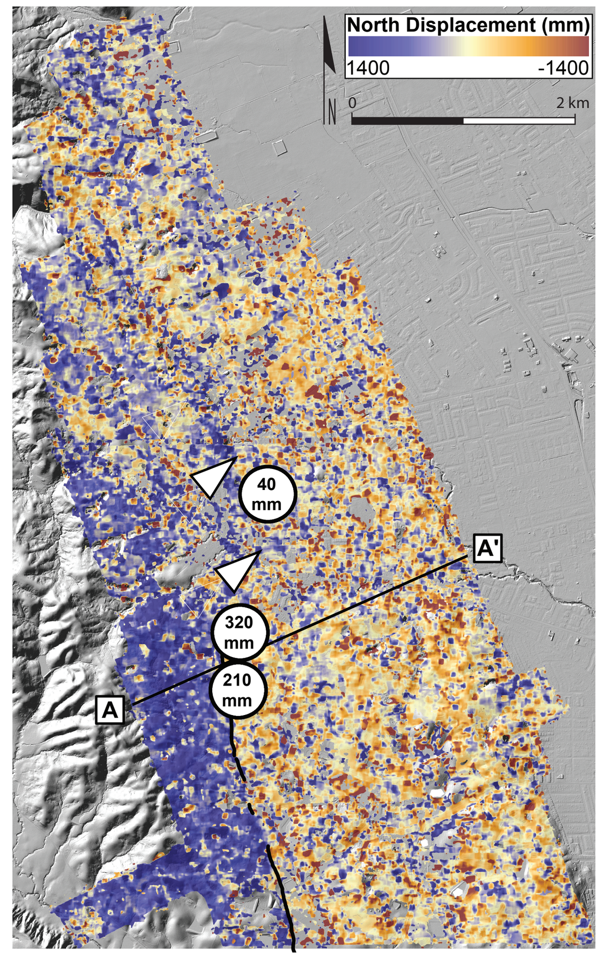
Figure X (above): Offset measurement from Structure-from-Motion point cloud. Displaced features recorded with photographs permit quantitative measurements can be made in the office after the fact. This offset curb that was repaired within 3 days of the event.

Figure X (right): Slip distribution from data collected on the first day after the earthquake. Black squares are our data points and the line shows the slip envelope. The dashed lines show where we were unable to accurately map the tips of the rupture. No error estimates were made collecting these data so are therefore not portrayed on this figure.

Slip Distribution



North Displacement from COSI-Corr



Profile A-A'

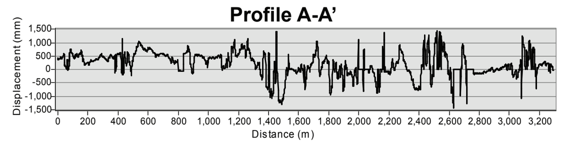
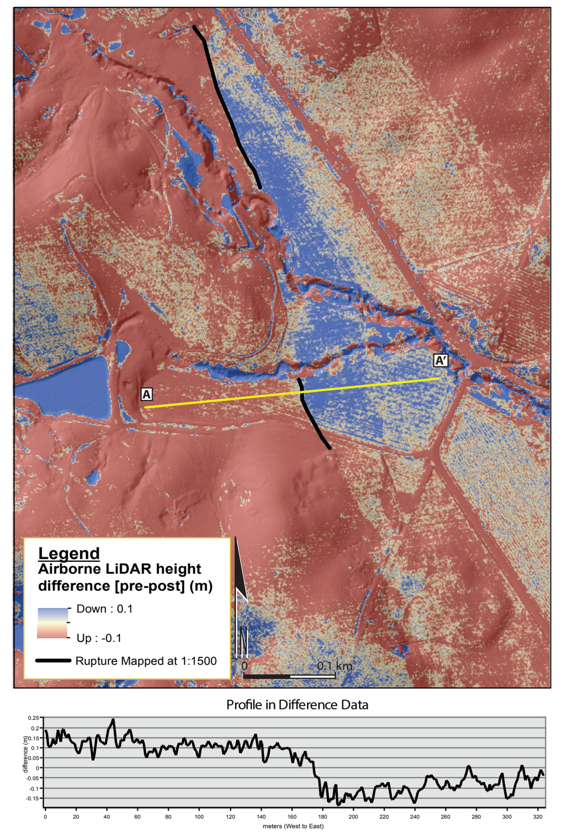
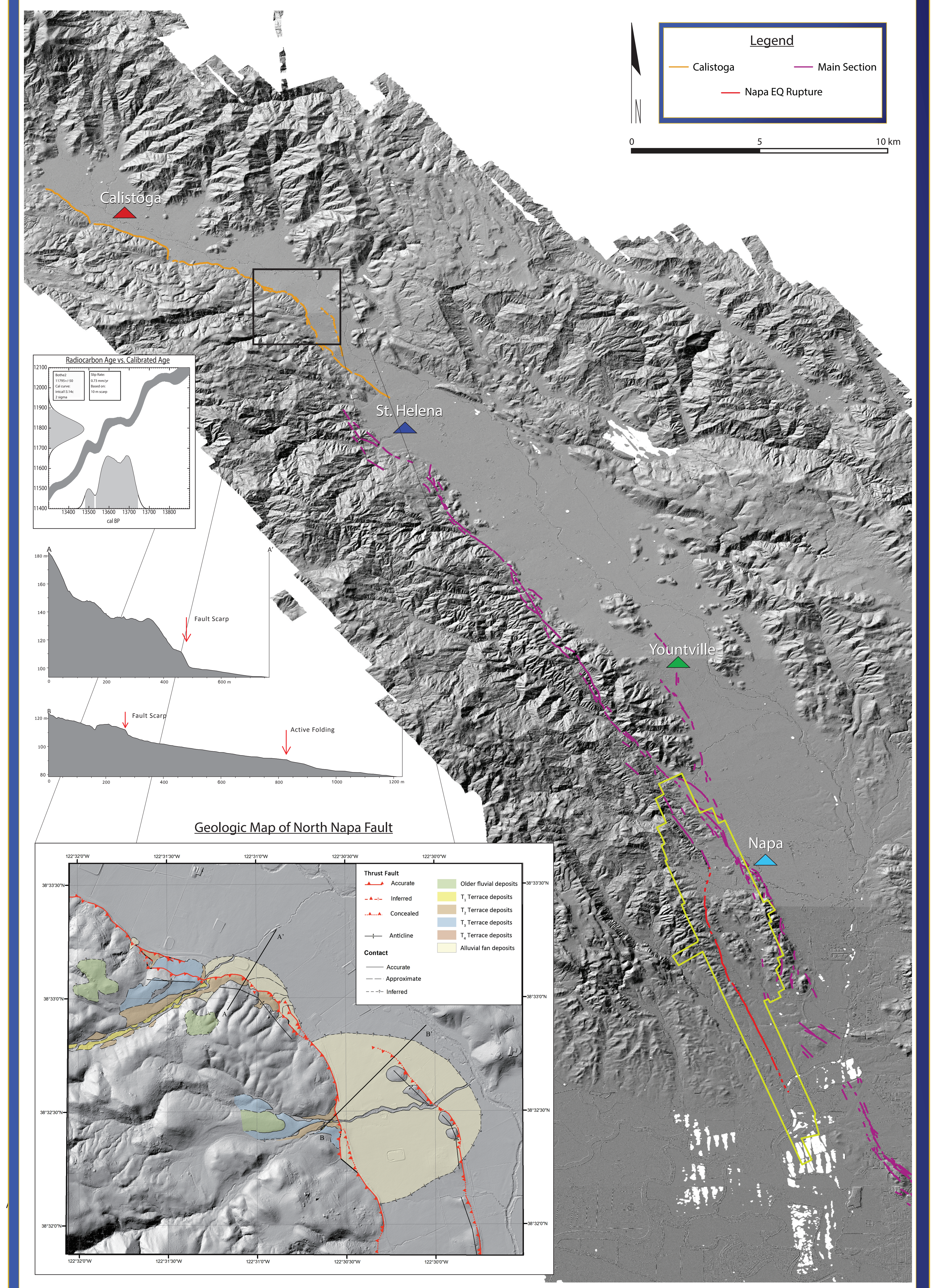


Figure X (left): North-south displacement map for Browns Valley region using COSI-Corr. Input data is lidar-derived hillshade maps from 2003 and 2014. White circles are field-observed displacements (cm). Black line is mapped surface rupture. White arrows indicate northward extension of fault.

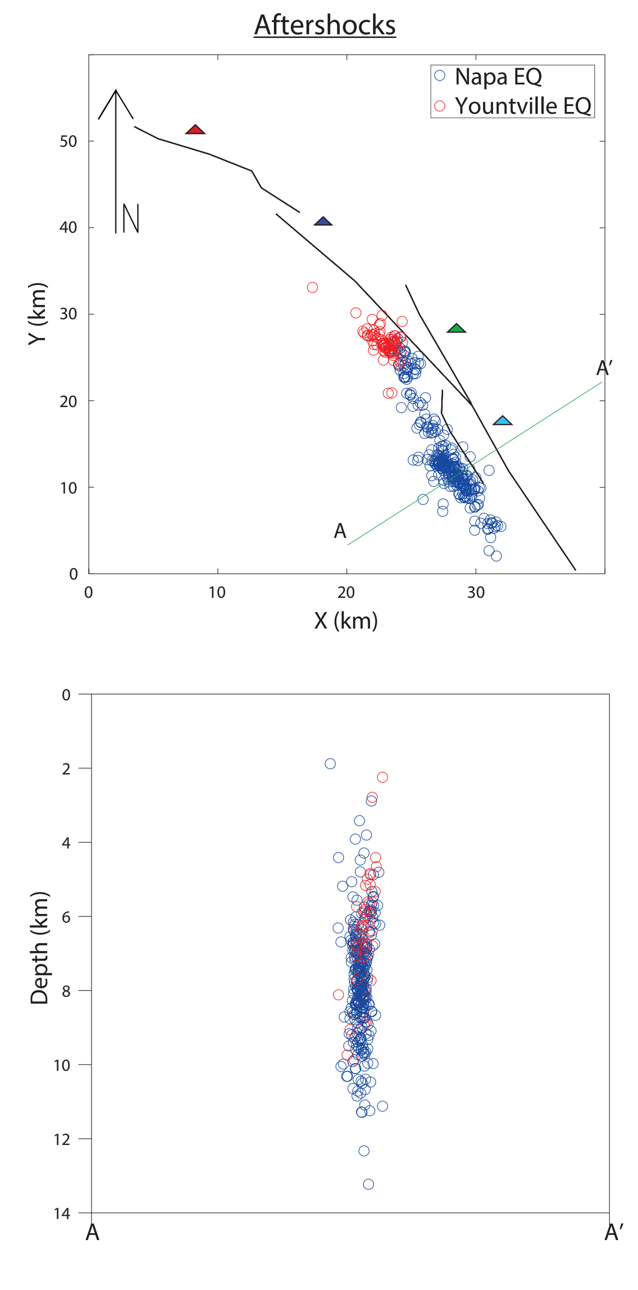
Figure X (below): LiDAR subtraction map (2003 - 2014). Positive values indicate subsidence. The black line shows 2014 rupture mapped from the post-event dataset. The profile (**below**) taken across the difference data shows a 20 cm-high scarp and westward tilting of east side of fault.



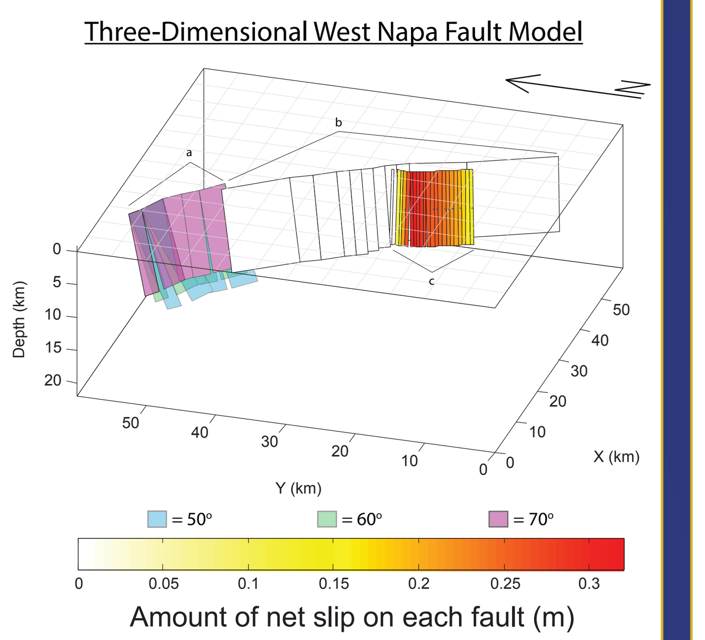


WHAT WOULD A M7 EARTHQUAKE LOOK LIKE?

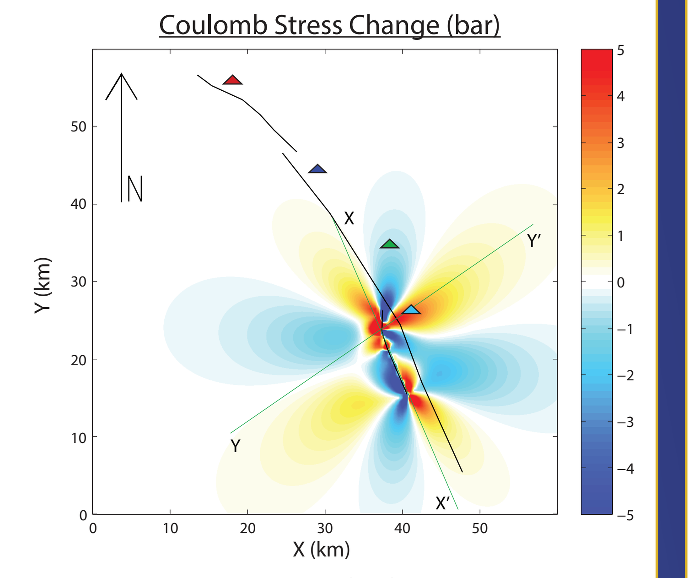
Aftershocks



Three-Dimensional West Napa Fault Model

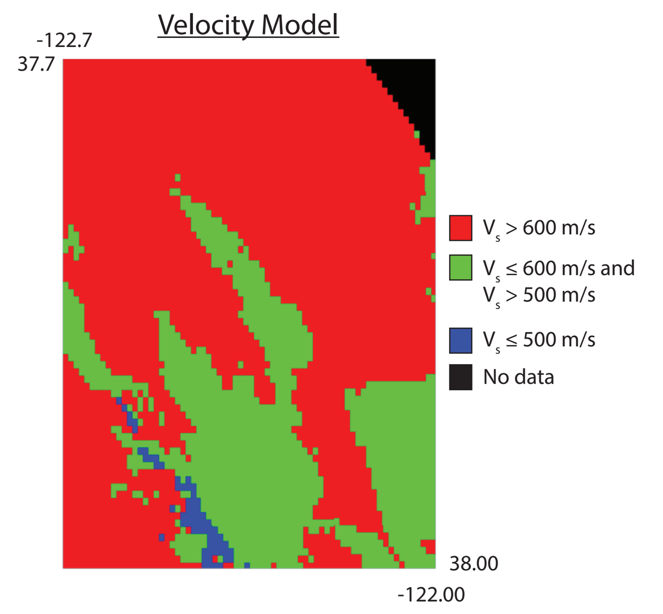


Coulomb Stress Change (bar)



Stress$_n$ = azimuth°, plunge°
S_1 = 30.3°, 10.8° S_2 = 136.3°, 55.4° S_3 = -66.6°, 32.3°

Velocity Model



Spectral Acceleration

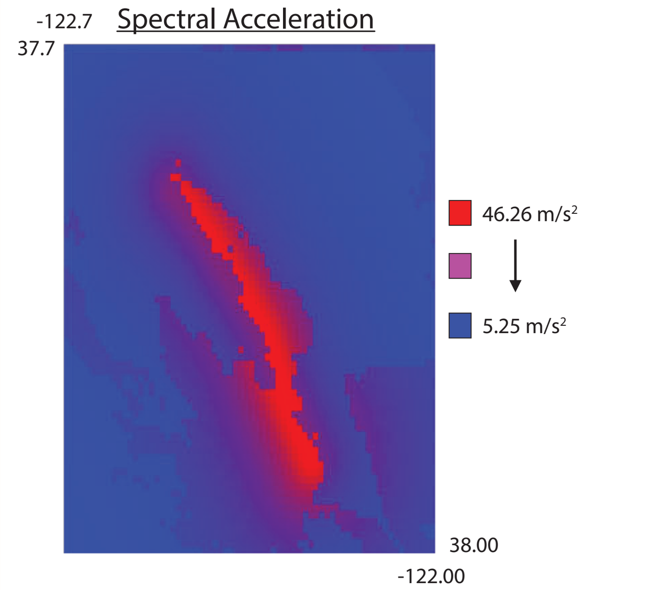


Figure X (above, upper): Aftershock sequences (NCEDC) from 2000 Yountville and 2014 South Napa earthquakes are collinear along West Napa fault. The 2000 Yountville earthquake aftershocks are in red and the 2014 south Napa earthquake aftershocks are in blue. Green line identifies cross section line for A-A'.

Figure X (above, lower): Cross section of aftershock sequences. A plane of best fit was applied to the 2000 Yountville and 2014 Napa aftershock sequences in Matlab using a least squared regression and bootstrapping function was applied to verify accuracy of dip. The best fit dips are 70°W ± 2.2° for the Yountville section and 85°W ± 2.2° for the Napa section.

Figure X (above, upper): Oblique view of three-dimensional model of the West Napa fault. (a) The Calistoga section of the fault has a dip of 60° ± 10° (alternate planes of dip shown) as derived from Langenheim et al., 2006. (b) Aftershocks from the 2000 Yountville and 2014 South Napa earthquakes (NCEDC) define dips for main segment, raging from 85° in the south to 70° in the north. (c) Slip model for 2014 earthquake derived by extrapolation of surface rupture data.

Figure X (above, lower): Coulomb stress change resulting from the 2014 South Napa earthquake. Regional stress orientations from Provost and Houston's (2003) northern California stress inversion. Stress increased on unruptured portions of the West Napa fault by up to 5 bars. All models built in Coulomb 3.3 (Lin & Stein, 2004; Toda et al., 2005).

Figure X (above, upper): Shallow **velocity model of Napa Valley and surroundings, from Aagaard (2011).** Velocities were used to determine bedrock versus soil classification for empirical model of acceleration resulting from a M7.0 earthquake on the West Napa fault.

Figure X (above, lower): Empirical spectral acceleration model simulating a M 7.0 earthquake on the West Napa fault. Peak ground acceleration at 2.0 second period shown. Computed using the empirical relationships described in Abrahamson and Silva (1997). Note how soft sediments in Napa Valley enhances shaking.

Preliminary Peak Ground Acceleration from Numerical Rupture Simulation

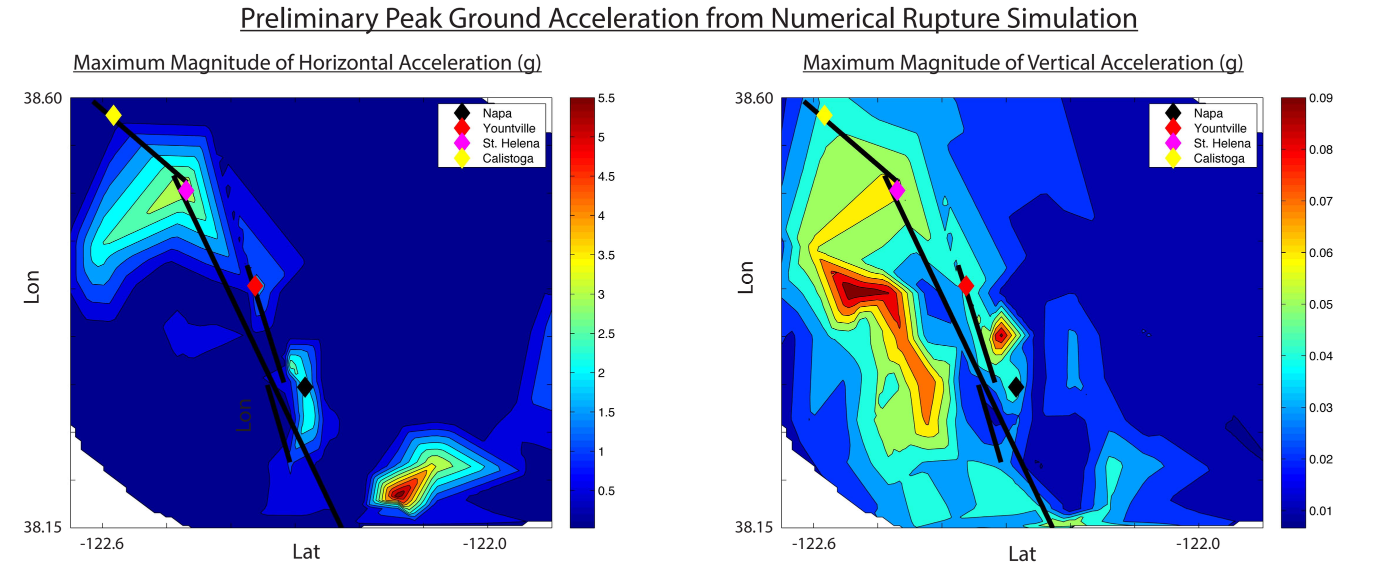


Figure X: Preliminary results for maximum horizontal and vertical acceleration from a simulated magnitude 6.9 earthquake on the West Napa fault. Modeled using SW4 (www.geodynamics.org). The 70 km-long rupture is comprised of 292 subfaults with slip distribution provided from a finite source rupture model of the 1989 Loma Prieta, CA Earthquake (Emolo and Zollo, 2005). The period of the modeled waveforms is 1 second. The maximum magnitude of the horizontal acceleration calculated is 5.56 g where as the maximum vertical acceleration is 0.10 g.

Special Thanks:

Arthur Rodgers for assistance with SW4 model
California Department of Water Resources, California Geological Survey, and U.S. Geological Survey for granting access to post-earthquake Lidar data

Funding:

NSF Award #1135588 (CI-TEAM)
NSF Award #1461595 (RAPID)