Pre and post rupture Fault Mapping Comparisons applications to Probabilistic Fault Displacement Hazard

Rachel Adam, Joseph Powell, John Ford, Chelsea Scott, Ramon Arrowsmith
School of Earth and Space Exploration, Arizona State University

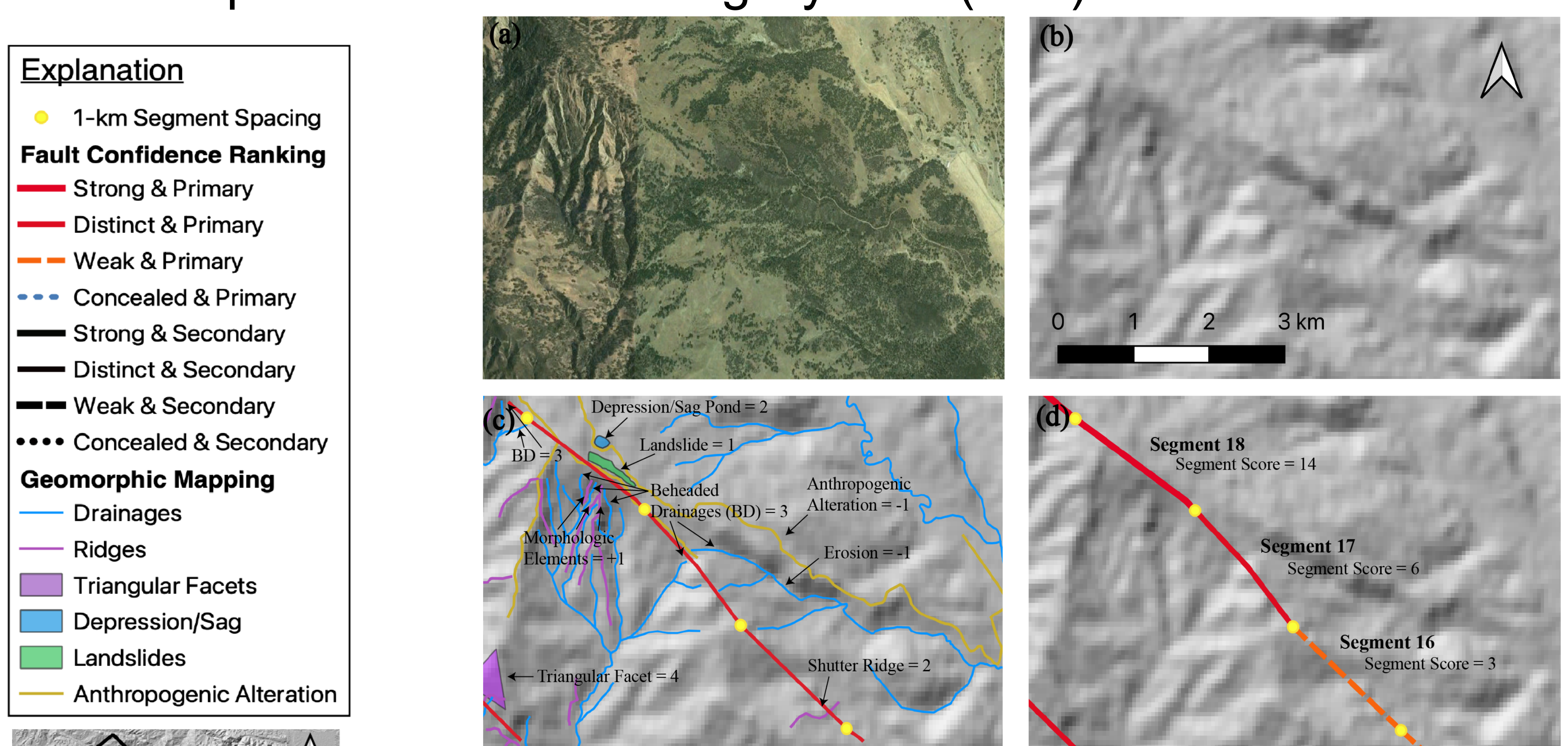
1. Introduction

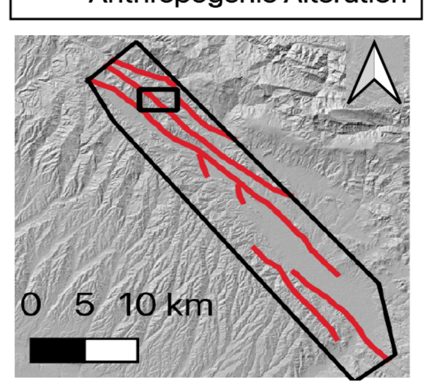
- Pre- and post- earthquake fault maps inform Probabilistic Fault Displacement Hazard Assessment (PFDHA) of our ability to anticipate the location and probability of future coseismic ruptures.
- Our goal is to create pre-rupture fault maps for a series of recent ground rupturing earthquakes by using geomorphic landforms as indicators of surface rupture
- We developed the Geomorphic Indicator Ranking (GIR) system as a quantitative and repeatable approach to place a certainty level (e.g., strong, distinct, weak, concealed) on the mapped fault segments
- A qualitative and quantitative comparison between the pre and post earthquake rupture will result in a more accurate and systematic mapping process

2. Background

- Earthquakes included in this project are : Parkfield,California (2004, M6.0); Kaikoura, New Zealand (2016, M7.8); Napa, California (2014, M6.0); Iwaki/Fukushima-Hamadori, Japan (2011, M6.6); Borah Peak, Idaho (1983, M6.9); El Mayor Cucapah, Mexico (2010, M7.2); Kumamoto, Japan (2016, M7.0)
- Pre- rupture faults maps are made using remote sensing datasets consisting of airborne and satellite- based optical imagery and structure-from-motion, lidar and radar topography collected prior to the rupture.
- We simulated an environment where mappers- who were novice students with no prior knowledge of the earthquakes events- were given pre-event data sets to use for the pre-rupture fault mapping.
- This approach minimized pre knowledge bias. It is important to reduce bias as prior experience may result in preconceived conclusions without considering variables that may lead the mapper to a different conclusion

3. Geomorphic Indicator Ranking System (GIR)



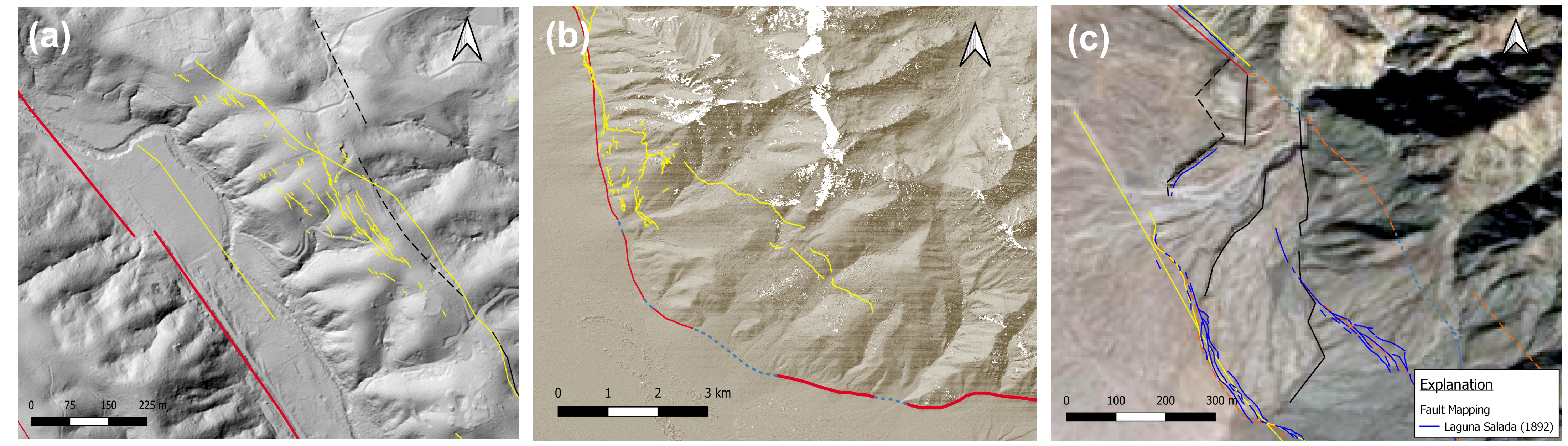


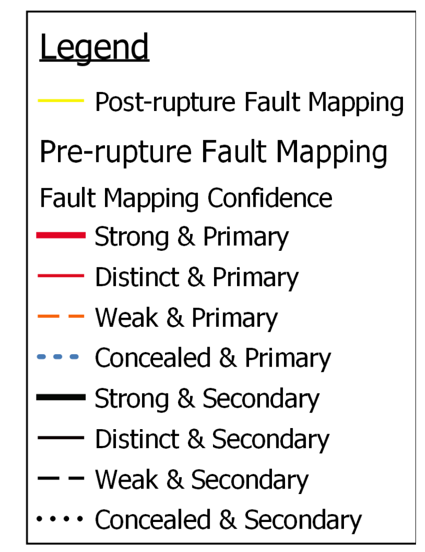
Segment #	Geomorphic Features	Segment Score	Scaled Score	Fault Confidence Ranking
18	**3** Beheaded Drainages (Score = 3), **1** Depression/Sag (1), **1** Landslide (+1), **3** Morphologic Elements (+1)	14	1	Strong & Primary
17	**2** Beheaded Drainages (3)	6	2	Distinct & Primary
16	**1** Shutter Ridge (2), **1** Beheaded Drainage (3), **1** Erosion (-1), **1** Anthropogenic Alteration (-1)	3	3	Weak & Primary

- Above is a example of the GIR application for the pre-rupture fault map of the 2004 Parkfield, CA earthquake.
- Development and applicaiton of the GIR results in a more systematic approach to quantifying rupture evidence and assigning a confidence ranking to a given fault segment
- These features are mapped and counted to be placed into our calculation to give a final condifence ranking for the fault segment.
- This scoring and assessment of features in used in qualitative analyses to observe reuslting differences in pre- and post- rupture mapping

4. Qualitative Analysis

- We compare our pre-rupture mapping with post-rupture fault mapping to inform the epistemic and aleatoric uncertainty that arises from making pre-rupture fault maps





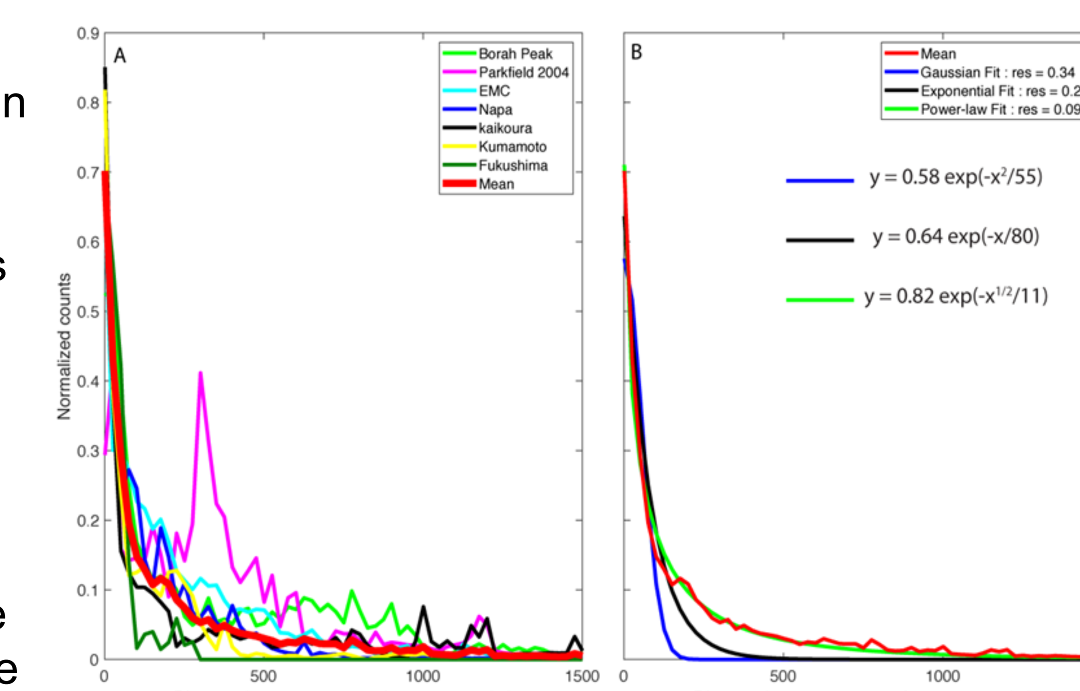
(a) - Continuity of Traces: Faults in pre-rupture maps are more continuous than faults in post-rupture maps. (Napa, CA)

(b) - Range front placement: pre-rupture fault maps often placed fault trace at base of range front while the earthquake ruptures a fault uphill, downslope, or along the range front base. (Borah Peak, ID)

(c) - Bias from previous rupture: Ruptures from the penultimate earthquake are often better preserved than older ruptures and the associated faults are likely to be preferentially mapped. (El Mayor Cucapah, Mexico)

5. Quantitative Analysis

- The quantitative analysis further explores diferences in pre- and post- rupture fault locations by:
  1) Analysis of offset between the sets of traces
  2) Analysis of the validity that the pre-rupture maps had in anticipating the ruptures
  3) Addressing the level of impact that the pre-rupture mapping certainty had on the measured offset between pre- and post- rupture traces
- Discussion of aleatoric uncertainty as it relates to the differences in rupture location for two earthquakes in the same area is analyzed based on rupture patterns



6. Conclusion

- Future work improving the GIR includes adding more features in different faulting environments and adjusting the feature ranking depending on the level of preservation/ landscape.
- We hope to standardize and improve understanding of uncertainties in pre-rupture fault trace mapping
- Upon completion of the quantitative and qualitative analysis, the results can inform work to improve the accuracy of the comparison for the PFDHA model.

References: Reitman, N.G., Briggs, R.W., Gold, R.D., and DuRoss, C., 2015, Surface Deformation Associated with the 1983 Borah Peak Earthquake Measured from Digital Surface Model Differencing: AGU Fall Meeting Abstract.
Rockwell, T.K., Fletcher, J.M., Teran, O.J., Hernandez, A.P., Mueller, K.J., Salisbury, J.B., Akciz, S.O., and Štěpančíková, P., 2015, Reassessment of the 1892 Laguna Salada Earthquake: Fault Kinematics and Rupture Patterns: Bulletin of the Seismological Society of America, v. 105, p. 2885–2893, doi:10.1785/0120140274.
Rymer, M.J., 2006, Surface Fault Slip Associated with the 2004 Parkfield, California, Earthquake: Bulletin of the Seismological Society of America, v. 96, p. S11–S27, doi:10.1785/0120050830.
Teran, O.J., Fletcher, J.M., Oskin, M.E., Rockwell, T.K., Hudnut, K.W., Spelz, R.M., Akciz, S.O., Hernandez-Flores, A.P., and Morelan, A.E., 2015, Geologic and structural controls on rupture zone fabric: A field-based study of the 2010 Mw 7.2 El Mayor-Cucapah earthquake surface rupture: Geosphere, v. 11, p. 899–920, doi:10.1130/GES01078.1.

Acknowledgements: Chris Madugo (PGE), Albert Kottke (PGE), Tim Dawson (CGS), Rich Koehler (UNR), Alex Sarmiento (UCLA), Steve Thompson (LCI), Brian Gray (LCI)
We gratefully acknowledge the funding from Pacific Gas and Electric to support this project as well as the students in 'Mapping Tectonic Faults from Geomorphology' that contributed pre-rupture faults maps to the project. We gratefully acknowledge SCEC and NSF for the funding and support for this meeting.