Development of the Geomorphic Indicator Ranking System for pre-rupture fault mapping

Rachel Adam[1], Chelsea Scott[1], Ramon Arrowsmith[1], Malinda Zuckerman[1], Christopher Madugo[2], Rich Koehler[3], Darryl Reano[1], Özgür Kozaci[4]

[1]Arizona State University, [2]Pacific Gas and Electric, [3]University of Nevada Reno, [4]InfraTerra Inc.

Introduction

Pre-rupture fault mapping informs potential future rupture hazard with implications towards reducing critical hazards associated with infrastructure development.

We build on efforts to **standardize the pre-rupture fault mapping process** with the Geomorphic Indicator Ranking System (GIR) as a tool to quantify geomorphic evidence on the surface indicative of active faulting to assign a certainty level (strong, distinct, weak, uncertain) to the mapped fault segments.

Background

The GIR consolidates the geomorphologic features associated with active faulting into a single framework on a grading system from 1 - 4 (1 being the weakest indication and 4 being the strongest) with additional modifiers with a +/- 1 score that increase or lower the mappers' confidence on the fault location.

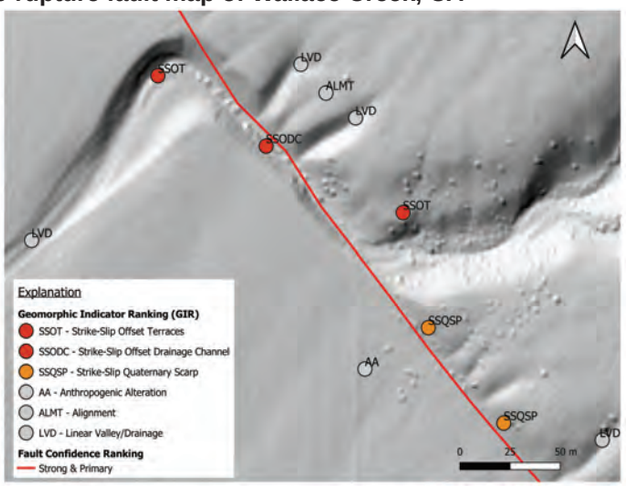
Features are mapped prior to placing any faulting symbology to help locate the fault and assign a confidence.

GIR Table

Feature	Rank	Description	Justification as fault indicator
Offset terraces (OT)	4	Laterally and obliquely offset fluvial terraces	Coseismic slip offsets terraces and terrace risers
Offset drainage channel (ODC)	4	A channel with two ~90° bends that is otherwise straight	Offset caused by differential translation of a stream by a fault

First few lines of the GIR table

Pre-rupture fault map of Wallace Creek, CA



GIR points and fault confidence ranking linework displayed on a 1 m/pixel hillshade for Wallace Creek, CA. (DSM; from the B4 project https://doi.org/10.5069/G97P8W9T)

The fault confidence ranking is determined either by geologic intuition (the mapper decides on a confidence ranking) or by adding the GIR scores along a segment and scaling them to a 1 -4 scale (corresponds with confidence ranking scale).

This methodology emphasizes how to best map faults from remote- sensing data for use in regional seismic hazard.

Results

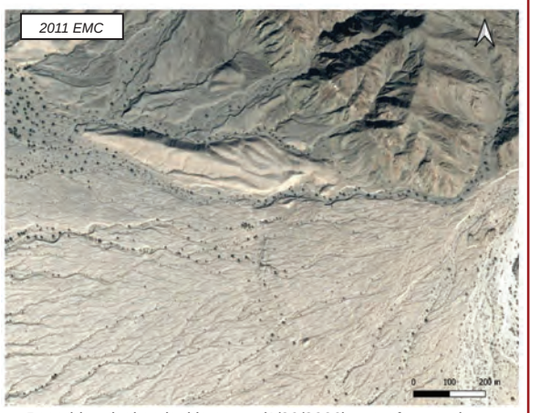
We tested the efficacy of the GIR as both a **teaching tool and an industry tool.**

The framework was introduced to a fault mapping class with 19 participants (ASU and UNR) in the Spring of 2022 (panels a & b).

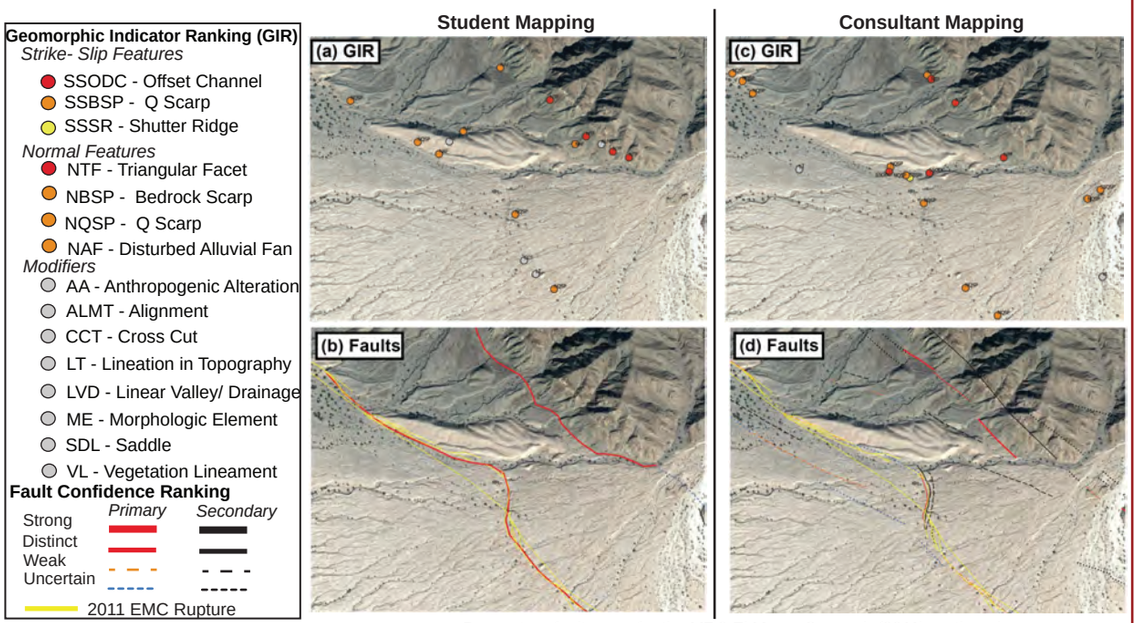
5 professional geologists were hired to complete the same mapping as the students using the GIR (panels c & d).

Mapping areas included varying regional environments, faulting styles, deformation, and surface expression. The locations: 1) El Mayor Cucapah, Mexico, 2) Ridgecrest, CA, 4) Borah Peak, Idaho 5) Fukushima, Japan included varying levels of pre-rupture data including SRTM, lidar, georeferenced optical imagery, etc.

Both the student and the consultant **predicted the rupture** (shown in yellow) well, with supporting GIR features mapped along or near the fault trace



Base historical optical imagery (1/20/2006) georeferenced ~ 1 m/pixel resolution



Pre-rupture fault maps for the M7.2 El Mayor Cucapah (2011) earthquake.

Conclusion

The Geomorphic Indicator Ranking System is an effective tool providing a systematic and repeatable approach to pre-rupture fault mapping. It provides a framework to mark all the available evidence on the surface and determine a fault location based on GIR point locations.

Further work includes: 1) comparing the fault confidence ranking score from geologic intuition and the GIR segment score and 2) determining which GIR features are better at predicting future rupture locations.

To better understand the difficulty associated with pre-rupture fault mapping, we are researching qualitative studies into the decision-making process for mappers at both a student and industry level. Results from this work will inform the epistemic uncertainty and anchoring/confirmation bias associated with active fault mapping.

Citations: Scharer, K.M.; Weldon II, R.J.; Fumal, T.E.; and Biasi, G.P. Paleoearthquakes on the southern San Andreas Fault, Wrightwood, California, 3000 to 1500 B.C.: A new method for evaluating paleoseismic evidence and earthquake horizons. 2007. Bulletin of the Seismological Society of America.

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