Preservation and interpretation of the geomorphic record of earthquakes

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1. Motivation

Earthquake surface ruptures are not preserved as complete records. They narrow, simplify, and then are interpreted with tens of meters of mapper uncertainty.

- Surface ruptures record fault location, width, and distributed deformation.
- Surface processes erase and simplify that record.
- Mappers then interpret what remains, adding epistemic uncertainty.

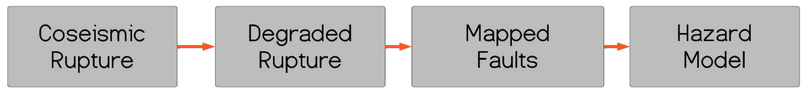


Figure 1: *Flowchart emphasizing how hazard models come from mapped faults that are mapped from degraded landforms.*

2. Geomorphic Preservation

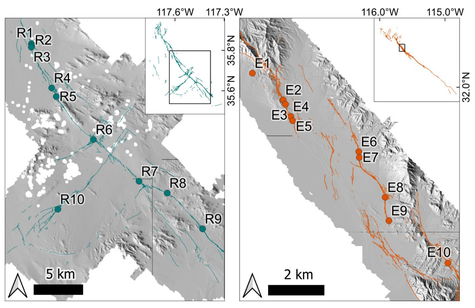
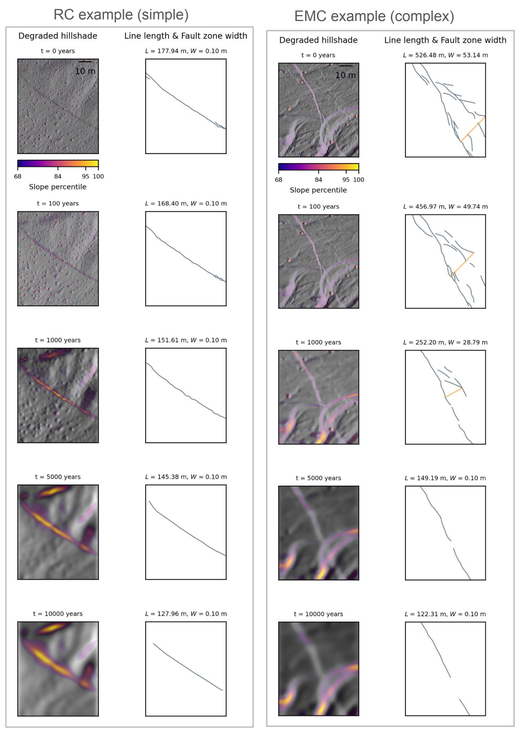


Figure 2: *Location maps of study sites. Ridgecrest (left) & El Mayor-Cucapah (right)*

STUDY SET-UP

- 20 rupture locations with visible vertical displacement.
- 0.5 m/pix lidar-derived DEMs of the 2019 M7.1 and M6.4 Ridgecrest and 2010 El Mayor-Cucapah (EMC) earthquake rupture landscapes.
- 2D linear diffusion in Landlab
- Time steps: 0, 100, 1k, 5k, 10k years.



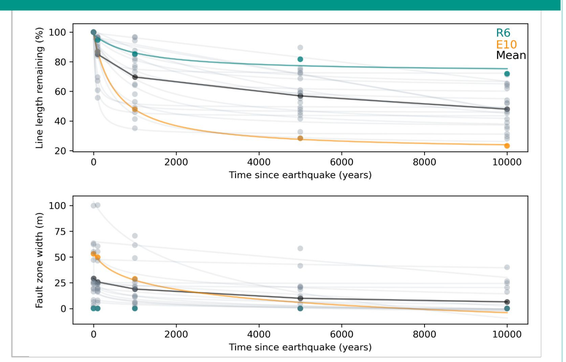


Figure 3 (left): *Line length and fault zone width for degraded maps.* ***Figure 4 (above):*** *All line length and fault zone width results.*

RESULTS

- 20-80% of original trace length remains after 10 kyr
- Fault zone width narrows from ~30-40 m to ~2 m
- Degradation is fastest in the first 100 yrs
- Complex, distributed ruptures degrade faster than simple single-strand ruptures

3. Mapping Uncertainty

STUDY SET-UP

- 23 mappers with different experience (undergraduates through senior professional geologists)
- Pre-earthquake remote sensing datasets and a systematic geomorphic fault mapping workflow
- Compared mapped faults to later coseismic ruptures

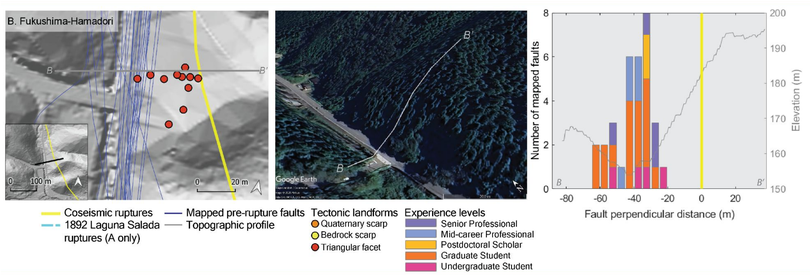
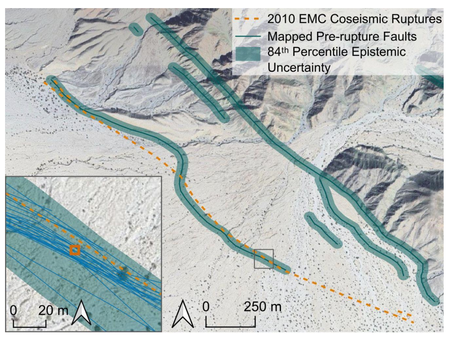


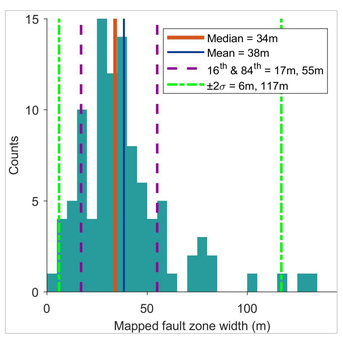
Figure 5: *Mapped faults next to a triangular facet. No mappers predicted the rupture along the upper third of the facet.*

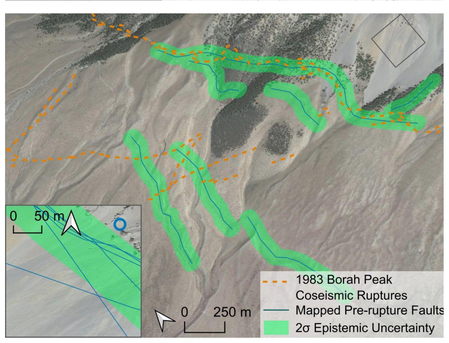
RESULTS

- Professionals did somewhat better, but experience beyond graduate level only modestly improved results.
- All experience groups missed subtle or ambiguous future ruptures.

Figure 6 (right): *Epistemic uncertainty ranges created from the mapped fault zone width by mappers with a range of experience.*







EPISTEMIC UNCERTAINTY

- The same landscape can support multiple reasonable fault interpretations.
- Uncertainty increases where evidence is subtle or distributed.
- Buffer zone width should be appropriate to the mapping uncertainty around a given fault zone.

4. Information Loss

Degradation and interpretation reinforce each other.

Process	What It Removes	Consequence
Degradation	Secondary scarps, cracks, distributed traces	Fault zones look narrower and simpler
Interpretation	Consistent fault location and confidence	Fault maps vary by tens of meters
Combined	Original rupture geometry	Older ruptures are underestimated

- Physical degradation weakens the geomorphic signal.
- Weaker signals increase interpretive uncertainty.
- Older ruptures may appear narrower, simpler, and more confidently located than they were in the original surface rupture record.

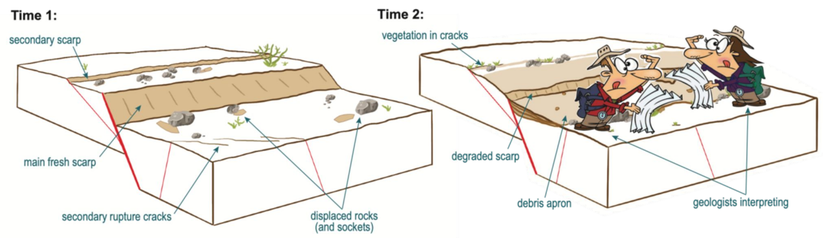


Figure 7: *After time has passed and scarps have degraded, geologists are interpreting an inherently incomplete dataset.*

5. Hazard Implications

Hazard models need to account for what the landscape no longer preserves.

IMPLICATIONS FOR FAULT DISPLACEMENT HAZARD MODELS

- Fault maps based on degraded landscapes likely underestimate original rupture width.
- Distributed deformation may be especially underrepresented.
- Accommodation zones and PFDHA logic trees should include both preservation limits and epistemic mapper uncertainty.
- Rapid documentation after earthquakes matters because the most diagnostic features are short-lived.

WHAT SHOULD CHANGE?

- Use multiple mappers or alternative fault geometries to represent epistemic uncertainty.
- Account for time since last rupture and local diffusivity.
- Inflate apparent fault-zone width where degradation is likely.
- Prioritize rapid post-earthquake lidar/UAV/field documentation.

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Quantifying the erasure of earthquakes in desert landscapes

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The impact of mapper experience and data on the quality of geomorphic fault mapping

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