Geomorphic evidence of earthquakes: linking landform degradation, fragile geologic features, and mapper accuracy.

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Motivation

- Earthquake hazard assessments can be informed by findings from geomorphic mapping studies and post-seismic field observations.
- That evidence is incomplete and uncertain due to surface processes and interpretation.
- This project tackles *three key factors*: **preservation**, **fragile geologic features**, and **human interpretation**.

Fig 1. Water pipe broken during the 2019 Ridgecrest EQ sequence (Brandenberg et al., '19)

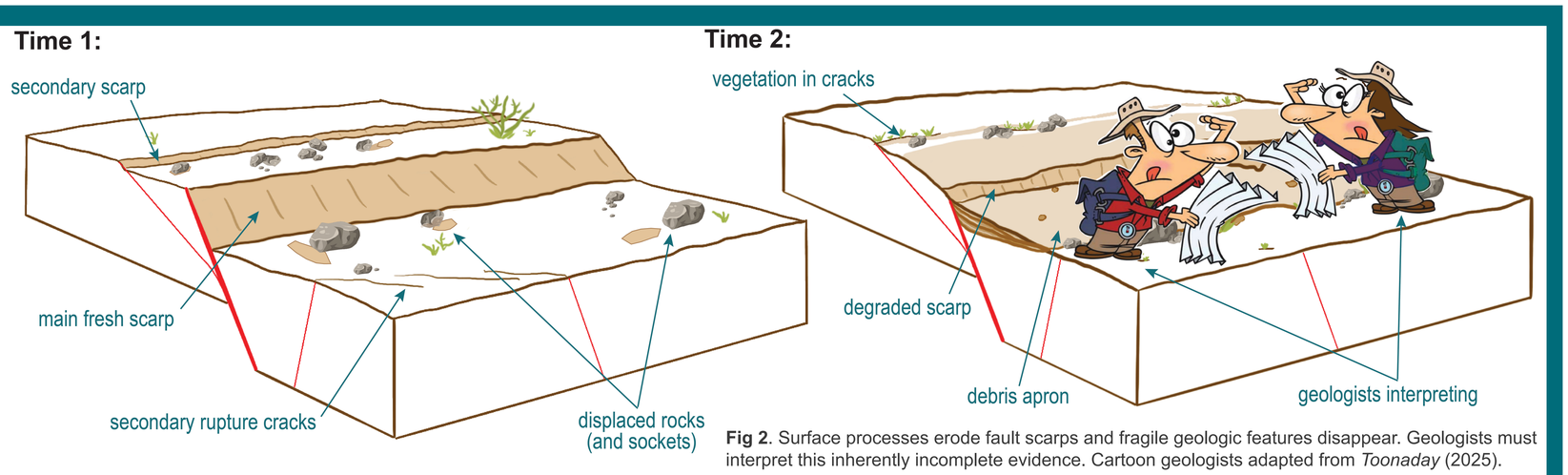


Fig 2. Surface processes erode fault scarps and fragile geologic features disappear. Geologists must interpret this inherently incomplete evidence. Cartoon geologists adapted from *Toonaday* (2025).

Case study 1: Preservation of fault scarps

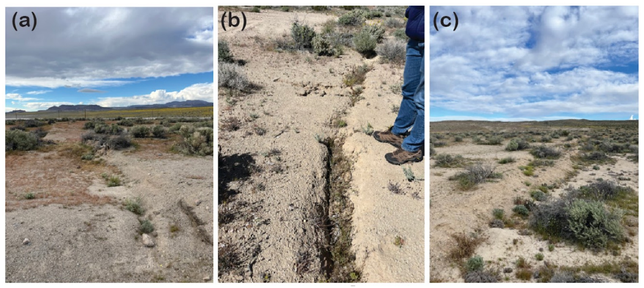


Fig 3. Degradation of fault evidence; 4.5yrs post Ridgecrest eq sequence.

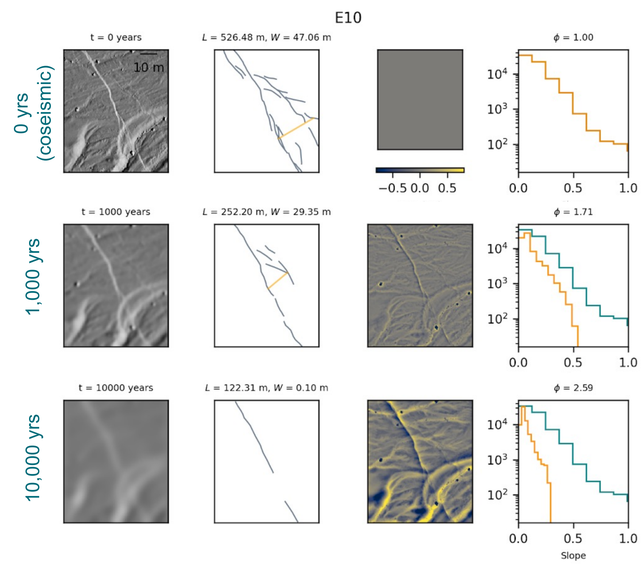


Fig 4. Over time, mappable fault length and fault zone width decrease.

- Used landscape evolution models with lidar data from the 2019 Ridgecrest and 2010 El Mayor-Cucapah EQs to simulate landform degradation over 100–10k yrs.
- Fault trace length decreases by 20–80% over 10k years, fault zone width shrinks from ~40 m to ~2 m, and most rapid degradation occurs within the first 100 years.

Case study 2: Fragile geologic features

Fig 5. Field photo of a rock flipped over by shaking from the July 2019 Ridgecrest sequence. The rock's displacement vector and orientation is measured from its empty socket (photo: Oct 2019).

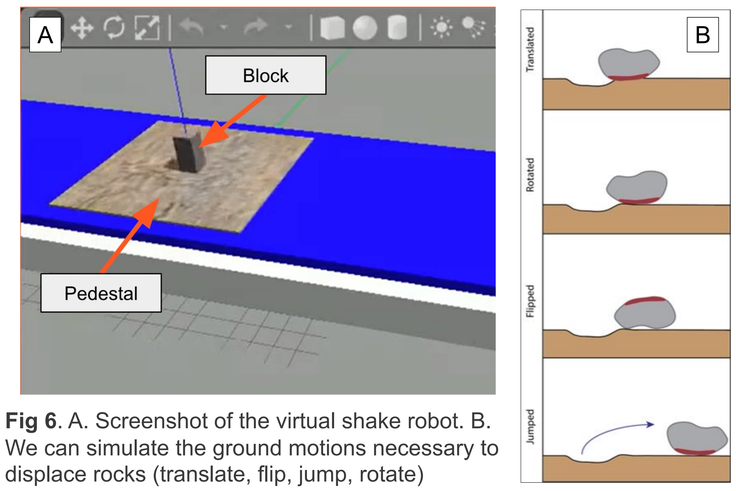


Fig 6. A. Screenshot of the virtual shake robot. B. We can simulate the ground motions necessary to displace rocks (translate, flip, jump, rotate)

- Measured displaced rocks in the field after the Ridgecrest sequence. Used these data to model ground motions using a virtual shake table that could displace rocks.
- Observations of displaced rocks during rupture mapping may be useful for dynamic rupture modeling or as ground motion model constraints.

Case study 3: Fault mapping interpretation

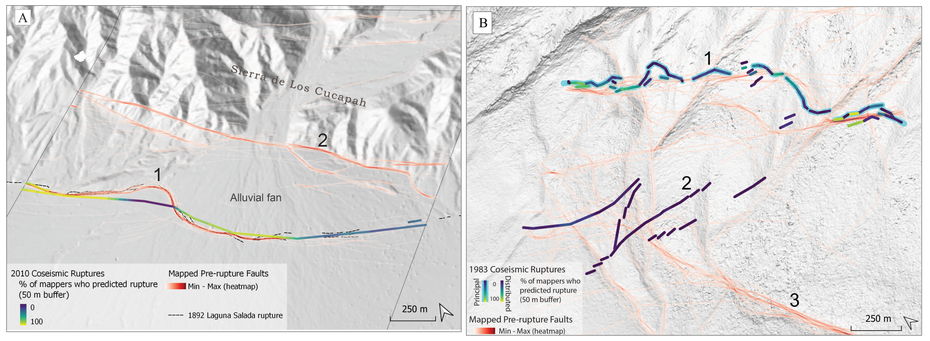
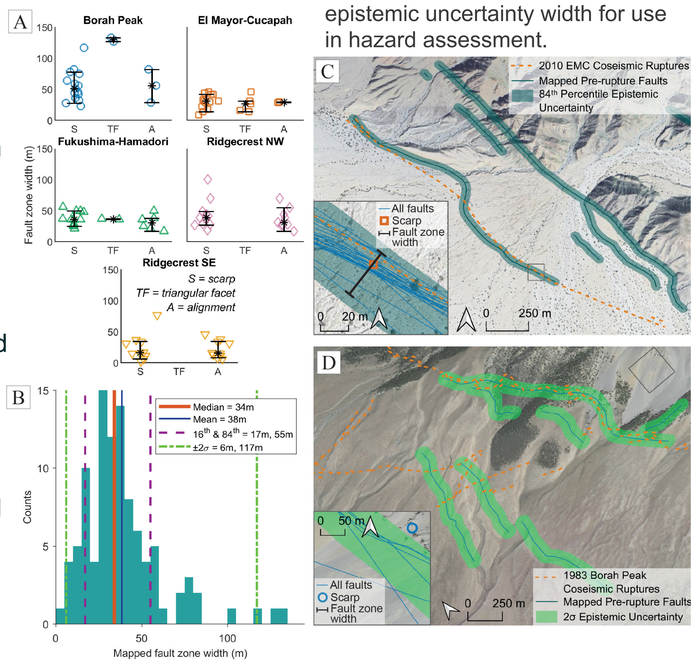


Fig 7. Repeat fault maps. 23 mappers with different experience levels mapped faults using pre-rupture data (red heat map lines). We compared the mapped faults to coseismic ruptures (yellow to blue lines). 2010 El Mayor Cucapah (A), 1983 Borah Peak (B), 2011 Fukushima-Hamadori, and 2019 Ridgecrest.

Fig 8. We used the spread of mapped faults near tectonic landforms to calculate an epistemic uncertainty width for use in hazard assessment.

- 23 participants (students to professionals) mapped faults from pre-EQ remote data.
- Professionals only slightly outperformed grad students; all missed some future ruptures; epistemic uncertainty = 55–117 m.
- Experience beyond grad level does not greatly improve results.



Conclusion

- Need to understand that fault traces may be longer and fault zones may be wider than what we see in the geologic record.
- Fragile features can extend datasets in poorly instrumented regions.
- Mapping uncertainty, especially epistemic, must be acknowledged in fault mapping and applied in fault displacement hazard assessment.

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