Damage zone patterns along creeping faults in the Navajo Sandstone, Utah.

2021 SOURCES

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Abstract

Faults that creep at a constant rate impose a steady influx of stress to their tips. The Needles Fault District and the Moab Fault Zone form arrays of normal faults cutting the Navajo Sandstone (Utah) that experience steady-state creep related to salt tectonics. We used a combination of aerial orthophotography and lidar data to map faults and secondary fractures at both locations. From these maps, we analyze the distribution of fracture density and orientation within fault damage zones. Fractures are organized into a single set at Moab and two perpendicular sets at Needles and may be indicative of regional tectonics instead of fault activity. Fracture densities are unevenly distributed along strike of the faults, focusing at fault tips and areas of geometrical complexity (bends and step-overs). At both locations, there is a gradient in fracture density throughout the fault array, where fracture density steadily decreases over two orders of magnitude with distance away from the locus of deformation. This indicates that, even if the fracture networks are inherited, their reactivation and growth respond to the ongoing fault creep.

Motivation and Study Areas

Motivation

Damage zones along creeping faults remain relatively unexplored, but may contain key information about the mechanics of their seismogenic counterparts, allowing distinction between the role of static and dynamic stresses in fracture generation and growth. We select two locations without active tectonics, so faults only creep.

March 25, 2018: Photograph scanning over faults and fractures NW of Moab, Utah.

Needles Fault District

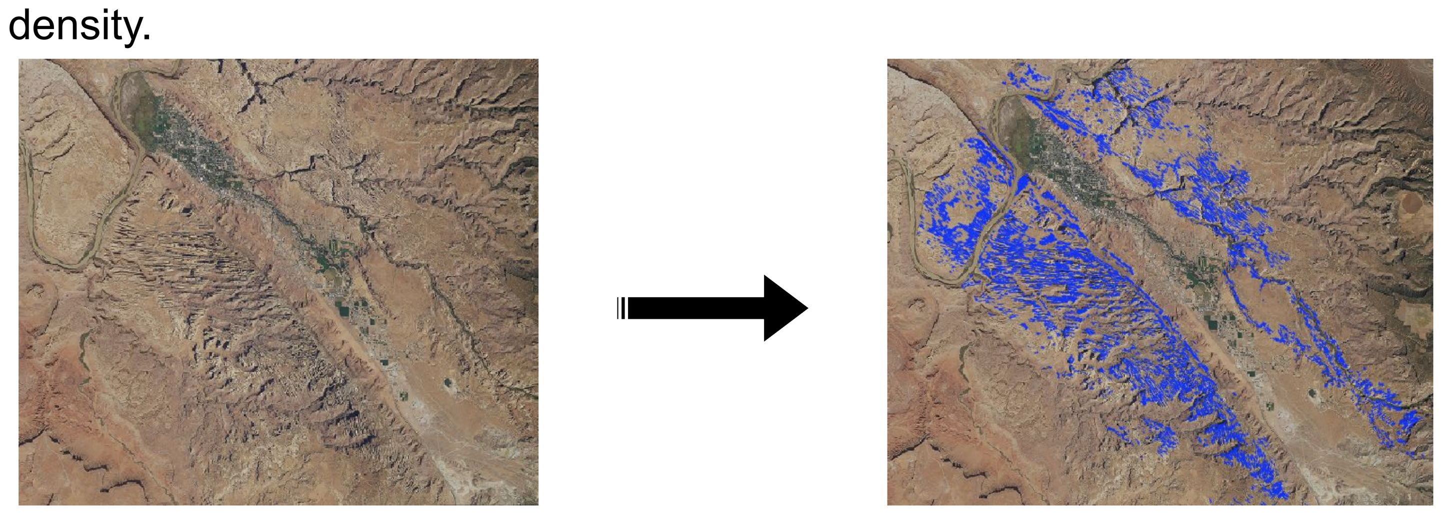
Faults in the Needles Fault District in Canyonlands National Park (UT) creep at a constant rate of 2 mm/yr due to dissolution of an underlying salt unit (Kravitz et al., 2020). Creep is distributed throughout an ~60 km² fault array.

Moab Fault Zone

The Moab Fault runs approximately NW to SE through the valley of Moab, Utah. Deformation on the Moab fault is also driven by dissolution of an underlying salt unit, though some workers have argued for a tectonic component as well. The fault slips at 0.014-0.036 mm/yr, very slowly! (Black et al., 2004).

Methods

We utilize 1 m high-resolution lidar and 60 cm aerial orthophotography from the Needles District and the valley of Moab to map faults and fractures in a free geographic information system application. We distinguish fractures from normal faults based on vertical offset. We use our maps to analyze the distribution of fracture orientations and fracture density.



Mapped Damage Zones

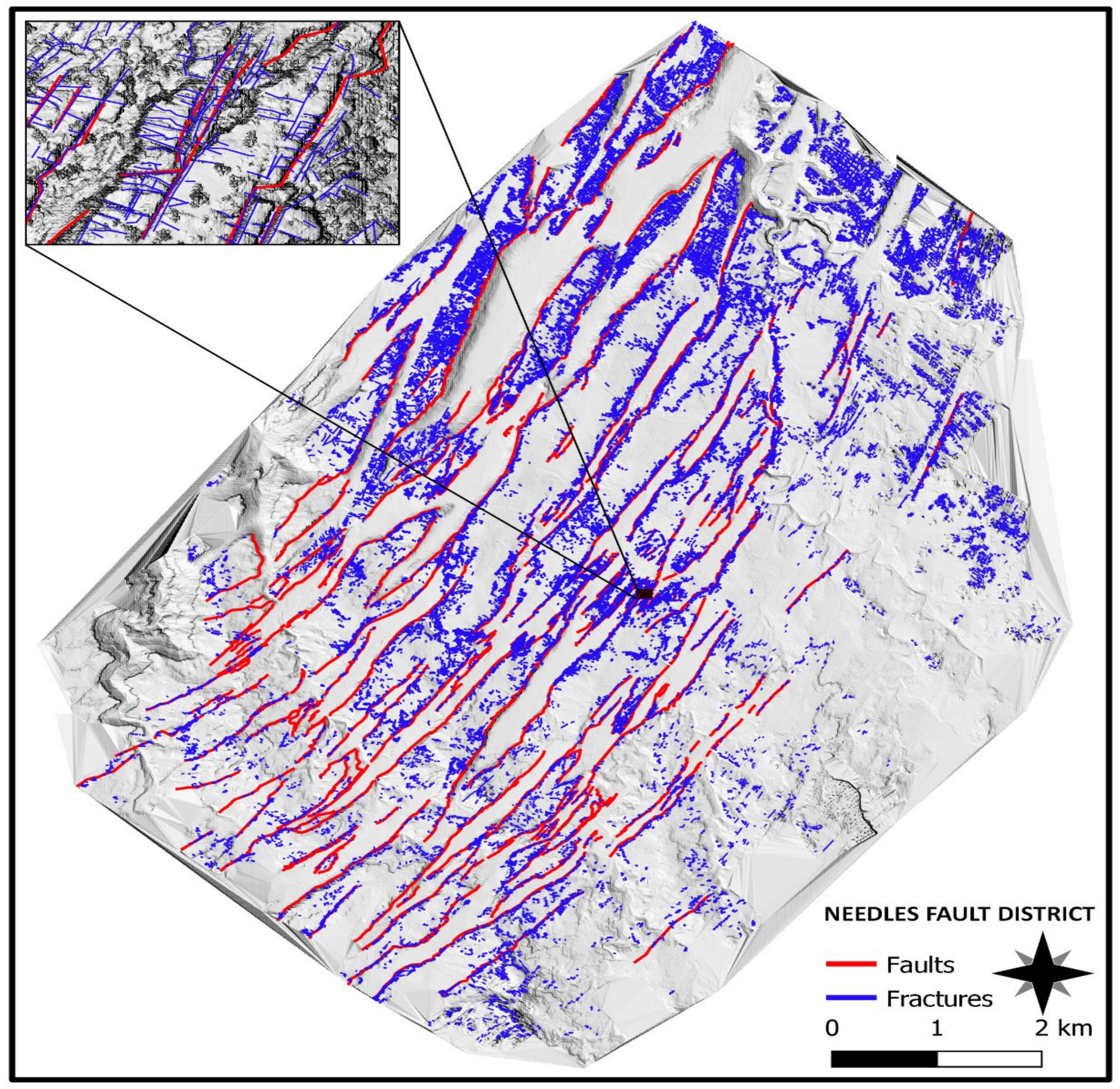


Figure A: Needles Fault District hillshade generated using lidar. We mapped faults and fractures, which are depicted in red and blue, respectively. A portion of the region with the highest fault tip fracture density may be seen is shown in the zoomed-in image. The purpose of enlargement is to improve the appearance and connections between cracks and faults.

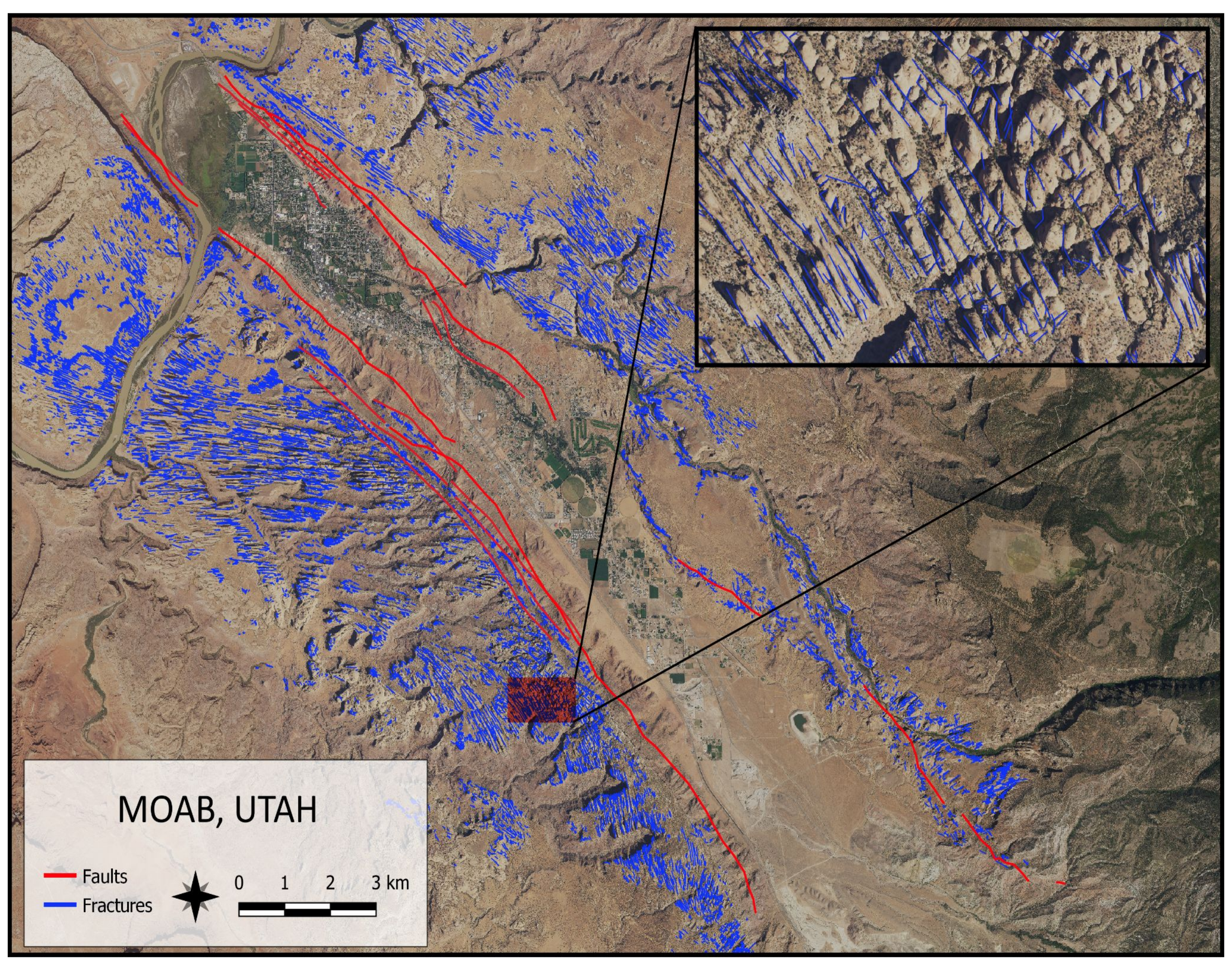


Figure B: Aerial orthophotography of the Moab Fault that extends through the Moab-Spanish Valley. I mapped Utah quaternary faults and fractures, which are depicted in red and blue, respectively. A portion of one of the regions with the highest fault tip fracture density is shown in the zoomed-in image.

Fracture Analysis

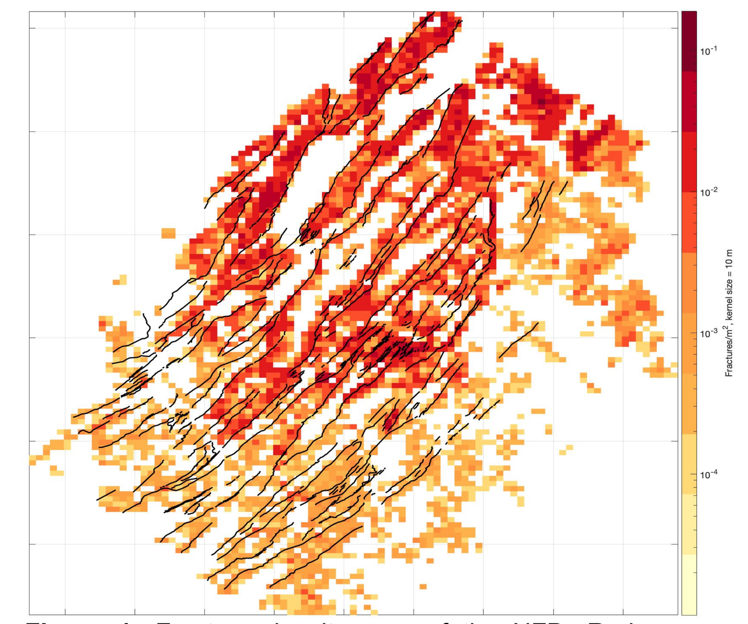


Figure 1: Fracture density map of the NFD. Red areas represent the highest fracture density. The northern faults have the highest fracture density throughout the entire scarp.

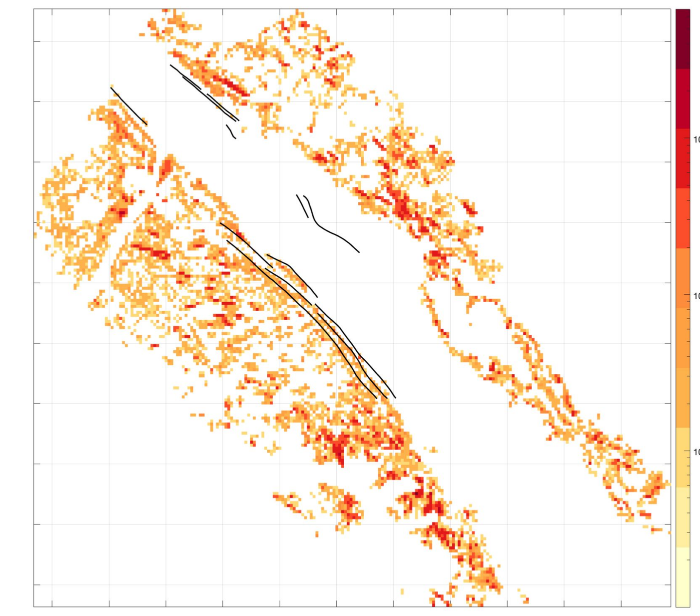


Figure 3: Fracture density map of the Moab Fault. Red areas represent the highest fracture density. The highest fracture density spread throughout the scarp.

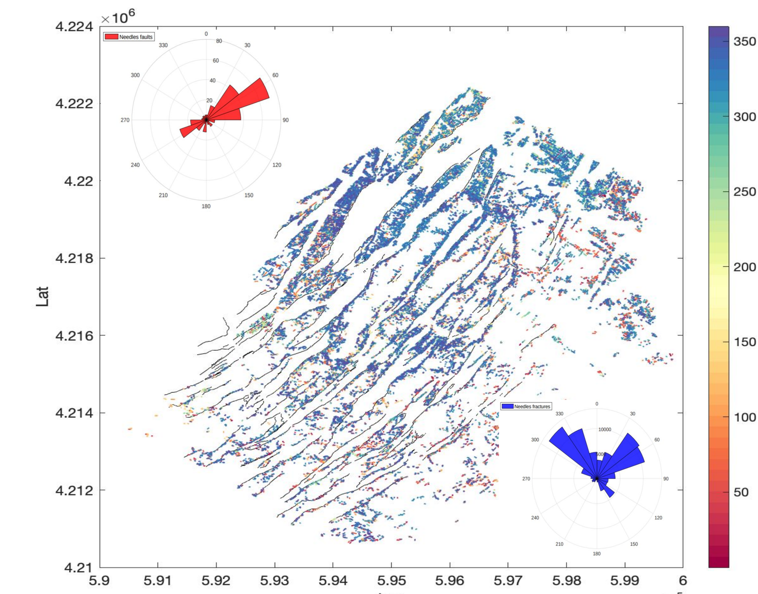


Figure 2: The orientation (in degrees) of the Needles Fault District faults and fractures based on the mapped damage zones with rose diagrams.

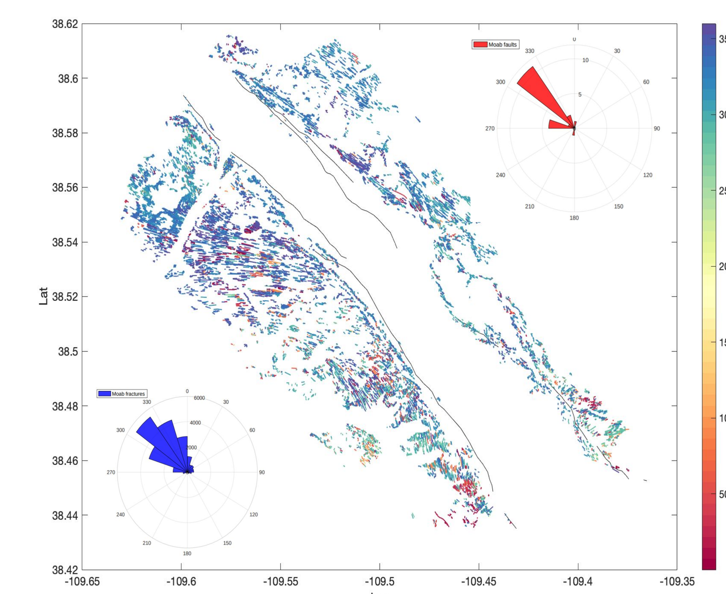


Figure 4: The orientation (in degrees) of the Moab faults and fractures based on the mapped damage zones with rose diagrams.

1. 476 faults and 85,267 fractures were mapped in the NFD (Figure A). The maximum fracture orientations are between 131º and 140º (Figure 1) and the maximum fault orientations are between 211º and 220º (Figure 2)
2. I mapped 23 faults and 22,598 fractures in Moab Fault Zone (Figure B). The maximum fracture orientations are between 130º and 140º (Figure 3) and the maximum fault orientations are between 145º and 155º (Figure 4)

Discussion

1. The fracture density decreases drastically from north to south in the Needles Fault District but remains constant across the Moab Fault Zone.
2. Fracture density at the Needles is comparably higher at fault tips and step-overs. Fault tips at Moab are buried so we cannot assess whether this is the case as well.
3. We plan to compare our damage zone map and analysis to data from seismogenic faults. This will help us better understand how static and dynamic stresses stimulate the generation and evolution of off-fault damage.

References

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