Characteristics of Surface Rupturing Earthquakes in the Walker Lane from Centimeter Scale Orthoimagery

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ABSTRACT

Centimeter scale drone based structure from motion orthoimagery was collected shortly following the 2019 M6.4 & 7.1 Ridgecrest and 2020 M6.5 Monte Cristo Range (MCRE) earthquakes. Fractures are mapped at high detail for tens of km along each rupture. Despite similarly ruptured materials and tectonic settings, each rupture displays distinctly different characteristics in not only the overall rupture pattern, but also finer scale fracturing. Ridgecrest ruptures are primarily confined to a few main traces, while MCRE are frequently discontinuous fields of numerous distributed cracks. Here examples of these different patterns are presented. We also show our locations for trenching work to commence later this fall.

METHODS

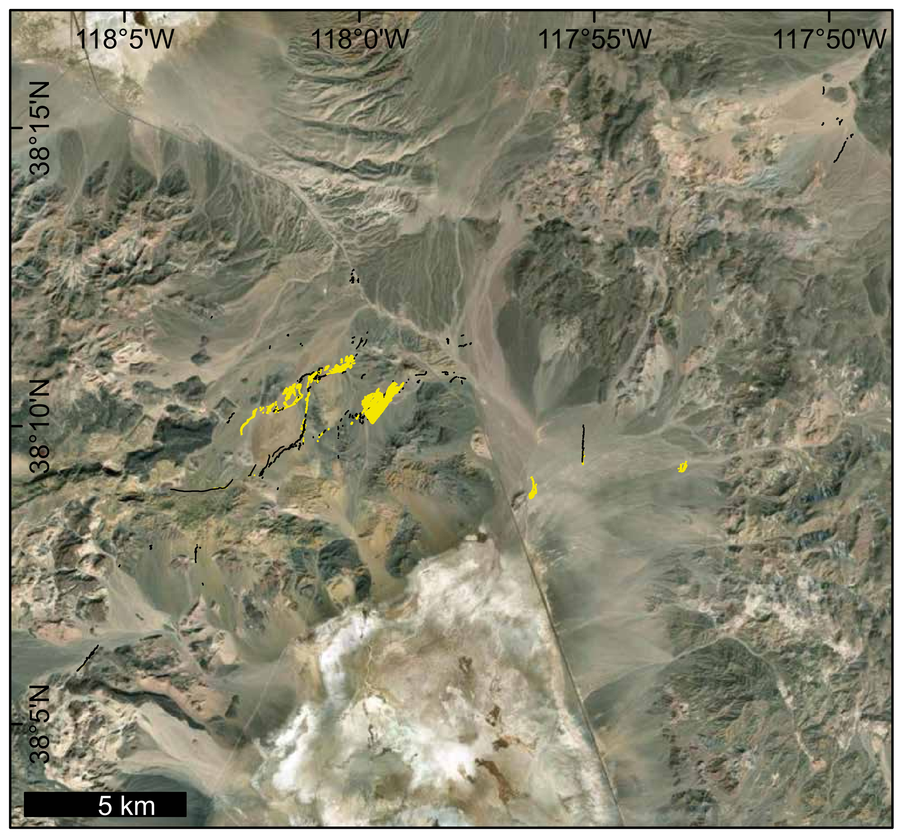
Images were collected using a variety of DJI drones along all three events in the days immediately following the earthquakes. Ridgecrest was this group's first experience collecting Structure from Motion (SfM) imagery of a recent surface rupture, and many lessons learned were applied to the acquisition of images following the MCRE. Rain in the days after the MCRE event obscured many ruptures prior to imagery acquisition. No Ground Control Points were collected prior to the aquisition of the Ridgecrest earthquake, but GCP's were collected for most of the MCRE imagery using a Trimble R10 GPS. Images were processed into orthophoto mosaics using Agisoft Metashape and Photoscan. Ridgecrest ruptures were flown manually, and as such resolution and coverage are inconsistent, and vary from ~2 cm/pixel to ~20 cm /pixel depending on the area flown. MCRE ruptures were flown both manually and using an autopilot function and resolution is generally 0.7-1.0 cm/pixel. Cracks/fractures were then mapped using ArcGIS. The MCRE ruptures were generally mapped at a scale between 1:30 and 1:60. Ridgecrest ruptures were generally mapped at ~1:300.

OBSERVATIONS

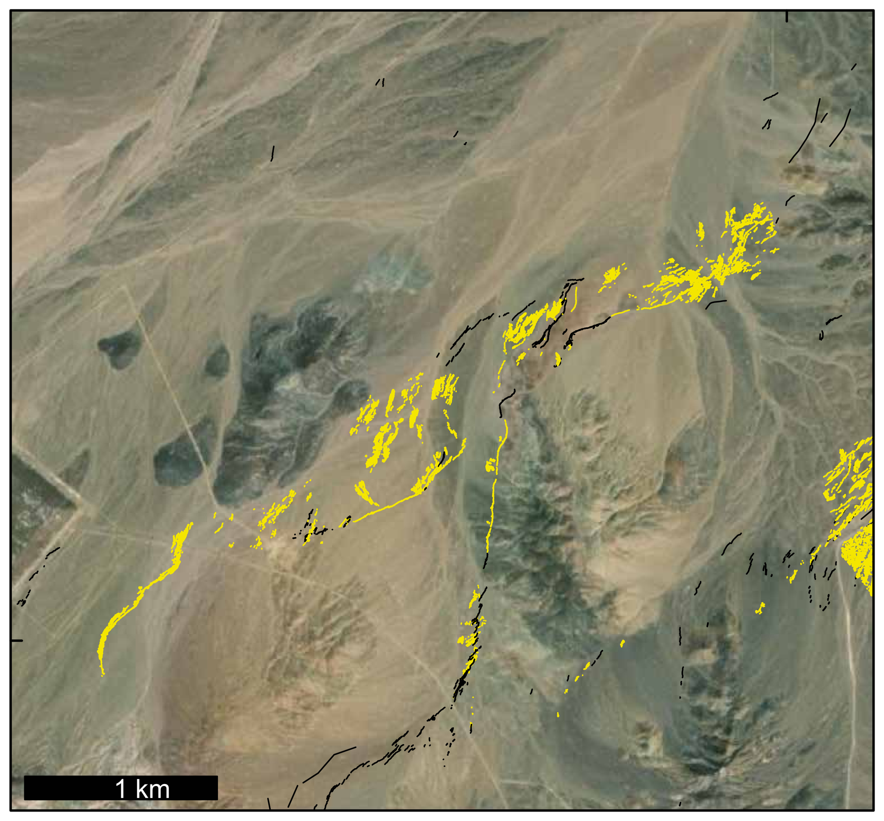
Each rupture occurred in a similar arid environment, dominated by Quaternary alluvial fans. The bedrock geology of the two areas is different, as is the orientation of the focal mechanisms, and the local stress field. The Ridgecrest events had nearly vertical focal mechanisms, while the MCRE focal mechanism was oblique. The MCRE ruptures follow an anastiomosing pattern of broad subparalell ruptures that intersect and diverge. The Ridgecrest rupture generally follows a single trace, with multiple, discrete subparallel traces spaced out over several kilometers. The MCRE ruptures are far more complex in both width, number of fractures, orientation, and pattern than the Ridgecrest ruptures. The MCRE ruptures also produced considerably less surface slip than the Ridgecrest ruptures. Despite a similar magnitude as the M6.4 Ridgecrest event, the MCRE is considerably more complex. The obliquity of the MCRE ruptures likely increased this apparent complexity.

NEXT

Parameters describing the differences between the ruptures will be developed to quantitatively assess how these ruptures vary along strike. Measurements of rupture width, orientation, number of fractures, fracture density, maximum displacement, total displacement, surface type/geomorphology etc. will be sampled in evenly spaced increments along the total rupture length of each rupture. Workflows and funding avenues should be developed to rapidly collect extensive SfM data immediately following all surface rupturing earthquakes.

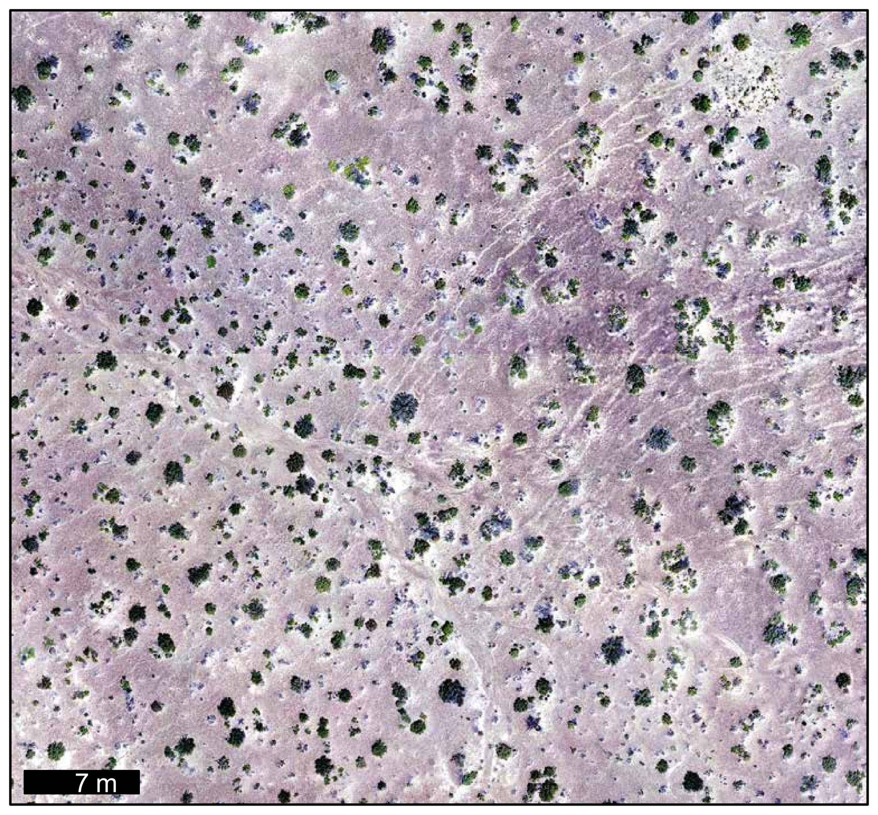


Overview of the MCRE rupture. Yellow are ruptures mapped from SfM imagery.

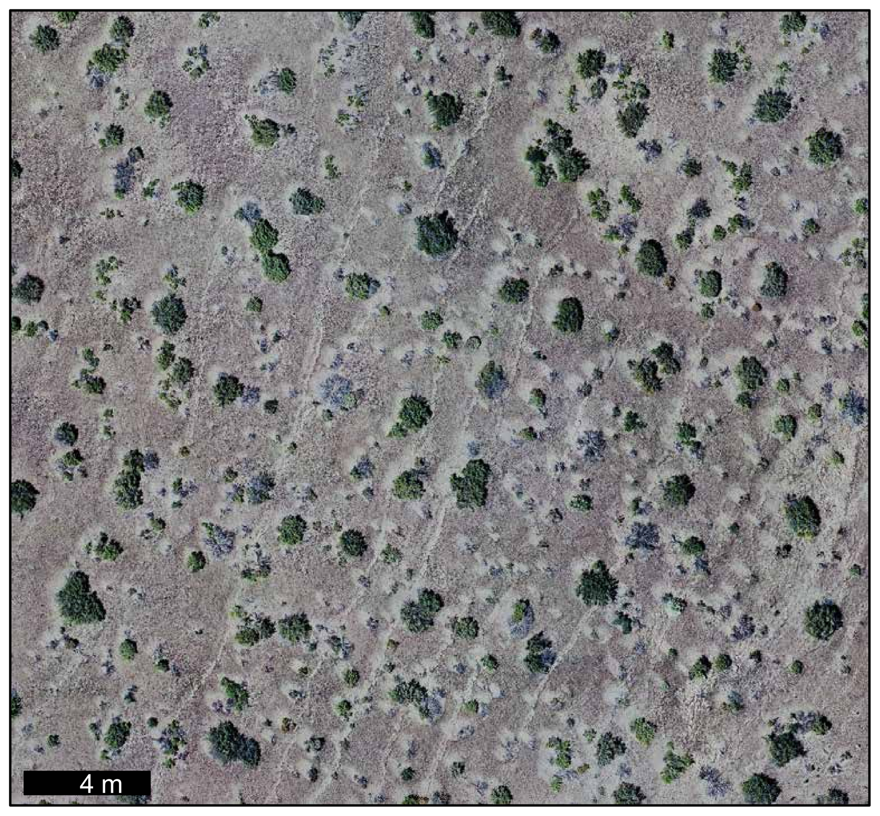


Enlargement of the "main" MCRE rupture. In many places the ruptures form a pattern that appears similar to a metamorphic foliation.

MCRE rupture width frequently exceeds 250 m. The "simplest" rupture zones still frequently exceed 3 m. Maximum slip measured along a single fracture here is on the order of 20 cm of vertical and 20 cm of left-lateral. These are mostly small extensional cracks with displacements too small to measure in the field (<2 cm).

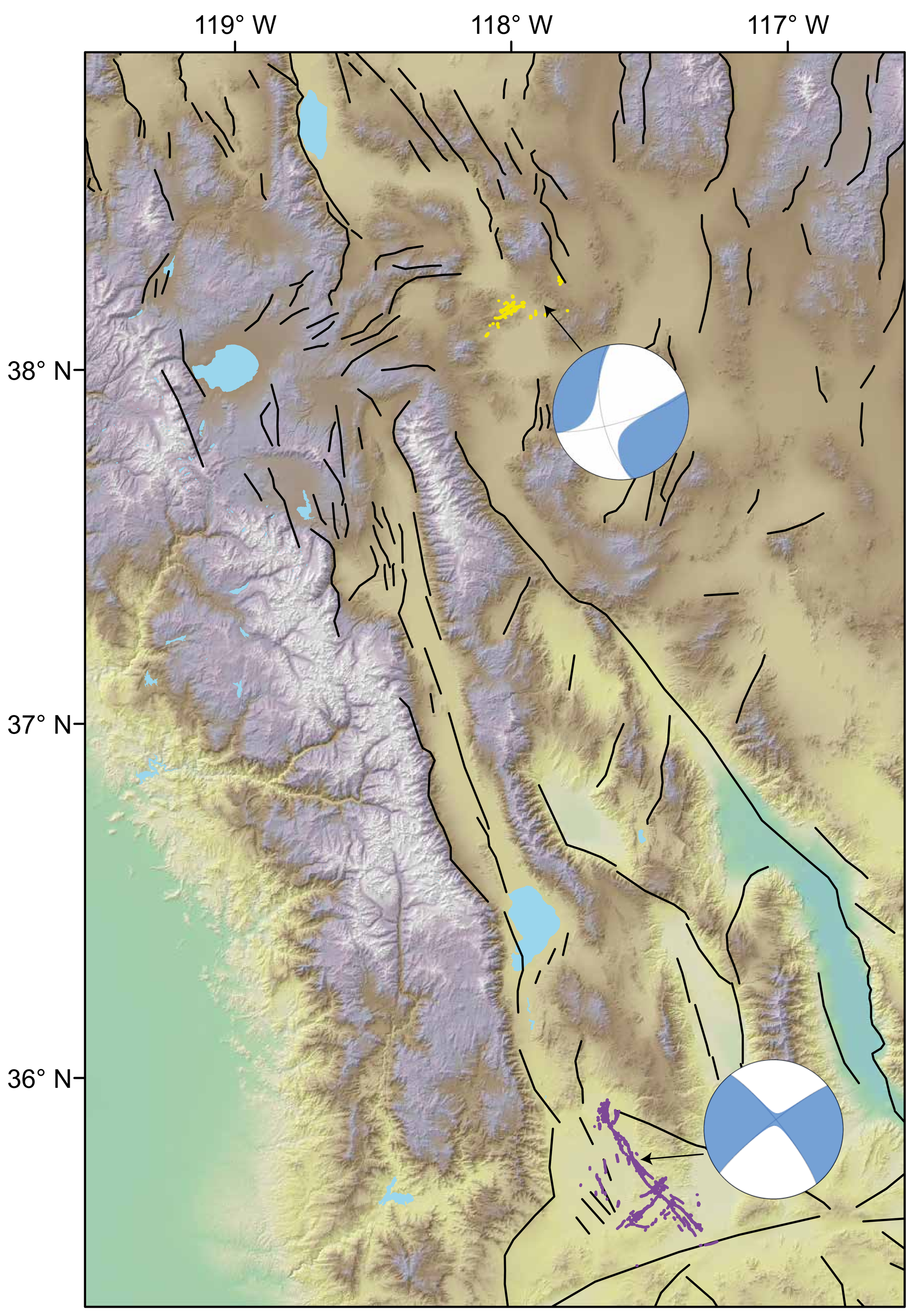


In this color enhanced image, fractures appear as white lines. In the upper right portion of the image fractures cut a well developed desert pavement surface. In the lower left, fewer fractures are visible in a younger alluvial surface. Fracture complexity and density in the MCRE appears to primarily be controlled by surface geomorphology.



Color enhanced 0.7 cm/pixel SfM image showing characteristic rupture pattern for the MCRE. Here distributed cracks in a desert pavement surface produce a broad pattern of northeast oriented light colored stripes, where the dark pavement surface has been disrupted, colloquialy refered to as "tiger stripes".

Color enhanced 0.7 cm/pixel SfM image of the MCRE rupture. This is the maximum field observed sinistal offset of ~20 cm.



Overview of the Southern and Central Walker Lane showing major faults (black) and the Ridgecrest (blue) and MCRE (yellow) surface ruptures. Moment tensors from USGS.

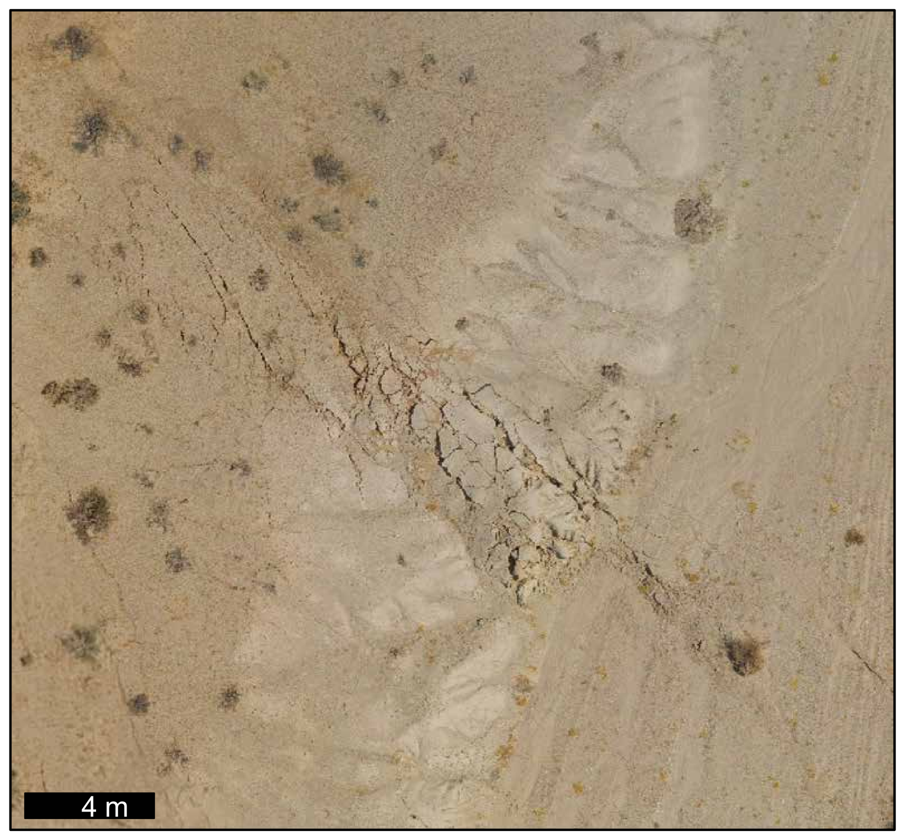
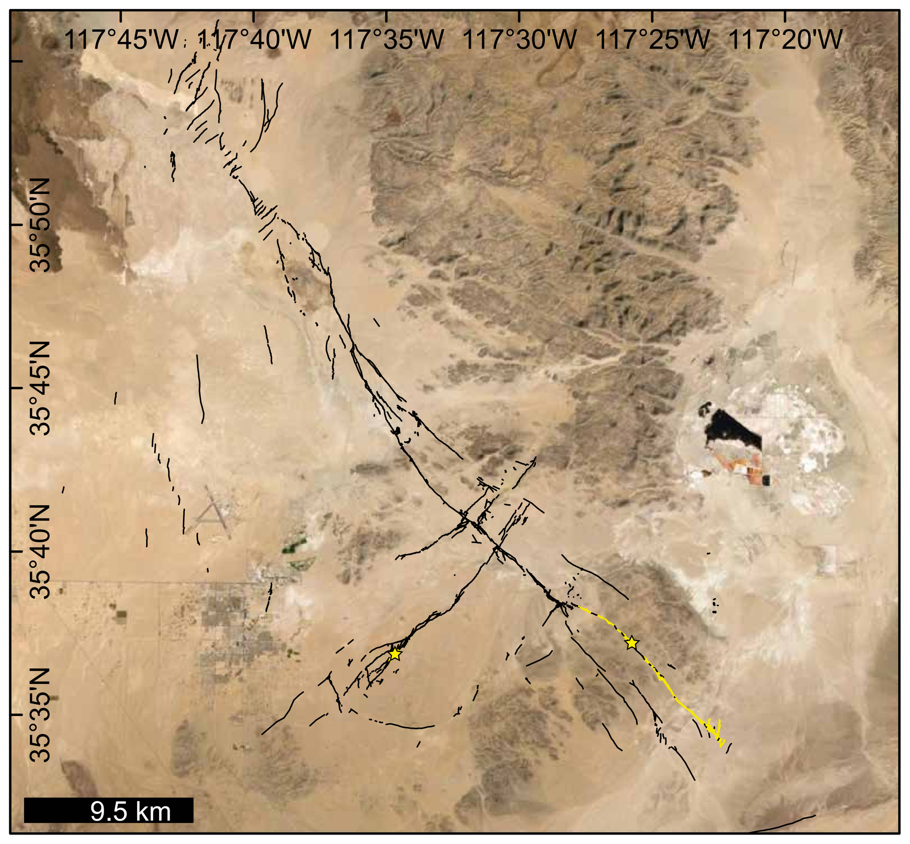
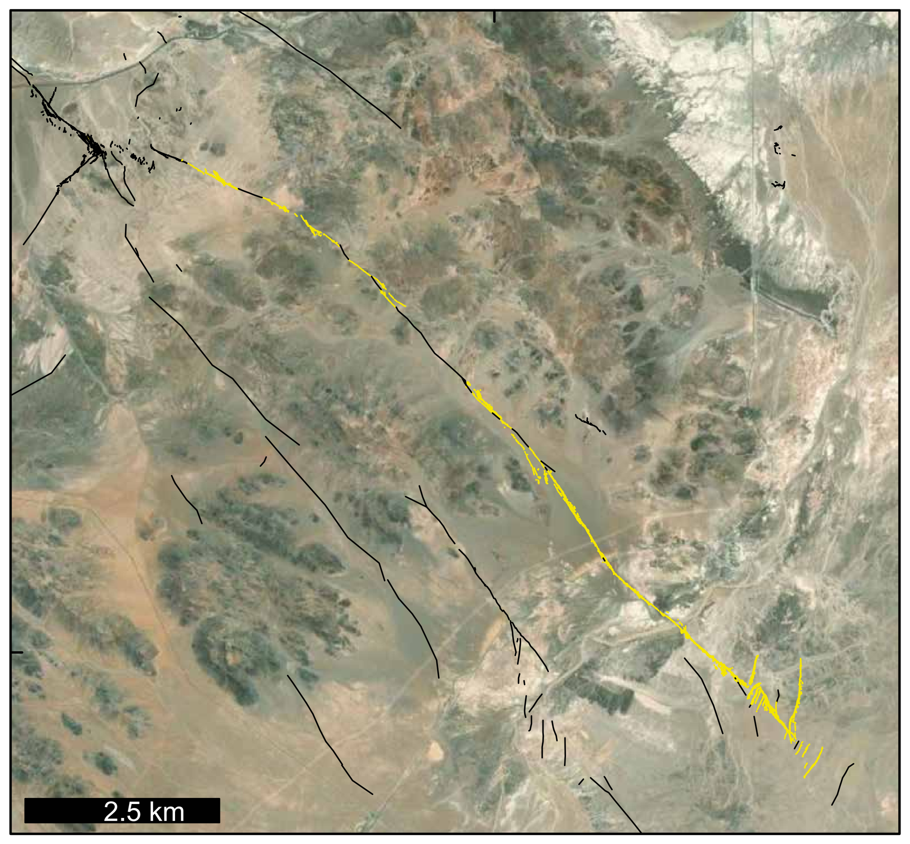


Image of a section of "mole-track" along the M7.1 Ridgecrest rupture.

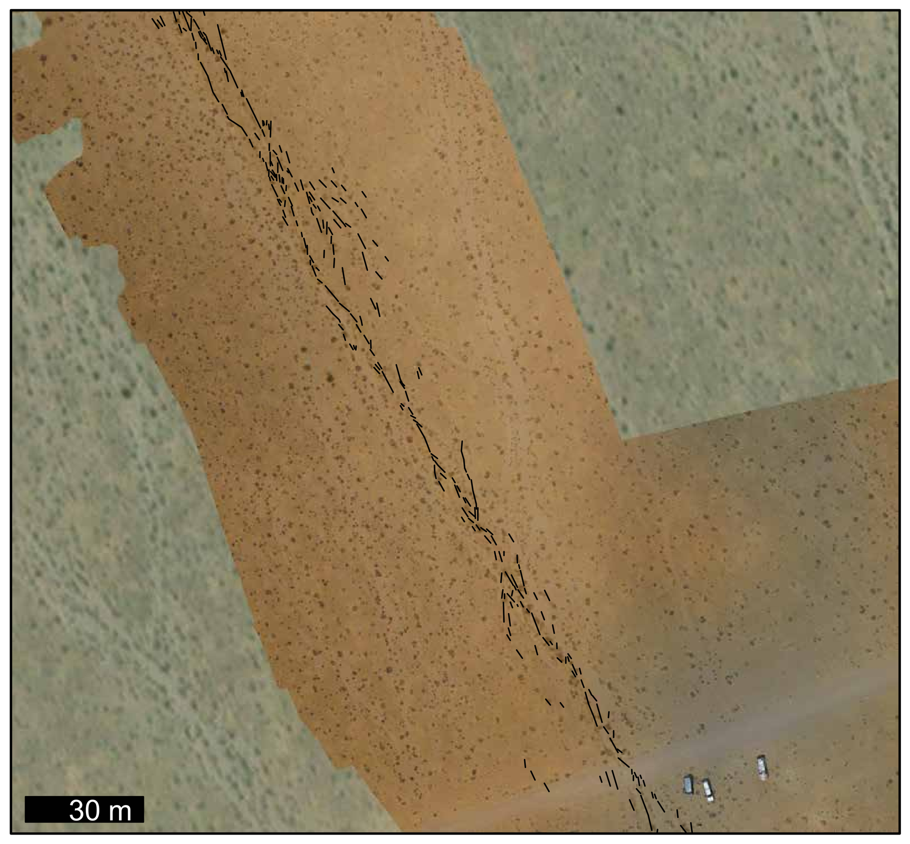
4.5 cm/pixel image of the main 7.1 Ridgecrest trace showing a ~60 cm dextral offset of a road.



Overview of the Ridgecrest ruptures. Yellow are ruptures mapped from SfM imagery. Stars indicate target trench sites for later this fall.



Enlargement of the southern part of the M7.1 Ridgecrest rupture mapped using SfM imagery. The main portion of the rupture forms a nearly linear rupture trace.



Ridgecrest rupture width is generally <30 m in zones with complexity, or <2 m along "simple" linear sections. Maximum dextral surface slip observed along this section is on the order of 1-1.5 m. Ruptures commonly form a "mole-track" pushup feature along the main trace.

Ridgecrest rupture width is generally a function of fault complexity, i.e., stepovers, terminations, splays, and intersections have a wider rupture width than linear sections. Here a left step creates a wider deformation zone along the otherwise narrow primary surface rupture of the Ridgecrest M7.1.