2020 SCEC Proposal FINAL REPORT

Focal mechanisms and stress field in the region of the 2019 Ridgecrest earthquake sequence

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***Proposal Categories*:**
Integration and Theory

SCEC Research Priorities:
P1.c, P1.d, P1.e

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Summary

The studies performed in this project provide detailed results on processes associated with the 2019 Ridgecrest earthquake sequence by analyzing space-time variations of seismicity, potency values and focal mechanisms of earthquakes leading to and during the sequence. Over the 20 years before the M_w7.1 mainshock, the percentage of normal faulting events decreased gradually from 25% to below 10%, indicating a long-term increase of shear stress. The M_w6.4 and M_w7.1 ruptures terminated at areas with strong changes of seismic velocity or intersections with other faults producing arresting barriers. The aftershocks are characterized by highly diverse focal mechanisms and produced volumetric brittle deformation concentrated in a 5-10 km wide zone around the main ruptures. Early aftershocks of the M_w7.1 event extended over a wide area below typical seismogenic depth, consistent with a transient deepening of the brittle-ductile transition. The Ridgecrest earthquake sequence produced considerable rock damage in the surrounding crust including below the nominal seismogenic zone. The research done in the project includes derivation of focal mechanisms of small events using a deep learning algorithms.

Intellectual Merit

The Ridgecrest earthquake sequence occurred along a previously not well-recognized fault zone and had high geometrical complexity. The performed analyses quantify the geometrical complexity of the earthquake sequence with basic measures of earthquake source properties and several additional important issues. These include the preparation process that allowed the M_w6.4 and M_w7.1 ruptures to propagate along such a disordered fault zone, the barrier that separates the NW end of the M6.4 event and epicenter of the 7.1 earthquake 34 hours later, and interactions of the Ridgecrest sequence with the surrounding volume. The results indicate that the fraction of normal faulting events in the area dropped in the past 20 yr from >25% to <10%, implying increasing shear stress. The M_w6.4 and M_w7.1 events terminated at areas with strong changes of seismic velocity or junctions with other faults acting as barriers. Aftershocks with diverse mechanisms produced significant seismic potency in a 5-10 km wide zone, including deeper-than-usual early events. The pattern of deep early aftershocks is consistent with a transient deepening of the brittle-ductile transition due to the coseismic high strain rate in the nominal ductile substrate, rather than a transition from stable to unstable frictional behavior on a deep localized fault surface.

Broader impact

The results are relevant to broad issues of crustal and fault dynamics in the complex plate-boundary region in southern California. The derived characteristics of volumetric deformation both in the brittle crust and viscoelastic substrate have important general implications on earthquake processes. The derived focal mechanisms of small events can be useful for various other studies. The deep learning algorithms used to derive the mechanisms can be used more broadly in other regions (paper on this is currently in preparation). The project supported a female PhD student (Yifang Cheng).

Publications supported by the project

Cheng, Y. and Y. Ben-Zion, 2020. Variations of earthquake properties before, during and after the 2019 M7.1 Ridgecrest, CA, earthquake, *Geophys.*, *Res*., *Lett.,* 47, e2020GL089650, doi: 10.1029/2020GL089650.

Data sets supported by the project

Cheng, Y., and Y. Ben-Zion, 2020. A focal mechanism catalog for Ridgecrest sequence derived with deep learning algorithms, Mendeley Data, V1, http://dx.doi.org/10.17632/h6rbr6d6n2.1.

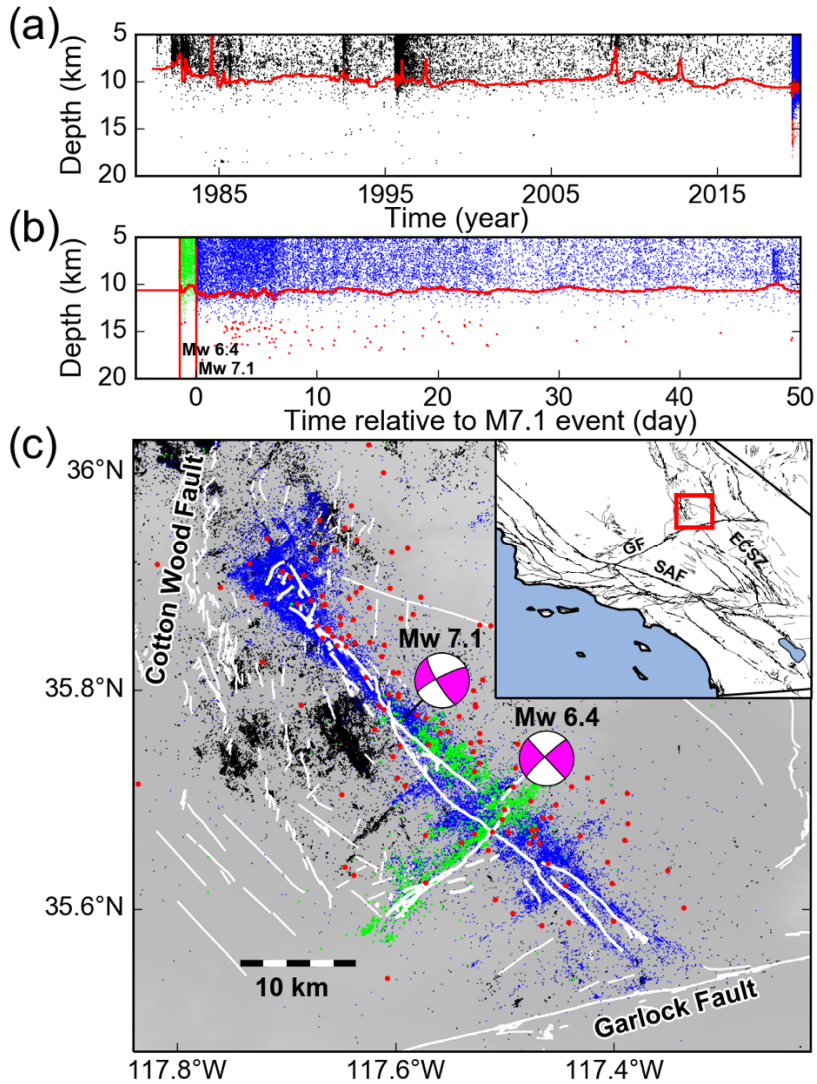

Fig. 1. (a) Depth-time plots of earthquakes from 1981 to 2019 and (b) from 5 days before to 50 days after the 2019 M_w7.1 Ridgecrest earthquake. (c) A map view of events from 1981 to the 2019 M_w6.4 earthquake (black dots), between the M_w6.4 and M_w7.1 events (green dots) and within 50 days after the M_w7.1 mainshock (red dots: depth > 14km, blue dots: depth < 14km). Red curves denote the D95 of 500 events with a 99% overlapping moving time window. From Cheng and Ben-Zion (2020).

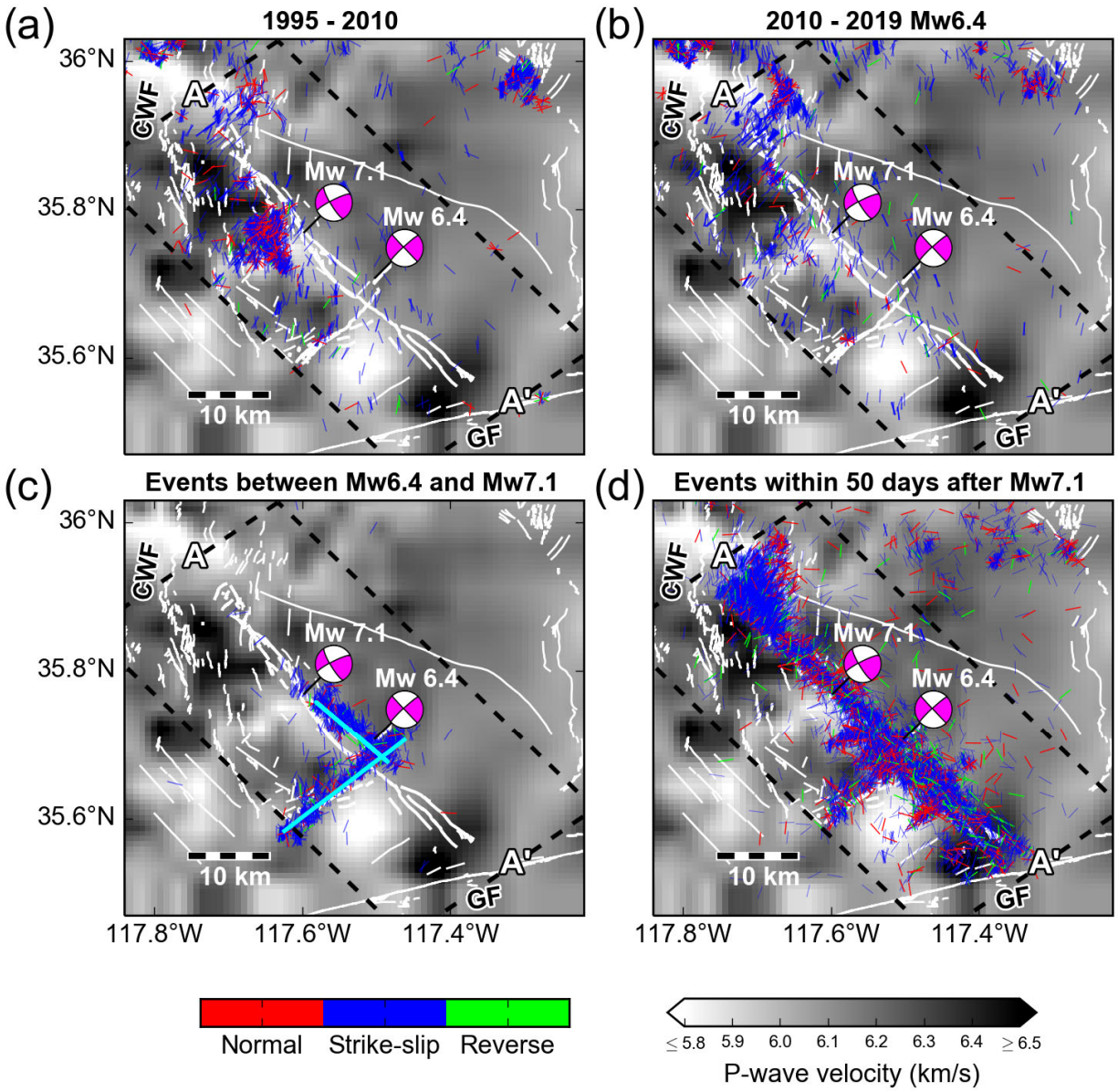

Fig. 2. Map views of P-wave velocity at 6 km depth (Zhang and Lin, 2014) and P-axis distributions of source mechanisms of events that occurred (a) from 1995 to 2010, (b) from 2010 to the 2019 M_w6.4 event, (c) between the M_w6.4 and M_w7.1 events, and (d) within 0-50 days after the M_w7.1 event. The P-axes are centered at the events' hypocenters and colored by their faulting types. Cyan solid lines in (c) represent the fault geometry for the M_w6.4 slip model (Liu et al., 2019). From Cheng and Ben-Zion (2020).