Foreshocks, Aftershocks, and Faulting Complexity: the 2019 Ridgecrest Earthquake Sequence in High Resolution

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Abstract

The 2019 Ridgecrest earthquake sequence provides a fascinating example of earthquake interaction processes and faulting complexity, captured by modern seismic and geodetic networks. Notable features of the sequence include 1) a rich foreshock sequence, including the July 4, M 6.4 event and its foreshocks; 2) apparent multi-fault rupture of the M 6.4 event, with two nearly perpendicular fault segments activated; and 3) complexity of the July 6, M 7.1 mainshock rupture, which included multiple splays at the NW and SE rupture tips, and apparently ruptured both NW and SE of the NW-striking limb of the earlier M 6.4 foreshock.

Here, I use cross-correlation and double-difference relocation to detect and precisely locate additional uncatalogued events, leveraging ~13,000 earthquakes routinely cataloged by the Southern California Seismic Network (SCSN) for July 4-16 as waveform templates. Preliminary efforts detect and precisely locate ~34,000 events, including ~21,000 newly detected events. These preliminary results suggest that the foreshocks preceding the M 6.4 event were concentrated near the intersection of the two main faults, near the bottom of the seismogenic zone. The M 6.4 aftershock sequence shows pronounced spatial "holes," which may reflect areas of major co-seismic slip. The M 7.1 event nucleated near the northernmost aftershocks from the M 6.4, a zone which became highly active following a M 5.4 event ~16 hours prior to the M 7.1 mainshock. The M 7.1 ruptured either through or around the NW-striking limb of M 6.4 rupture, expanding the earlier rupture zone both to the NW and SE. This high-resolution catalog will provide a basis for examining earthquake interaction and rupture physics in three dimensions.

Summary

1. Using ~13,000 SCSN catalog events as waveform templates (July 4-16), I detected and precisely located ~34,000 events for the same time period (~21,000 newly detected and located).

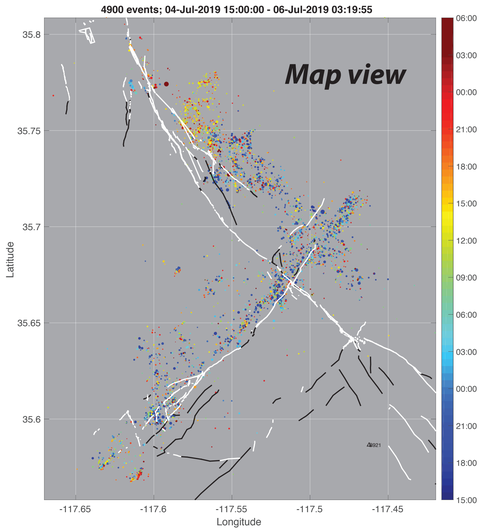
2. Precise seismicity relocations show a highly complex rupture geometry, with multiple cross-cutting faults, stepovers, and splays, consistent with mapped surface rupture geometry.

3. An M 5.4 earthquake nearby and ~16 hours prior to the M 7.1 mainshock apparently ruptured a conjugate SW-striking left-lateral fault, which had its own vigorous aftershock sequence.

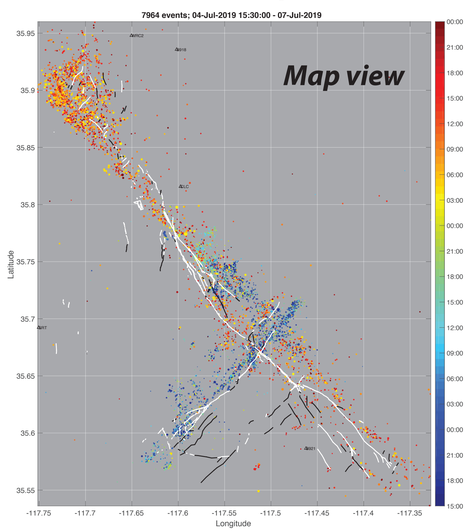
4. The M 7.1 mainshock may have ruptured around the NW-striking fault ruptured in the M 6.4 event, but then stepped back to the east to rejoin the primary NW-striking fault, extending the earlier rupture to the SE.

5. The M 7.1 rupture exhibited at multiple splays at its SE terminus. Its NW terminus activated a dense zone of faulting, primarily in the dilatational quadrant to the NE of the primary rupture.

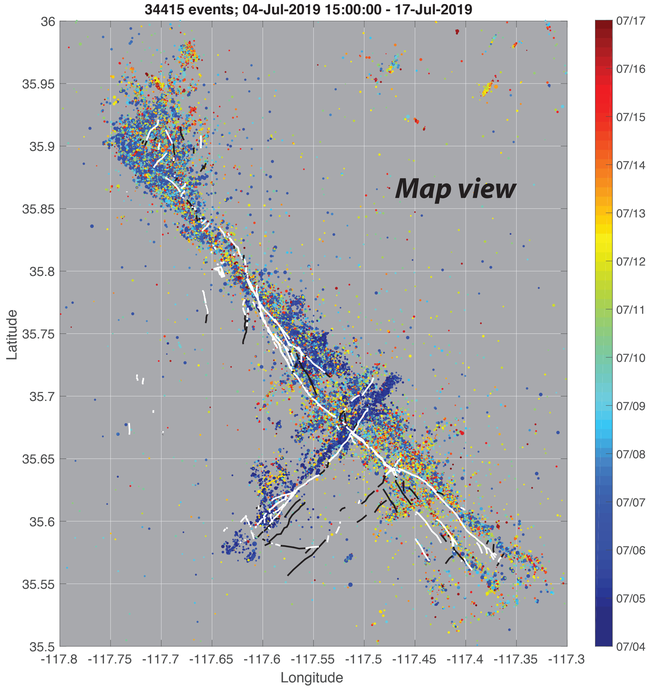
Foreshock sequence

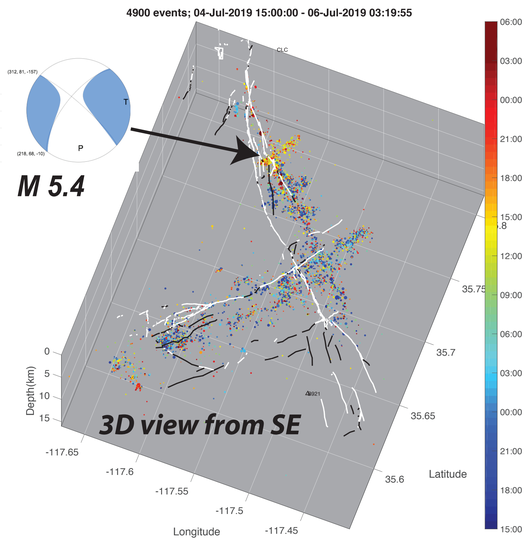


Foreshocks + ~1 day of aftershocks



Foreshocks + 11 days of aftershocks

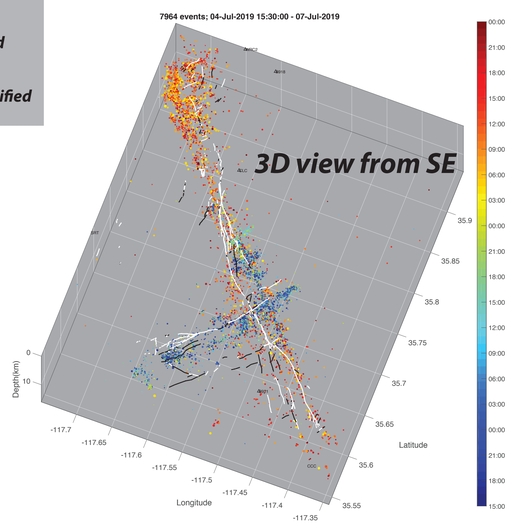




Surface rupture from Kendrick et al. (this meeting)

Field verified

Not fully verified



A highly complex rupture sequence

The M 6.4 event apparently ruptured two nearly perpendicular faults. Precisely located aftershocks of this event illuminate additional cross-cutting fault structures. Perhaps most notably, a M 5.4 event ~16 hours prior and spatially proximal to the M 7.1 mainshock appears to have ruptured a SW-striking fault in a left-lateral sense (see moment tensor at left).

Based on the aftershock sequence and surface rupture, the M 7.1 rupture was also highly complex. This included at least three sub-parallel splay faults at its SE rupture terminus, and a broad, dense zone of seismicity at its NW terminus, primarily in the dilatational quadrant. Additionally, the M 7.1 may have ruptured around the NW-striking limb of the M 6.4 rupture, perhaps stepping back over to the east to rejoin the M 6.4 fault and extend rupture further SW.

Acknowledgements

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References

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