

# **Absolute Location of 2019 Ridgecrest Seismicity Reveals Duplex Mw6.4 Ruptures, Migrating and Pulsing Mw7.1 Foreshocks, and Unusually Shallow Mw7.1 Nucleation. Did the Mw7.1 Rupture Require Incitation by Mw6.4-Like Rupture?**

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## **Abstract**

The 2019 Ridgecrest, California sequence includes an  $M_w$ 6.4 earthquake on July 4 and an  $M_w$ 7.1 mainshock 34 hours later. We examine absolute location of  $M \geq 1.0$  Ridgecrest events using multiple velocity models, station corrections, and a location algorithm robust to velocity model and arrival-time error. The obtained seismicity is mainly  $\sim 3$ - $12$ km deep, with few shallower events. The  $M_w$ 6.4 hypocenter is  $\sim 12$ km deep, compatible with hypocentral depths of most  $M \geq 6$  earthquakes in southern California. The  $M_w$ 7.1 hypocenter, however, is unusually shallow at  $\sim 4$ km.

The immediate post- $M_w$ 6.4 seismicity defines a deep,  $\sim 12$ km long, SE-NW structure containing the  $M_w$ 6.4 hypocenter, and a shallower, orthogonal,  $\sim 18$ km long NE-SW structure. These duplex structures have little or no intersection, making the  $M_w$ 6.4 event a double earthquake, rupturing first the deeper and then the shallower structure.

The ensuing, pre- $M_w$ 7.1 seismicity extends the SE-NW structure northwestwards to within  $\sim 3$ km of the future  $M_w$ 7.1 hypocenter and illuminates a new crossing structure, while small clusters of events within 2km of the future  $M_w$ 7.1 hypocenter activate several times in pulses from a few hours after the  $M_w$ 6.4 event through  $M_w$ 7.1 initiation.

This pre- $M_w$ 7.1 seismicity suggests  $M_w$ 7.1 rupture initiation was *triggered* by the pulsing clusters, and early  $M_w$ 7.1 rupture growth was *incited* by stress changes from the  $M_w$ 6.4 event and its aftershocks. Moreover,  $M_w$ 7.1 nucleation at shallow depth, where spontaneous rupture growth into a large earthquake is not expected, may have *required* incitation by the  $M_w$ 6.4 event. Otherwise,  $M_w$ 7.1-like rupture might not have occurred until long in the future, either through incitation by another  $M_w$ 6.4-like event, or with nucleation at greater depth. Such a dependency of very large event rupture on a large inciting event is a significant complication for hazard estimation.

3D visualizations of absolute relocation of  $M \geq 1.0$  Ridgecrest seismicity with interpreted faulting structures: [http://alomax.net/projects/Ridgecrest\\_2019](http://alomax.net/projects/Ridgecrest_2019)