The 2020 Westmorland, California earthquake swarm as aftershocks of a slow slip event sustained by fluid flow

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- 5-min sampled GPS supplemented with InSAR resolves a shallow slow slip event, which preceded the swarm by 2 – 15 hours.
- Seismicity was driven in the early stage by slow slip event leading to non-linear expansion and later by fluid with propagating back front.
- A stress-driven model explains the overall evolution of seismicity and provides constraints on friction and fluid pressure.

Mainshock-Aftershocks
- clearly identifiable mainshock
- aftershocks follow Omori’s power law decay
- driven by stress changes induced by the mainshock

Swarm
- burst of small earthquakes
- behaviors are enigmatic, no well-defined pattern
- driven by aseismic processes (e.g. slow slip, fluids)

The 2020 Westmorland, California swarm

- Swarms are common in the Brawley Seismic Zone, which hosted a mixture of left-lateral strike-slip step-over faults that connect shorter segments of the main right-lateral strike-slip fault.
- The sequence began around 22:00 UTC on Sep 30, 2020 and lasted for approximately 140 hours.
- There were > 2000 events with Mw 4.9 being the largest.
- Peak seismicity rate is > 10,000 times the background rate.

Triggering mechanisms

(1) Shallow slow slip preceded the swarm
- Depth < 5 km: There is fault slip but no seismicity \( \rightarrow \) aseismic
- Depth > 5 km: Geodetic moment ~ seismic moment \( \rightarrow \) seismic

(2) Stressing front from slow slip event triggered seismicity with log(t) propagation
- A stress-driven model (Dieterich, 1994) explains the observed seismicity and the time delay

(3) Pore-pressure diffusion + (4) Back front
- A stress-driven model cannot explain the latter part of the swarm, requiring secondary mechanisms.
- Pore-pressure diffusion is a plausible candidate due to existence of propagating back front.

Seismicity

- Geodetic data (GPS, InSAR)

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- sedimentary cover
- basement
- non-interacting earthquakes driven by slow slip event
- en-echelon fractures (reactivated with fluids)
- interacting earthquakes driven by fluids
- pore-pressure diffusion
- creeping zone
- Seismogenic zone
- Ductile deformation (no earthquakes)

Slow slip driven 45 – 65%
Inter-earthquake interactions 10 – 35%
Fluids 10 – 30%