#241 Triggered slip and afterslip in the 2019 Ridgecrest earthquakes: influence of fault zone fabric

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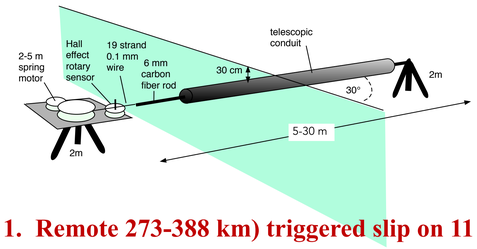
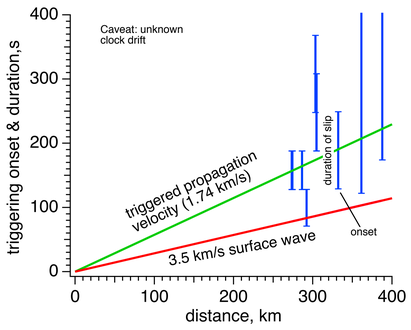


Configuration of the carbon rod creepmeters used in this project. Installation time 2-4 hours (30-50 cm deep trench). System operates for a year on alkaline batteries Resolution≈3 µm. Unattended measurement range is ≈2 m. i.e can measure coseismic slip. Thermoelastic sensitivity 10E-7/°C. Cost is ≈$5k/site

1. Remote 273-388 km) triggered slip on 11 creepmeters:

- triggered slip quantified on 11 creepmeters 1 min. sample, 3 µm precision (c.f. USGS creep array 10 min. sample, 50-100 µm precision)
- 20 µm - 4.3 mm, 273-388 km from Ridgecrest.
- max slip velocity Mecca Hills 3.8 mm/minute
- Mw7.1 triggering amplitude > 3 x Mw6.4 triggered amplitude
- Mecca events propagate NW & SE at 5-55 cm/s, days after triggering.
- >6 weeks of afterslip in northern Mecca Hills following triggering
- Negligible slip on North Shore segment & faults that have recently hosted creep
- µm left lateral slip on Imperial fault consistent with seasonal clay contraction
- triggered slip duration increases with distance (surface wave dispersion?)
- propagation velocity 1.7±1.7 km/s to center of slip duration (≈max slip velocity)



Travel time plot for triggered slip for both Ridgecrest earthquakes

2. Insignificant afterslip (microns/day) on 7 new creepmeters on faults in the Ridgecrest mezzoseismal area:

- creepmeters installed 2-15 days after earthquakes (assembly delays)
- *Tau*=16 days on Mw=6.4 & Mw=7.1 ruptures. Initial rate 0.1 mm/week.
- negligible afterslip on Garlock 5 µm/day with decaying rate.
- no access to northern end of Mw7.1 rupture
- Little lake Mw5.1 aftershock registered 0.4 mm of extension across Mw6.4 rupture; but ≤20 microns across Garlock fault.

3. Influence of phacoidal fault zone fabric on aseismic slip

Within 5 m of the surface trace of the San Andreas fault on Durmid Hill and in the Mecca Hills (and on other faults) we observe a shear fabric consisting of 10-20 cm dimension phacoidal clasts with their long axes elongated obliquely to the fault zone (≈45°), roughly in the direction of en-echelon surface cracks whose formation they presumably control. The clasts are separated by polished and slickensided clay surfaces indicative of repeated but limited differential motion. The polished surfaces surrounding each clast presumably results from oscillatory motion.

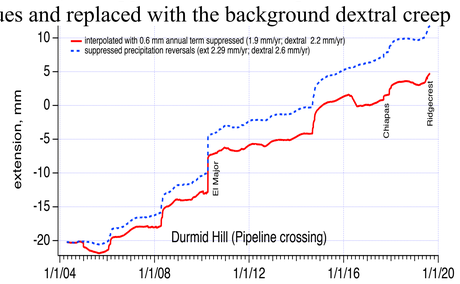
Triggered slip (≤0.8 mm) from the Ridgecrest Mw=7.1 earthquake at Salt Creek measured by two non-parallel creepmeters revealed 25 µstrain fault zone contraction! The Chiapas 2017 Mw8.1 earthquake triggered identical strain changes within the fault zone, as did a subsequent creep event.

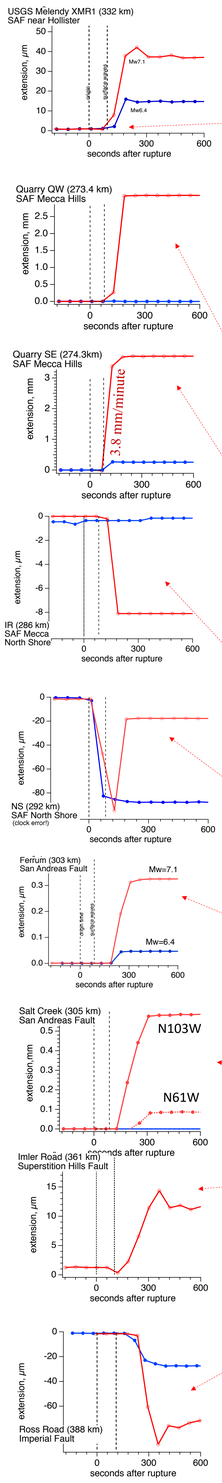
We interpret these strain changes in terms of cyclic dilation caused by varying shear stress applied to phacoidal texture during the creep-event cycle. Between creep events we hypothesize that dextral shear strain in the fault zone causes clasts to rotate clockwise, increasing fault-normal stress, which is released during a creep event. Similar shear fabrics have been observed in the SAFOD hole, within the North Anatolian fault, and in oceanic thrust zones, and may play a crucial role in the nucleation in creep events. The surface San Andreas fault provides a natural laboratory for the study of these processes.

An explanation for apparent slip reversals associated with rain? Heavy rain often perturbs SAF creepmeter records as an apparent reversal of dextral creep. We propose that fluid lubrication of the main shear zone reduces friction and permits the dilated phacoidal fabric to relax to its undilated condition, thereby contracting the flanks of the fault zone. The contraction of the fault zone shortens the distance between creepmeter anchors and is manifest as an apparent reversal of slip.

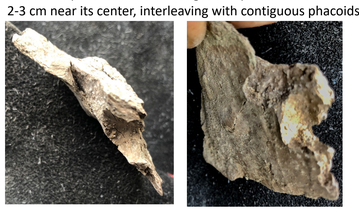
With this supposition we have attempted to suppress raininduced noise in the past two decades of data from the southern San Andreas fault. A seasonal thermoelastic term is first removed, and apparent aseismic-slip reversals are identified in daily mean values and replaced with the background dextral creep rate for each site.

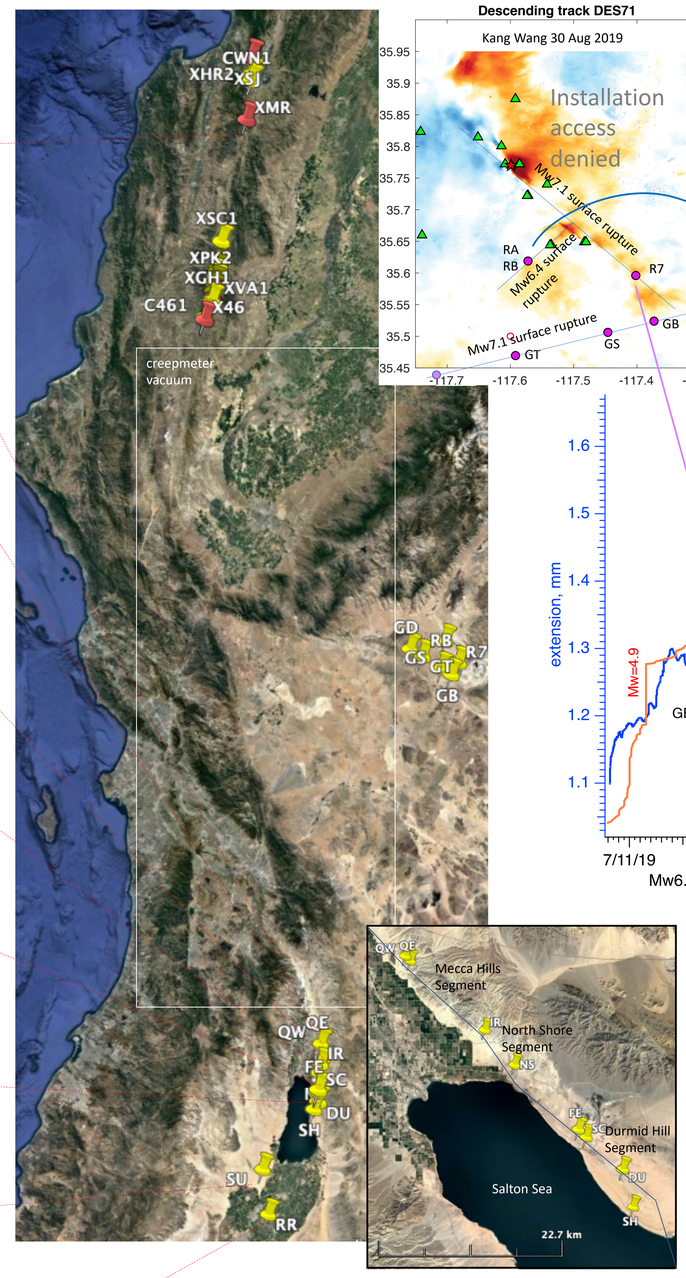
An example of this form of noise suppression is shown for the southernmost San Andreas fault through Durmid Hill

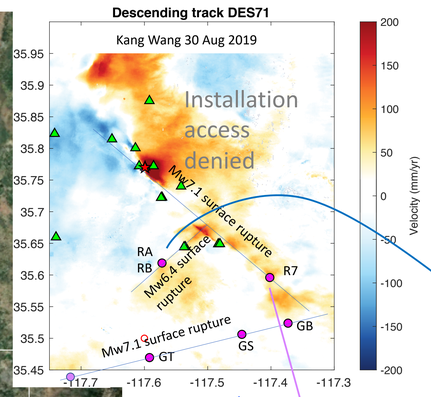




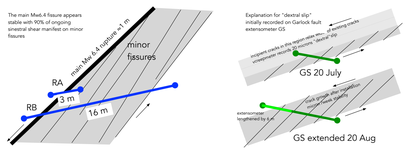
A typical 10 cm phacoidal clast from the Mecca Hills SAF fault gouge. Its concave and convex longitudinal faces are striated or polished, its distal edges sharp and it thickens to 2-3 cm near its center, interleaving with contiguous phacoids

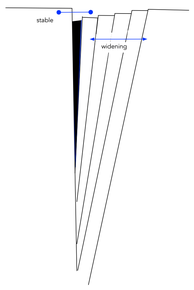


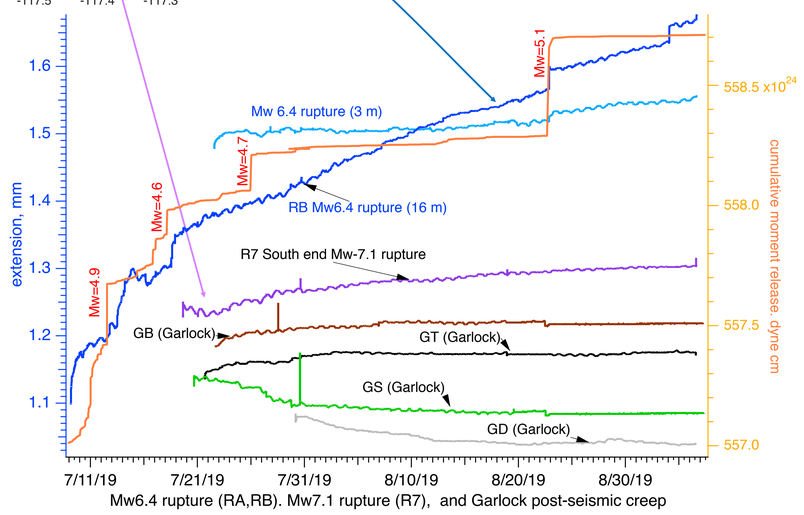


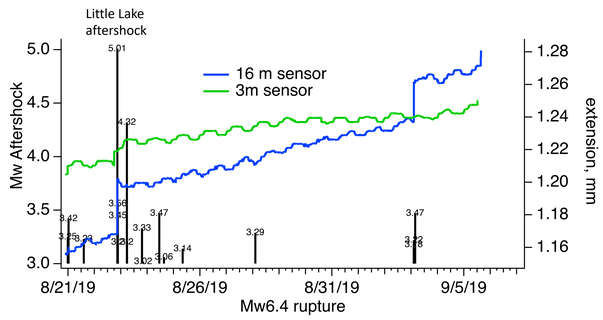


Evolution of surface fissures near the epicenter

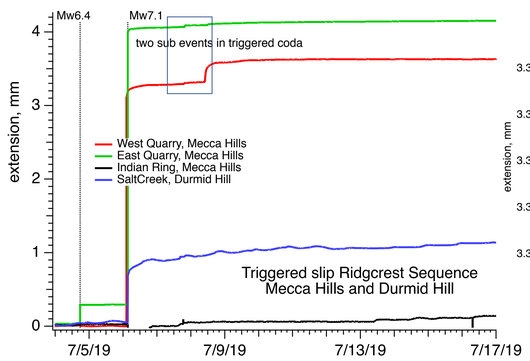


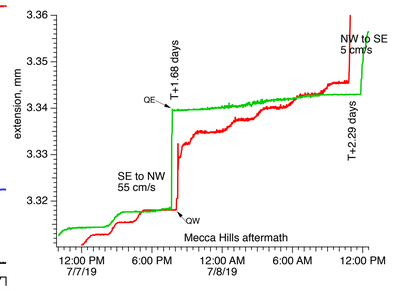


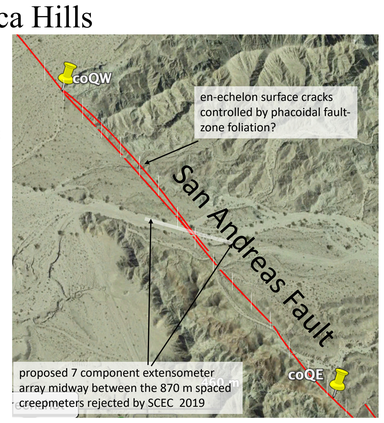




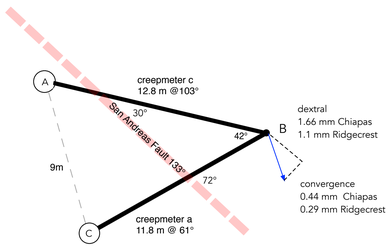
Continuing aseismic slip 2 months after triggered slip in the Mecca Hills



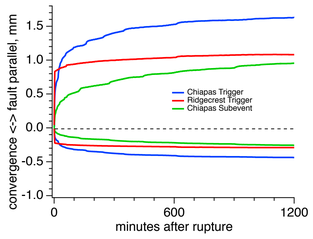




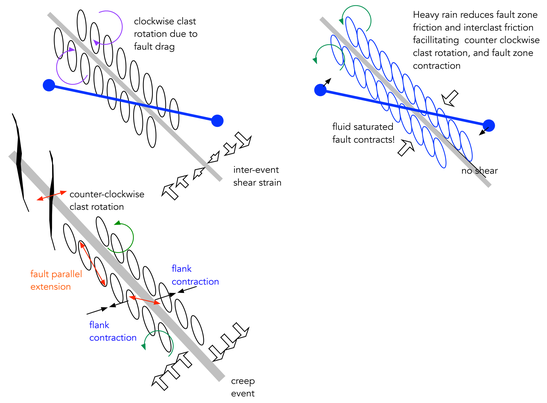
Plan view of two creepmeters recording creep at Salt Creek on the southern San Andreas fault near the Salton Sea



Triggered slip recorded by the two creepmeters for three triggered events. Assumption: Azimuth and length of AC are constant (Invalid because strain is a tensor)



1. aseismic shear dilates fault zone (foliation rotated clockwise)
2. creep event relaxes flank shear (en echelon cracks subparallel to foliation)



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Bilham, R., & Castillo, R. (2019, 08). Triggered slip and afterslip in the 2019 Ridgecrest earthquakes: evidence for rotation of fault zone fabrics. Poster Presentation at 2019 SCEC Annual Meeting.