Surface slip variations and off-fault deformation patterns in complex cross-fault systems revealed from 3D high-resolution satellite optical image correlation: the 2019 Ridgecrest earthquakes (California, 2019)

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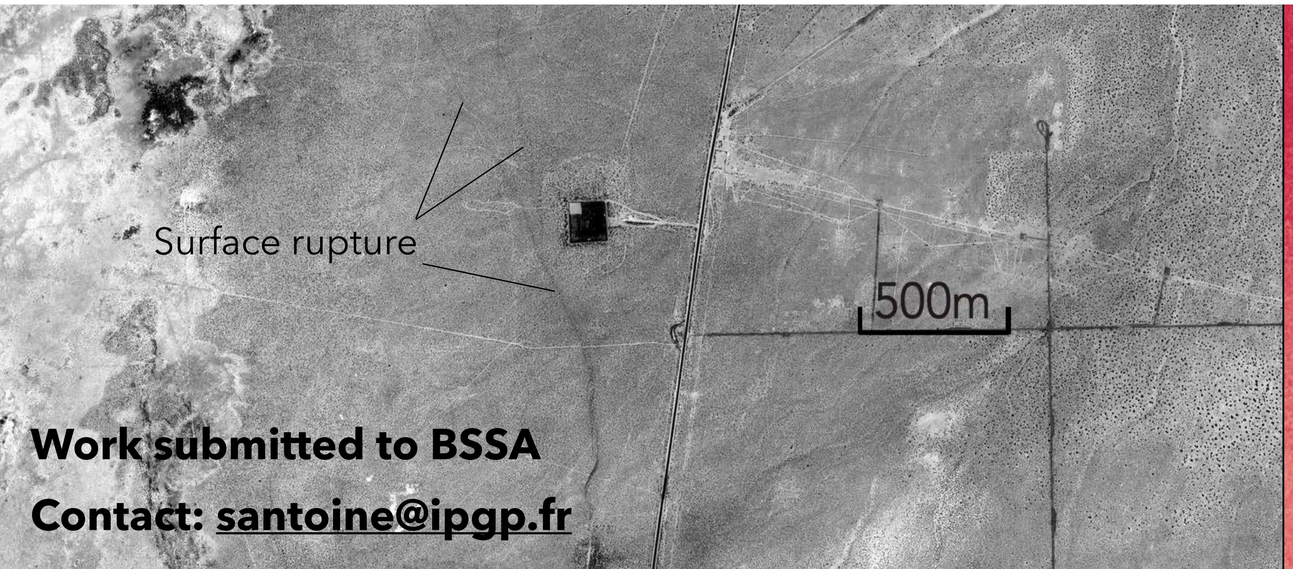
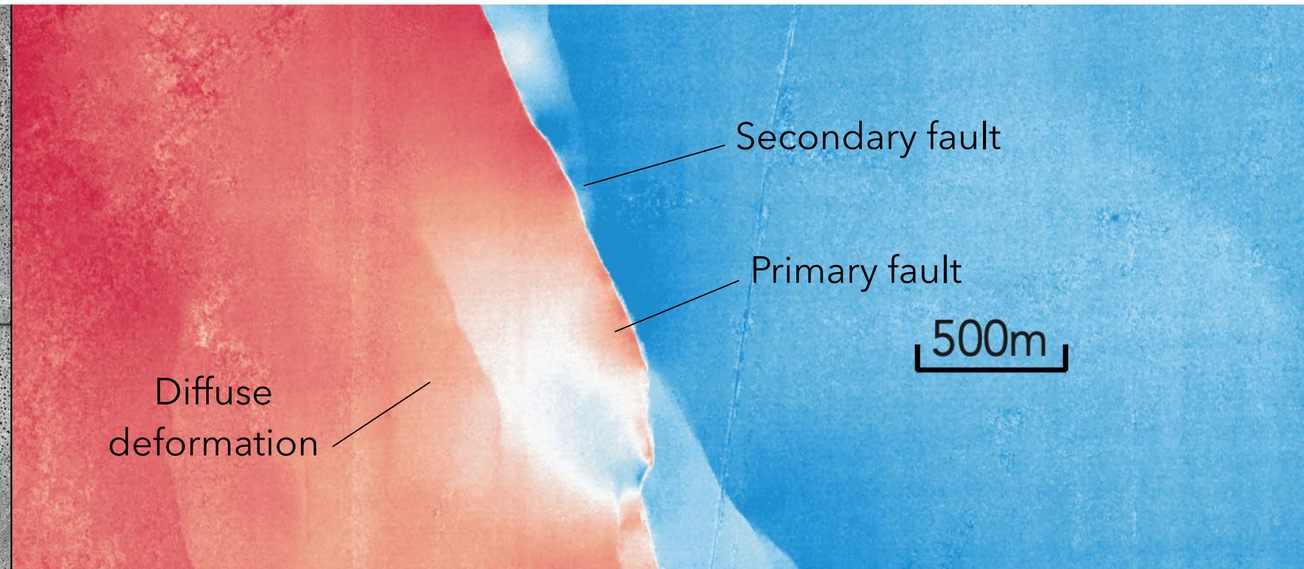
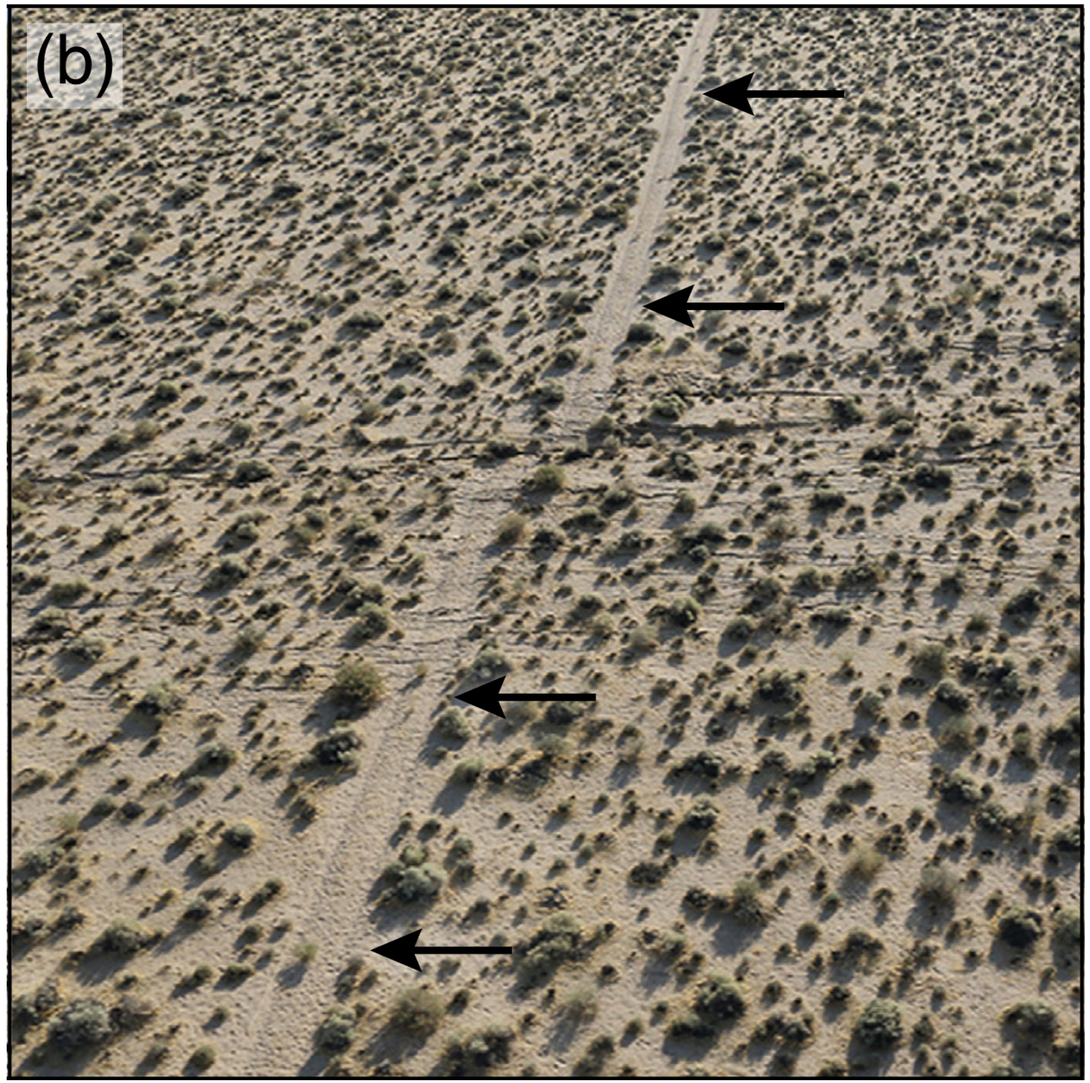




Work submitted to BSSA

Contact: santoine@ipgp.fr

Surface deformation is distributed:

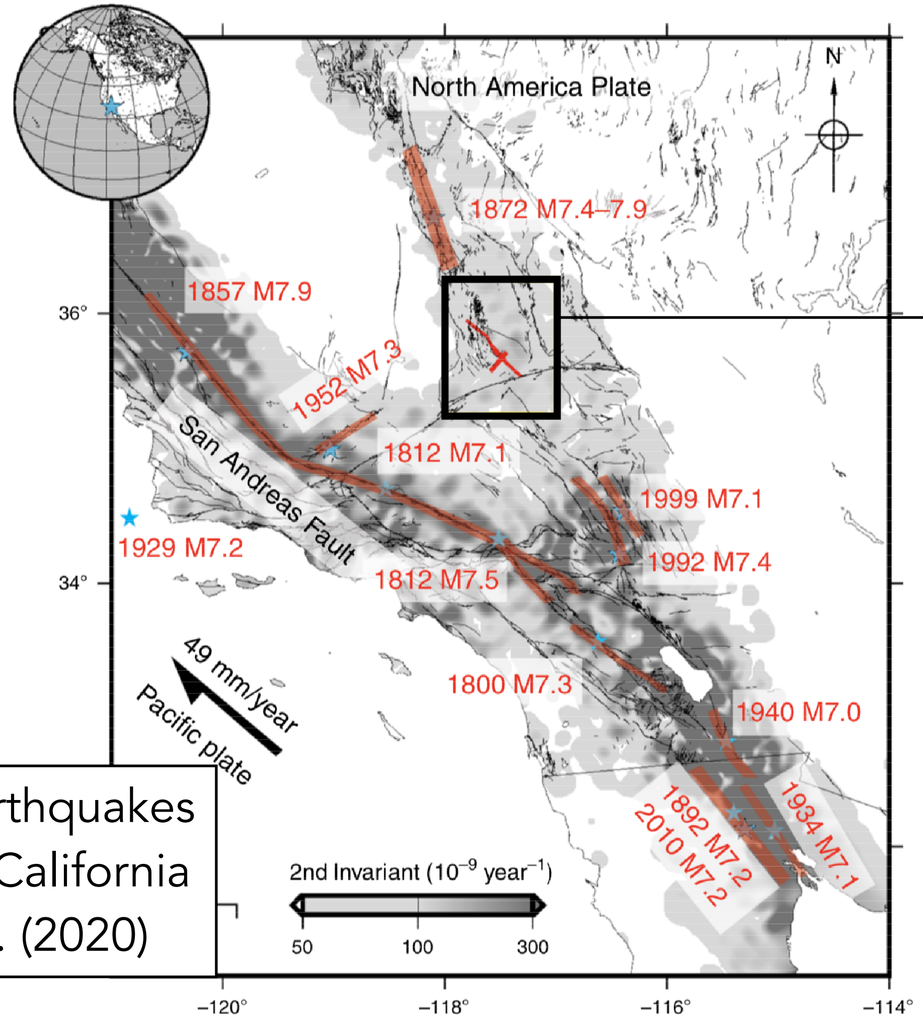


What is the total surface deformation after an earthquake and how does it distributes in space? Following which mechanisms?

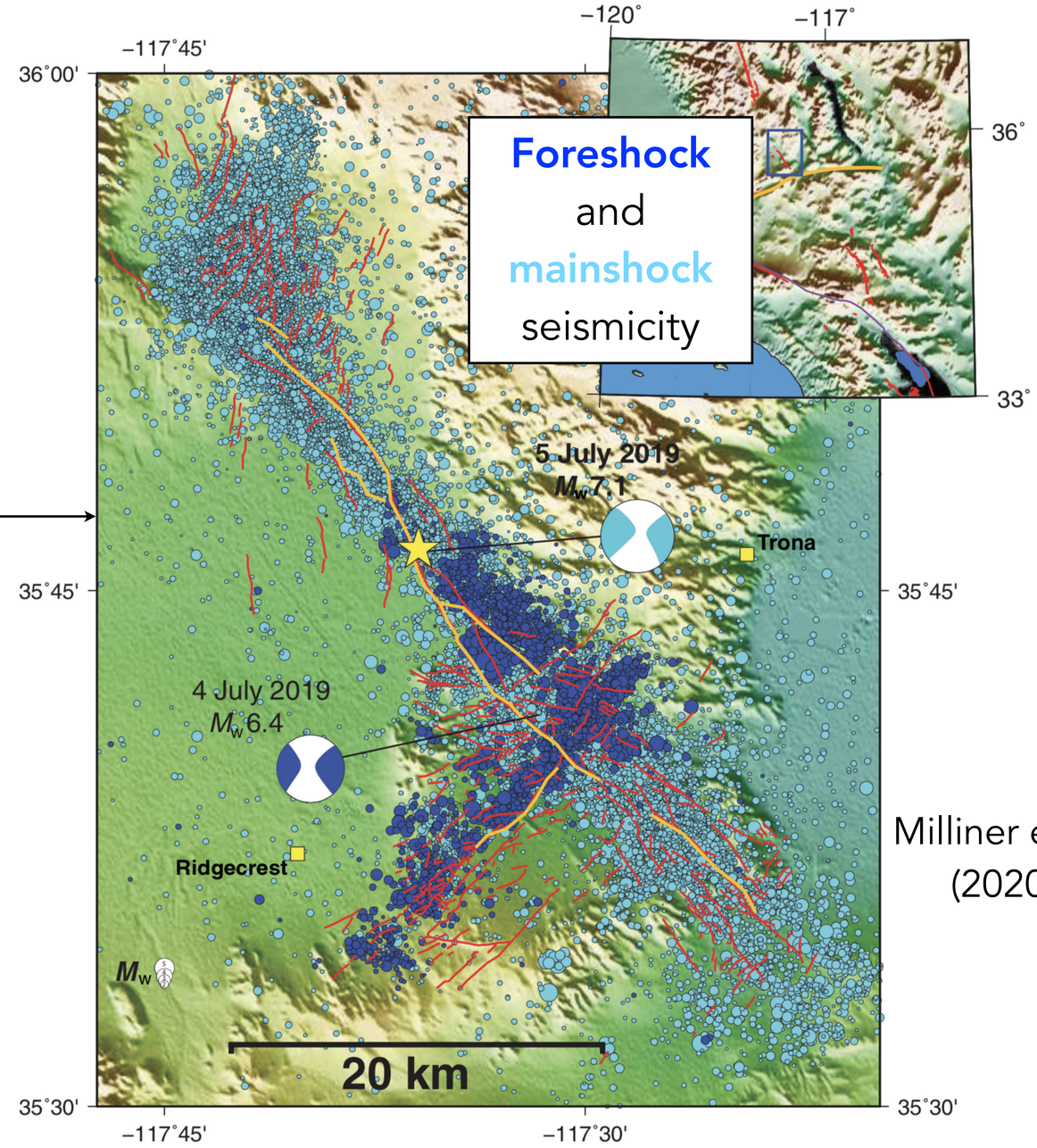
Drone photography of the Ridgecrest surface rupture (Duross et al., 2020)

The Ridgecrest earthquakes (California, 4th and 6th of July 2019):

The sequence ruptured two cross-cutting faults within 34 hours

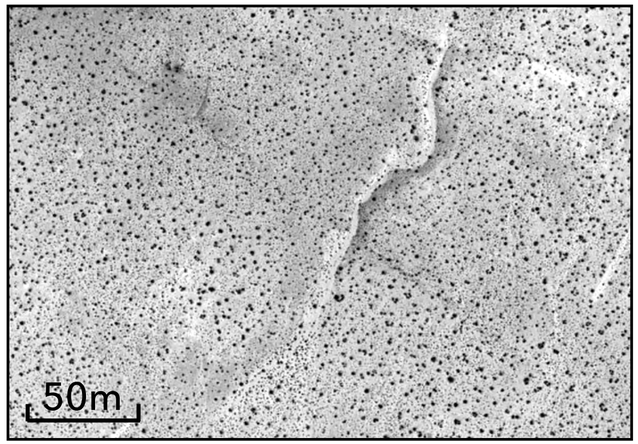


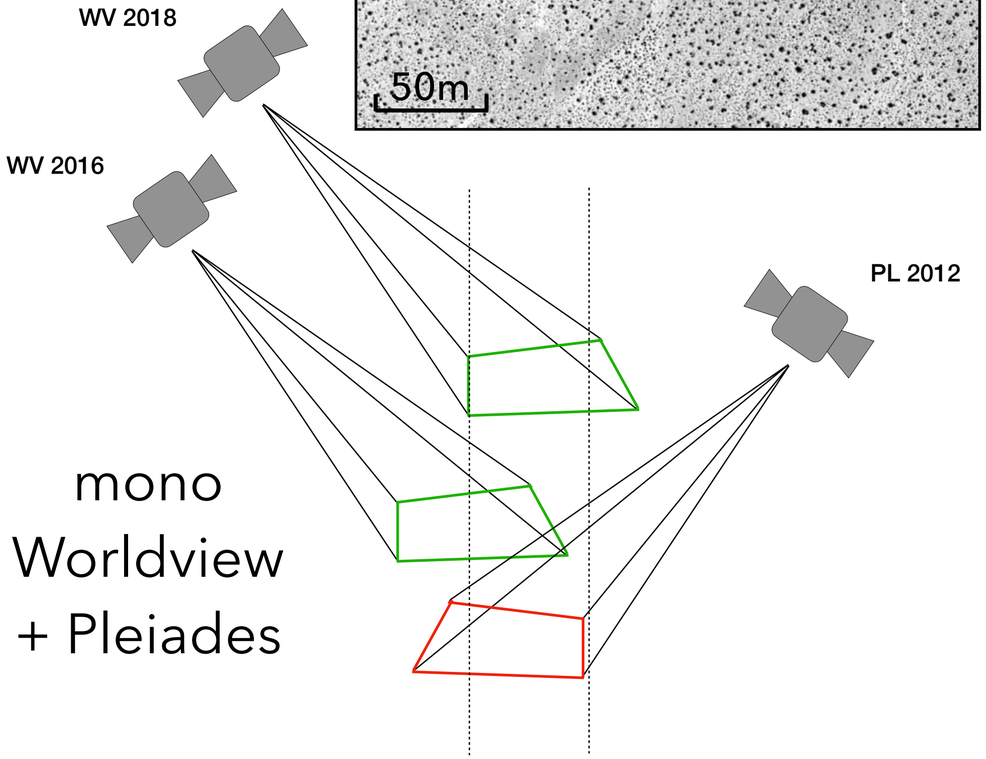
Historical earthquakes in Southern California Chen et al. (2020)



Milliner et al. (2020)

Correlation of high-resolution (0.5 meters) pre- and post-earthquake optical images:

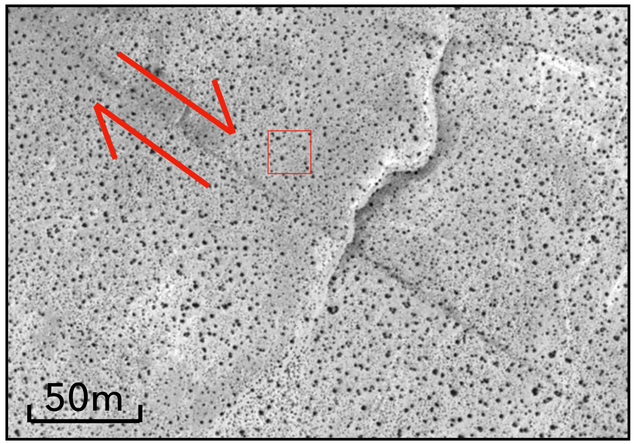


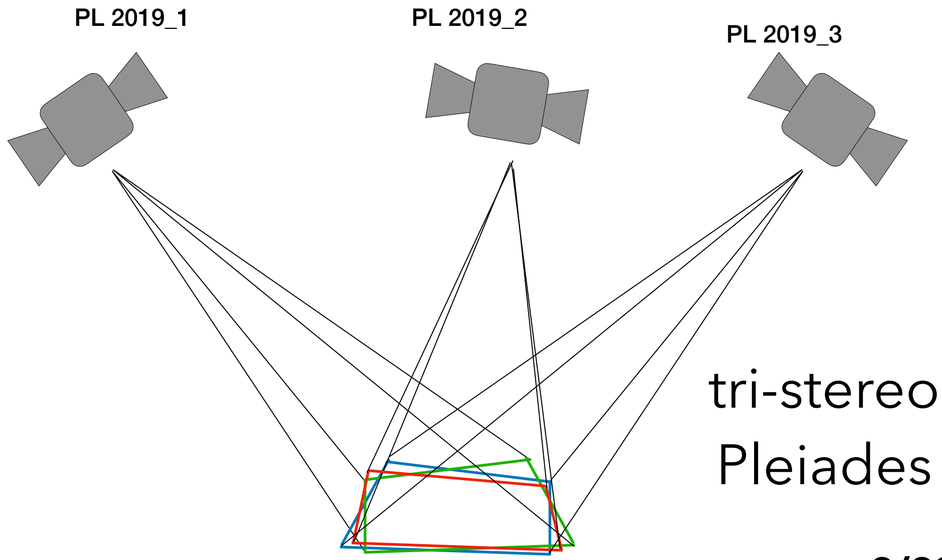


mono
Worldview
+ Pleiades

Ridgecrest sequence

MicMac
correlation
software
(IGN & IPGP)

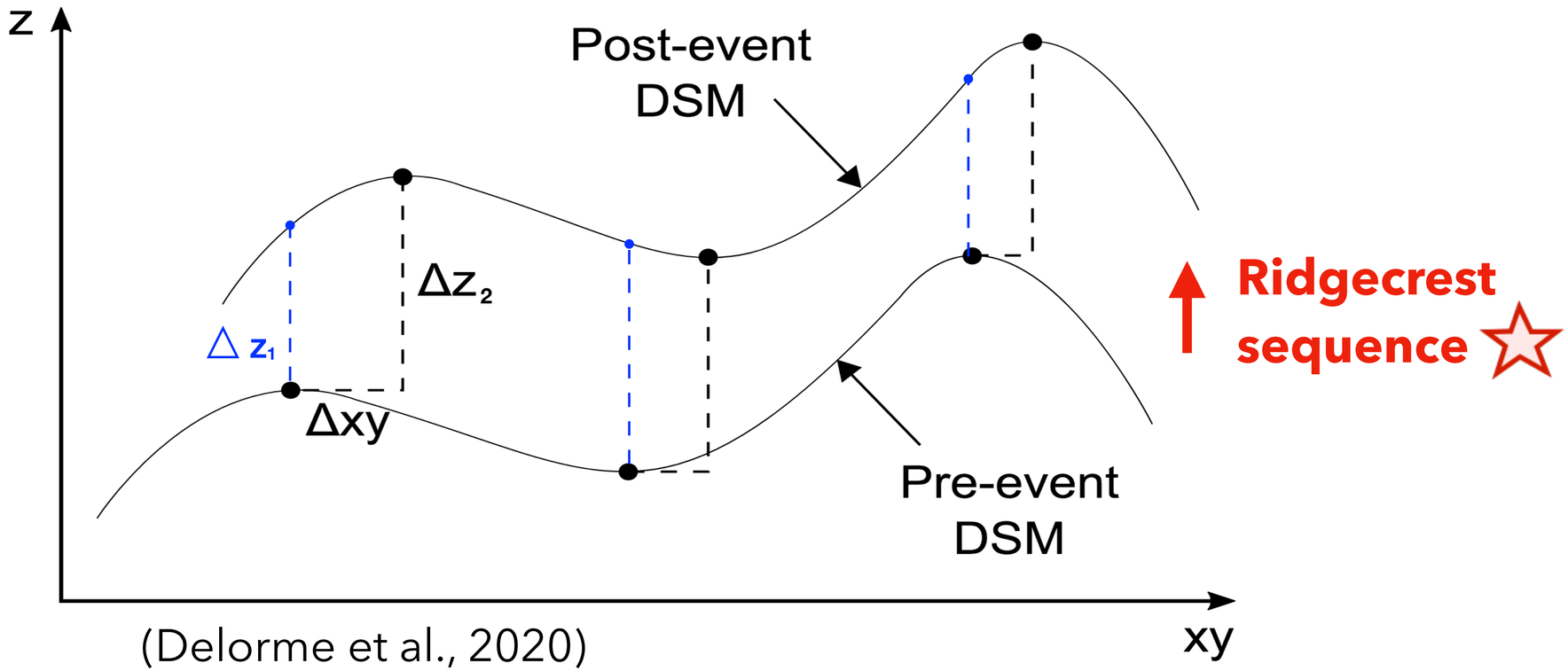




tri-stereo
Pleiades

Difference of pre- and post-earthquake Digital Surface Models to measure the co-seismic vertical displacement:

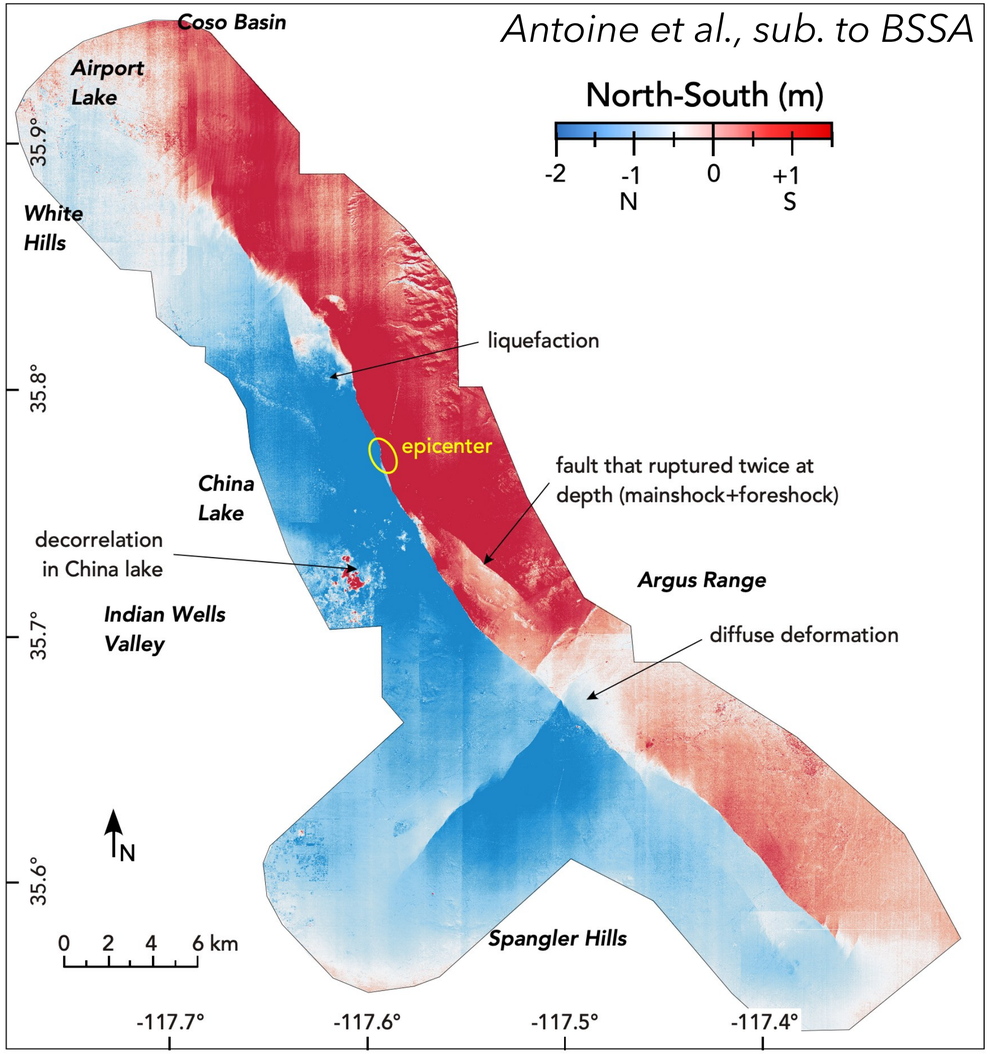
We transform the pre-earthquake DSM using the horizontal co-seismic displacements measured (Δ_{xy}):

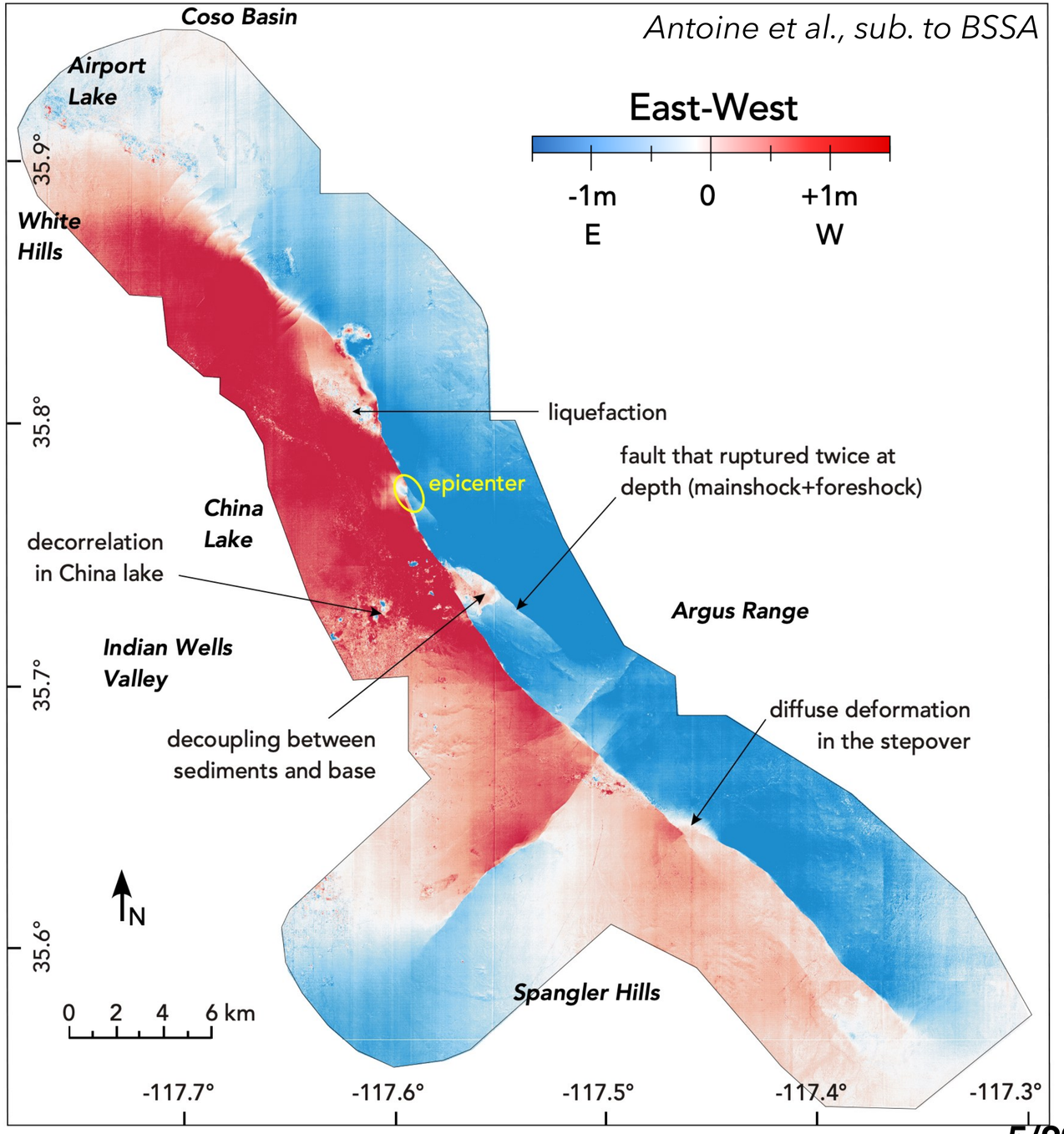


(Delorme et al., 2020)

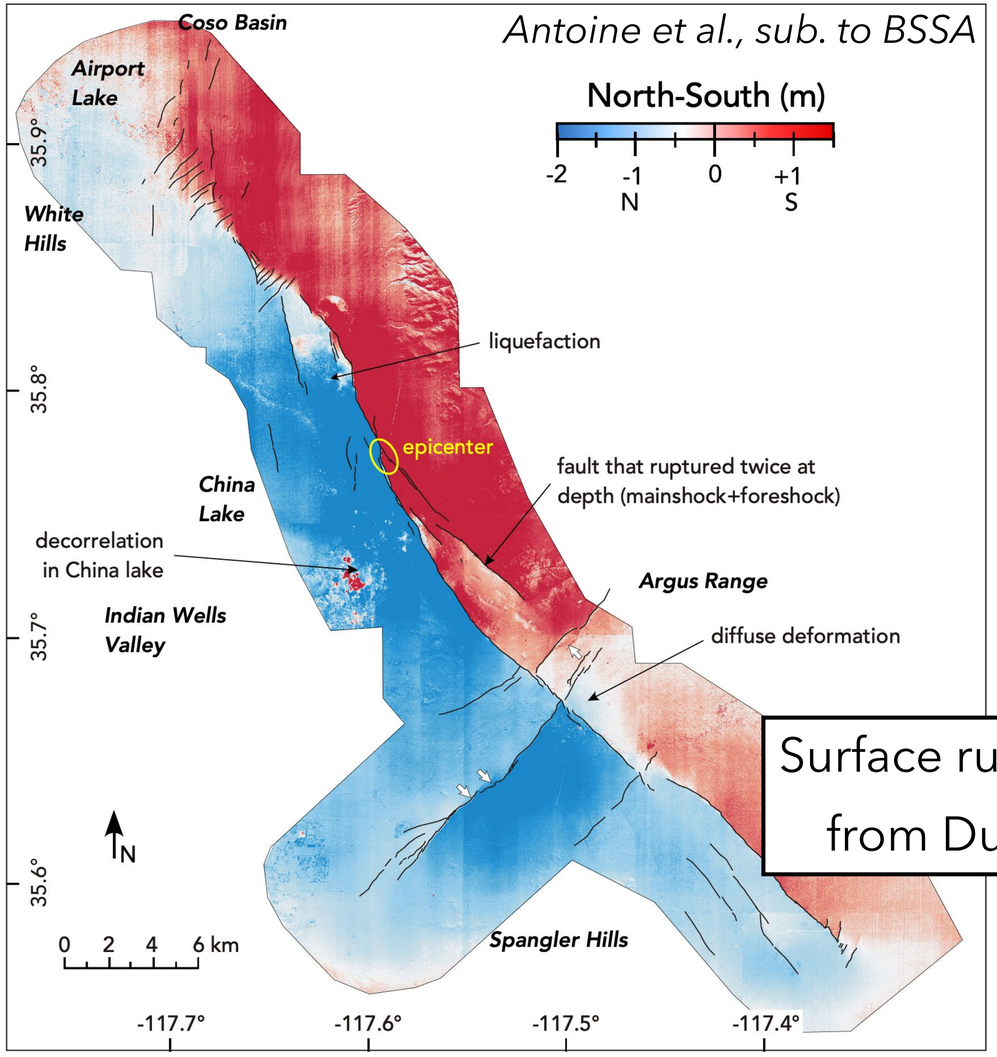
The displacement field is heterogeneous and complex:

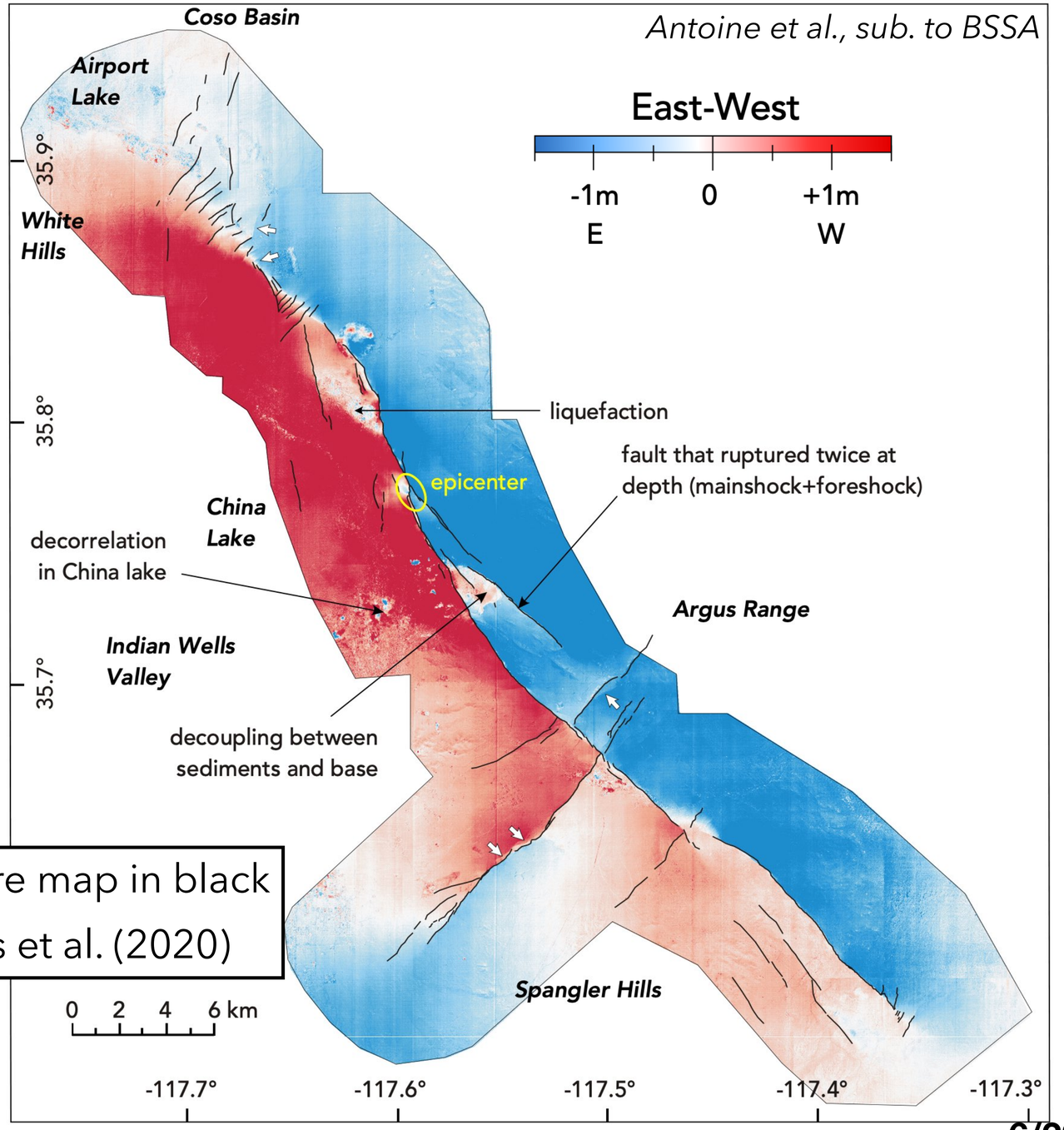
More than 50 discontinuous faults ruptured





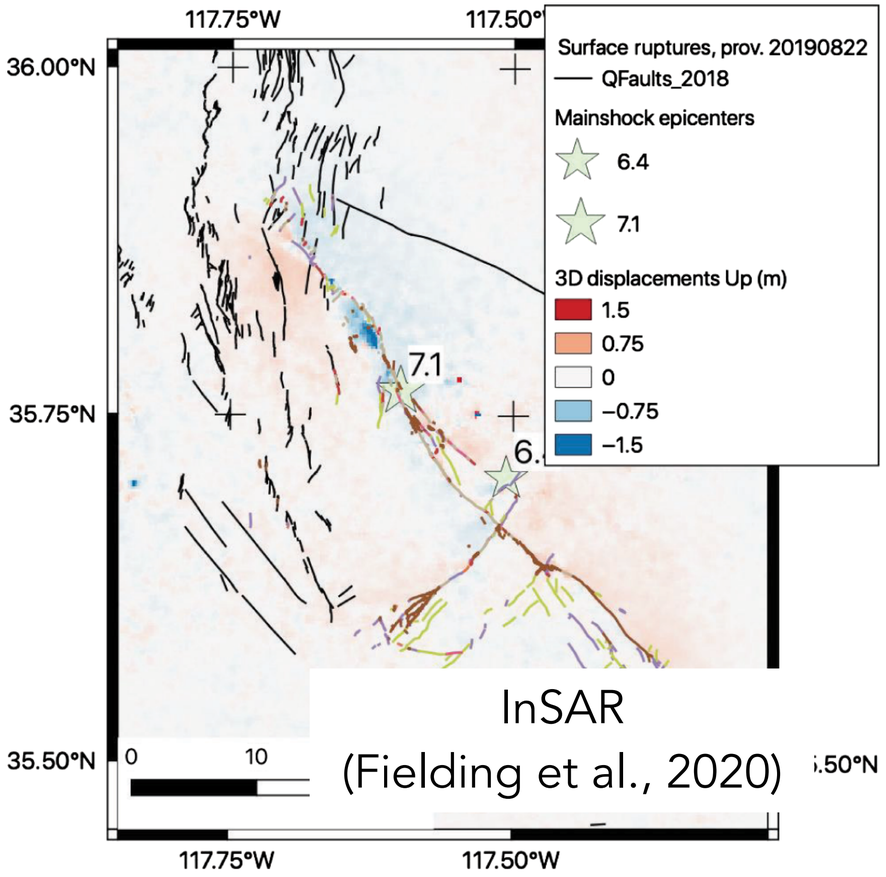
Good concordance with the field-based rupture map:





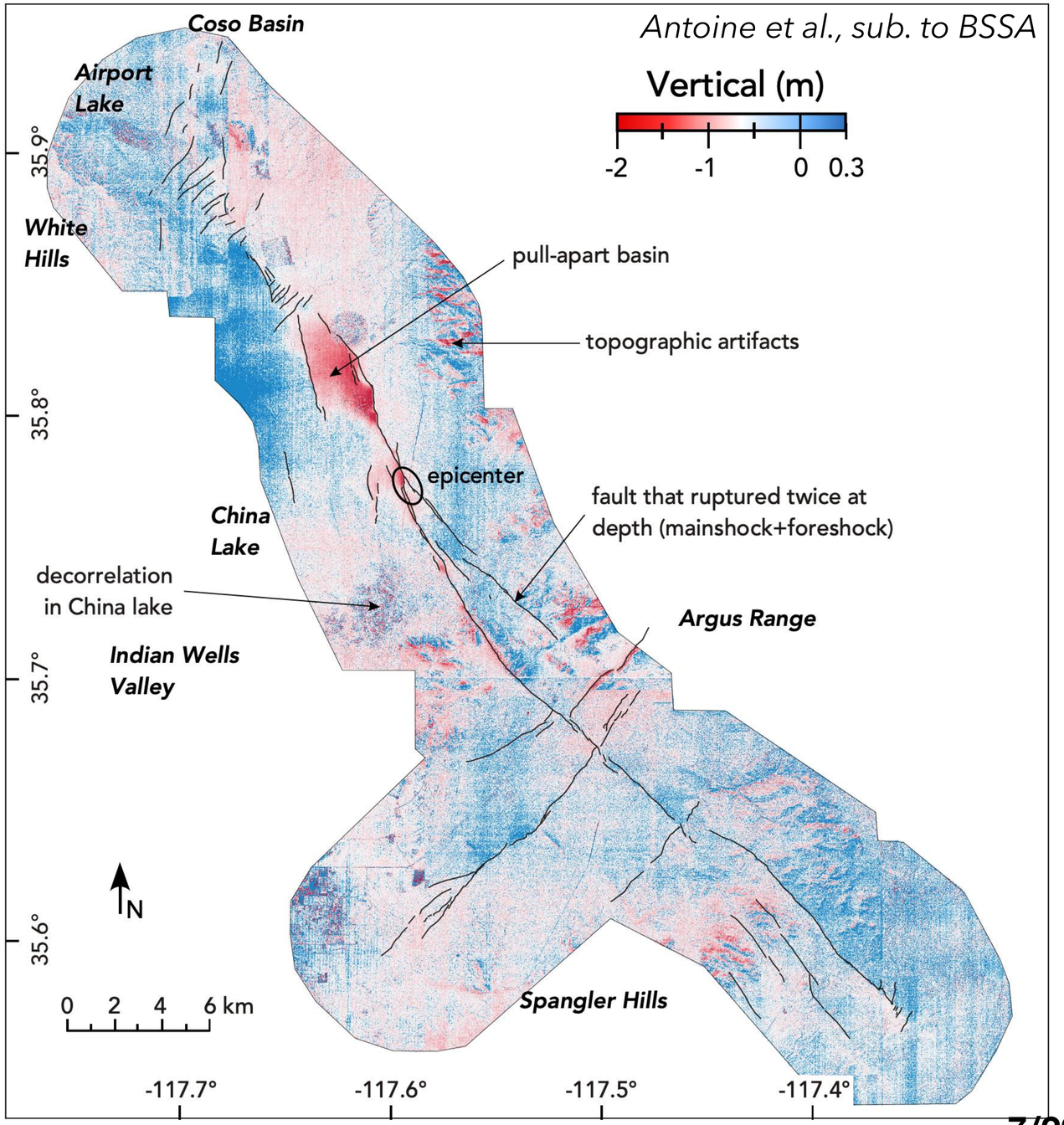
Surface rupture map in black from Duross et al. (2020)

Vertical map is coherent with other studies and long-term topography:

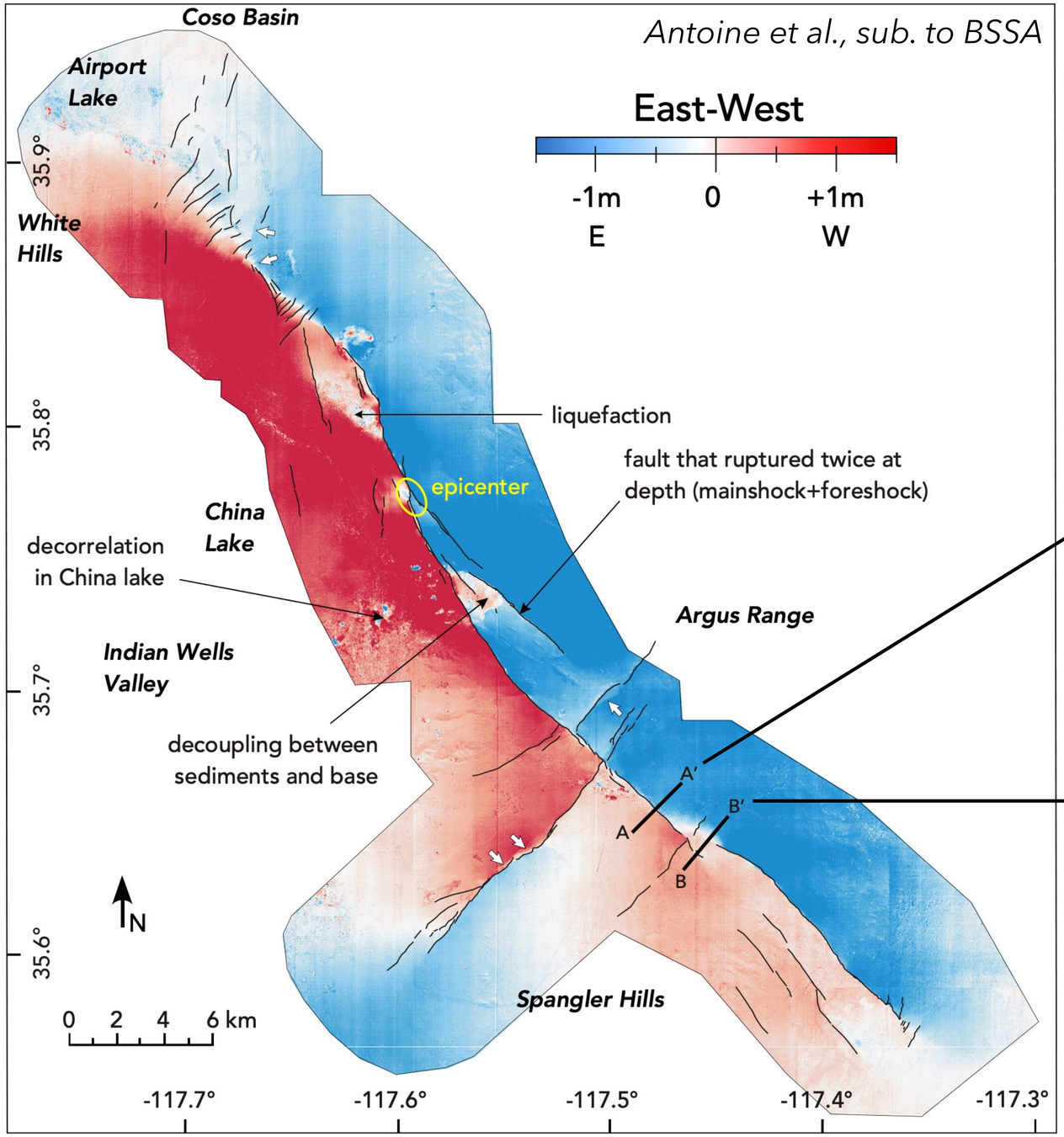


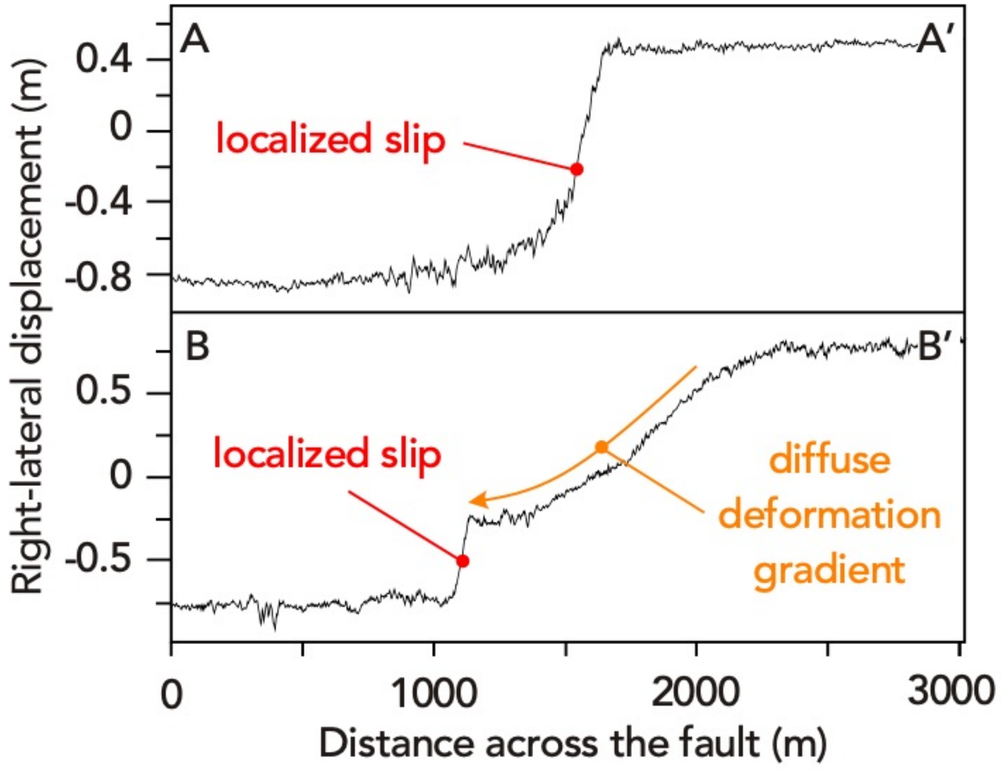
InSAR
(Fielding et al., 2020)

+ Image correlation (Barnhart et al., 2020)



Part of the surface deformation is diffuse in the medium:





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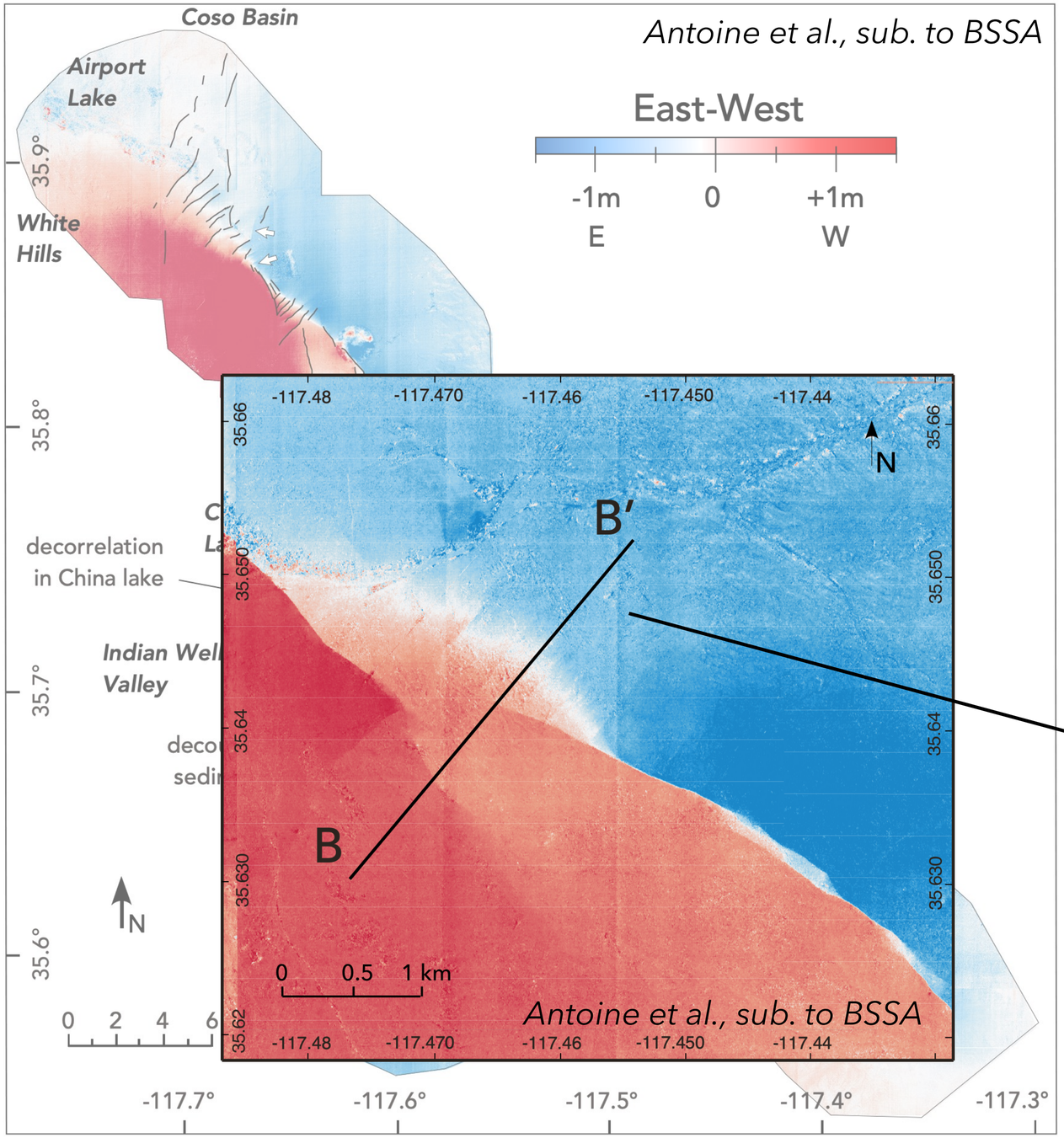

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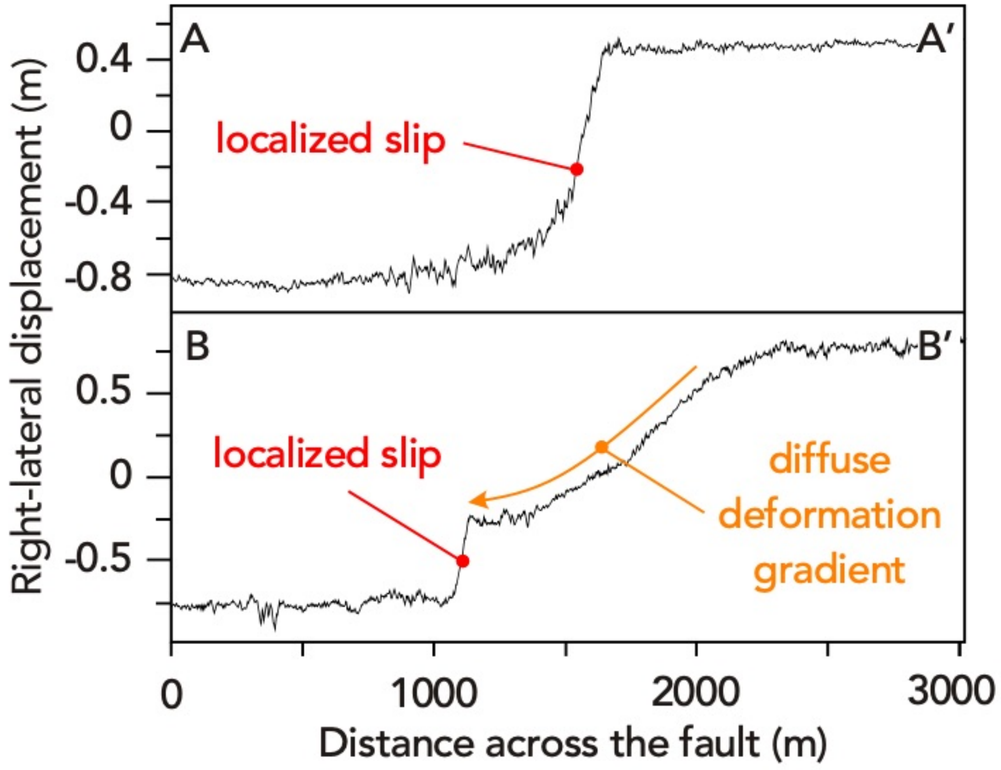

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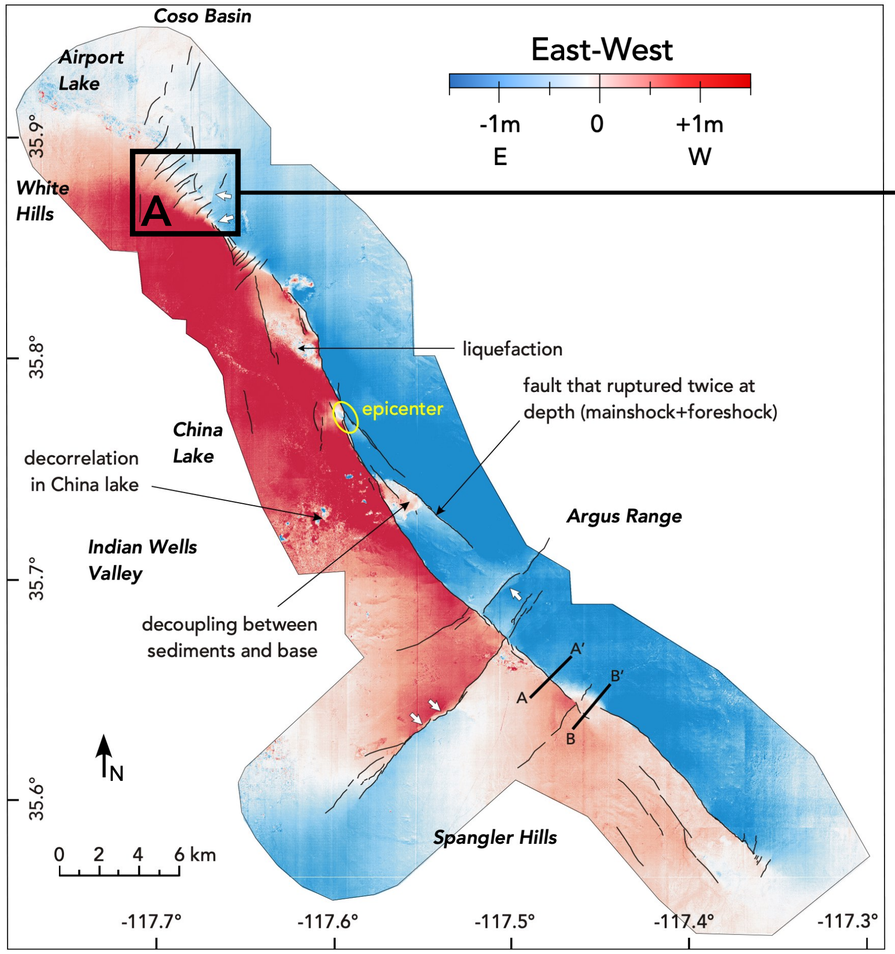
Sometimes, all the surface deformation is diffuse, meaning that the primary fault is blind:



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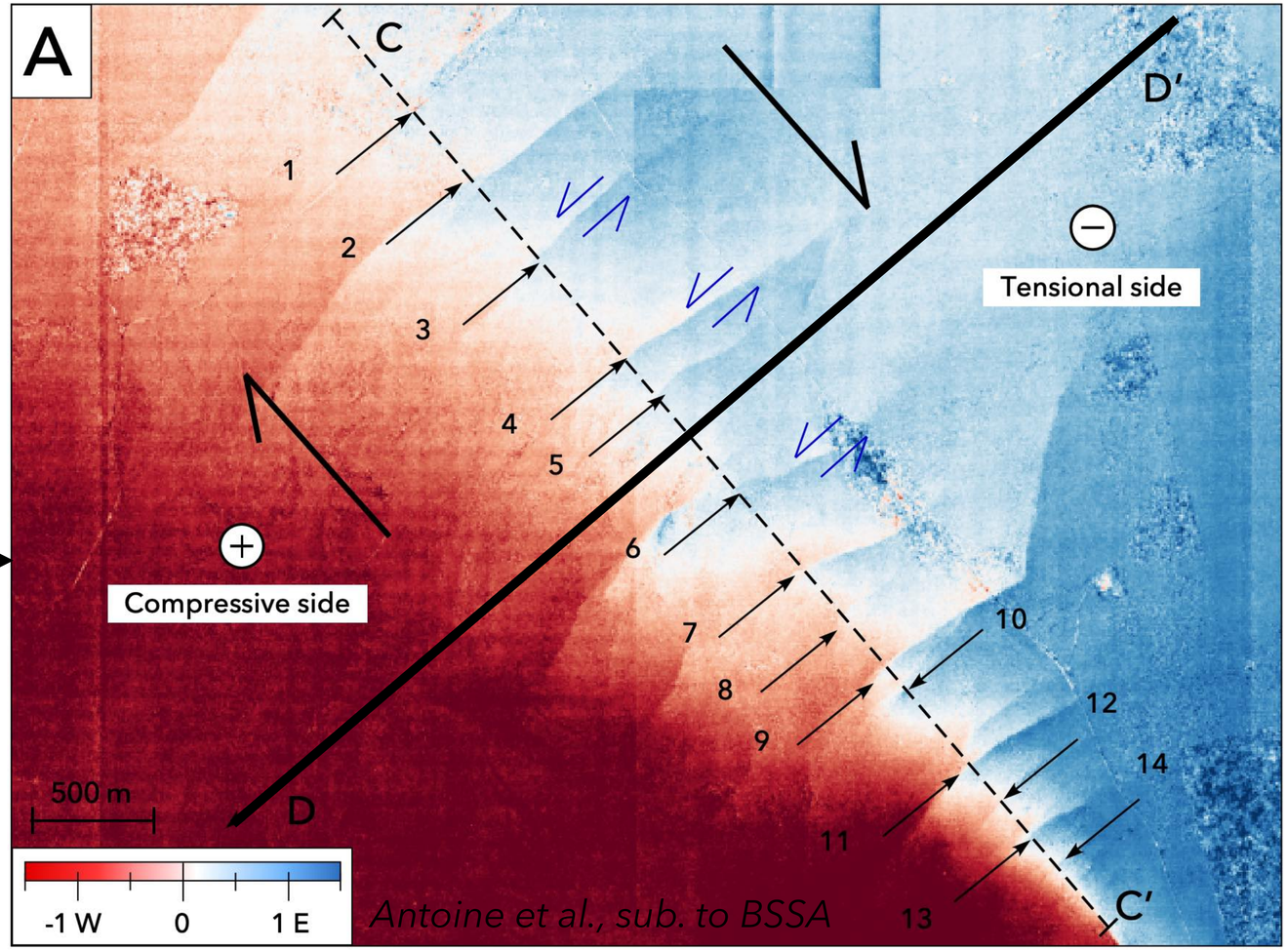
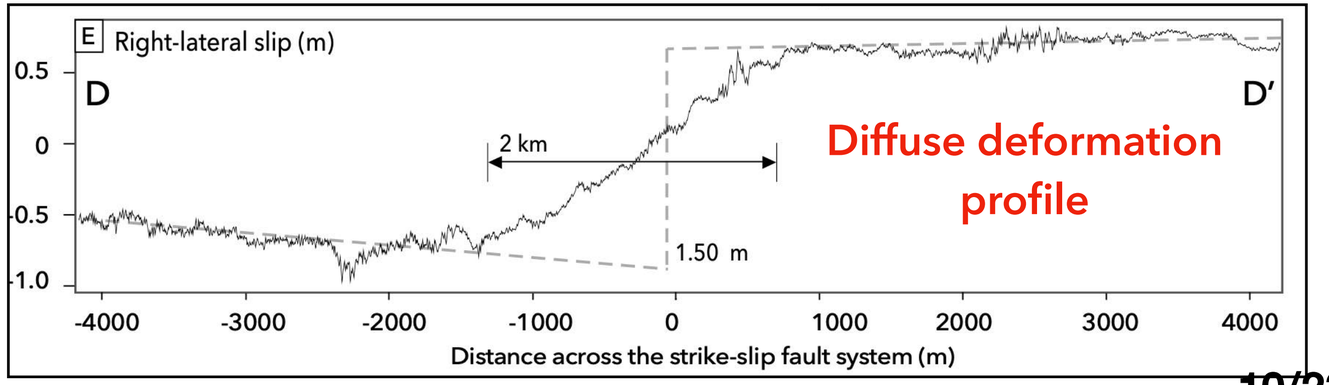
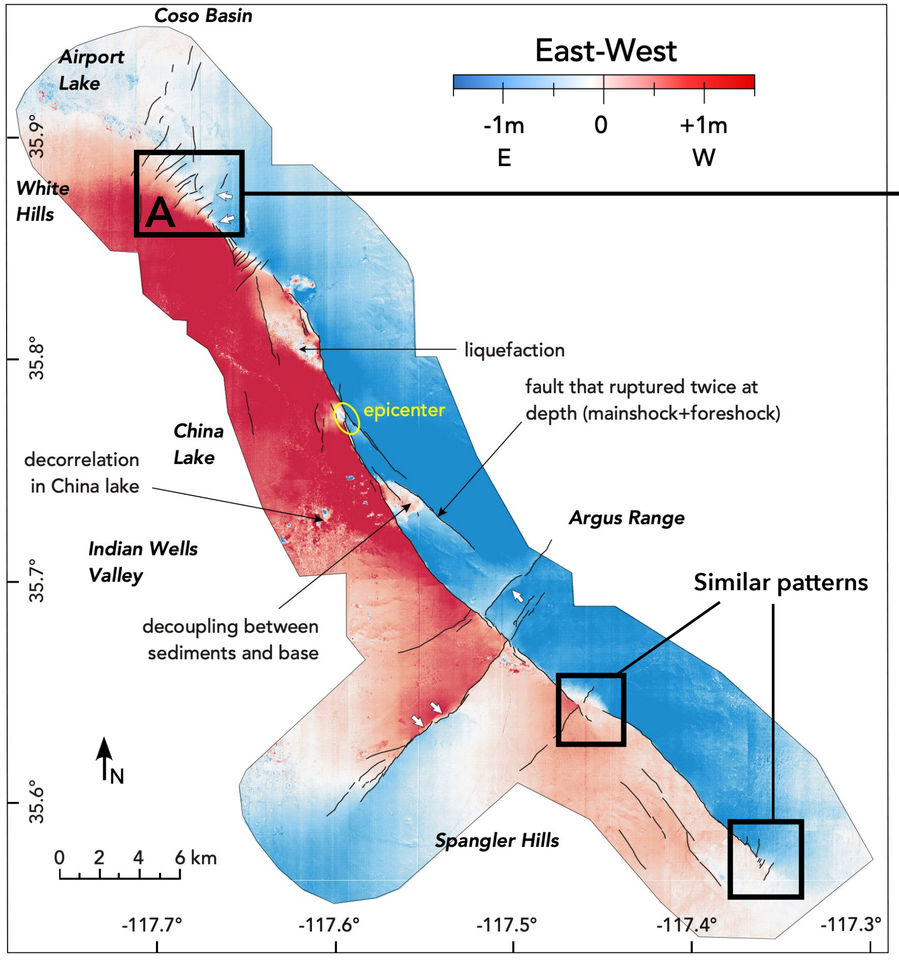




Cross-cutting left-lateral faults were activated during the mainshock:



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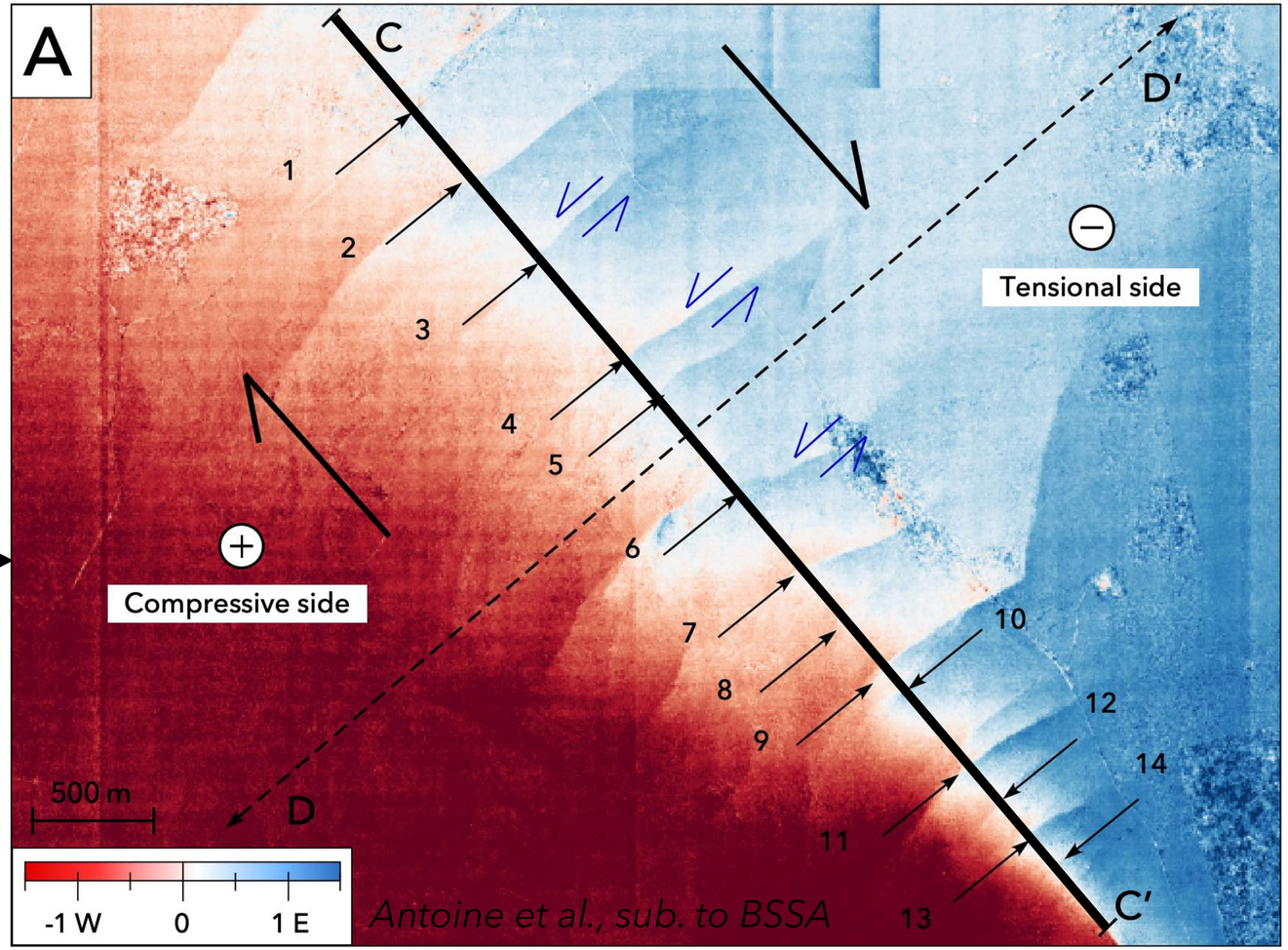
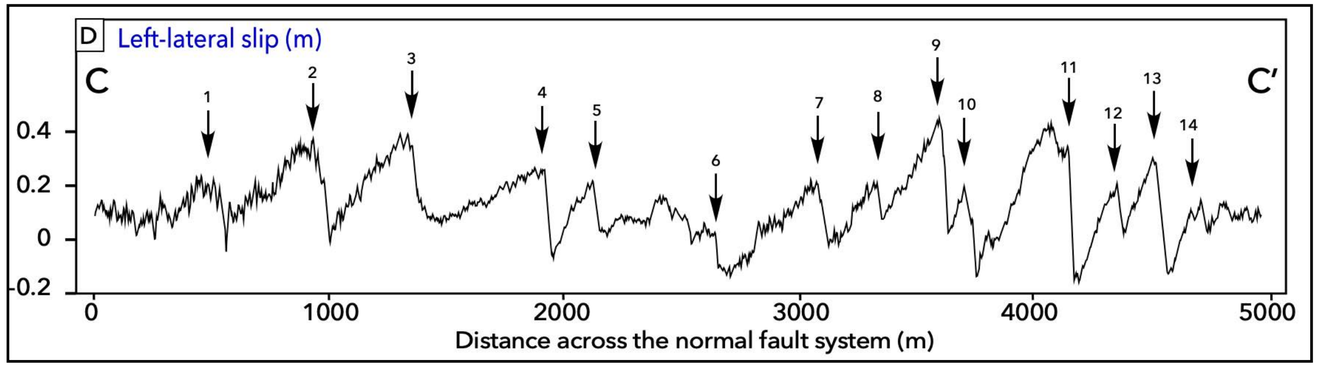
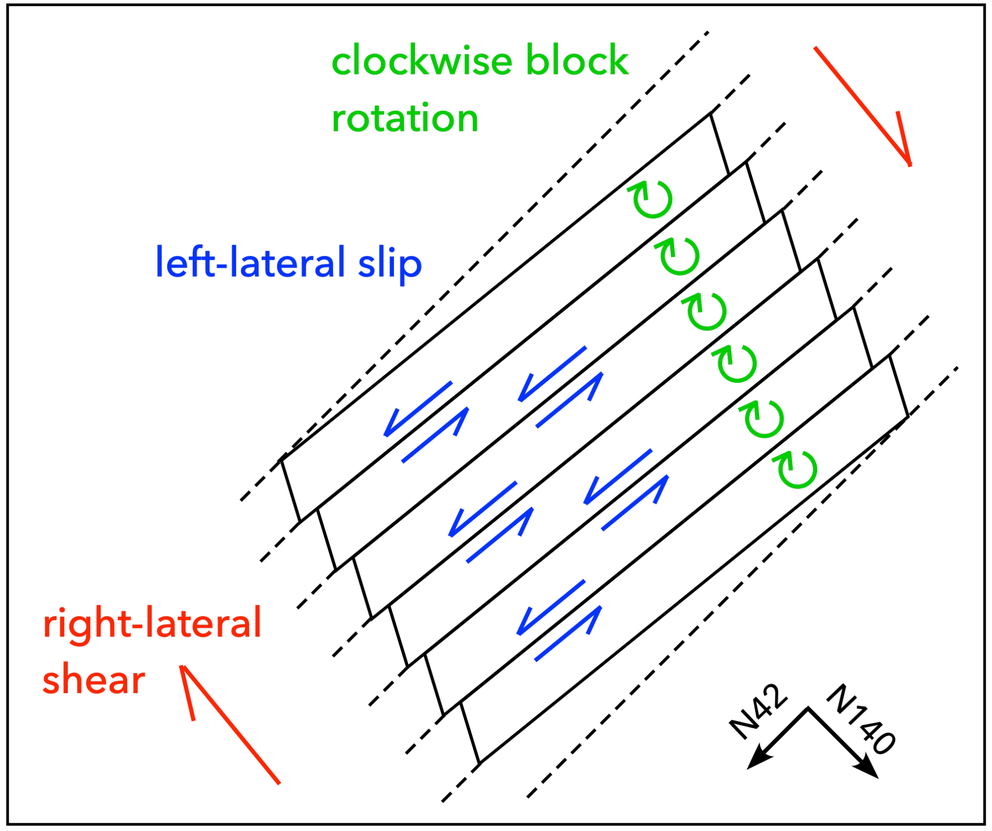
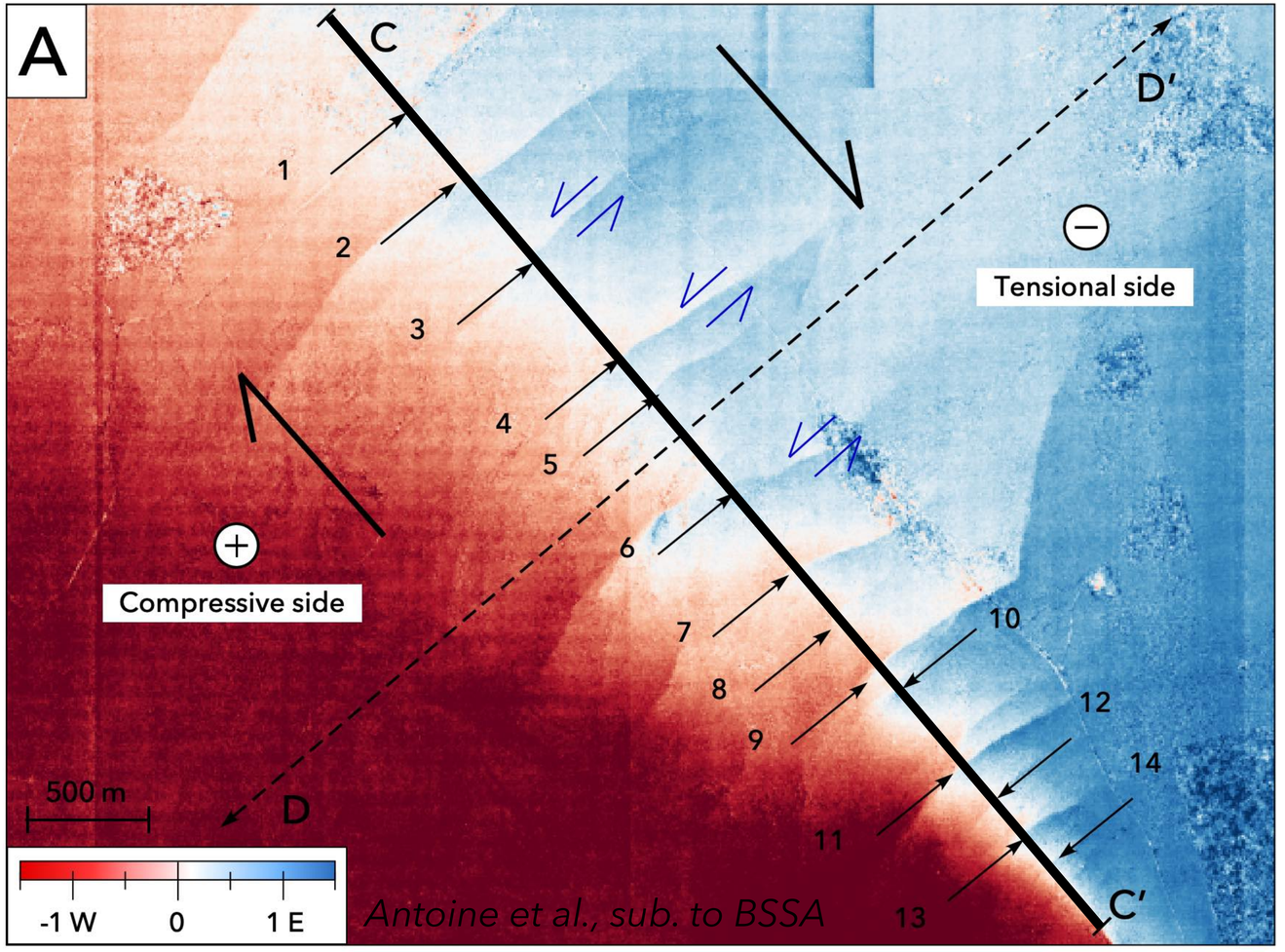


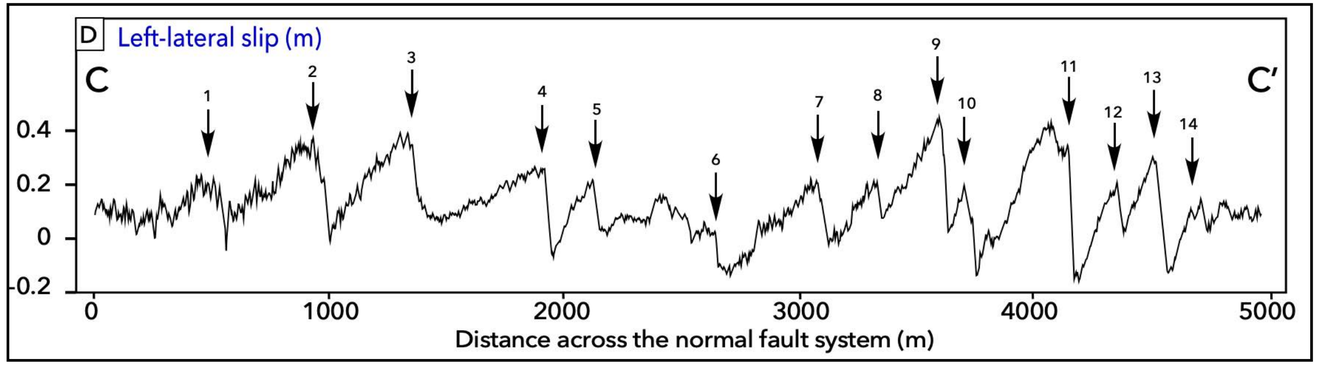


No cumulative slip across the faults → bookshelf faulting:

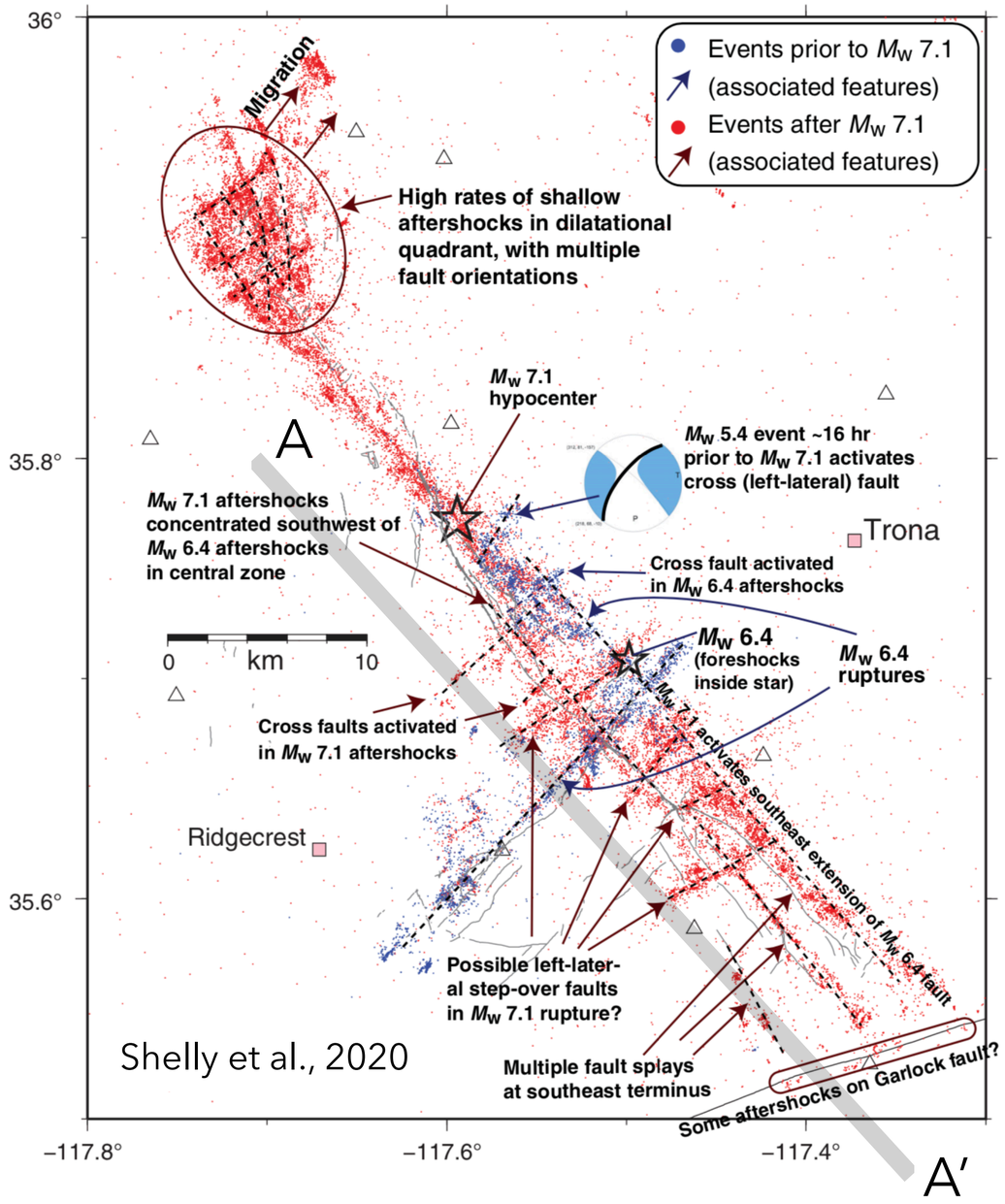


modified from Tapponnier et al. (1990)



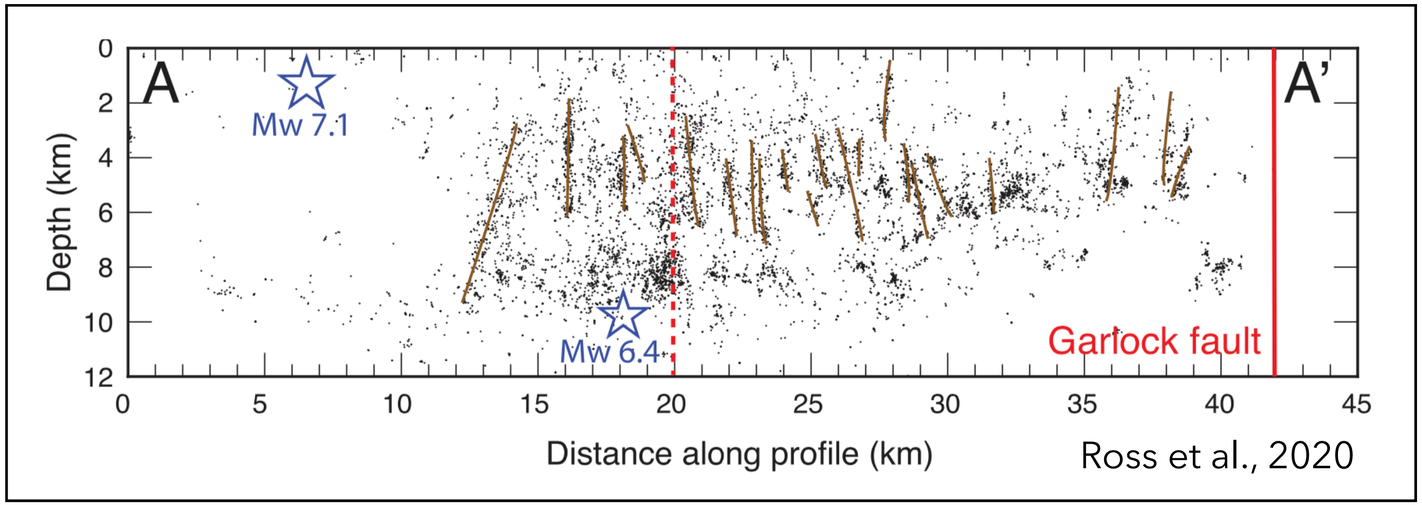


Cross-cutting faults are also detected in the seismicity:



Shelly et al., 2020

Seismicity cross section parallel to the mainshock azimuth:

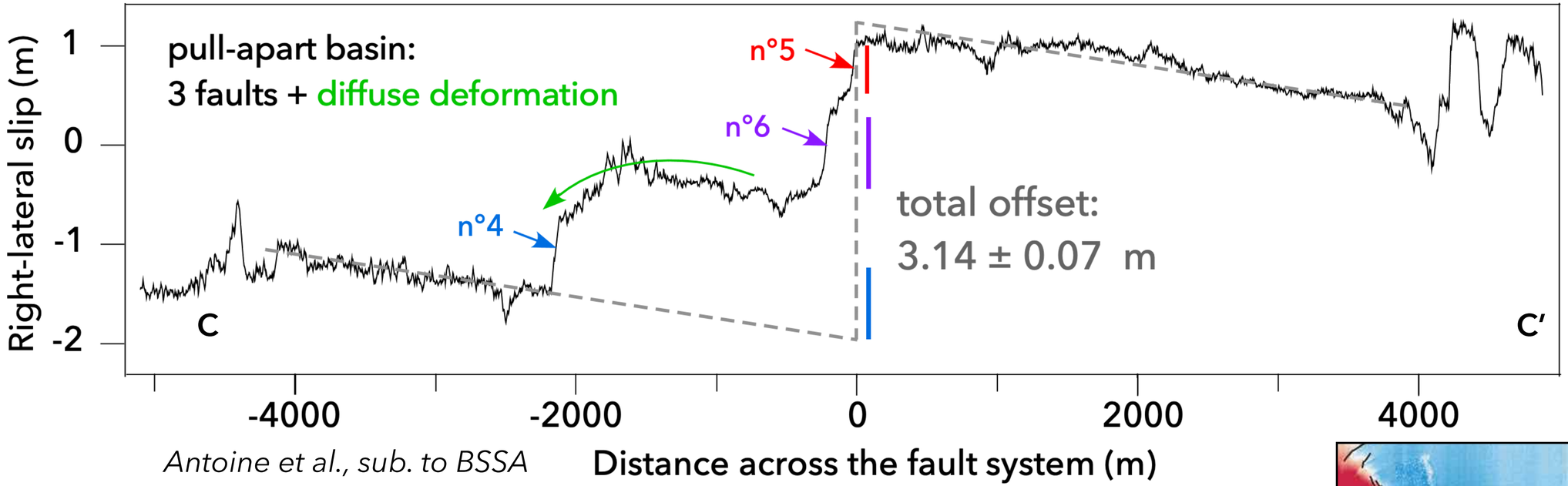


Ross et al., 2020

→ Regional basement fabric?

What influence on the general displacement pattern?

Systematic quantification of right-lateral slip along-strike:



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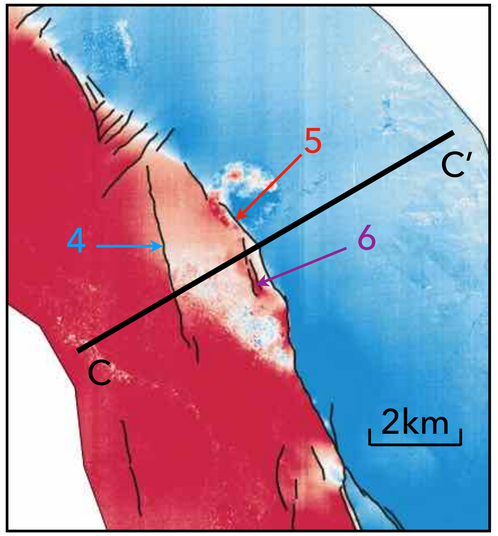
(1) Quantification of the total displacement offset across the fault zone

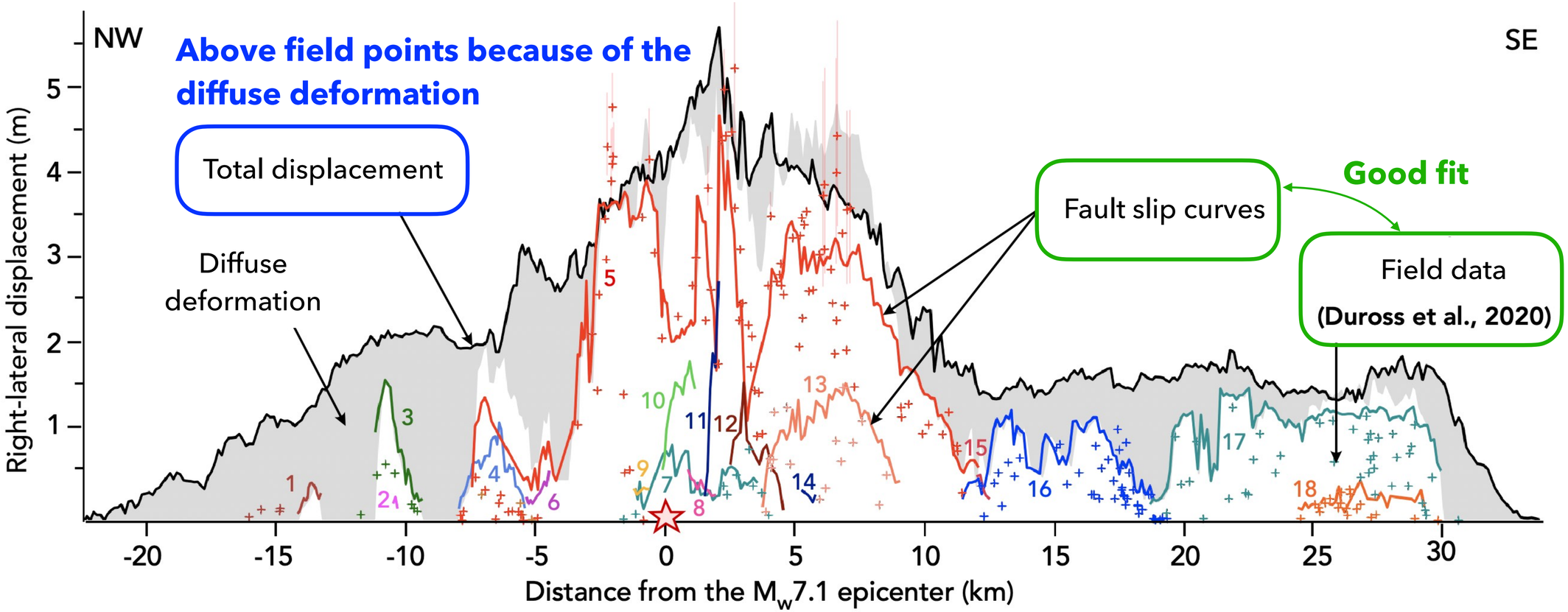
(2) Quantification of each fault slip offset

(3) Quantification of diffuse deformation



Fault slip curves fit field data points but total slip curve does not because ~30% of the deformation is diffuse:

Surface slip budget:



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Predictions of surface slip from kinematic inversions fit our total slip budget:

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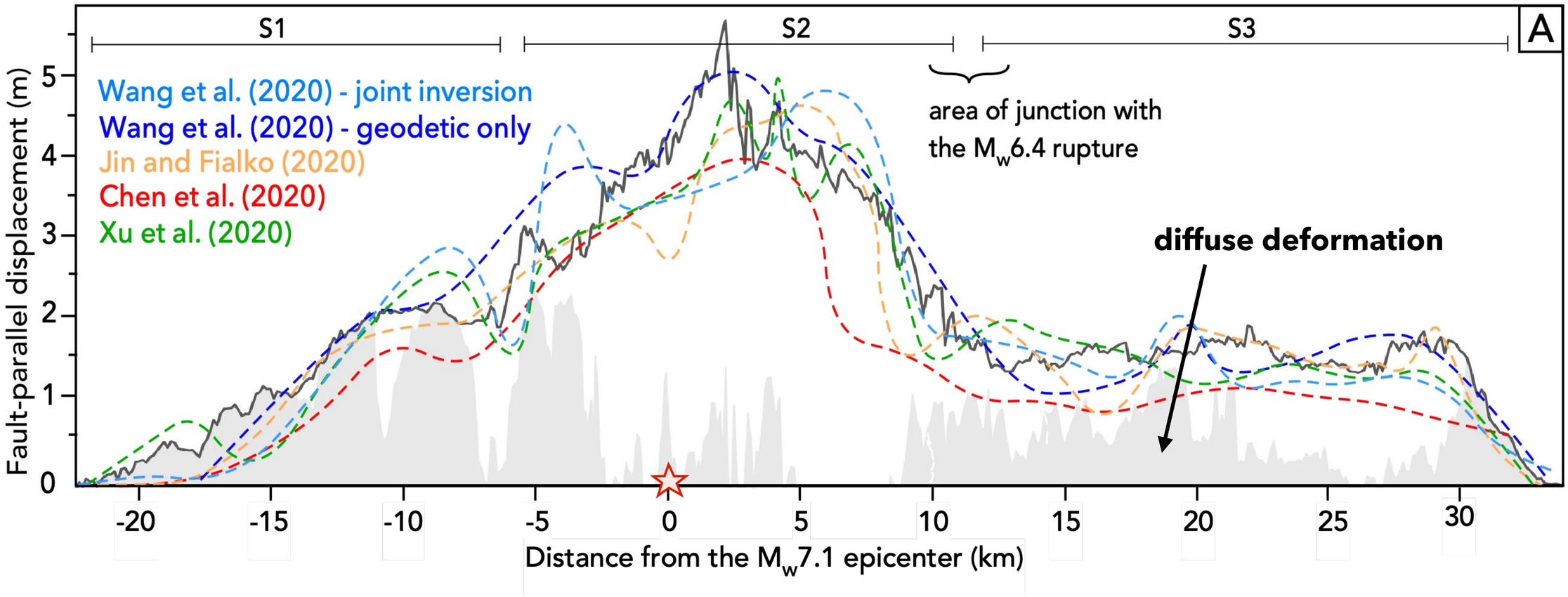
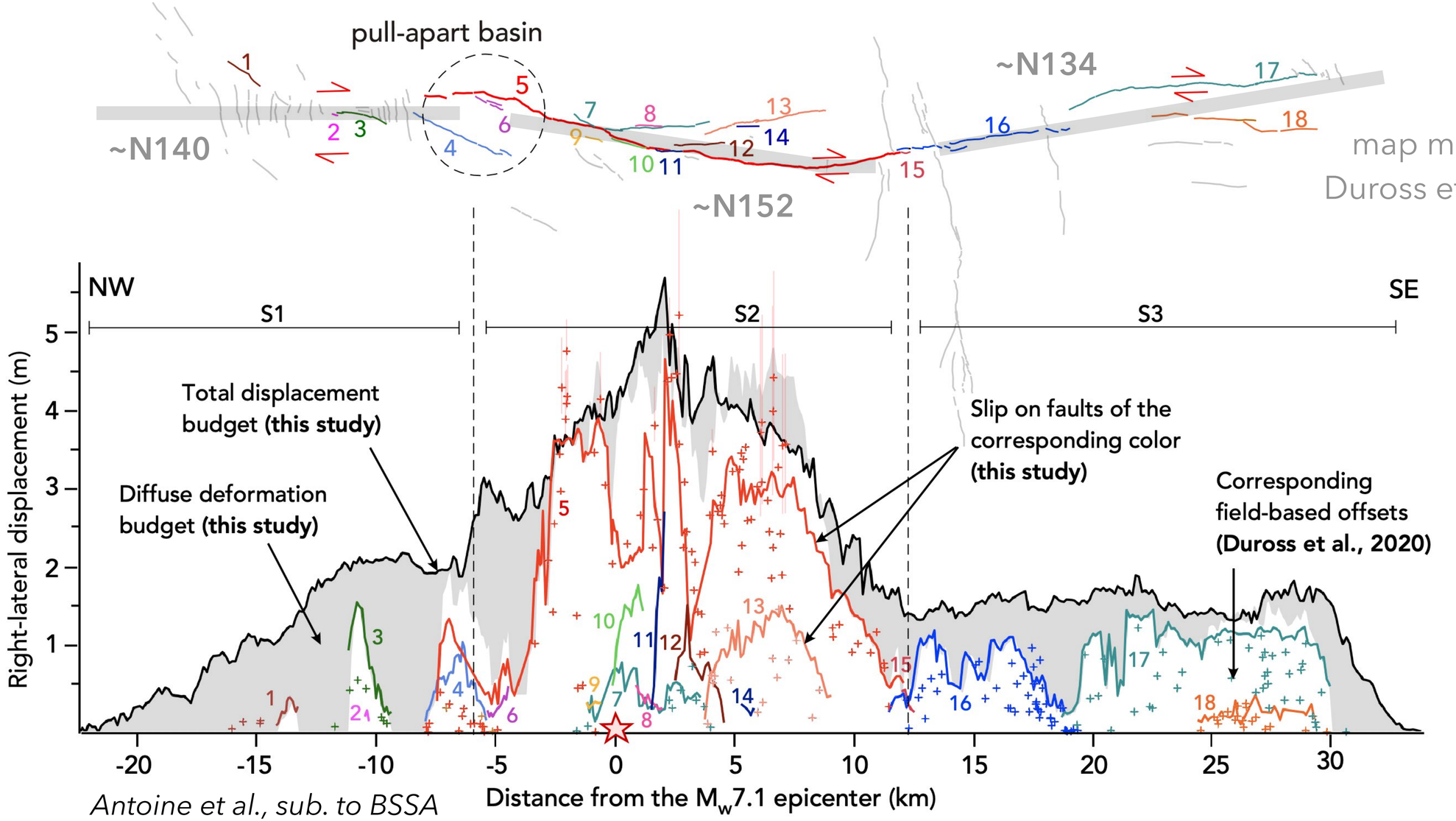
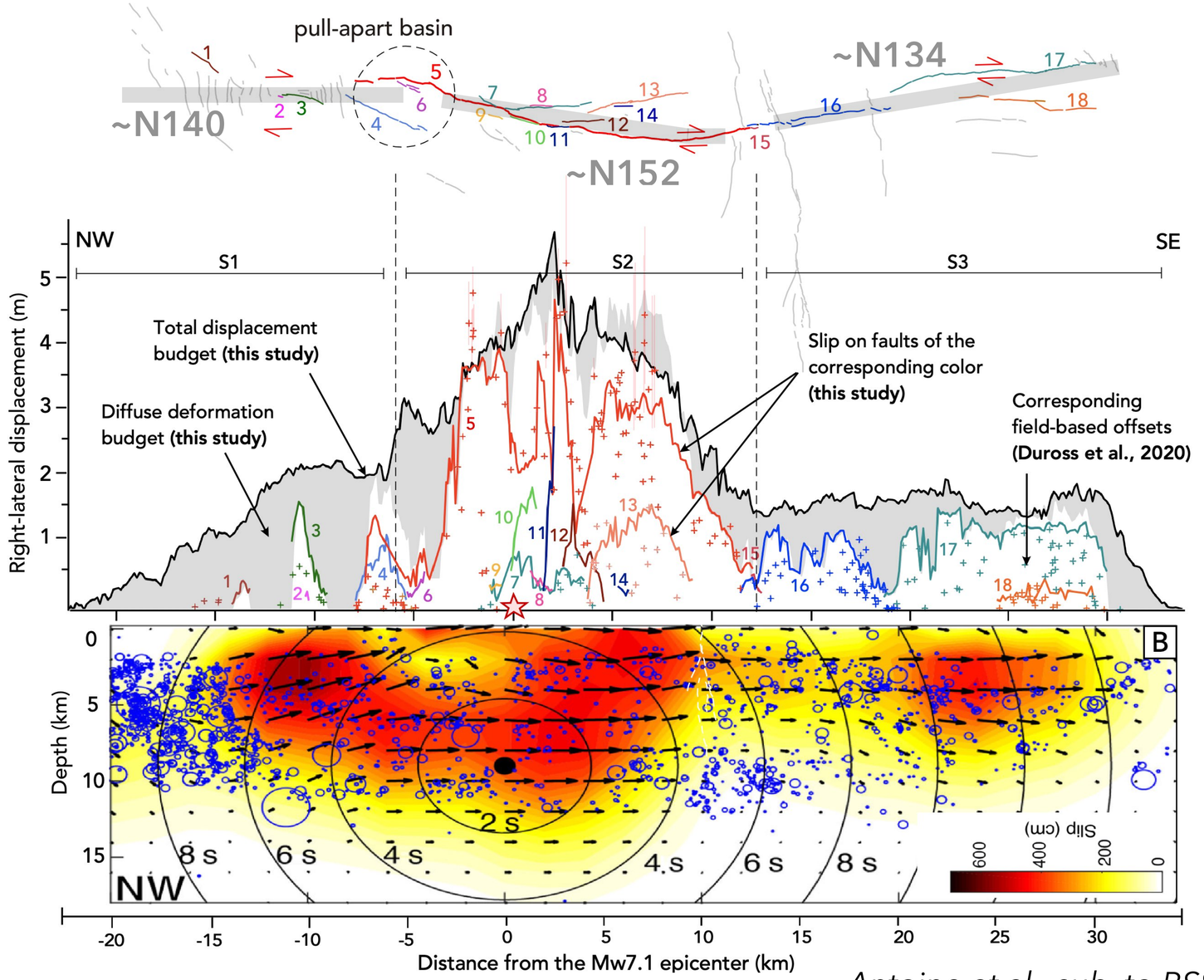


Inversions are based on various data sets (InSAR, optical, GNSS, seismology) and using various geometries (see Wang et al., 2020):

3 domains with different proportions of fault slip and diffuse deformation:



Segments are co-located with sub-event distribution of slip at depth:



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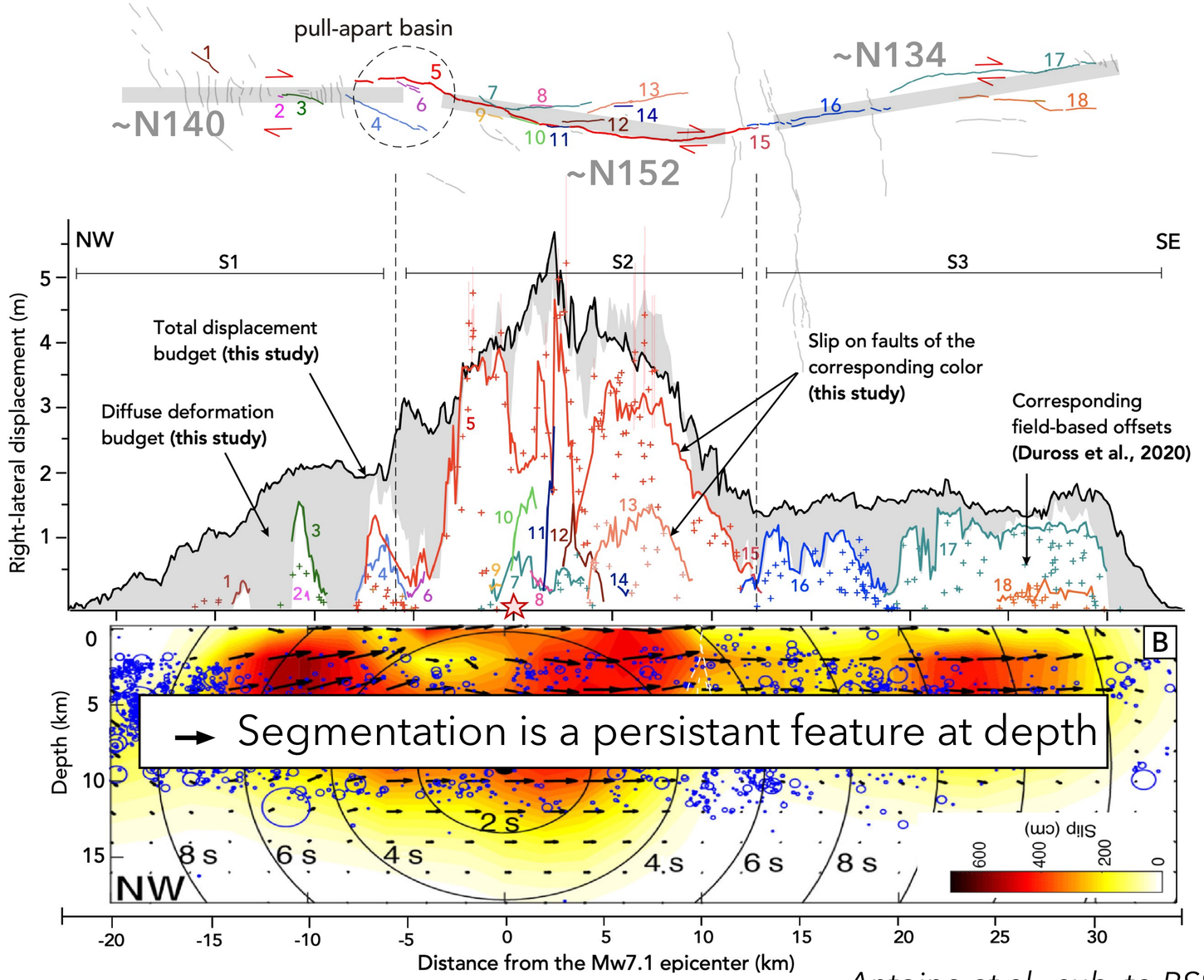

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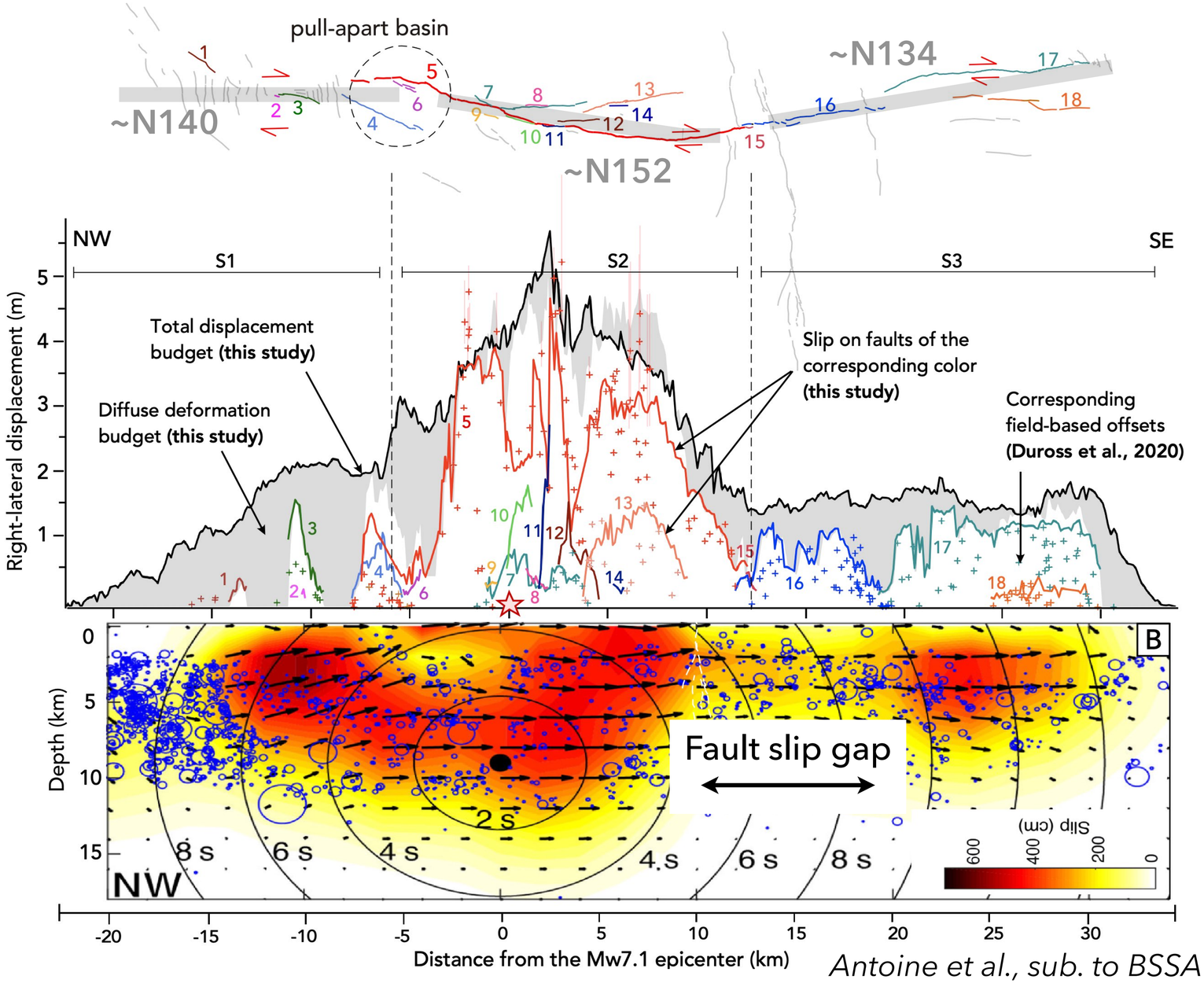
Asymmetric slip pattern around the M_w6.4 rupture:



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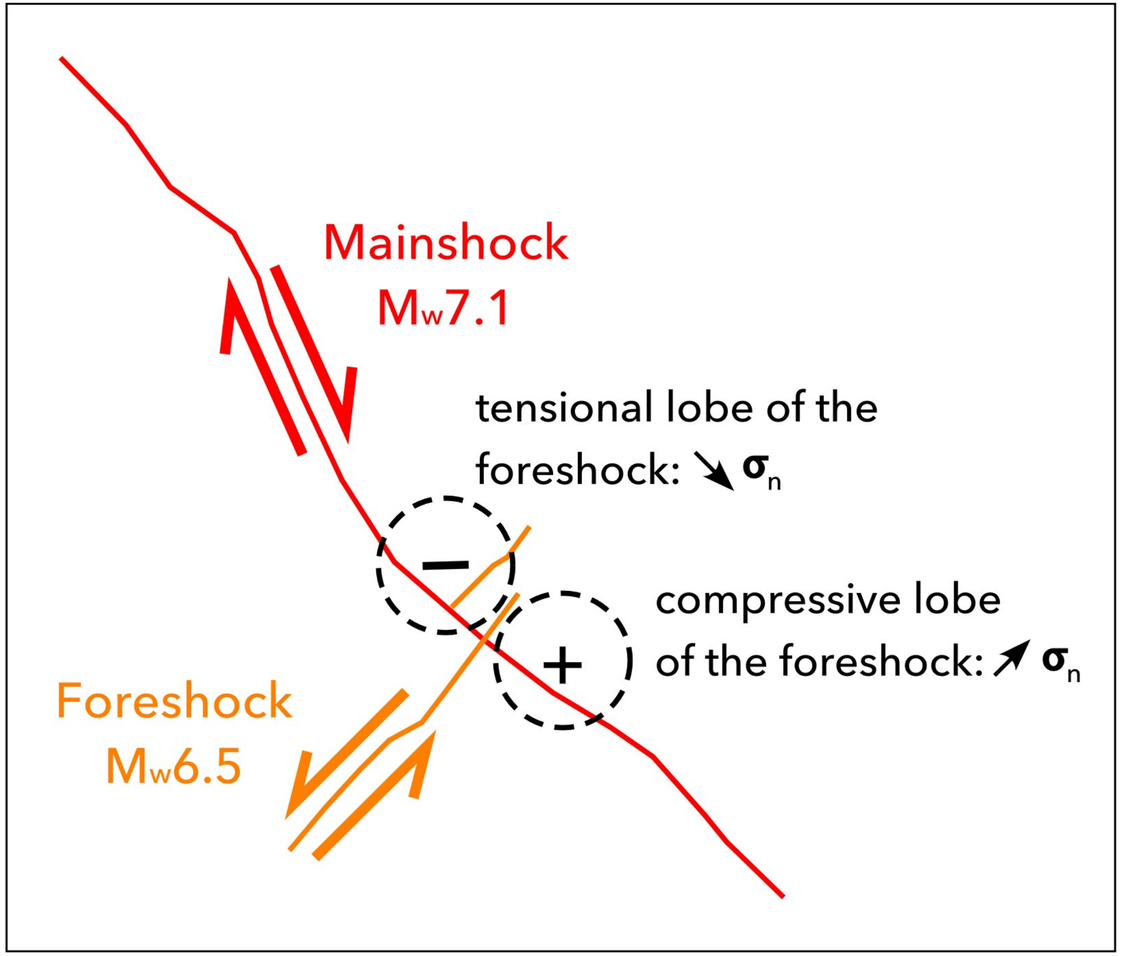
The compressive lobe of the foreshock inhibits fault slip at the beginning of S3 on the mainshock:



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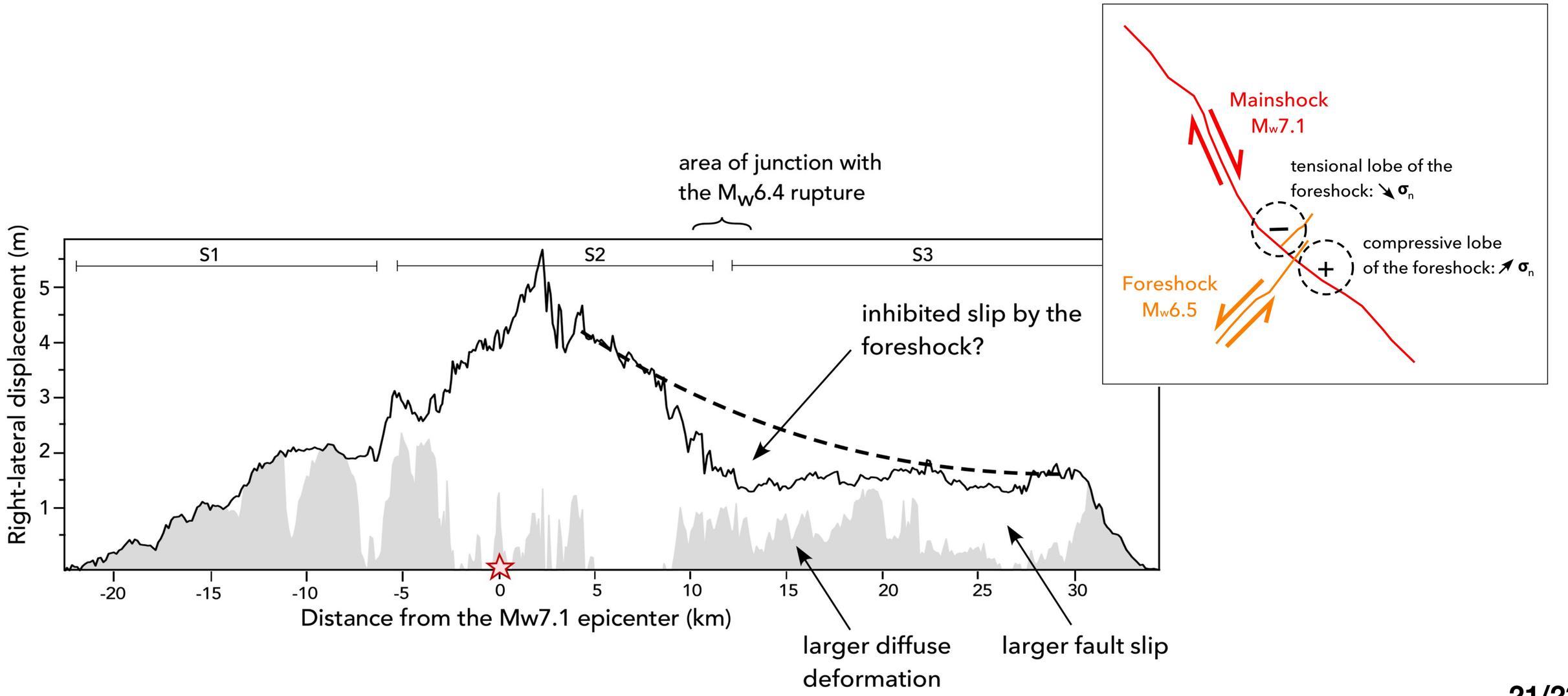
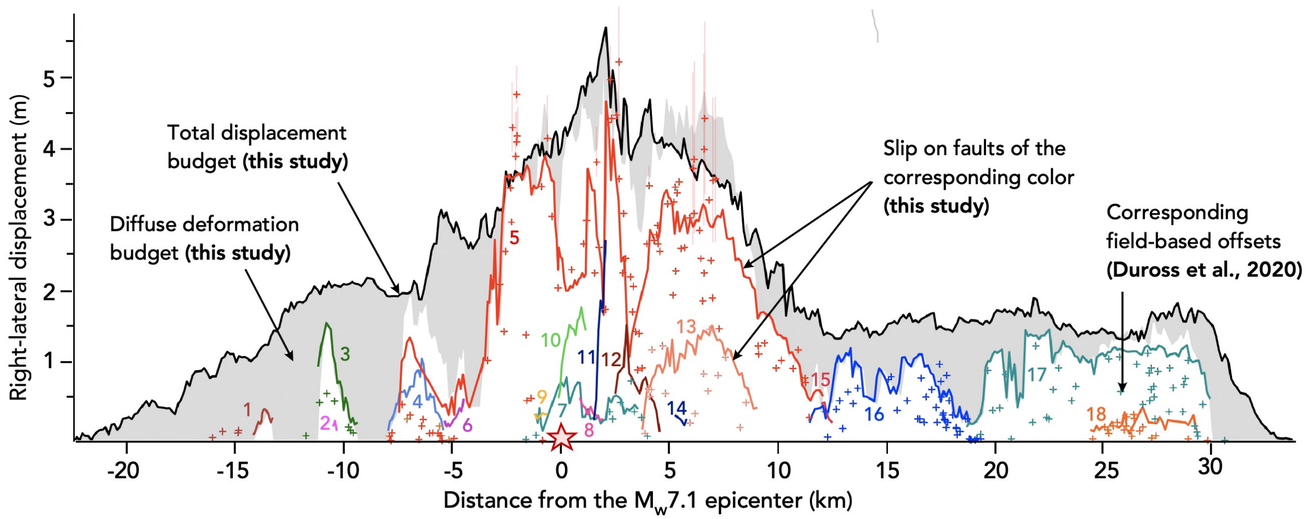
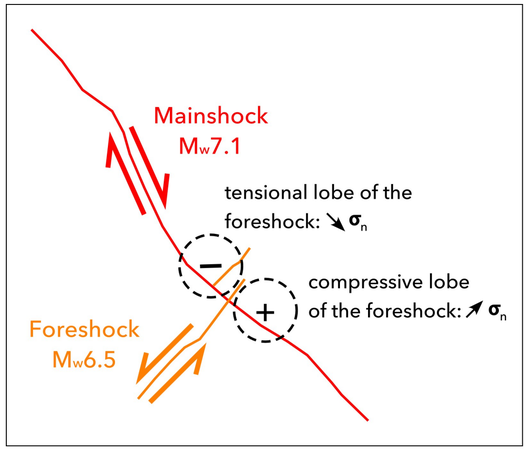


Using high-resolution optical image correlation we can quantify slip on all the faults of the system as well as diffuse deformation

(1) The rupture is segmented:



(2) The foreshock rupture impacted the mainshock displacement pattern:



(3) The basement fabric accommodates diffuse shear at the surface: