The evolving structural complexity of restraining bends impacts slip rate

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UMASS geosciences

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Structural complexity

Density of active faults

Connectivity of faults

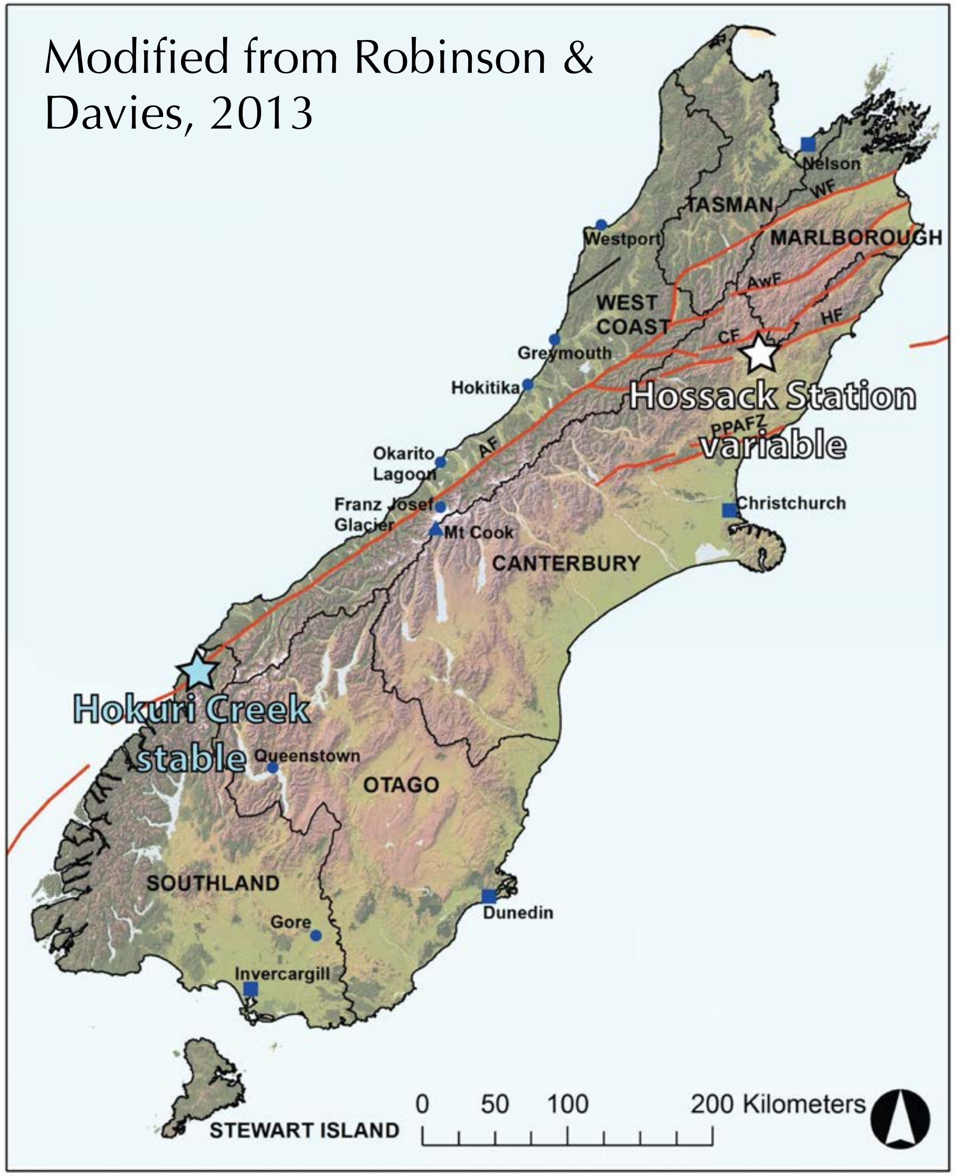
Less complex

More complex

Slip rate variations

Hokuri Creek – stable slip rate through time (*e.g., Berryman et al., 2012*)

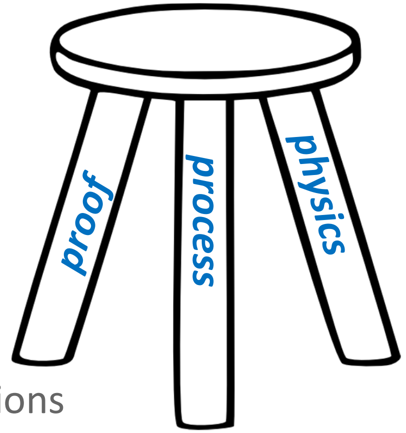
Hossack Station – variable slip rate through time (*Hatem et al., 2020*)



Modified from Robinson & Davies, 2013

Physical experiments of crustal faulting

Physical experiments provide a way to directly observe processes that occur over large time and spatial scales.

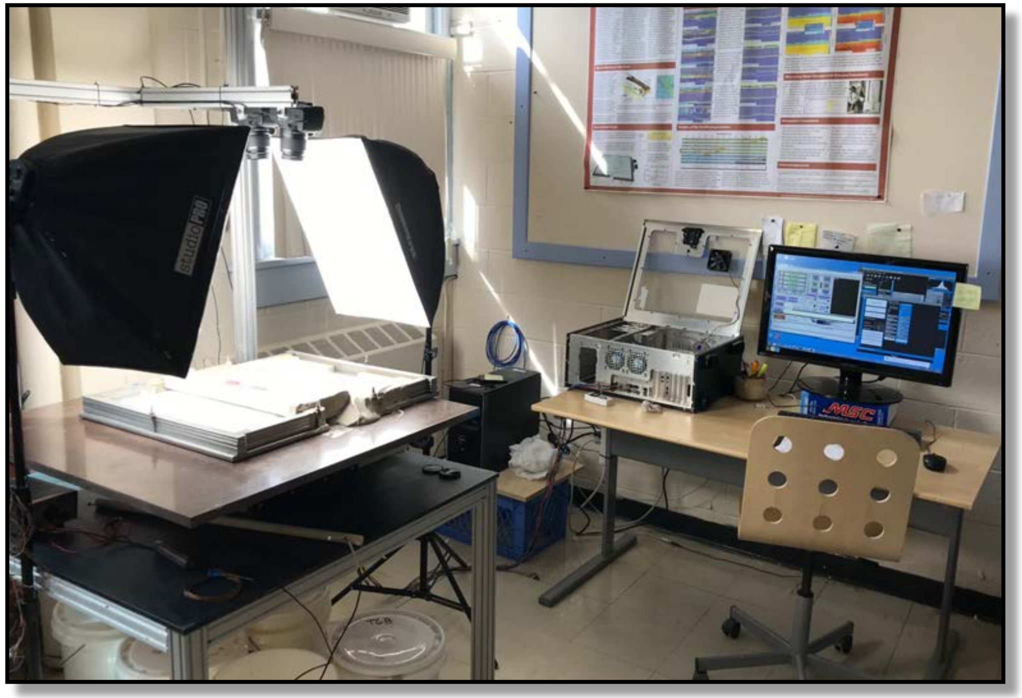


Cooke, Reber & Haq. (2017) stool from Chris Kincaid

Ever wish you could watch faults evolve?

Analog experiments: Not a new idea

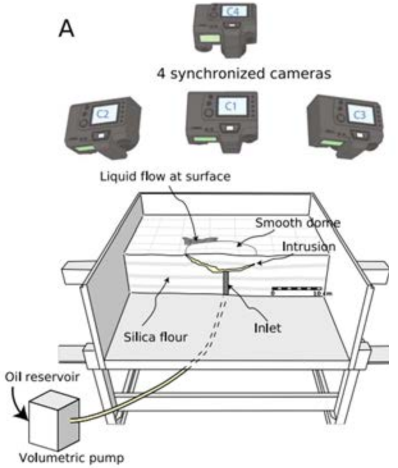
Cadell in 1890s



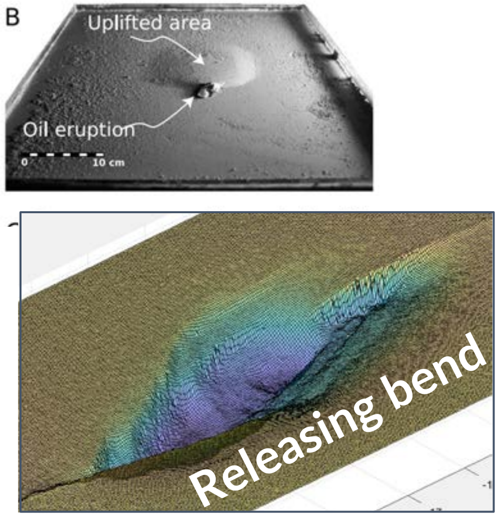
UMass in the 2010s

Experimental innovations

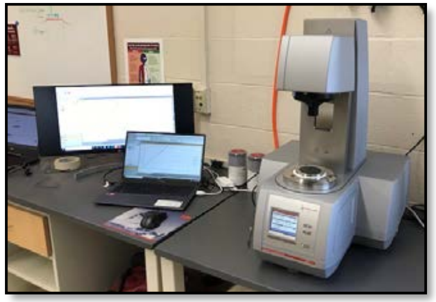
Structure from Motion
e.g. Olso, Cergy-Pontoise, UMass



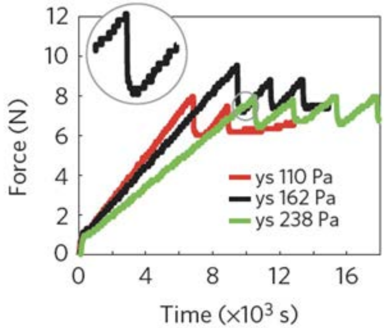
Galland et al., (2016)



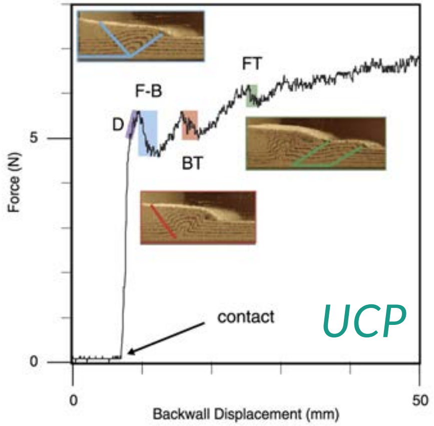
Rheometers
e.g.,UMass, Iowa State, GFZ Potsdam



Force measurements
e.g., Iowa State, Cergy-Pontoise , GFZ Potsdam, Stanford

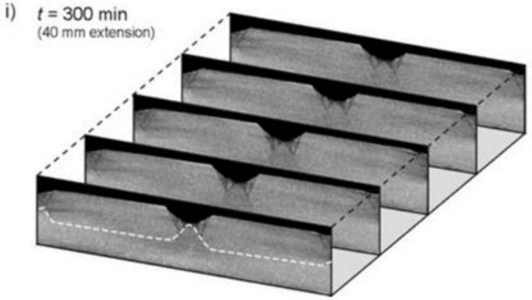


Reber et al. (2015)



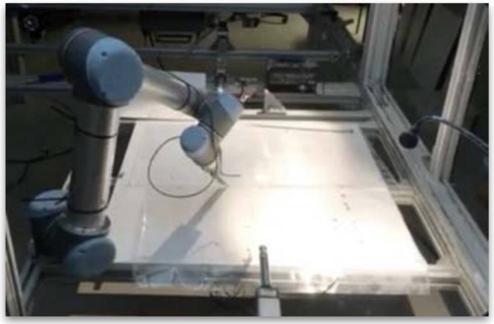
Herbert et al. (2015)

Xray scanning
e.g. Bern, IFP



Zwaan et al. (2019)

Robots
e.g.,Trieste

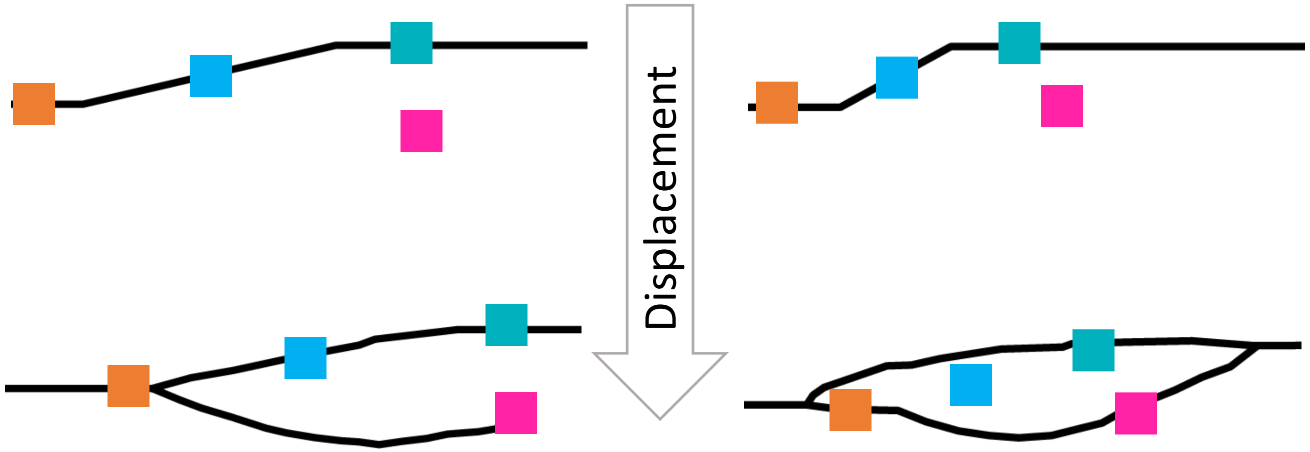


Assessing how evolving structural complexity of restraining bends impacts slip rate

Greater initial bend angles can produce more structurally complex fault systems

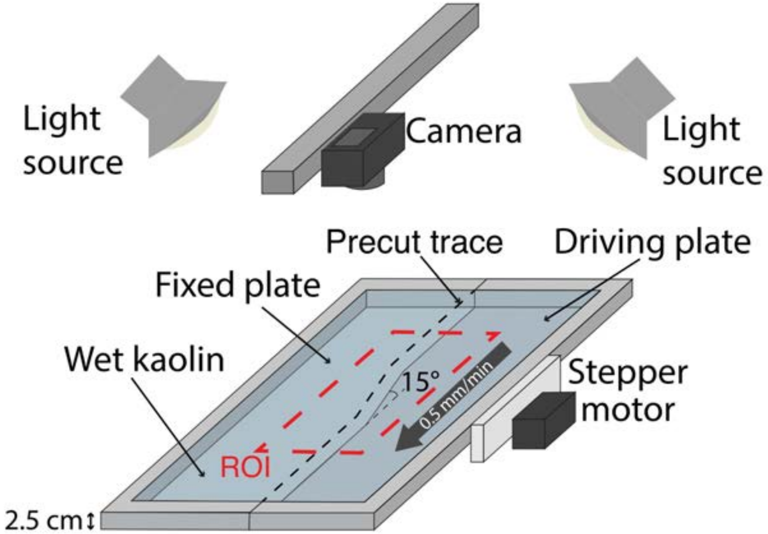
15° bend

30° bend

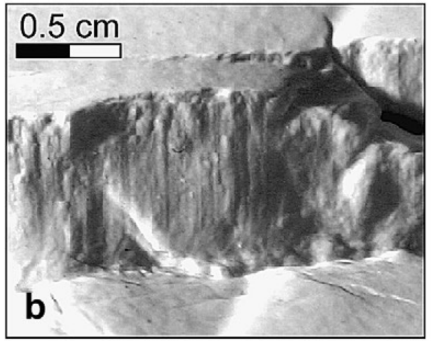


Track slip rates at 4 sites along the experimental faults

Wet kaolin analog models

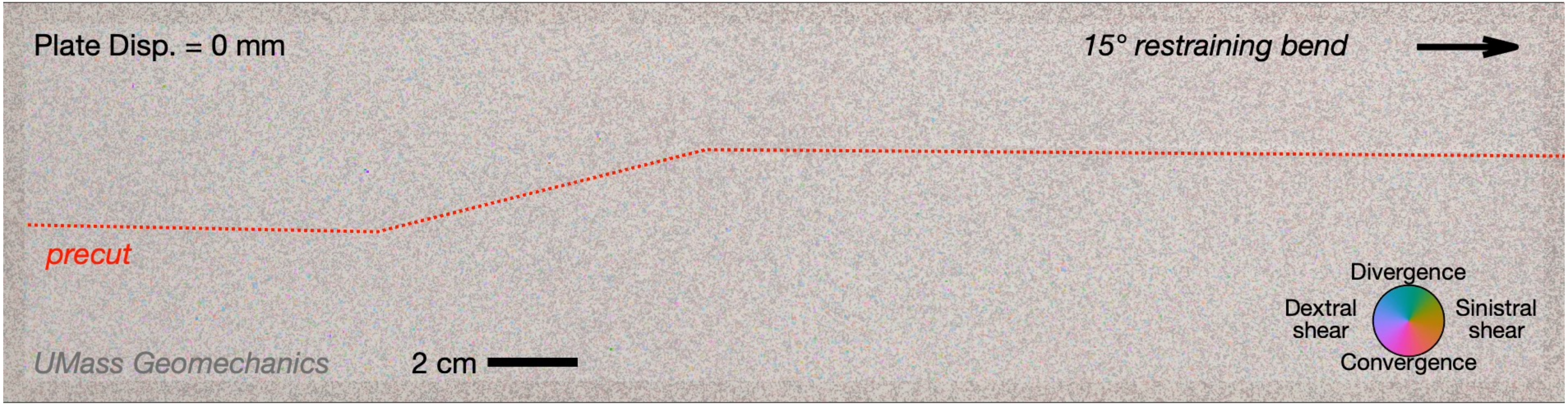


Elston et al., 2022



Slickenlines on wet kaolin fault from Henza et al, 2010

15° restraining bend evolution

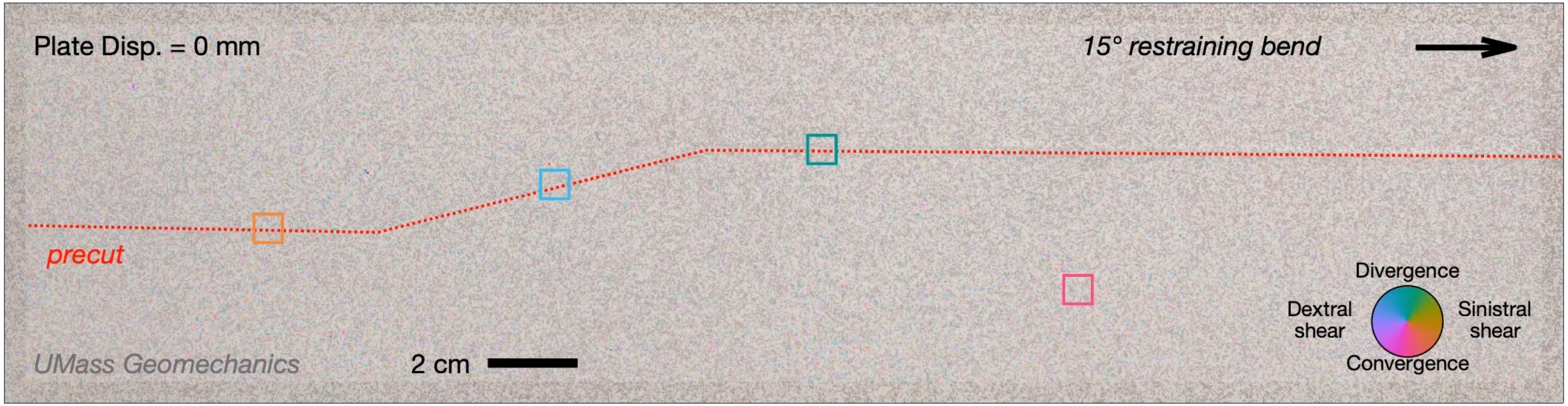


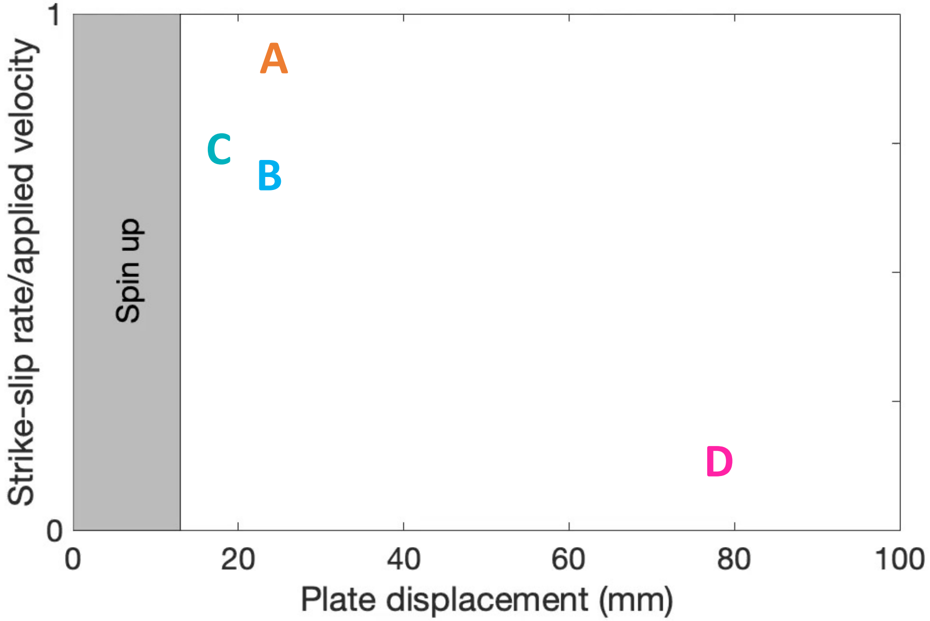
1 cm kaolin = 1-2 km crust

Hue = slip sense
Saturation = strain rate magnitude

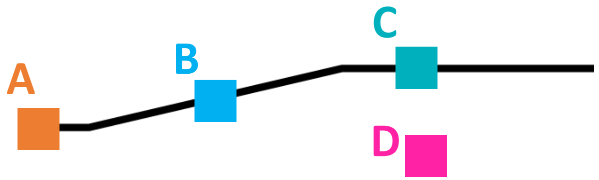
1 new fault has oblique-reverse slip

15° restraining bend slip rates at sites

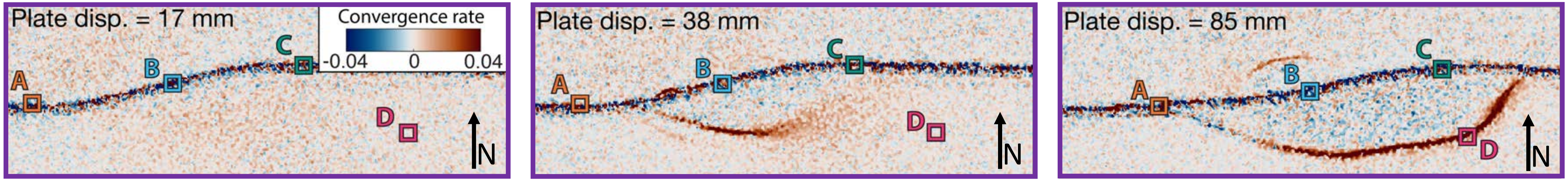


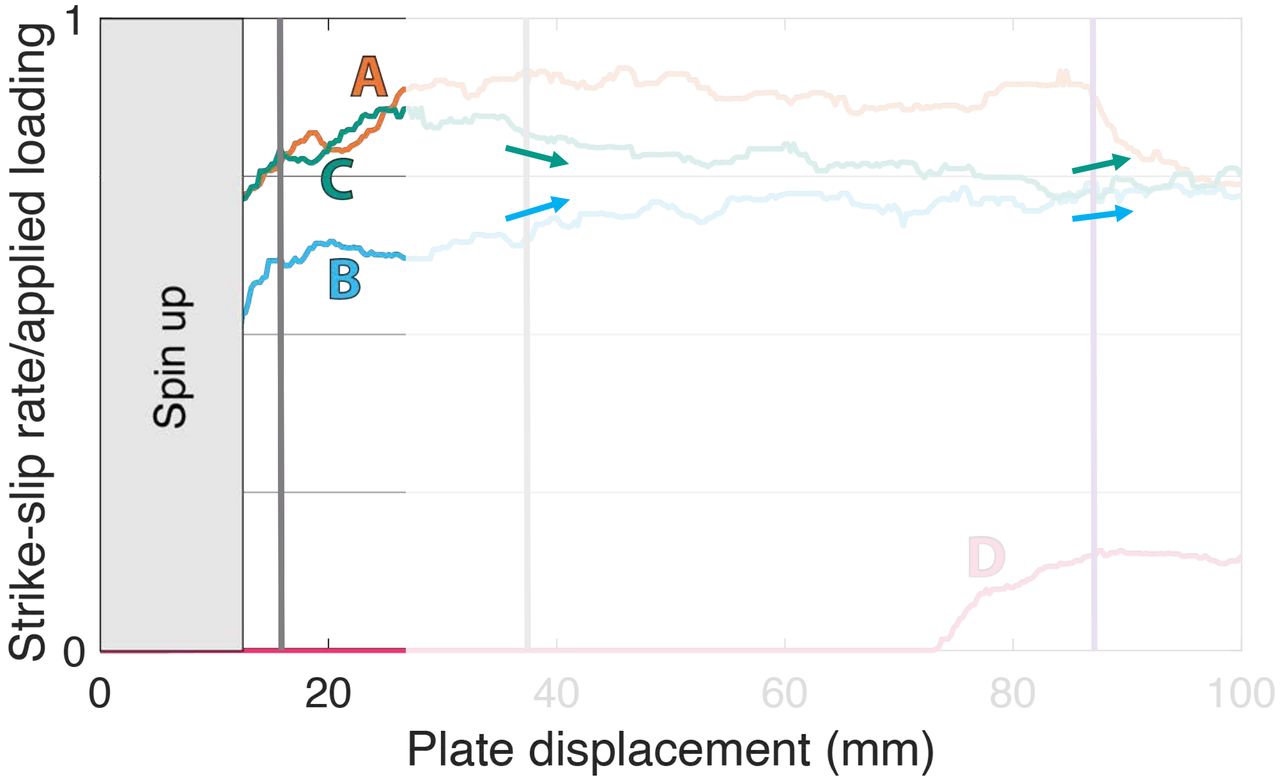


Slip rates vary by < 20% over entire experiment



Evolving complexity impacts strain partitioning and slip rates



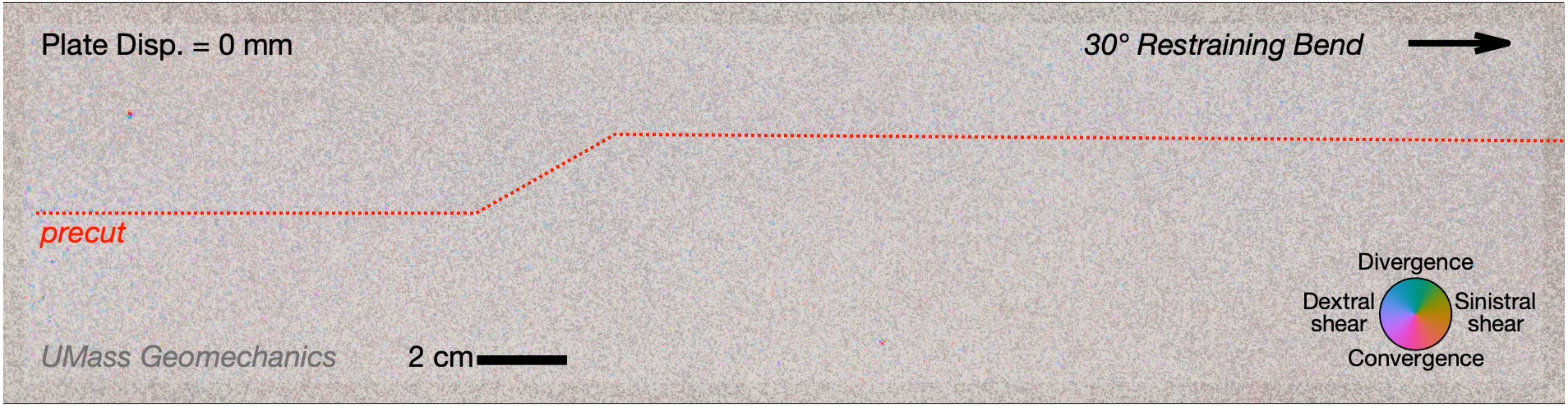


17 mm – Off-fault convergence clamps precut restraining segment

38 mm – Off-fault divergence in hanging wall of new fault unclamps precut restraining segment while zone of convergence clamps precut fault near site C

85 mm – Both sites C and B are in hanging wall of new fault along unclamped segments

30° restraining bend evolution

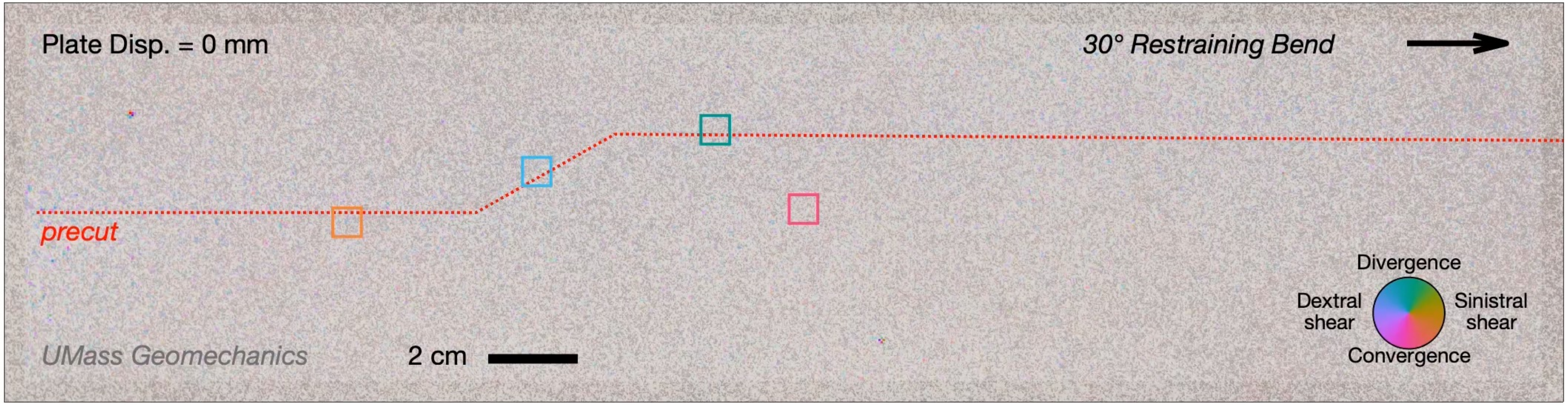


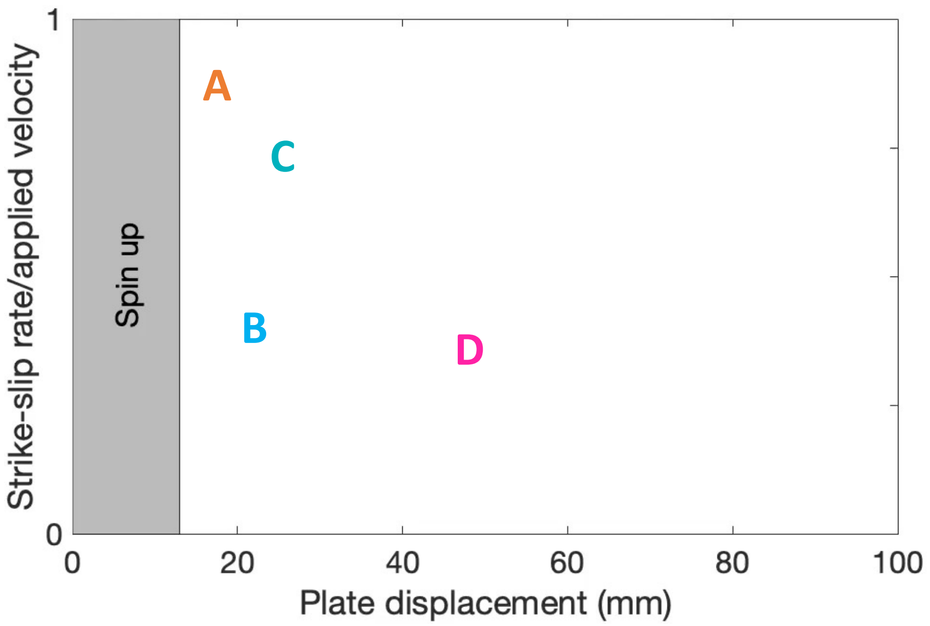
1 cm kaolin = 1-2 km crust

Hue = slip sense
Saturation = strain rate magnitude

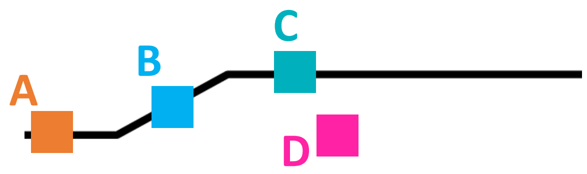
Multiple new faults grow to accommodate dextral shear and convergence

30° restraining bend slip rates at sites

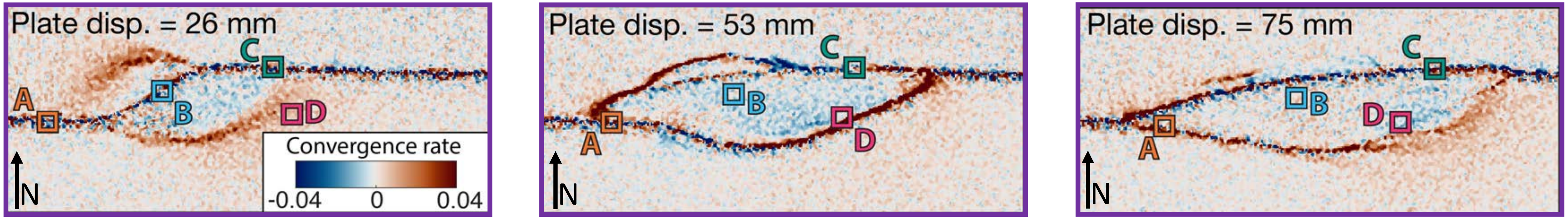


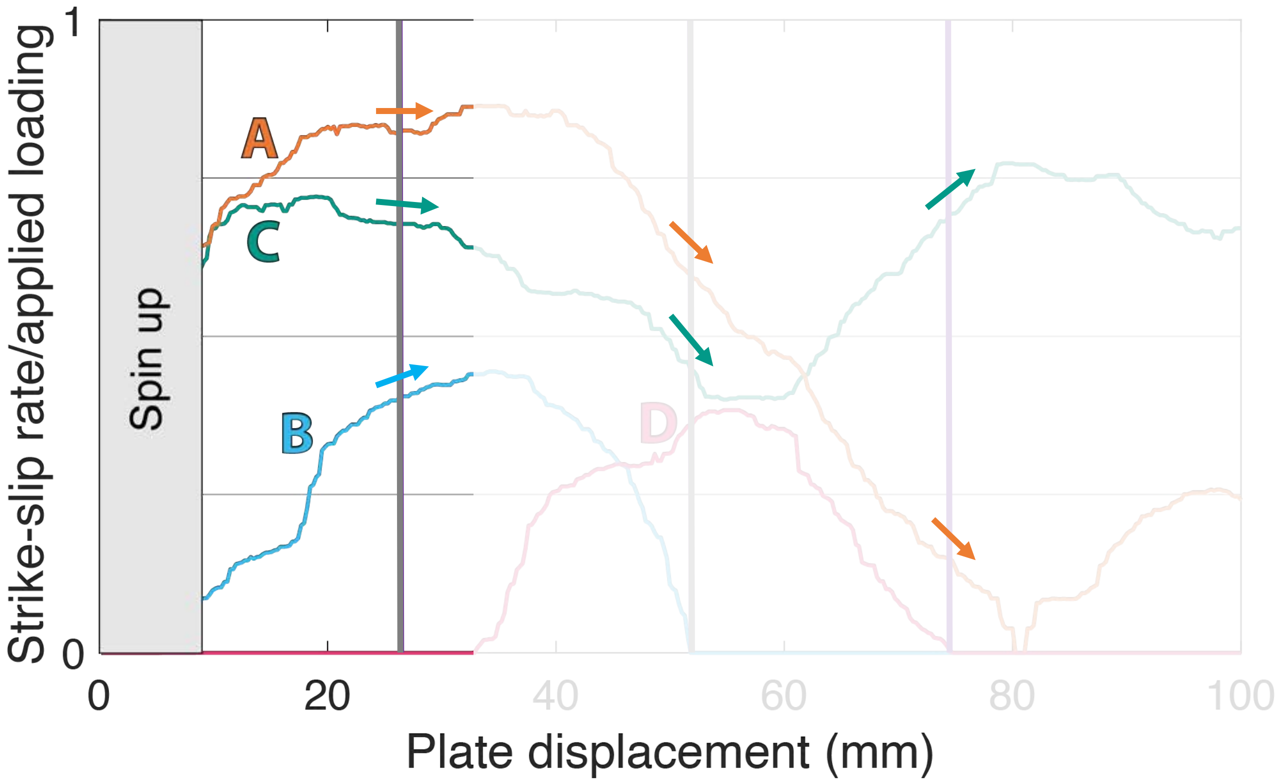


Slip rates vary up to 85% over entire experiment



Evolving complexity impacts strain partitioning and slip rates





26 mm – spatial variation in off-fault convergence.
clamping: B<<A <C

53 mm – Off-fault convergence clamps part of central pathway and northern pathway reorganizes

75 mm – Northern outboard fault provides through-going pathway

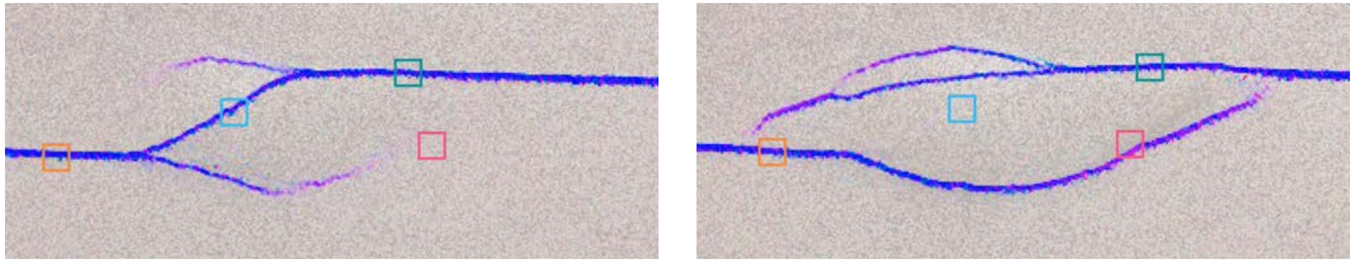
Conclusions

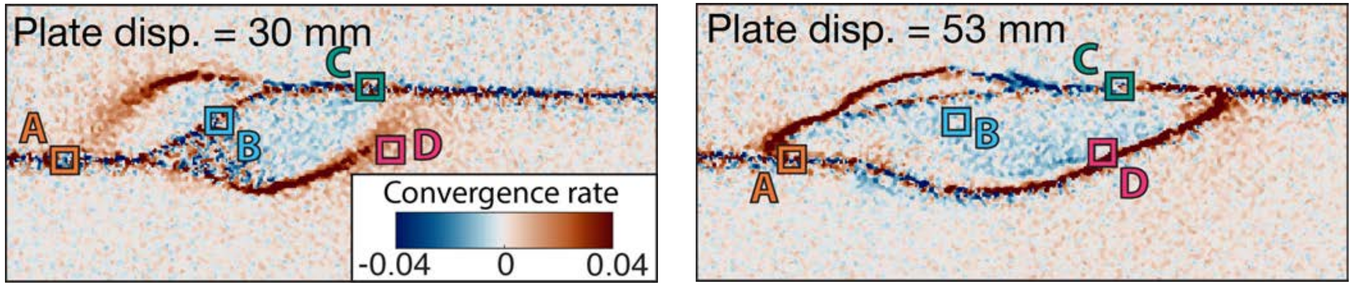
Structural complexity changes

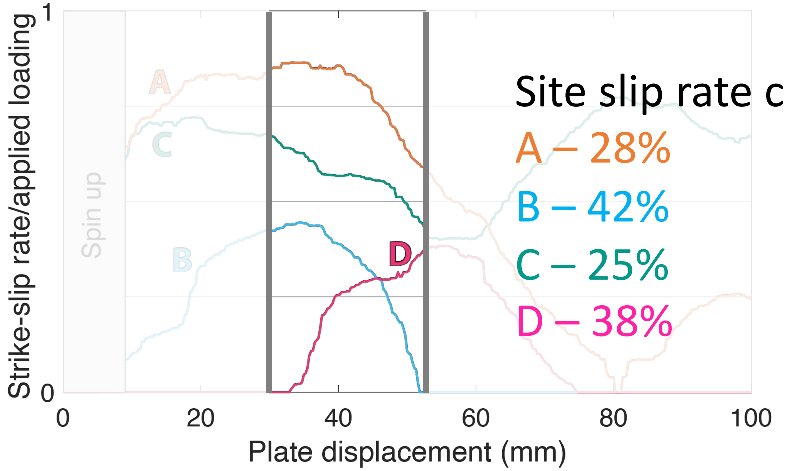
Strain partitioning changes

Slip rates change

Greater structural complexity can produce greater slip rate variations





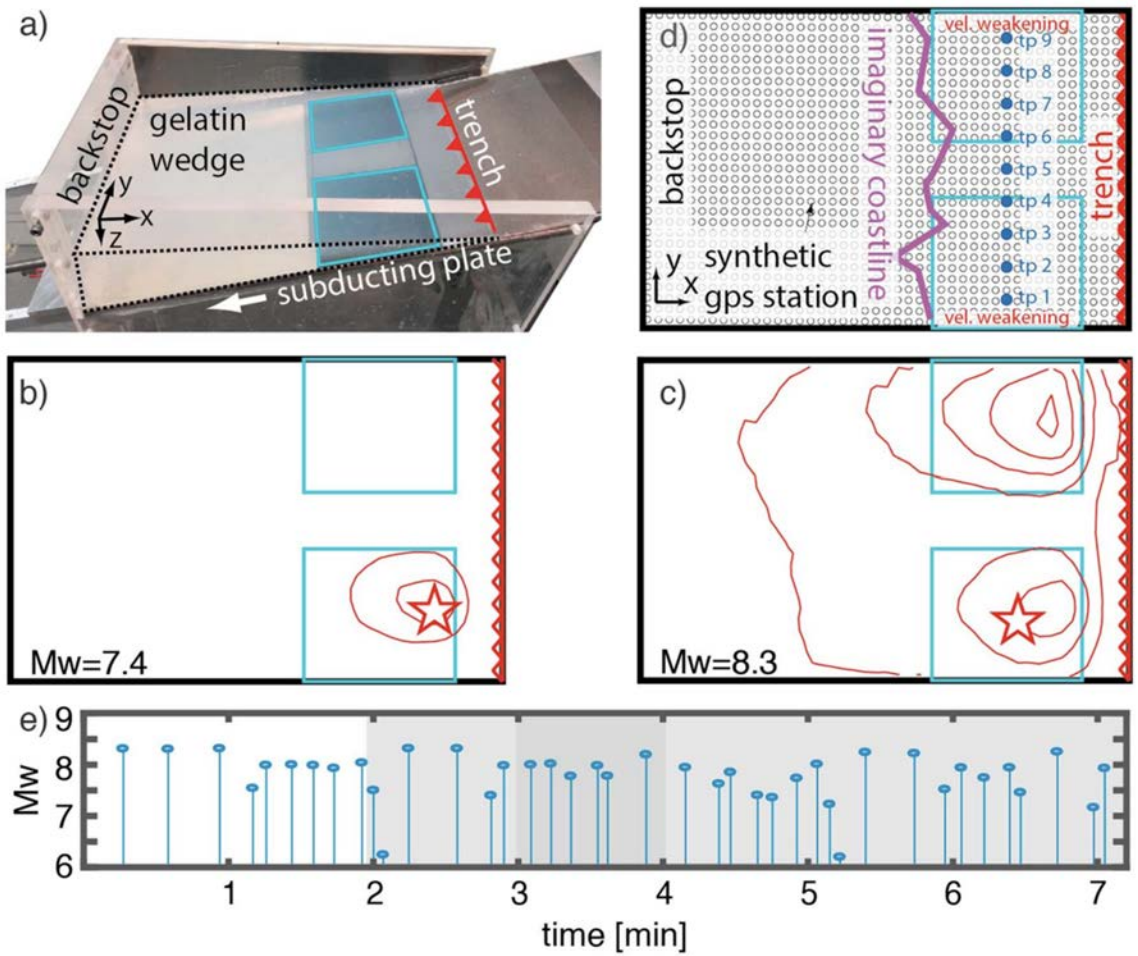


Site slip rate change:
A – 28%
B – 42%
C – 25%
D – 38%

Lab quakes

Velocity weakening analog materials can be used to simulate earthquakes.

Plexiglas (e.g. *Rubino et al., 2015; Rosakis et al., 2020*); Foam *(e.g., Brune, 1973; Caniven et al., 2015; Rosenau et al, 2017)*; Rubber pellets *(e.g., Rosenau & Oncken 2009; Rosenau et al., 2017)*; Gelatin *(e.g., Corbi et al., 2013; Corbi et al., 2019)*



Corbi et al., 2019

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The seismic cycle at subduction thrusts: 2. Dynamic implications of geodynamic simulations validated with laboratory models

Y. van Dinther, T. V. Gerya, L. A. Dalguer, F. Corbi, F. Funiciello, P. M. Mai

First published: 25 April 2013 | https://doi.org/10.1029/2012JB009479 | Citations: 70

This article is a companion to *Corbi et al.* [2013] doi:10.1029/2012JB009481.

Conclusions

Structural complexity changes

Strain partitioning changes

Slip rates change

Constraining recent evolution of faulting could inform the reliability of past slip rates to represent future behavior

Greater structural complexity can produce greater slip rate variations