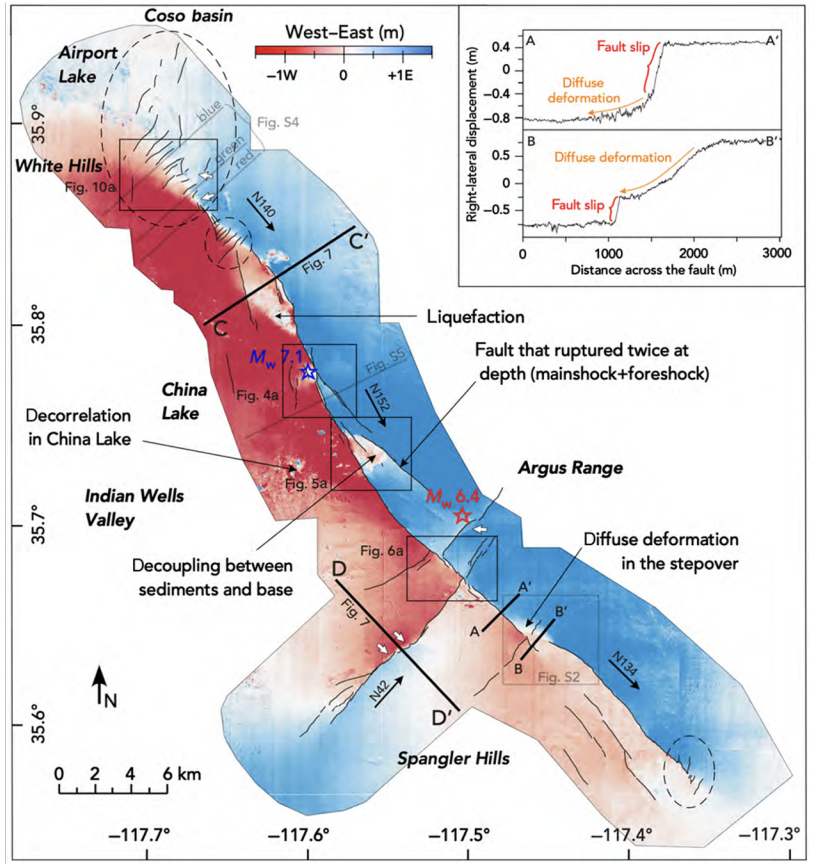
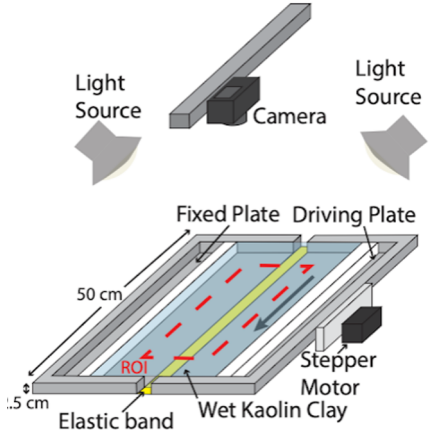
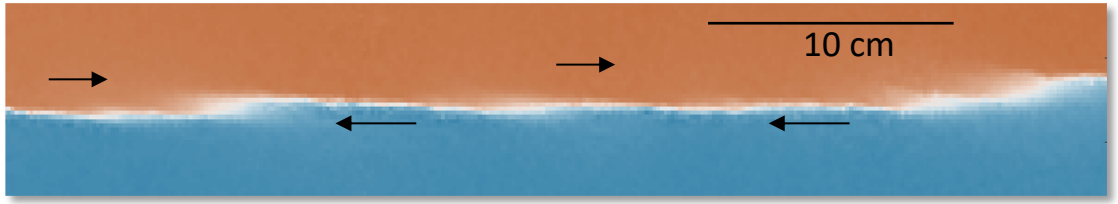
Prediction of Off-Fault Deformation from Strike-slip Fault Structures in clay and sand experiments using Convolutional Neural Networks

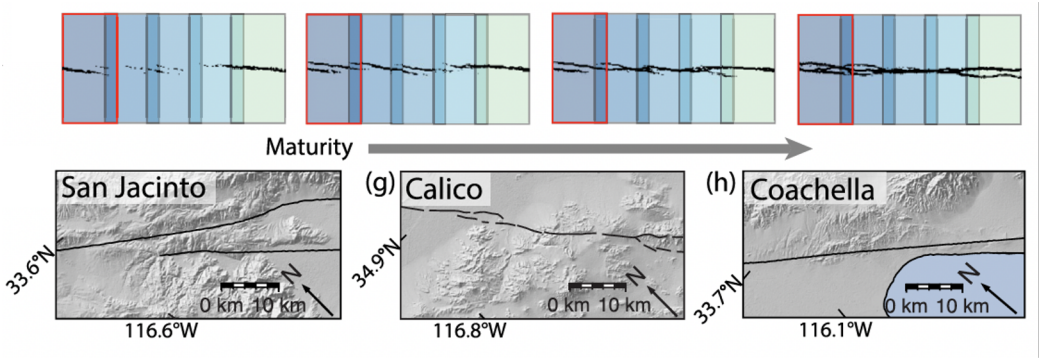
M. Cooke, H. Elston, L. Chaipornkaew , S. Visage,
P Souloumiac and T. Mukerji





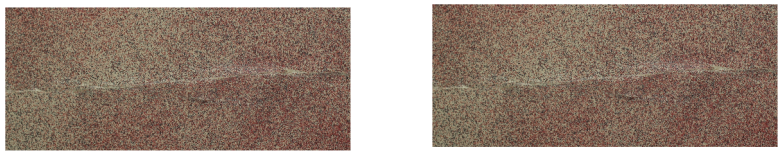


Optical differencing reveals off fault deformation from the 2019 Ridgecrest earthquake sequence. From *Antoine et al* (2021)

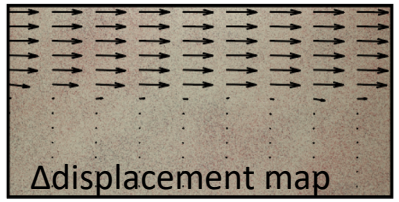


Measuring and predicting kinematic efficiency

$$\textit{Kinematic Efficiency} = \frac{\text{rate of fault slip}}{\text{applied velocity}}$$



Digital Image Correlation



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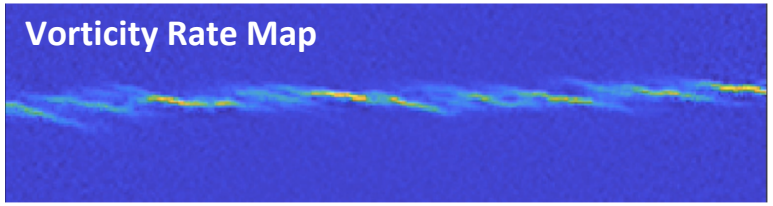
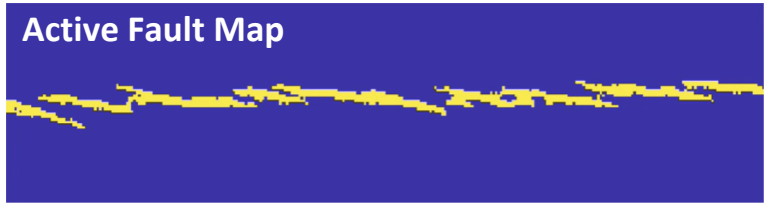
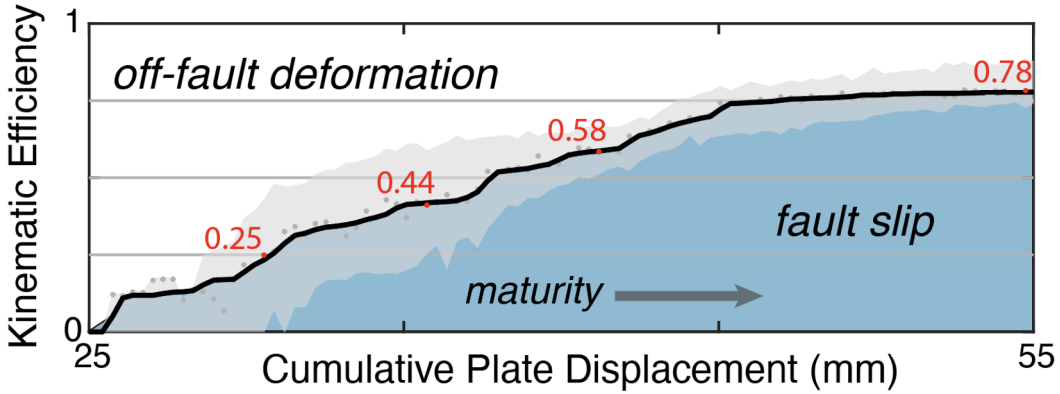
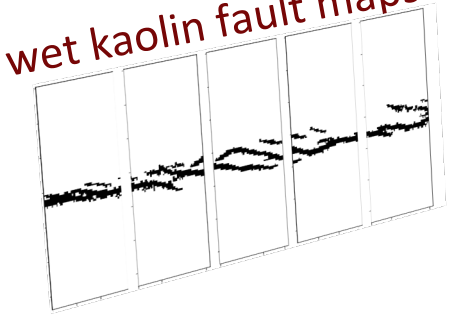


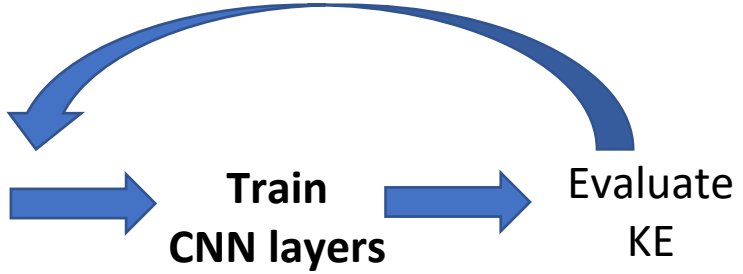
Adaptive Threshold



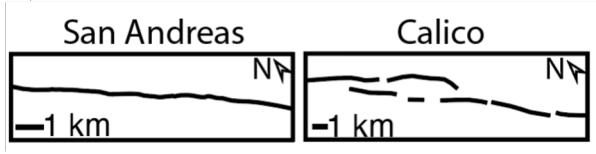


wet kaolin fault maps





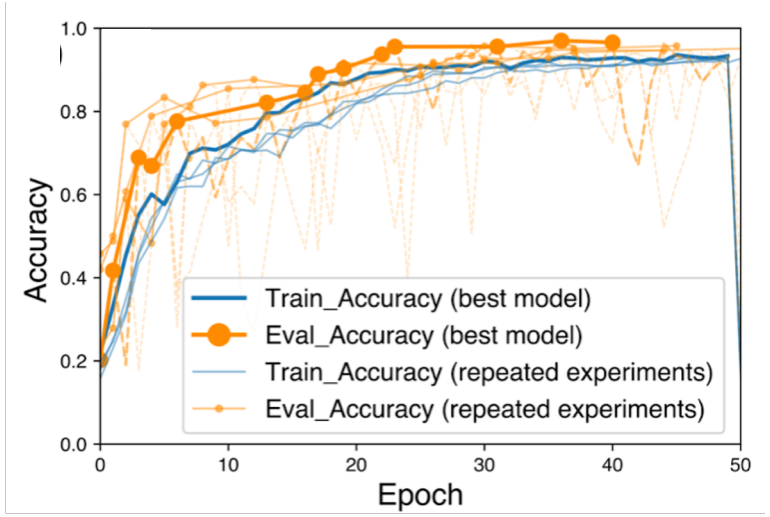
Sand fault maps from CYU

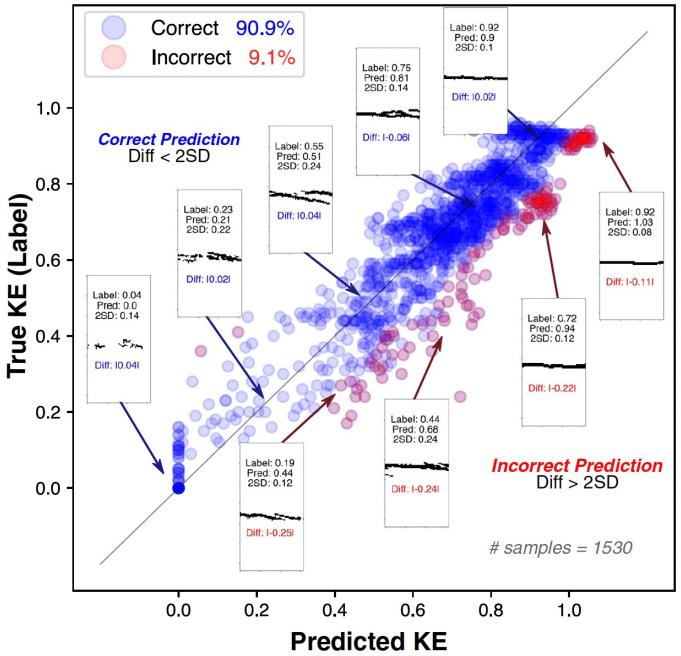


sand & crustal fault maps → CNN → Predict KE

Training and testing on clay

Training and evaluation for best model with maximum accuracy but also before over-fitting



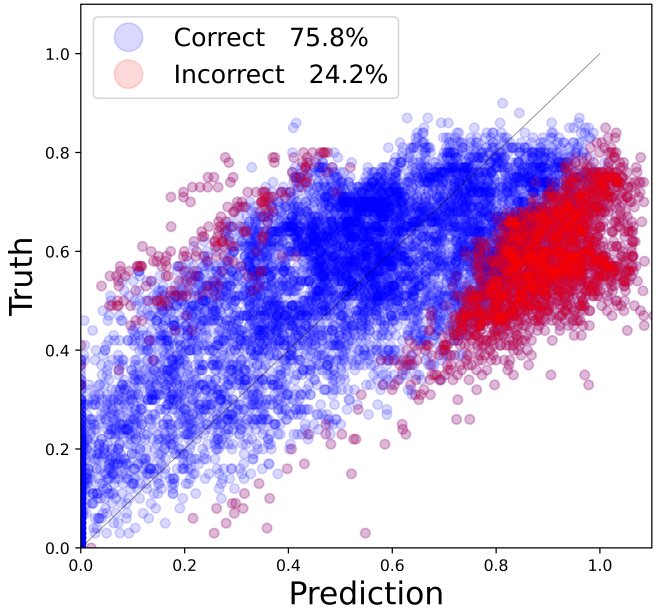


The CNN tested on unseen data predict kinematic efficiency

From Chaipornkaew et al., 2002, GRL

Testing sand with clay-trained CNN

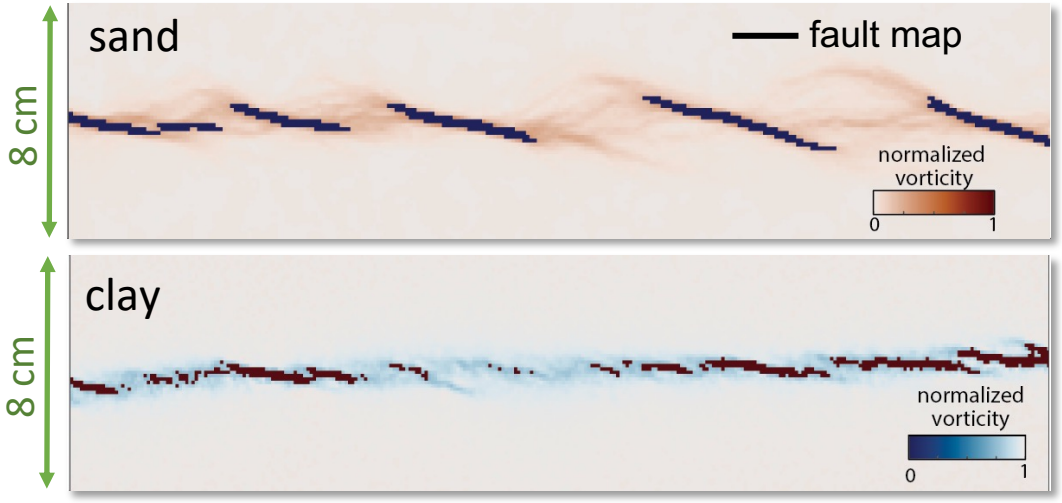
CNN trained on clay predicts kinematic efficiency from sand fault maps



Even with the larger standard deviation of KE in the sand experiments, the clay-trained CNN has large error in predicting sand KE.

For mature faults (KE>0.5) the clay-trained CNN systematically overpredicts KE.

Immature faults

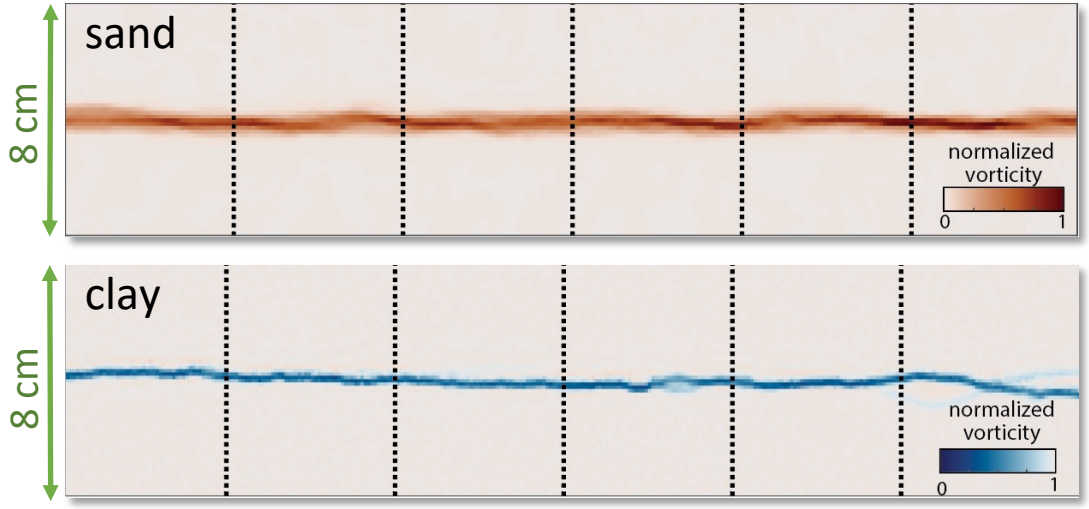


Average KE = 0.24

Average KE = 0.25

Immature faults have the same KE and similar echelon fault maps

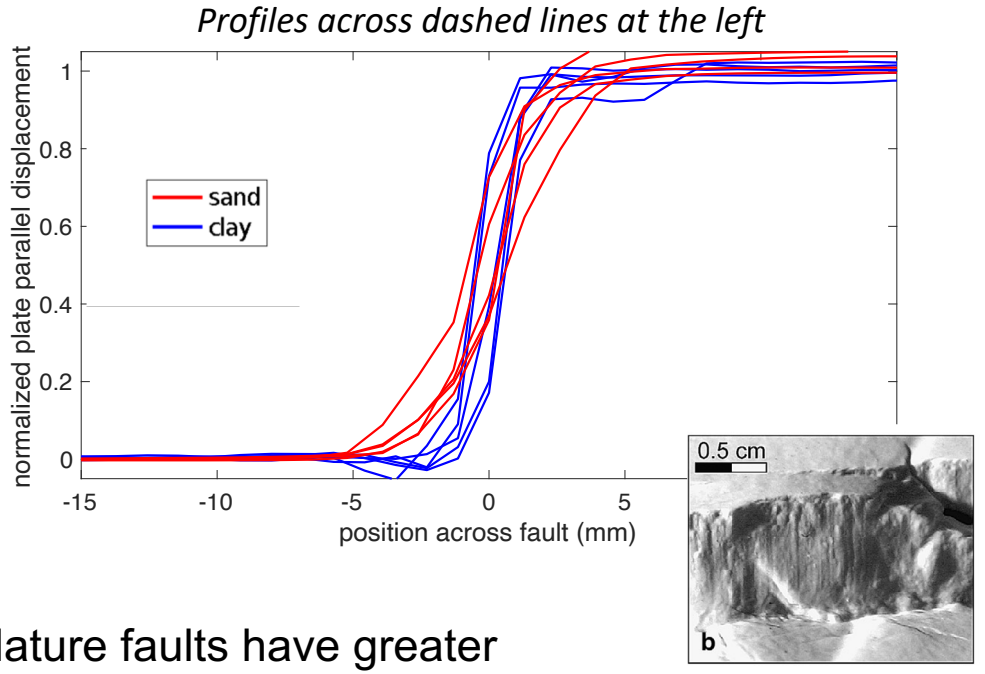
Mature faults



Average KE = 0.57

Average KE = 0.97

Mature faults have different KE but similar fault-map

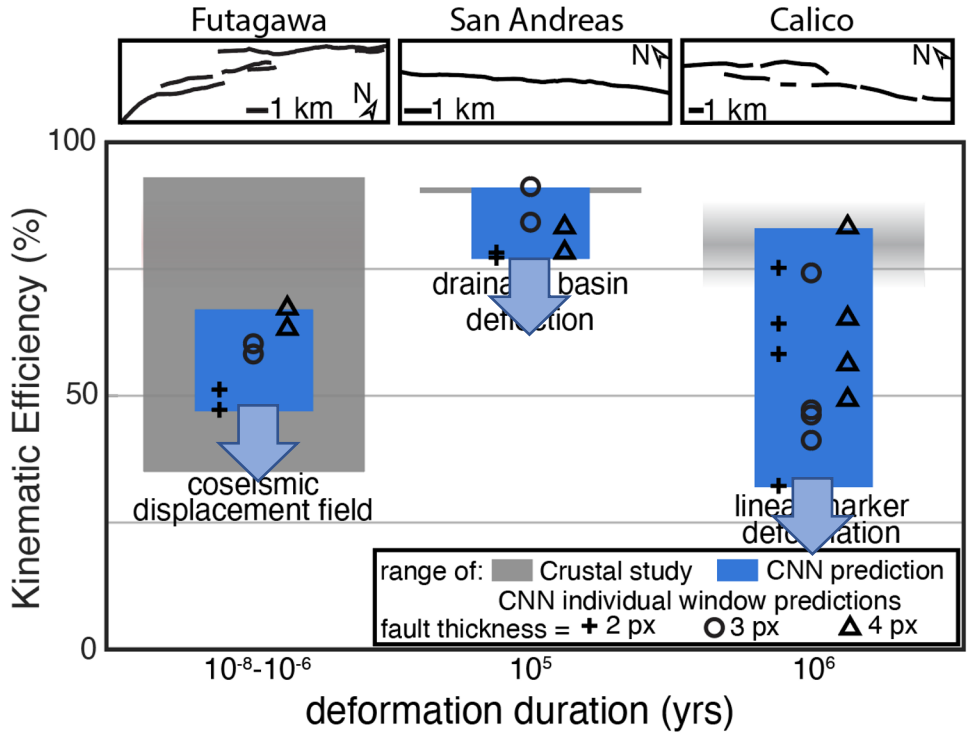


Henza et al. (2010)

Mature faults have greater localized slip in clay than sand. Potential role of fault thickness

Application to crustal faults

Clay-trained CNN predicts KE of crustal faults consistent with available measurements.



Because sand experiments produce greater off-fault deformation, we expect that a sand-trained CNN will predict lower KE.

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Predicting Off-Fault Deformation From Experimental Strike-Slip Fault Images Using Convolutional Neural Networks

Key Points:

- Proposed convolutional neural networks can predict off-fault deformation directly from binary fault maps
- Analog models provide abundant and

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- *Futagawa fault: Scott et al., 2019*
- *San Andreas fault: Gray et al. 2018*
- *Calico fault: Shelef & Oskin, 2010*

Harnessing analog models and machine learning allows us to provide estimates for parameters that are difficult to measure in the crust.

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