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What's the damage? Multiscale analyses of attributes in fault damage zones – fracture length distributions, orientation scale transitions and network connectivity

Roberto Emanuele Rizzo[1], David Healy[1], Natalie Jane Farrell[1], Giles Ostermeijer[2], Telemaco Tesei[3], John D Bedford[4], Michael John Heap[5] and Thomas M Mitchell[2],
(1)University of Aberdeen, Aberdeen, United Kingdom, (2)University College London, Department of Earth Sciences, London, United Kingdom, (3)University of Durham, Durham, United Kingdom, (4)University of Liverpool, Earth, Ocean and Ecological Sciences, Liverpool, United Kingdom, (5)Université de Strasbourg/EOST, Strasbourg, France, Strasbourg, France,

Our current understanding of the laws describing the statistical distributions of fracture properties has been dominated by interpretations of power-law scaling, and possibly fractal behaviour, from observations in bedded sedimentary rocks with tensile joints (e.g. Gillespie et al., 1993; Odling 1997). Yet shear fractures and fault zones are important for fluid flow and storage (Caine et al., 1996; Faulkner et al., 2010), and their damage zones host critical changes in elastic properties with consequences for slip on 'weak' faults, rupture propagation and seismic velocities.
We present progress we have made in understanding the scaling of fractures in fault damage zones by extracting information from large digital datasets. From rock deformation experiments on sandstone, we have already shown that there is a critical length scale, a function of the grain size and the effective pressure, at which fracture orientations in and around the nascent fault change significantly (Rizzo et al., 2017b, 2018). This correlates to the change from small scale intragranular tensile cracking to larger scale coalescence into shear fractures. We now extend this work to include studies on crystalline granite and dolostone, at different scales.
We use Maximum Likelihood Estimators to robustly evaluate the statistical distribution of fracture lengths (Rizzo et al., 2017a) and asses hierarchical behaviour within the network. We use anisotropic wavelets to find length scales at which fracture orientations undergo significant changes (or scale transitions; Rizzo et al., 2017b, 2018). We analyse the changes in connectivity (X-, Y- and I-node types) with scale and distance from the fault plane. We present results from 2D fracture maps from damage zones at scales ranging from micrometres (thin section image mosaics of laboratory deformed samples) to decametres (photo-mosaics from outcrops of fault zones). All analyses were performed with open source code FracPaQ (Healy et al., 2017).