Riding the Right Wavelet: Detecting Fracture and Fault Orientation Scale Transitions Using Morlet Wavelets

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Riding the Right Wavelet: Detecting Fracture and Fault Orientation Scale Transitions Using Morlet Wavelets

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The analysis of images through two-dimensional (2D) continuous wavelet transforms makes it possible to acquire local information at different scales of resolution. This characteristic allows us to use wavelet analysis to quantify anisotropic random fields such as networks of fractures. Previous studies [1] have used 2D anisotropic Mexican hat wavelets to analyse the organisation of fracture networks from cm- to km-scales. However, Antoine et al. [2] explained that this technique can have a relatively poor directional selectivity. This suggests the use of a wavelet whose transform is more sensitive to directions of linear features, i.e. 2D Morlet wavelets [3]. In this work, we use a fully-anisotropic Morlet wavelet as implemented by Neupauer & Powell [4], which is anisotropic in its real and imaginary parts and also in its magnitude. We demonstrate the validity of this analytical technique by application to both synthetic - generated according to known distributions of orientations and lengths - and experimentally produced fracture networks. We have analysed SEM Back Scattered Electron images of thin sections of Hopeman Sandstone (Scotland, UK) deformed under triaxial conditions. We find that the Morlet wavelet, compared to the Mexican hat, is more precise in detecting dominant orientations in fracture scale transition at every scale from intra-grain fractures (μm-scale) up to the faults cutting the whole thin section (cm-scale). Through this analysis we can determine the relationship between the initial orientation of tensile microcracks and the final geometry of the through-going shear fault, with total areal coverage of the analysed image. By comparing thin sections from experiments at different confining pressures, we can quantitatively explore the relationship between the observed geometry and the inferred mechanical processes.

[1] Ouillon et al., Nonlinear Processes in Geophysics (1995) 2:158 - 177. [2] Antoine et al., Cambridge University Press (2008) 192-194. [3] Antoine et al., Signal Processing (1993) 31:241 - 272. [4] Neupauer & Powell, Computer & Geosciences (2005) 31:456 - 471.

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FracPaQ: a MATLAB™ Toolbox for the Quantification of Fracture Patterns

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The patterns of fractures in deformed rocks are rarely uniform or random. Fracture orientations, sizes, shapes and spatial distributions often exhibit some kind of order. In detail, there may be relationships among the different fracture attributes e.g. small fractures dominated by one orientation, larger fractures by another. These relationships are important because the mechanical (e.g. strength, anisotropy) and transport (e.g. fluids, heat) properties of rock depend on these fracture patterns and fracture attributes. This presentation describes an open source toolbox to quantify fracture patterns, including distributions in fracture attributes and their spatial variation. Software has been developed to quantify fracture patterns from 2-D digital images, such as thin section micrographs, geological maps, outcrop or aerial photographs or satellite images. The toolbox comprises a suite of MATLAB™ scripts based on published quantitative methods for the analysis of fracture attributes: orientations, lengths, intensity, density and connectivity. An estimate of permeability in 2-D is made using a parallel plate model. The software provides an objective and consistent methodology for quantifying fracture patterns and their variations in 2-D across a wide range of length scales. Our current focus for the application of the software is on quantifying the fracture patterns in and around fault zones. There is a large body of published work on the quantification of relatively simple joint patterns, but fault zones present a bigger, and arguably more important, challenge. The method presented is inherently scale independent, and a key task will be to analyse and integrate quantitative fracture pattern data from micro- to macro-scales. Planned future releases will incorporate multi-scale analyses based on a wavelet method to look for scale transitions and combining fracture traces from multiple 2-D images to derive the statistically equivalent 3-D fracture pattern.