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Benefits of maximum likelihood estimators for fracture attribute analysis: Implications for permeability and up-scaling

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The success of any predictive model is largely dependent on the accuracy with which its parameters are known. When characterising fracture networks in rocks, one of the main issues is accurately scaling the parameters governing the distribution of fracture attributes. Optimal characterisation and analysis of fracture lengths and apertures are fundamental to estimate bulk permeability and therefore fluid flow, especially for rocks with low primary porosity where most of the flow takes place within fractures.

The main objective of this work is to demonstrate a more accurate statistical approach to increase utility, meaningfulness, and reliability of data from fractured outcrop analogues. We collected outcrop data from a fractured upper Miocene biosiliceous mudstone formation (California, USA), which exhibits seepage of bitumen-rich fluids through the fractures. The dataset was analysed using Maximum Likelihood Estimators to extract the underlying scaling parameters, and we found a log-normal distribution to be the best representative statistic for both fracture lengths and apertures in the study area. This result can be related to a characteristic length scale, probably the bedding within the sedimentary succession.

Finding the best statistical distribution governing a dataset is of critical importance when predicting the tendency of fracture attributes towards small and large scales. The application of Maximum Likelihood Estimators allowed us firstly to individuate the best statistical distribution for fracture attributes measured on outcrop (specifically, length and aperture); secondly, we
used the calculated scaling parameter to generate synthetic fracture networks, which by design are more likely to resemble
the distribution and spatial organisation observed on outcrop. Finally, we employed the derived distributions for a 2D estimation of the bulk permeability tensor, yielding consistent values of anisotropic permeability for highly fractured rock masses, such as the
studied areas.