Fault density scaling: analysis of power-law systems in two dimensions

T. Manzocchi, J.J. Walsh and W.R. Bailey[1]
Fault Analysis Group, Department of Geology, University College Dublin, Ireland
[1]Present Address: CSIRO Petroleum, Perth, WA6151, Australia
Email: fault@fag.ucd.ie

Bailey et al. (2001) analysed fault populations, strain and fault density in sub-areas of a large ($1000km^2$), high resolution (ca. 2 orders of magnitude throw) fault map from East Pennine Coalfield (UK). They found that population slopes of fault size (maximum throw, trace length and geometric moment) are lower in smaller sample-areas, an observation that cannot be reconciled quantitatively with the current understanding of fault populations. Their scale-specific measurements of strain and other fault density terms indicate that large variability at particular scales is the norm, however existing analytical methods allow prediction only of scale-specific density averages.

We present graphically a novel analytical treatment which derives scale-specific fault length, maximum throw and geometric moment probability density functions (*pdfs*) based on the assumption of a power-law population of uniformly-distributed faults in a larger, "parent" area. Our treatment uses a more statistical approach than has previously been applied to quantitative fault population analyses, by including explicitly the probabilities of sampling faults censored to particular sizes. Although strictly non-power-law, these *pdfs* approximate power-laws, and match the scale-specific average population slopes observed in the East Pennine Coalfield fault system. Since we have determined the full *pdfs* of fault size, the Central Limit Theorem can be used to estimate scale-specific distributions of strain and other measures of fault density. As with the fault population slopes, we find that our analytical determinations of the distributions of fault density match closely the distributions measured in the Coalfield fault system.

These new results allow for the first time an estimation of the distribution of fault or fracture density expected at a particular scale, and are therefore relevant to many practical applications since they provide a more realistic basis than exists at present for fault density prediction in risking or modelling studies. Examples include groundwater aquifer or hydrocarbon reservoir characterisation, in which potentially fracture-controlled porosity and permeability fields are modelled in flow simulators with specific cell sizes; major civil engineering projects, in which the presence of an anomalously high fracture density may jeopardise the site integrity; or fracture-hosted mineral exploration, in which a correct estimation of the average and variation in tonnage per volume of rock is an important economic concern.

Bailey, W.R., Manzocchi, T., and Walsh, J.J. The size and spatial characteristics of faults in the East Pennines Coalfield. TSG Meeting, 2001.