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Do fault-related folds follow the same scaling law as their associated faults? A study using 3D seismic reflection data

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Fractal distributions are largely agreed to follow a power-law distribution. Power-law scaling relationships describe the size distribution of fault lengths or displacements. Being able to identify these scaling properties provides a powerful tool for predicting the numbers of geological structures, such as small-scale faults in sedimentary basins that are below the resolution of seismic reflection data. The aim of this study is to determine whether fault-related folds follow the same power law scaling properties, or if they follow a different scaling law.

We use TrapTester to interpret a 3D seismic volume from the Gulf of Mexico to construct fault planes and cut-off lines along selected horizons in the vicinity of fault upper tip lines. Fault-related folds are particularly well developed above steeply plunging tip lines, but are discontinuous along the strike of the fault plane. Folding is less well developed on horizons that intersect, or lie close to, the locus of maximum throw (bullseye) of the fault plane. We then measured fold amplitudes and fault throws across these same horizons using a one-dimensional multi-line sampling approach. Graphs of fault throw and fold amplitude vs. distance parallel to fault strike show that folds occur where there is no resolvable fault throw, and that fault throw and fold amplitudes show an approximately inverse relationship. Close to the locus of maximum throw, there is largely just faulting, whilst at the upper tip line folding predominates.

By plotting cumulative frequency against throw for the fault and fold data we can investigate whether the data follow a power law, log normal or exponential distribution. Plotting the data on log vs. log (power law), linear vs. log (log normal) and log vs. linear (exponential) axes allow us to establish which displays the best "straight-line fit". We observed that the fault throw data satisfied a straight-line on a log vs. log graph – implying a power law distribution – and also returned an exponent within the accepted range of 0.4-1.0. The fold amplitude data displays the best "straight-line fit" on log vs. linear axes, consistent with an exponential distribution; however a reasonable "straight-line fit" was achieved for log vs. log axes, returning an exponent just outside the upper range that is accepted for fault distribution. We plan to test these initial conclusions using the Kolomogorov-Smirnov test, but our preliminary results show that 3D seismic data provide a useful tool to investigate the scaling and kinematics of fault-related folding.