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The three-dimensional geometries of segmented normal faults

John Walsh^{1,2}, **Vincent Roche**^{1,2}, Giovanni Camanni³, Conrad Childs^{1,2}, Tom Manzcchi^{1,2}, John Conneally^{1,2}, Muhammad Mudasar Saqab⁴, and Efstratios Delogkos^{1,2}

¹Fault Analysis Group, UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland

²Irish Centre for Research in Applied Geosciences, UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland

³DiSTAR, Università degli Studi di Napoli "Federico II", Naples, Italy

⁴Norwegian Geotechnical Institute, 40 St Georges Terrace, Perth WA 6000 Australia

Normal faults are often complex three dimensional structures comprising multiple sub-parallel segments separated by intervening relay zones. In this study we outline geometrical characterisations capturing this 3D complexity and providing a semi-quantitative basis for the comparison of faults and for defining the factors controlling their geometrical evolution.

Individual relay zones can be assigned to one of four types according to their form (i.e. whether the bounding segments are unconnected in 3D or merge into a single surface) and their orientation (i.e. whether they are slip-parallel or slip-perpendicular). From the detailed analysis of 84 fault arrays mapped from 3D seismic reflection surveys (including 63 from our mapping of 8 different study areas and 21 derived from the literature), we show that the 3D geometry of fault arrays can be quantitatively defined on the basis of the relative numbers of these types of relay zones.

Detailed mapping of fault zones indicates that whilst they can individually contain all four types of relay zone, their relative proportions varies between different study areas. Differences in the proportions of relay zone types are attributed to two primary controls, the mechanical heterogeneity of the faulted sequence and the presence of basement structure. For example, relay zones with an upward bifurcating geometry are prevalent in faults that reactivate deeper structures, whereas the formation of laterally bifurcating relays is promoted by heterogeneous mechanical stratigraphy.

Fault arrays in the literature generally do not contain the full range of possible relay zone type but tend to comprise either all bifurcating relay zones or all unconnected relay zones. These end-member fault geometries have led to contrasting conceptual models for the growth of faults. The mapping conducted here suggests that the proportion of bifurcating relay zones increases as data resolution increases and that fault surface bifurcation is ubiquitous. Models for the geometrical evolution of fault arrays must account for the full range of relay zone geometries that appears to be a characteristic of all faults.