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Geometrical characterisation of fault arrays in three dimensions

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Normal faults are often complex three-dimensional structures comprising multiple sub-parallel segments separated by intact or breached 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. Relay zones are classified according to whether they step in the strike or dip direction and whether the relay zone-bounding fault segments are unconnected in 3D or bifurcate from a single surface. Complex fault surface geometry is then described in terms of the relative numbers of different types of relay zones to allow comparison of fault geometry between different faults and different geological settings. A large database of 87 fault arrays compiled primarily from mapping 3D seismic reflection surveys and classified according to this scheme, reveals the diversity of 3D fault geometry. Analysis demonstrates that mapped fault geometries depend on geological controls, primarily the heterogeneity of the faulted sequence and the presence of a pre-existing 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. In addition, mapped segmentation depends on resolution limits and biases in fault mapping from seismic data. In particular, the results suggest that the proportion of bifurcating relay zones increases as data resolution increases. Overall, where a significant number of relay zones are mapped on a single fault, a wide variety of relay zone geometries occurs, demonstrating that individual faults can comprise segments that are both bifurcating and unconnected in three dimensions. Models for the geometrical evolution of fault arrays must therefore account for the full range of relay zone geometries that appears to be a characteristic of all faults.