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Three-dimensional geometries of relay zones in normal faults

Giovanni Camanni[1,2], Vincent Roche[2,3], Conrad Childs[2,3], Tom Manzocchi[2,3], John Walsh[2,3], John Conneally[2,3], Muhammad Mudasar Saqab[4], and Efstratios Delogkos[2,3]
[1]Università degli Studi di Napoli Federico II, Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Italy (giovanni.camanni@unina.it)
[2]Fault Analysis Group, UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland
[3]Irish Centre for Research in Applied Geosciences (iCRAG), UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland
[4]Norwegian Geotechnical Institute, 40 St Georges Terrace, Perth, WA 6000, Australia

Individual normal faults are rarely single planar surfaces and often comprise arrays of fault segments arising from the earliest stages of fault propagation. Current models for the geometry and formation of relay zones between adjacent fault segments have been informed mainly by 2D analysis from either maps or cross-sections observed in outcrop and, to a lesser extent, by the analysis of relay zones from 3D seismic reflection data. Using high quality 3D seismic reflection datasets from a selection of sedimentary basins, we investigate fundamental characteristics of segmentation from the analysis of 67 normal faults with modest displacements (< ca. 190 m) which preserve the 3D geometry of 532 relay zones. Our analysis shows that relay zones most often develop by bifurcation from a single fault surface but can also arise from the formation of segments which are disconnected in 3D. Relay zones generally occur between fault segments that step in either the dip or strike direction, and oblique relay zones with an intermediate orientation are less frequent. This is attributed to the influence of mechanical stratigraphy, and to a tendency for faults to locally propagate laterally and vertically rather than obliquely. Cross-sectional stepping of relay zones typically forms contractional rather than extensional relay zones, a configuration which is attributed to the development of early stage Riedel shears associated with fault localisation. Comparing datasets from different geological settings suggests that the mechanical heterogeneity of the faulted sequence and the influence of pre-existing structure are the underlying controls on the geometrical characteristics of relay zones in normal faults, and different combinations of these two controls can account for the variation in fault zone structure observed between datasets.