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Geometry and evolution of natural transtensional folded reservoir and associated fractures

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The development of folds in zones of wrench-dominated transtension, where the direction of divergence lies at $<30^\circ$ to the deformation zone boundaries, is predicted by both theoretical and analogue modelling studies. There are very few detailed accounts of such folds in upper crustal settings. Here we document in detail onshore (Northumberland Basin, UK) and offshore (North Sumatra Basin) examples of transtensional folds and associated fracture networks developed in rift basin settings. A highly heterogeneous, mesoscale structural pattern is developed with commonly markedly curvilinear and locally curviplanar folds compartmentalised by strike-slip and/or normal faults. In outcrop-scale examples, significant amounts of hinge-parallel extension have been accommodated by normal faulting, tensile veins and tension gash arrays. The fold-fracture associations here contrast strongly with the more widely recognised patterns of strike-slip conjugate shear planes and extension fractures associated with folds developed in compressional and wrench tectonic settings. In sub-surface examples analysed using 3D seismic reflection data, there is clear evidence that fold amplification occurred contemporaneously with ongoing sedimentation and the development of normal growth faults oriented at 90° to the fold hinge. The observation that minor structures associated with transtensional folds are significantly different compared to folds developed in other tectonic environments is an important diagnostic feature since, during regional basin analysis, such folds can be erroneously interpreted to result from phases of compressional inversion or a separate phase of wrench tectonics.

Our findings also have important applications in terms of modelling reservoirs rocks parameters in transtensional folds since features such as fracture orientation, size, 3-D geometry and structural permeability patterns will be significantly different for this group of folds compared to those formed in other tectonic environments. This has important implications for the prediction of fracture systems in folded reservoirs from kilometre to centimetre-scales.