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Spatial characterization of deformation in high porosity sandstones: from outcrop data to fluid flow circulation

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Understanding the evolution of fault zone geometrical and hydromechanical properties during fault growth and network development is of major importance in fluid flow prediction in the crust. In porous rocks, faulting produces zones of deformation bands rather than planar fracture surfaces. Cataclastic deformation bands (CDBs) are mm-cm thick brittle shear zones that form through the combined effects of compaction and cataclasis.

Plans for CO₂ storage in porous sandstones must consider the role of deformation band-dominated faults in trapping or retarding the flow of CO₂. Most commonly CDBs show a reduction of porosity, associated with a reduction of permeability. This permeability decrease is largest for the most evolved and thick zones of CDBs. Conversely, slip planes can potentially have a higher permeability than the host rock. Therefore CDBs in sandstone reservoirs can potentially retard fluid flow circulation and act as barriers to fluids, whereas slip planes could be conduits for flow. Previous studies have examined the effect of connected deformation band systems on flow, but have not considered the effect of “open” slip planes. To predict the effect of such structures on fluid flow we must consider the 3D connectivity of the relatively low permeability CDBs and any high permeability slip planes. To characterise this connectivity we have chosen to undertake detailed mapping of structures affecting deformed sandstones in the United Kingdom (Isle of Arran), France (Provence) and USA (Utah).

Detailed maps allow us to identify potential fluid flow pathways through the mapped network, and to derive statistics to describe the density, tortuosity and connectivity of such pathways. For instance, the thickness of the low permeability CDBs is an important variable for retardation of flow, but this flow barrier may be compromised by a large number of through-going or cross-cutting high permeability slip surfaces. The field data collected by this method were used to derive variograms of key fault zone components (e.g. fault zone thickness, CDB width, number of cross-cutting slip surfaces) to characterise their variation along strike. These variograms can be used to generate numerical realisations of faults at depth with robust statistically-based fault zone properties that vary along strike. The choice of different lithologies, different tectonic events and different burial depths will allow this research to better constrain the relationship between the fault statistics we derive from a variety of field exposures and the properties of faults at depth.