Flow Properties in Sandstones with laboratory induced deformation bands

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Compaction and shear bands are modes of localised deformation that develop during bulk strain accumulation in rocks. In outcrops of porous sandstones, both deformation bands are nearly-planar zones with a thickness of 3 to 6 grain size; however, they usually develop multiple, over-printing strands to create cm-scale or thicker zones. Grain-scale mechanisms in such bands indicate local porosity reduction by grain crushing and movement of the resulting fragments into pores, along with grain movements allowing re-arrangement in tighter packing states. Therefore, such deformation features may act as fluid/gas flow baffles.

Triaxial compression experiments on dry porous sandstone samples [1,2,3], coupled with a range of non-destructive experimental techniques, such as X-ray Computed Tomography, 3D Digital Image Correlation, Acoustic Emission location and micro-crack typing/characterisation (before, during and after the lab-induced deformation), shed light into the occurred micro-processes that took place during strain localisation at the laboratory scale. Shear and compaction bands have been characterised as higher density zones, which include self-organised regions of dilation and compaction, plus shear. Grain crushing and pore collapse has been documented in both cases together with shearing due to the movement of the grain fragment.

Various research teams have undertaken conventional laboratory experiments together with syn-deformation fluid-flow measurements (non-local measurements), which lead to a conclusion that the textural changes inside such deformation bands cause orders-of-magnitude reductions of the permeability compared to that of the host-rock material. Herein, we employ digital-rock methods in 3D to derive local estimates of the flow-property effects of the lab-induced localised deformation features and of the surrounding host-rock. High-resolution X-ray images mapping the region of both the laboratory induced deformation band and the host-rock, together with local higher-resolution SEM images of sub-regions, enable the creation of mm-scale 3D models of deformed-rock sandstone. These models are used to calculate single- and multi-phase flow properties of the identified sub-regions of the bands that relate to local variations in strain states and Acoustic Emission locations. The permeability of such bands is, indeed, reduced by approximately 10^{-4} compared to the permeability of the host-rock material, confirming the received wisdom. The digital-rock method also allows an estimation of multi-phase flow properties, which are less easy to estimate via experiments. Here, we illustrate the value of the digital-rocks methods by predicting multi-phase flow in sample-sized regions that contain different and/or multiple bands.

Literature References

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