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# Fluid-driven fracture propagation in a layered and fractured elastic medium

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Naturally-fractured carbonate reservoirs make up a large proportion (>60%) of the global hydrocarbon resources. During hydraulic fracturing, the mechanical behaviour of rocks and their heterogeneities, such as layering, faults and joints, impact permeability and are controlling factors which dictate the ease or difficulty of fluid flow in a system. This permeability reaches the percolation threshold when the fractures are linked and form a network. Such a network could, in turn, improve hydrocarbon recovery factor and make a project more economical.

We present results from a series of analogue experiments that investigate the impact of heterogeneity in rock bodies on fluid-driven fracture propagation. Here we employ gelatine solids of varying elastic properties which are scaled as an analogue for layered rocks. Gelatine mixtures of concentration 2.5 and 3 wt.% were prepared and then poured sequentially into a clear-Perspex tank to create a layered elastic medium. Each layer was cooled to 5 – 10˚C before the next was emplaced. With two-layered solids, the upper layer was either higher, lower, or of equal stiffness to the lower layer. Pre-existing (natural) fractures were introduced into the gelatine solid using a heated knife. During the experiments, air was injected into the gelatine at a constant rate to create a buoyant hydrofracture. Cooled gelatine is transparent and viscoelastic so that the stress evolution could be visualised using polarizing plates. Quantitative measurements of fracture geometry and growth rate were extracted from the recordings (in three orientations) to understand fracture behaviour at and nearby the layered interface and natural fractures.

Preliminary results show that fracture properties, such as fracture toughness of the interface, control the horizontal deflection, with contraction in the initial vertical section whilst the deflected fracture propagates along the interface. More so, the initial fracture in the bottom layer continues to take in fluid from the source to support the horizontal fracture propagation and, subsequently links up or bypasses a natural vertical fracture in the top layer. However, in most cases, the vertical fractures act as a temporary barrier to horizontal propagation, thereby creating a complex stress regime at the tip of the fracture and around the natural fracture. The result also shows that as the initial vertical fracture approaches a horizontal interface, there is a clear change in the stress front. As the propagating fluid hits the interface, the minimum principal compressive stress ($\sigma_3$) rotates by $\sim$90°. When the propagating tip encounters a vertical fracture in the top layer, in most cases, the local stress field becomes more complex. The stress magnitude decreases close to the boundary because the interface absorbs some of the stresses at the front of the propagating fluid-driven fracture.

At a constant injection rate, our results show that natural fractures do not necessarily enhance vertical fluid flow. In some cases, they inhibit horizontal flow where the surface area of the propagating fracture tip is not favourable. The results are likely to improve our understanding of flow behaviour from tight reservoirs and aid secondary recovery processes such as waterflooding projects in fractured reservoirs.