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SIMULATING LEAK-OFF IN SHALE HYDRAULIC FRACTURING USING DUAL- AND TRIPLE- PORO-THERMO-ELASTIC ANISOTROPIC SOLUTIONS

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Imaging studies of unconventional shale reservoir rocks have revealed the multi-porosity multi-permeability nature of these intricate formations. In particular, the porosity spectrum of shale reservoir rocks often comprises of the nano-porosity in the organic matters, the inter-particle micro-porosity, and the macroscopic porosity of the natural fracture network. Figure 1 illustrates the multi-porosity system in shale using FESEM images. Moreover, the natural fracture network might span multiple scales, as demonstrated in Figure 2, which further contributes to the multi-porosity multi-permeability nature of shale.

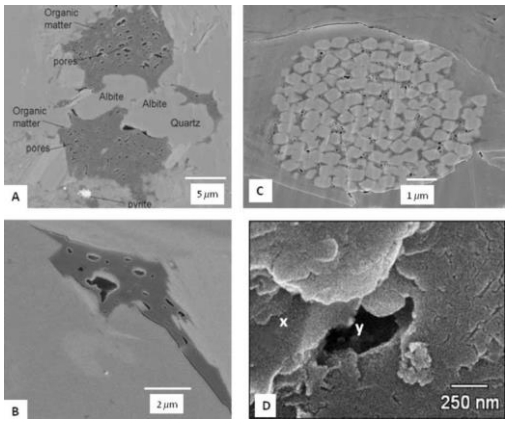

Figure 1. FESEM images [1] show multi-porosity multi-permeability nature of shale (A, B): Pores in organic matter, Longmaxi Shale; (C) The pyrite framboids with porous organic matter, Longmaxi Shale; (D) Pore between organic clad clay, Woodford Shale.

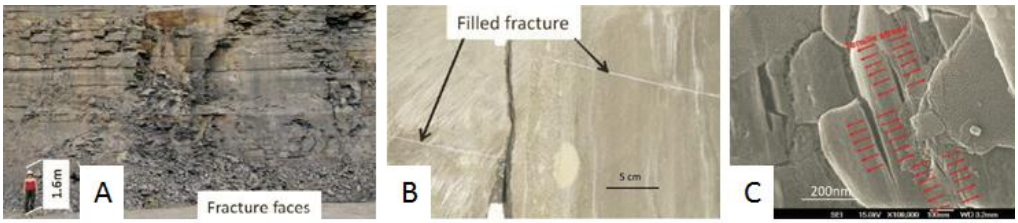

Figure 2. Multi-scale fractures in shale [2]
(A) Large, open fractures in a Woodford Shale quarry; (B) Calcite-filled fracture in the Barnett Shale; (C) Nano-scale, oriented fractures in a Woodford Shale sample.

Larger leak-off rate may occur during hydraulic fracturing in multi-porosity multi-permeability shale formations compared to expectations from only the most dominant porosity and permeability. Furthermore, the temperature difference between fracturing fluid and shale could also play an important role in hydraulic fracturing [3, 4]. The thermal diffusion will alter the formation pore pressure distribution and evolution, which in turn will influence the leak-off rate. Since accurate prediction of leak-off rate is essential for the simulation of hydraulic fracture width and length, simply using the traditional Carter's leak-off rate formula may produce erroneous stimulation results.

In this work, newly derived dual- and triple- poro-thermo-elastic one-dimensional simulations are used to study the leak-off rate during hydraulic fracturing of shale. Important factors including temperature difference between fracturing fluid and shale formation and natural fracture permeability and density are analyzed to investigate their influence on leak-off rate and therefore hydraulic fracture dimensions. The newly derived multi-porosity multi-permeability solutions are also compared to the single porosity counterpart to study the multi-porosity multi-permeability effects on leak-off and hydraulic fracturing.

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