AAPG Datapages/Search and Discovery Article #91206 © Rocky Mountain Section Meeting, Bismarck, North Dakota, June 4-6, 2023

Advancing our Understanding of Non-linear Flow Behavior in X-Crossing Fractures through 3D Printing Technology

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Abstract

Fractured reservoir systems play a critical role in the efficient management of hydrocarbon resources, CO_2 storage, and geothermal energy extraction. Understanding the behavior and characteristics of these systems is essential for optimizing recovery, reducing carbon footprint, and increasing efficiency. However, fractures within reservoir systems create complex geometries and can make fluid flow behavior complex and difficult to predict. Replicating these complex geometries in the laboratory has been challenging, but advancements in 3D printing technology have made it possible to create accurate models of rough-walled fracture geometries. In this study, the impact of geometric characteristics on fluid flow behavior in connected fractures was investigated using 3D-printed specimens with X-junction shapes, different roughness, intersection angles, and apertures. The experimental study was conducted using core flooding, and sensitivity analysis was performed on sixteen specimens to determine critical parameters affecting fluid flow behavior. Results showed that intersection angle had a significant impact on fluid flow behavior, with higher angles presenting more restriction than lower angles. Furthermore, the roughness and the aperture are affecting the fluid flow behavior dramatically, thus the increasing roughness and decreasing aperture create more restrictions to the fluid flow. The experiments suggest that fracture permeability estimation is greatly influenced by the angle at which fractures intersect. Fractures with low-angle intersections exhibit higher permeability than those with high-angle intersections. These findings provide valuable insights into the fluid flow behavior in complex fracture geometries and demonstrate the potential of 3D printing technology in paving the way for future research in such systems.