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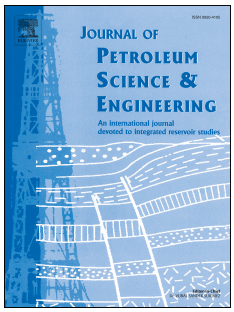

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Surface Characteristics and Permeability Enhancement of Shale Fractures due to Water and Supercritical Carbon Dioxide Fracturing

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Abstract

Carbon dioxide (CO_2) is an alternative working fluid to water for hydraulic fracturing in shale reservoirs. It offers advantages as a substitute for the use of large quantities of potable water and for the concurrent sequestration of CO_2, however sorption and swelling effects, and their impact on permeability may be detrimental and are undefined. Hence, it is of great importance to understand the mechanism of supercritical carbon dioxide fracturing in shale and its effect on shale permeability enhancement. We conduct hydraulic fracturing experiments on shale samples using both water (H_2O) and supercritical carbon dioxide (Sc-CO_2) as fracturing fluids to explore the surface characteristics and permeability evolution of fluid-driven fractures. We use profilometry to measure the roughness and complexity of the resulting fracture surfaces and measure the permeability of the fractures. Results indicate that: (1) Sc-CO_2 fracturing creates fractures with larger tortuosity relative to H_2O fracturing (macroscale); (2) the topography of Sc-CO_2 fracture surfaces is more rough and complex compared to that of H_2O fractured surfaces; (3) larger mineral grains are removed and relocated from induced fracture surfaces by Sc-CO_2 fracturing – these acting as micro proppants that result in a larger fracture aperture; (4) correspondingly, the permeability of shale fractures increases by ~5 orders of magnitude with Sc-CO_2 fracturing and this enhancement is ~3 orders of magnitude higher than that by traditional hydraulic fracturing. This observation potentially validates the feasibility of Sc-CO_2 as a fracturing fluid for the stimulation of shale reservoirs.

Key words: Surface Characteristics, Permeability Enhancement, Hydraulic Fracturing, Supercritical Carbon Dioxide (Sc-CO_2)

1. Introduction

Over the last decade, shale gas has been successfully recovered in the United States due to the application of improved techniques of horizontal drilling and massive