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Impact of Varying Stress on the Flow of Gas and Brine through Proppant-Packed Fractured Shale Samples: A Micro-Scale Experimental Investigation

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ABSTRACT

The results of a micro-scale experimental investigation on two-phase gas/brine flow through proppant-packed fractured shale samples under increasing net confining stresses of up to 5,000 psi are presented in this paper. We use a miniature core-flooding apparatus integrated with a high-resolution X-ray micro-CT scanner to perform the flow experiments. Geomechanical deformation and its impact on displacement mechanisms governing fluid transport within the packed fractures are studied at the pore scale under certain flow and stress conditions. These conditions were carefully designed to represent reservoir depletion and/or transport of water and associated solutes through such media. Since proppant grains maintain long-term conductivity of the induced fractures, they significantly influence the geomechanical and multi-phase flow behavior during reservoir depletion. The effectiveness of modified resin coated sand (compared to a basic white sand) in maintaining the induced fractures hydraulic conductivity in shale reservoir samples was of particular interest to our study. Proppant packing, breaking, crushing and embedment and corresponding aperture closures were probed using high-resolution pore-scale images obtained during flow experiments in reservoir samples. Different mechanisms were found to be responsible for production loss in the samples packed with different proppants. White sand showed some level of breaking under 2500 psi closure stress and experienced sever crushing under 5,000 psi stress condition. Resin-coated sand, on the other hand, did not break and only embedded into the shale fracture walls under high closure stresses, e.g., 5,000 psi. Relatively significant embedment and proppant breaking under relatively low stress conditions were found to be the shortcomings of the tested proppants. The improved insight could be further used to design more effective proppants by considering rock mechanical properties and mineralogy. For the first time, wettability alteration of the proppant pack from water-wet to oil-wet was observed in a gas/brine system. Wettability alteration thought to be due to deposition of the organic matter released after significant proppant embedment. This study is concluded with a set of recommendations that can be used to design improved proppants to effectively maintain hydraulic conductivity of propped fractures for extended period of time.