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Using Low-Field Nuclear Magnetic Resonance and Computed Tomography Imaging to Explore Potential of Ureolysis-Induced Calcium Carbonate Precipitation Treatment to Seal Fractures in Shale

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Ureolysis-Induced Calcium Carbonate Precipitation (UICP) is an emerging biotechnology which utilizes the enzyme urease to convert urea and calcium into calcium carbonate (CaCO3) deposits for numerous engineering applications. Studies have shown that UICP can be used to seal fractures in shale, raising the possibility of applying this technology to restimulate fracking wells by plugging underperforming fractures. For this and other applications to become a reality, a study is needed to determine how effectively UICP seals shale fractures under subsurface conditions. These fractures constitute a "macroporous"environment in which microorganisms and calcium mineralizing media flow and react between pieces of proppant, though shale itself is an ultralow porous material on the order of nanometers. Thus, it is also of interest to explore if the shale is affected by UICP treatment. Low-field nuclear magnetic resonance (LF-NMR) is a non-invasive approach used to study porosity and pore-size distributions in porous media using the principles of NMR relaxometry. In saturated shale samples, hydrogen nuclei from water trapped in pores and fractures of increasing size have increasingly longer rates of NMR T1 and T2 relaxation. Additionally, shale is rich in organics such as bitumen and kerogen, which have a unique T1 and T2 relaxation signature. Thus, a T1- T2 relaxation correlation can provide insight into the organic and pore/fracture populations within the shale. Tracking how the populations shift after UICP treatment can reveal the extent of biomineralization and may indicate how the organic fraction is affected by UICP. Further insight is provided by X-Ray computed tomography (CT) imaging, another non-invasive technique, which can quantify changes in fracture volume along the length of the core and reveal how CaCO3 is distributed within the fracture. In this study, two-inch long and one-inch wide shale cores with 1-2 mm fracture gap were biomineralized with UICP treatment at 60℃ to mimic subsurface conditions although elevated pressures were not applied. UICP treatment encompassed injection of S. pasteurii microorganisms into the fracture, a brief attachment period, and then an injection of urea and calcium solution, followed by a two-hour batch reaction time. Injections were repeated until three orders of magnitude permeability reduction were measured. This study will present the results of CT imaging and NMR analysis of the biomineralized cores. Non-invasive tools such as NMR and CT help reveal how UICP treatment at elevated temperature affects shale properties and the extent of biomineralization within fractures —and ultimately its suitability for deployment in the subsurface.

Participation

In-Person

References

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