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Theoretical and Experimental Investigation of Shale-Fluid Interactions for Optimized Drilling Practices

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ABSTRACT

Shale drilling problems and challenges are well documented in literature. Shale formations with high content of clay are highly reactive in water-based drilling fluids. The use of water-based drilling fluids to drill shale formations can cause wellbore stability problems as a result of the reaction of water with clay minerals. Examples of wellbore stability problems include shale disintegration, swelling and sloughing. Consequently, there will be higher solids loading in the wellbore. Hence, the chance to get pipe stuck increases and the hole cleaning efficiency of drilling fluid decreases significantly. In this work, one laterally-extensive shale formation in the kingdom of Saudi Arabia is studied utilizing experimental and modeling techniques. Four samples from different locations were collected and analyzed and results showed the significant heterogeneity of that formation. Characterization scheme consisted of three stages: imaging and topographical studies, then, mineralogical, elemental and organic content studies and finally, shale reactivity studies. This was supported by investigating the moisture content and adsorption potential of the samples. Imbibition study was carried out using Nuclear Magnetic Resonance to explain the imbibition of different fluids into shale pore network. In addition, inhibition performance testing was carried out to study the swelling and dispersion characteristics of the shale samples. It was found that the main clay type in downhole samples is illite and illite-smectite mixed layer. While illite does not have strong tendency to swelling, illite-smectite showed high level of swelling when tested experimentally. Moreover, Molecular modeling technique was utilized to provide theoretical background on the rock-fluid interactions at molecular scale. Molecular dynamics simulation was conducted to study the behavior of illite-smectite mixed layer that exists in abundance in the tested shale formation samples. Results of total energy simulated values showed agreement with those values generated using first principle calculations. Also, modeling the interlayer spacing revealed the swelling behavior of this mixed layer upon hydration. The approach used in this study provides a basis upon which future drilling fluids planning can be optimized to mitigate wellbore stability issues.