Unraveling the Influence of Clay Coating in Sandstone on Reservoir Quality through 3D Multiphase-Field Investigation

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One of the key parameters that might impact reservoir quality of sandstones is the presence or absence of clay coatings on the surfaces of quartz grains. Porosity and permeability are crucial hydraulic and mechanical parameters for sandstone reservoirs, determining their capacity to store geothermal energy, groundwater, hydrocarbons, and the extraction rate of these valuable resources. The phase-field method is widely used in material science for modeling interface motion and phase transitions like solidification and grain growth. It has also gained prominence in computational modeling of geological processes, such as mineral cementation. Utilizing a thermodynamically consistent multiphase-field model, this work examines the influence of clay coating on the surfaces of quartz grains concerning the resultant porosity and permeability in different sandstone types. In this work, we achieved precise control over the coating of quartz grains within a three-dimensional digital sandstone. We investigate two crucial aspects: 1) the influence of varying levels of argillaceous mineral deposition over quartz grains, and 2) the impact of the size of the quartz grains on the overall porosity and permeability evolution of the reservoir rock over time. Computational fluid dynamics analysis was conducted to determine the permeability of sandstone at various stages of coated quartz grain precipitation. Subsequently, the collected data sets were examined to investigate the influence of the quantity of clay-coated grains and rock properties like grain size on porosity, permeability, and their correlations in sandstones experiencing quartz precipitation. The findings suggest that sandstones with higher proportions of coated grains are likely to exhibit higher permeabilities due to restricted grain growth on the coated grain surfaces. The findings form a basis for more quantitative reservoir prediction, benefiting applications like geothermal energy, water resources, and carbon capture.