Decoding the Dynamic Impact of Clay-Coated Quartz Grains in Sandstone through Multiphase-Field Modeling

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Abstract

The reservoir quality of sandstones hinges significantly on the presence or absence of clay coatings enveloping quartz grain surfaces. Porosity and permeability, pivotal hydraulic and mechanical parameters, exert a profound impact on the storage potential of sandstone reservoirs, encompassing geothermal energy, groundwater, and hydrocarbons. Employing the multiphase-field method, a widely embraced tool in material science, this study ventures into the modelling of interface motion and phase transitions, extending its utility to geological phenomena like mineral cementation.

Through the application of a thermodynamically consistent multiphase-field model, our investigation delves into the intricate influence of clay coatings on quartz grain surfaces, shedding light on the ensuing variations in porosity and permeability across diverse sandstone compositions. A meticulous three-dimensional digital representation of sandstone allows for precise control over quartz grain coating. This
research addresses two primary facets: 1) examining the impact of varying levels of clay coating on quartz overgrowth cement volumes, and 2) scrutinizing the repercussions of quartz grain size on the dynamic evolution of overall porosity and permeability within the reservoir rock.

To assess the evolving sandstone permeability during the precipitation of quartz on partially to completely clay mineral coated quartz grains, computational fluid dynamics analysis is conducted at various stages. Subsequent scrutiny of the amassed data reveals intricate correlations among the grain coating coverage, rock properties, and their collective impact on porosity, permeability, and their interplay during quartz precipitation.

Our computational studies indicate that sandstones boasting a higher grain coating coverage result in lower quartz cement contents, and therefore preserve porosity during diagenesis. These revelations furnish a foundational understanding for more nuanced reservoir quality predictions, with potential applications spanning geothermal energy, water resources, and the storage of carbon and hydrogen.

Keyword

clay-coating, multiphase-field model, quartz, cementation