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Petrophysical and capillary properties of the host porous medium on the evaporation process during CO2 injection in a deep saline aquifer

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Geological sequestration of carbon dioxide offers a promising solution for reducing net emissions of greenhouse gases into the atmosphere. Indeed, CO2 can be injected into saline aquifers in the supercritical state in order to achieve a higher density and therefore occupy less volume of the targeted porous rock underground. Massive CO2 injection in deep saline reservoirs can cause physical and geochemical disequilibria of the host aquifer and in some cases injectivity could decline due to several complex mechanisms including mineral dissolution/precipitation reactions, thermal and mechanical processes and petrophysical properties modifications (capillary pressure, wettability, relative permeabilities, etc.) due to advanced and/or complete water desaturation of near wellbore through drying.

The near-wellbore injection zone is investigated in the framework of this study because it is an hydrogeological system particularly impacted by supercritical CO2 injection and major modifications of porosity and permeability are expected. Among the different processes able to occur in this zone, desiccation of the near-wellbore porous media submitted to gas injections is a well-known process at laboratory and field scales. Firstly, the massive and continuous injection of CO2 in a porous medium involves water displacement and evaporation: mobile water is removed by the injected supercritical CO2. At the end of this phase, immobile residual water, entrapped in pores or distributed on grain surface as a thin film, is in contact with the flowing dry CO2 (i.e. with very low relative humidity). Consequently, a continuous and extensive evaporation process appears in the porous medium, leading to the precipitation of salts and possibly secondary minerals. The injection flow rate and the Peclet number are important parameters controlling the position of the precipitated salts in the porous medium, even if it is still difficult to predict the direct effect on permeabilities of flowing fluids. Moreover, according to the typology of the initial brine, a large variety of salts having contrasted molar volumes and surface properties can precipitate. Indeed, if some salts have a minimal impact on porosity and permeability, some of them can however affect dramatically the pattern of the flow rate field around the injection well.

This study is based on a numerical approach to investigate these coupled and complex processes (chemical, thermal and hydrogeological), which are able to occur in the near-wellbore zone. The numerical results highlighted the key role of the injection flow rate and capillary properties on the desiccation mechanisms. The amount of salt deposits is related to different parameters as the salinity of the initial brine, the residual water content, the gas injection flow rate and the capillary forces. The numerical simulations showed that the capillary properties of the rock prevent a sudden evaporation of the irreducible water by continuously and sustained feeding the injection zone with “new” brine coming from reservoir zones distant from the injection well. It is showed that the CO2 injection flow rate and the resulting capillary forces inside the porous medium are intimately linked and control the chemical behaviour of precipitated salts. Moreover, this study also underlines the importance of the relationship between pressure-temperature and injection flow rate in the management and sustaining injectivity during the exploitation of the injection well. A sensitivity analysis is made on different parameters (injection temperature, flow rate, etc.) in order to determine the most adequate conditions to successfully maintain injectivity during the industrial exploitation of an injection well.

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