Modeling CO_2 Circulation Test, as a Key Element of CO_2 Plume Geothermal (CPG), at An Active CO_2 Storage Site

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A drastic reduction of global carbon dioxide (CO_2) emissions is urgently required to meet global climate targets, such as the goals set by the Paris Agreement in 2015. Across most scenarios for achieving these targets, the safe storage of CO_2 in the geological subsurface, a concept widely known as Carbon, Capture, and Storage (CCS), will be an essential element of carbon dioxide removal (CDR) options. However, instead of treating CO_2 as a waste product to be disposed of, emerging Carbon, Capture, Utilization, and Storage (CCUS) technologies such as CO_2 Plume Geothermal (CPG) offer the possibility to utilize the disposed CO_2 as a geothermal (i.e. subsurface) working fluid to produce sustainable geothermal energy. Profiting from the unique thermodynamical and fluid-dynamical properties of supercritical CO_2, geothermal energy production could potentially be expanded to geological regions with geologic temperature gradients that are much lower than what is commonly required for economic energy utilization with groundwater/brine. At the same time, CPG still enables permanently sequestering 100% of the injected CO_2 in the geological reservoir. For more information on the concept of CPG systems, the reader is referred to Randolph and Saar (2011), Adams et al. (2015), Garapati et al. (2015), and Adams et al. (2021) and references therein.

In this work, we examine the response of the Aquistore CCS-site, Saskatchewan, Canada, to the circulation of CO_2, as a key element of a CPG system. The Aquistore project is the most comprehensive full-scale geological field laboratory in the world, where the CO_2 is captured from an adjacent coal fired power plant and injected into a more than 3.4 km deep hypersaline aquifer (Movahedzadeh et al., 2021; Rangriz Shokri et al., 2021). Of significance to the application of CPG systems, we initially looked into the multi-phase and fractional flow of CO_2/brine systems in a conceptual model of the Aquistore reservoir. This preliminary work proves that a stable CO_2 circulation between an injector and a producer within the CO_2 plume could be achieved (Hau 2020; Hau et al. 2021). Building on this exercise, we explore the feasibility of a pilot CO_2 circulation test at the Aquistore site. To do this, a sector model is extracted from the available full geological model of Aquistore (Rangriz Shokri, 2019), and it is re-constructed to test further simulations of CO_2 circulation. Based on a full-scale history-matched reservoir model, we investigate the feasibility of CO_2 circulation between an injector and a producer at Aquistore. For our simulation, we assumed that the two existing wells (one CO_2 injection and one observation well) on-site can be used as potential injection and production wells.

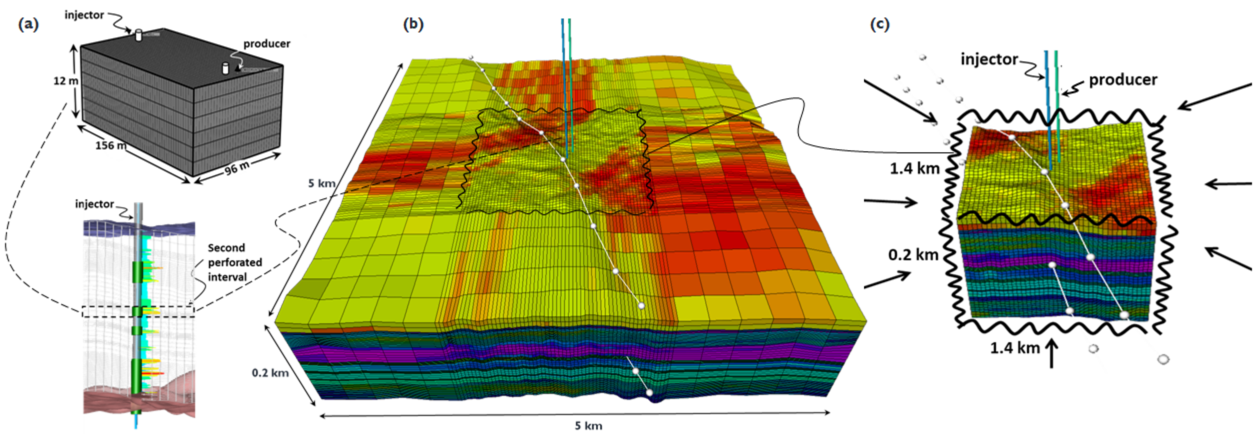

Figure 1: (a) Simplified model of the 2nd perforated interval between an injector and a producer, (b) full geological model used during the history-matching process to initialize the sector model, (c) the sector model employed for further simulations of the CO_2 circulation test.

The preliminary results from our semi-analytical and simplified numerical models, with homogenous reservoir properties, suggest that supercritical CO_2, with predominantly gas-like phase properties, preferably enters the producer through the 2nd perforated interval of the Aquistore well. The results indicate that the eventual (steady-state) CO_2 saturation in the producer is high (85-90%), independent of the assumed absolute and relative reservoir permeabilities. More comprehensive workflows include the appraisal of the most probable realizations of the CO_2 plume extent and shape from the latest available seismic surveys and history matched flow simulations (White et al., 2021). Our simulations also suggest that sustained CO_2 circulation appears feasible at Aquistore and that, after a few days to weeks, it does not result in the continuous production of large volumes of brine from the aquifer. However, an early brine breakthrough is expected and would be managed through proper surface facility preparation. Reservoir heterogeneity and operational variables of both injection and production wells are among the key parameters that need to be determined in order to control the performance of the CO_2 circulation within the subsurface CO_2 plume.

The outcomes of this study will help to understand the reservoir parameters involved and properties required for successful CO_2 circulation. The findings provide answers to some key questions related to CPG development and operation, and ultimately the feasibility of a pilot test at a geologic CO_2 storage site, such as Aquistore.

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