Impact of reservoir heterogeneity on plume migration and storage security of CO_2 in saline aquifers

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ABSTRACT

Carbon dioxide (CO_2) sequestration is one of the most promising methods to mitigate anthropogenic greenhouse gas emissions without disrupting the current energy infrastructure. One of the significant uncertainties during a carbon injection project is a site selection for the injection wells to ensure long-term containment of the injected CO_2 without the possibility of leakage through the undetected cracks or reactivated fractures in the caprock. This study aims to investigate the impact of stratigraphic heterogeneities on flow properties on the plume migration within the Desmoinesian age formation in Canadian county, Oklahoma (Fig. 1). The ongoing study helps identify the best location for injection within the reservoir.

The site area is a producing field comprising ~8,000 ft of Pennsylvanian – Devonian stacked reservoirs consisting of 82,830 acres confined by ~1350ft of low-permeability Permian sediments. The study area is within 10 miles of the Enid-Purdy CO_2 pipeline and within an 50 miles of significant emitters catering to Oklahoma City. Log calibration indicates that the average porosity within the Desmoinesian formation, which drapes over structures created from the Early Pennsyvalian orogeny, varies between 0.12 (warmer colors; Figure 1) and 0.06 (darker regions; Figure 1). The stratigraphic compartmentalization of the Desmoinesian formation mainly occues due to erosion of the bedrock, mainly silty clay, followed by channel fills that range from massive sand to laminated clay depending on energy of the fluvial system. Consequently, a significant variation in permeability occurs. Based on the analoges (nearby Desmoinesian producing fields), we assigned 1mD to black and 500 millidarcy to red color in Figure 1. We use a composition reservoir simulation to simulate a 300-year process with ten years of active injection followed by a post-injection phase. Ongoing study varies the placement of the injection wells at various regions to calculate the fraction of CO_2 sequestered by dissolution and residual trapping during the injection and post-injection phases.

It is common knowledge that CO_2 trapped by dissolution and capillary forces is highly dependent on the porosity and permeability of the injection zone. The high permeability-porosity zones showed enhanced trapping through dissolution, whereas the low permeability-porosity zones enhanced residual trapping. Naturally, the presence of channels and vertical barriers will have a significant impact on the migration of the ScCO2.

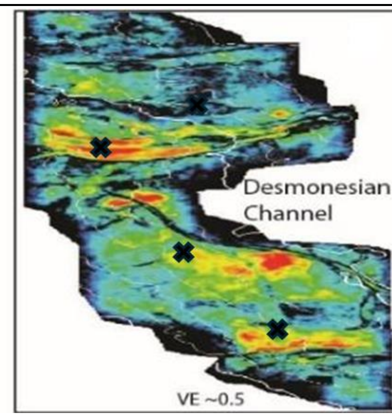

Figure 1. Scaled amplitude map of Desmoinesian horizon in the study area with warmer colors indicating higher porosity. The black regions are interpreted as stratigraphic discontinuities possibly creating permeability barriers from shale deposition. The ongoing study examines plume propagation originating at three different locations marked by X with the goal of identifing the best scenario for long-term retention of $scCO_2$ in the subsurface.

We are testing the hypothesis that injecting the plume in the highest porosity region (red; Figure 1) may not lead to the most efficient storage as free energy may inhibit movement of the plume from high porosity to low porosity regions. On the other hand, injecting in mediocre porosity zones (yellow to green; Figure 1) will first trap the plume in a sizeable region of the bedrock which will then naturally find its way into the higher porosity regions.

This work presents a numerical flow simulation of CO_2 across various regions with different permeability and porosity in a heterogeneous reservoir. The results provide guidelines for optimal injection zones for maximum dissolution and residual trapping. Although significant uncertainties and knowledge gaps exist, this study provides preliminary results that can be used for site selection for the safe storage of CO_2 in a heterogeneous reservoir with varying permeability and porosity.

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