Investigating the Effects of Caprock Morphology and Reservoir Boundary on the CO_2 Storage

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Introduction

The atmospheric concentrations of CO_2 has been rising, and its role on global warming, have prompted efforts to reduce its emissions from burning of fossil fuels.

An attractive mitigation option under consideration in many countries is the injection of the CO_2 from stationary sources, such as fossil-fuel power plants, into deep, stable geologic formations, where it would be safely stored and kept out of the atmosphere for time periods of hundreds to thousands of years. Potential geologic storage reservoirs include depleted or depleting oil and gas reservoirs, coal beds and saline formations.

In order to have a better understanding of the CO_2 migration and also to predict the storage boundaries, the characterizing the storage site becomes important. Therefore it is essential to study the site boundaries and also the nature of the caprock.

Methodology

a. Caprock morphology

The first part of this study focuses on the impacts of the caprock shape on the CO_2 dissolution and plume migration in the saline formations. Various caprock surfaces are considered which their corresponding equations are listed in Table 1.

A compositional reservoir simulator (ECLIPSE E300) was utilized in this study. A Cartesian model with a grid dimension of (81 × 1 × 100) and a cell size of (250 m× 8000 m× 1 m) was considered through the study. The CO_2 was injected for 30 years, followed by 1000 years post injection period. The injector is located in the centre of the models.

Table 1: Equations of each caprock surface.

Name	Case #	Top Surface Equation
arccot_neg_slope	a	1500 + (-5) * atan (x/1500)
arccot_pos_slope	b	1500 + 5 * atan (x/1500)
arccot_pos_slope_sine	c	1500 + 5 * atan (x/1500) + 0.5 * sin (2*pi.*x/500)
flat	d	1500
sine_1000	e	1500 + 2* sin (2*pi.*x/1000)
sine_2000	f	1500 + 2* sin (2*pi.*x/2000)
sin_tan_1000	g	1500 + 2* sin (2*pi.*x/1000)+x*tan (2.*pi/180)
sin_tan_2000	h	1500 + 2* sin (2*pi.*x/2000)+x*tan (2.*pi/180)
sine_over_x	i	1500 + 1000* sin (x)./x
sine_over_x_tan	j	1500 + 10000* sin (x)./x + x*tan (pi/180)

b. Reservoir boundary

In the second part, the impacts of boundary condition in CO_2 plume migration and dissolution are investigated. Horizontal and tilted (0.5º clockwise) flat models were considered. The cell size is changed to (175 m× 8000 m× 1 m) while the other properties are the same as the first section.

To represent different boundaries, nine cases are built using three sets of multipliers (1e5, 1e7 and 1e9) for the porosity, located in left, right and both sides of the 2D model. In order to keep the reservoir pressure and size the same, the multipliers which are in both sides are divided by two.

Results

a.

The Figure 1, shows the saturation of CO_2 Plume at the end of simulation. As we see, due to its lower density, the plume migrates upward till it reaches the caprock. Once the first sand ridge has been filled to its spill point, the free CO_2 moves up dip beneath the caprock to the next available one.

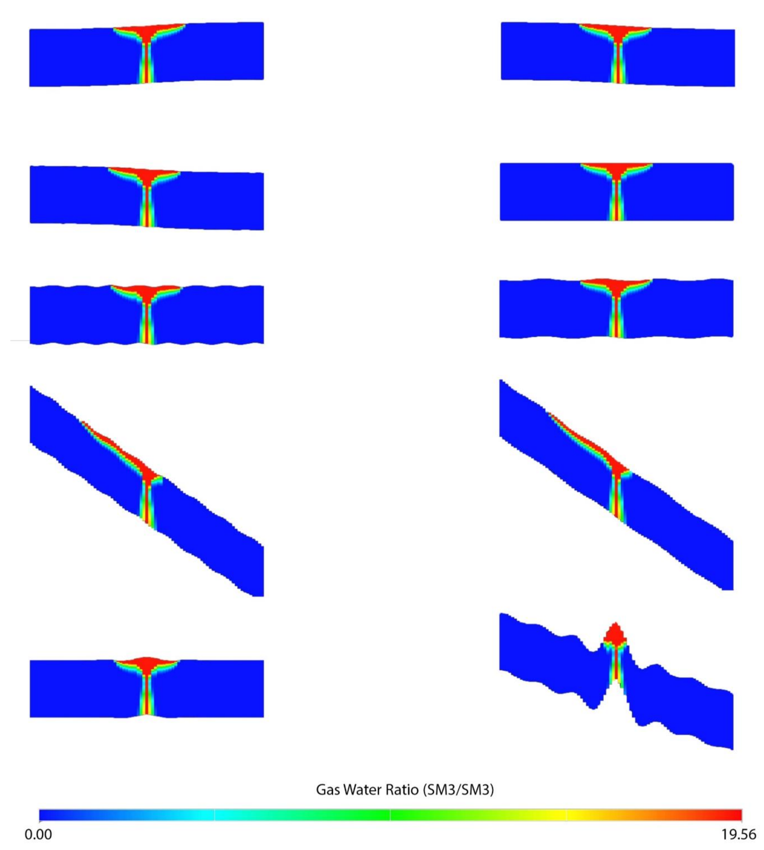

Figure 1, Gas saturation 1000 years after CO_2 injection in all models.

Figure 2 illustrates the amount of dissolved CO_2 in the water. It is clear that in the tilted reservoirs (cases g and h) where the CO_2 migrates upwards and interacts with more fresh water, the dissolution is maximum. The lowest dissolution occurs in case j, where the CO_2 is trapped in a sand ridge or an anticline.

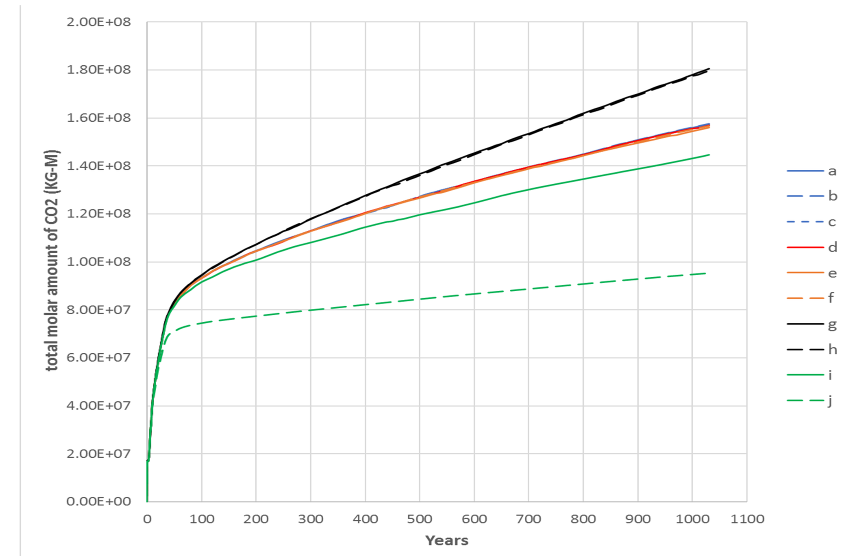

Figure 2, Amount of dissolved CO_2 at the end of simulation in all models.

b.

Figures 3 and 4 illustrate the percentage of dissolved CO_2 at the end of injection and post injection periods respectively for the horizontal flat model.

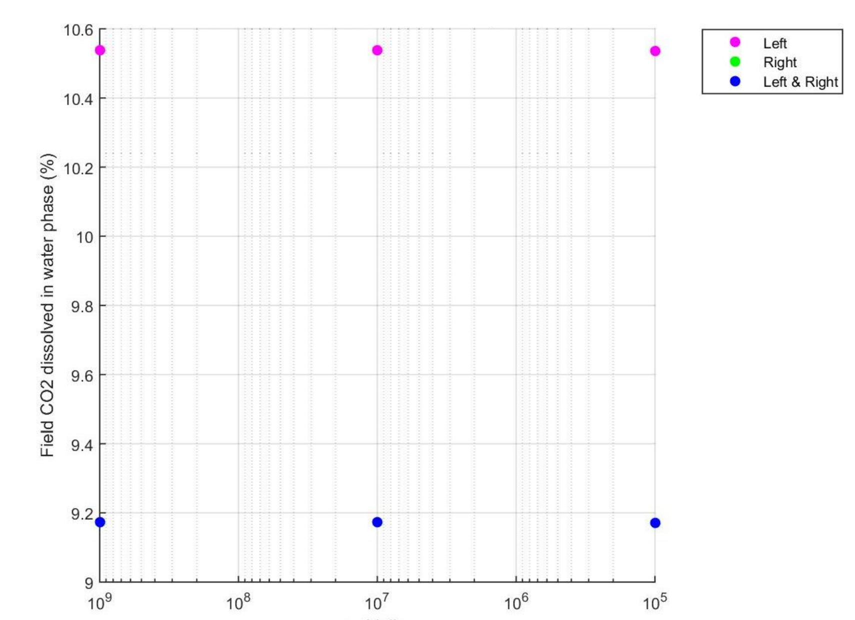

Figure 3, Percentage of dissolved CO_2 at the end of injection (horizontal model).

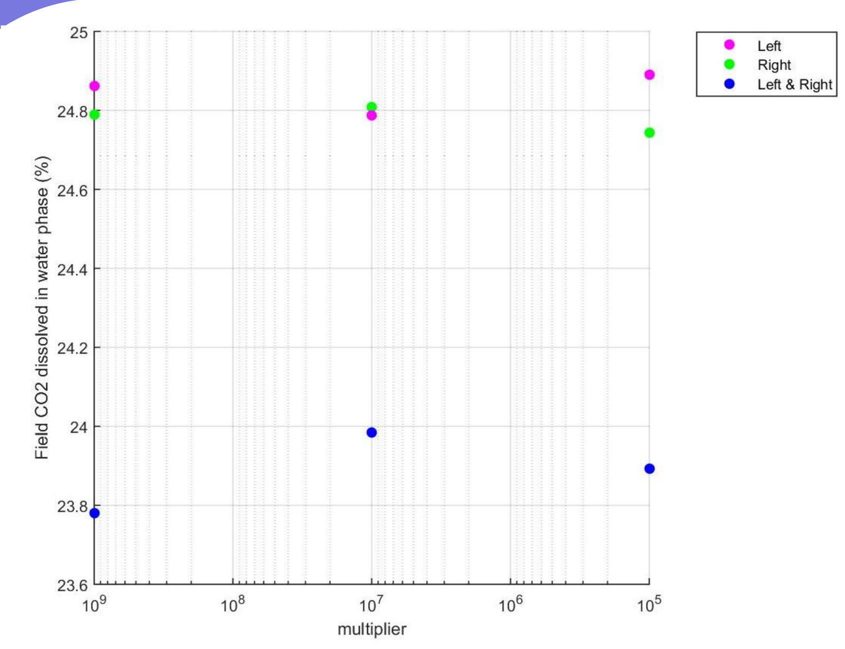

Figure 4, Percentage of dissolved CO_2 at the end of simulation (horizontal model).

Since the model is symmetric, the dissolution for both cases where the multiplier is on left or right side of the reservoir are the same. There is a minor difference in figure 4 (after the post injection), which is due to numerical errors and is negligible.

However as it is clear, the dissolution is more dominant when the reservoir is open from one side, rather than both sides. Which means the driving force of a large one-sided multiplier is more predominant than two half in both sides, therefore CO_2 touches more fresh water.

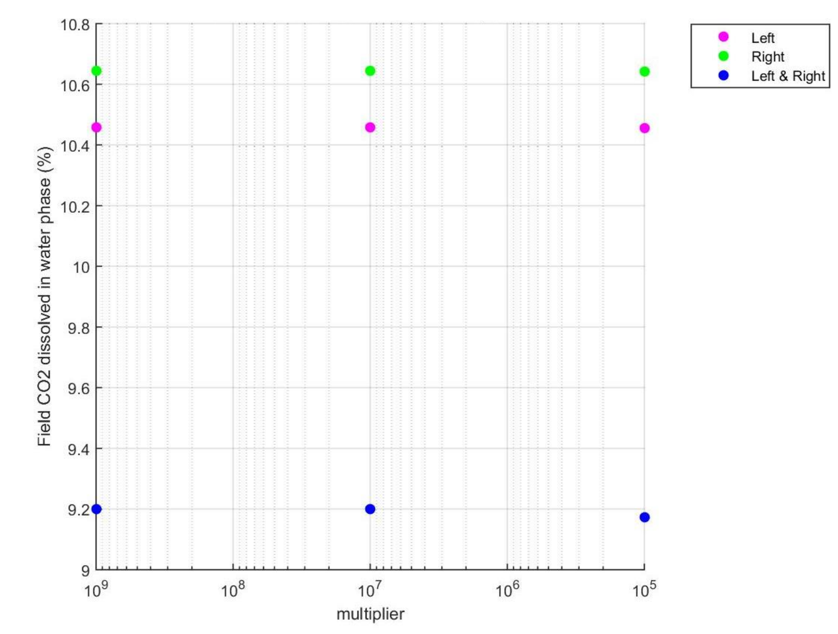

Figure 5, Percentage of dissolved CO_2 at the end of injection (tilted model).

Figures 5 and 6 show the same results for the tilted models. Since the model is tilted in clockwise direction, the buoyancy force leads the plume to the left hand side, as the result the main dissolution occurs in that region. Having the multiplier in right side leads a portion of the plume to fresh waters there, thus result in a higher dissolution. Moreover the overall dissolution is higher than the horizontal case.

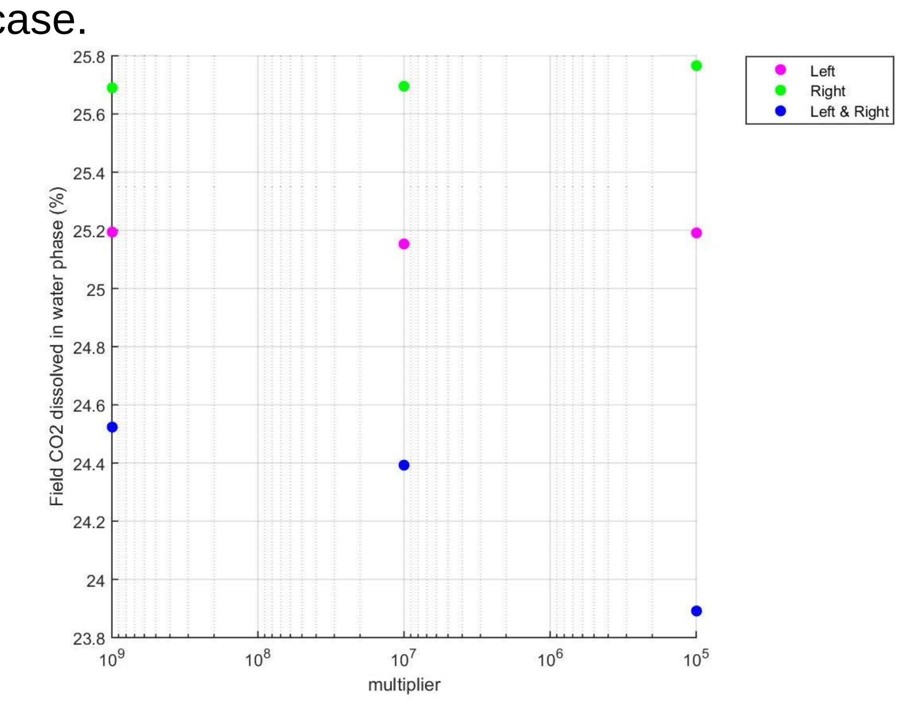

Figure 6, Percentage of dissolved CO_2 at the end of simulation (tilted model).

Acknowledgment

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