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CO_2 Sequestration Influence on Low Permeable Geological Formations

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Abstract—*Carbon dioxide (CO_2) is a major greenhouse effective gas that contributes to Earth's global warming. The idea is to inject the CO_2 in to the low permeable geological formation to allow the sufficient time for the trapping mechanisms by controlling the migration of CO_2 towards surface. MATLAB Reservoir Simulation Toolbox (MRST) is used to study the trapping of CO_2 in geological formation and migration. MRST-co_2lab is a collection of open source computational tools for modelling large-scale and long-time migration of CO_2 in conductive aquifers, combining ideas from basin modelling, computational geometry, hydrology, and reservoir simulation. All computational methods implemented in MRST-co_2lab are formulated based on a hybrid 2D grid that represents the 3D aquifer in terms of its top and bottom surfaces. The main objective of this work is to identify the geologically potential storage spill point for the storing CO_2 and the migration. We considered a volume of 5km x 5km x 50 m having homogeneous porosity of 0.25 that lies below the 1000m depth from the surface. The top surface will be placed on the grid structure.*

Keywords*: Storage, migration, MRST-co2lab, spill point, spill region.*

1. INTRODUCTION

Activities such as burning of fossil fuels along with cement making have led to a significant increase in the CO_2 concentration in the atmosphere since the start of the industrial revolution [IPCC 2007]. CO_2 being a strong and long-lived Green House Gas (GHG), its increased concentrations in the atmosphere has led to increase in the global temperature [IPCC 2007]. Carbon Capture, Storage and Sequestration are presently viewed as an important strategy to reduce the concentration of CO_2 in the atmosphere. One way to conflict climate change is to prevent the release of CO_2 to the environment by storing it in natural underground reservoirs. This paper describes the concept and outlines some of the issues involved in estimating the trapping of CO_2 in geological formation. CO_2 emitted by large sources, such as power plants and other industrial processes, could be captured and stored underground using Depleted oil as well as gas fields, Coal seams and deep saline reservoirs. Shaping the maximum amount of CO_2 that can be injected and firmly contained is a key matter. When injected into the geological formations, density differences will drive CO2 to form a separate (the CO2 plume) mobile phase, which is driven upwards by buoyancy. To prevent CO2 from moving straight forwardly upward, it is injected into a low permeable formation bounded upwards by a sealing caprock. Below this seal, CO2 will spread out and slowly migrate in the upslope direction. Disregarding other trapping mechanisms, this migration continues until the plume encounters a trap in the top surface where CO2 will accumulate. Once a trap is filled, excess CO2 will spill over and keep migrating upwards to the next trap, and so on until the top of the formation is reached. In the short term, structural and stratigraphic trapping are key mechanisms for geological storage of CO2. Herein, our primary concern is to develop methods that can quickly compute bounds on the overall capacity for structural trapping and select good positions for placing injection points. These methods have later been combined with simulation tools based on an assumption of vertical equilibrium simulation [H. M. Nilsen et al] to provide flow visualization and strategy to select injection point, observe the plume behaviour of co2 and provide the result of trapping.

2. GEOLOGICAL STORAGE OF CARBON DIOXIDE

One way to combat climate the change is to prevent the release of CO_2 to the atmosphere by storing it in natural underground reservoirs and catch the topographical stockpiling of CO_2 give an approach to withdraw from transmitting CO_2 into the climate[Capture of CO_2 Kelly *et al*] [Geological storage of CO_2 by IEA].This segment looks at these procedures and their impact on land stockpiling of CO_2.Thusly, the experience picked up from existing profound liquid infusion activities is important as far as the style of operation and is of a comparative size to what might be required for geographical stockpiling of CO_2.

2.1. Physical Properties of CO_2

The physical state of CO_2 shifts with temperature and pressure. At ambient conditions CO_2 is a gas; however it becomes liquid at greater depth. At high temperature, CO_2 is a supercritical fluid when pressure is high enough. The transition from one state to another relies on upon the geothermal slope. In most sequestration scenarios, CO_2 are infused in liquid structure (low T, humble to high P), yet it changes into a supercritical fluid as it is injected and warms to the temperature of the development. In saline aquifers and oil reservoirs, CO_2 is less dense than the in situ fluids, so it ascends to the base of the seal. Clearly, maintaining an impermeable caprock is essential to containing the buoyant CO_2.

2.2. CO_2 Migration Behaviour

When CO_2 is injected into deep geological formations, it displaces the pore fluid. Depending on the fluid's properties, CO_2 is either miscible that is it can mix completely to form a single liquid phase or immiscible, so the phases stay separate. At conditions expected for sequestration, CO_2 and water are immiscible [CO2 Sequestration in Deep Sedimentary Formations Sally by M. Benson *et al*]. Oil and CO_2 may or may not be miscible, contingent upon the structure of the oil and the formation pressure. CO_2 and natural gas are miscible. When the fluids are miscible, the CO_2 eventually displaces nearly all of the original fluid. Injection of an immiscible liquid sidesteps some part of the pore space, catching some of the original fluid. With the limited exception of dry-gas supplies, most sequestration ventures will require immiscible displacement to one degree or another [Carbon Dioxide Sequestration by David R. Cole *et al*]. For example, although oil and CO_2 are miscible, the water that is almost always present in formations is not miscible with oil or CO_2 oil mixtures. Equilibration of CO_2 between oil and water depends on the composition of the oil.

3. TRAPPING MECHANISMS OF CO_2

These trapping processes take place over a lot of years at dissimilar rates from days to years to thousands of years, but in general, geologically stored CO_2 become more strongly trapped with time. Demonstration of a variety of geological storage of CO_2 is already being carried out in a range of projects of varying scale.

3.1. Structural/Stratigraphic trapping

Firstly, physical trapping of CO_2 below low permeability seals (cap rocks), such as very low permeability shale or salt beds, is the prime means to accumulate CO_2 in geological formations. Sedimentary basins have such closed, physically bound traps or structures, which are occupied mostly by saline water, oil and gas. Structural traps are those shaped by fold or fractured rocks. Faults can operate as permeability barriers in some circumstances and as preferential pathways for fluid flow in other conditions. Stratigraphic traps are formed by lateral changes in rock type caused by variation in the setting where the rocks were settled down. Both of these types of traps are good for CO_2 storage. A special folder for structural trapping can take place in saline formations that do not have a closed trap but consists of a slightly tilted aquifer where fluids move very slowly over long distances. When CO_2 is injected into a formation, it dislocates saline formation water and subsequently migrates buoyantly upwards, since it is less dense than the water. When it reaches the top of the storage formation, it continue to migrate as a separate phase until it is dissolved (potentially helped by the gravity instability and mixing), trapped as residual CO_2 saturation or gets blocked in local stratigraphic traps under the sealing formation [IPCC 2005].

3.2. Residual trapping

Consider a medium that is primarily packed with water or brine. The solid grains are usually made of minerals that are obviously wetting to water and, consequently the medium is particularly water wet. During CO_2 injection into the aquifer or reservoir, the non wetting CO_2 phase occupies the pore space. This is a drainage process in which the only mechanism for displacement of water by CO_2 is piston type displacement the CO_2 invades the porous medium in the form of a uninterrupted, associated cluster. Water, still, remain not only in small pores that have not been packed with CO_2 but also in the corners and gaps of the pores that have been invaded. Consider now the dislocation of the CO_2 by water. During this process, there are some physical mechanisms by which the water can displace the CO_2 [Lenormand et al., 1983]. In accumulation to piston type displacement, accommodating pore body filling and snap-off may take place. For water wet rocks, snap off is the leading mechanism [Al-Futaisi and Patzek, 2003; Valvatne and Blunt, 2004].

3.3. Solubility Trapping

The dissolution of CO_2 and other flue gas impurities into the pore water can lead to trapping by solubility. The amount of gas that can dissolve into the water depends on several factors, most particularly pressure, temperature, and salinity of the brine [e.g. Spycher et al. 2003; Lagneau et al. 2005; Koschel et al. 2006; Oldenburg 2007].At the conditions expected for maximum geological sequestration, CO_2 solubility increases with rising pressure (i.e. depth) but decreases with rising temperature and salinity. Benchscale experiments reveal that CO_2 dissolution is quick at high pressure when the water and CO_2 shares the same pore space [Czernichowski-Lauriol et al (1996)].Still, in a real injection system, CO_2 dissolution may be rate-limited by the magnitude of the contact area between the CO_2 and the fluid phase. The principal benefit of solubility trapping is that once the CO_2 is dissolved, there is less CO_2 subject to the buoyant forces that drive it upwards.

3.4. Mineral Trapping

This mechanism occurs when dissolved CO_2 reacts directly or indirectly with minerals in the geologic formation, helpful for the precipitation of carbonate minerals [Oelkers et al. 2008]. Mineral trapping is attractive because it could arrest CO_2 for very long periods [Gunter et al. 1997].However, the process is thought to be comparatively slow because it depends on dissolution of silicate minerals, so the global impact may not be realized for tens to hundreds of years or longer.

4. METHODOLOGY

Trapping can be estimated using simple geometrical algorithms that compute traps and catchment areas for the top surface of a grid model. Simple percolation methods can be used to estimate spill paths, assuming that CO_2 is injected at an infinitesimal rate. These methods are implemented in free software in the MRST [MRST and s.krogstad et al (2007)]. The MRST-CO_2lab module [SINTEF ICT (oct 2014)] includes a graphical and numerical interface for interactively exhibiting structural trapping, input routines for standard input formats, and scripts to be download, unpack and process publicly available datasets. [E. K. Halland (2011), G. Eigestad (2008)]. Altogether, MRST provides a wonderful platform for supporting research, which we demonstrate here in providing complete scripts for all realistic examples.

4.1. The Spill Point Approach to Trap Analysis

We use the word spill path to refer to the path follow by CO_2 under the caprock on its buoyant migration, assume infinitesimal flow. While a trap has been totally filled by CO_2, any other quantity entering the trap will direct to an equivalent amount exit. For infinitesimal quantity, the flow will go after a spill path out of the trap that either terminate in a different trap or exits the area. Like such, individual traps are able to be seen to be linked by spill paths, greatly the way lakes are associated by rivers. In line by means of the principle of industry standard reservoir descriptions. We refer to this mesh as a top surface grid when resulting from a 3D reservoir model [Halvor Møll Nilsen et al]. Discovering all traps and spill paths for a known model can be finished by inspecting the geometry of this mesh. Even though the process is simple in principle, it is responsive to small change in input information. The algorithms make like results in the majority cases, but now and then the differences are significant. The figure1 explains the selection of spill point and spill path which will allow more amount of CO_2 as the approach explained above.

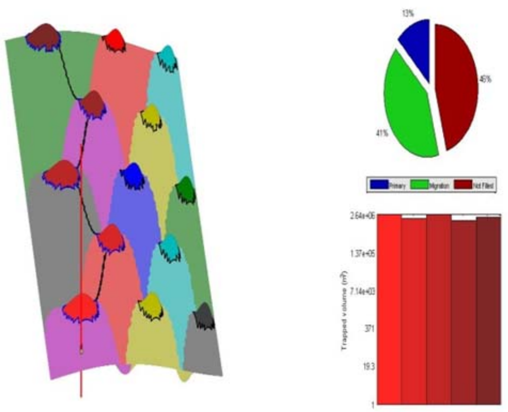


Fig. 1: Interactive vision in onward mode.

The pie chart presents the volume of the trap whose catchment area contains the injection point ('Primary'), the united volume of traps by the side of the associated spill path ('Migration'), and the volume of all other traps ('Not filled'). The bar plot shows the volume of each trap along the spill path. The scale is logarithmic because realistic scenario tends to have widely varying trap sizes.

4.2. Interface and implementation in MRST CO_2 Lab

To utilize the functionality in MRST-CO_2lab, the first item one has to do is to make a semi-2D report of the top surface which includes a deposit of data objects that offer mapping between each cell in the 2D surface grid and a version of the volumetric column that lie under in 3D. The top surface grid can moreover be generate from a 3D volumetric grid by means of the function top Surface Grid. As a descriptive model of the type of information that can be obtain from this purpose. We consider box geometry of 5,000 × 5,000 × 50 m3. We initiate a sinusoidal perturbation of the top as well as bottom surfaces, shift the box to a depth of 1000 m also assign a uniform porosity of 0.25. Fig. 2 showsthe 3D grid along with the extracted top surface plotted on the similar axes. Assuming that the surface represents impermeable seal (Caprock), the local domes will symbolize structural traps.

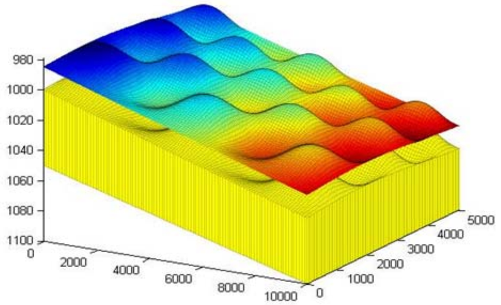


Fig. 2: Visionary model illuminate the trapping arrangement. The visualized extracted top-surface grid has been shifted slightly upwards and coloured by depth values to clearly discriminate it from the yellow 3D grid.

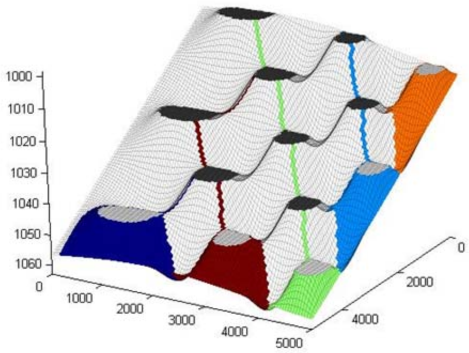


Fig. 3: Leaf traps depressed at the spill point (light gray), the neighbouring catchment areas (Shown in different colours), and the spill paths to the top of the field. The spill levels of up slope traps are exposed in dark gray.

The complete setup and all statements necessary to produce Figures 1, 2 and 3 can be found in the script trappingExample1.m. in MRST

5. RESULTS AND DISCUSSION

Through our simulations we have tried to express the flow of CO_2 in reservoir using vertical equilibrium model. The results were given for homogeneous aquifer in view of assuming the reservoir with geomentric volume of $2.302e^{+09}$ m^3 and 10000 cells were taken for constructing the reservoir. The injection site was located at cell: 1898 with(x: 9750, y: 925, i=98, j=19). The rate of CO_2 injected per year is 0.3 megatonnes, pressure is 200 bars, migration time is 75 years and the injection time is 5 years. As it is a homogeneous and low permeable reservoir the permeability and porosity are maintained equal in all the cells permeability is taken 250mD (milli Darcy) and the porosity is taken as 0.25. the total trapping capacity is taken $4.948e^{+06}$ and this amounts to 39.58%of total pore volume of $1.25e^{+07}$ .With these circumstances we have simulated the vertical equilibrium model and found the flow behaviour and type of trapping as shown in the Fig. 4 and Fig. 5 they describe behaviour of CO_2 at injection and migration period.

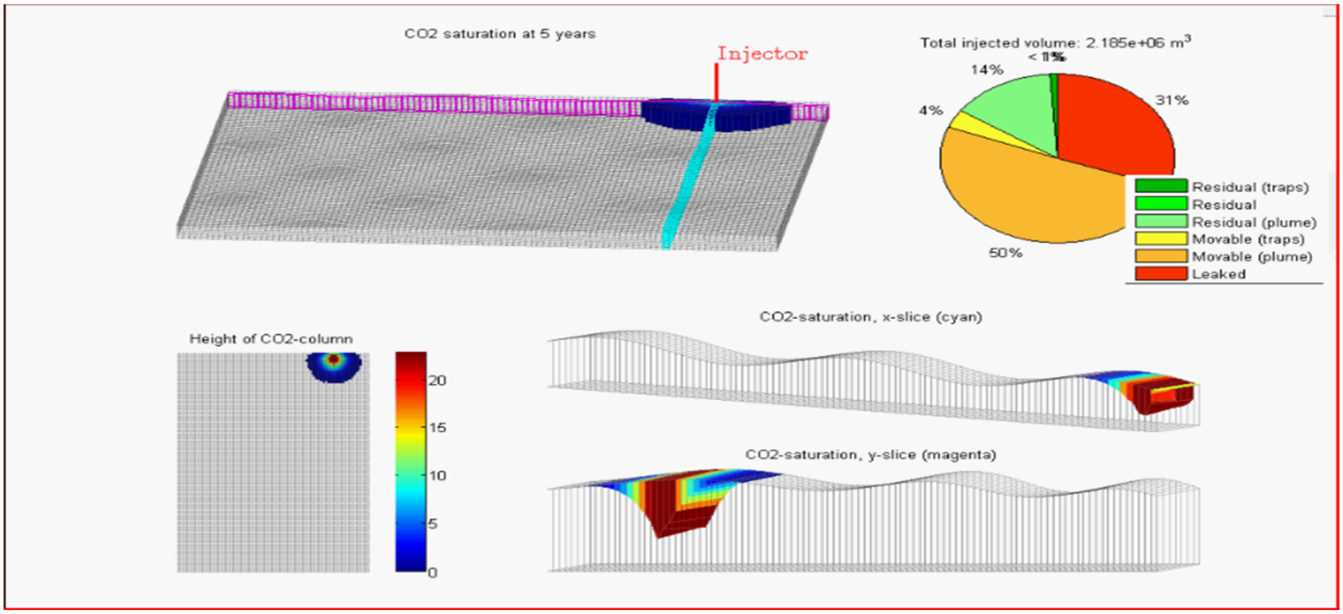


Fig. 4: The result of simulation at the end of injection. It illustrates the height of CO_2 at injection point is more and due to buoyant effect the CO_2 is flowing towards the cap rock

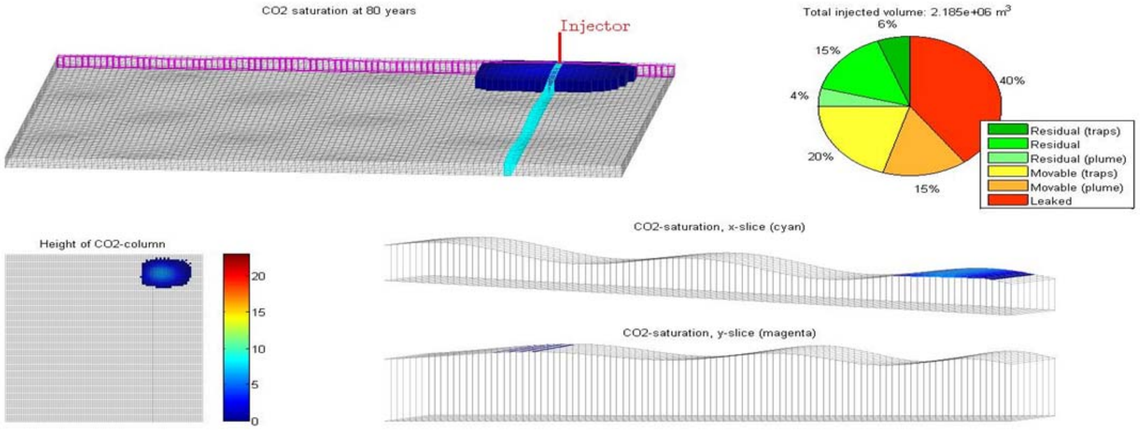
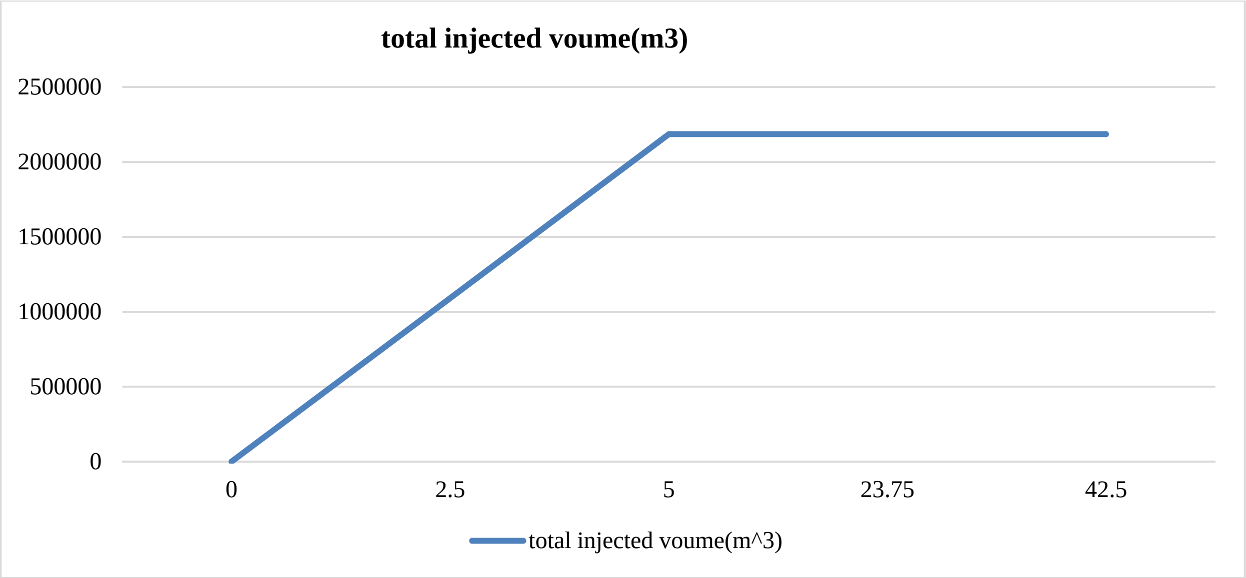


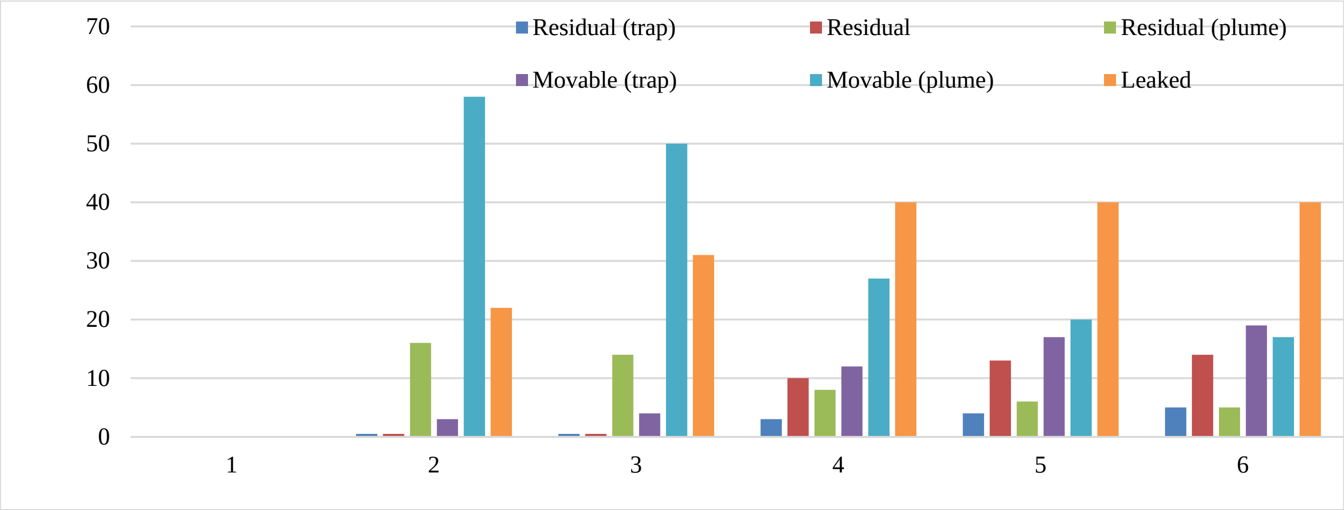
Fig. 5: The result of simulation at the end of migration. Here the Fig. illustrates the flow of co_2 saturation at 80 years and due the buoyant effect the co_2 is moving towards the cap rock

5.1. Graphs

The graphs are based on the results obtained at the time of simulation



The above graph will give the information about total injected volume at particular year (x-axis : years and y-axis: total injected volume



The above graph is exposing the result of simulation at particular time steps discussing about residual and movable trap mechanism. Here x-axis: time steps and y-axis: percentage.

6. CONCLUSION

We have exposed the results of full 3D vertical equilibrium simulations of effective migration of CO$_2$ in a model of a site where CO$_2$ can be stored. The investigation of these results proves that for the specific case of CO$_2$ migration in the low permeable geological formations. Vertical equilibrium models present solutions that are more exact. The Vertical equilibrium model is much faster than equivalent 3D simulations that resolve the similar dynamics. This is mainly important for simulations of long period migration of CO$_2$, wherever the plume thins out as it moves beyond from the injection site [I. Ligaarden et al (2010)].Which create them more appropriate for sequential splitting approach. Based upon the results argued above, we propose that additional effort should go in to the development of more exact and faster vertical equilibrium models for simulating CO$_2$ migration. In addition, we look forward to that the renewed interest in vertical equilibrium models will result in the growth of new simulators that would be able to represent more complicated physical mechanisms that affect CO$_2$ migration in low permeable reservoirs.

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