

# Reactive transport simulation of CO<sub>2</sub> WAG in carbonate reservoirs

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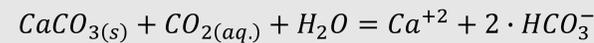


## 1 BACKGROUND

Carbonate reservoirs are typically more geochemically reactive and the flow mechanisms are distinct from non-fractured sandstone reservoirs. In addition, in areas such as the Brazilian pre-salt layer, the possibility of injecting carbon dioxide (CO<sub>2</sub>) in this ultra-deep environment adds more challenges to overcome.

## 3 METHODOLOGY

- We analysed the carbonic acid system in the presence of calcite under chemical equilibrium assumption by using PHREEQC (thermodynamic software). The identified global reaction for CO<sub>2</sub> projects is:



- We assumed that the concentration of all chemical species that are not in the global reaction is conserved and therefore the charge difference between anions and cations (excluding Ca and HCO<sub>3</sub>) is a non-zero constant value named  $\epsilon$ .

- We combined the equilibrium relation associated to the global reaction with the charge balance in solution to find an approximation for the dissolved Ca:

$$m_{Ca} \approx \frac{\sqrt{2 \cdot m_{CO_2} K_{sp,1}} + \epsilon}{2}$$

where  $m_{CO_2}$  and  $K_{sp,1}$  are respectively the molality of CO<sub>2</sub> in pure water and the equilibrium constant both specified at a given temperature and pressure.

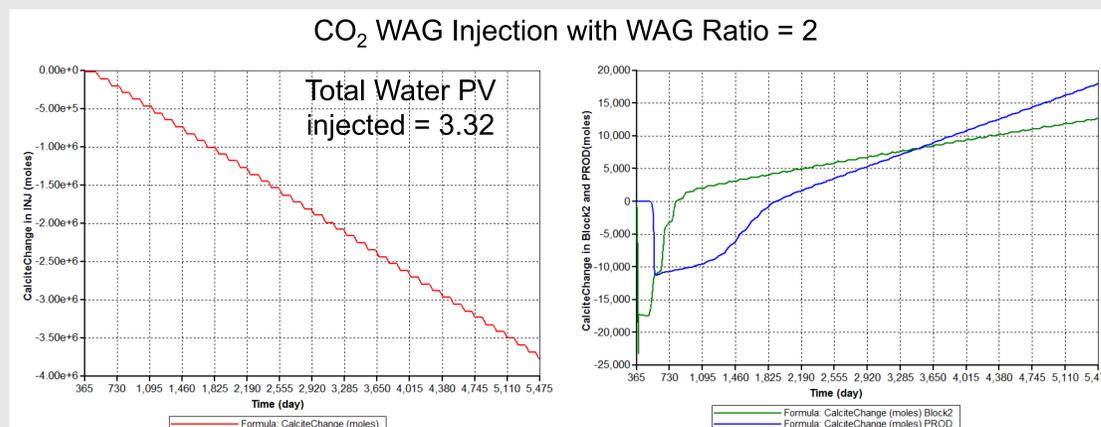
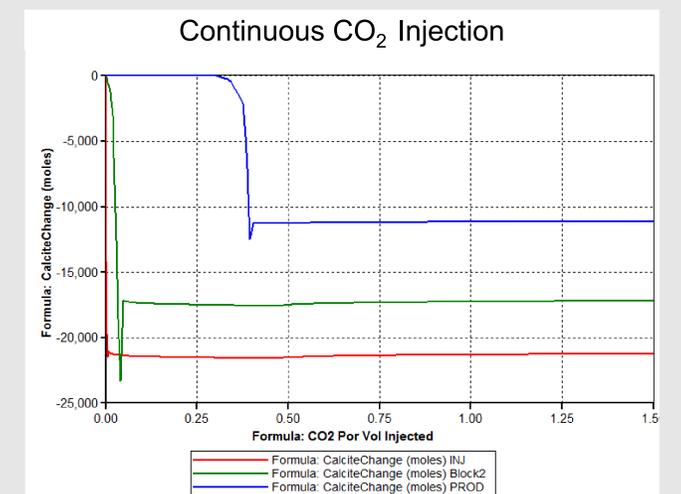
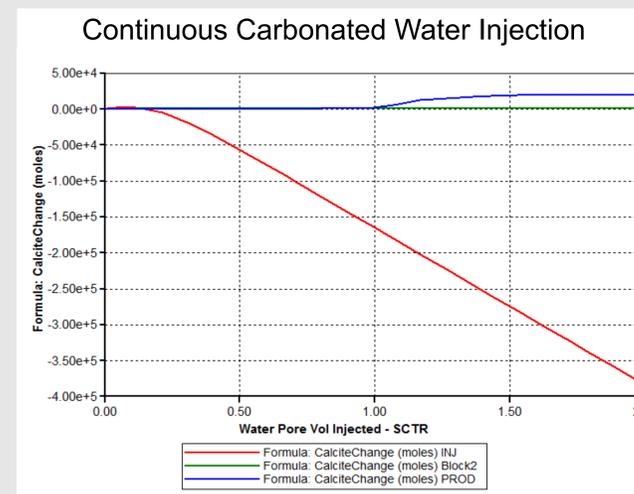
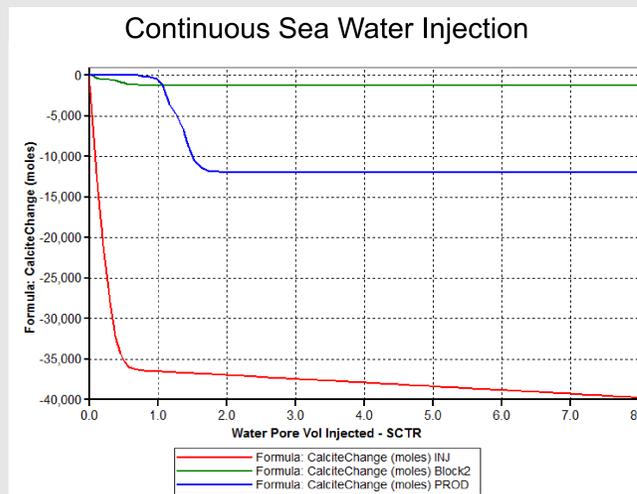
- We performed a reactive transport simulation with injection of Sea Water, CO<sub>2</sub> gas, Carbonated Water and CO<sub>2</sub> WAG in a carbonate reservoir (@60°C, 500 bar) using CMG GEM.

	Carbonated Water	Sea Water	Formation Water
pH	5.429	7.621	5.5
CO <sub>2</sub>	89.38 mM	0.0159 mM	1.036 mM
Ca	32.72 mM	9.929 mM	575 mM
HCO <sub>3</sub>	26.33 mM	0.884 mM	0.146 mM
Na	500 mM	500 mM	2267 mM
Cl	539 mM	519 mM	3508 mM
$\epsilon$	39.11 meq	18.97 meq	1149.9 meq

## 2 Why / PURPOSE

Understanding the chemical interaction between carbonate rocks and carbon dioxide in the aqueous phase has been shown to be very important during CO<sub>2</sub> injection, carbonated water injection or CO<sub>2</sub> water alternating gas (CO<sub>2</sub> WAG) injection processes. In regions with high concentrations of CO<sub>2</sub>, calcite (CaCO<sub>3</sub>) will dissolve, increasing the porosity and permeability of the rock. On the other hand, in regions of high Ca concentrations, combined with lower injection flow, calcium carbonate precipitates, plugging the pores. While **mineral precipitation can reduce reservoir porosity and permeability** and also severely block wellbores, **high dissolution of the rock matrix can lead to formation damage and also CO<sub>2</sub> leakage**. Therefore, a reactive transport model is required for modelling and management of CO<sub>2</sub> projects for both economic and environmental reasons.

## 4 RESULTS



- Porosity increase near the **injector** is higher during **Carbonated Water injection** than for **Sea Water**, while it is limited for **CO<sub>2</sub> gas**.
- Dissolution in the **producer** begins earlier for **CO<sub>2</sub> gas** because it travels faster through the reservoir.
- In the **CO<sub>2</sub> WAG** cycle, dissolution happens only when water is being injected. However, the injected **CO<sub>2</sub> gas** dissolves in the injected water and enhances the dissolution in the **injector**, which leads to precipitation elsewhere, including the **producer**.