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Caprock integrity evaluation for geosequestration of CO2 in low-temperature reservoirs.

AMINAHO, E.N.

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Caprock Integrity Evaluation for Geosequestration of CO_2 in Low-Temperature Reservoirs

By

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Presentation Outline

- ✓ Introduction
- ✓ Aim and Objectives
- ✓ Methodology
- ✓ Results
- ✓ Conclusions
- ✓ Recommendations

Introduction

Carbon dioxide (CO_2) geosequestration – a promising option for reducing atmospheric emissions of CO_2.

CO_2 - stored in aquifers or depleted petroleum reservoirs.

Low-temperature reservoirs: ≤ 100^0C

Acid gases - compressed and stored with CO_2.

Caprock integrity evaluation metric – Brittleness Index.

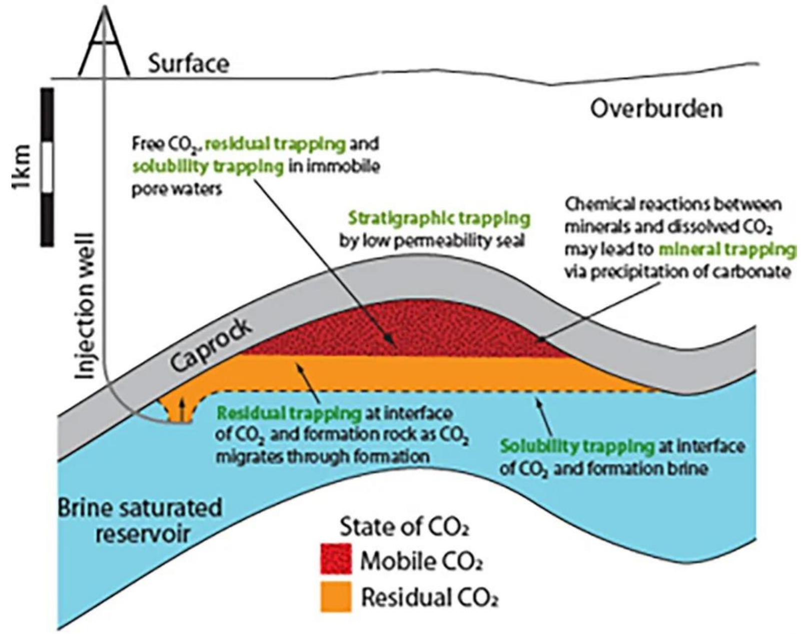

Figure 1: CO_2 storage (https://ukccsrc.ac.uk/ccs-explained/carbon-storage/)

Aim and Objectives

✓ To evaluate caprock integrity and identify suitable reservoirs for CO_2 storage

- Evaluate the impact of impurities in CO_2 on geochemical composition, porosity, and permeability of reservoirs and caprock
- Evaluate the impact of impurities in CO_2 on the brittleness of reservoirs and caprock
- Determine suitable reservoirs for CO_2 storage

Methodology

Mathematical models and numerical simulations.

Mathematical models developed:

$$BI_{min} = \frac{\sum_{j=1}^{nB} \frac{v_j \overline{M}_j}{\overline{V}_j}}{\sum_{i=1}^{nm} \frac{v_i \overline{M}_i}{\overline{V}_i}}$$

$$BI_{bm} = \frac{\frac{v_Q \overline{M}_Q}{\overline{V}_Q} + \frac{0.49 v_F \overline{M}_F}{\overline{V}_F} + \frac{0.51 v_C \overline{M}_C}{\overline{V}_C} + \frac{0.44 v_D \overline{M}_D}{\overline{V}_D}}{\sum_{i=1}^{nm} \frac{v_i \overline{M}_i}{\overline{V}_i}}$$

$\overline{M}$ - Molecular weight [g/mol]
$\overline{V}$ - Molar volume [m^3/mol]
v - Volume fraction
BI - Brittleness index

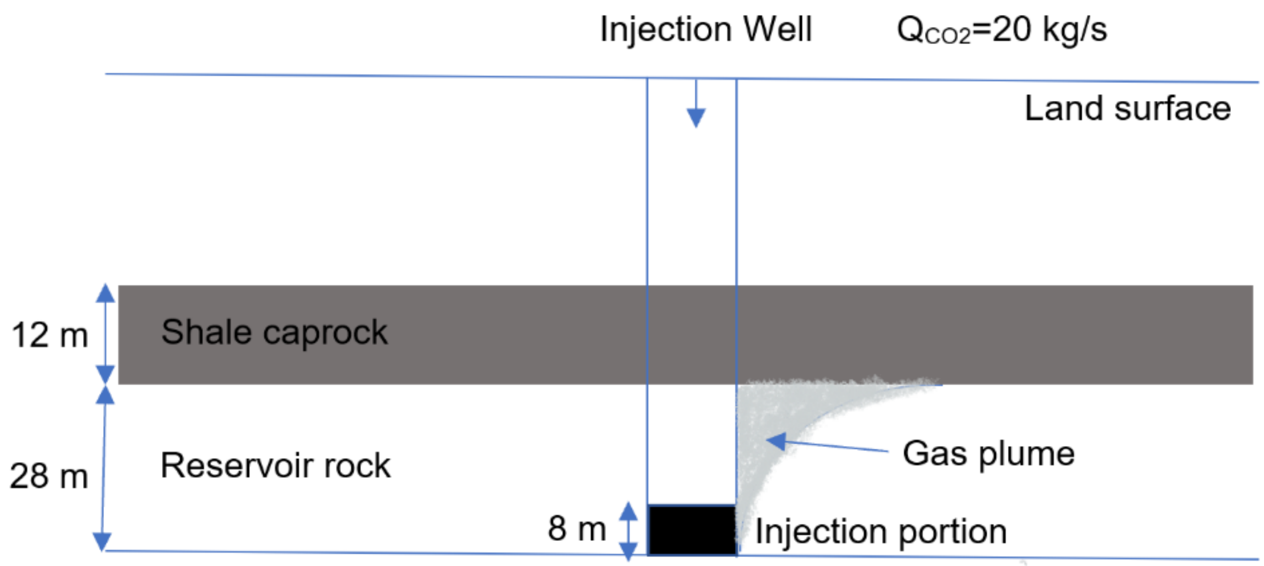

Figure 2: Well flow model for CO_2 geosequestration

Methodology (Cont'd)

Table 1: Hydrogeological parameters.

Parameters	Formation		
	Carbonate	Sandstone	Shale caprock
Porosity	0.34	0.34	0.07
Horiizontal permeability (m^2)	2.264×10^{-12}	2.264×10^{-13}	2.264×10^{-16}
Vertical permeability (m^2)	2.264×10^{-13}	2.264×10^{-14}	2.264×10^{-17}
Pore compressibility (Pa^{-1})	2.10×10^{-9}	2.10×10^{-9}	2.10×10^{-9}
Rock grain density (kg/m^3)	2600	2600	2600
Formation heat conductivity (W/m ^{0}C)	2.51	2.51	2.51
Rock grain specific heat (J/kg ^{0}C)	920.0	920.0	920.0
Temperature (^{0}C)	40.0	40.0	40.0
Salinity (mass fraction)	0.06	0.06	0.06
Pressure (bar)	100	100	100
CO_2 injection rate (kg/s)	20.0	20.0	-
P_0: strength coefficient	19.61 kPa	19.61 kPa	19.61 kPa

Table 3: CO_2 geosequestration cases.

Simulation groups	Injection scenarios	Formation	Salinity
1	CO_2 only	Carbonate and shale	0.06
2	CO_2 and H_2S	Carbonate and shale	0.06
3	CO_2 and SO_2	Carbonate and shale	0.06
4	CO_2 only	Sandstone and shale	0.06
5	CO_2 and H_2S	Sandstone and shale	0.06
6	CO_2 and SO_2	Sandstone and shale	0.06

Table 2: Initial mineral volume fractions.

Mineral name	Chemical formula	Carbonate formation (volume percent of solid)	Sandstone formation (volume percent of solid)	Shale Caprock (volume percent of solid)
Illite	$K_{0.6}Mg_{0.25}Al_{1.8}(Al_{0.5}Si_{3.5}O_{10})(OH)_2$	0	2.80	65.30
Kaolinite	$Al_2Si_2O_5(OH)$	0	0.90	1.11
Smectite-Ca	$Ca_{0.145}Mg_{0.26}Al_{1.77}Si_{3.97}O_{10}(OH)_2$	0	0	6.96
Chlorite	$Mg_{2.5}Fe_{2.5}Al_2Si_3O_{10}(OH)_8$	0	2.70	6.40
Quartz	SiO_2	0	25.80	8.00
K-feldspar	$KAlSi_3O_8$	0	23.30	2.80
Albite	$NaAlSi_3O_8$	0	41.50	3.20
Calcite	$CaCO_3$	40.00	3.00	0.80
Pyrite	FeS_2	0	0	1.43
Dolomite	$CaMg(CO_3)_2$	60.00	0	0
Anhydrite	$CaSO_4$	0	0	4.00
Siderite	$FeCO_3$	0	0	0
Alunite	$KAl_3(OH)_6(SO_4)_2$	0	0	0
Ankerite	$CaMg_{0.3}Fe_{0.7}(CO_3)_2$	0	0	0
Dawsonite	$NaAlCO_3(OH)_2$	0	0	0
Magnesite	$MgCO_3$	0	0	0
Smectite-Na	$Na_{0.290}Mg_{0.26}Al_{1.77}Si_{3.97}O_{10}(OH)_2$	0	0	0
Hematite	Fe_2O_3	0	0	0
Anorthite	$CaAl_2Si_2O_8$	0	0	0
Muscovite	$KAl_2(AlSi_3O_{10})(F,OH)_2$	0	0	0
Oligoclase	$CaNa_4Al_6Si_{14}O_{40}$	0	0	0

Results

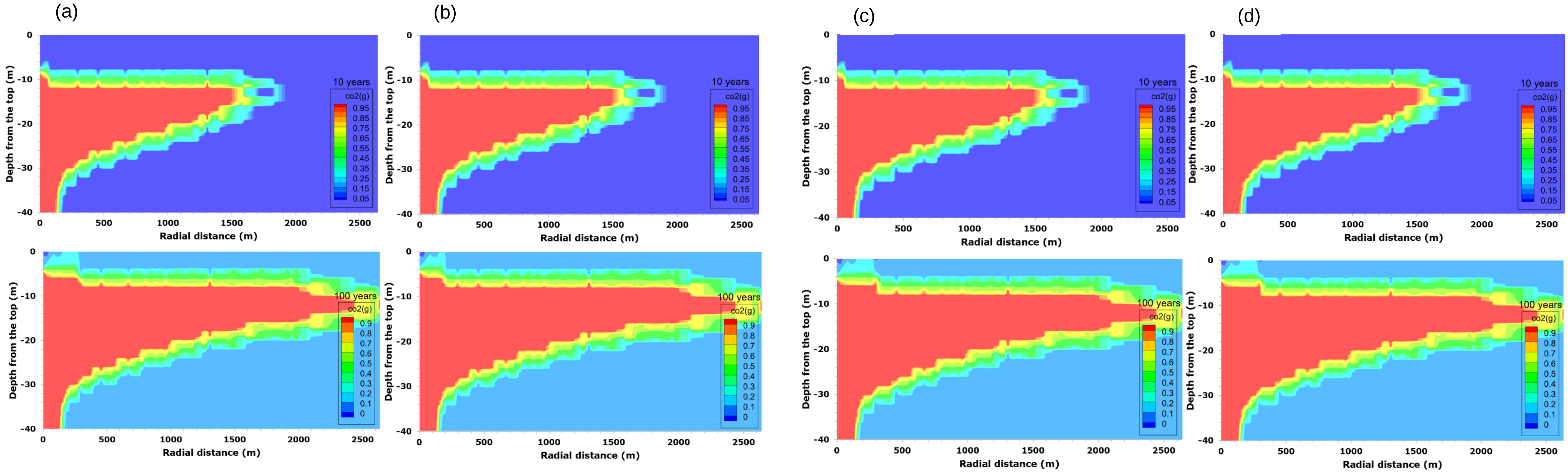

Figure 3: (a) CO_2 in CO_2-H_2S(b) CO_2 in CO_2-SO_2 in the carbonate reservoir; and (c) CO_2 in CO_2-H_2S(d) CO_2 in CO_2-SO_2 in the sandstone reservoir

Results (Cont'd)

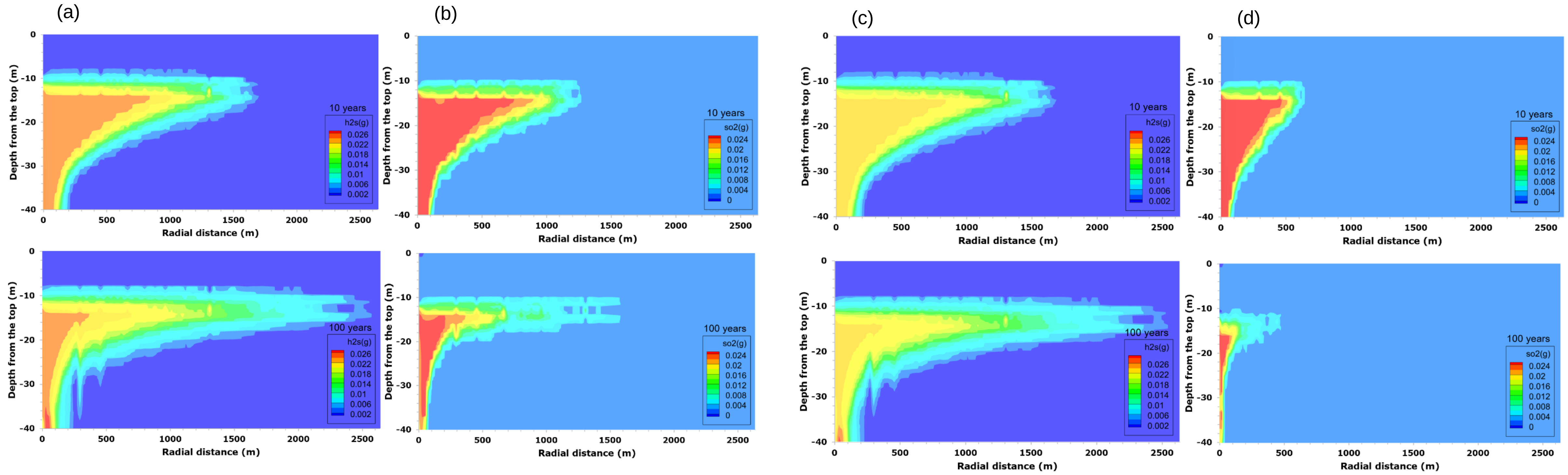

Figure 4: (a) H_2S (b) SO_2 in the carbonate reservoir; and (c) H_2S (d) SO_2 in the sandstone reservoir

Results (Cont'd)

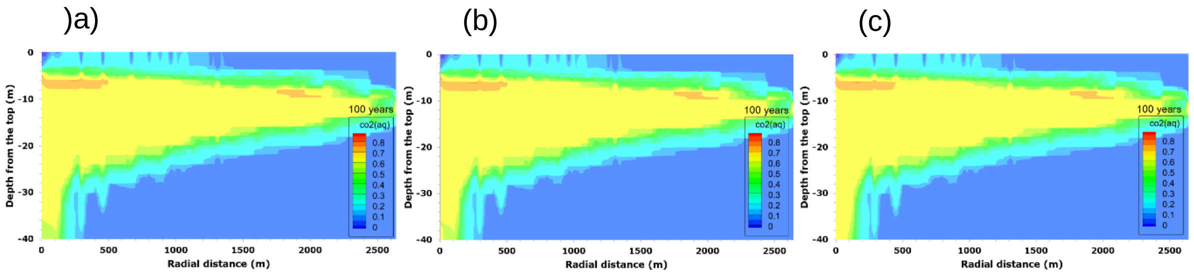

Figure 5: TDC in the carbonate reservoir and shale caprock for (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

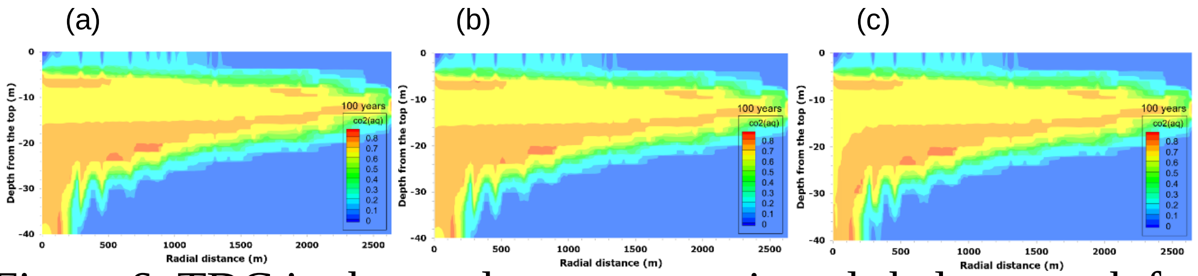

Figure 6: TDC in the sandstone reservoir and shale caprock for (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

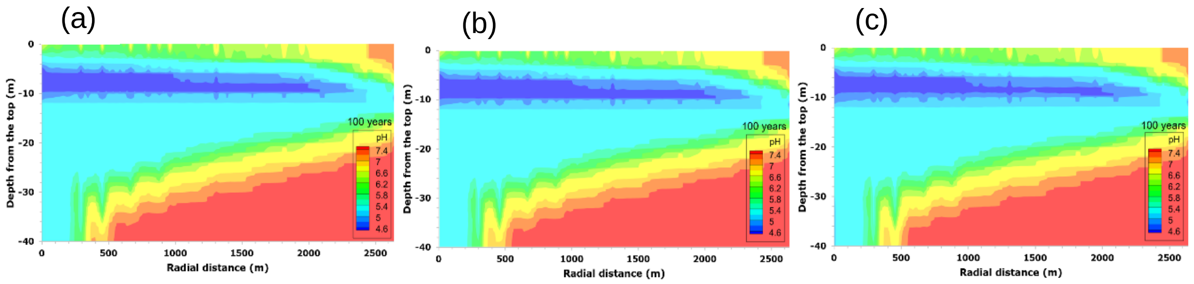

Figure 7: pH in the carbonate reservoir and shale caprock for (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

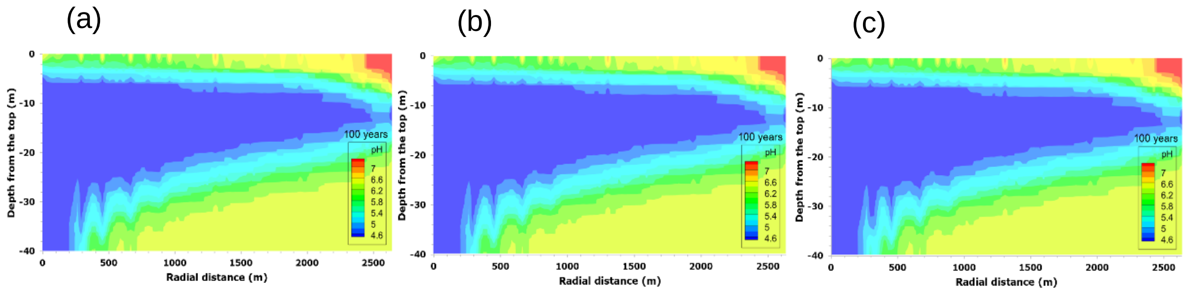

Figure 8: pH in the sandstone reservoir and shale caprock for (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

Results (Cont'd)

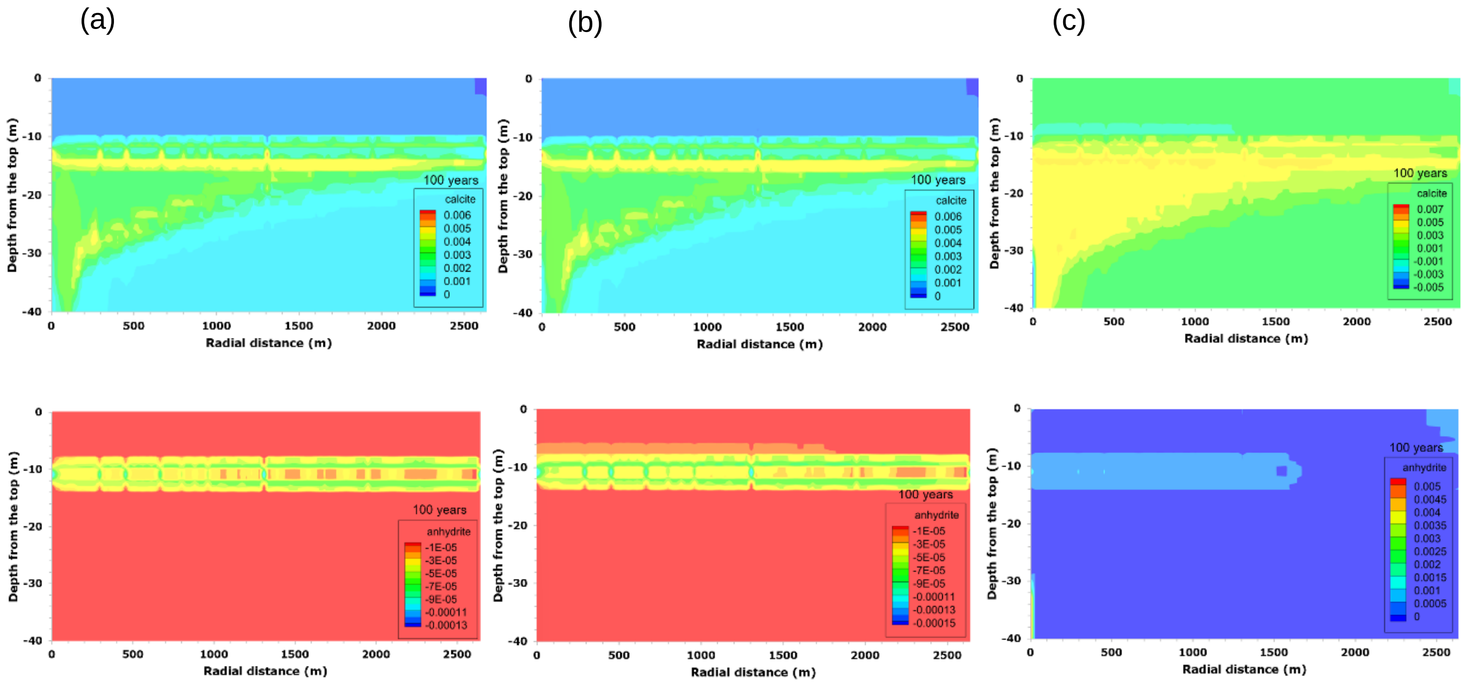

Figure 9: Calcite and anhydrite change in volume fraction in the carbonate reservoir and shale caprock for (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

Results (Cont'd)

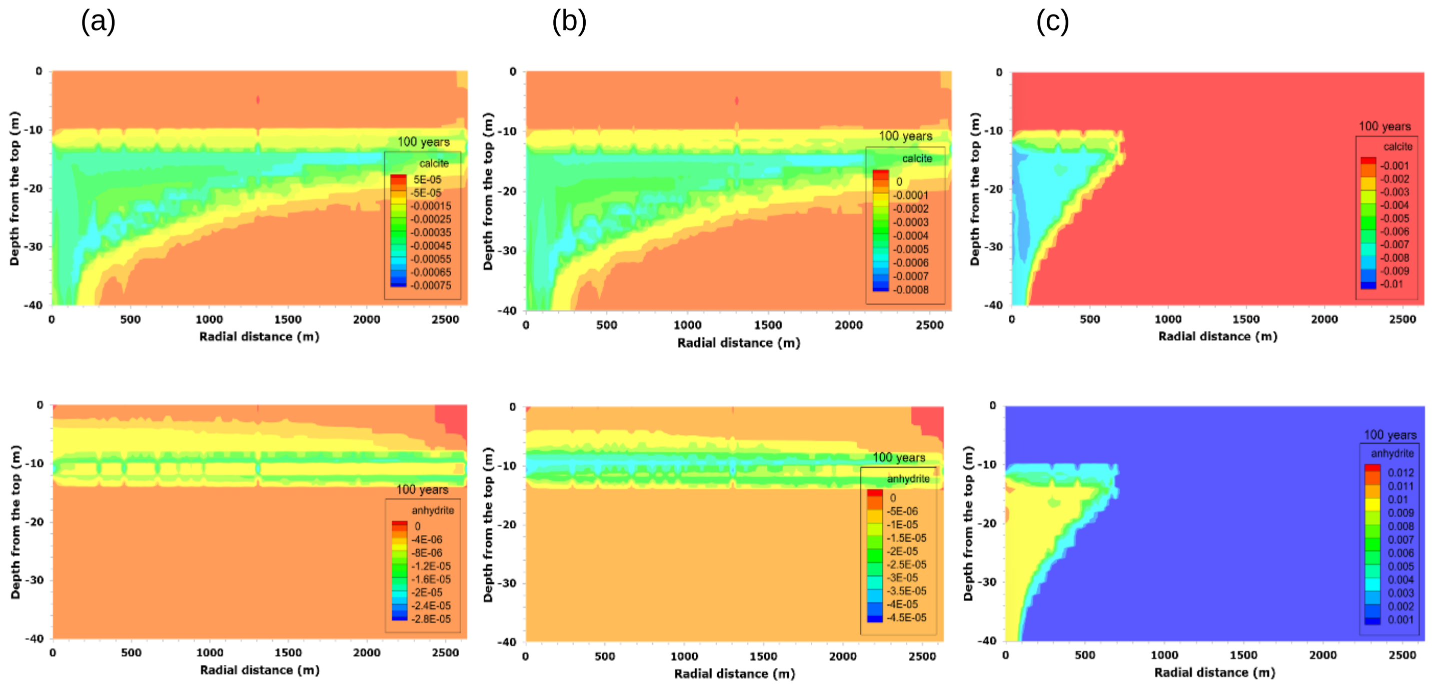

Figure 10: Calcite and anhydrite change in volume fraction in the sandstone reservoir and shale caprock for (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

Results (Cont'd)

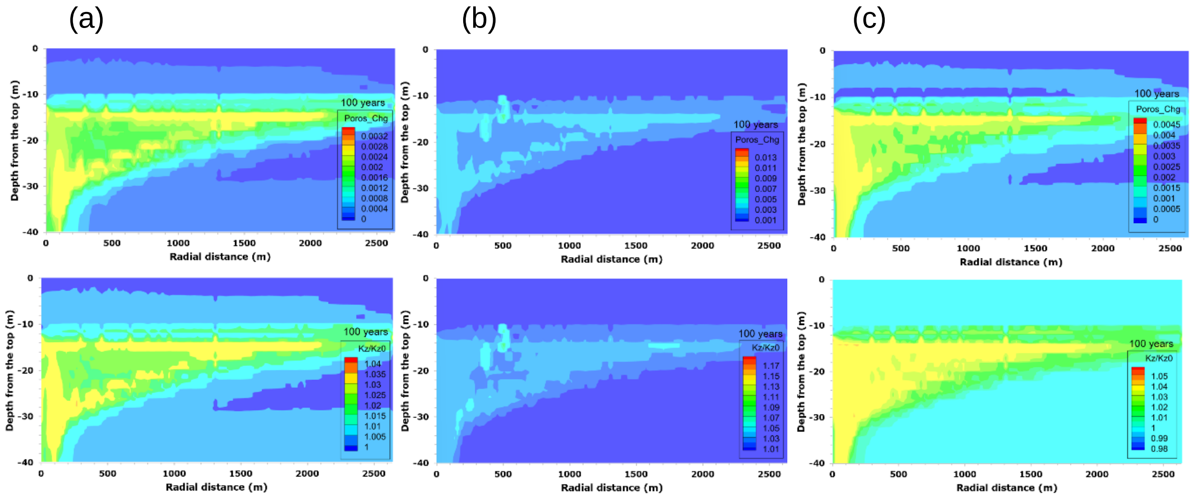

Figure 11: Porosity change and permeability ratio in the carbonate reservoir and shale caprock (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

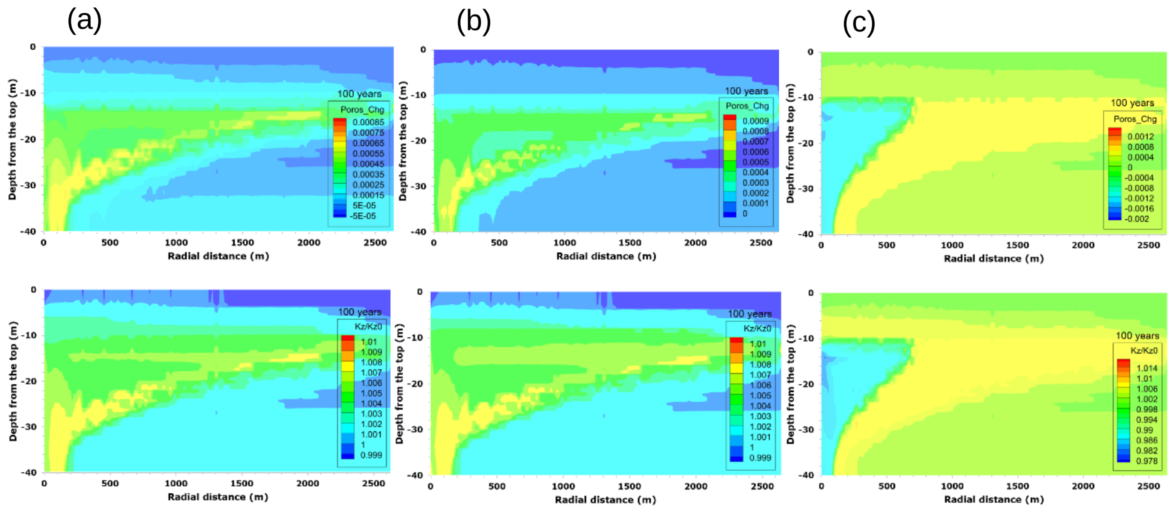

Figure 12: Porosity change and permeability ratio in the sandstone reservoir and shale caprock (a) CO_2 alone case (b) CO_2-H_2S case (c) CO_2-SO_2 case.

Results (Cont'd)

Table 4: Percentage change in porosity and permeability of the reservoirs and caprock

Formation type	Petrophysics	After sequestration, t=100 years		
		CO_2	CO_2-H_2S	CO_2-SO_2
Shale	Change in porosity (%)	0.00 - 0.13	0.00 – 0.16	0.00 – 0.11
	Change in permeability (%)	0.00 - 0.39	0.00 – 0.47	0.00 – 0.34
Sandstone	Change in porosity (%)	0.07 – 0.27	0.06 – 0.25	-ve (0.29 - 0.61)
	Change in permeability (%)	0.28 – 1.09	0.23 – 1.02	-ve (1.18 - 2.40)
Carbonate	Change in porosity (%)	0.21 – 0.76	0.15 – 1.00	0.08 – 1.38
	Change in permeability (%)	0.84 -3.11	0.59 – 4.10	0.32 – 5.68

Results (Cont'd)

Table 5: Brittleness index of the formation before and after CO_2 geosequestration.

Formation type	Brittleness index	Before sequestration, t=0			After sequestration, t=100 years		
		CO_2	CO_2-H_2S	CO_2-SO_2	CO_2	CO_2-H_2S	CO_2-SO_2
Shale	BI_{bm}	0.0377	0.0377	0.0377	0.0375 – 0.0376	0.0375 – 0.0376	0.0374 – 0.0376
Sandstone	BI_{bm}	0.4593	0.4593	0.4593	0.4591 – 0.4592	0.4591 – 0.4592	0.4533 – 0.4551
Carbonate	BI_{bm}	0.4586	0.4586	0.4586	0.4587 – 0.4591	0.4587 – 0.4592	0.4548 – 0.4592

Conclusions

- ✓ SO_2 dissolves more than H_2S in reservoirs, especially in sandstone formations.
- ✓ Anhydrite precipitation is negligible in carbonate reservoirs with high amounts of dolomite.
- ✓ Porosity and permeability of the carbonate reservoir increased during CO_2 geosequestration.
- ✓ The brittleness index of the sandstone reservoir decreased during CO_2 geosequestration.
- ✓ The brittleness index of the shale caprock is low and decreases during CO_2 storage.
- ✓ Carbonate reservoirs may be suitable for short-term CO_2 storage and cyclic storage.
- ✓ Sandstone reservoirs are suitable for CO_2 storage, except for CO_2-SO_2 case in this study.

Recommendations

- ✓ Explore carbonate reservoirs for cyclic injection and withdrawal of CO_2.
- ✓ Investigate changes in rock mechanical properties during the CO_2-SO_2 case.

THANK YOU!

QUESTIONS!!!

Backup Slides

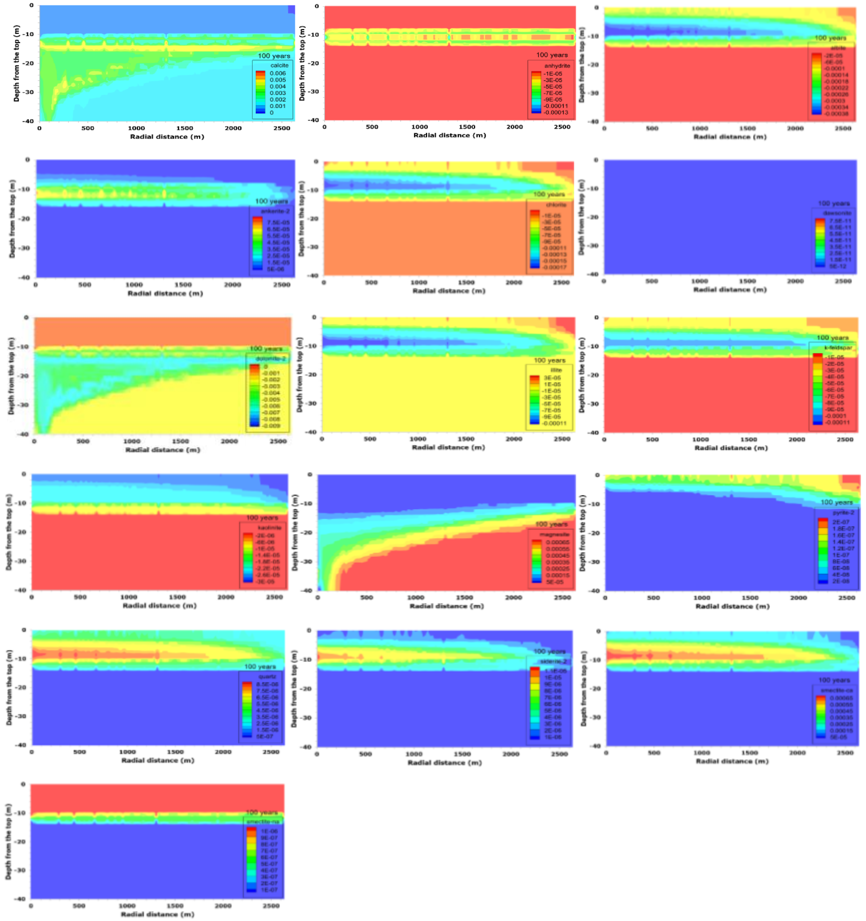

Figure 13: Mineral change in volume fraction in the carbonate reservoir and shale caprock for CO_2 alone case.

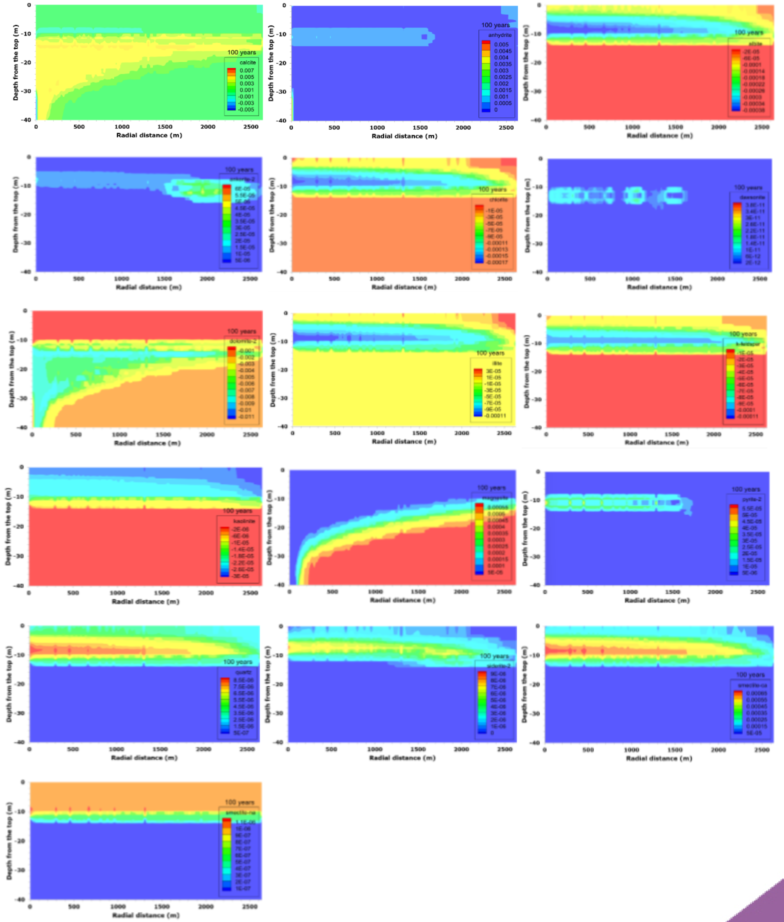

Figure 14: Mineral change in volume fraction in the carbonate reservoir and shale caprock for CO_2-SO_2 case.

Backup Slides

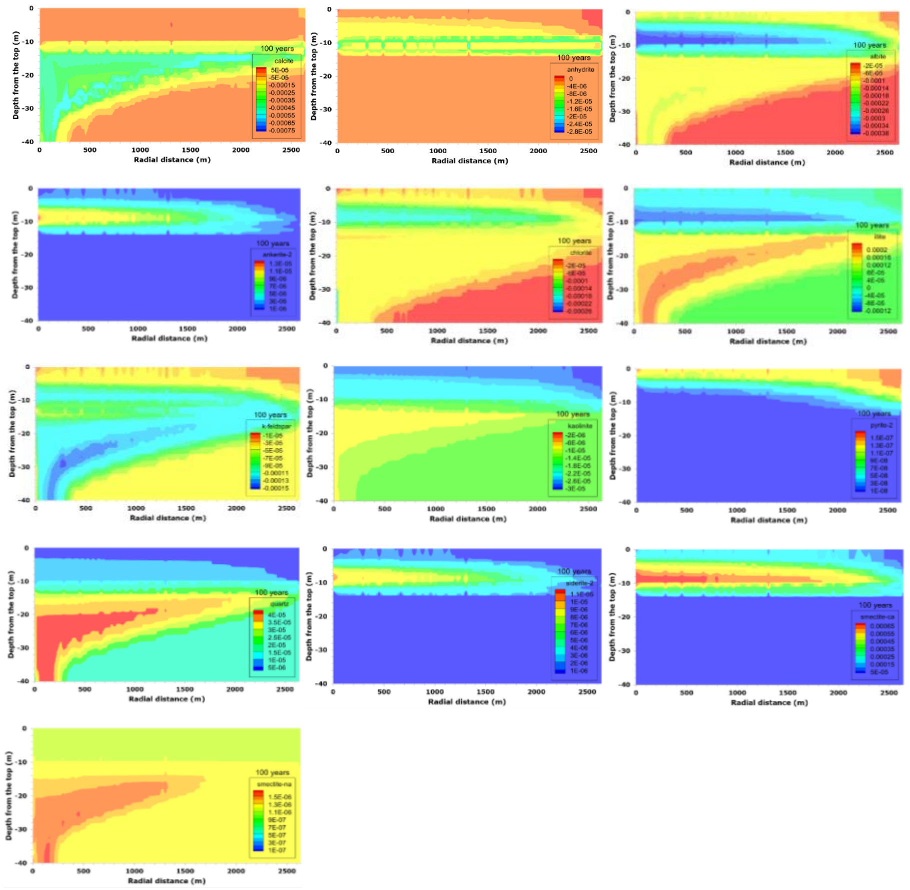

Figure 15: Mineral change in volume fraction in the sandstone reservoir and shale caprock for CO_2 alone case.

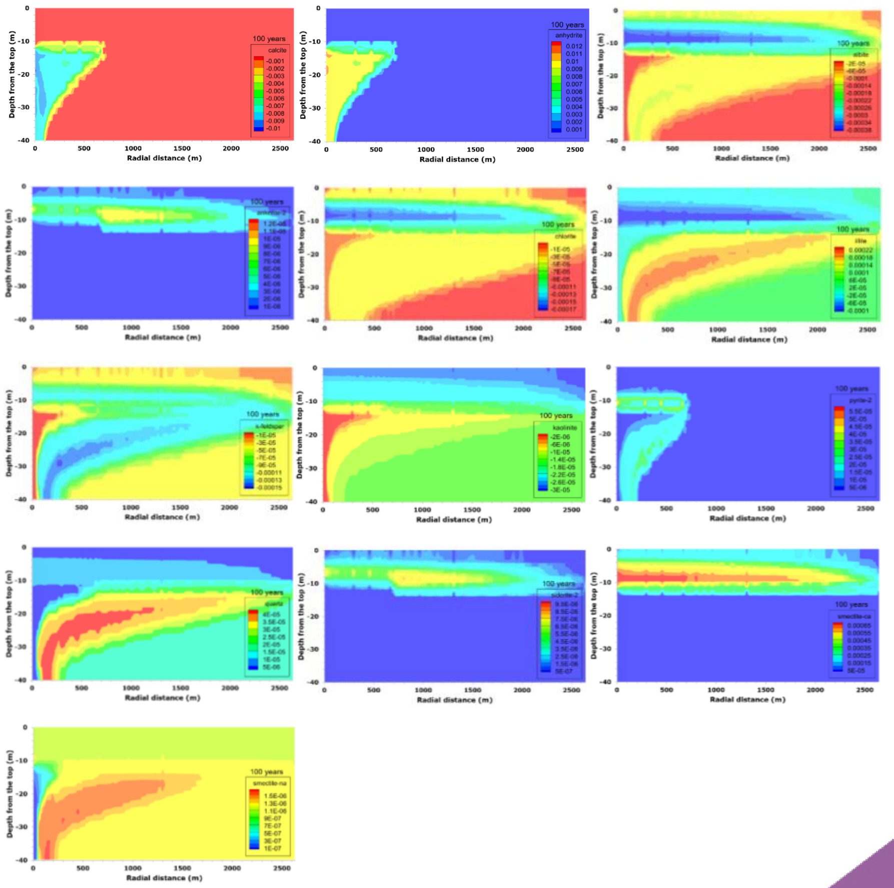

Figure 16: Mineral change in volume fraction in the sandstone reservoir and shale caprock for CO_2-SO_2 case.