SAYINDERE CAP ROCK INTEGRITY DURING POSSIBLE CO2 SEQUESTRATION IN TURKEY

DALKHAA, C.* & OKANDAN, E.
Department of Petroleum and Natural Gas Engineering
Middle East Technical University (METU), Ankara Turkey

INTRODUCTION

The crucial public concern aboout Carbon Capture and Sequestration (CCS) is whether stored CO_2 will leak back to groundwater sources, the surface and finally into the atmosphere. This would be a hazard because CO_2 at high concentrations is hazardous. It would also mean that the process would not be working as a climate change mitigation method

For the prevention of injected CO_2 leakage into atmosphere, the possible paths and the mechanisms triggering these paths must be examined and identified. It is known that the leakage paths can be due to CO_2 - rock interaction and CO_2 – well interaction after massive injection of CO_2.

This study focuses on the CO_2 – cap rock interaction . It is known that the injected supercritical CO2 moves upward with favorable vertical permeability and the buoyancy effects, from the injection point and accumulates under the overlying cap rock after a few years of injection. Once the CO_2 has reached the base of the cap rock it will dissolve into the cap rock formation water and then diffuse vertically upward into the cap rock. The cap rock formation water is acidized as the CO_2 dissolves in it. The acidification due the solubility of CO_2 into brine results in geochemical reactions with the rock minerals present in the cap rock.

Geochemical reactions between dissolved CO_2 and the minerals present in the cap rock lead to porosity and thus permeability changes. Porosity can be increased due the dissolution of initial cap rock minerals in the acidized formation water whereas it can be decreased as a result of the precipitation of secondary minerals (minerals which are not available at the beginning of the reaction). A porosity increase would be undesirable since this would make the injected CO_2 leak through the cap rock. However, a porosity decrease is an advantage, which would further increase the sealing capacity of the cap rock.

OBJECTIVE

The objective of this research is to identify the geochemical reactions of the dissolved CO_2 in the synthetic formation water with the rock minerals of the Sayindere cap rock by laboratory experiments. It is also aimed to model and simulate the experiments using ToughReact software. The Sayindere formation is a regionally extensive cap rock for many oil fields in southeastern Turkey.

MATERIALS AND METHODS

- Collection of necessary materials for the experimental work
  - -cores from Sayindere cap rock formation
  - -formation water analysis results of Caylarbasi Field
- Preparation of synthetic formation water
- Fluid chemistry analysis *(prior to and after the experiment)* to measure the available dissolved elements in the formation water by following techniques:
  - IC
  - ICP-EOS
  - titration
  - pH
- Mineral investigation *(prior to and after the experiment)* to identify the rock compositions by
  - Thin section analysis
  - SEM (Scanning Electron Microscopy)
  - XRD (X-Ray Diffraction)
- Carry out the static and dynamic experiments
- Geochemical modeling and simulation using TOUGHREACT

EXPERIMENTAL INVESTIGATION

THE STATIC EXPERIMENT

In static experiment, two original cores from Sayindere cap rock are put in the core holders separately and filled with CO_2 saturated synthetic formation water and are left for 30 days and 100 days under a pressure of around 100 bar (1450 psia) and a temperature of 90°C, representing the field conditions.

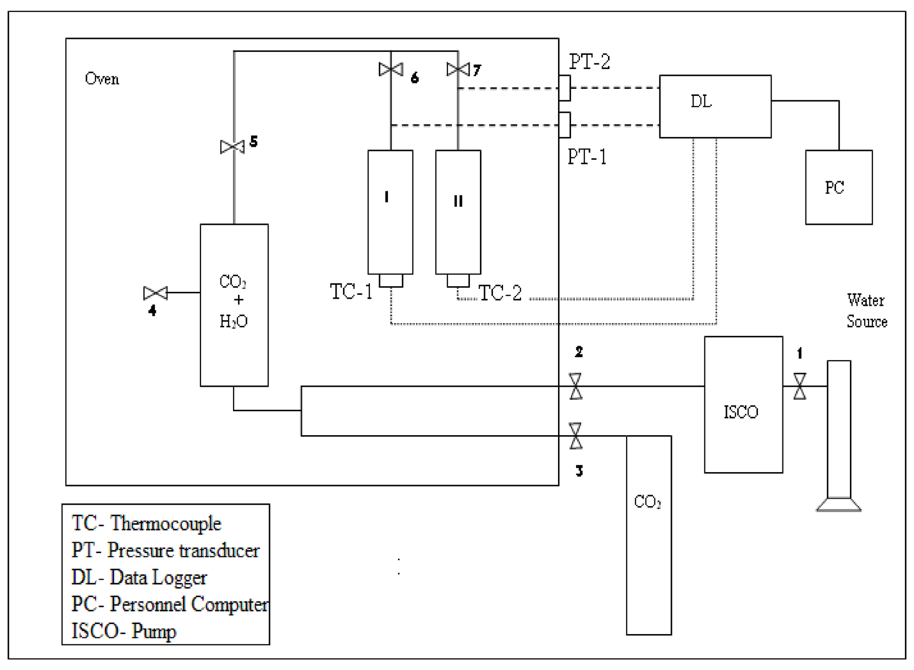

Fig 1. Scheme of static experiments

Fig 2. Photo of static experimental set-up

From the SEM photos, it is seen that near to surface part of the core is looser than the inner part due to the CO_2 diffusion process (Fig. 3). Also, there is a deposition layer on the surface of core in 100 day experiment, which is seen as lighter coloured layer (Fig 4).There are also wormholes created on the core surface due to heteregenous dissolution pattern of calcite. (Fig 5)

Table1. Water compositions prior to and after the 30-, 100- day experiments

	Prior to the 30-day experiment	After the 30-day experiment	Prior to the 100-day experiment	After the 100-day experiment
	(ppm)		(ppm)	
Sodium	693.2	752.7	693.2	616.7
Calcium	41.92	382.2	41.92	335.2
Magnesium	47.36	152.1	47.36	52.94
Iron	1.19	0.443	1.19	0.591
Sulfate	15	117.18	15	202.58
Chloride	725	903.26	725	642.75
Bicarbonate	613	619	613	628
Silicon		16.14		

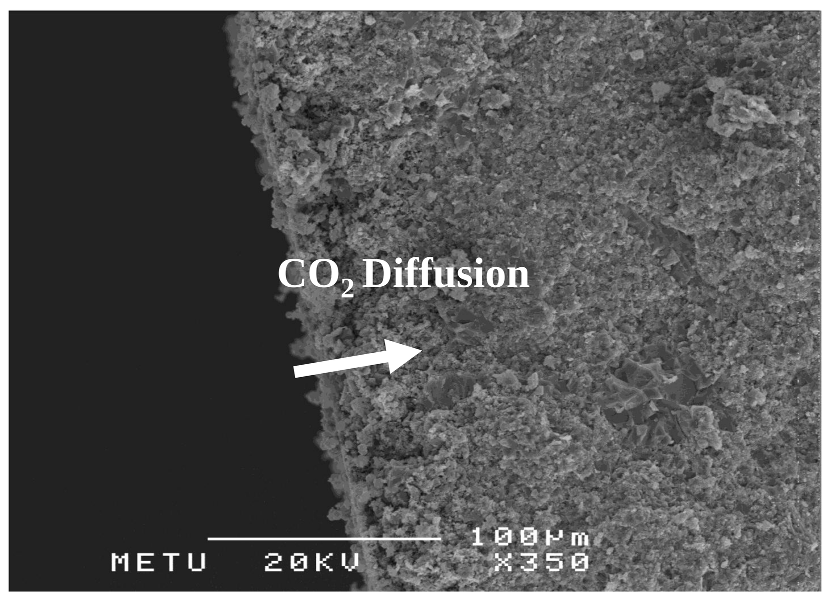

Fig 3. CO_2 diffusion intocore after 30 days

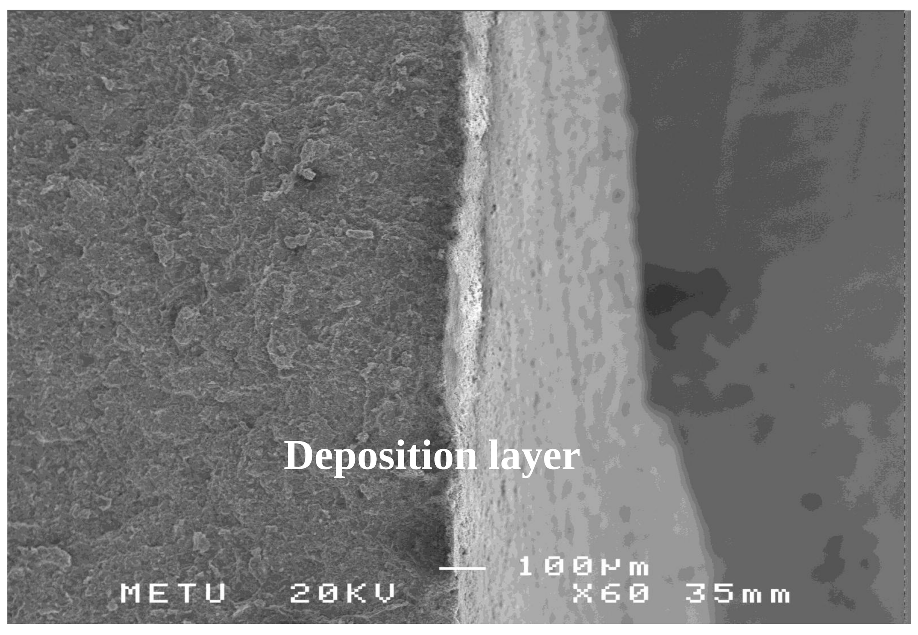

Fig 4. Deposition layer on the core surface after 100 days

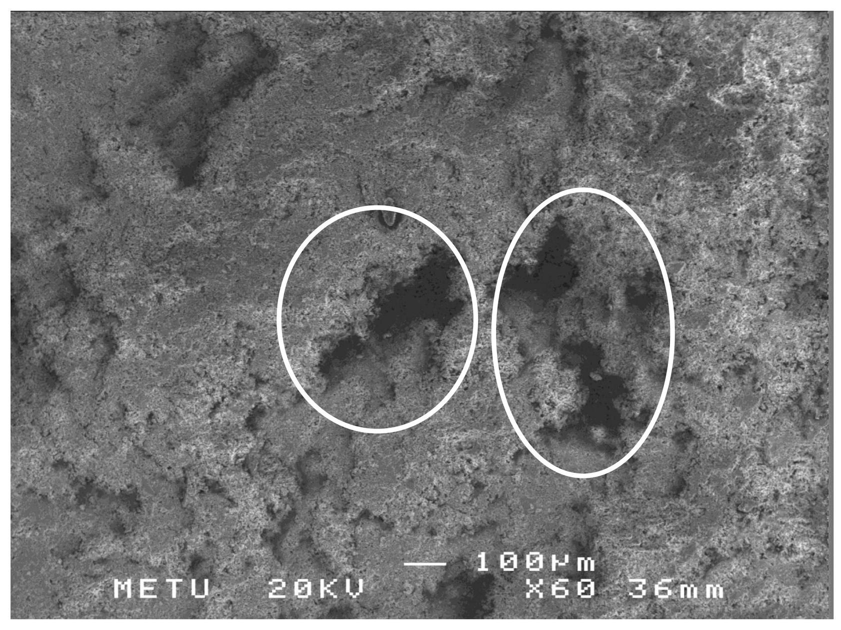

Fig 5. Wormholes created due to calcite dissolution after 100 days

It explains:
The Ca bearing minerals are dissolved into the CO_2 saturated formation water. From the water analysis given in Table 1, the Ca ion concentrations increased from 41.92 ppm to 382.2 ppm through the first 30 days, and after the 100 days, the Ca ion concentration ion is 335.2 ppm.
(The elemental analysis of the SEM-EDX also supports the explanation given above.)

DYNAMIC EXPERIMENT

- Core was grinded into less than 60 mesh size -250 micron
- XRD analysis of the powdered core was made.
  XRD Analysis reveals: *76% Calcite, 22.7 % Quarts and 1.3% Kaolinite*
- CO_2 and water mixture is being injected to the packed core at constant pressure of 75 bar and temperature of 90° C
- The fluid is being produced at around 0.01 cc/min under 1 bar pressure difference
- Produced water analyses(ICP-OES, IC, pH and titration) was made at different times; 23, 75, 99 days
- From the water analysis, it is also observed that calcite is dissolved

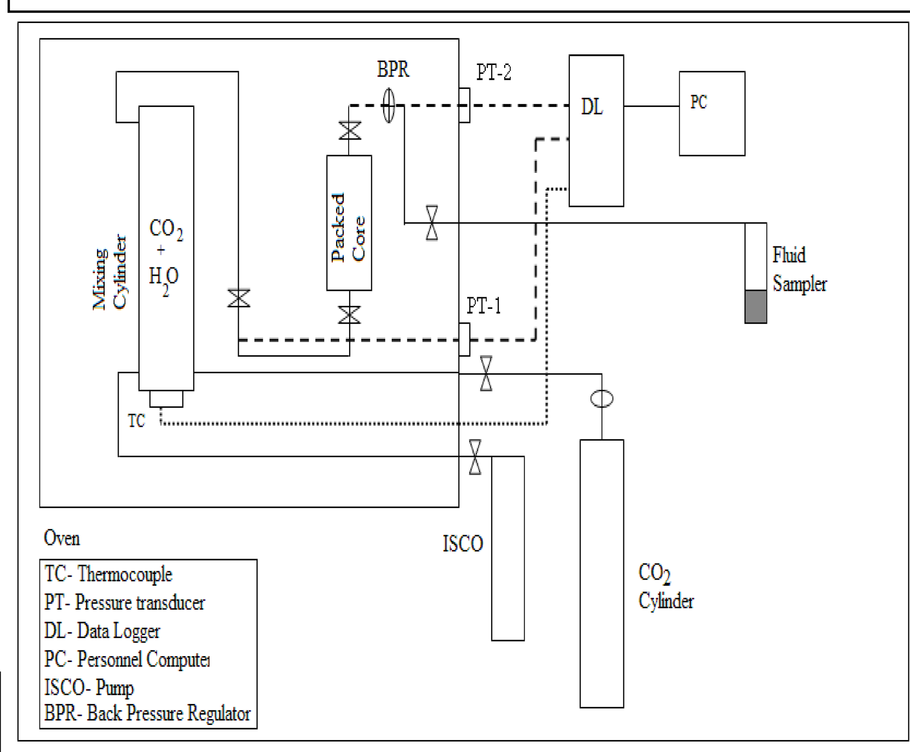

Fig 6. The scheme of the dynamic experiment

Table 2. Water analyses of the dynamic experiment

	ppm (prior to the exp.)	ppm (after 23 days)	ppm (after 75 days)	ppm (after 99 days)
Sodium	519.0 2.1	602.6 11.2	509.4 9.2	568 6.6
Calcium	37.5 0.6	219.9 3.1	87.95 1.73	35.29 0.01
Magnesium	45.0 0.3	52.97 0.33	44.99 0.33	52.63 0.96
Iron	0.05 0.002	0.081 0.001	0.146 0.004	0.676 0.004
Sulfate	14.0806	477.3	26.79	25
Chloride	746.886	723.25	840.58	979
Bicarbonate	658	74	866	732
Normal carbonate	-	444	-	
Silicon		21.72 0.19	17.58 0.16	5.55 0.03
pH (24 C)	7.789	8.360	6.678	5.928

REACTIVE TRANSPORT MODELING & SIMULATION

The modeling and simulation study of the dynamic experiment is carried out by using the code TOUGHREACT. In addition to the simulation of the injection, the CO_2 saturated water injection into the packed core minerals of the Sayındere formation is stopped after 99 days of the injection and the further simulation is continued for 25 years to monitor the cap rock mineralogical and the water chemistry evolutions and particularly, the long term effect on the porosity and permeability of the packed Sayındere core.

The porosity and permeability are increased by 0.001% and 0.004%, respectively. From the point of view of the monitoring CO_2 storage after the injection and risk assessment associated with the CO_2 storage, the porosity and permeability increases as results of the geochemical reactions induced of CO_2 storage are not desirable since these increases can result in possible leakage paths for the CO_2 to escape into groundwater sources and finally into the atmosphere back. The increases in porosity and permeability show that the Sayındere cap rock integrity must be monitored in the field if application is planned.

ACKNOWLEDGMENT

The Scientific and Technological Council of Turkey (TUBITAK) is greatly acknowledged to award Dalkhaa, one of the authors, the Phd Fellowship for Foreign Citizens. Petroleum Research Center (PAL) and Department of Petroleum and Natural Gas Engineering, METU are also acknowledged to provide the financial and technical supports to carry out this work.

Contact: Chantsalmaa Dalkhaa, dchantsa@gmail.com, Applied Geochemistry Group, Department of Geoscience, University of Calgary, Alberta, Canada Prof.Dr. Ender Okandan, okandan@metu.edu.tr, Department of Petroleum and Natural Gas Engineering, Middle East Technical University, 06531 Ankara Turkey.