Laboratory CO_2 injection in Utrillas Sandstone (Cretaceous): Analysis of changes in porous media using Hg porosimetry

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Deep geological storage of CO_2 is a promising option to mitigate greenhouse gas emissions in the atmosphere. The most favourable sites for the definitive storage of CO_2 in the Iberian Peninsula are deep saline aquifers and the Utrillas Formation in the Mesozoic basement of the Duero Basin (central Spain) is a promising rock formation for CO_2 storage.

PmaCO2 — Porosity and CO_2 trapping mechanisms project

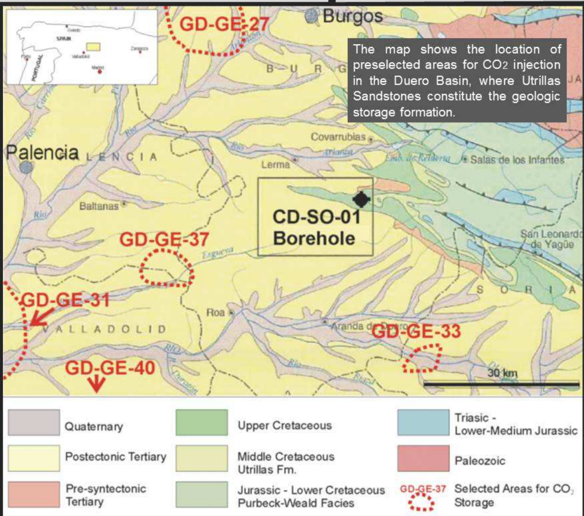
The aim of this project is the characterisation the Utrillas porous system before and after CO_2 injection to understand the trapping mechanisms.

There are four types of trapping mechanisms of CO_2

- Structural-stratigraphic
- Residual
- Dissolution
- Mineral trapping.

Mineral trapping is important to long term, whereas the first three mechanisms dominate to short and medium terms.

The rock microstructure plays an important role in the trapping of CO_2. Accurate knowledge of the microstructure is essential for determining the storage capacity and efficiency of CO_2 transport or retention for a rock.



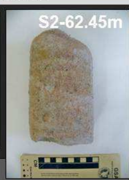
The map shows the location of preselected areas for CO_2 injection in the Duero Basin, where Utrillas Sandstones constitute the geologic storage formation.

1. Evaluate this system as a potential CO_2 storage formation.
2. Estimate the storage capacity of these systems.
3. Assess the retention mechanisms and changes after injection of CO_2.

Changes in the pore space microstructure can not only significantly modify the storage capacity but also change the pattern and velocity of movement or the fluid through a rock.

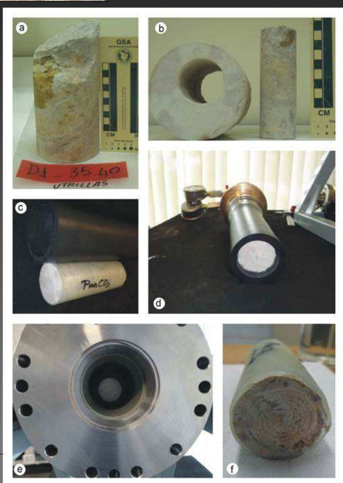
The goal of this study is to determine variations in pore space microstructure caused by the injection of CO_2 in supercritical state in two samples of sandstone of almost identical chemical composition and different texture. We want to remark the key role of the initial rock texture in determining variations in the pore space and trapping mechanisms.

The Utrillas Sandstones is a sedimentary siliciclastic formation whose age is located at the Lower-Upper limit of the Cretaceous. The lithological, structural and geometric characteristics of Utrillas Sandstones make it a favourable geological formation for CO_2 injection and storage. Sampling rocks was carried out in the CD-S0-01 borehole to 35.4 and 62.45 m depth in a fine and medium-coarse grain facies respectively.

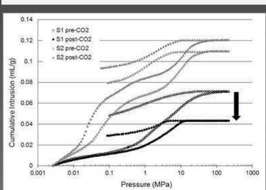


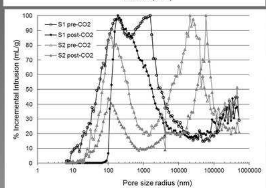
We have studied two Samples. The **S1 and S2 pre-injection** represents the original state before the injection and **S1 and S2 post-injection** represents the state after injection.

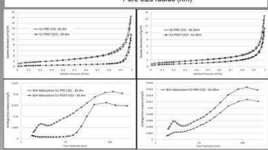
The injection experiment was performed using a core sample resized to ø=38 mm and 100 mm length. The sample was saturated in synthetic saline water (brine), before being put into the CO_2 injection cell. The synthetic water was prepared specifically for this experiment by IMDEA-Agua. The hydrogeochemical code PHREEQC, developed by the U.S. Geological Survey (USGS), was used to model the water chemistry.



To carry out the experiment, a thermo-resistant cover was put on the dry sample. Then, both were put inside a Viton cylinder with high elasticity, high resistance to aggressive fluids and high temperatures. After, the sample in the Viton was placed inside the injection cell. The injection cell was built for this type of test for the Petrophysical Institute Foundation, with which we have collaborated on the project. Once the sample was saturated with brine, the injection cell was connected to supercritical carbon dioxide generator with the injection and evacuation or production valves opened. This way, displacement of the brine due to the injection of CO_2 was simulated. Once the sample with CO_2sc was saturated, the cell remained closed for two months with pressure (8Mpa) and temperature conditions (32ºC) controlled daily.







The resulting variations in porosity and pore distribution and size were analyze and verified by Hg porosimetry. These results were confirmed by N_2 adsorption.

Following the test, significant changes in the pore space were found, which in turn produced variations in the storage capacity and CO_2 flow pattern through the rock. The reduction in porosity affected a large volume of pore space, but in a selective way, mainly to mesopores in fine grained sandstone. A moderate increase of porosity, along with a reduction in the size of the smallest pores was observed in the thick grained sandstone sample.

A decrease in the BET and micropore area was observed in the two samples of sandstone before and after the CO_2 injection.

	Spc.	Total Intrs.Vol. x 10^{-3} (m^3/kg)	Total Pore Area x 10^3 (m^2/Kg)	Average Pore Diameter (2V/A) (nm)	Porosity (%)	Charact. length (µm)	Tortuosity
S1 - pre CO2	1	0.073	1.79	81.50	15.93	3.4E+05	7.30
	2	0.068	1.54	87.80	15.02	4.2E+05	6.96
	3	0.074	1.52	97.30	16.10	2.8E+05	9.03
	4	0.066	1.71	77.40	14.76	3.8E+05	8.53
	5	0.065	1.56	82.70	14.49	3.3E+05	7.34
	6	0.081	1.50	108.10	17.55	3.8E+05	8.02
	Averg.	0.071	1.60	89.13	15.64	3.5E+05	7.86
S1 - post CO2	1	0.056	0.29	380.40	12.24	4.7E+05	3.78
	2	0.034	0.33	208.60	7.88	4.5E+05	4.32
	3	0.036	0.30	239.40	8.28	4.2E+05	4.21
	4	0.053	0.31	347.00	11.73	3.3E+05	4.64
	5	0.048	0.51	185.60	10.56	3.8E+05	4.05
	6	0.032	0.35	185.00	7.49	3.3E+05	4.49
	Averg.	0.043	0.35	257.67	9.70	4.0E+05	4.25
S2 - pre CO2	1	0.109	1.37	319.60	22.06	3.4E+05	4.26
	2	0.113	1.18	382.50	22.37	3.4E+05	4.62
	3	0.119	1.20	395.70	23.53	4.8E+05	4.14
	4	0.111	1.40	317.50	22.20	5.2E+05	4.38
	5	0.099	1.42	278.60	20.37	2.8E+04	5.97
	6	0.106	1.52	278.70	21.29	4.7E+05	3.84
	Averg.	0.110	1.35	328.77	21.97	3.6E+05	4.54
S2 - post CO2	1	0.118	1.47	323.40	23.08	5.1E+05	4.36
	2	0.112	1.33	336.10	22.44	6.5E+04	4.05
	3	0.125	1.30	383.80	23.60	3.6E+05	4.22
	4	0.114	1.31	347.40	22.47	4.7E+05	4.19
	5	0.125	1.30	384.20	23.95	2.7E+05	5.21
	6	0.127	1.34	380.40	24.18	8.1E+04	3.24
	Averg.	0.120	1.34	359.22	23.29	2.9E+05	4.21

The most plausible cause for the mesoporosity loss is mineral precipitation in the pores of smaller size. The reduction of porosity and subsequent reduction of their effective storage capacity after CO_2 injection should be taken into account when assessing the potential formations for geological CO_2 storage.

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