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II Coloquio Hispano-Francés sobre

Almacenamiento Geológico de CO_2

Ponferrada España

24 ▸▸ 26 OCTUBRE 2011 PONFERRADA

24 > 25 : Coloquio

26 : Monográfico Hontomín

THE UNIVERSITY OF A CORUÑA

Permeability Change Associated to the Injection of CO_2-saturated Distilled Water Through Siliceous Sandstone from the Arcera Formation (Burgos, Northern Spain)

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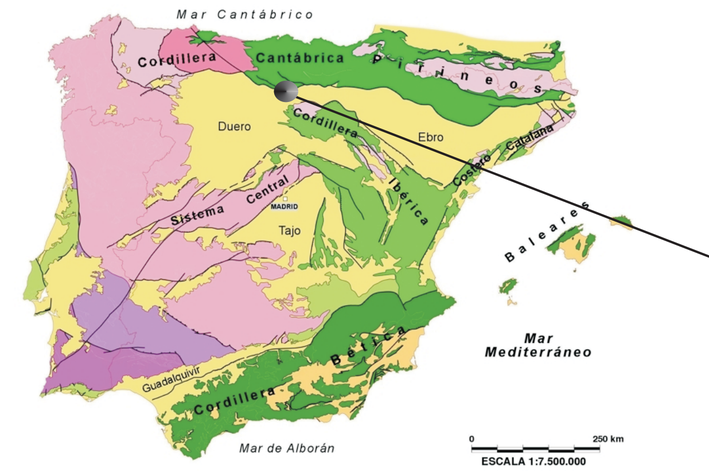
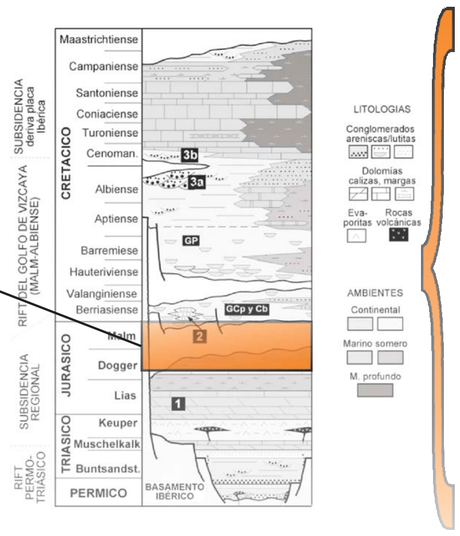
Rock Properties and Sample Preparation



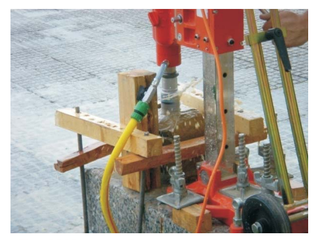


- UTM-X: 0414003
- UTM-Y: 4747617
- Sample I.D.: A 1.3
- Medium-coarse grained sandstone in 0.5 to 1 m thick banks and large-scale cross bedding.
- Apparent density: 2430 kg/m^3
- ϕ_{mean}: 8.25 % (7.3 % in the tested sample)
- Mineralogy (% volume - DRX):
  - Quartz: ~80.2 %
  - Muscovite: ~8 %
  - Microcline: ~3.2 %
  - Fe oxides: ~8 %
  - Clay minerals: ~0.08 %
  - *Calcite: ~0.44 % (estimated from LOI-FRX)*

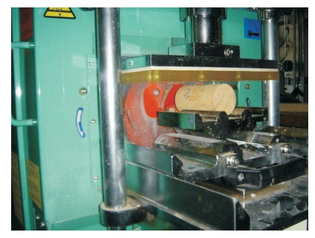
- **High permeability (~500 mD – 500/1000 mD; Levosen, 1967)**
- **Poor reservoir rock (ϕ~8 % – 5/10 %; Levosen, 1967)**

(Levosen, A. I. (1967) Geology of Petroleum. W. H. Freeman Ed.)

Rock block slicing



Drilling the rock block

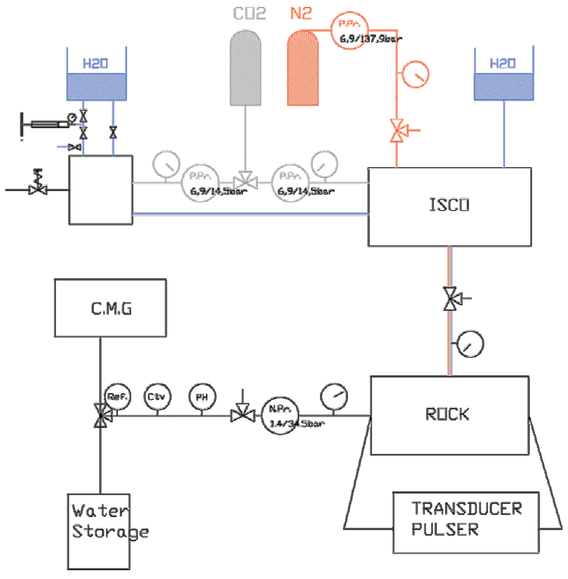


Plug facing

Dimensional verification

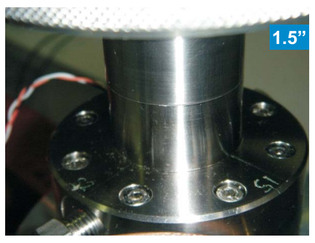
The rock studied belong to a detritic formation associated with secondary reservoir of the Hontomín TDP. The sample is made of mineral phases of relatively low reactivity but with a good hydraulic conductivity. Its porosity is not high enough to be considered a good reservoir formation althoght the pore space is well conected. The tested core plug was obtained from an outcrop assumed representative of the deep formation.

Experimental Device

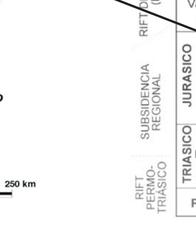


Isco pump (pore pressure)

Modified Hoek cell with sleeve

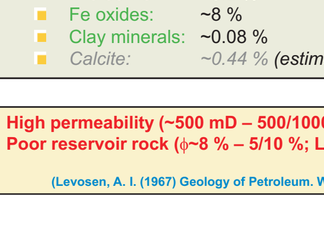


Inyection platens w. P and S wave transducers



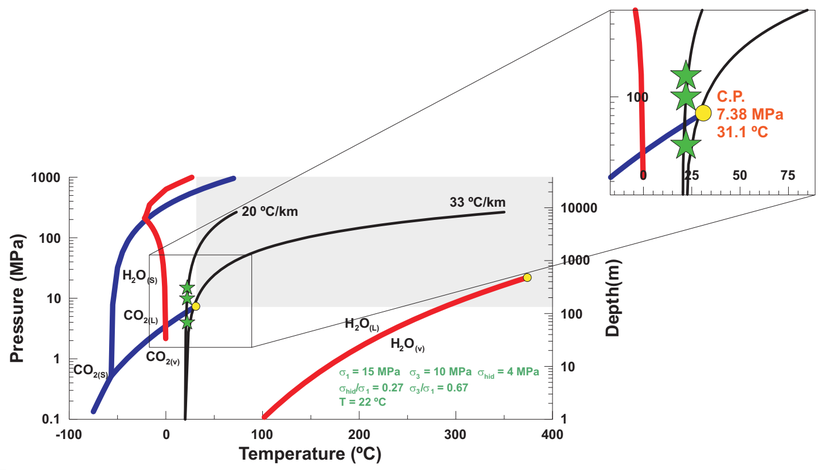
Gas mass flow meter (Agilent Technologies)

DAS for microelectrodes array (NICO 2000)



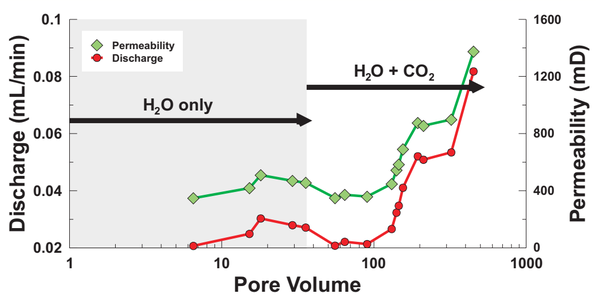
Low P microelectrodes array

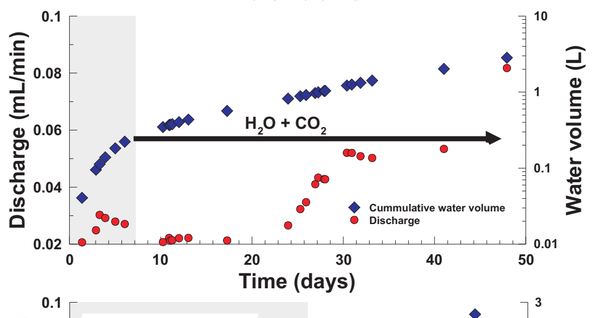
Experimental Conditions & Stages

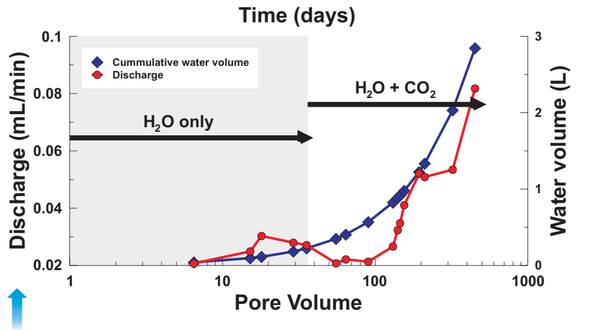


The experimental stages were: a) N_2 injection for the determination of permeability and measurement of sonic velocities in the dry sample; b) Saturation with distilled water; and c) injection of CO_2-satured distilled water. The pore pressure outlet was kept at atmospheric pressure, room temperature (~22 ^{0}C). Therefore, prevailing conditions are subcritical.

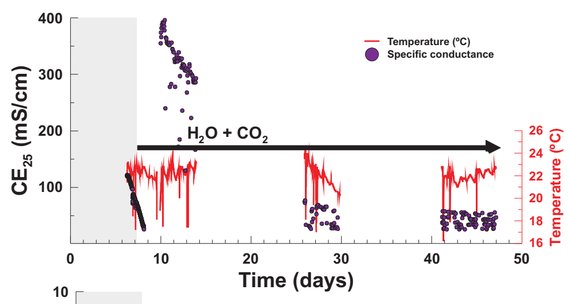
Results and Discussion

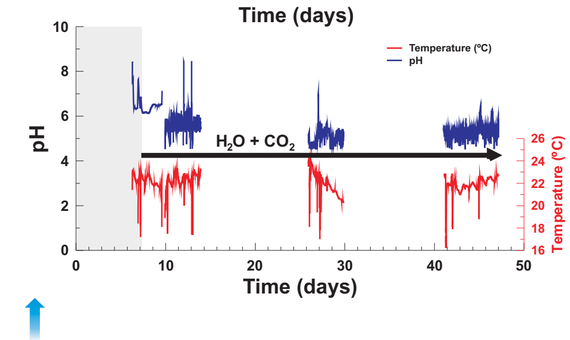






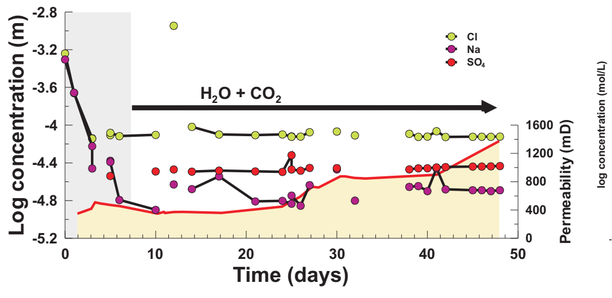
Nearly 500 pore volumes circulated through the sample. In the H_2O-only injection phase, a slight permeability increase is observed due to the dissolution of readily soluble salts present in the sample. After ~100 PV,during the CO_2 inyection stage, it suddenly increases. Since the beginning to the end of the experiment, the permeability increased by a 3-fold factor.

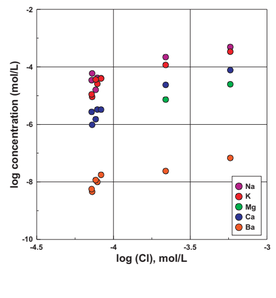


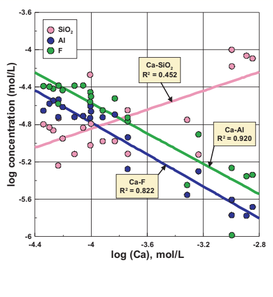


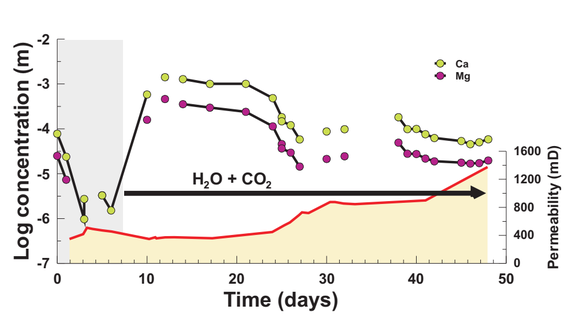
The results look consistent, with a “steady” pH value at room conditions close to 5.5. The noise in the signal is due to the bubbling caused by the despressurization. CE_{25} shows an interesting evolution: a) washout of readily soluble salts (H_2O-only flooding stage); b) sudden increase due to the arrival of CO_2-saturated water and dissolution of mineral carbonates; c) decrease as carbonate minerals become exhausted.Finally, steady background CE_{25} seems to be linked to the less significant contribution of solutes through the dissolution of silicates.

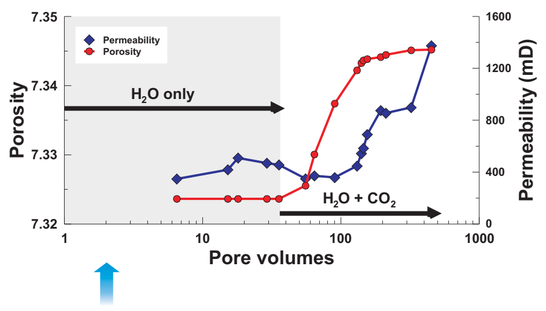
Ca & Mg concentrations show a mirror pattern. They readily respond to the arrival of the acidic fluid. It is likely that they are both released by a common mineral source via a co-dissolution process: magnesian calcite. Its theoretical stoichiometry would be $Ca_{0.67}Mg_{0.33}CO_3$. Assuming that the change in the concentrations of Ca & Mg are directly related with the dissolution of carbonates, a mass balance can be assessed. The increase in permeability would be related with the exhaustion of accesible mineral carbonates. However, we cannot rule out additional effects as mechanical cracking or grain collapse due to the dissolution of sandstone cement.



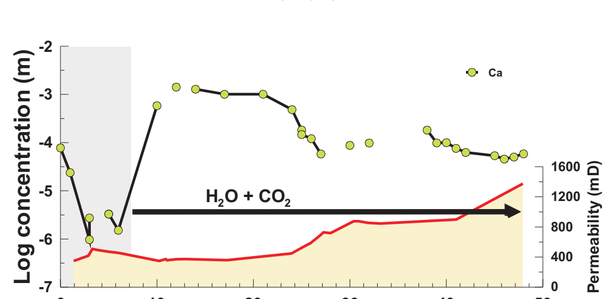


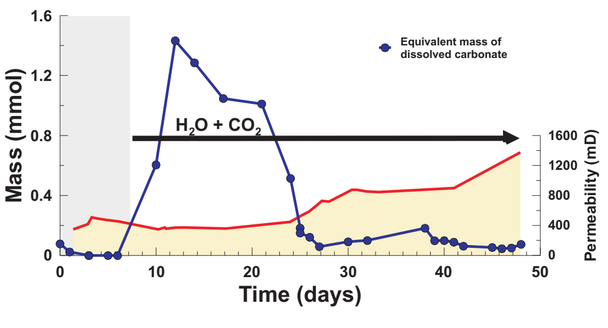


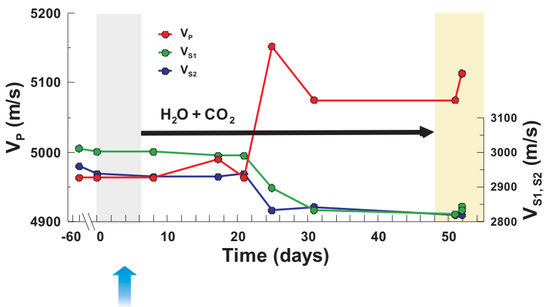




The poroperm relationship is complex; permeability does not change significantly up to more than 100 pore volumes have circulated. Then, its increase is abrupt. It is likely that not only chemical processes govern the hydrodynamic behavior of the sample: Mechanical processes might be also very important.







Sonic velocities clearly identify the different experimental stages; the V_P velocity increases when flooding with the CO_2-saturated occurs and also V_{S1} & V_{S2} become equal at the final stage of the experiment what would be consistent with the conjectured microcracking.

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