III Coloquio Franco-Español sobre Almacenamiento Geológico de CO_2

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THE UNIVERSITY OF A CORUÑA

In-depth Characterization of Reservoir and Seal Rocks for CO_2 Geosequestration

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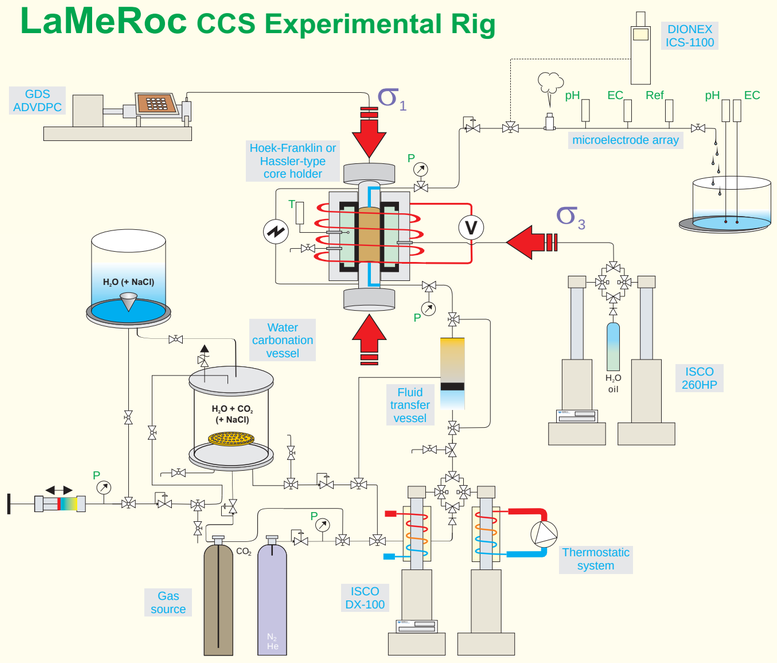
La ME ROC

Characterization of Reservoir Rocks

Characterizing the Storage Complex

LaMeRoc CCS Experimental Rig



According to the criteria for the characterisation and assessment of the potential storage complex and surrounding area referred to in Article 4(3) of the European Directive 2009/31/EC (CCS Directive) it is stated that data collection shall provide sufficient information to construct a volumetric 3D static earth model for the storage site and the storage complex. The intrinsic characteristics stated on this Directive, which shall be study to the well understanding of the storage complex. That includes volumetric calculation of pore volume for CO_2 injection, geochemical aspects (as dissolution/mineralisation rates), geomechanics concerning the seal and reservoir conditions, etc. However, it is worth noting that no associated procedures are given to fulfil these necessities. This contribution of the LaMeRoc represents a first attempt to summarize some key information with the objective of identifying laboratory procedures for rock characterization in CCS projects.

Reference Materials

When studying the properties of rocks (either chemical, mineralogical or mechanical) it is important to have at hand reference materials with which compare results, perform intercomparison (benchmark or ring) tests of specific experimental procedures, etc. Literature refers to a number of well-known sandstone reference materials (Berea and Fontaineblau sandstones, for instance). In general, any rock type could be used as reference material provided that a number of criteria (homogeneity, availability, accessibility, etc.) are met. In our case, we are considering a siliceous continental Tertiary sandstone (Arenisca de Corvio®) as a potential reference material. Here we present a summary of the characterization results obtained so far.

Sample: Corvio sandstone
Description: Light grey with occasional purple veins. Medium grain size.

Plugs available: n=240

Dry density (kg m^{-3}): 2027.64 ± 0.14 [n=240]

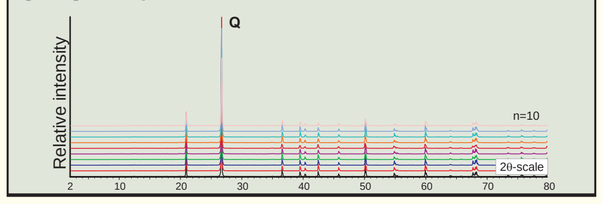
Porosity (%): 21.54 ± 0.93 [n=9]

Specific surface – BET (m^2 g^{-1}): 4.92 ± 1.34 [n=10]

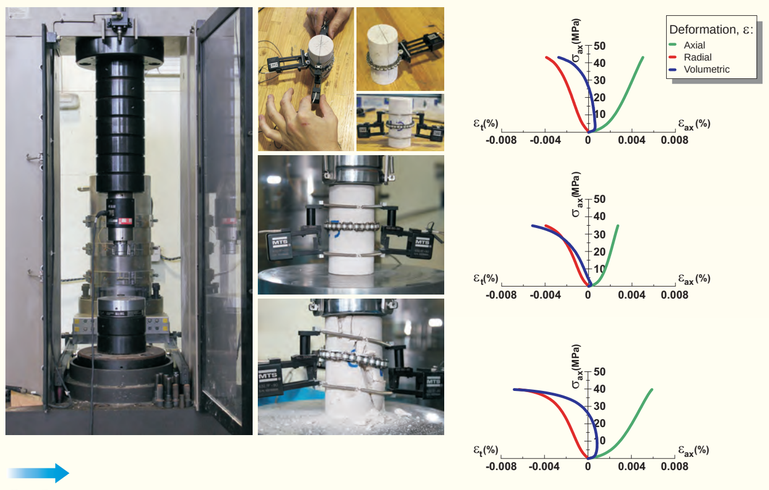
Chemical composition (% volume – XRF): [n=10]

Al_2O_3:	4.92 ± 1.34
K_2O:	0.72 ± 0.20
TiO_2:	0.34 ± 0.05
Fe_2O_3:	0.12 ± 0.02
MgO:	0.10 ± 0.03
ZrO_2:	0.03 ± 0.01
CaO:	0.04 ± 0.00
LOI:	0.71 ± 0.09

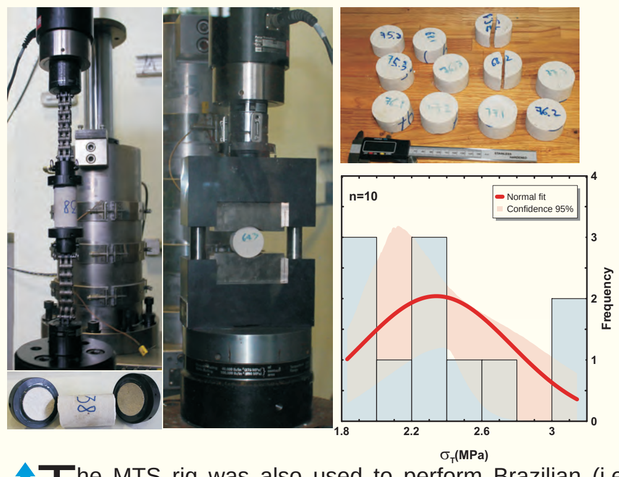
Mineralogy (% volume – XRD): [n=10] Quartz: ~100%



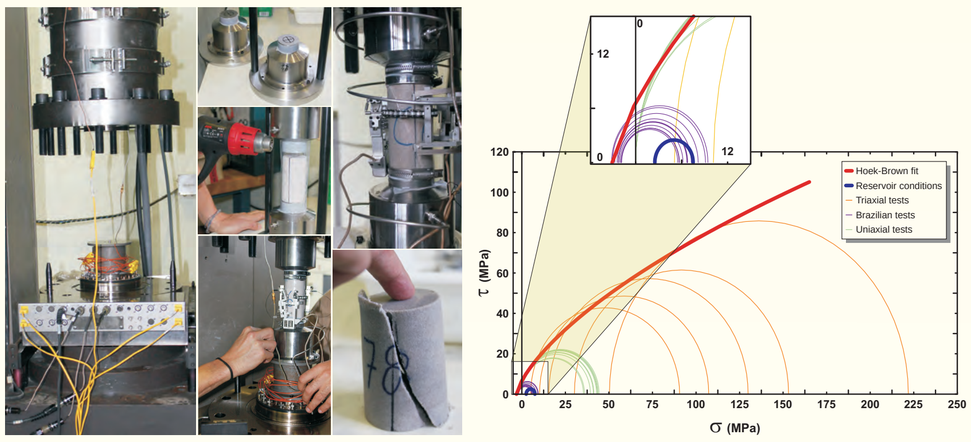
Geomechanical Testing



Unconfined compressive strength tests were carried out on 10 plugs sampled from the same rock using a MTS Systems Corporation (mod. 815) triaxial frame. Radial and axial extensometers provide information on strains useful for the calculation of static moduli (above).



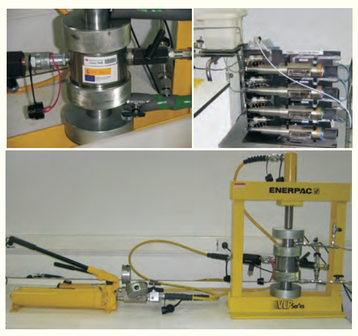
The MTS rig was also used to perform Brazilian (i.e. indirect tension) tests on 10 randomly oriented samples. The low tensile strength of the sample and the presence of anisotropy planes (bedding) resulted in a high number of failed experiments when tested under direct tension mode.

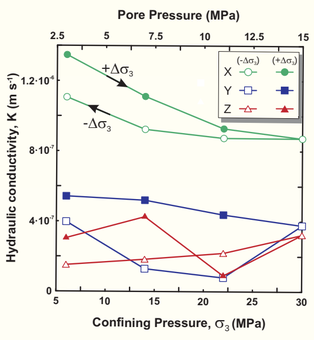


Drained triaxial tests were performed with 5 plug under different confinement conditions and simultaneous recording of axial and radial strains. The battery of mechanical tests executed on the MTS triaxial frame (25 samples) allowed the assessment of the strength of the Corvio Sandstone according to the well-known Hoek-Brown intact rock criterion and the program RocLab®.

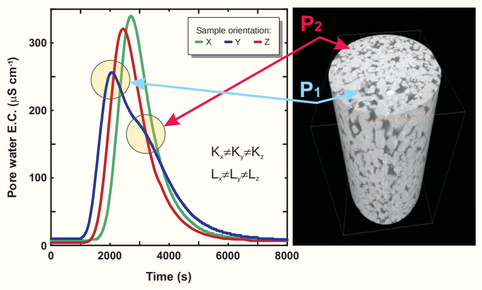
Transport Properties: Permeability & Pore Distribution

Several plugs were extracted following three orthogonal directions in order to assess anisotropic phenomena in the rock. Different properties, including the porosity distribution have been also characterized via X-Ray micro-tomography. Worth mentioning is the development of pressure-dependent hysteretic phenomena affecting permeability.

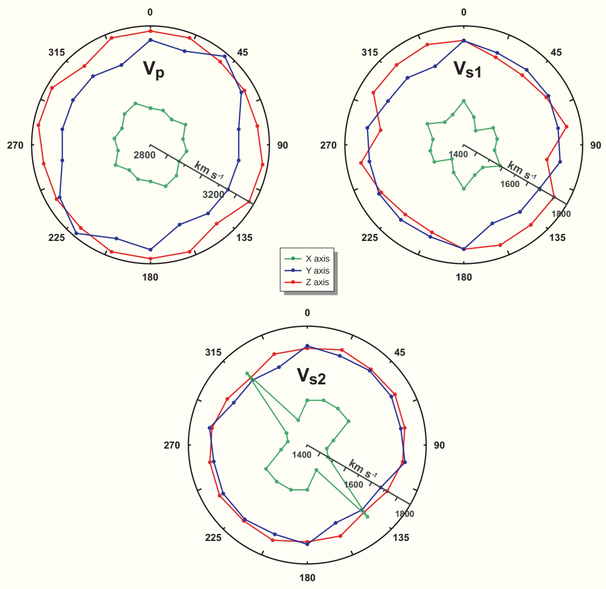




In a preliminary assessment, transport processes were studied in three orthogonal sections of the rock using electrical conductivity as conservative tracer. Steady flow conditions were set in the experiments: An initial constant DIW flow was followed by the injection of a monovalent (NaCl) saline solution (1000 µS cm^{-1}) up to reach an equivalent volume of one half of the pore volume of the plug. Temperature-corrected EC data was gathered downstream with a flow-thru microelectrode. Results are being modeled.



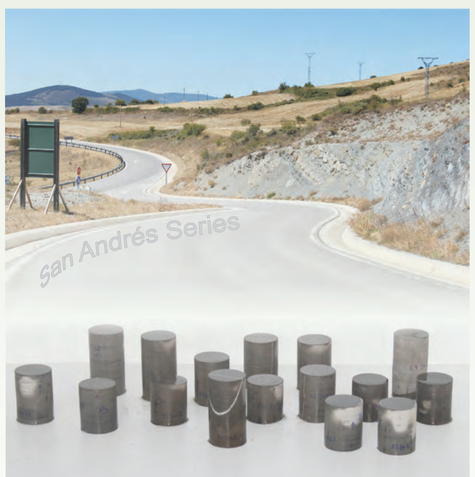
Acoustic Wave Velocities



The anisotropic behaviour of the rock was also tested from the point of view of its direction-dependent acoustic response. The arrival time of P, S_1 and S_2 waves were picked orienting X-Y-Z samples in different directions (20º steps). The results illustrate that significantly lower velocities are obtained in the X direction. This is consistent with what it is observed with permeability: The highest value is observed also in this direction.

Characterization of Seal Rocks

Rock Properties & Location



Geological Formation: Camino (JC)

Age: Pliesbachiense (Lower Jurasic)

Series: San Andrés
Lithologies: Alternance of marls, limestones and claystone

Location: San Andrés, Cantabria (Spain)
(UTM30T - WGS84)
X:0410625 Y: 4751207 Z:938

Available plugs for testing (number): n= 21

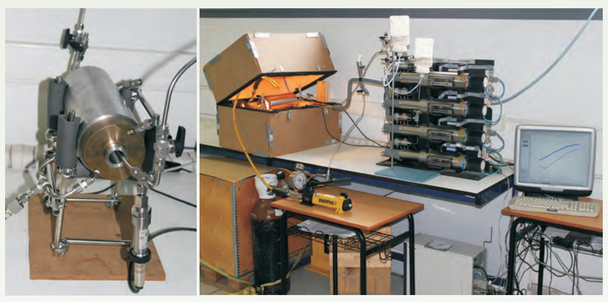
Samples I.D. (Subseries):
S2 [n=4] Grey marlstone with joints
S3 [n=7] Black claystone with joints
S4 [n=3] Grey marlstone with joints
S5 [n=7] Light grey marlstone with joints

Dry density 2628.63 ± 0.04 kg m^{-3} [n=21]

Porosity (%): 2.03 ± 0.19 [n=3]

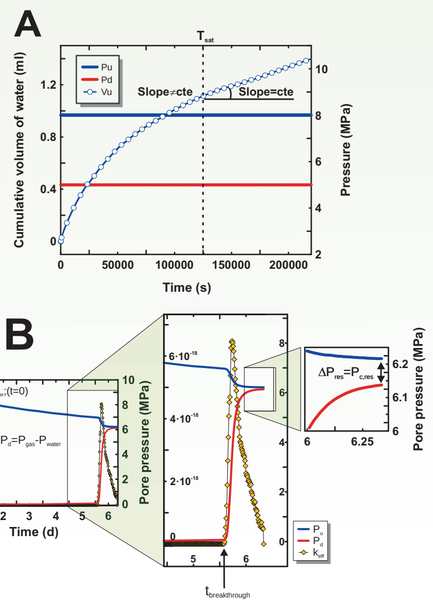
Directive 2009/31/EC says that the data required to construct a 3D model for the storage site and the reservoir complex shall include caprock and surrounding areas. We have sampled some outcrops of representative seal formations for the Hontomin TDP: The San Andrés series marls (Camino Formation). The sealing capacity is being tested in terms of permeability and gas migration potential. Permeability and breakthrough pressure measurements tests are being performed using an experimental rig composed by a thermally-isolated high pressure core holder (Hassler-type) and pumps. The hydraulic system is compartimented in order to get good control of the volumetric properties and pressure.

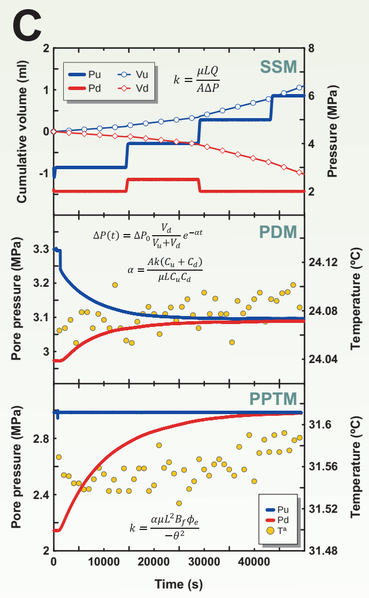
Permeability & Breakthrough Pressure



The applied methodology allows for the sequential determination of both permeability and capillary or breakthrough pressures. i) First, samples are saturated, based on a criterion of linearity: Setting steady state conditions, when water flow becomes constant, it can be assumed that effective pore volume is full of water (see T_{sat} on Graph A). Once saturated, the circuit is evacuated and dried before a gas is injected (He in the example of graph B) upstream (upstream pressure - P_u). ii) After a certain time ($t_{breakthrough}$), the gas flows through the sample and the recorded downstream pressure (P_d) changes and tends to approach P_u. iii) The residual pressure difference is the breakthrough pressure. iv) The effective permeability of the gas can be also determined (k_{eff}).

Saturation steps can be then repeated in order to determinate the permeability by one of three methods described in the literature (Graph C): steady state (SSM), pulse decay (PDM) or pore-pressure transmission (PPTM).





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