AGU 100 ADVANCING EARTH AND SPACE SCIENCE | FALL MEETING
Washington, D.C. | 10-14 Dec 2018

Pore Fluid Distribution in Saline Sandstone CO_2 Storage Reservoirs with Aligned Fractures: Experimental Geophysical Assessment

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Summary

Here we present, to our knowledge, the first **brine-CO_2 flow-through** test using a **fractured sandstone** with well-defined fracture network, under realistic geological conditions of confining (40 MPa) and pore (10 MPa) pressure.

The test simulates the CO_2 injection process (**drainage**) and the natural aquifer recharge post-injection (**imbibition**).

During the test, we measured ultrasonic **P/S waves** (velocity & attenuation), together with **electrical resistivity** (converted into degree of CO_2 saturation) and volumetric deformation.

Context

Carbon Capture and Storage (**CCS**) has aroused public concerns over potential surface leakage of CO_2 from geological reservoirs, limiting the number of potential storage sites.

From the microscopic **scale** to large faulting systems, **fractures** are present in any rock formation of the **Earth crust**.

The assessment of **crack distribution** and **fluid dynamic** is crucial to determine the suitability of a reservoir for CCS, and to predict the **advance** of the **CO_2 plume** underground.

Geophysical tools offer information about fractures and fluid distribution during CO_2 injection.

Rock sample

We used a **synthetic sandstone** core sample, containing **fractures aligned** at **45°** to the fracture normal, with well-defined frature density (ε_f) and fracture aspect ratio (a/b).

Fig 1a. Rock sample

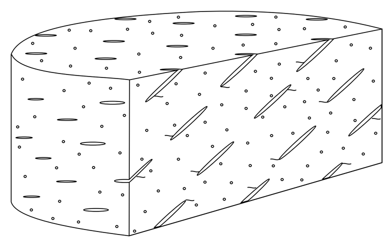

Fig 1b. Rock sample schematic section

Table 1. Rock sample properties

Length (cm)	Diameter (cm)	Porosity (%)	Permeability (mD)	ε_f	a/b
2	5	27.3	5.48	~0.03	~0.089

Experimental setup & test procedure

The test was conducted using the experimental rig for multi-flow tests at the **Rock Physics lab** in the **National Oceanography Centre, Southampton**. The setup was configured to measure simultaneously ultrasonic P- (V_P) and two orthogonal S-wave velocities (V_{S1} & V_{S2}, corresponding to shear wave polarization at 0° and 90° to the fracture normal, respectively) and their attenuations ($1/Q_P$, $1/Q_{S1}$ and $1/Q_{S2}$), electrical resistivity, volumetric strain (ε_v), during the co-injection of brine and CO_2 (under flow and pressure control). ***See test procedure in the QR-linked video***

Rig video

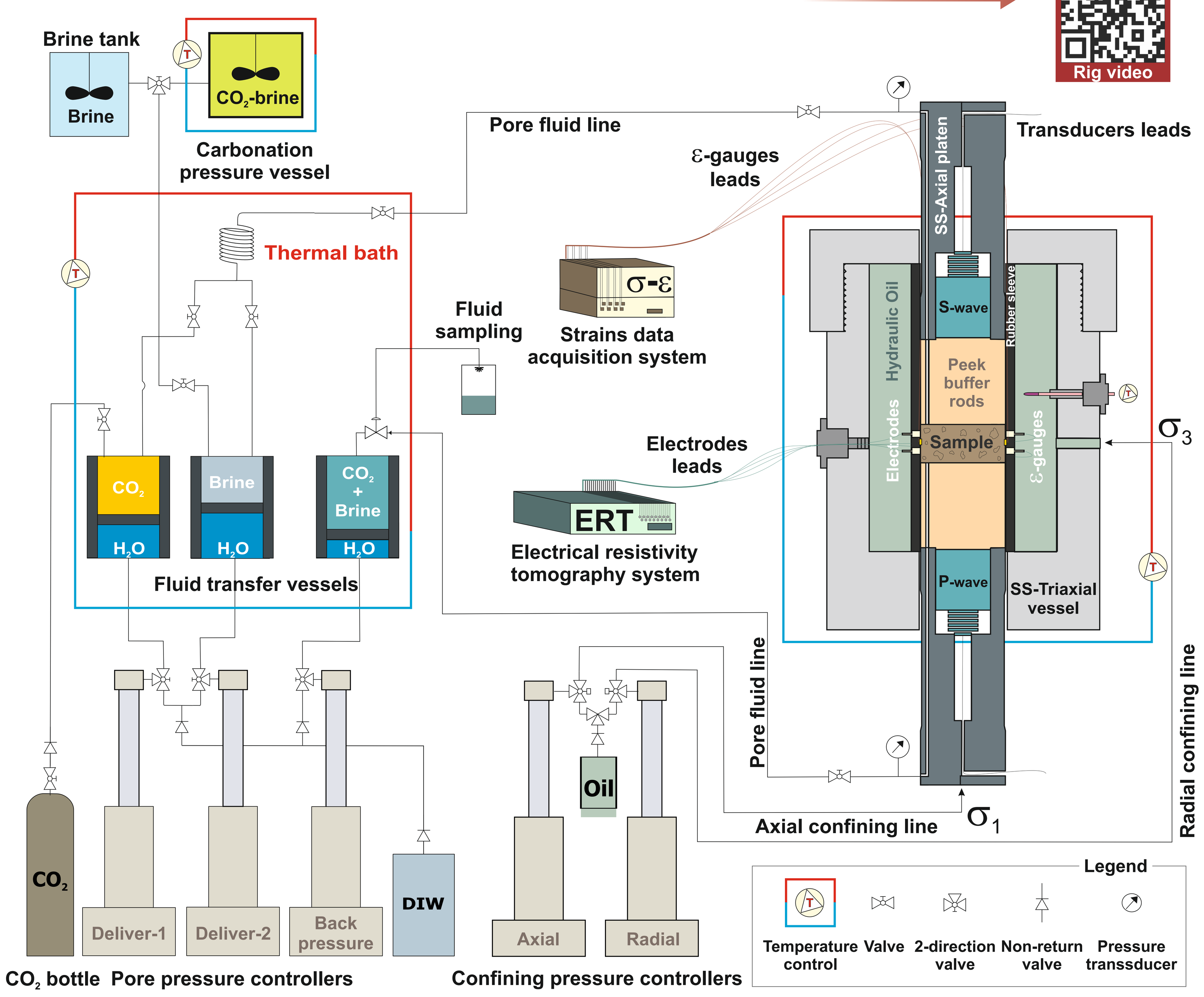

Fig 2. Experimental rig at the Rock Physics laboratory in the National Oceanography Centre, Southampton

Brine-CO_2 Flow-Through (BCFT) test

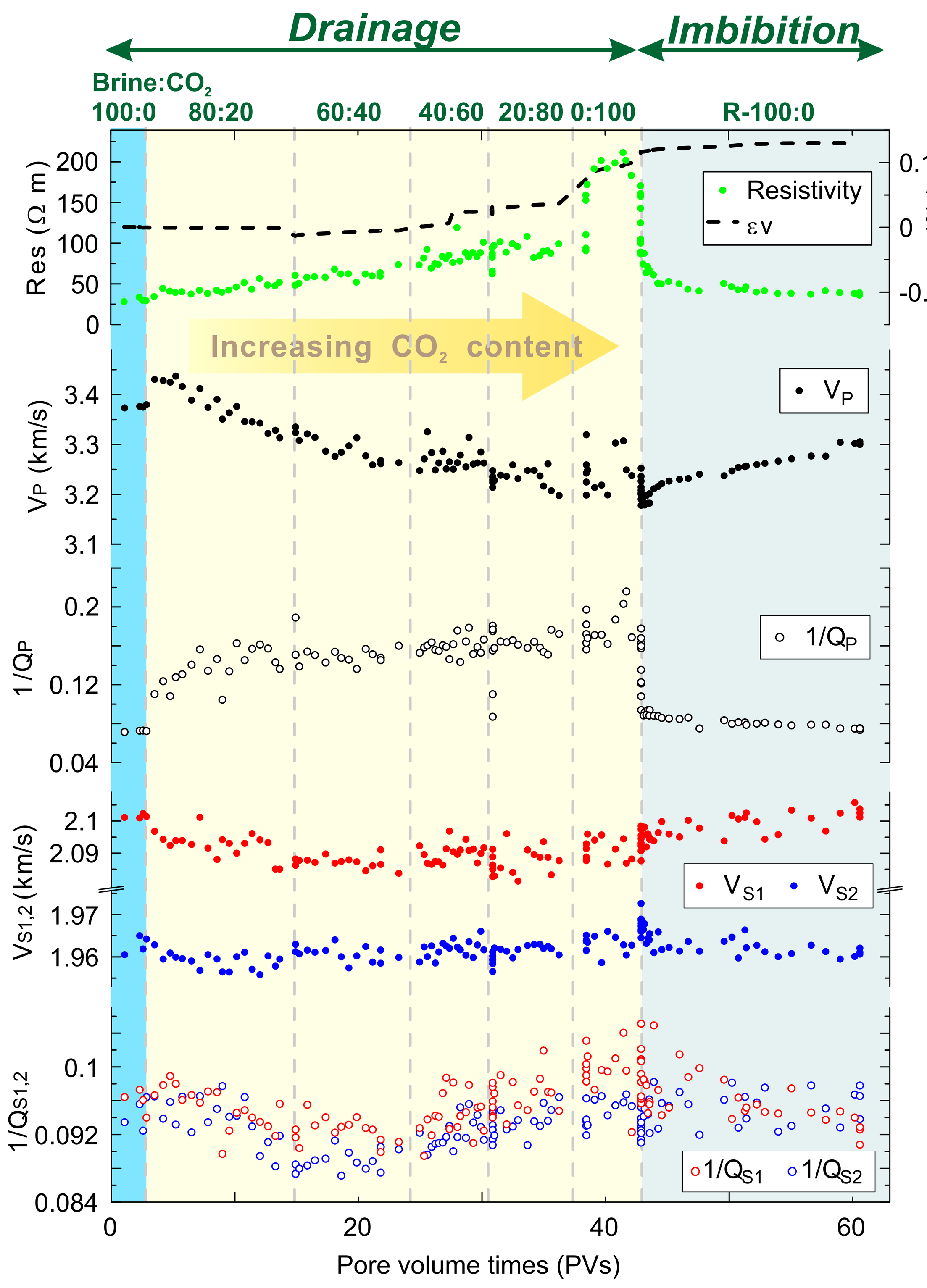

Fig 3. Results from the BCFT

- The **BCFT** test lasted ~75 h (i.e., **~63 PV throughputs**).
- **Resistivity** increases **progressively** with the CO_2 partial flow during multi-flow, but **sharply** when only CO_2 is injected.
- First **CO_2 arrival** leads to the most significant changes in ultrasonic properties.
- P-wave properties are more affected by the CO_2 injection (**ΔV_P <7%; $\Delta 1/Q_P$ <67%**)
- **S-waves** show very little variations in velocity (<1%), and slightly higher (<3%) in attenuations.
- During the **imbibition stage**, all properties are partially recovered

Partial saturation *versus* ultrasonic properties

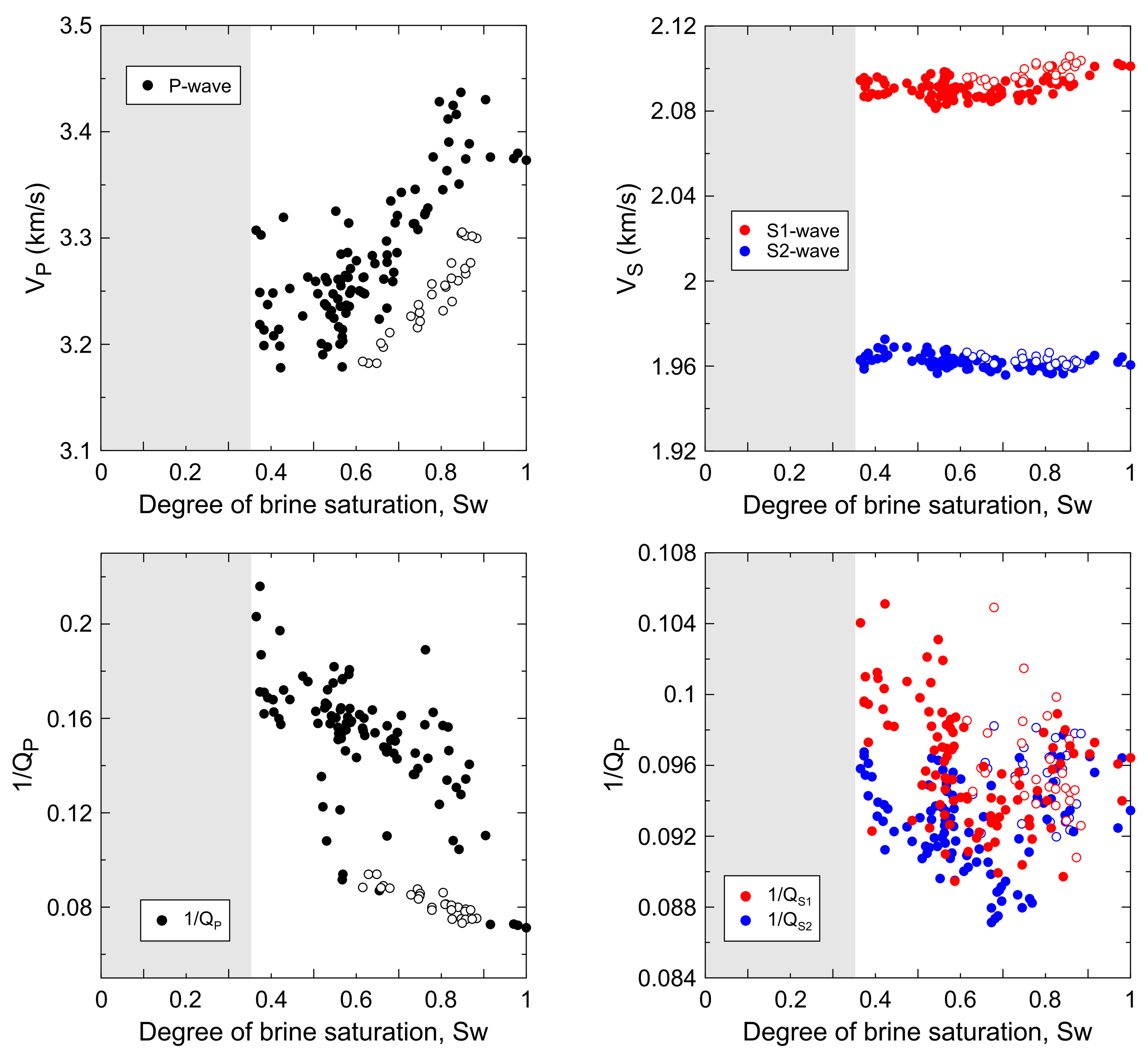

Fig 4. Ultrasonic P & S1,2 velocities (top) and attenuations (bottom) versus partial saturation of brine (S_w = 1-S_{CO2}) for the drainage (solid points) and imbibition (empty points) saturation paths.

- Electrical resistivity converted into degree of saturation: Maximum CO_2 saturation **$S_{CO2,max}$ ~63%**.
- V_P and **$1/Q_P$** show the most significant **variations** from **drainage** to **imbibition** paths.
- **V_{S1}/ V_{S2}** between **6-7%**, while **Q_{S2}/ Q_{S1}** mostly **<4%**.

Future work

We are using the data to develop a **new rock physics model** to improve the distinction between **fracture anisotropy** and **fluid distribution** from seismic data, **during** and **after** the **CO_2 injection** in fractured saline CCS-reservoirs, by simultaneous fitting of **ultrasonic** P-$S_{1,2}$-wave **data**.

GASRIP

Acknowledgements: This project has received finantial support from the **UK's Natural Environment Research Council** (grant **NE/R013535/1 GASRIP**) and the **Xunta de Galicia** and the European Union (**European Social Fund** – ESF).