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Quantification of Paragenetic Controls on Chemomechanical Sensitivity of the Morrow B Sandstone During CO_2 Injection, Farnsworth Unit, Texas

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Introduction

Objective: to assess what degree paragenetically controlled properties influence chemically-affected rock strength and stiffness in separate lithofacies of Morrow B Sandstone

Justification: in Farnsworth Unit, Texas, injected CO_2 is changing brine chemistry. Mechanical responses that result from changes in subsurface chemistry are poorly characterized

Hypothesis: the paragenetic sequence can predict mechanical reservoir sensitivity to changes in pore-water chemistry

Planned Work: we couple flow-through of a CO_2 rich solution with mechanical testing on two lithofacies of the Morrow B sandstone, a CO_2-EOR reservoir in the Farnsworth Unit, Texas. The lithofacies are sandstones with different degrees and types of cementation: siderite, and pore-filling clay

- Cement mineralogy, burial history, and cement texture control mechanical sensitivity of Morrow B sandstone to CO_2 injection
- This work will test the porosity facies remaining after Wu et al. (submitted). We show results from four CO_2 enriched flow-through tests on siderite and clay cemented samples
- Currently we are running two brine only control tests to compare results
- Mechanical strength degradation expected in siderite samples based on paragenetic sequence

Methods

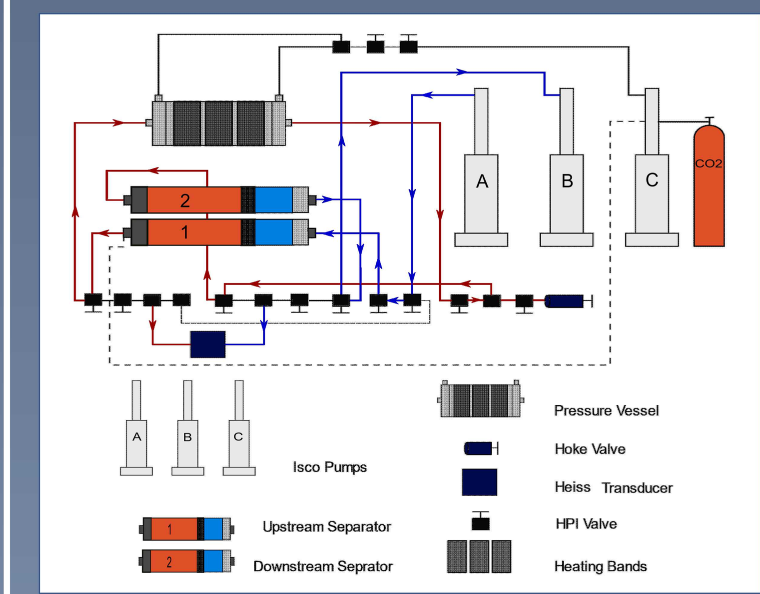
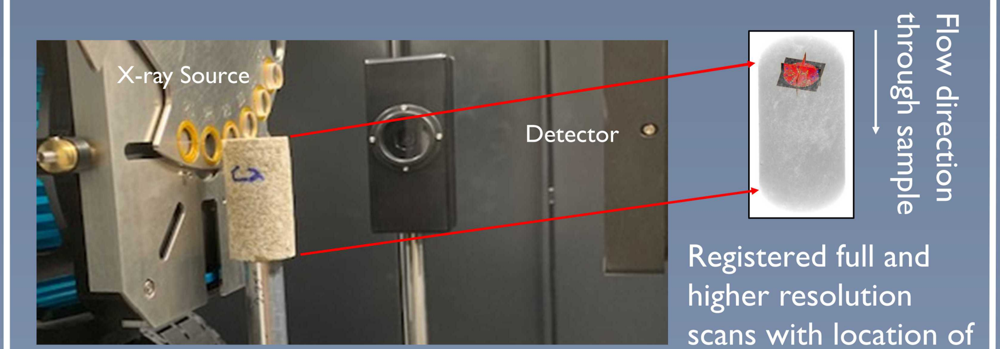


Figure 1. Flow-through set up. Blue lines indicate flow of DI water and red indicates the flow of CO_2-enriched brackish solution, although DI water flows through all lines before and after each experiment. Arrows indicate flow direction

- *In situ* flow-through of CO_2
  - 71°C
  - 290 bar pore fluid pressure
  - Brackish reservoir fluid
- 345 bar confining pressure
- Major ion chemical analysis
- Flow rates
  - 0.01 and 0.1 ml/min
- Pre- and Post-test
  - Thin Sections
  - Ultrasonics (1 MHz resonant frequency)
  - X-ray Computed Tomography
- Unconfined Compressive Strength

microXRCT

- Micro-XRCT scans performed on a Zeiss Xradia 520 Versa
- Scans performed over the entire core plugs at 27-µm pixel size
- Higher resolution 11-µm scan at core top



Registered full and higher resolution scans with location of plots below

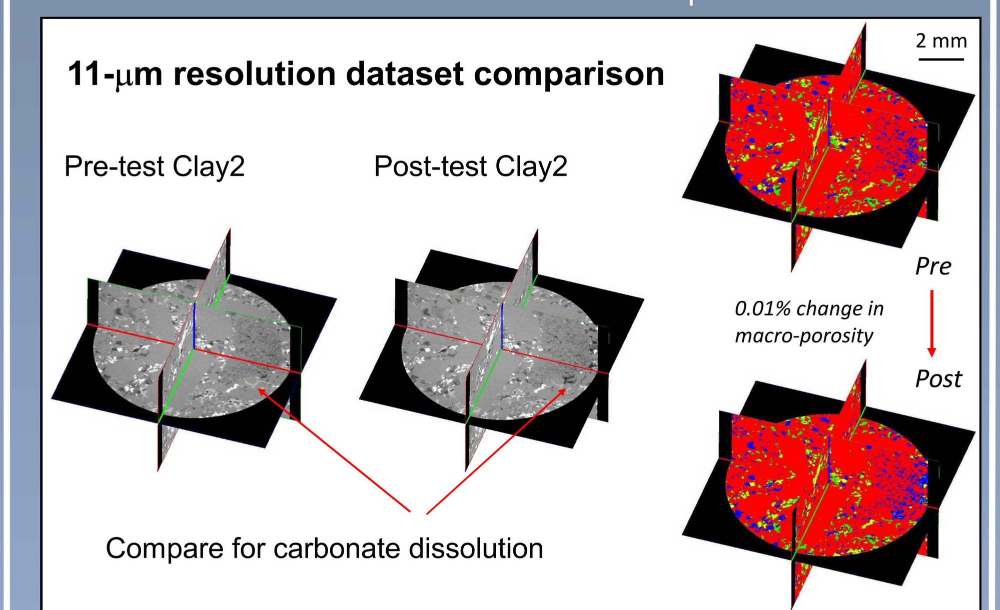
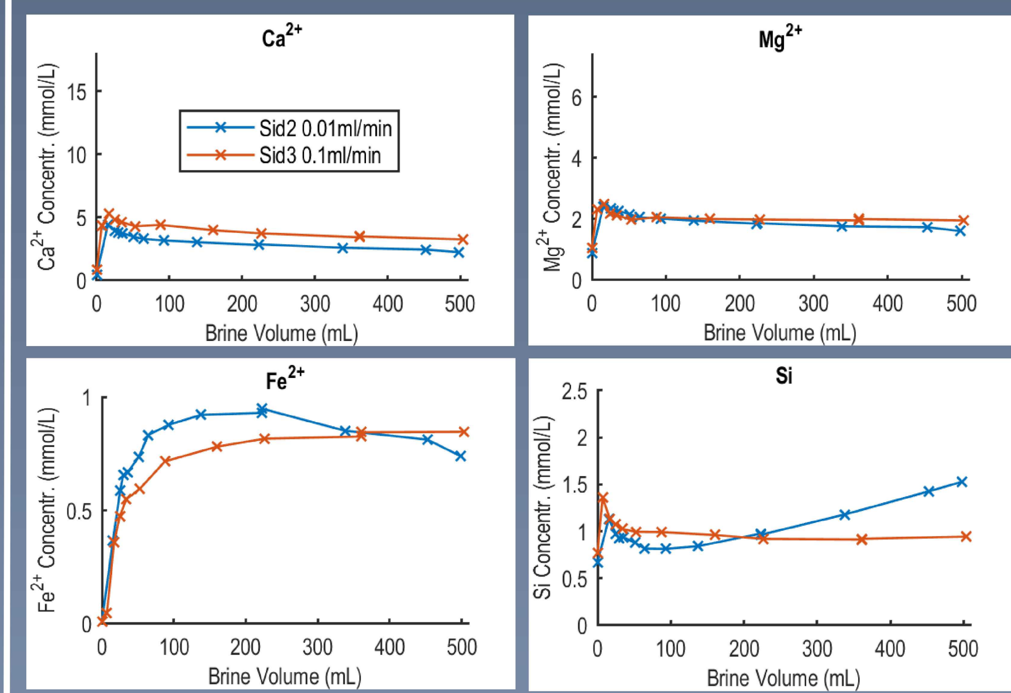


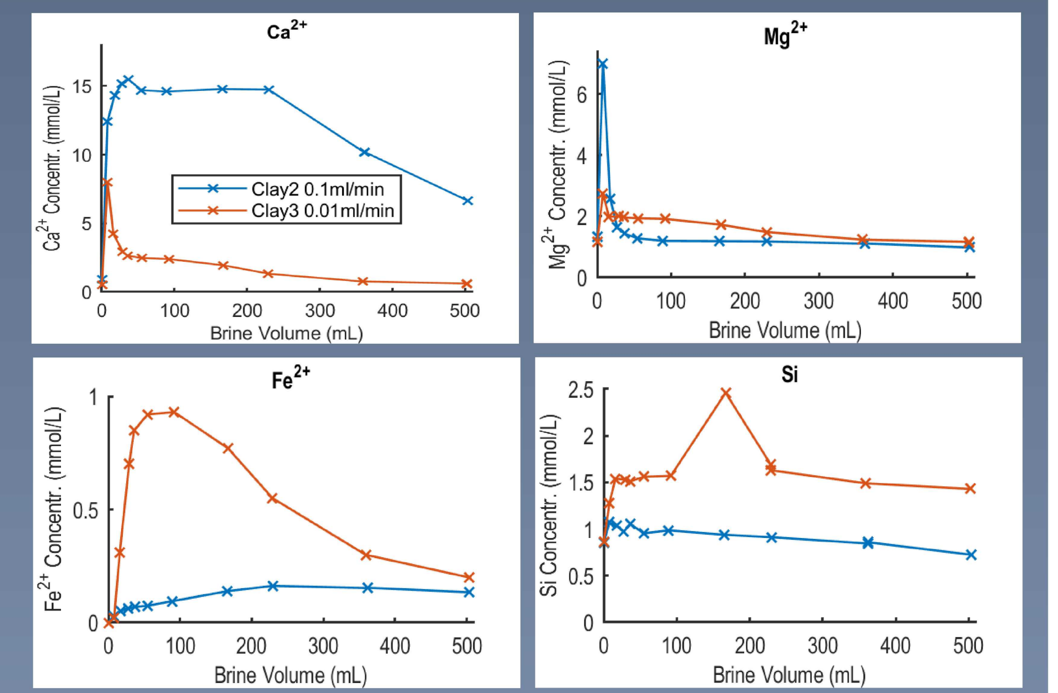
Figure 6. Clay2 pre- and post-test scans. Red represents framework grains, green and yellow are two cements assumed to be carbonates, dark blue represents micropores and clays, and lighter blue is macropores. Some of the green phase is dissolved post-test.

Downstream Water Chemistry



Siderite-cemented samples

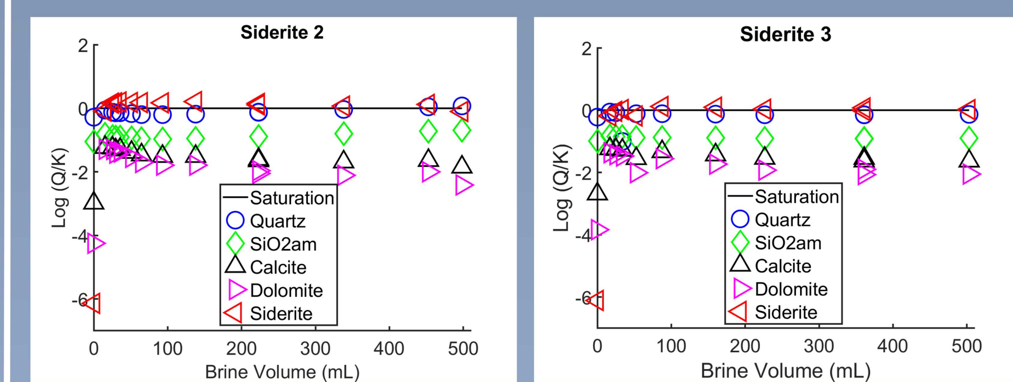
Figure 9. Concentration of major cations through time for siderite cemented facies. Rapid increase of Ca^{2+}, Mg^{2+}, and Fe^{2+} attributed to dissolution of carbonate cements



Clay-cemented samples

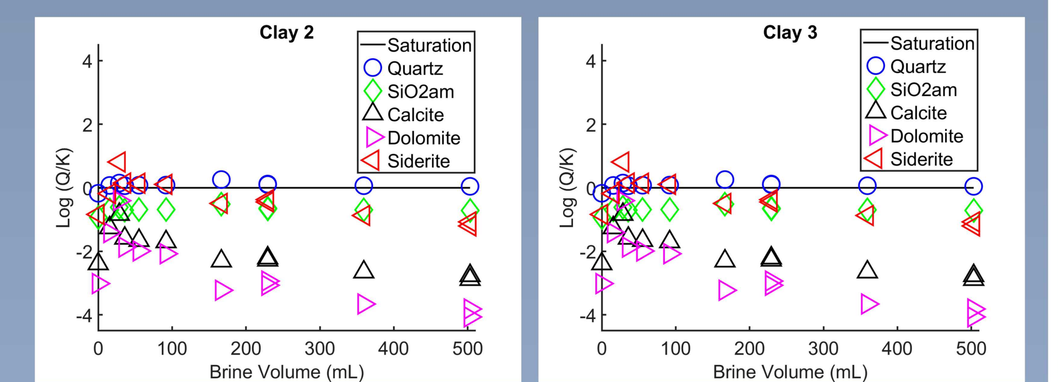
Figure 10. Concentration of major cations through time for clay cemented facies. Clay2 shows high input of Ca^{2+} from calcite and Mg^{2+} from dolomite dissolution. Some ion exchange possible

Saturation Indices



Siderite-cemented samples

Figure 11. Carbonate minerals are generally undersaturated in the initial experimental solution, but fluids are generally saturated with respect to quartz and siderite upon exiting the core



Clay-cemented samples

Figure 12. Outlet fluids were generally near saturation with respect to calcite, dolomite, siderite, and quartz during the Clay2 experiment, while saturated minerals in outlet fluids were limited to siderite and quartz during the Clay3 experiment

Ultrasonics

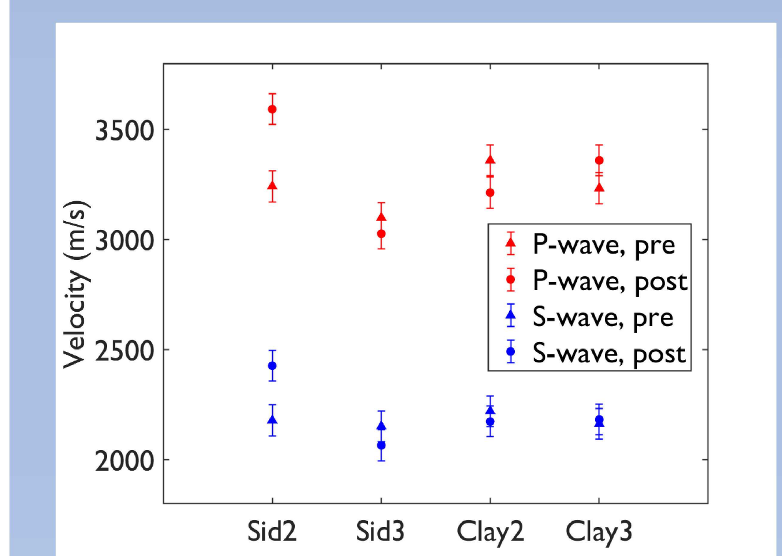


Figure 3. P- and S-wave velocities for four samples and photo of the ultrasonic rig at Sandia National L:abratory. TOA for P- and S- waves were picked. TOA and core length were used to calculate velocities (**Vp** and **Vs**)

Porosity

Sample ID	Dry Mass g	Sat Mass g	Density$_B$ g/cm³	Porosity %
Sid2	62.70	65.43	2.37	10.50
Sid3	56.81	60.63	2.25	15.10
Sid4	56.70	60.23	2.27	14.20
C2	64.05	67.13	2.45	7.36
C3	61.33	63.48	2.42	8.50
C5	59.76	62.95	2.32	12.40
C6	61.37	64.42	2.34	11.60

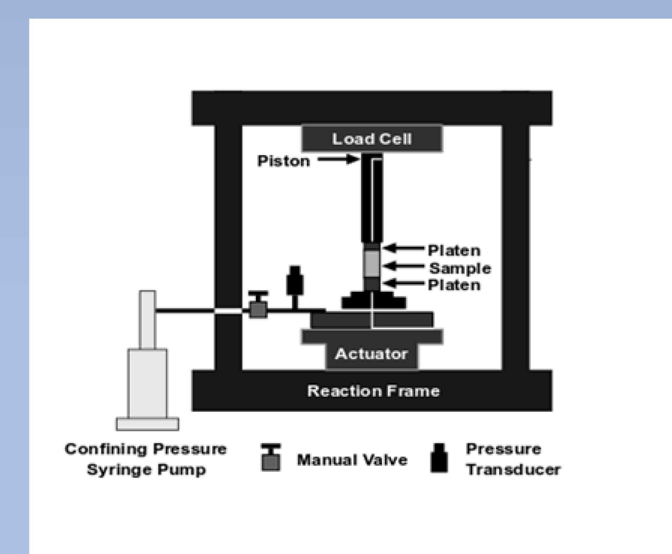
Permeability

Sample ID	Pre-test Perm mD	Post-test Perm mD	Change mD
Sid2	6.58	9.65	3.07
Sid3	6.04	10.94	4.90
Clay2	0.17	1.22	1.05
Clay3	0.40	0.38	-0.02

Discussion

- Siderite and clay cemented sandstones show some changes from pre- to post-test P- and S-wave velocities. Control test velocity changes will provide insight on degradation influence
- Porosity variations based on depositional and diagenetic history observed for these lithofacies
- Permeability constrained using a series of flow rates both pre- and post-test to provide better resolution with less uncertainty
- Micro-CT data confirms presence of cement mineral alterations in Clay2. This is identified as change in the green phase of figure 6 (carbonate cement) and a large macropore shown in the grayscale image. New porosity is attributed to the removal of carbonate cements
- Chemical data confirms input of ions from carbonate (calcite, dolomite, siderite), and possibly clay (illite, chlorite) cements. Ion inputs for siderite cements at both flow-rates are consistent and expected based on mineralogy, however vast differences and large quantities of carbonate cements in Clay2 and Clay3 were somewhat unexpected. This interval is expected to be rich in clay minerals (kaolinite) and fluid analysis has shown little indication of this. This may be because kaolinite has shown stability under CO_2 conditions, resisting dissolution and providing no aluminum input. Thin section and microprobe analysis will confirm cement mineralogy

Future Work



- Post-test unconfined compressive strength
  - Provide elastic moduli, yield point
- Thin section analysis
- Flow-through of remaining samples
- Post-test XRCT of remaining cores

Acknowledgments

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