Supplementary Information

Mechanistic Understanding of Carbon Mineralization in Fracture Systems Using Microfluidics

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I. Flow channel design:

There were four dead-end channels of different widths 0.5 to 1 mm and different lengths of 5 mm and 9 mm. A detailed figure with the horizontal dimensions of the channel provided in the Figure below has been added to the supplementary information as Figure S1. The thickness is about 20 microns giving an approximate pore-volume with all channels combined between 4-5 mm^3. For the simulations, 5 lattice nodes were set to the main channel to resolve a parabolic velocity profile and 1 lattice node to the dead-end channel to match the experimental design. This choice includes a priori that reactant transport in dead-end channels is diffusion dominated, and it is not necessary to set 5 lattice nodes to capture the velocity profile.

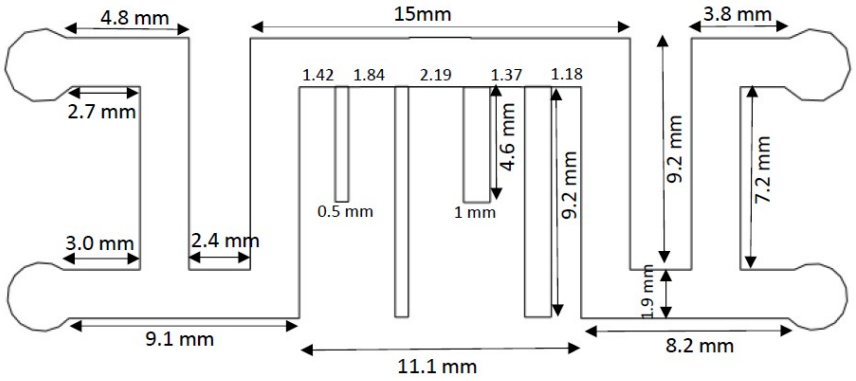

Figure S1. Flow channel design with details of the horizontal dimensions.

II. Sample preparation procedure:

1. Sample Size:
   - Prepare a sample measuring approximately 5 cm × 2.5 cm × 1 cm which is usually appropriate for the microfluidics setup.
2. Cutting the Sample:
   - Cut the sample using the saw cut from the original rock or mineral source.
   - When cutting from an irregular-shaped bulk material, ensure that you select a piece large enough to extract the desired chip size.
3. Sanding and Polishing:
   - Smooth all sample surfaces using the sanding machine, starting with coarse grit sandpaper followed by fine grit sandpaper.
   - Follow the relevant procedure carefully for cutting and polishing.
4. Sample Measurement:
   - Measure and record the length and width dimensions of the finalized sample. These dimensions are critical for accurately trimming the top and bottom acrylic covers.
5. Acrylic Covers Fabrication:
   - Use a Laser Gravograph to trim the top and bottom covers from an acrylic sheet.
   - Both covers have identical length and width dimensions. Additionally, the top cover must include four drilled holes designated as flow port connections.
6. Flow Channel Fabrication:

- Using the Laser Gravograph, fabricate the comb-shaped Teflon channel. This channel will be sandwiched between the top acrylic cover and the top face of the sample, forming the primary fluid flow pathway.

7. Flow Port Alignment:
   - Align the top acrylic cover precisely over the sample surface and clearly mark the locations of the flow ports.
8. Drilling Flow Ports:
   - Drill small grooves at the marked flow port locations using a drill press equipped with a 3/32-inch drill bit.
9. Initial Epoxy Application (Epoxy A: DP420 Off-White Epoxy Adhesive):
   - Prepare a small quantity of two-part epoxy (Epoxy A). Using a toothpick, apply minimal amounts of epoxy around the drilled flow ports.
   - This step prevents unintended fluid leakage around the flow ports during experiments.
10. Sample Assembly:
    - Assemble the sample components in the following order: Bottom cover followed by the sample followed by the Teflon channel followed by the top cover
    - Secure this assembled stack firmly with clamps.
11. Sealing the Assembly (Epoxy B: J-B Weld Steel Reinforced Epoxy):
    - Prepare another epoxy batch (Epoxy B).
    - Using a toothpick, carefully apply Epoxy B to seal all edges and side faces of the assembled stack. Do not apply epoxy on the top and bottom surfaces.
    - Pay close attention to fully covering all joints to prevent any fluid leakage during operation.
12. Flow Port Attachment and Final Epoxy Application:
    - After the assembly has dried, prepare additional Epoxy A.
    - Apply a small amount around the rim of each flow port fitting and attach them to the sample.
    - Once positioned, reinforce the attachment by applying more epoxy around each flow port fitting.
    - Carefully ensure accurate alignment of the flow ports for optimal fluid flow.
13. Drying Period:
    - Allow the assembled sample to dry and cure overnight.
14. Leak Inspection:
    - On the following day, test the robustness of the sample assembly by injecting air into each flow port using a syringe. Verify that there are no leaks and confirm that the flow channels are functioning correctly.

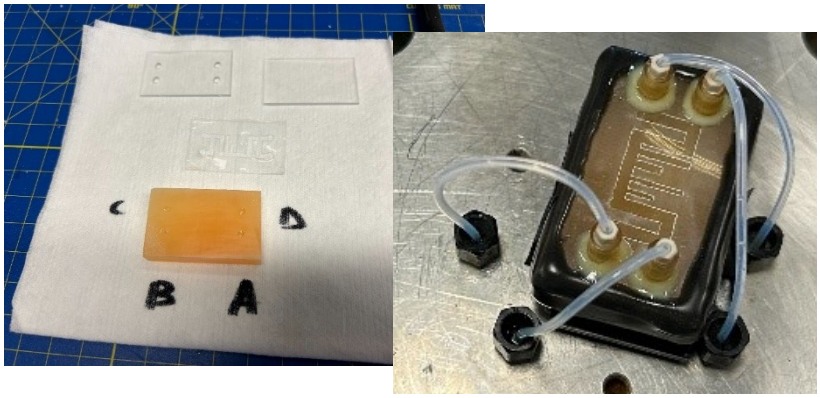

Figure S2. (Left) Components making up the sample including the top and bottom acrylic covers, the comb-shaped Teflon channel, and the mineral substrate. (Right) Assembled sample on the high-pressure sample stage.

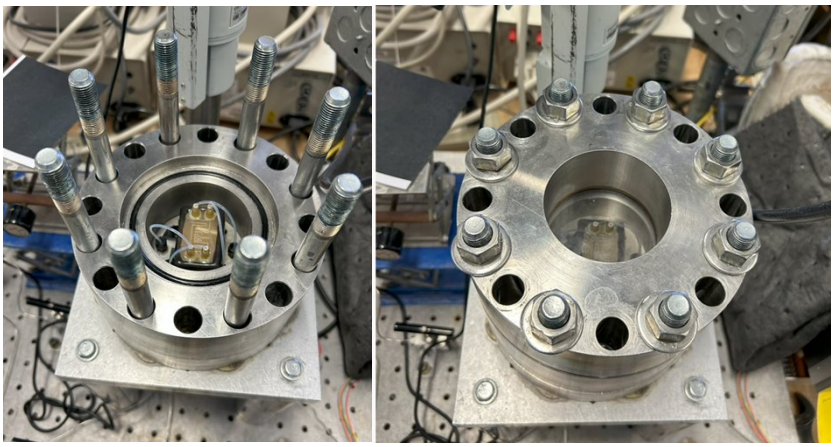

Figure S3. Sample placed inside the high-pressure chamber on the sample stage (left) top cover of the pressure vessel open (right) top cover placed.

III. Differential pressure measurements:

Figure S3 shows the pressure differentials recorded during the microfluidics experiments. These were found to be approximately constant for the three slower flow rates (1, 10, and 60 µL/min) with no substantial evidence of clogging. For the 100 µL/min case, however, we observed that there were some pressure peaks and drops which may be indicative of clogging. This is consistent with our observation of more precipitation in the faster flowing systems. However, as the fluid did not remain solely in the channel for the 100 µL/min, we did not use this to measure permeability changes.

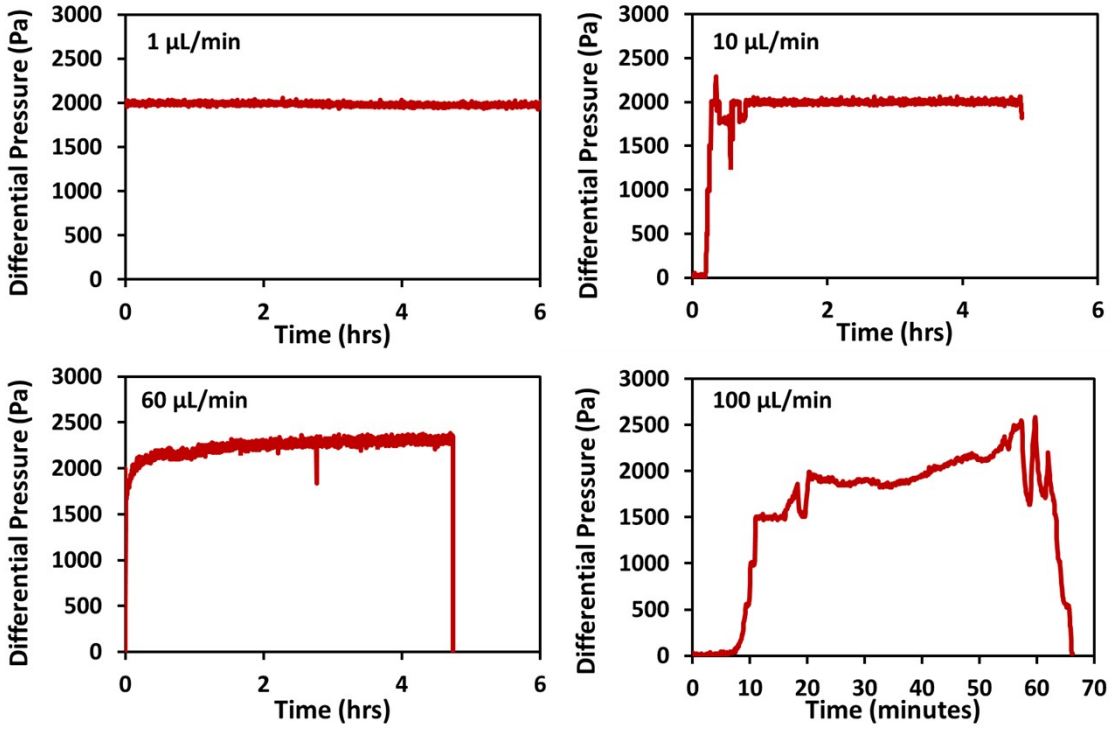

Figure S4. Pressure differential was essentially constant for the three slower flow rates (1, 10, and 60 µL/min) with no substantial evidence of clogging. Pressure peaks and drops in the 100 µL/min system may be indicative of clogging, consistent with our observation of more precipitation in the faster flowing system. However, as the fluid did not remain solely in the channel for the 100 µL/min, it is not possible to measure permeability changes.