Pore-Scale Controls of Reactive Transport in Carbonate Porous Media

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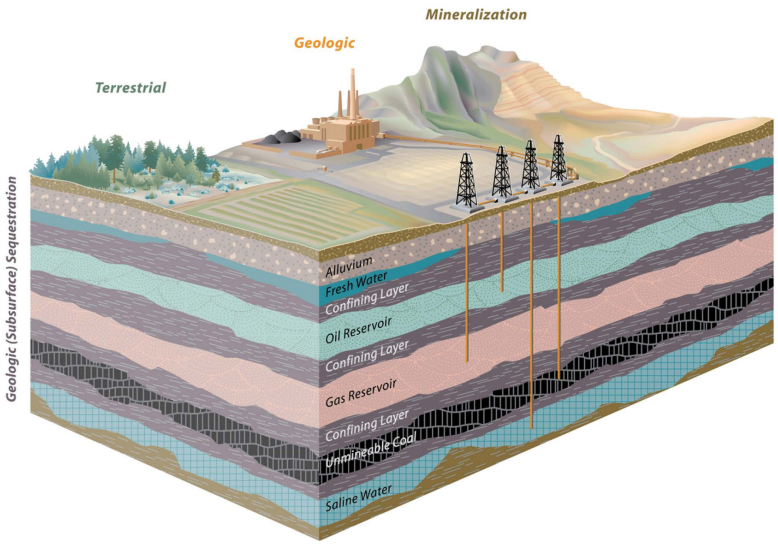
Geological CO_2 Storage: Security Assessment

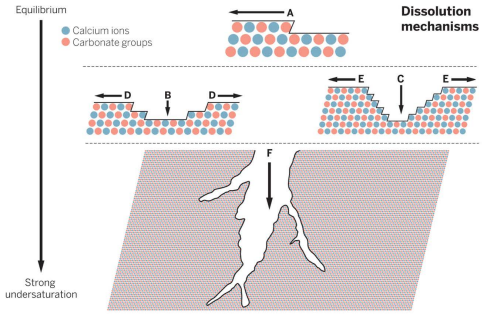
Geological Storage

atmospheric emission of CO_2 > 40 billion tons/year



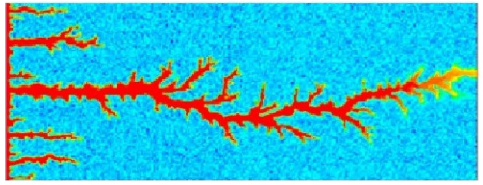
Reactive Transport

$H^+ + CaCO_3 \rightarrow CO_2 + H_2O + Ca^{2+}$



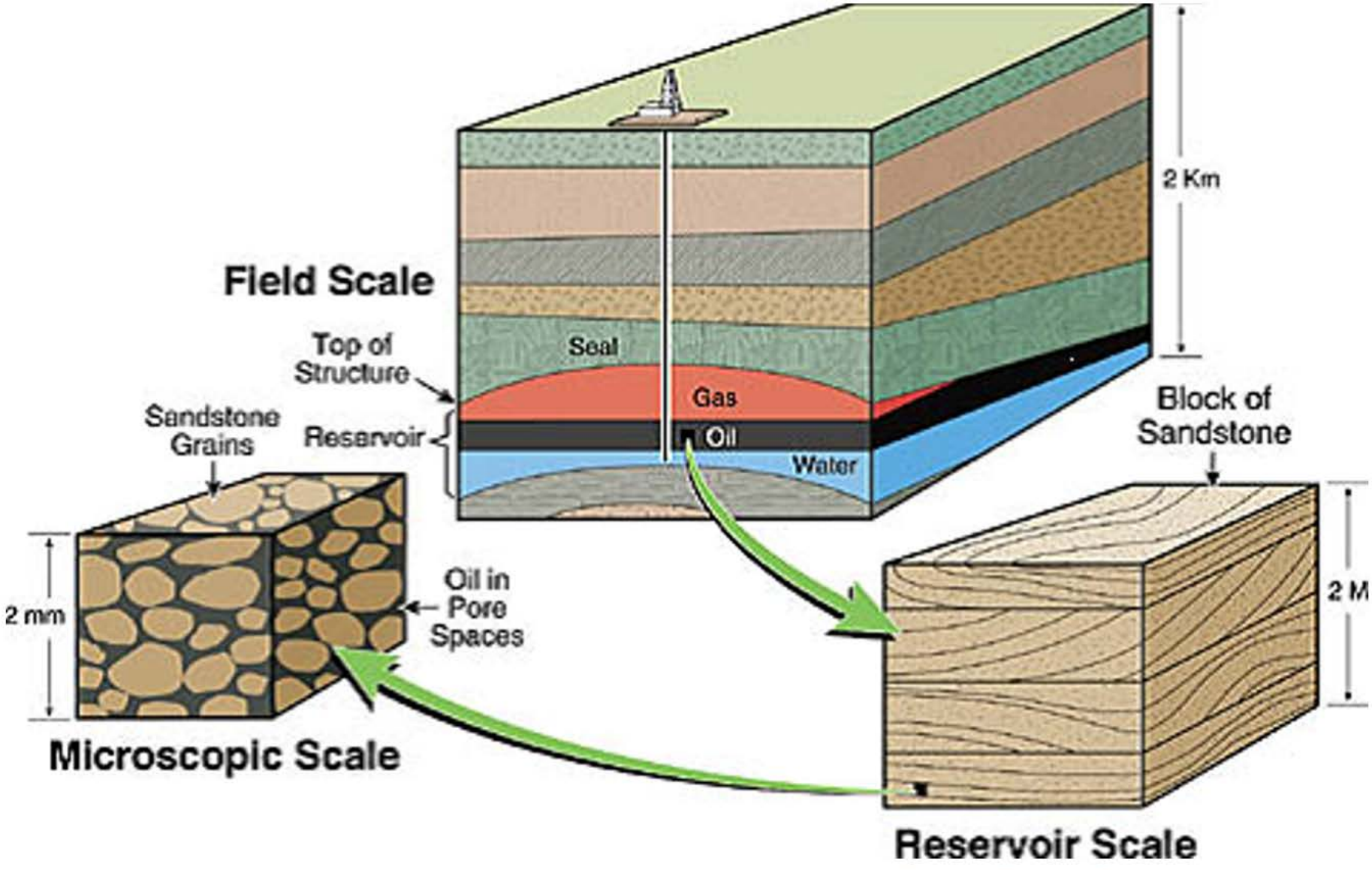
- CO_2-acidified storage brine
- Modifications to storage reservoir structural integrity

Wormholing



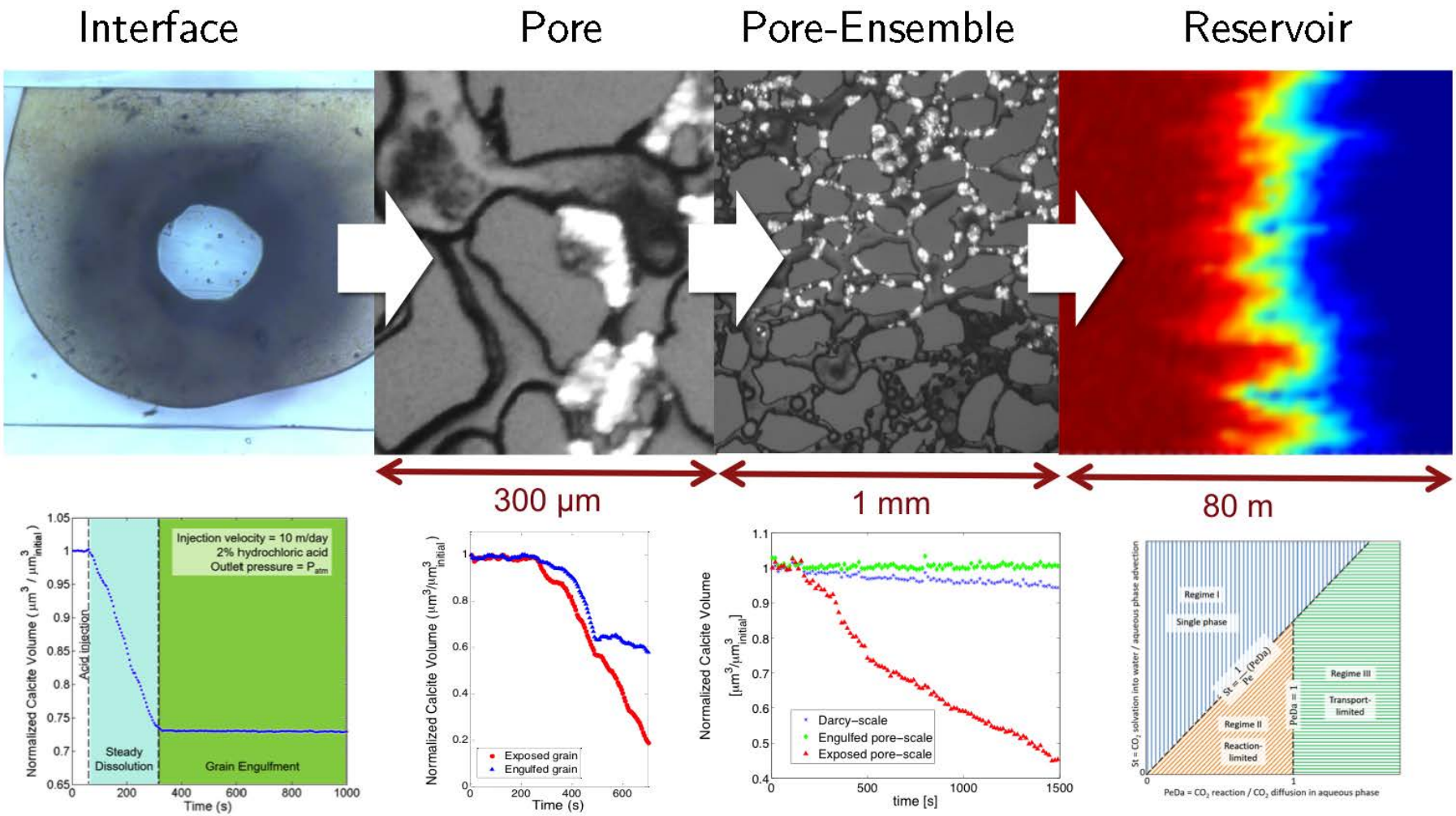
- Pathways for leakage

Subsurface Engineering: A Question of Scales



Society of Petroleum Engineers

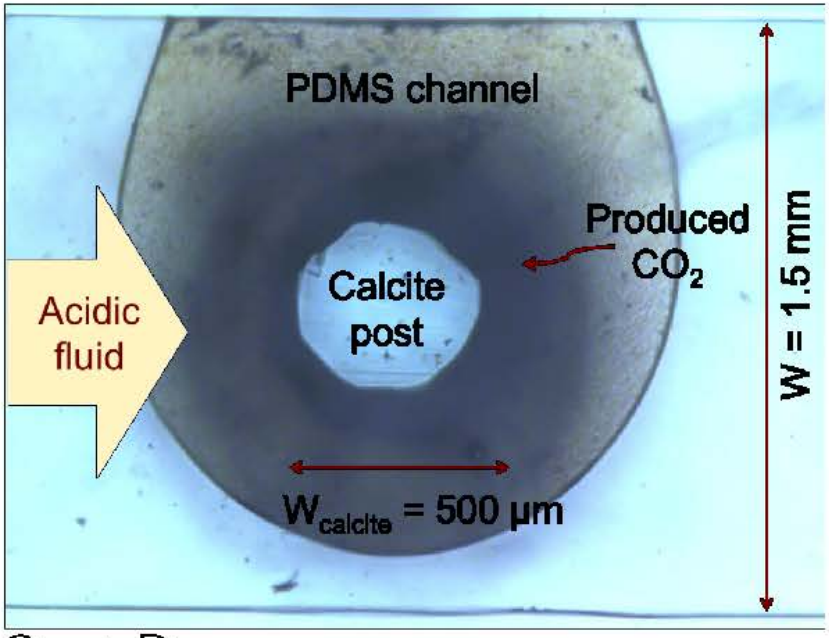
Reactive Transport in Carbonates



Interface-Scale Dynamics: Fundamental Mechanism Discovery

Grain-Engulfment Mechanism

$$CaCO_{3(s)} + 2H^{+}_{(aq)} \rightarrow CO_{2(g)} + Ca^{2+}_{(aq)} + H_2O_{(l)}$$

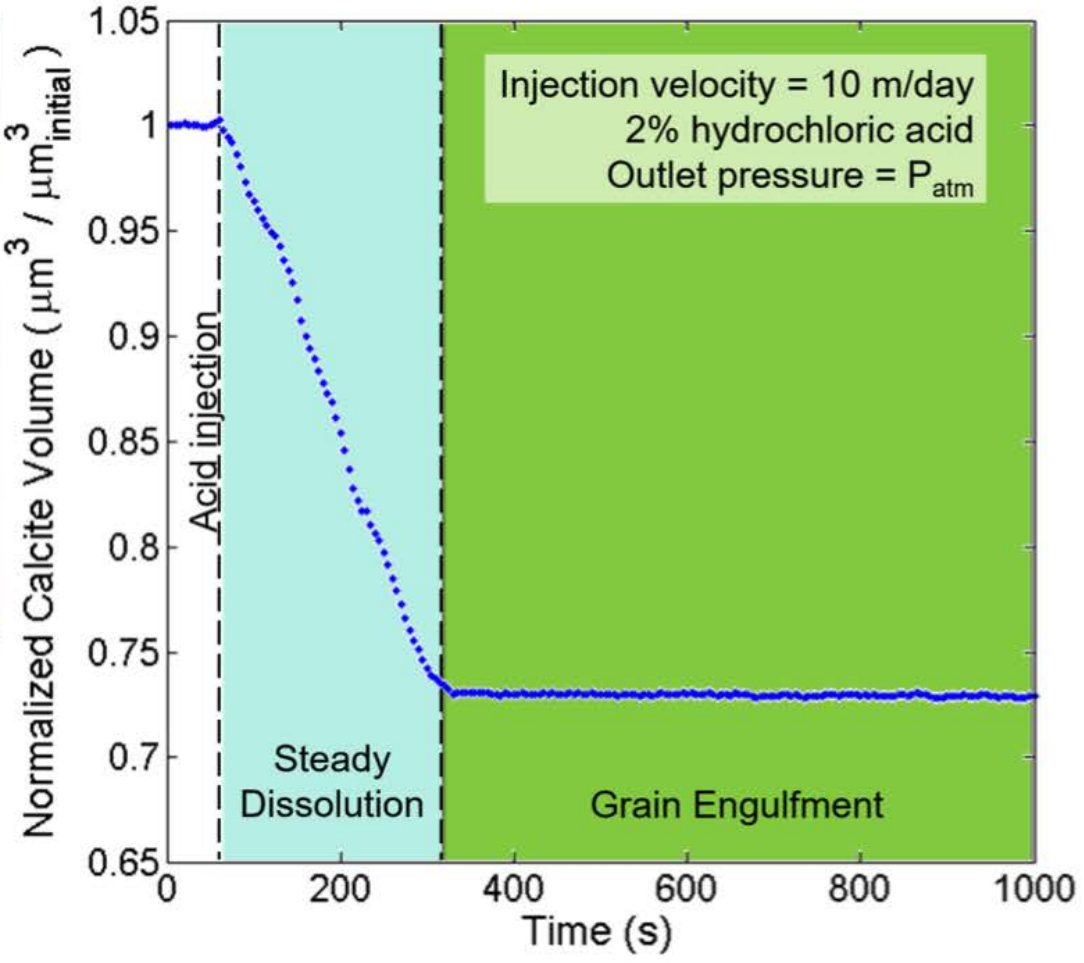


St < Da

PeDa > 1

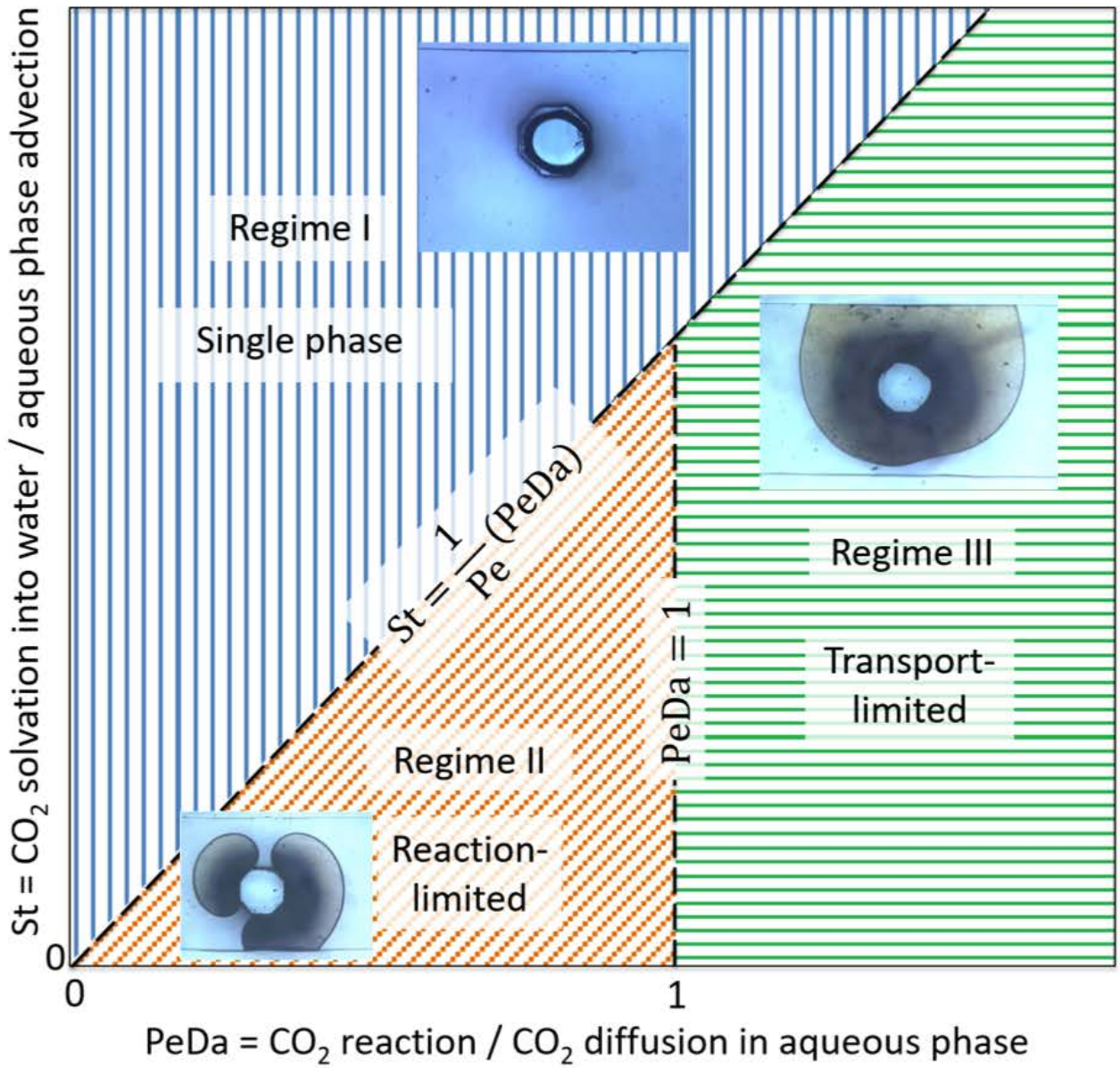
Two-phase transport-limited reactive transport

Grain-Engulfment Regime



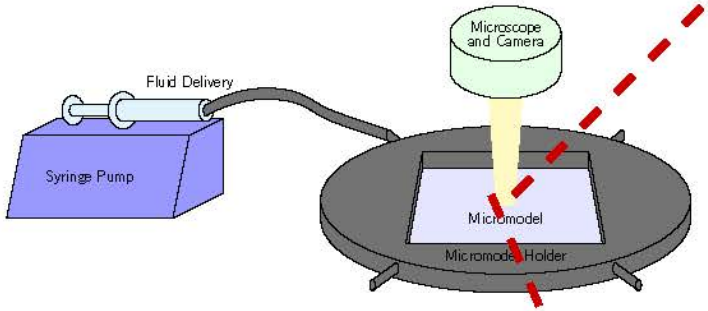
[Song et al (2018) Lab on a Chip]

Phase Diagram



[Song et al (2018) Lab on a Chip]

Biogenic Calcite Microfluidics: Geometrically and Mineralogically Representative Model



Sporosarcina pasteurii

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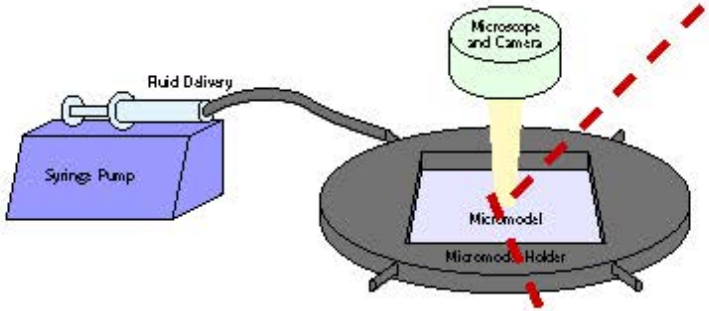
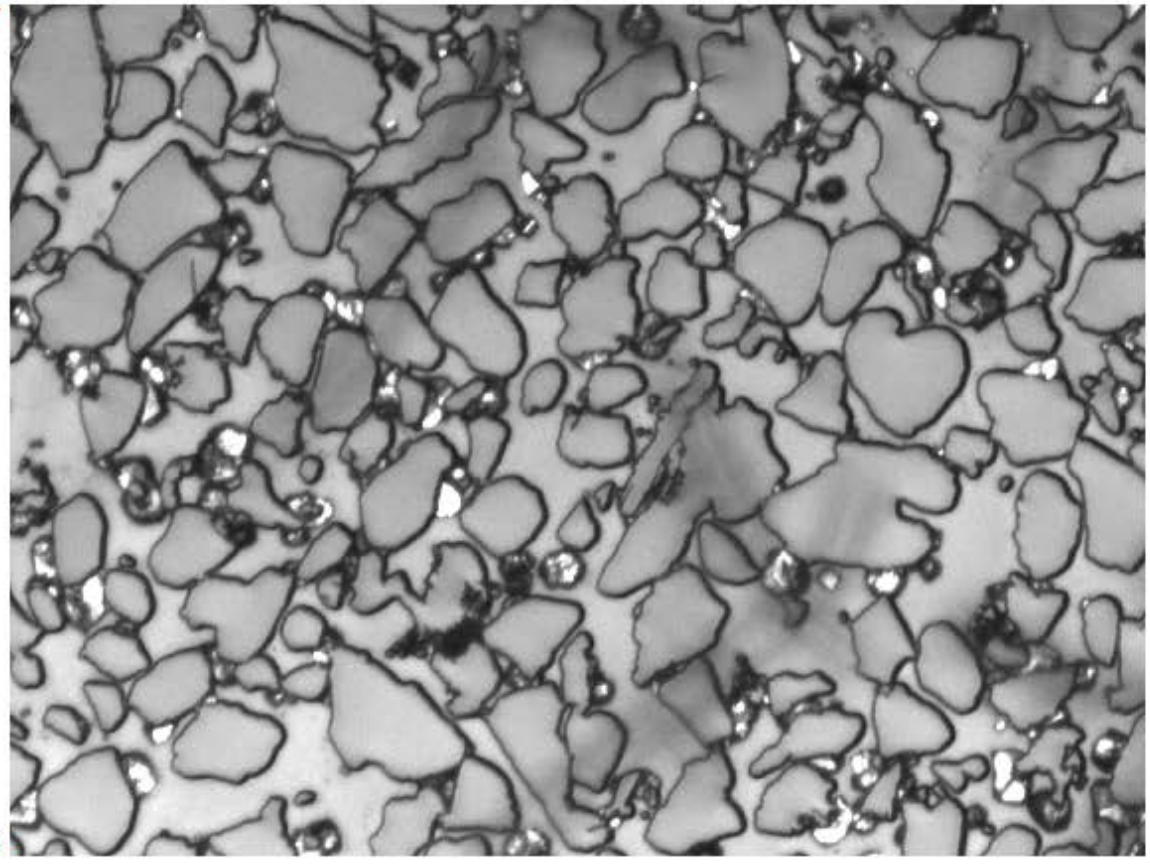


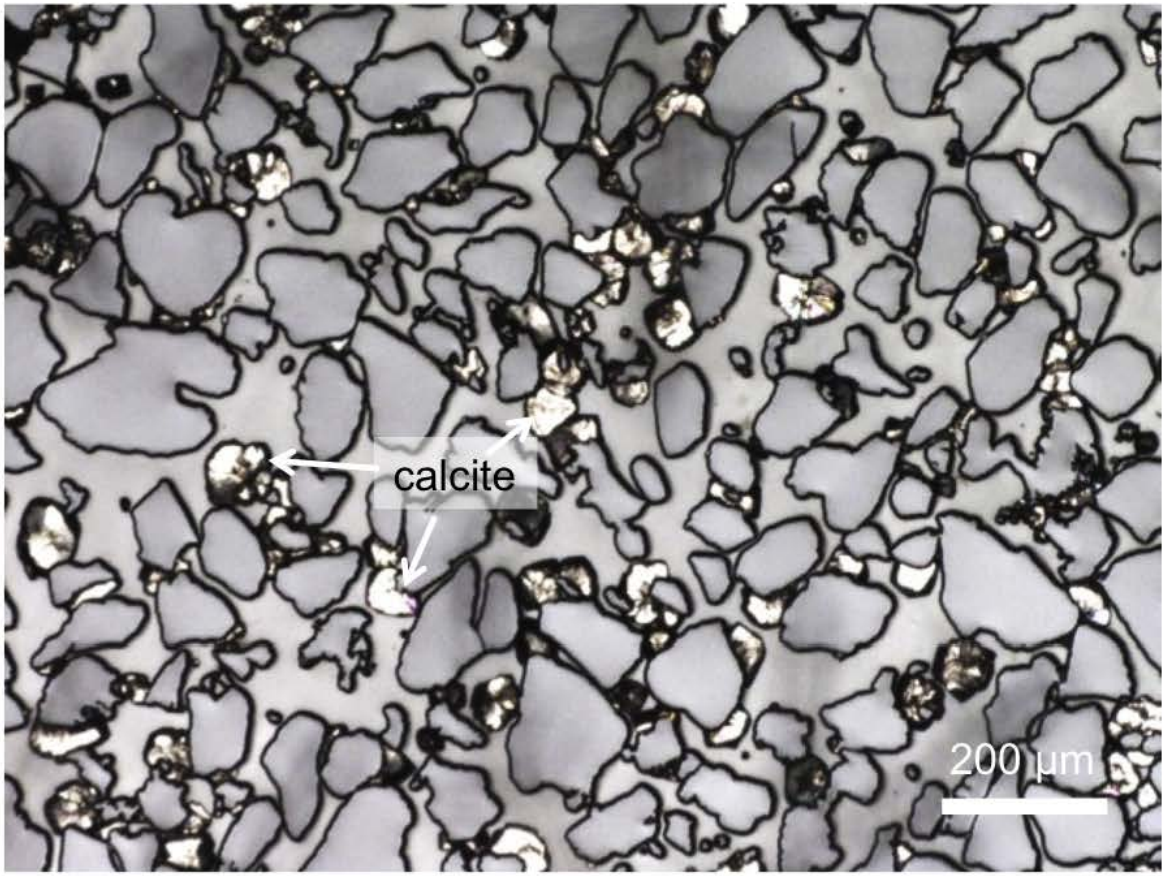
Cementation Fluid:

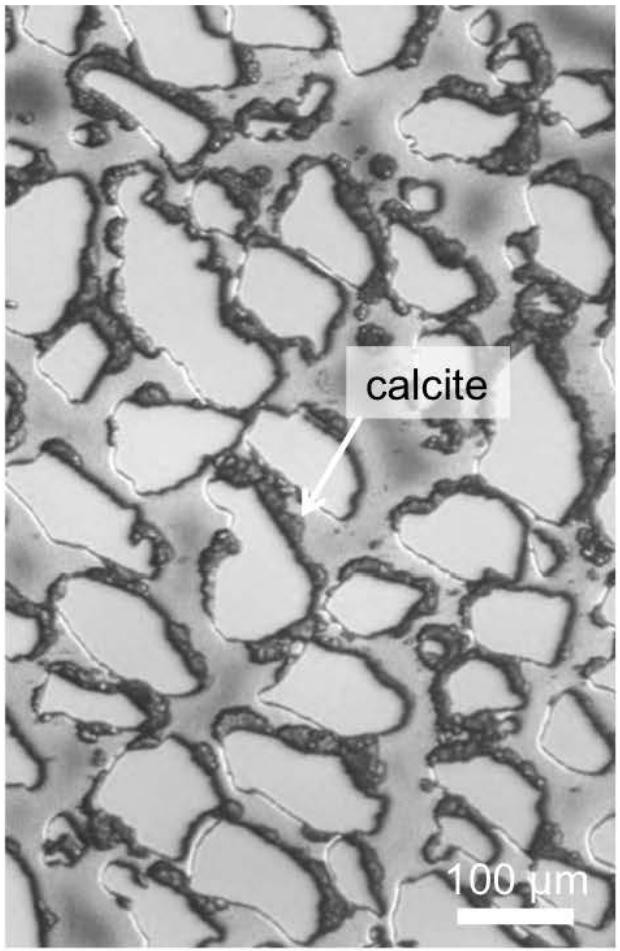
- 1M urea
- $CaCl_2$



[Song et al (2018) Lab on a Chip]

Biogenic Calcite-Functionalization of Micromodel

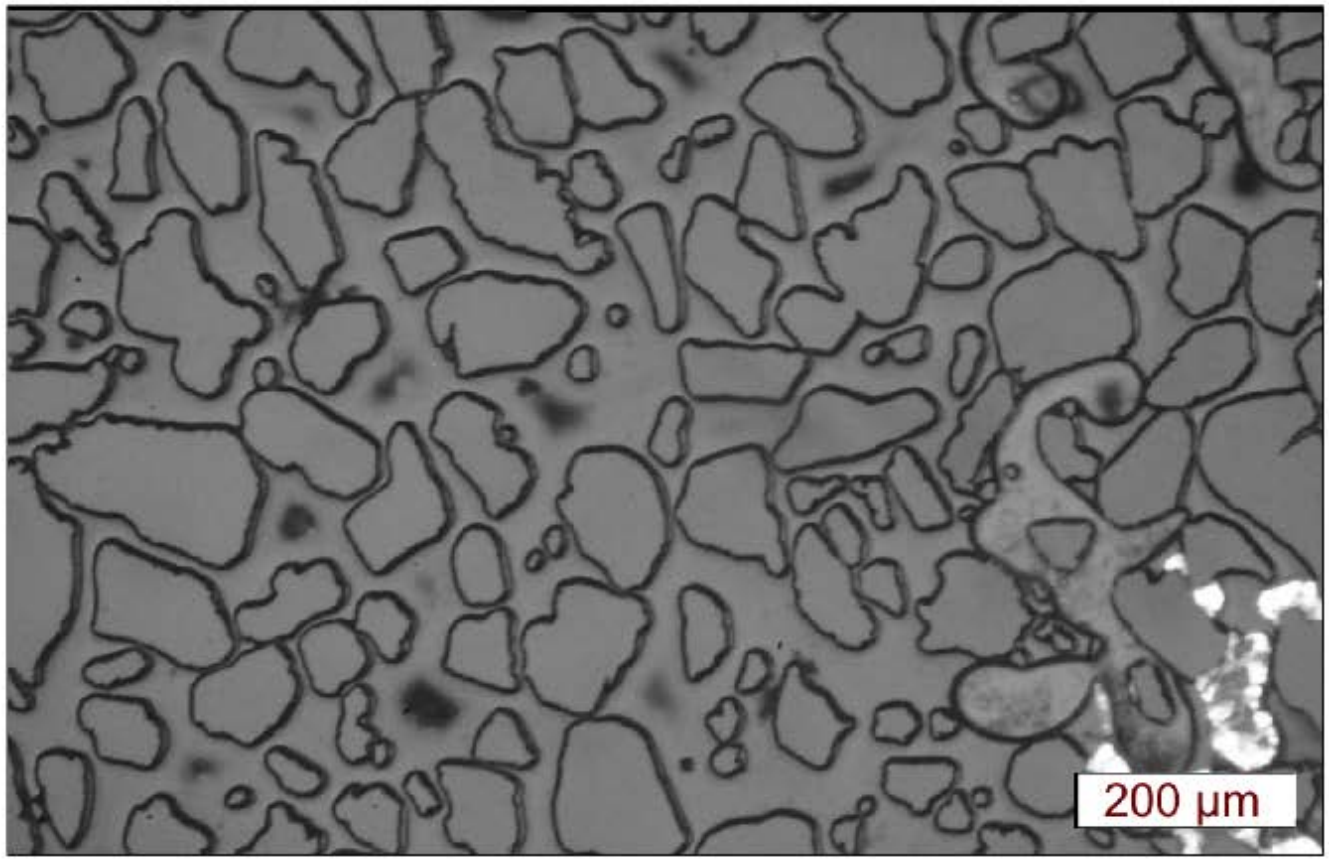




[Song et al (2018) Lab on a Chip]

Grain Engulfment in Porous Media

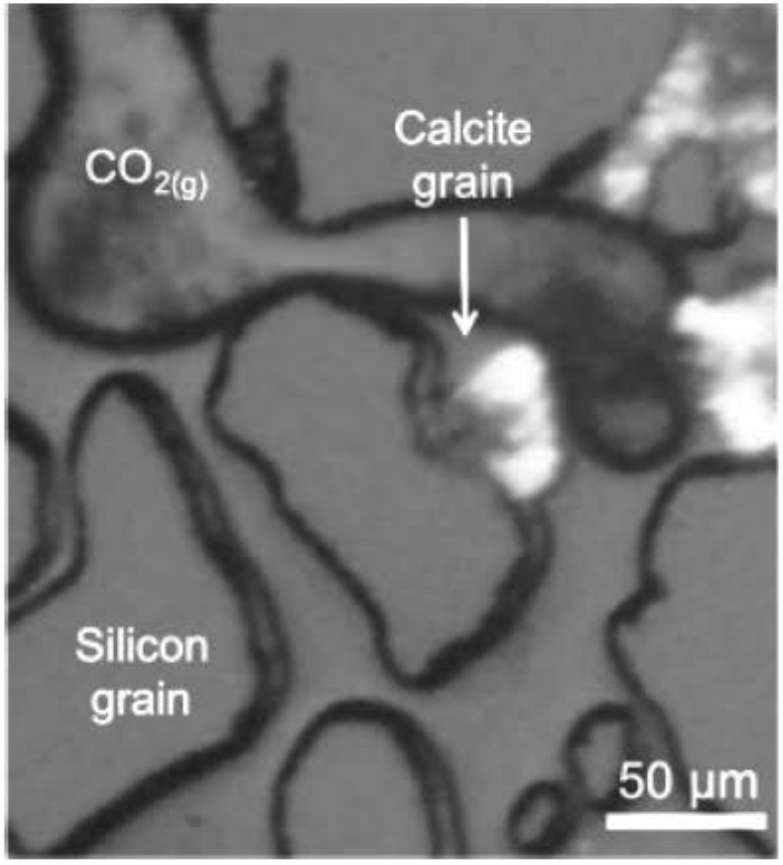
- 50 m/day 2% HCl injection
- 5 psi, 35°C
- Sped up 60x
- Separate CO2 gas phase evolved
- Protective grain-engulfment effect locally



Sped up 60x

[Song et al (2018) Lab on a Chip]

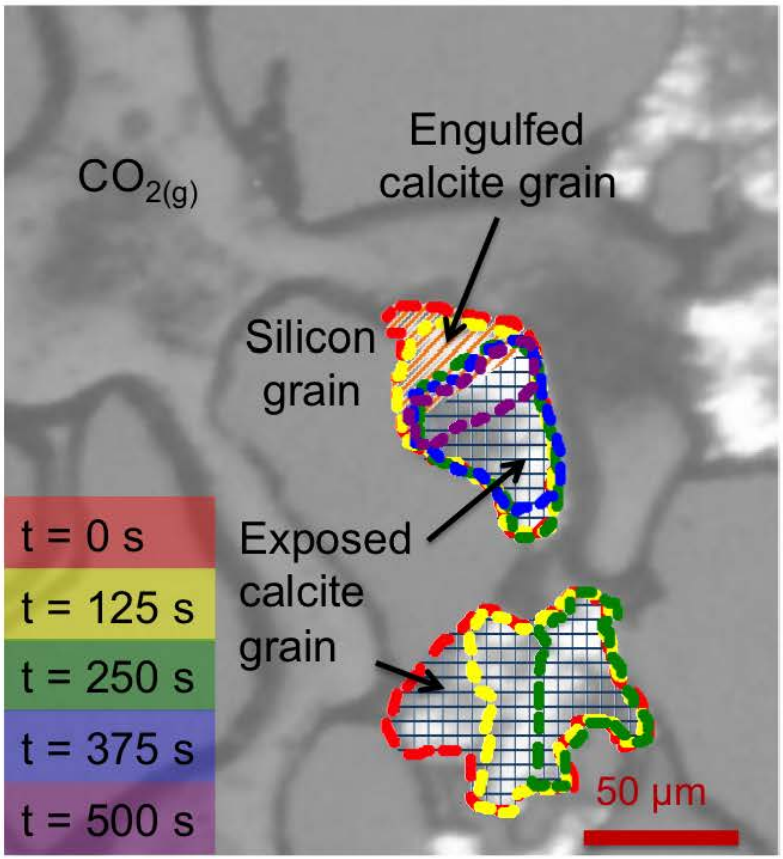
Grain Engulfment: Pore Scale Dynamics

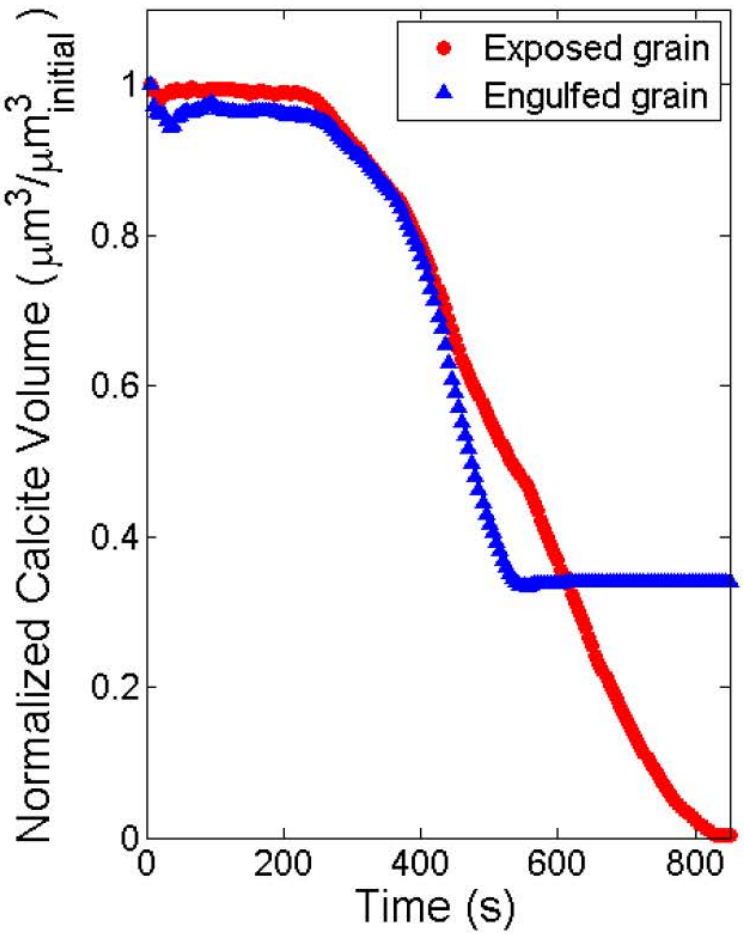


Sped up 120x

[Song et al (2018) Lab on a Chip]

Grain Engulfment on Local Dissolution

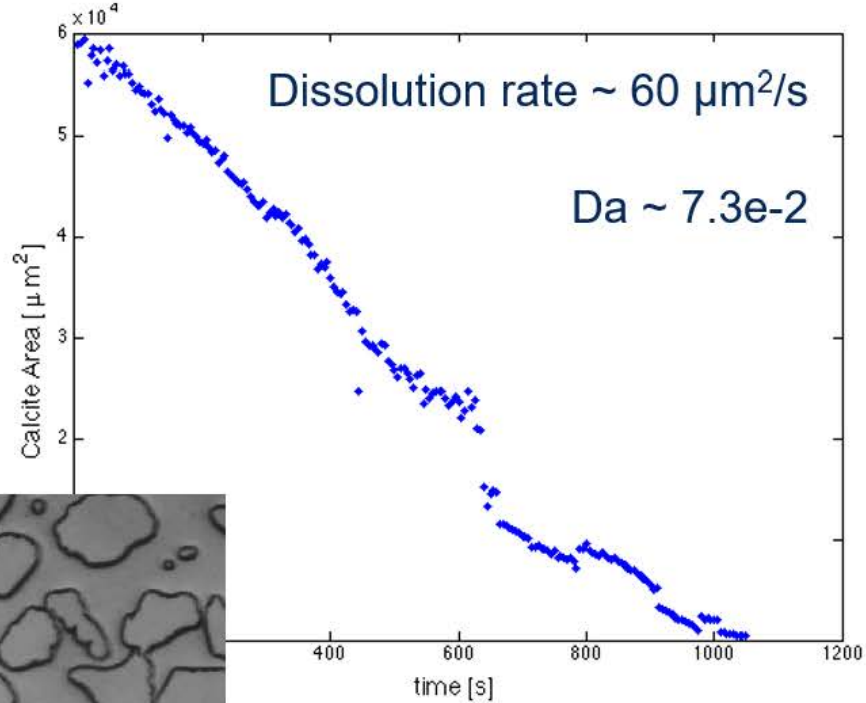


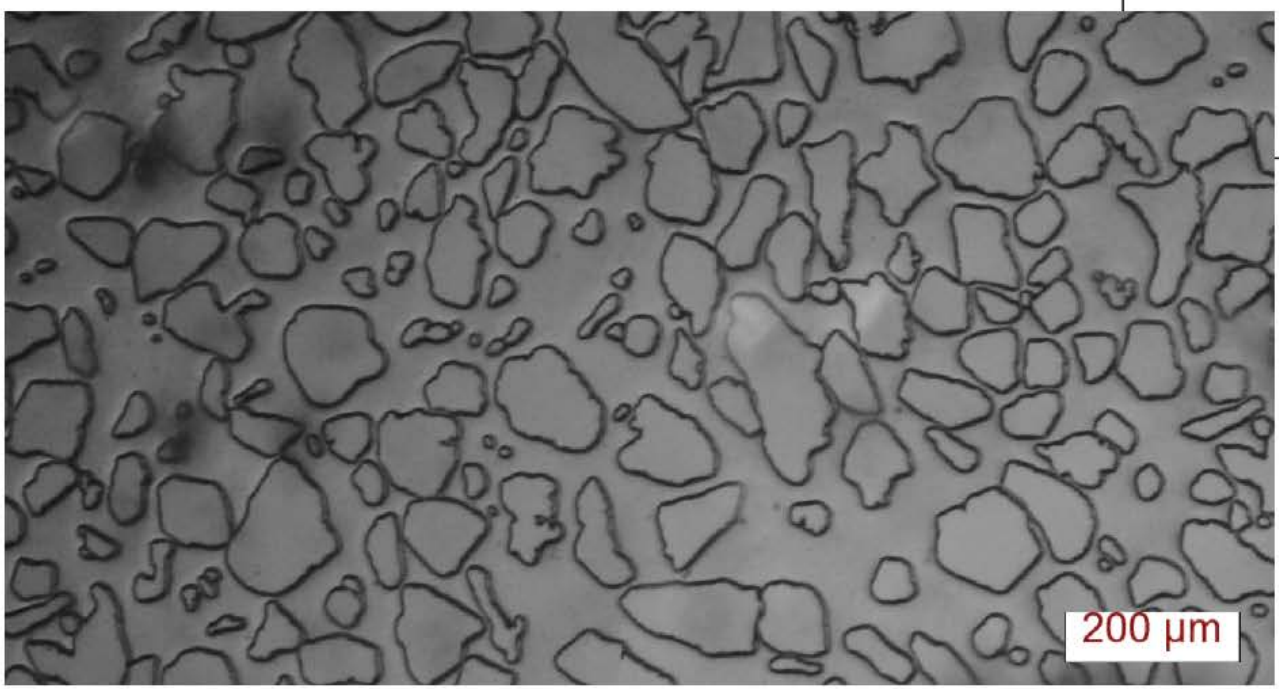


[Song et al (2018) Lab on a Chip]

Reservoir Implications: Far from CO_2 Injector

- 50 m/day injection of 2 % HCl
- 1200 psi, 35 °C
- No separate CO_2 phase evolution, constant rate of calcite dissolution

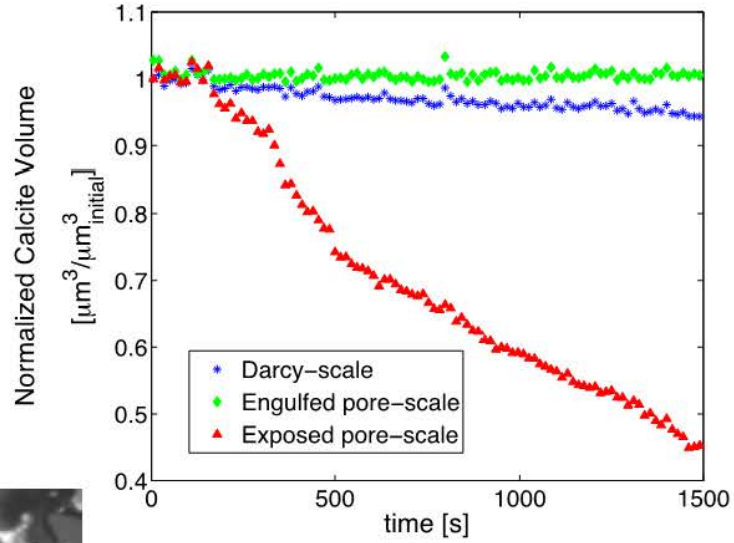


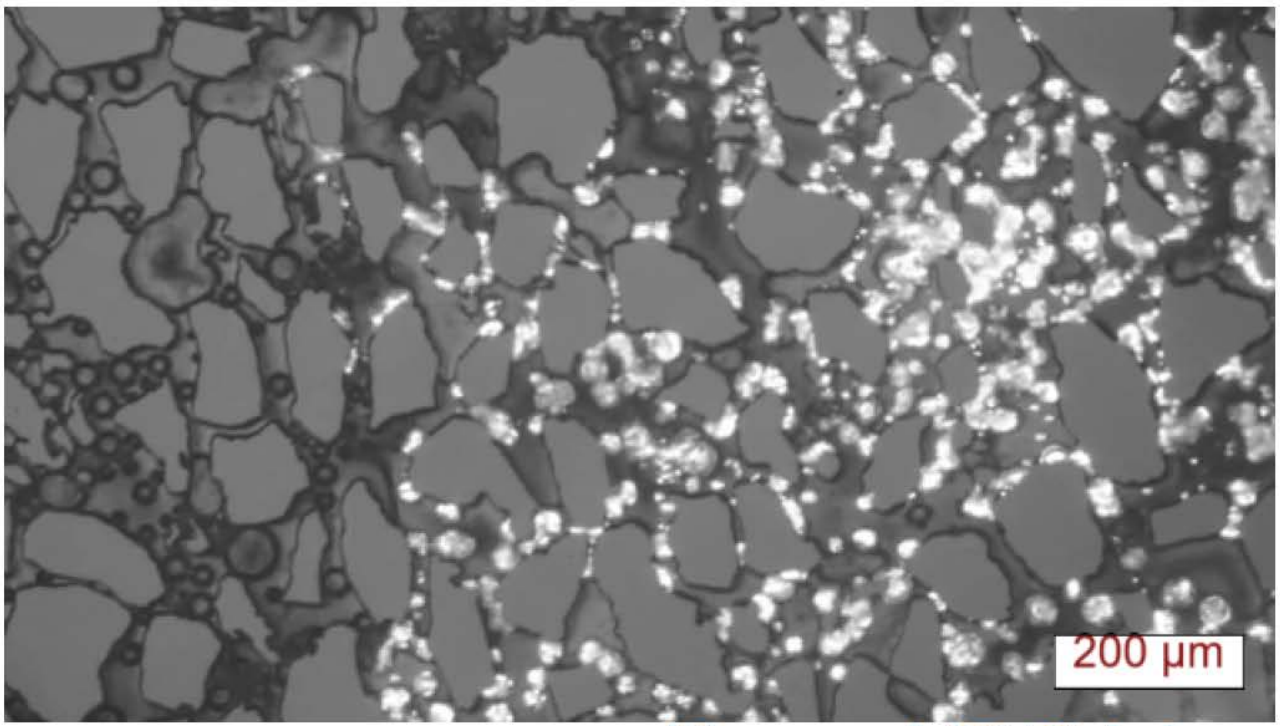


[Song et al (2018) Lab on a Chip]

Reservoir Implications: Close to CO_2 Injector

- 50 m/day injection of 2 % HCl saturated with CO_2
- 1200 psi, 35 °C
- Separate supercritical CO_2 phase evolution, reduced rate of local calcite dissolution





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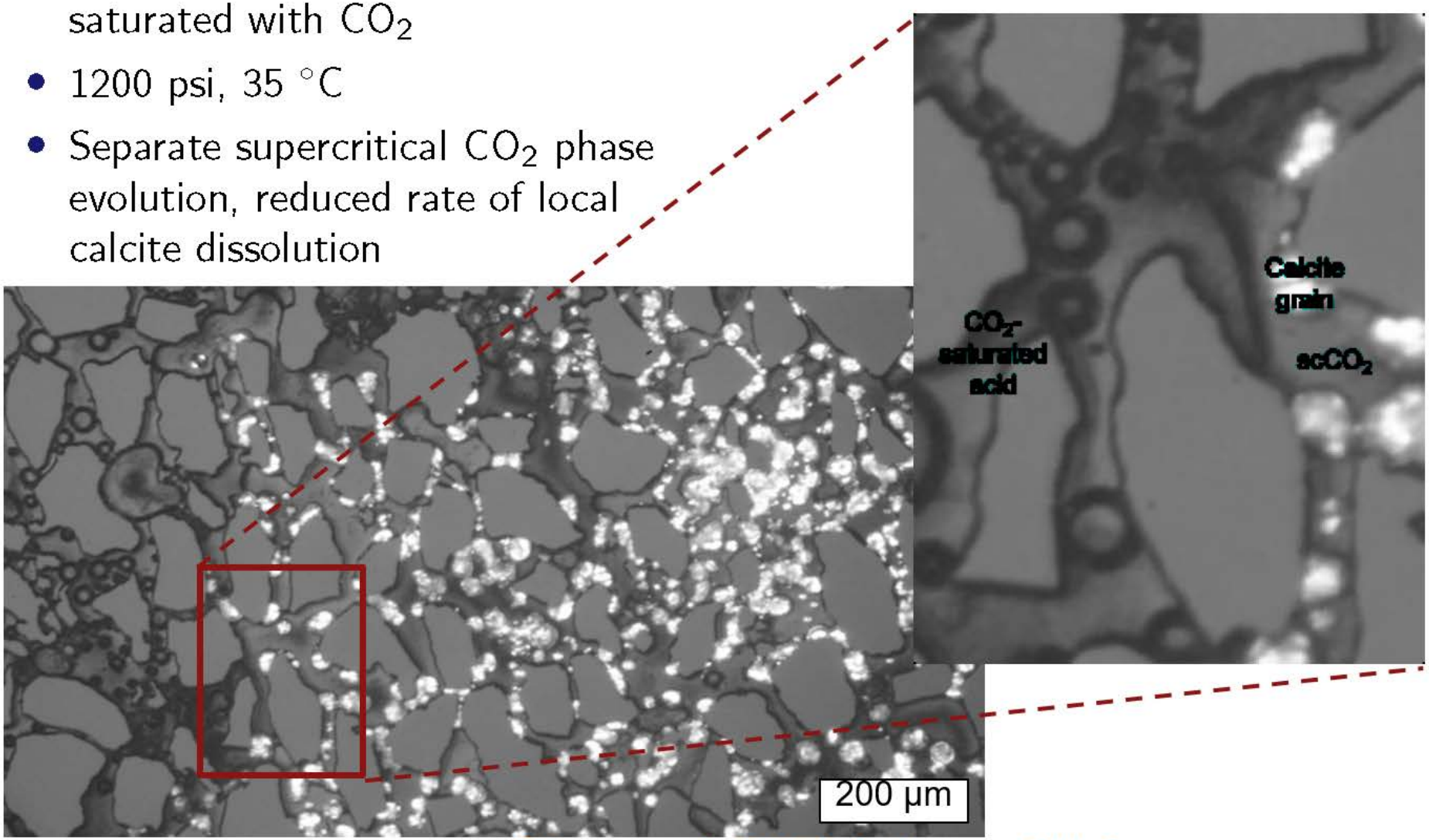

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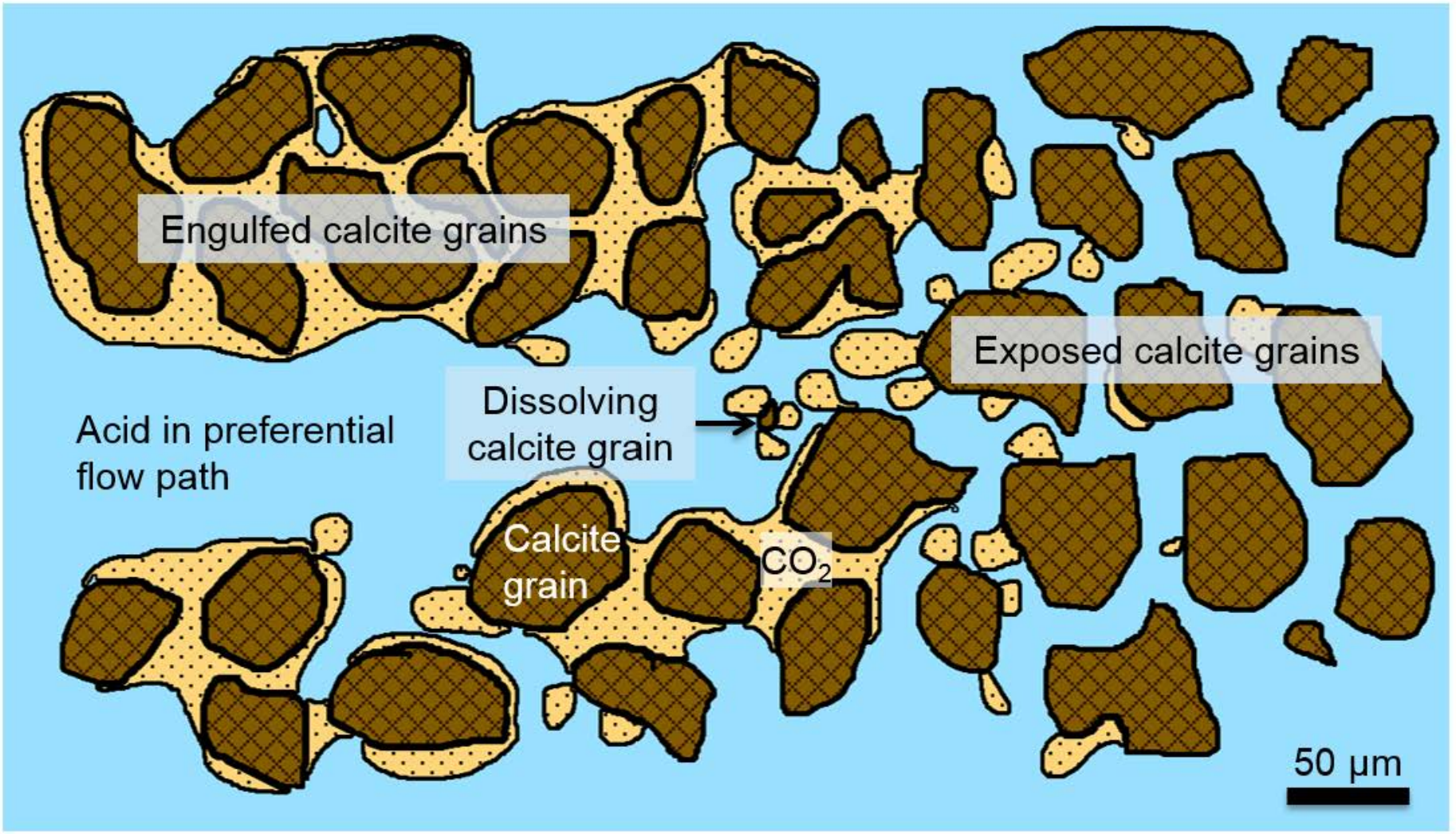
Discovery: Fundamental Mechanism



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Engineering Science Advances: Micro/Nanofluidics in Energy

Infrastructure Development

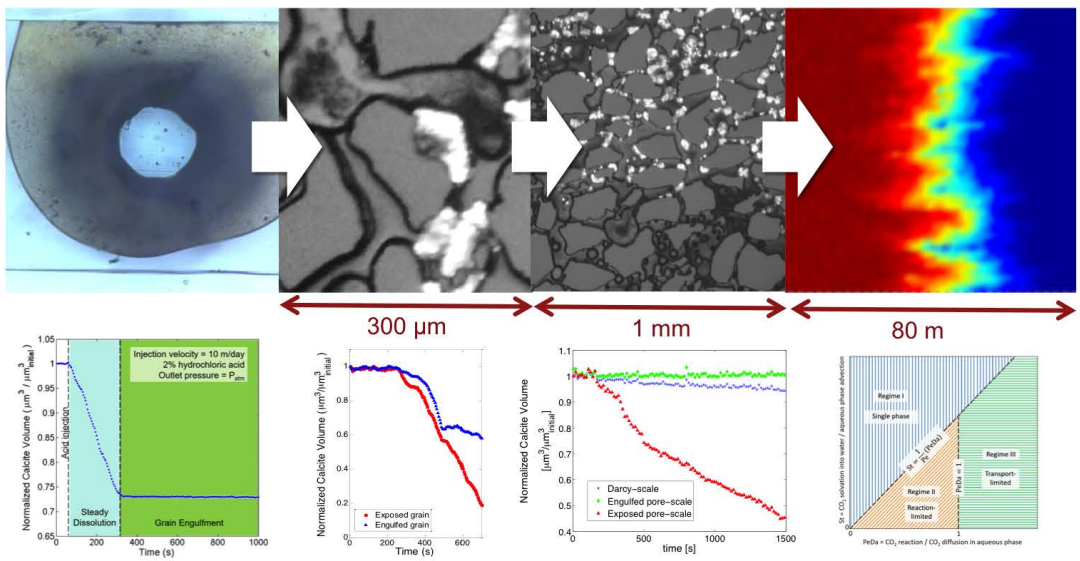
- Real-Rock Microfluidics for Fundamental Pore-Scale Understanding

Fundamental Discovery

- Grain-Engulfment on Local Reactive Transport

Real-World Impact

- Mechanistic Depiction of Wormholing in Carbonate CO_2 Storage Reservoirs



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Acknowledgement

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