UiO : Universitetet i Oslo

SUbsurface CO2 storage- Critical Elements and Superior Strategy

CO_2 Injectivity: Formation drying-out and salting-out

By:

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Drying-out and salting-out

- During CO_2 injection, the permeability in the near-well area might be severely reduced by salt precipitation triggered by the evaporation of brine into the CO_2 stream. This induces extra pressure build-up and a decline of injectivity over the course of injection.

- Field experiences confirm the occurrence of this phenomenon during production/injection from gas reservoirs (Bette and Heinemann, 1989; Kleinitz et al., 2001) and during storage of natural gas (Place Jr and Smith, 1984).

- The source of extra pressure build-up in the Ketzin (Baumann et al., 2014) and Snøhvit (Grude et al., 2014) CO_2 storage projects is partly assigned to salt precipitation.

Question:

The primary questions investigated were whether trapped water films in porous media have enough continuity and conductivity to transport fresh brine to an evaporating front, and therefore whether these can cause increased rates and quantities of salt precipitation.

Method:

Two glass micro-chips were fabricated using laser ablation technique: (1) a two dimensional network which employed a lattice of square grains (~500 μm×500 μm) connected through throats with polygonal cross section of widths 250 μm.(2) a single, one dimensional channel (~2 mm×100 mm) which is connected to a two dimensional network similar to the first pattern. The micro-chips were saturated with NaCl solution and replaced afterwards with dry CO_2 under different rates of injection. Pore-scale salt precipitation was visualized under bright field imaging using advanced polarized light microscopy.

Results:
The results suggest that salt precipitation is a time evolving (dynamic) process which has several elements.

1- Salt has a hydrophilic nature which gives massive capillarity to the salt aggregates to imbibe water.

2- Salt grows as porous aggregates in the gas phase enhancing the distribution of brine, and increasing the surface area for evaporation, and therefore increasing the evaporation rate.

3- Evaporation induces nucleation and precipitation which induces further capillary transport *i.e.* salt aggregates imbibe more water to compensate the increased evaporation.

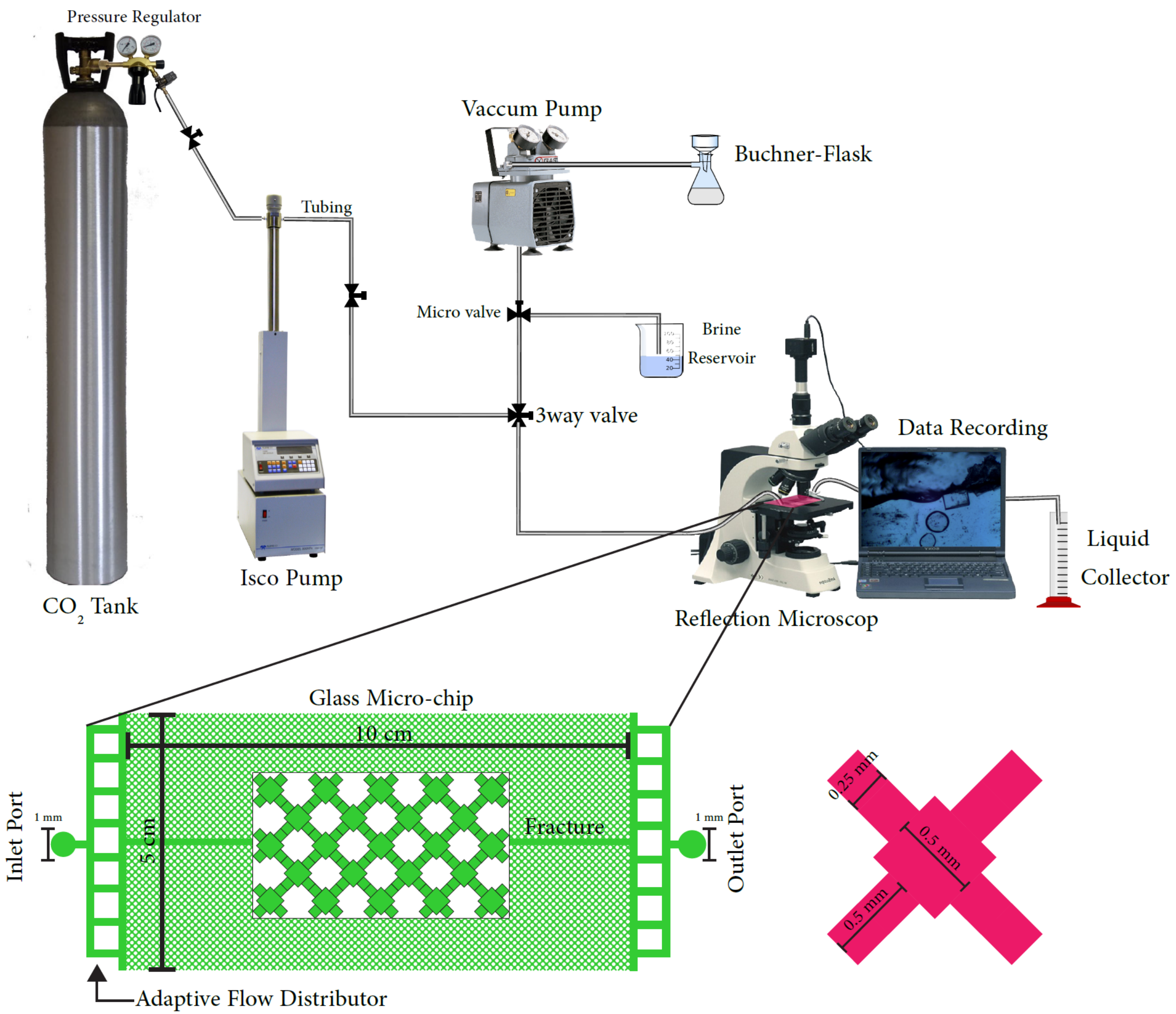
Results:

The net outcome of these elements is a massive salt accumulation in the CO_2 pathways, through a mechanism which is self-enhancing.

An important insight is the viable dynamic stability and strong conductivity of the water films owing to the pressure gradient imposed by capillary imbibition.

experimental and numerical works which neglect this effect impose improper boundary conditions to their models and thus underestimate the amount of precipitation. Therefore, effect of water films must be taken into account in the assessment of the salt precipitation, permeability and injectivity in porous media.

Lab-on-chip experiment



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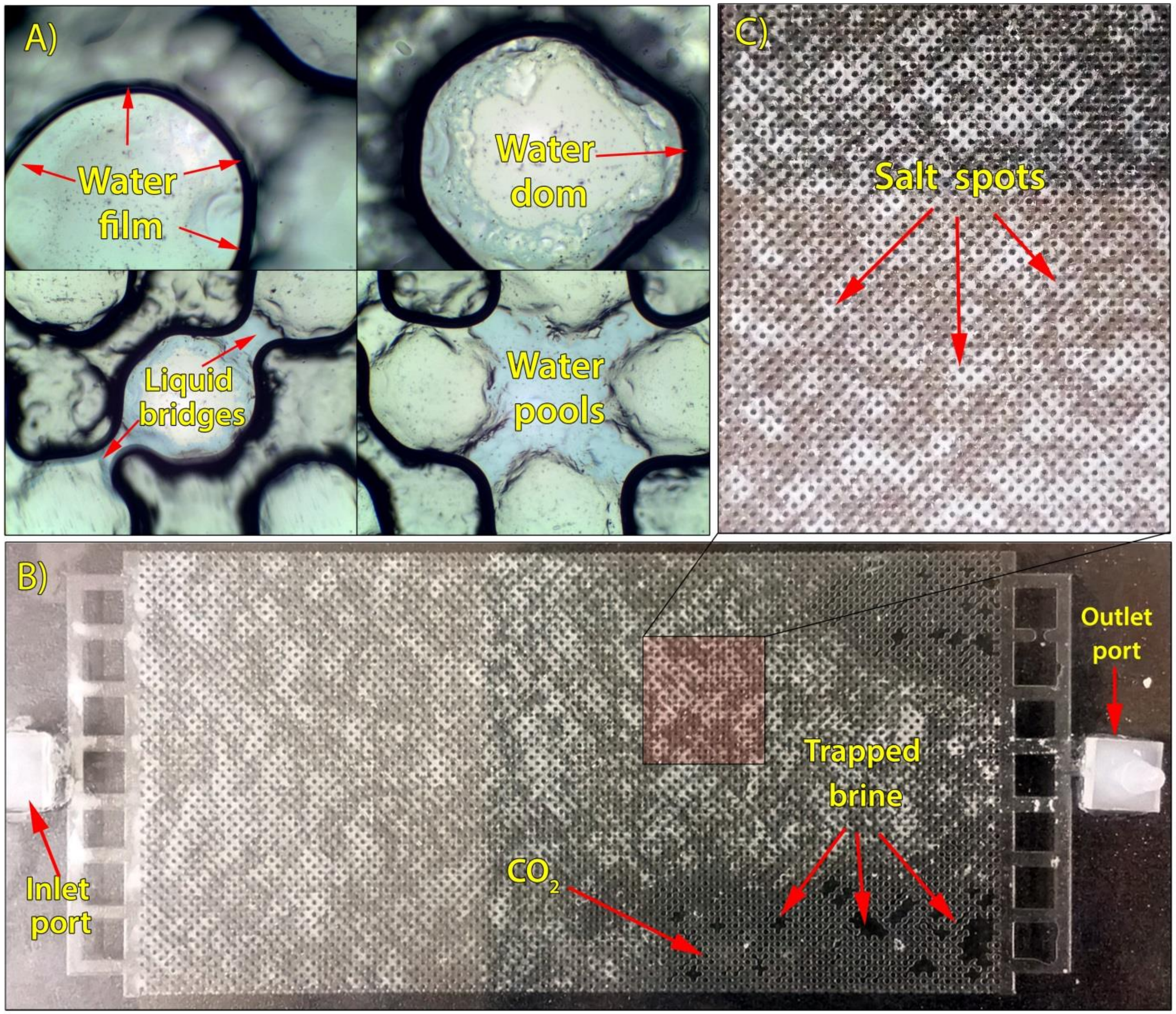

Distribution of liquid and solid (salt) phases following injection of CO_2 (50 ml/min) in the homogenous micro-chip. (a) Pore-scale configurations of trapped liquid phase at 3 min after injection. (b) salt distribution at 85 min after injection

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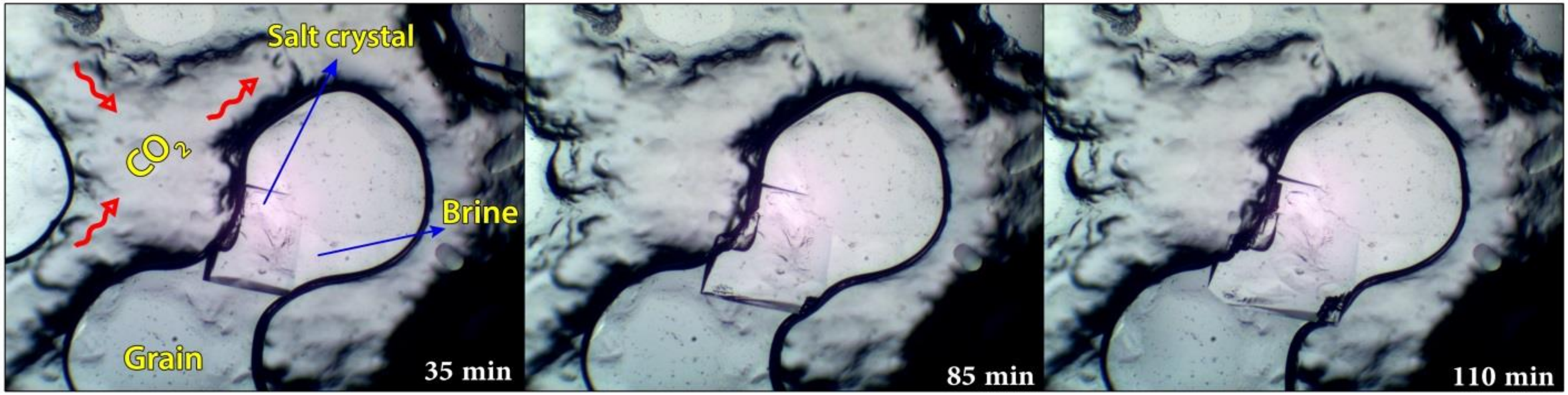

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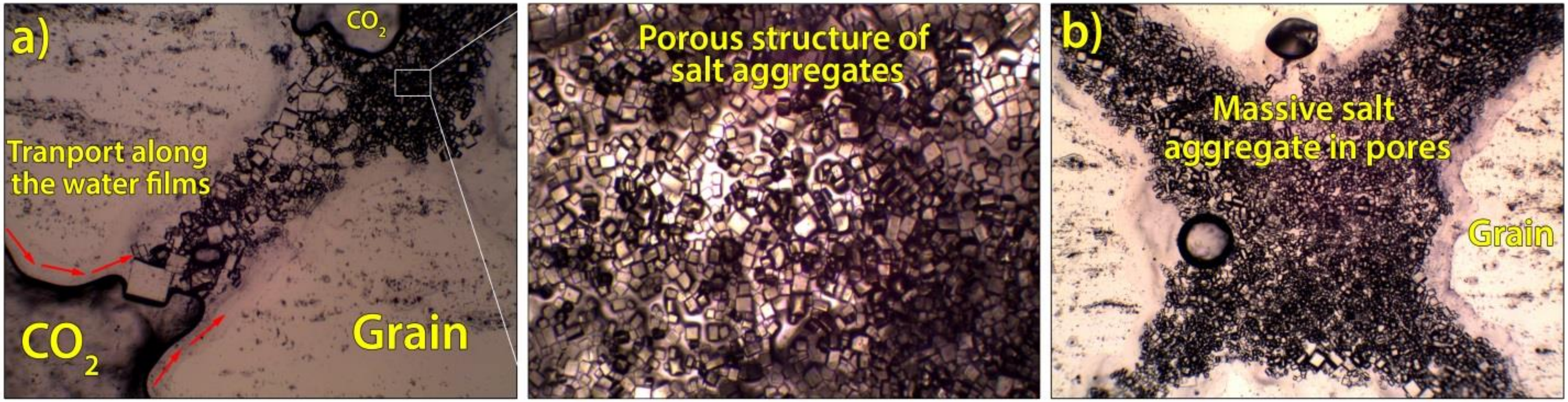

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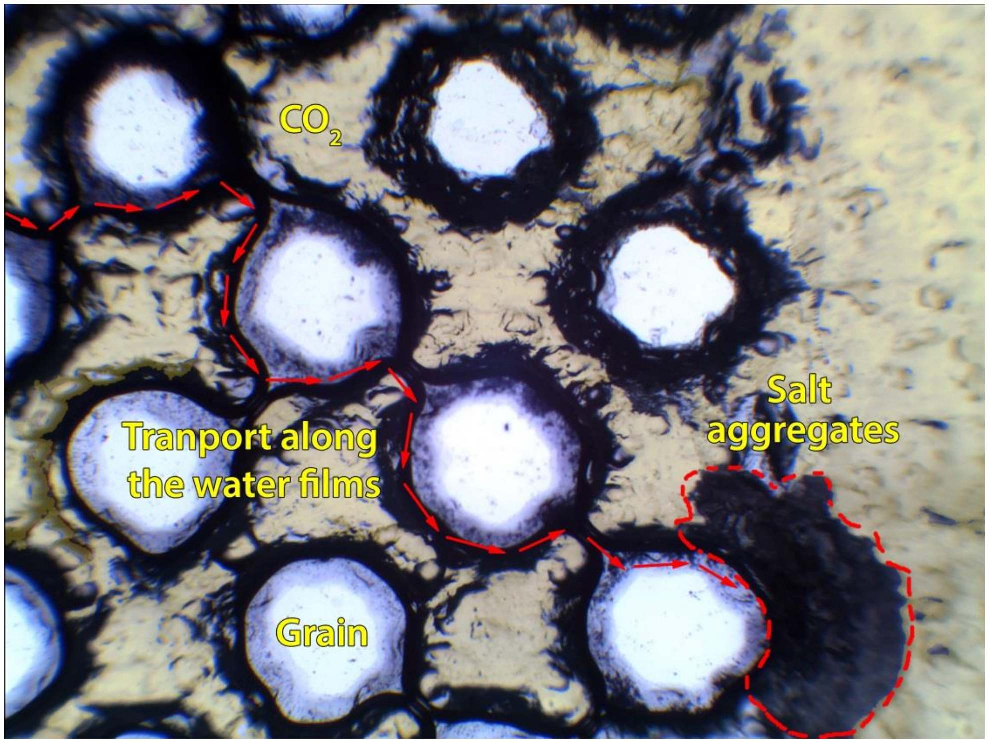

Pore-scale visualization of aggregate growth in the homogenous micro-chip. Aggregates are supported with the transport of water through the capillary continuous water films. The images show that even very thin liquid bridges have a significant hydraulic conductivity.

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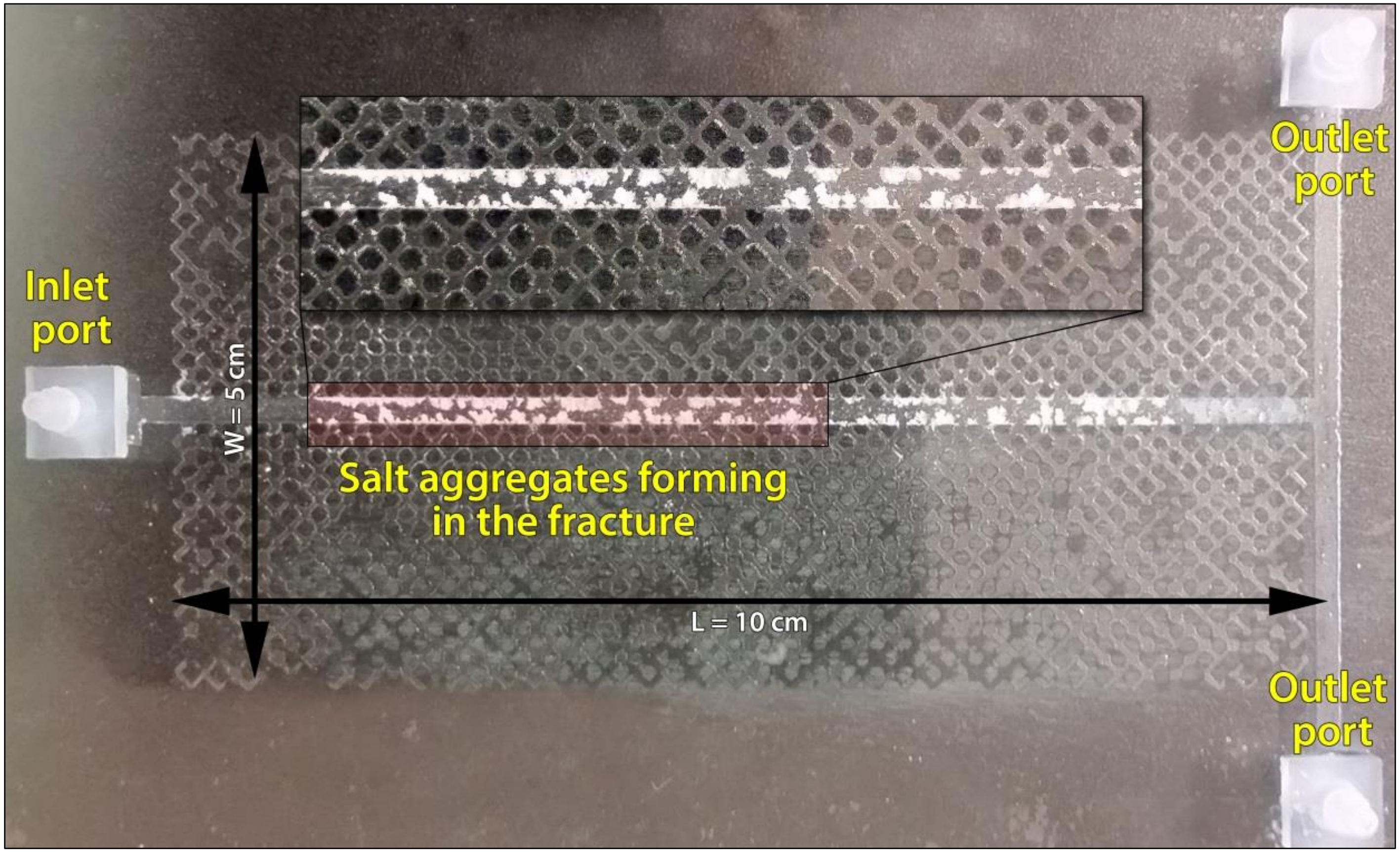
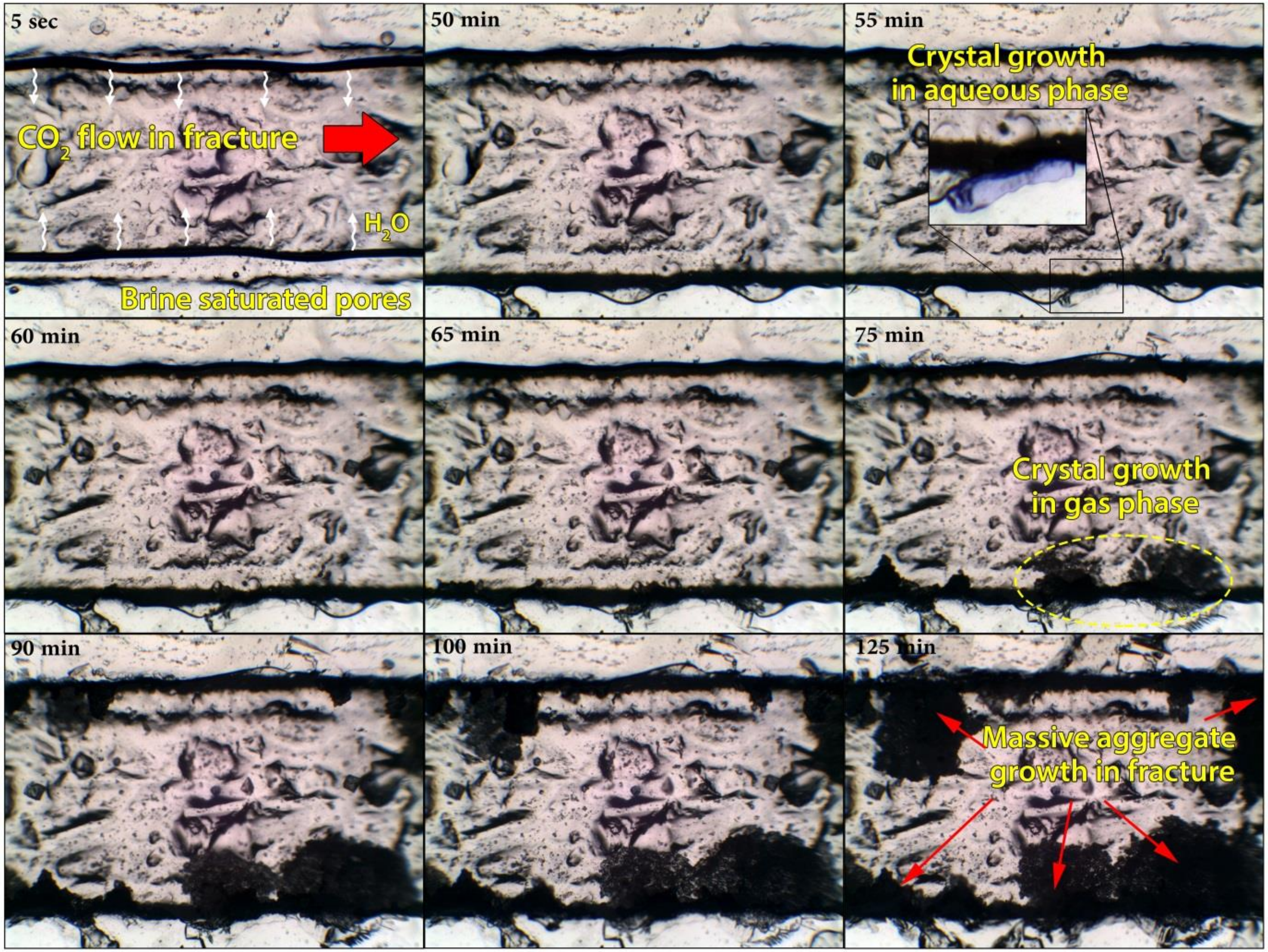


Image shows salt precipitation in the heterogonous micro-chip at very end stage of drying. The surface of fracture is covered with massive precipitate.

Drying-out and salting-out



Conclusions:

1. Salt precipitation in porous media is a complicated process which involves several coupled physics such as diffusion, convection, capillary suction, film flow…
2. Previously performed experiments do not represent a complete picture of the process
3. Continues water film may exist at certain condition of wettability
4. This provide flow of water and salt toward the evaporation front

Thank you for your attention

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