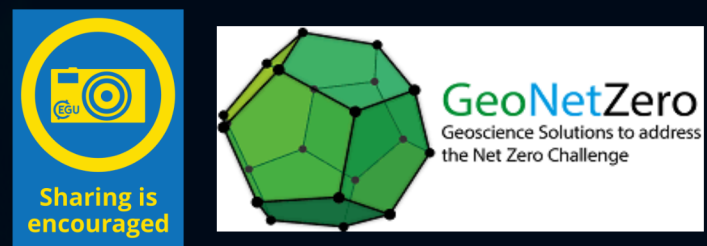


Exploiting induced carbonate precipitation to improve reservoir storage integrity and geothermal system efficiency

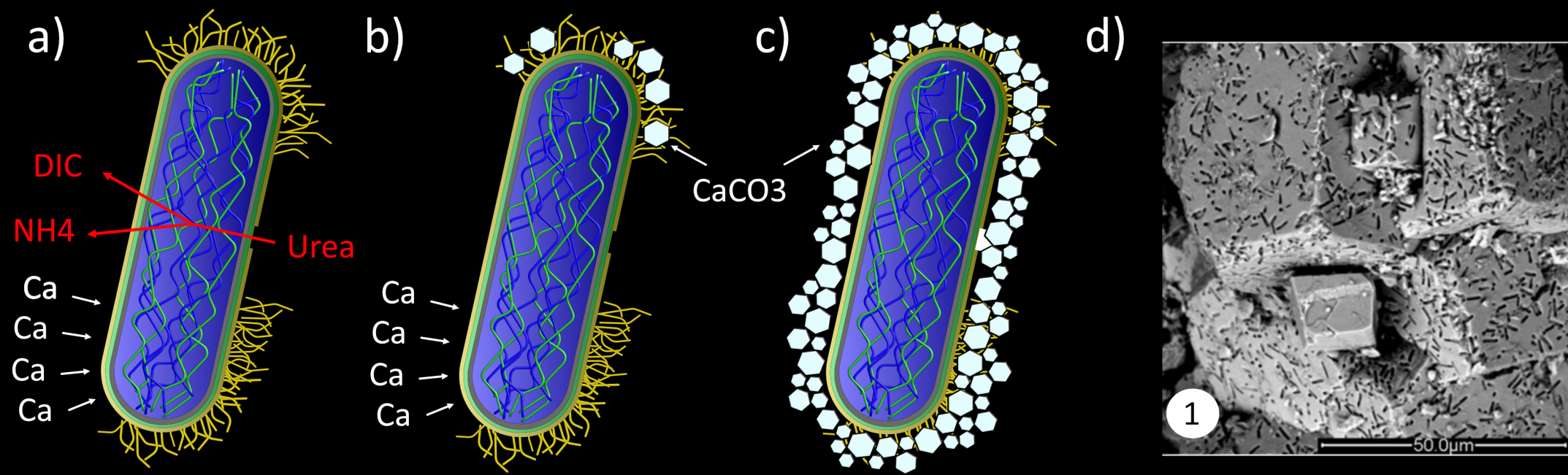
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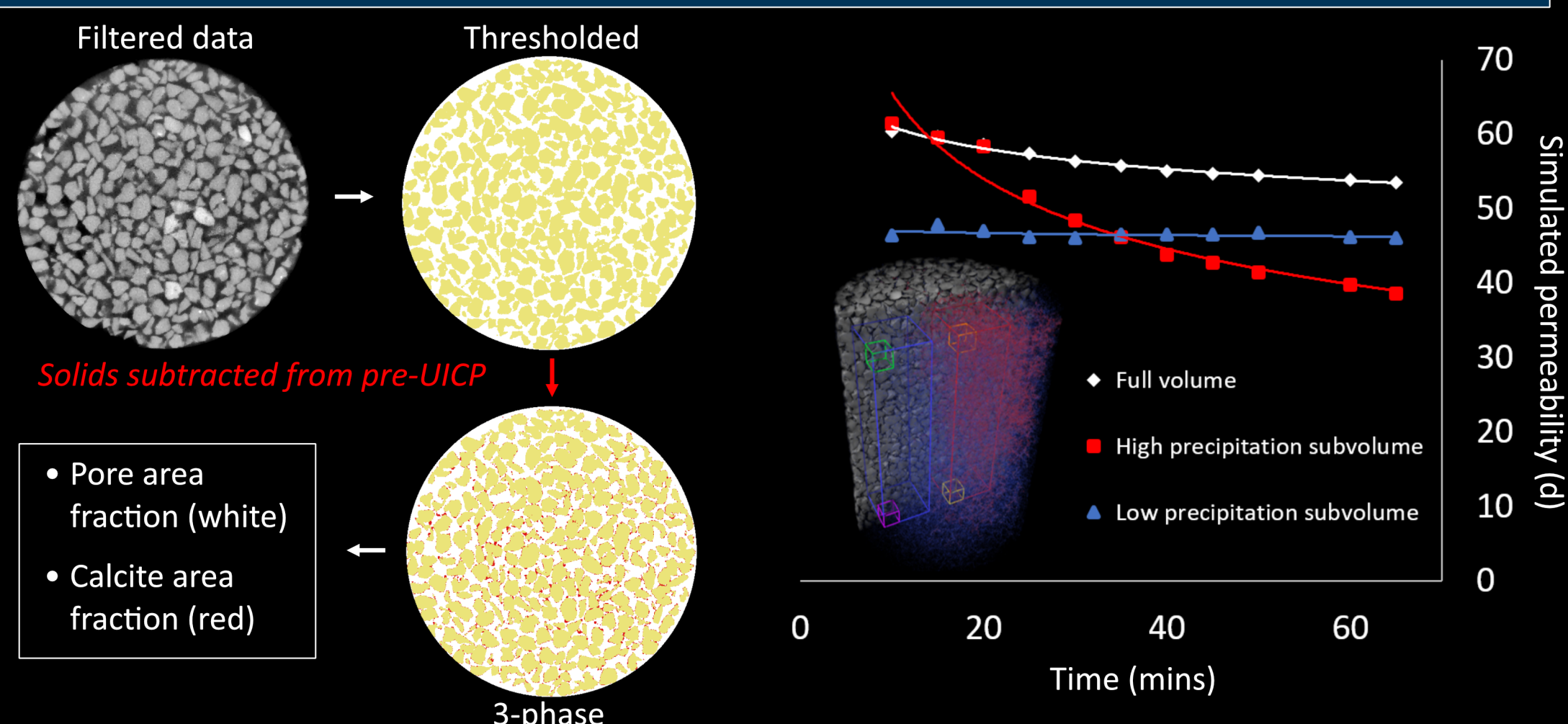
The dynamics of biologically induced crystallization

What is ureolytic induced carbonate precipitation (UICP)?

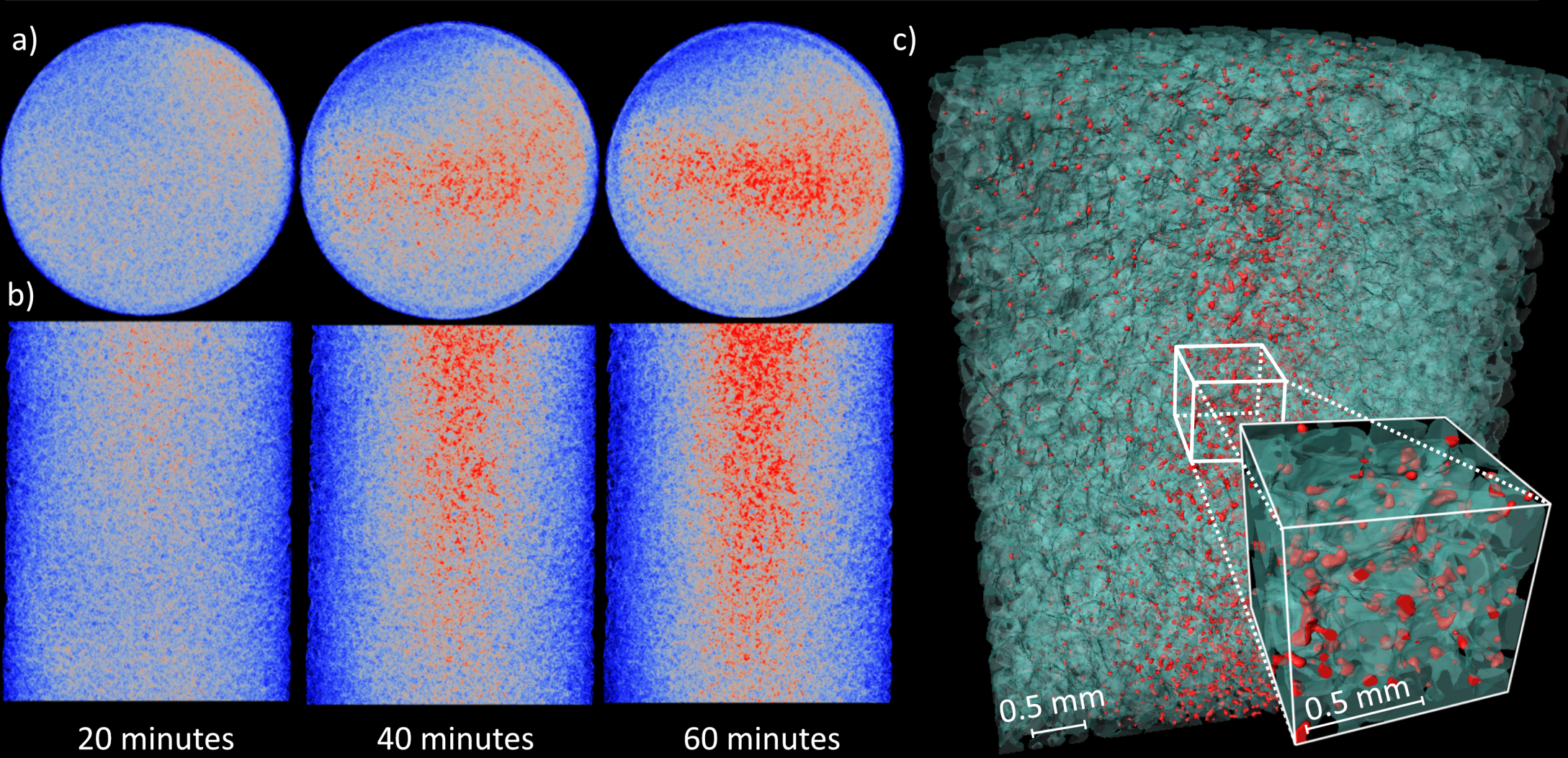
UICP mimics a naturally occurring biomineralization process caused by soil bacteria that produce the enzyme urease. We investigate the subsurface engineering applications of this intra-aggregate precipitation process using real-time 4D (3D + time) X-Ray Computed Tomography (XCT).



The mechanism of calcite nucleation on the cell walls of urease producing bacteria (a-c). d) shows a scanning electron microscope image of microbially induced CaCO₃ [1]. The indentations are what is left of bacterial cells that became entombed in the growing calcite crystal.



Permeability simulations across smaller subvolumes (red: high precipitation and blue: low precipitation) allow us to assess the real-time effect of precipitated CaCO₃ on flow. The QR code (across) shows a video of the 3D distribution of CaCO₃.



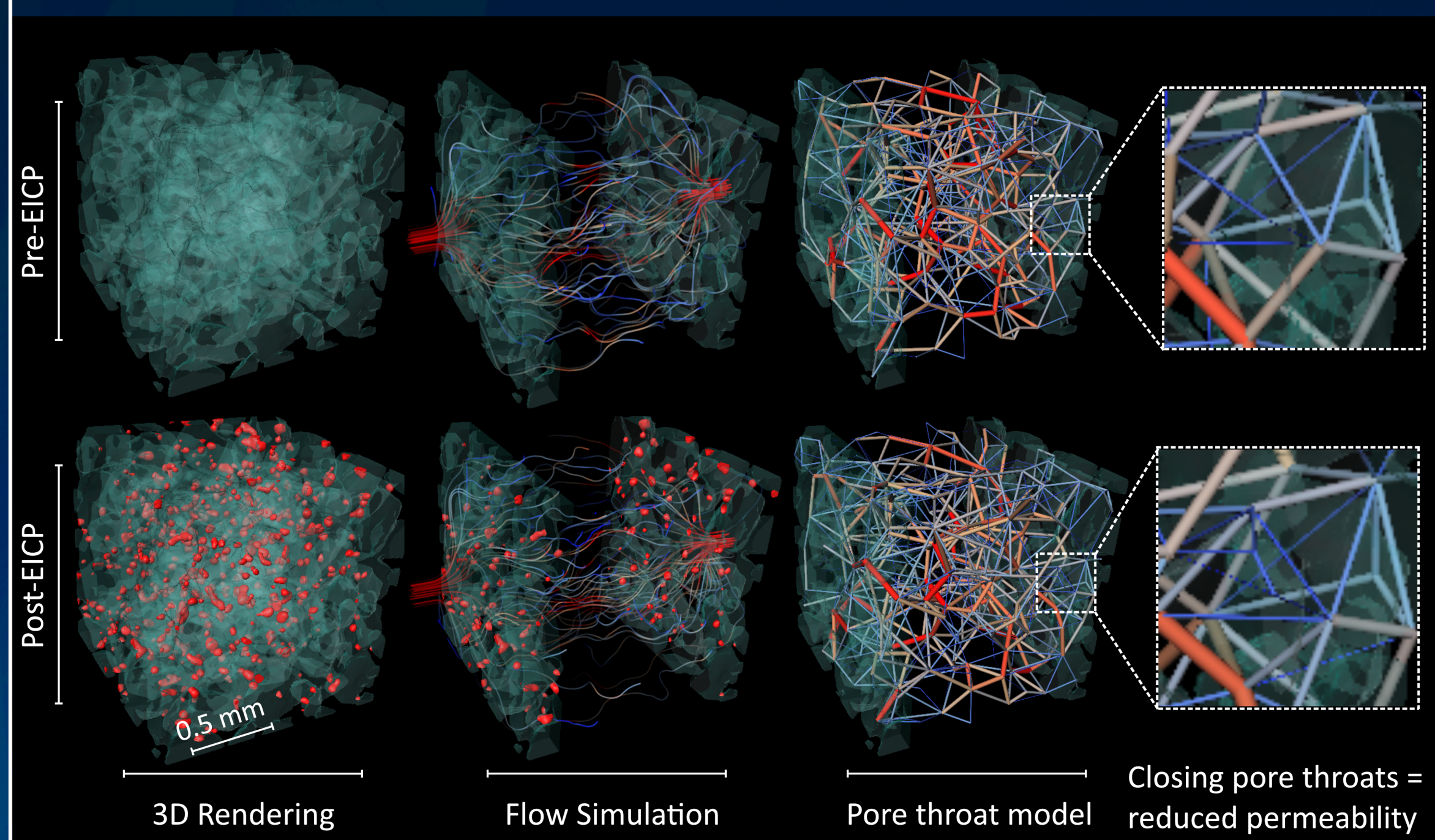
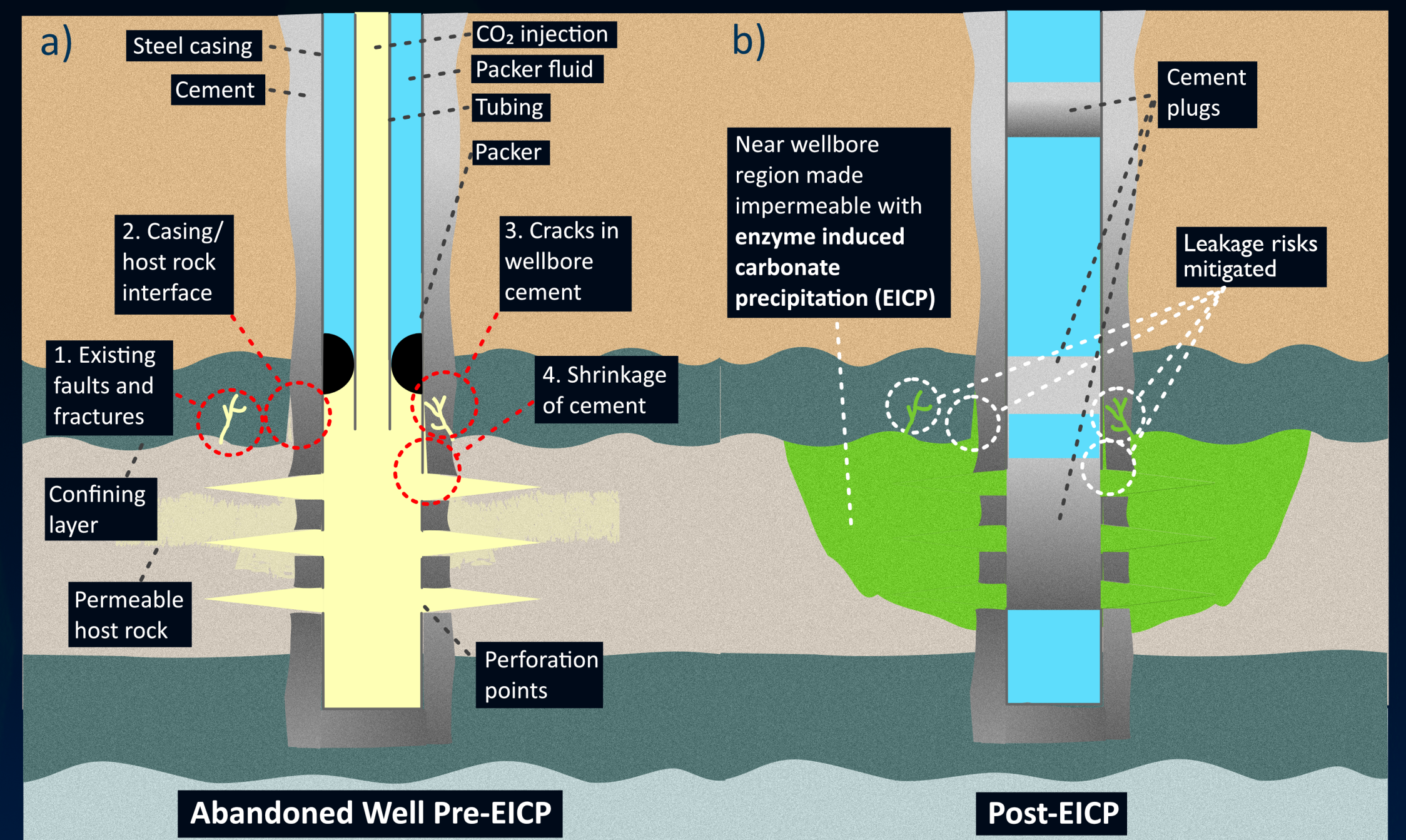
Low fluid mixing rates during 2-phase UICP may allow the formation of larger crystals. However, the overall precipitation efficiency and spatial homogeneity of precipitated CaCO₃ is likely reduced (Above: mean CaCO₃ distribution a) radial, b) axial, and c) the 3D distribution of CaCO₃ (red) 65 minutes post 2-phase UICP).

CO₂ Storage & Utilisation: Improving storage integrity

Reduced permeability, Reduced leakage risk

When CO₂ dissolves in water it forms carbonic acid, which is corrosive to carbonate minerals. We plan to explore the buffering effect of dissolved calcite on migration of the reactive front. By better understanding how pore networks develop during UICP, and in the presence of CO₂ enriched brines, the required volume of biomineralized material is calculated, and experimentally validated to prevent leakage.

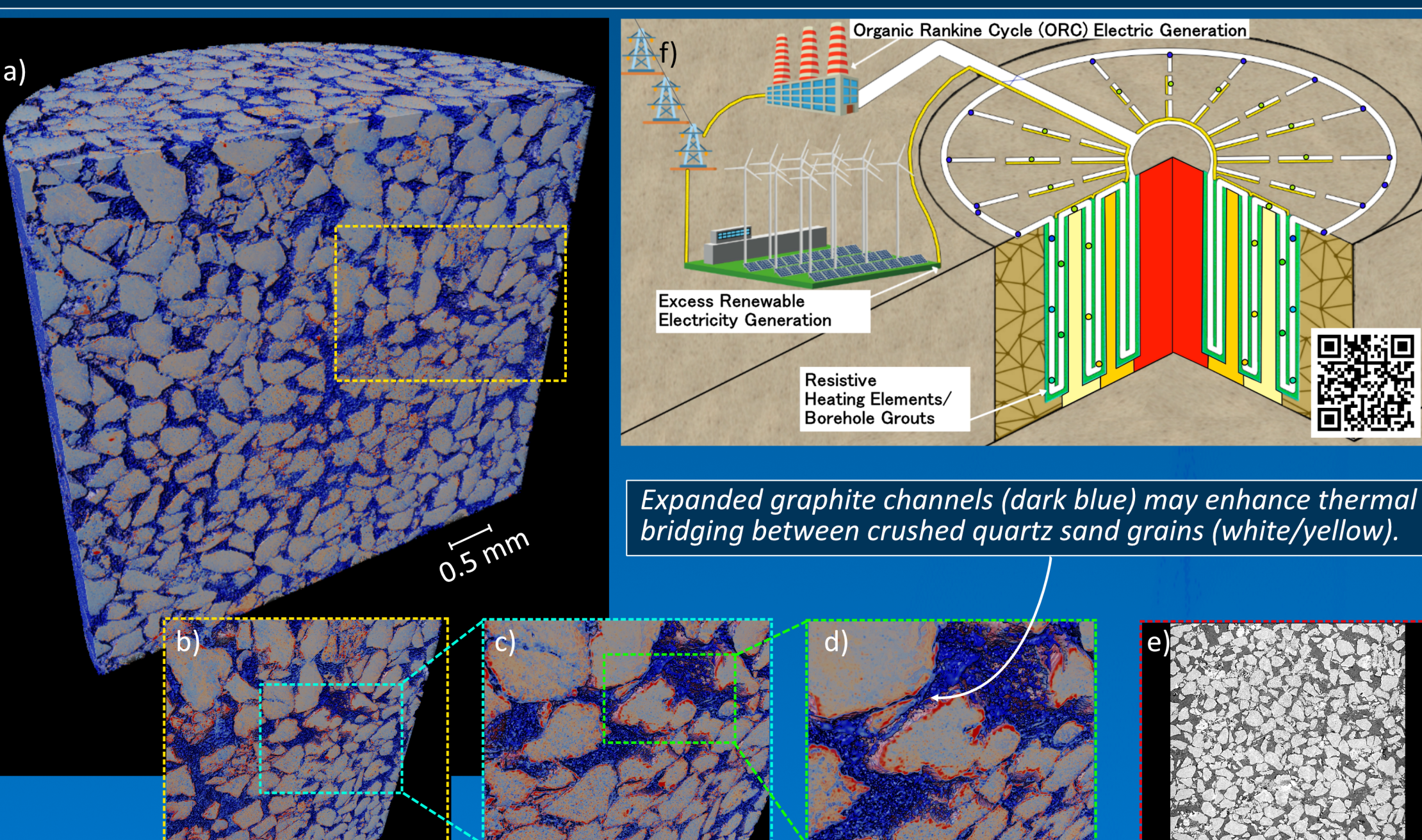
- In situ environmental conditions using high temperature and pressure flow cells
- Tests across a range of grain size/shape distributions and mineralogies
- Permeability simulation and pore network modeling allow correlation between microstructural properties and fluid flow/reactive transport



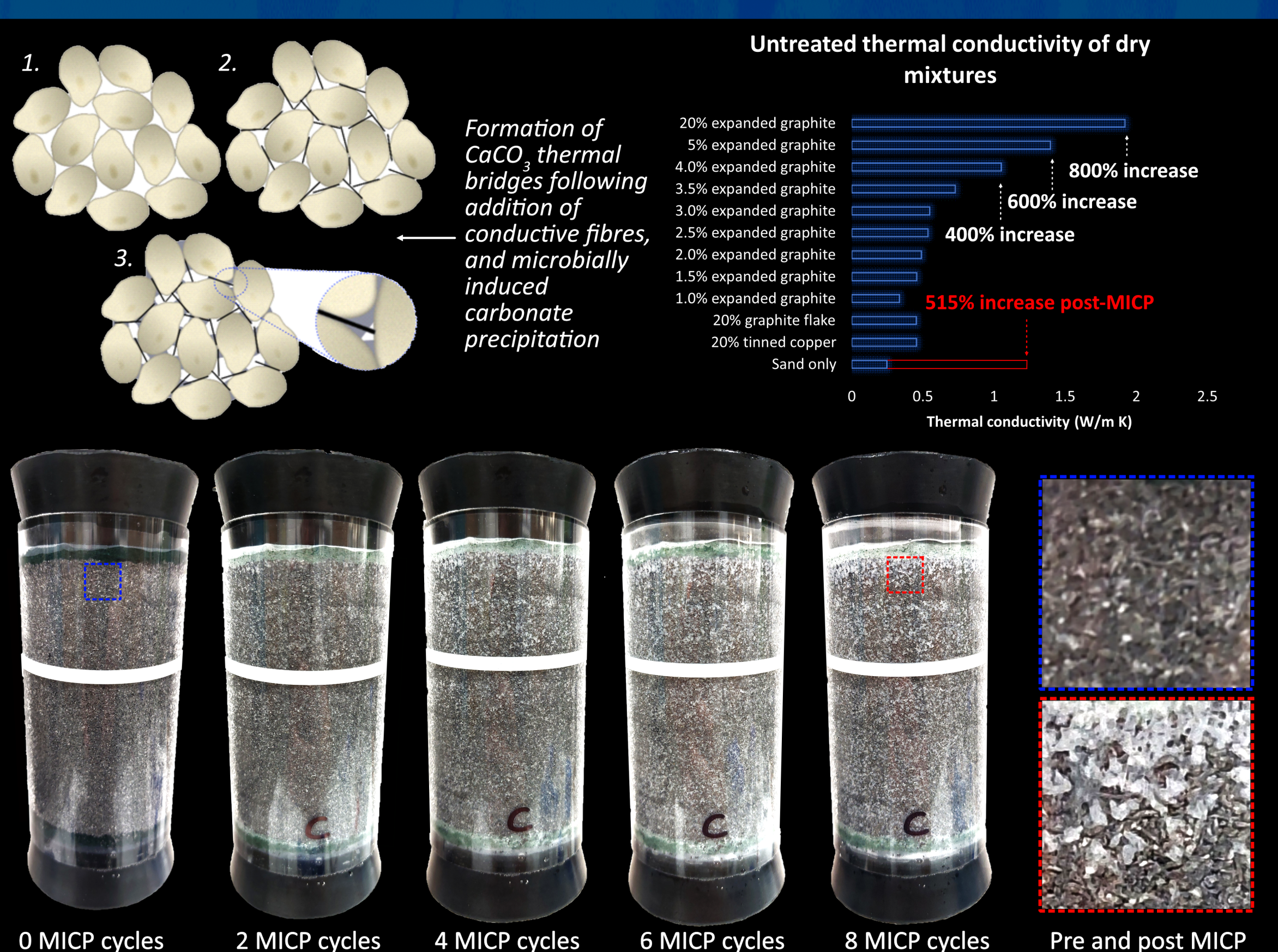
Geothermal and thermal energy storage

Improving the thermal properties of soils and well casings

Precipitated minerals at the intergranular contacts between soil grains following microbially induced carbonate precipitation (MICP) can greatly increase the thermal conductivity of the ground [2]. We investigate enhancing this effect further with inclusion of highly conductive additives.



Crushed quartz sand (99 wt%) and expanded graphite (1 wt%) prior to MICP at various magnifications (a - d). e) a single greyscale projection and f) a theoretical borehole thermal energy storage system that utilises thermally enhanced grouts to store surplus renewable electricity. For the full video please follow the QR code.



Quartz sand (95 wt%) and expanded graphite (5 wt%) at various stages during microbially induced carbonate precipitation (MICP). The columns become progressively lighter as calcite is precipitated. The % increase in thermal conductivity (above) is relative to dry quartz sand.