ION FLUX FLOW REGIMES OF ELECTROKINETIC TRANSPORT IN LOW PERMEABILITY POROUS MEDIA RALATED TO IN-SITU RECOVERY

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MUTRIS

Sections

1. Micro-CT based understanding of the fracture/pore and mineral distribution
2. Fundamental understanding of fluid/ion flow in the ore from a pore-scale solver
3. Experimental setup for EK-based chalcopyrite leaching

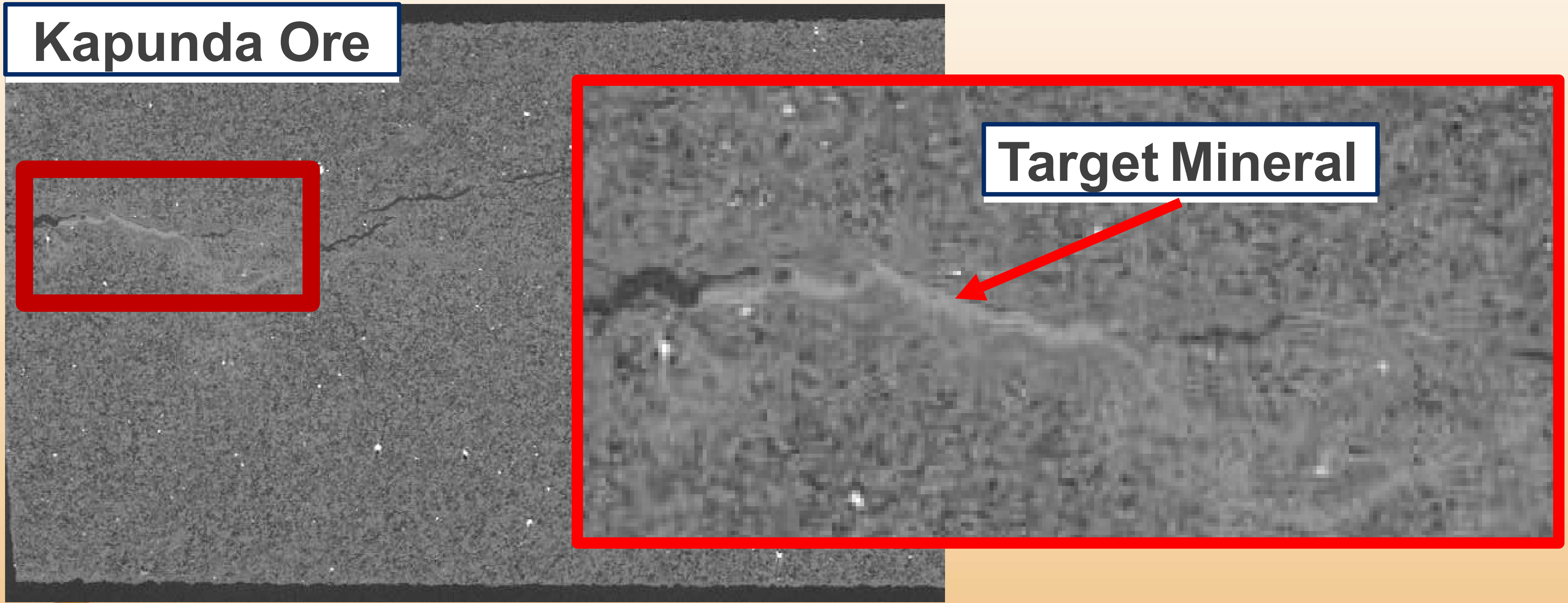
OPEN QUESTIONS:
What are the mineral compositions?
Do the minerals dissolve?
Where are the minerals located?
Does the ore have permeability?

Screening criteria:
Is this mine suitable for in-situ recovery from a pore-scale perspective?

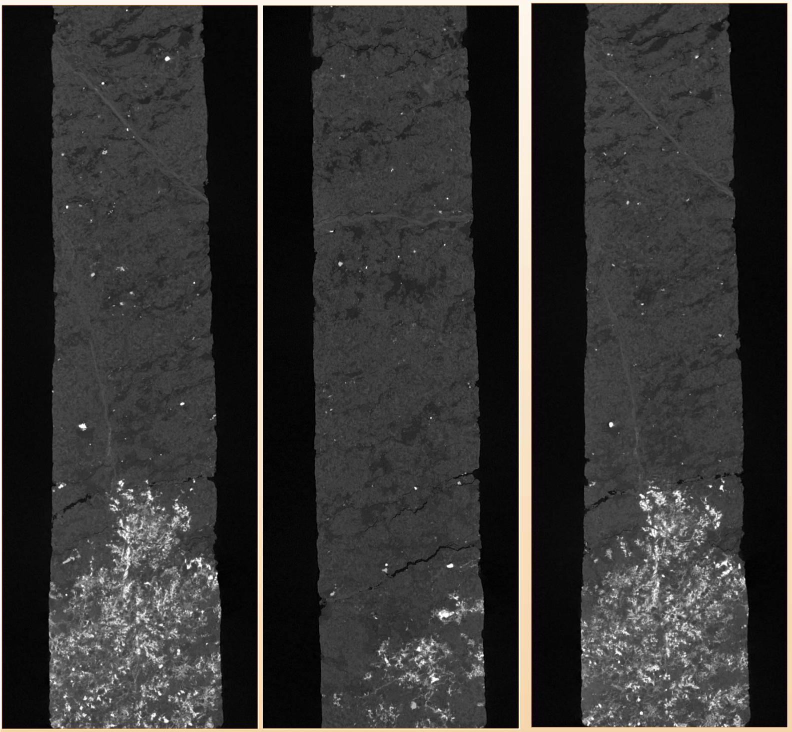
Micro-CT 3D scan of a Kapunda copper ore

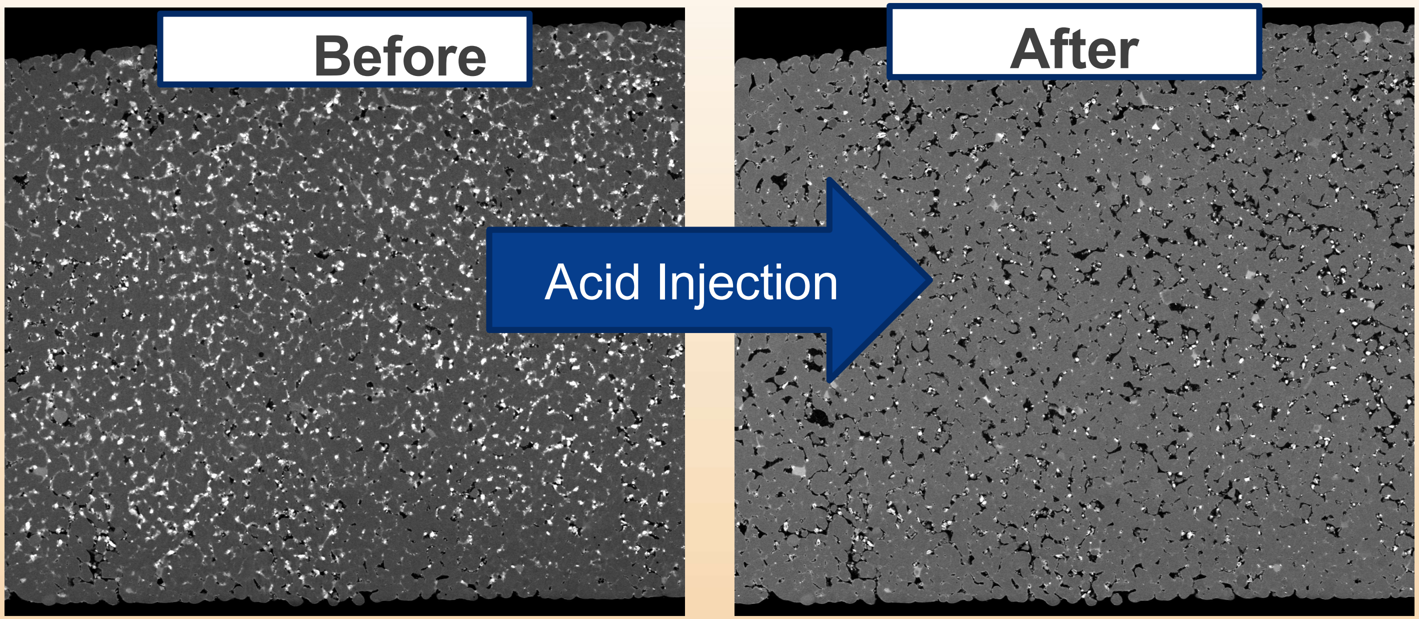
Old Dutch Saying: “Wie het kleine niet leert, doet het grote verkeerd”
(S)He who does not study the small scale, will mess up the big scale

3D Mineral and fracture distribution can be characterised with micro-CT.



X-ray Computed Microtomography

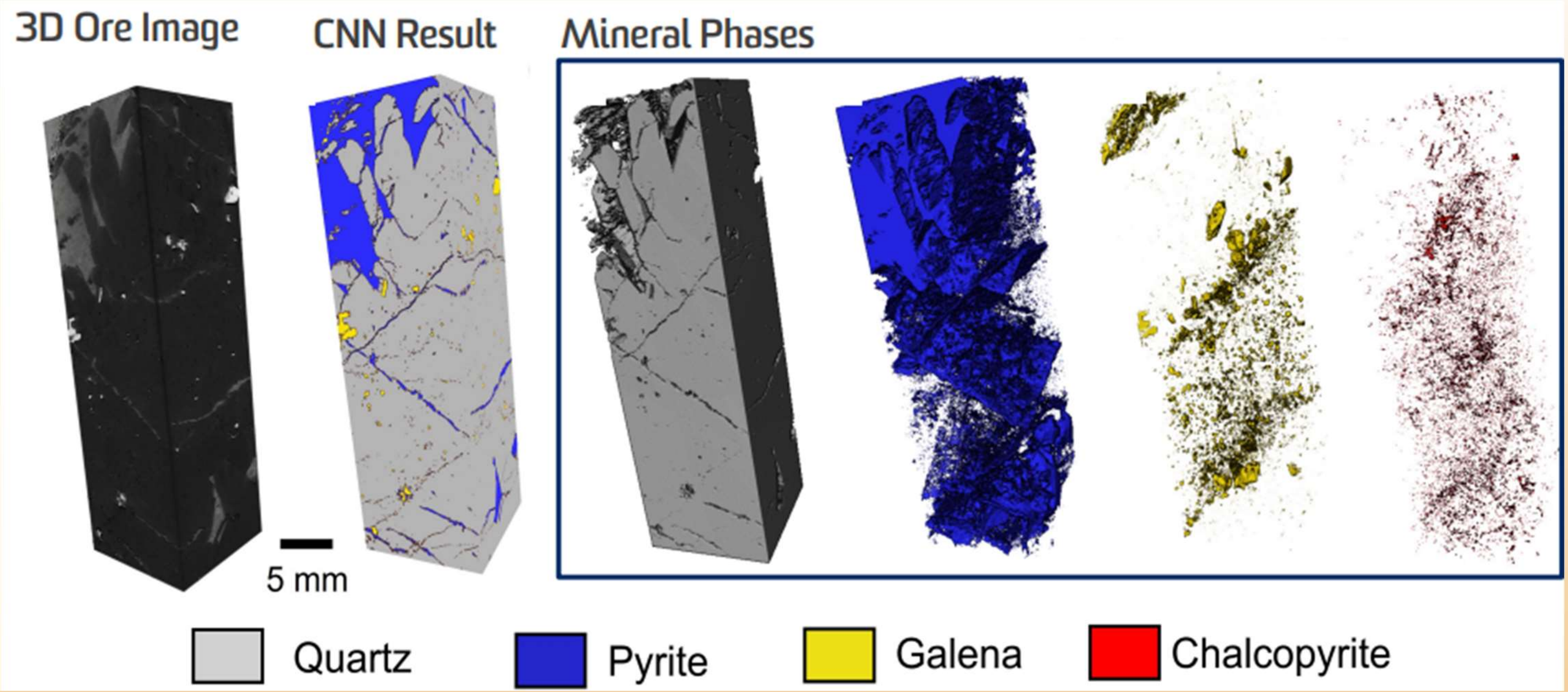




Diameter: 2 mm
Length: 12 mm
Spatial resolution: 2 um

Diameter: 1 cm
Length: 3 cm
Spatial resolution: 5 micron

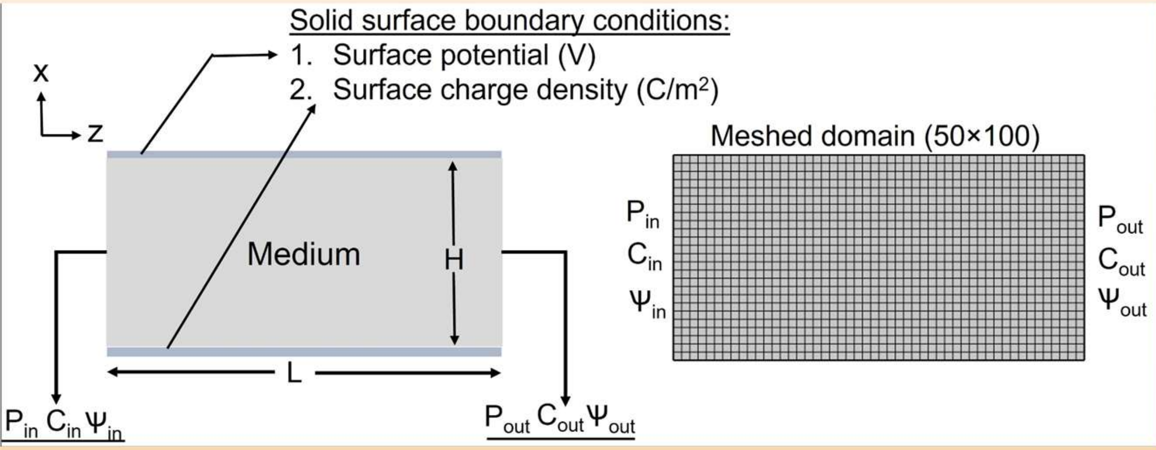
For accurately characterizing the mineral distribution and occurrence on the micro-CT image, we design a workflow that using the 2D mineral information (micro-XRF, QEMSCAN, SEM) and propagate into 3D with deep learning.

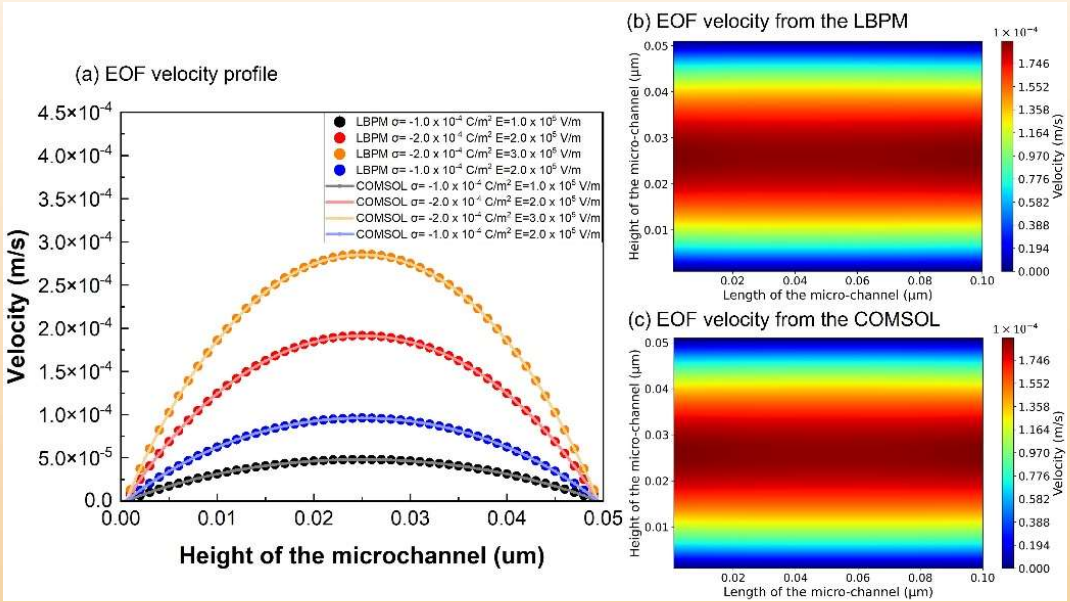


Fundamental understanding of fluid/ion flow in the ore for ISR

Mechanisms of lixiviant and ion flow for ISR or EK-ISR:

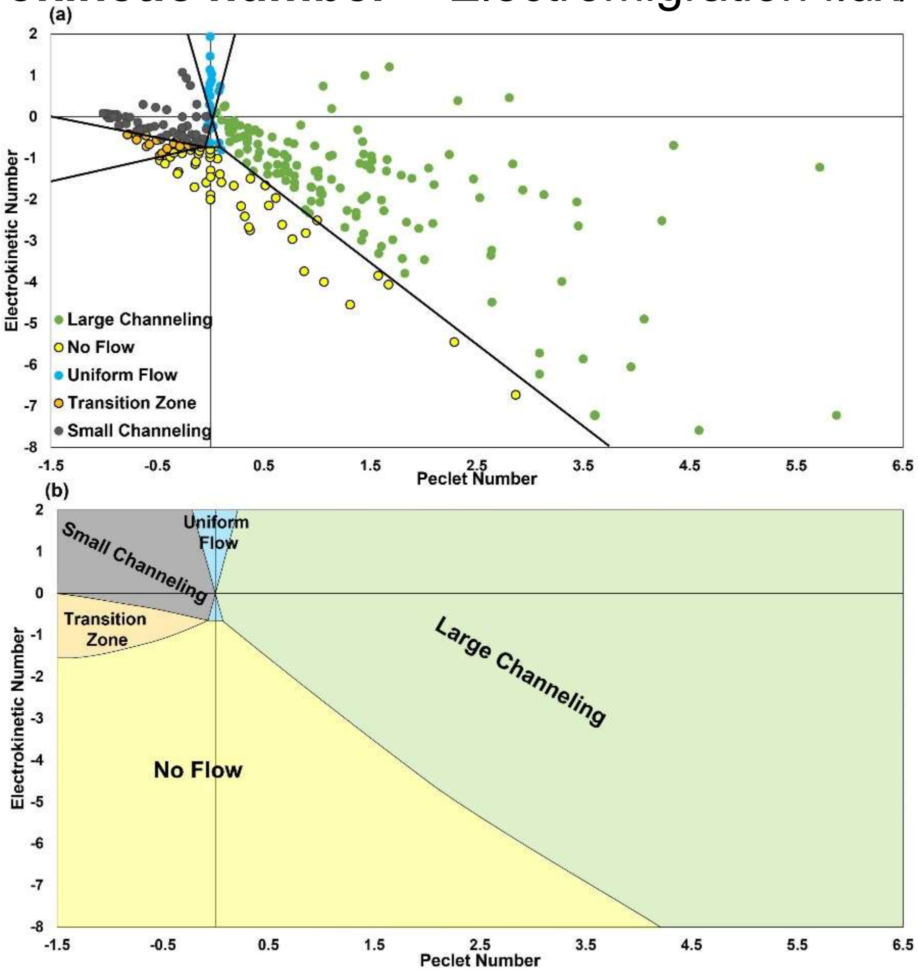
Lixiviant: Hydraulic pressure, Electroosmosis (EOF)
Ion: Hydraulic pressure, Electromigration, Diffusion (Concentration gradient)

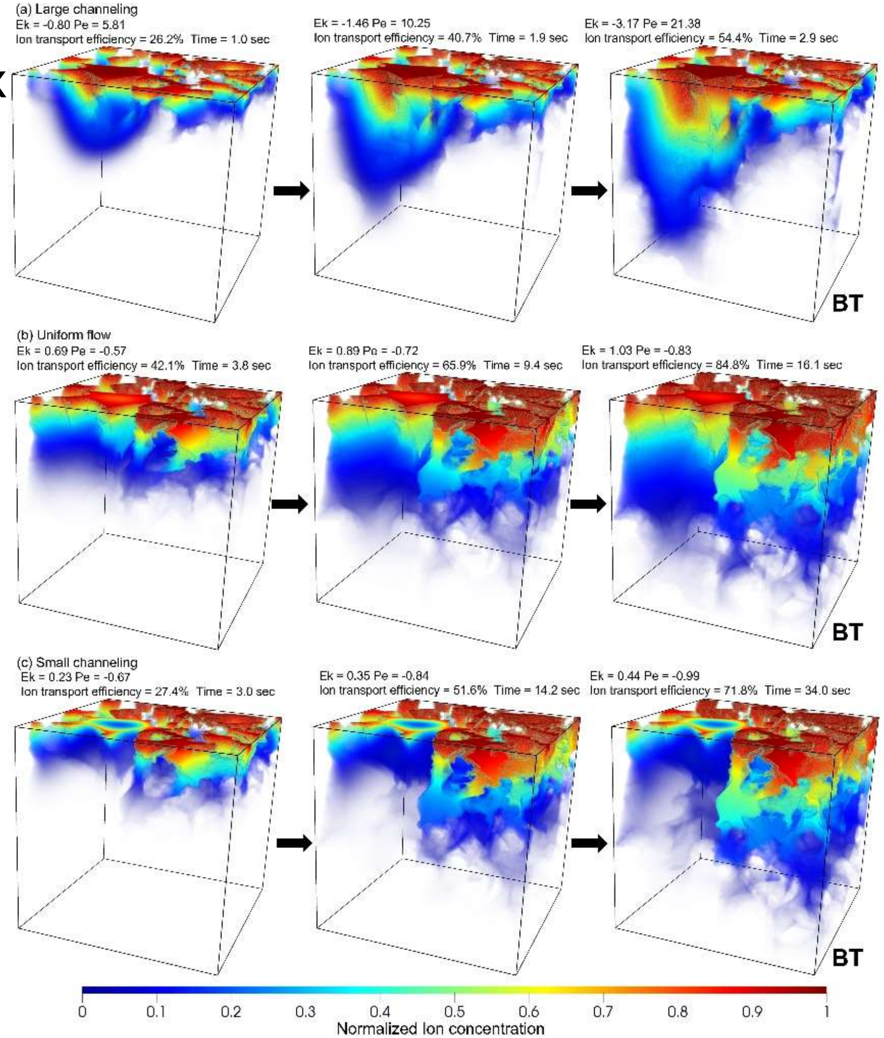




Peclet number = Advection flux / Diffusion flux

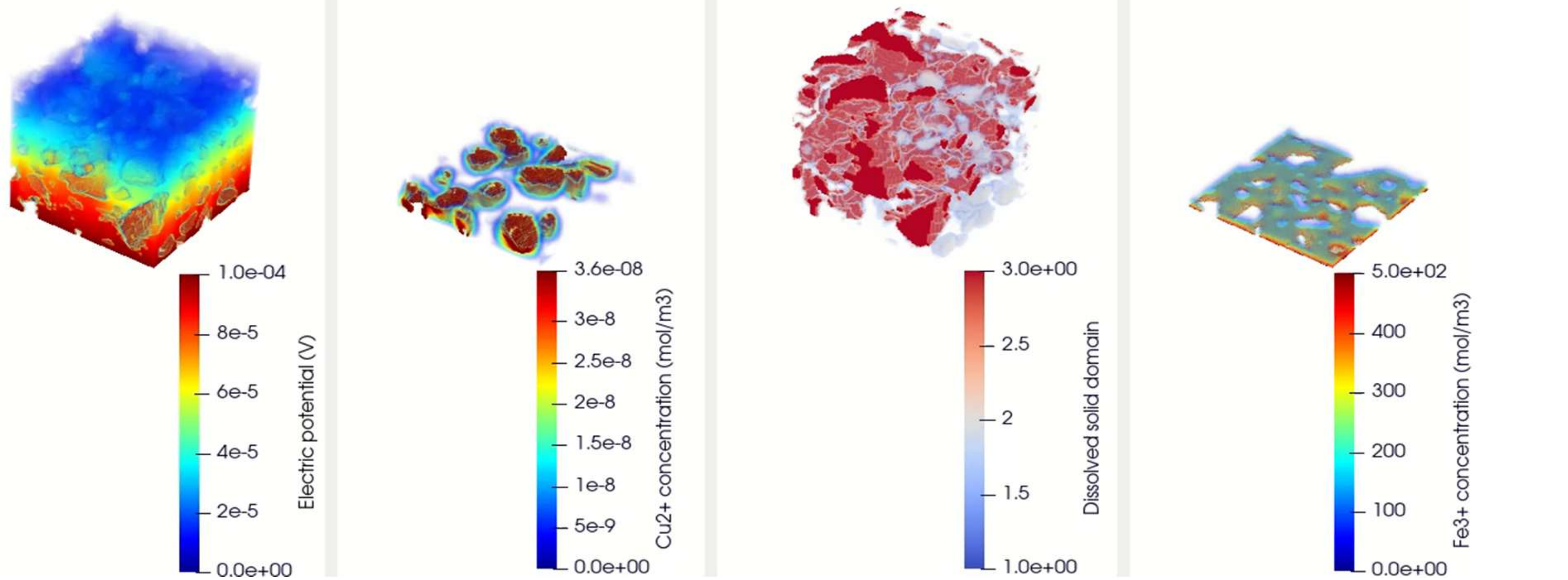
Electrokinetic number = Electromigration flux/ Diffusion flux





Fully coupled simulation of electrokinetic transport of Lixiviant, reaction with chalcopyrite, and recovery of copper.

Electric potential | Cu^{2+} extraction | Chalcopyrite | Lixiviant injected



A little bit details about the governing equations we used:

The flow of the electrolyte solution is governed by the incompressible conservation of mass and Navier–Stokes equation:

$$\nabla \cdot \boldsymbol{u} = 0, \qquad (1)$$
$$\rho_0 \frac{\partial \boldsymbol{u}}{\partial t} + \rho_0 \boldsymbol{u} \cdot \nabla \boldsymbol{u} = -\nabla p + \mu \nabla^2 \boldsymbol{u} + \boldsymbol{F},$$

The electric potential of the distribution of ions was solved by the Poisson equation:

$$\nabla^2 \psi = -\frac{\rho_e}{\varepsilon_r \varepsilon_0}, \qquad \boldsymbol{u} = -\frac{\epsilon \zeta}{\mu} \nabla_T \psi, \quad \text{for } \boldsymbol{x} \in \partial\Omega,$$

Ion transport is governed by the Nernst–Planck equation, which incorporates electrochemical migration as an extra drift term into the mass flux:

$$\frac{\partial C_i}{\partial t} + \nabla \cdot \left[\left(\boldsymbol{u} - \frac{z_i D_i}{V_T} \nabla \psi \right) C_i \right] = D_i \nabla^2 C_i, \qquad (3)$$

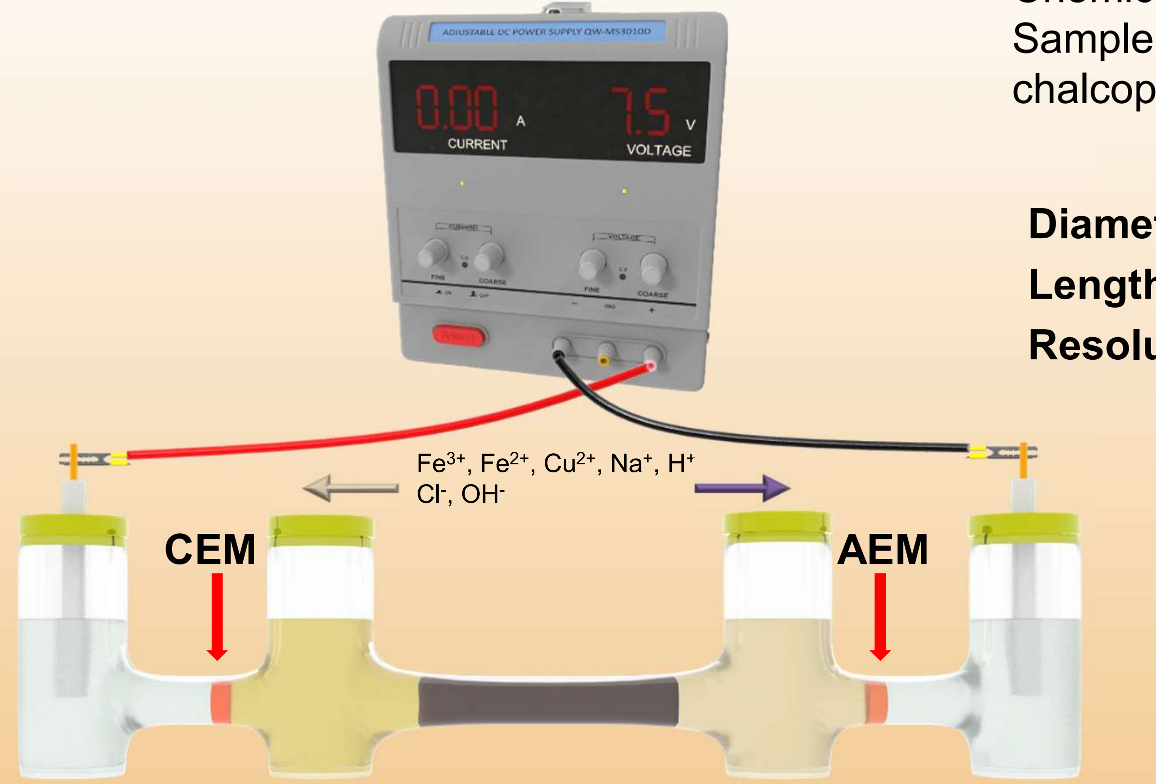
The LBPM flow solver is coupled with Phreeqc where geochemical reaction is simulated for simulating the reactive transport in the real 3D micro-CT image of the ore.

Considering the effects of: Zeta potential, pH, Ionic concentration, Tortuosity, Heterogeneity , Porosity, Permeability, Columbic interaction, Mineral occurrence, etc.

Solver: https://github.com/OPM/LBPM
Related paper: https://arxiv.org/abs/2303.17150

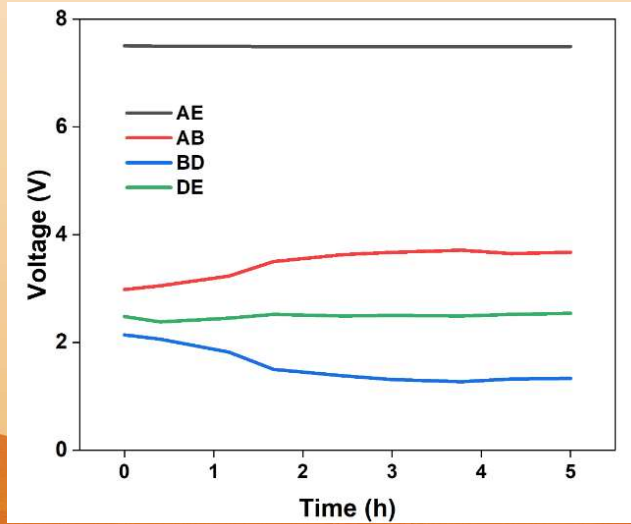
3. Experimental setup for EK-based chalcopyrite leaching (Uniform flow)

Chemical: FeCl3 lixiviant
Sample: Synthetic sample (Consolidate chalcopyrite-glass bead sample)

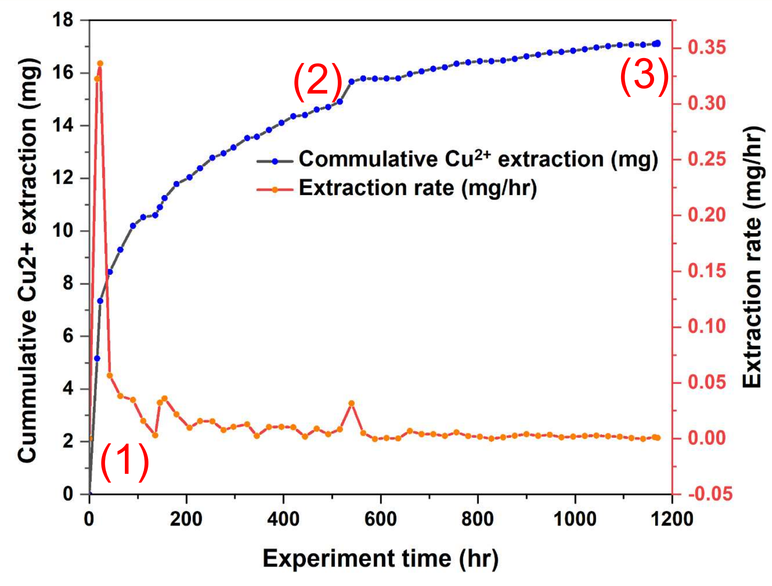


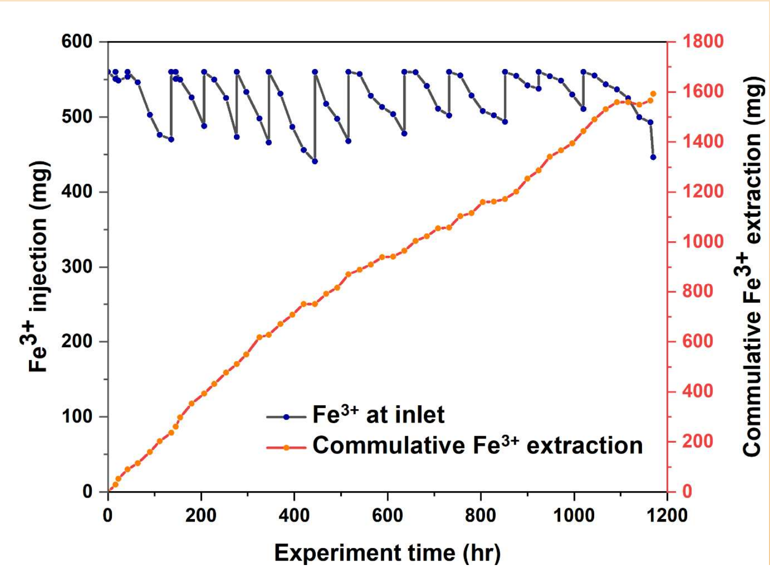
	A	B	C	D	E
	Anode reservoir	Source reservoir	Rock core	Target reservoir	Cathode reservoir
Initial setting	50 mM Na_2SO_4	$FeCl_3$ (0.5 M) in 0.2 M HCl	0.137 L 100 mM NaCl	0.3 M NaCl in 0.2 M HCl	100 mM NaCl

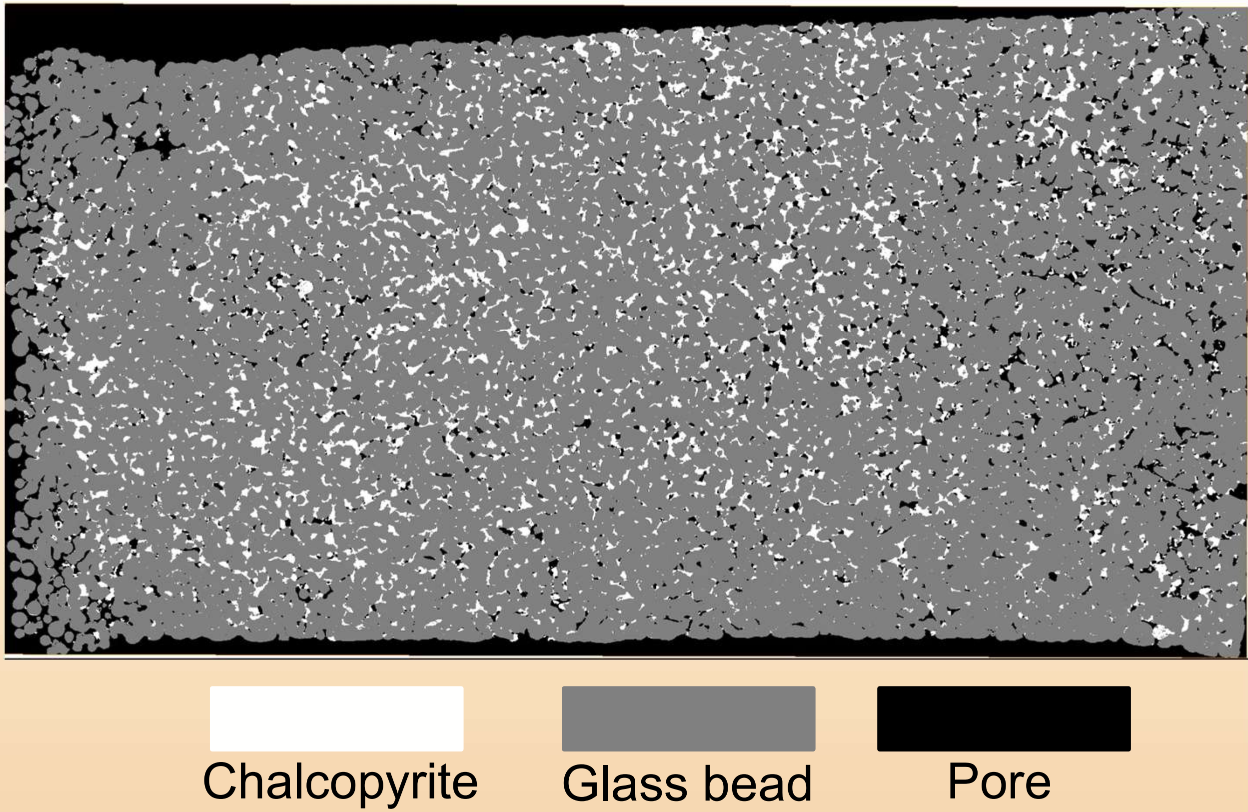
Diameter: 1 cm
Length: 3 cm
Resolution: 5 micron



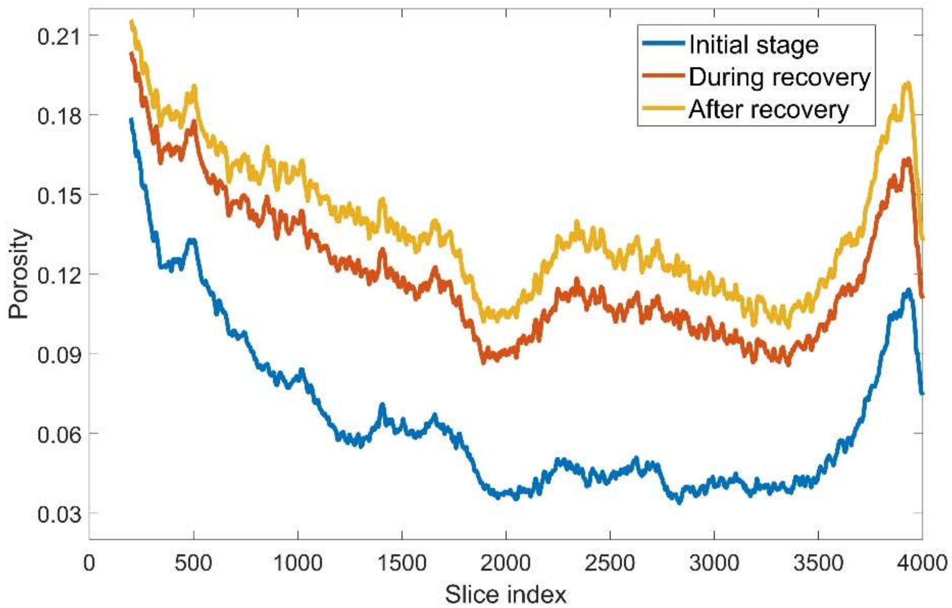
Three timesteps are scanned during experiments



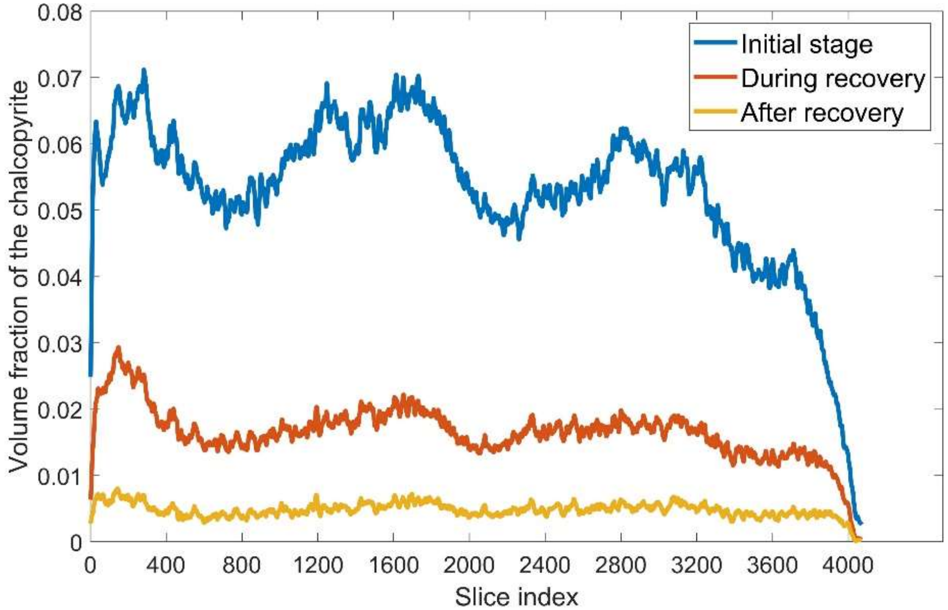




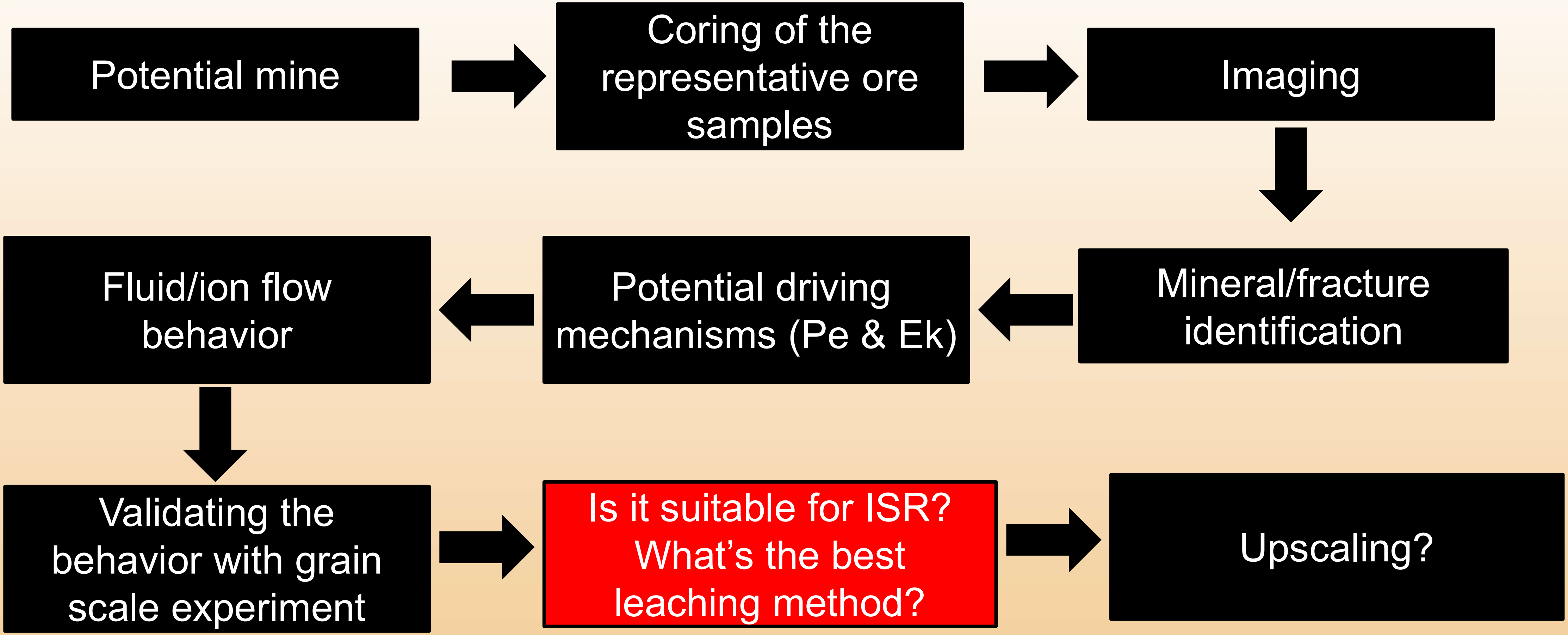
Porosity



Chalcopyrite volume frac



Screening criteria:
Is this mine suitable for in-situ recovery from a pore-scale perspective?



Extention

Grain Scale Experiments

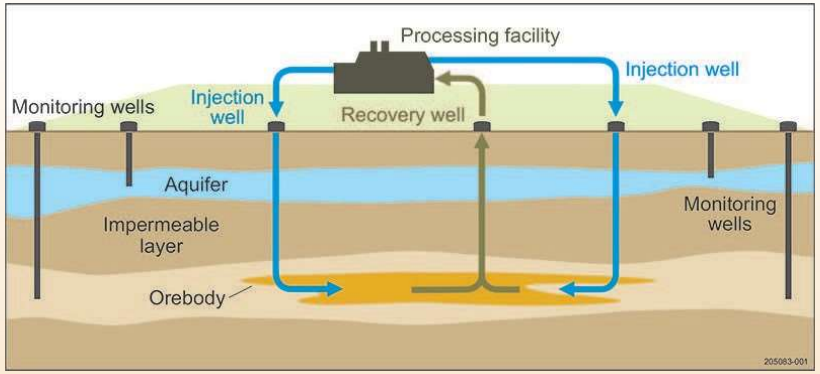
Before

After

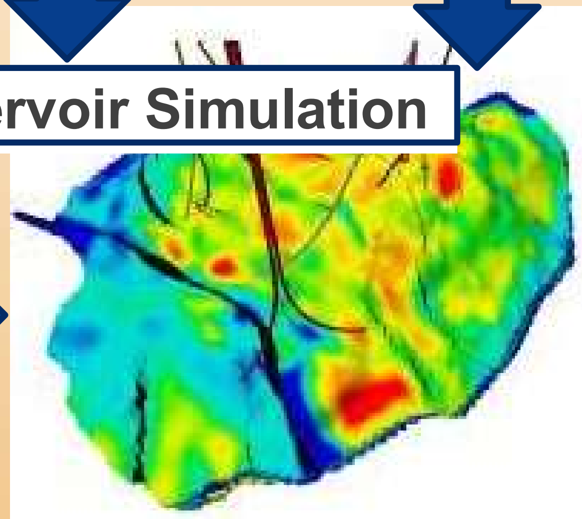
Grain Scale Simulations

Pilot Scale

Pilot Study



Reservoir Simulation



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Multiscale Transport in Porous Systems

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