MULTI-SCALE X-RAY MICROTOMOGRAPHY IMAGING OF IMMISCIBLE FLUIDS AFTER IMBIBITION

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ABSTRACT

A major issue for CO_2 storage security is the efficiency and long-term reliability of the trapping mechanisms occurring in the reservoir where CO_2 is injected. Residual trapping is one of the key processes for storage security beyond the primary stratigraphic seal. Although classical conceptual models of residual fluid trapping assume that disconnected ganglia are permanently immobilized, multiple mechanisms exist which could allow the remobilization of residually trapped CO_2.
The aim of this study is to quantify fluid phases saturation, connectivity and morphology after imbibition using x-ray microtomography in order to evaluate potential changes in droplets organization due to differences in capillary pressure between disconnected ganglia. Particular emphasis is placed on the effect of image resolution. Synchrotron-based x-ray microtomographic datasets of air-water spontaneous imbibition were acquired in sintered glass beads and sandstone samples with voxel sizes varying from 0.64 to 3.28 µm. The results show that for the sandstone the residual air phase consists of disconnected clusters of multiple sizes and morphologies. The multi-scale analysis of subsamples of few pores and throats imaged at the same location of the sample reveals significant variations in the estimation of size, connectivity and shape of the fluid phases.

OBJECTIVES

- Image and quantify fluid phases distribution, connectivity and morphology at the pore scale after spontaneous imbibition
- Measure interfacial curvatures between the wetting and non-wetting phases using different methods to assess possible remobilization by Ostwald ripening mechanism
- Investigate the impact of the image resolution on the identification of the different phases and the curvature estimates

MATERIALS & METHODS

Data acquisition

Advanced Light Source (ALS), LBNL
Beamline 8.3.2 – microtomography

Spontaneous imbibition: the sample is initially dry (saturated with air) wrapped with heat shrink tube, then water (+0.7M KI) is drawn into the sample by capillary action

25keV, 2049 proj., PCO.Edge with OP
2X (3.28 µm) 4X (1.62 µm) 10x (0.64 µm)

Glass beads (250-400 µm)
Fontainebleau sandstone

Image analysis

Reconstruction (+phase retrieval algorithm) with Octopus

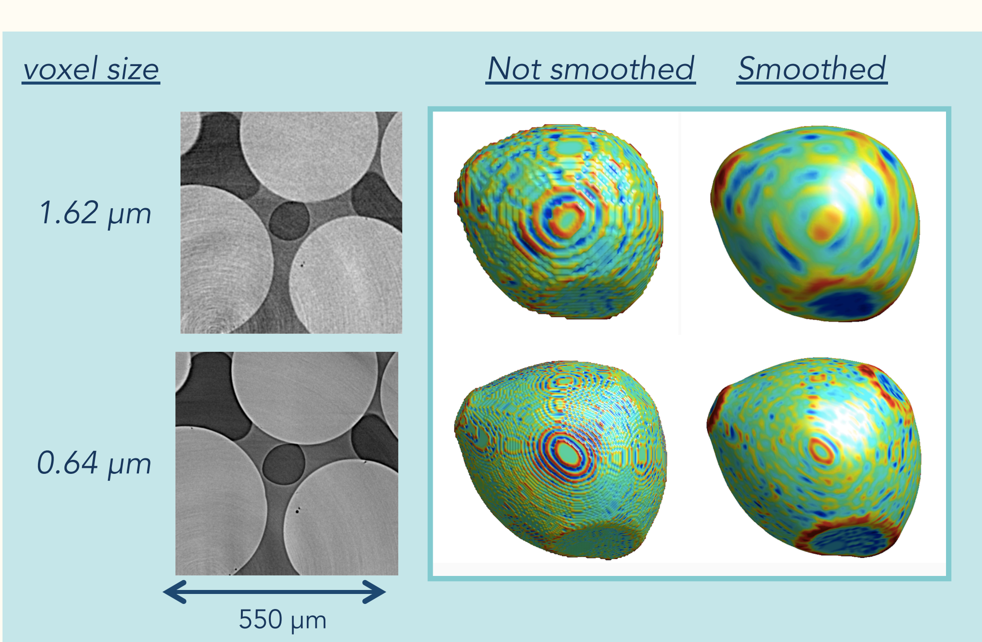
Three-phase segmentation (solid matrix / air / brine) with Fiji

Connectivity analysis with Avizo Fire (Reconstruct algorithm)

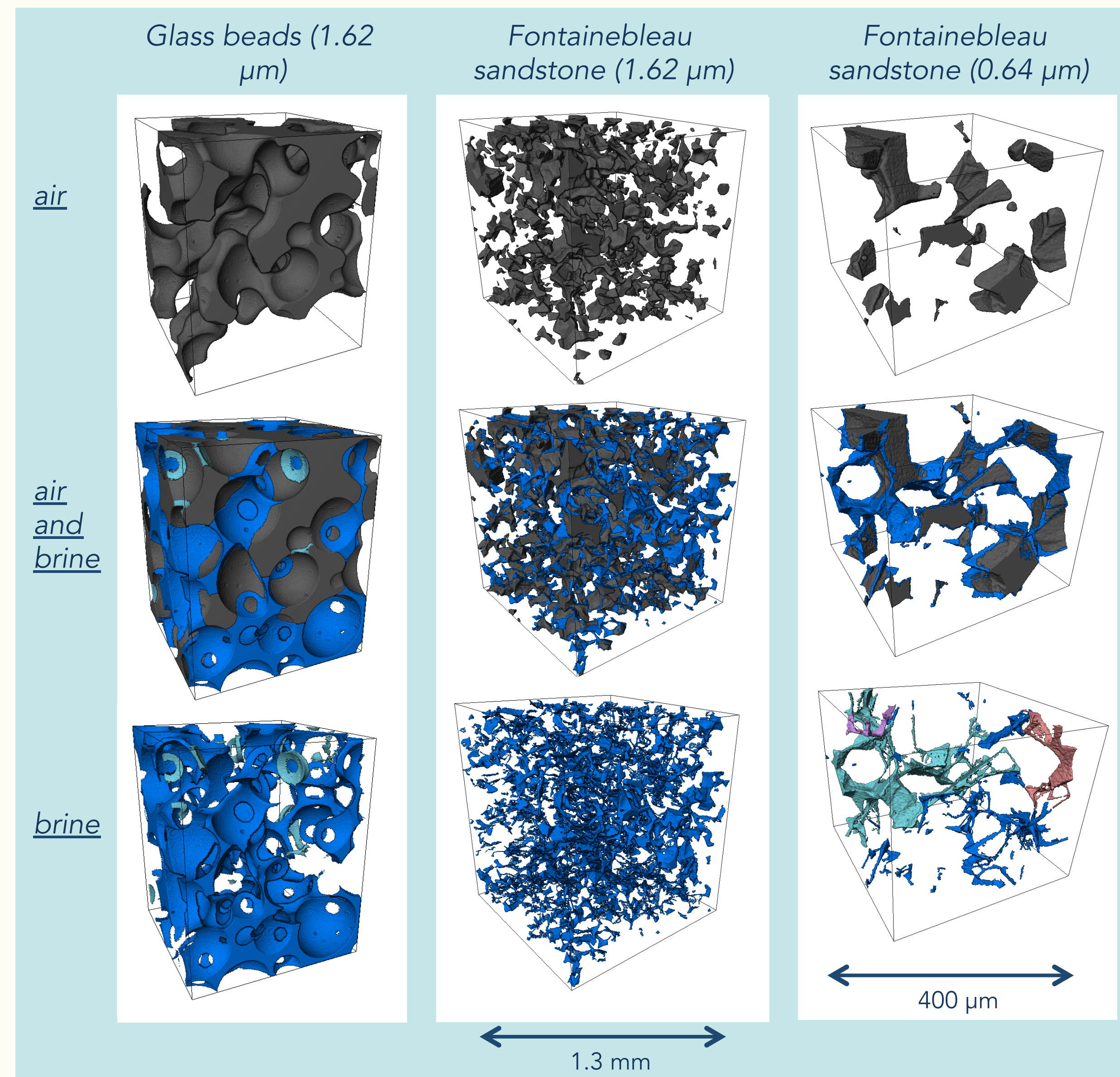
Interfacial curvature:
- find and mesh air surfaces
- smooth mesh if necessary
- find air/water interface
- compute mean interfacial curvature (Peyre, Kroon, Avizo)

RESULTS

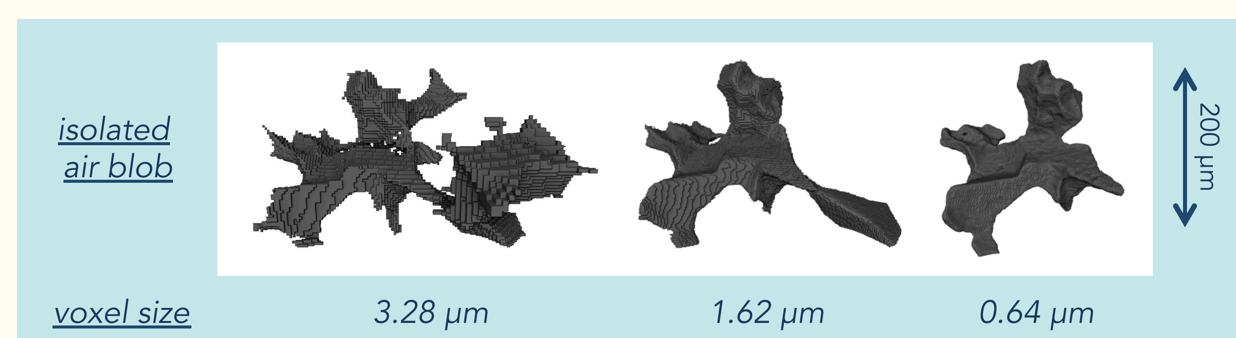
Curvature measurements



Phase distribution and connectivity



The distribution and morphology of both phases highly depends on the pore structure



Strong impact of image resolution on the identification of a same isolated air blob

CONCLUSION

- The residual air phase in Fontainebleau sandstone consists of disconnected blob of various size and shape and the identification of each isolated ganglia is highly dependent on the image resolution.
- The brine phase also appears poorly connected. As it presents very small features, it might not be adequately identified, even with the highest image resolution (voxel size of 0.64 µm).
- Curvatures, hence capillary pressures, can be efficiently calculated on the glass beads data set since the two phases display large interfaces. However the interfaces are very thin in the case of the sandstone.
- Further work involves using a pressure vessel to study brine/scCO2 system and repeated scans to investigate the temporal evolution of the distribution, connectivity and morphology of the fluid phases

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