SEMS: RESEARCH PROJECT DESCRIPTION

1. Project Background and Description

Multi-scale simulation of reactive-multiphase transport in porous media for geo-energy applications

We propose to develop our understanding of multi-phase reactive flow simulations in porous media, coupled with heat transfer, at pore, core and reservoir scale, with applications in CO2 storage and geothermal energy, in addition to hydrocarbon recovery.

The storage of CO2 in geological reservoirs has recently been considered as a promising method to mitigate climate change. However, the uncertainty associated with storage of CO2 underground, particularly near urban areas, has led to negative public opinion and delay or cancellation of storage projects. To reduce the uncertainty of the fate of CO2 once injected in subterranean reservoirs, modelling and simulation has become a powerful tool, as experiments are difficult or impossible.

For this purpose, we developed a suite of simulation codes, based on the Lattice-Boltzmann (LB) method, using parallel GPU computing technology. As input we use a representative 3D micro-CT pore space image of a specific rock sample, which is then used in subsequent flow simulations.

First, when CO2 is injected in aquifer reservoirs, it reacts with the water to yield an acidic brine. The acid solution may dissolve the reservoir rock, forming “wormholes”, which may have beneficial effects (permeability increase) or detrimental effects (reservoir instability), depending on reservoir conditions. However, the formation of such wormholes is still poorly understood. For this reason, we have investigated the chemical mechanisms of dissolution in a calcite rock sample and unravelled the dynamics of wormhole formation, see Figure 1 and ref. [3] in publication list.

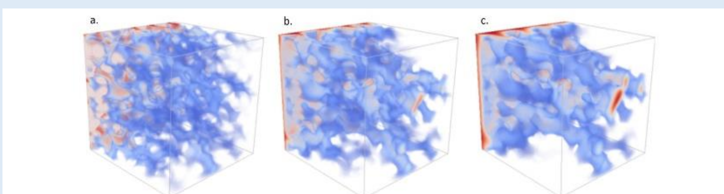

Figure 1: Dynamics of wormhole formation during dissolution of calcite rock obtained from LB simulations [3]

However, many reservoirs consist of rocks with varying wettability (CO2 / water / oil), and the effect of wettability on wormhole formation is still unknown. We have developed separate multi-phase flow simulations to study displacement processes in calcite rocks (see refs. 1, 2, 4), but have not yet coupled the reactive and multi-phase flow codes. We therefore propose here to develop our codes to include coupled reactive and multi-phase flow.

In addition, we consider geothermal energy applications. For this purpose, wells need to be drilled to great depth into the geothermal reservoir. The effect of temperature gradients and reactivity of drilling fluids on the porous rock and efficiency of the drilling process are important but largely unknown [5]. Therefore we propose to use our proposed reactive / multi-phase LB code and extend it to include heat transport, see **Error! Reference source not found.**. This will make a significant contribution to the development of geothermal heat sources in the framework of sustainable energy development.

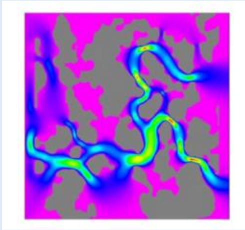

Figure 2: Fluid flow distribution in fractured geothermal reservoir [5]

[1] Zacharoudiou, I., Chapman, E., Boek, E., & Crawshaw, J. (2017), “Pore-filling events in single junction micro-models with corresponding lattice Boltzmann simulations”, Journal of Fluid Mechanics, 824, 550-573. doi:10.1017/jfm.2017.363
[2] Zacharoudiou, I., Boek, E.S., & Crawshaw, J. (2018), “Impact of drainage displacement patterns and Haines jumps on CO2 storage efficiency”, Nature Scientific Reports, 8:15561 DOI:10.1038/s41598-018-33502-y
[3] F.Gray, S. Shah, J.Crawshaw, B.Anabaraonye, E.S. Boek (2018), “Chemical Mechanisms of Dissolution of Calcite by HCl in Porous Media: Simulations and Experiment”, Advances in Water Resources. 121, 369-387.
[4] Zacharoudiou, I., Boek, E. S., & Crawshaw, J. (2020). Pore-Scale Modeling of Drainage Displacement Patterns in Association With Geological Sequestration of CO 2. Water Resources Research, 56(11), e2019WR026332.
[5] [5] R. Abdelaziz et al, (2015), Multiphase Thermal-fluid Flow through Geothermal Reservoirs, Energy Procedia 95, 22-28

2. Project Scope

Three research project objectives

1) Use experimental imaging techniques including micro-CT and FIB-SEM to acquire pore scale images
2) Develop computational methods for reactive / multi-phase flow at the pore scale for pore space images obtained from natural porous media such as saline aquifer reservoirs.
3) Develop a rational design approach to identify optimal operation conditions.

3. Desired Skills from the Student

Key skills needed for the PhD project

1) Undergraduate degree in science or engineering
2) Interest in computational methods and developing code
3) Interest in using experimental imaging techniques including micro-CT and FIB-SEM

4. Supervisory Team

Add supervisory team details

Primary supervisor: Dr Edo Boek, SEMS, e.boek@qmul@ac.uk

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