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PhD Project Description

Project Title

Modelling groundwater flow and heat transport in fractured aquifers with application to geothermal and underground thermal energy storage

Supervisors

Lead supervisor: Matthew Jackson (m.d.jackson@imperial.ac.uk)

Co-supervisors: Meissam Bahlali (Imperial), Carl Jacquemyn (Imperial), Ed Hough (British Geological Survey), Andres Gonzalez Quiros (British Geological Survey)

Research Group

The research will be hosted by the Novel Reservoir Modelling and Simulation (NORMS) group in the Department of Earth Science and Engineering at Imperial. The NORMS group is a vibrant, inclusive, multi-disciplinary collective of geoscientists, applied mathematicians, engineers, and experimental and computational physicists.

The project be jointly supervised with the British Geological Survey, providing access to oustanding expertise, field and laboratory experimental data, and analogue materials.

Project Summary

Production of geothermal energy, and storage and re-use of heat in underground aquifers, offers large-scale, stable, locally sourced, low carbon heating. Designing these systems for efficient operation involves numerical modelling of underground water flow and heat transport. This project will develop more accurate numerical methods for modelling fractured aquifers, which are an increasingly important resource. Existing approaches are inaccurate because they do not properly capture the exchange of heat between water flowing through the fractures, and the surrounding solid rock. The research will deliver fundamental new understanding of groundwater flow and heat transport in fractured aquifers, supporting ongoing research in geothermal energy and underground energy storage, along with practical simulation tools implemented in open-source software for wide adoption by the community.

Research Context and Objectives

Numerical models of groundwater flow and heat transport in aquifers typically assume that the water-saturated rock can be described by a single temperature at any given location. This assumption is reasonable when groundwater flows in the pore-space between small rock grains (of order a few microns to millimetres in size), allowing thermal conduction to efficiently exchange heat between the rock grains and the groundwater. However, if groundwater flow is focussed into fractures, thermal conduction may exchange heat too slowly to equilibrate the temperatures of the flowing groundwater and intact rock. Models that assume uniform temperature are inaccurate. Modelling flow and heat transport in these fractured aquifers is challenging but essential to design efficient, sustainable geothermal installations: however, the fractures are too small and numerous to be represented explicitly.

This project will develop new approaches to model flow and heat transport in fractured aquifers that are simple to apply, quick to run and can be calibrated against experimental or operational data. They will be applied to improve the numerical modelling of operating low temperature geothermal systems in the fractured Chalk aquifer of the UK, using data acquired as part of two large, ongoing research projects (ATESHAC and SMARTRES). These projects aim to grow the deployment of geothermal and underground energy storage technologies. The new approaches will have wide applicability in modelling fractured reservoirs elsewhere.

The project will involve the use and further development of advanced numerical methods for simulating fluid flow and heat transport, implemented in the open-source Imperial College Finite Element Reservoir Simulator (IC-FERST).

Further reading:

Jackson, M. D., Regnier, G., & Staffell, I. (2024). Aquifer Thermal Energy Storage for low carbon heating and cooling in the United Kingdom: Current status and future prospects. Applied Energy, 376, 124096.

Regnier, G., Salinas, P., Jacquemyn, C., & Jackson, M. D. (2022). Numerical simulation of aquifer thermal energy storage using surface-based geologic modelling and dynamic mesh optimisation. Hydrogeology Journal, 30(4), 1179-1198.

Salinas, P., Regnier, G., Jacquemyn, C., Pain, C. C., & Jackson, M. D. (2021). Dynamic mesh optimisation for geothermal reservoir modelling. Geothermics, 94, 102089.

Who are we looking for?

We are looking for a motivated, hard-working student with an excellent background in in a related subject such as geoscience, physics, engineering or mathematics and, ideally, some experience in numerical modelling and coding. Training will be provided as required in specific aspects of the project.

The successful applicant will have extensive opportunities to develop their career and profile by presenting at international conferences and publishing in leading journals. The project involves interaction with other research groups within and beyond ESE.