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PREDICTIVE MODELLING FOR GEOTHERMAL

REFLECT: Redefining geothermal fluid properties at extreme conditions

In a geothermal system, brine is transported from aquifers - subsurface water reservoirs - to the surface, with the aim of extracting its thermal energy. However, on the fluid's way towards the surface, its chemical equilibrium is disturbed, potentially causing **scaling** in the facilities.

The numerical code **porousMedia4Foam** has been developed in order to **predict** these scaling risks. It is an **open-source, multi-scale and multiphase package**, where **OpenFOAM®** is coupled with the **PHREEQC code*** to investigate hydro-geochemical interactions. The flow, transport of chemical species, evolution of porous media properties and temperature are handled by solving equations implemented in OpenFOAM® (Figure 1) whereas, the chemistry is exclusively handled by PHREEQC.

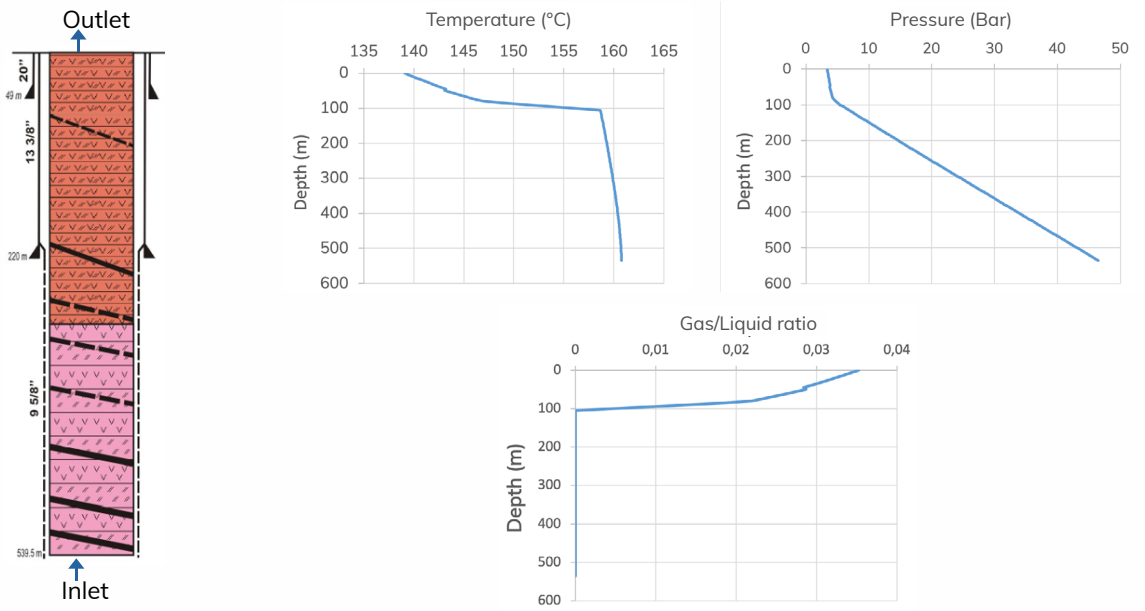

Figure 1: *Temperature, pressure and gas/liquid ratio profiles in a geothermal production well*

An accurate prediction of the scaling amount and location in the geothermal systems depends heavily on (1) the **characterization of the geothermal fluid**, which is impacted by the uncertainties in the fluid sampling and analysis and (2) the **interaction between flow hydrodynamics and precipitation**.

* Parkhurst, D.L., Appelo, C.A.J., 2013, *Description of input and examples for PHREEQC version 3 - A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations:* U.S Geological Survey Techniques and Methods, book 6, chap. A43: https://pubs.usgs.gov/tm/06/a43

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A workflow was developed and tested for uncertainty quantification in the fluid composition and its impact on scaling. A **full coupling between the PHREEQC code and hydraulic model** was made and the model was tested for two example conditions (flow in the pipes and wells and flow in heat exchangers), considering fluid composition uncertainties (Figure 2). The current workflow is being extended to different types of scaling, including calcite and lead. A software implementation for integrating uncertainty quantification workflow with geochemistry modelling is available ('Example D4.3' in the Further Information section). This workflow will enable operators to make a better decision about the operational settings and mitigation measures.

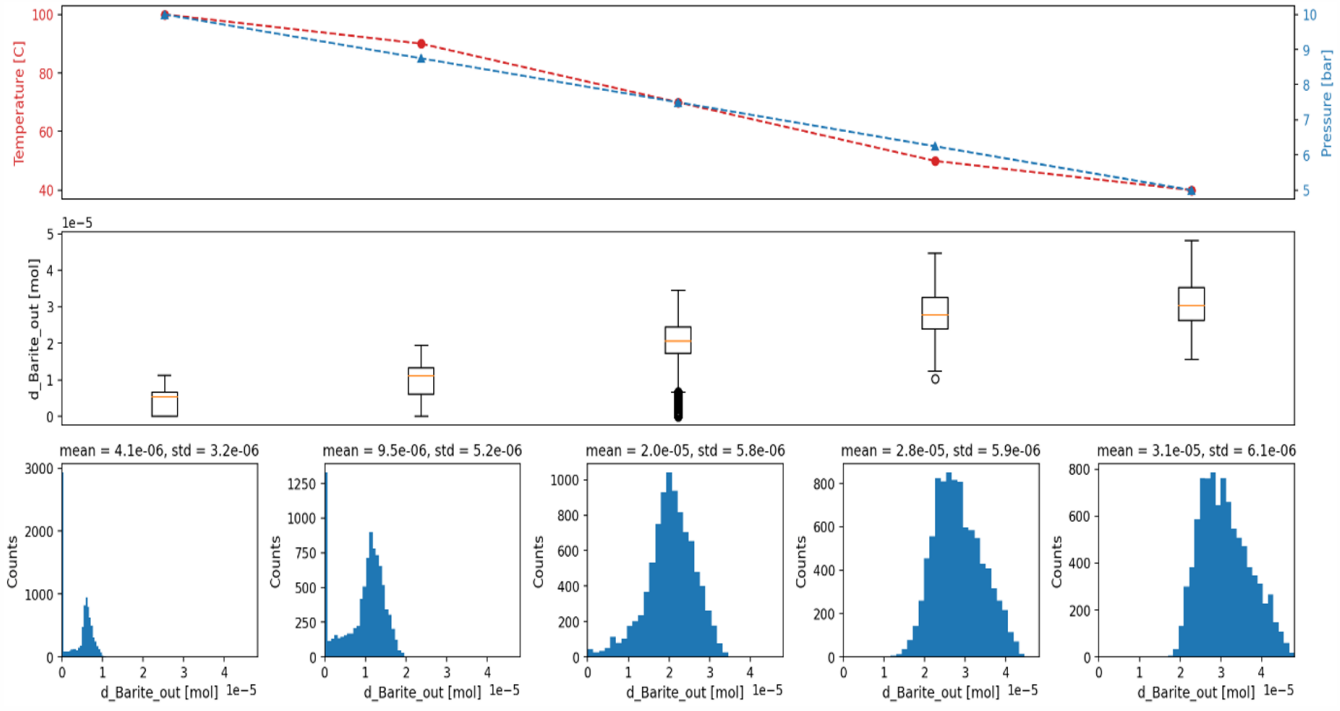

Figure 2: *Distribution of barite deposition layer considering geothermal brine composition uncertainties. Results are given at five different locations along a simplified heat exchanger pipe*

Further information available on the Results Section of the REFLECT website

- *Scientific publication:* porousMedia4Foam: Multi-scale open-source platform for hydro-geochemical simulations with OpenFOAM®
- Deliverable 4.2: Coupled hydro-thermal-chemical software porousMedia4Foam
- Deliverable 4.3: Impact of geochemical uncertainties on fluid production and scaling prediction
- Example D4.3: Example code to perform uncertainty quantification with geo-chemistry modelling using PHREEQC

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