Coupled thermal-hydraulic-chemical modelling of a cement-rock-brine-CO_2 system

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Wellbore integrity is a key factor for a secure and reliable CO_2 sequestration. CO_2 can migrate along a well resulting in a complex chemical system threatening the wellbore integrity. A successful well completion depends highly on the properties, treatment, and interaction of used materials during size-dependent installation processes.

To account for this aspect, a unique large-scale autoclave system, called COBRA (CO_2 Borehole Research Apparatus) was developed. It consists of two vessels that are bridged by a cement-filled casing of 2 m length. The lower vessel is filled with rock samples and brine, representing a brine-filled reservoir, and is pressurized by CO_2. The cemented casing is constantly in contact with the brine, thus leading to a realistic chemical setting inside a borehole of a CO_2 storage site.

A long-term experiment at temperature and pressure conditions of about 50°C and up to 60 bar was performed, with the goal to investigate the chemical processes in that cement-rock-brine-CO_2 system. During the experiment, in situ fluid samples were taken from the lower vessel, and additionally, the cement core was cut out of the casing after the experiment and was chemically analysed. The results show an interaction of the cement and the brine-CO_2 mixture, indicated by an alteration front on the bottom and lateral surfaces of the cement core, suggesting a highly permeable area at the interface between the cement and the steel casing.

Using the hydrochemical data such as pH-values obtained from the fluid samples during the experiment, we aim to further investigate the chemical interactions in this complex cement-rock-brine-CO_2 system by the means of numerical thermal-hydraulic-chemical modelling. The used coupled modelling approach is based on successful simulations which describe well the pressure variations, if in one of the vessels a minor pressure reduction is artificially imprinted. Thus, we use an axis-symmetrical 2D model, consisting of the cement core combined with a high permeable and porous area at the interface zone to the casing, and the lower vessel, which consist of the brine, the rock samples, and the injected CO_2.