Geothermal use of old mines: hydrogeological challenges for predicting efficiency and impacts

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1. Introduction

Groundwater in flooded abandoned mines could be used for geothermal purposes using heat-pumps and an open loop involving pumping and re-injection. This kind of low temperature geothermal doublet belongs to the aquifer thermal energy storage (ATES) systems. Usually, hydraulic conductivity values of the considered rock zones have been significantly increased by mining exploitation. Therefore, these zones can be often considered as aquifers. In any case, accurate hydrogeological characterization of the old mined zones is needed to gain a minimum knowledge about these variably fractured rock zones together with the remaining network of shafts and galleries.

2. Hydrogeological and geothermal conditions in old mines

Depending on the type of abandoned mine, the true geometry of the interconnected network of open galleries and shafts can be highly complex (Figure 1). A high-velocity water flow is expected in this network, while low-velocity groundwater flow occurs in the permeable fractured and porous rocks. Logically, hot water is expected to be pumped in the deep parts of the open network, and cold water is expected to be re-injected in the shallower parts (i.e. in shallower galleries or fractured rocks).

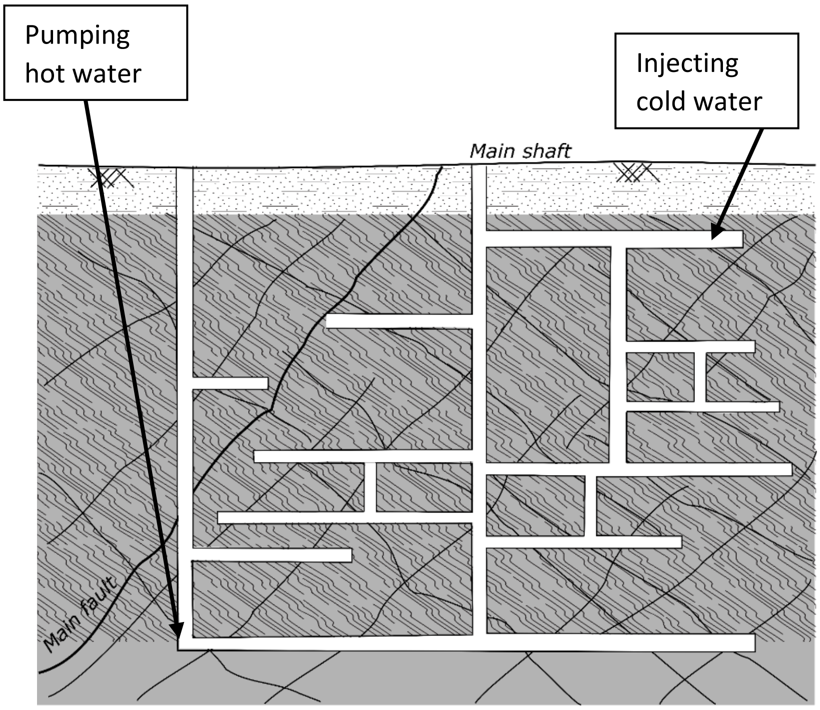

Figure 1: Schematic 2D vertical view of a simplified old mine network. In Belgium, old shafts could have been refilled with backfill materials, therefore it could be more efficient to drill new boreholes that directly reach the deep ancient open galleries for pumping hot water and reinjecting cold water (modified from Dassargues 2018).

3. Challenges and first results

Indeed, to assess the efficiency and the possible impacts of geothermal doublets in old mines, it could be critical to simulate the groundwater flow and associated temperature evolution in the pumping zones. Numerical simulations of such geothermal systems is not easy: variable density water flow and coupled heat transport must be simulated with a software allowing to describe accurately a combination of high-velocity ‘pipe-like’ water flows (in the galleries) and porous/fractured groundwater flow (in the rock matrix). The SUFT3D code allows to combine linear or distributed reservoirs to model groundwater flows in mine galleries and classical groundwater flow in the variably saturated equivalent porous surrounding media (Brouyère et al. 2009, Wildemeersch et al. 2010). Recent developments (Vopat 2017) allowed also to simulate the associated heat transfers using the similarities existing between solute and heat transport equations.

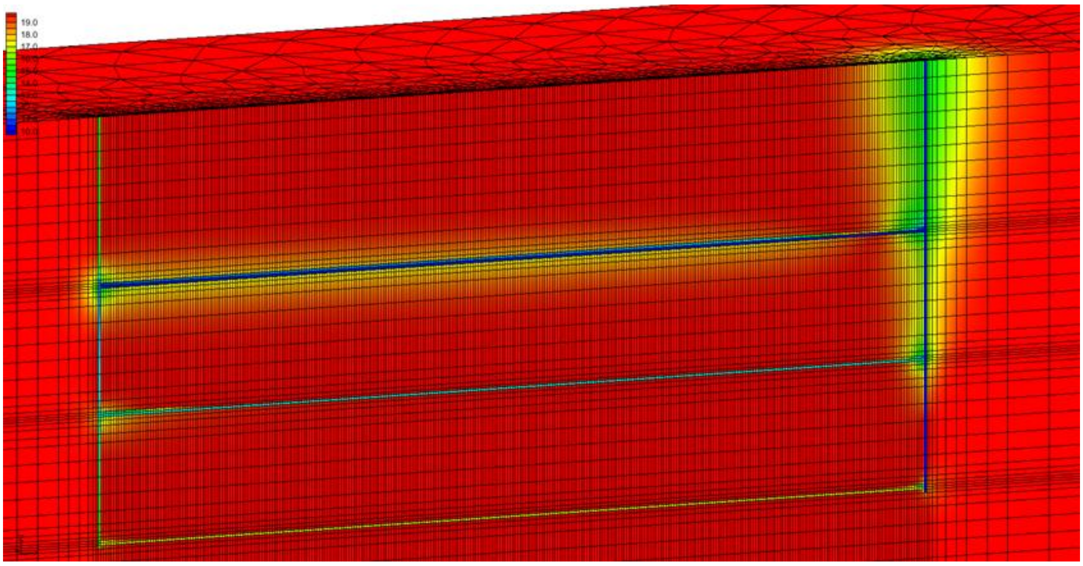

Figure 2: First results (using SUFT3D) showing the simulated stabilized (after 800 days) temperatures with a 130 m^3/h pumping initially at 19°C at the bottom of the left shaft (at a 500m depth) and reinjection at 10°C at the top of the right shaft (results are shown for a K_{shaft}/K_{rocks} ratio of 10^4; from Vopat 2017).

Results are showing clearly the differentiated temperatures as a consequence of heat/cold propagation in the galleries, shafts and the fractured rocks. Actual cases in relation with future projects, should thus be simulated taking the whole complexity/heterogeneity of the galleries network conjugated to the old mined rocks. Challenges will have still to be tackled in terms of characterization and numerical simulation with actual data. However, it is only on the basis of accurate predictions (i.e., about long term efficiency and possible expected impacts) that the financial risk associated with such new geothermal systems could be assessed for further practical decisions.

3. References

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