1 – Thanks a lot for joining

I’m going to talk about the recycling potential of old underground coal mines in the UK for geothermal usage.

The objective of my phd is to investigate the heat ressources of the flooded mines, in order to understand why different mines have different temperatures.

2- why is it important ?

Coal has been extensively extracted from underground mines from the XIX century

Today all those mines are closed, but as mining activities stopped, dewatering of the workings stop and the water started to rebound back to its natural level, filling the large mining voids left from mining.

This water is hotter than usually in aquifers from the Carboniferous deposits, and large volume could be extracted at quite high rate for geothermal utilization, using open-loop GSHP.

This technology has been installed to extract energy from mine at several places worldwide, including in Shettleston in Scotland. The most successful one is in the Netherlands. How does it work ?

Water is pumped from a borehole and heat extracted from it using a heat exchanger before being reinjected at a cooler temperature. 2 advantages:

* Local: 9% population located in former mining field could directly benefit from it. Today, 50% of energy consumption for residential heat. It was shown than 7 % of the energy demand could by sourced by water. Potential to contribute to the decarbonization targets.
* Pumping infrastuctures already in place: limit the cost linked to the drilling of new boreholes.

3- what is the issues?

* If we plan to extract hot water, we might want to **know how fast will heat be resplenished** into the system.
* It appears that there is **no correlation** between the temperature of minewater and the conductive geothermal gradient (rock temperature)
* However, it is essential to know **what defines the minewater temperature** in order to know **at which rate heat will be recharge** and thus, better **understand the sustainability** of heat extraction from mine.

Here are the 3 RQ to answer this problem.

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4- The first step to answer question 1 is no identify the main heat sources, and this has been done by creating a conceptual model of coal mine.

5- The geometry of mine is complex, and all the processes linked to this complexity tend to superimpose onto natural processes. By creating conceptual model, we therefore want to simplify the problem by isolating all the different element/processes to be later able to assess their relative contribution on the total heat generated in mines separately, using analytical, mathematical or numerical model. The things I will look at include:

* Geothermal heat flux (depends on geothermal gradient) / Solar
* RHP / Pyrite oxidation
* GW flow: can be sources from laterally/below or from rainwater, therefore entering the system with different temperatures, will flow through different type of voids.

6- once we know what, it is legitimate to ask how? **How heat is recharged to the system** and at **which rate**? What is the contribution from all the heat sources identified? Here the two processes of interest are conduction/advection, or heat advection through flowing groundwater.

7- One of the hypothesis I want to verify is that solar recharge is negligible relative to geothermal heat flux.

To answer this question I used a 1D model of heat extraction. The amount of solar recharge, that varies during the year, was determined by successive trial until the appropriate yearly variation in surface temperature was found. Here on the right, you can see that extracting from a BHE situated between 40-90m depth, you might induce similar but opposite flux toward the BHE. In using a flux instead of a constant temperature on the surface of model, the advantage is that when you start extracting heat, you will allow temperature to decrease on the surface and the not overestimating the recharge.

One of my preliminary conclusion is that the amount of solar recharge might initial depends on the state of the geothermal gradient, as steady state situation would not permit a positive downward flux of solar heat (in terms of yearly average).

8- In mines however, instead of directly mining heat, you extract hot water that will do the job. Therefore, the main question is **How fast will heat be mined/recharged by advective groundwater entering the system, depending on the source, relative to a case where you only have conductive recharge?** To answer this question, I will use 2D models of mines with simple geometry from which water is extracted and perform a sensitivity analysis on different model parameters and boundary conditions. Especially considering the differences with conventional geothermal aquifers.

The hypothesis I would like to verify here are:

* First, during production, heat is mainly transferred in tunnels via the advective groundwater, inducing conductive flux in the rock mass. 🡪 energy provided depends on the recharge water.
* Conductive heat recharge only becomes dominant during recovery 🡪 mine rock from heat

To conclude this chapter, I would like to show if the induced recharge fluxes will be balanced with the heat extracted to provide energy to a single house in the UK?

9- **To know if water is going to steal or give heat to the rock, that implied to know what is the actual rock temperature**. In former mine modelling studies, authors generally considered steady state undisturbed geothermal gradient to estimate the heat capacity of mines. However, this might not be true and the second objective of my PhD is to understand what is the impact of past mining activities on the thermal state within the mine, to evaluate what is the actual temperature distribution.

In the UK, coal beds are located in the Carboniferous succession that tends to form multi-layered aquifers. When you mine them, increasing the porosity/permeability of the rocks, it is expected that temperature of rock cools down, while you pump and implement some ventilation. After mining, hydrological systems formerly separated might now be connected, and the voids remaining from the mining activities might disturb the flows and thus the temperature.

10 – The first objective is to estimate the time necessary for a return to equilibrium. I will here use simple 2D models with simulations of flooding/mining to see if a partial equilibrium, following the trend of the initial geothermal gradient can be reached.

11- As the uncertainty in the BC has been a real issue in former mine modelling studies, the third objective is first to show that we can use temperature profile in shafts and time series during flooding to constrain the source of water. I will here use available data to calibrate the models.

12- Finally, the third chapter will be about trying to assess what are the key features we need to extract from complex mine plans, to faithfully model heat transfers in coal mines. To summarize, the coal authority which to know if the digitalized geometrical features from mine plans can be used to build models and if they are precise enough. For that, we want to know what level of details is necessary to represent heat transfer mechanisms in the long term and at the scale of the mine, and see if 2D models can be representative of 3D processes.

The hypothesis are the followings:

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13- To answer this model, I will use the **data available** from my 2 case studies, including GIS shapefile, the corresponding model and temperature/flow data to **create models of decreasing complexity** to identify how different features contribute to changing the energy content in the mine throughout production. One of the approaches we suggested **to assess the validity of 2D models** is to create a **statistical distribution of mining void** along a profile, to which different temperatures and properties will be attributed, and properly interconnected with tunnel/roadways.

14- To conclude, the first year will mostly be based on trying to assess the contribution from different heat sources and the recharge mechanisms in mines, based on conceptual models. The second and third years will aim at using available data to first, understand the perturbations within mines caused by past activities, and the key features required to extract from mine plans to build reresenttaive models. Hopefully, answering those three questions will help understanding why different mines have different temperatures, and what are they geothermal potential.

We hope that this project will allow the creation of a modelling/analytical tool that will support the licensing of heat, by better understanding the footprint area of heat extraction in mines.