How things change—a UK Geoenergy Observatory in Glasgow

By Alison Monaghan

When I started work as a geologist at BGS over 20 years ago my job was to make maps and 3D digital models of the subsurface in western central Scotland. By integrating fieldwork, coal mine plans and boreholes I mapped and modelled the lithology, stratigraphy and structure of Carboniferous rocks and basins of the Midland Valley. The results were a 'static' representation of what's beneath our feet.

Fast forward to today and the way a geologist works has changed significantly—towards understanding competing resources, impact and change in the subsurface e.g. for waste disposal, for energy resources and energy storage. However, impartial, freely available data to constrain a 'dynamic' understanding of subsurface change can be hard to come by. The UK Geoenergy Observatories project is an ambitious £31 million investment that will see BGS set up and operate two subsurface research laboratories on behalf of the Natural Environment Research Council and the UK Government department for Business, Energy and Industrial Strategy, to gain a better understanding of subsurface change beneath our feet.

One Geoenergy Observatory in the Thornton area of Cheshire will focus on a range of subsurface energy technologies to over a kilometre below the ground. The other Geoenergy Observatory will focus on low-temperature geothermal energy from the flooded mine workings below the east end of Glasgow to a depth of a few hundred metres. Here, scientists will be able to move from knowledge of say, their underpinning static geological models of Carboniferous Coal Measures rocks, to answer key research questions on low carbon, renewable, heat resources within those rocks—and enable more widespread use of the subsurface in a sustainable way.

First of all, I'll describe the concepts behind mine water geothermal energy and then summarise what is planned for the Geoenergy Observatory in Glasgow, the Glasgow Geothermal Energy Research Field Site.

What is mine water geothermal energy?

Many parts of the UK are underlain by abandoned coal mines. Upon closure, the mines became naturally flooded with water which becomes warmed due to the naturally increasing geothermal gradient with depth. For the relatively shallow mine workings in eastern Glasgow the water is thought to be around 12°C, with a stack of seven worked coal seams. These man-made workings have greatly increased permeability for groundwater and the mine working galleries, shafts, roadways and collapse-related fractures have been termed an 'anthropogenically-enhanced aquifer'. By taking advantage of this anthropogenic aquifer, warm water can be abstracted through a borehole and passed through a heat pump to provide a heat source for homes and businesses, before being returned within a sealed loop to a different part of the mine system (Figure 1).

A number of mine water geothermal schemes have been run successfully for tens of years. For example, a scheme in Shettleston in Glasgow provides for a small number of homes, and a much larger scheme

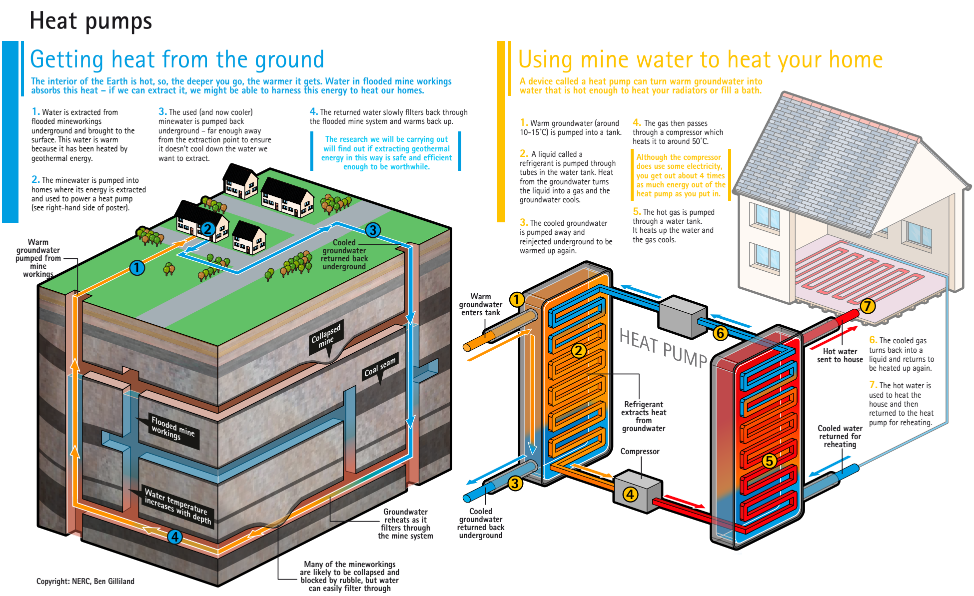

Figure 1 Infographic of mine water geothermal and how a heat pump works. British Geological Survey © UKRI 2019. All Rights Reserved

that also includes heat storage is running in Heerlen in the Netherlands. Several schemes e.g. at Markham in Derbyshire, have targeted mineshafts or roadways. However, few schemes target the much more extensive mine workings—either stoop and room, or 'waste' from total extraction—that it is planned to test at the Glasgow site. Also, most existing schemes have limited subsurface and environmental monitoring to record what happens to the subsurface environment when the warm mine water is abstracted, and the cooler mine water returned.

Mine water geothermal energy is a potentially significant source of low-cost, continuous low-carbon heat that is sustainable long-term. However, its contribution to the UK's energy mix, and to decarbonisation of its energy, is, as yet, largely unrealised. The Glasgow site was chosen as it has much in common with other parts of the UK with a mining history, relatively complex Carboniferous geology and a legacy of former industrial land use. Mine water geothermal, on its own or in combination with other heat sources, could provide community scale heat via district heating networks in former coalfield areas which commonly suffer from fuel poverty. Yet to achieve this there are a number of economic, regulatory and geoscientific challenges. Some geoscientific examples include:

- how quickly warm water is replenished—resource value and sustainability
- what minerals are in the water and how to minimise clogging of pipes etc.—hydrogeochemistry
- costs and risks of borehole drilling—does it matter what type and depth of mine working is targeted?
- subsurface connections between near surface land contamination and mine waters—environmental protection

This is where the UK Geoenergy Observatory in Glasgow comes in.

What's going to be at the Glasgow Geothermal Energy Research Field Site?

The subsurface Observatory will feature a number of boreholes of various depths, which will enable research into the area's geology, underground water systems and the potential for mine water geothermal heat. Measurements will be taken from the boreholes, such as temperature, water movement, water chemistry and of microorganisms (geomicrobiology). Environmental baseline monitoring of near-surface chemistry, gases and waters will also be measured, to provide a record of 'what is normal' before any geothermal research takes place.

Planning approval and permitting for the current characterisation and monitoring phase have been granted with the majority of the boreholes located at the Cuningar Loop, Rutherglen (Figure 2). Planned drill lengths are between around 10 to 90 metres. Six boreholes are targeted to characterise and monitor water in the Glasgow Upper and Glasgow Main coal workings (Figures 2, 3). Five boreholes will be used to record the environmental baseline near the top of the bedrock and superficial deposits. The boreholes are planned to have range of sensors such as resistivity and temperature cables, water data monitors will be installed, and regular water samples will be

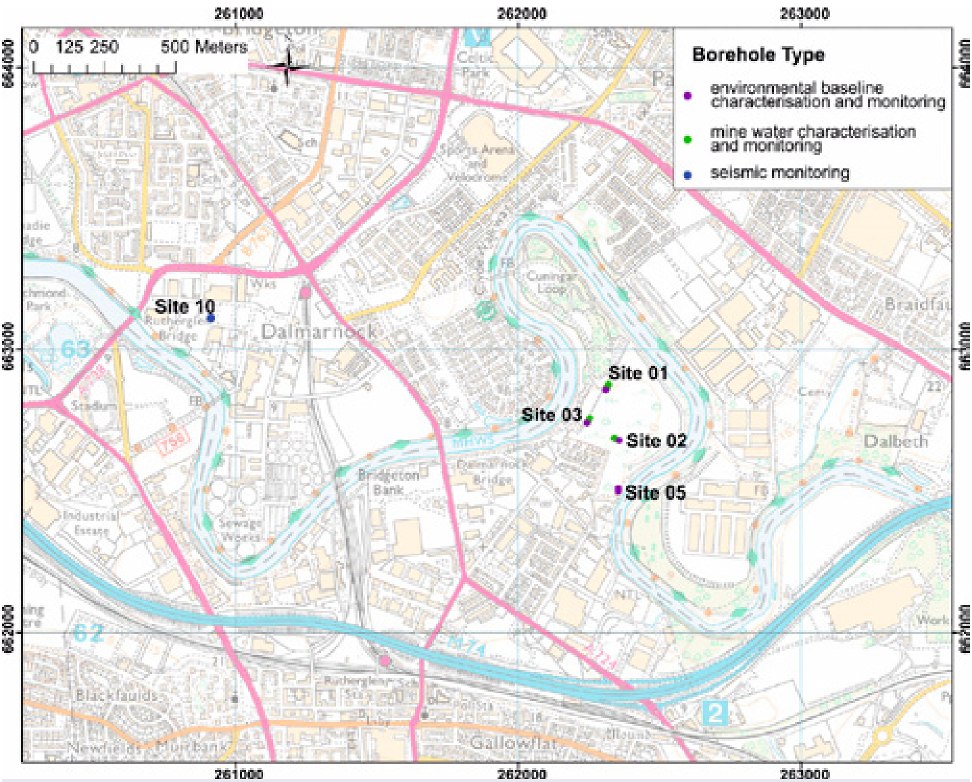

Figure 2 Map of the borehole locations. BGS©UKRI. Contains Ordnance Survey Data © Crown Copyright and database rights 2018. Ordnance Survey Licence no. 100021290.

taken. In addition, there is one seismic monitoring borehole of around 200 m drill length at Dalmarnock (Figure 2), which is planned to provide a borehole core. A new core scanning facility at BGS Keyworth will be used to give a geophysical, mineralogical, and geochemical and optical/X-ray downcore record.

Subsequent to the current phase and permissions for the installation of the pipes and heat pumps that will allow geothermal research, the observatory will be open to the whole of the UK science community to undertake research. Continuous data from state-of-the-art sensors from the boreholes will be open, free and accessible to the public, government, regulators, academia, and industry via an online portal.

Timescale

Planning permission and various permits are in place, with borehole drilling work started on site in November 2018. The aim is for all boreholes and monitoring equipment to be ready for research use from 2020 for a 15-year lifespan.

Geology of the research site

The Glasgow Geothermal Energy Research Field Site is located on the western side of the Central Coalfield of the Midland Valley of Scotland. It is located within glacial and post-glacial Quaternary superficial deposits, overlain by a variable thickness of artificial (made) ground. These deposits rest on approximately 300 m of Scottish Coal Measures Group bedrock. Underlying this are older Carboniferous strata of the hundreds of metres thick Clackmannan and Strathclyde groups.

The Quaternary deposits are of variable thickness, up to 30 m. The upper surface of bedrock was incised, with thicker accumulations of superficial deposits infilling a broadly NW-SE trending channel following the modern-day River Clyde. There is widespread made, filled and landscaped ground relating to a variety of prior industrial land use, in some places this is 10–15 m thick.

Bedrock strata of the Scottish Upper, Middle and Lower Coal Measures formations of the Westphalian Scottish Coal Measures Group are cyclical sedimentary rocks of sandstone, siltstone, mudstone and coal. Recorded coal mine workings in the area were active from 1810–1934 with total extraction and stoop and room workings shown. It is expected that total extraction areas collapsed within a few years of mining to form a waste, and that the mines will be flooded. Figure 3 illustrates a cross-section of the geology and two of the planned sets of boreholes in the Cuningar Loop area—our static model of the geology before we start

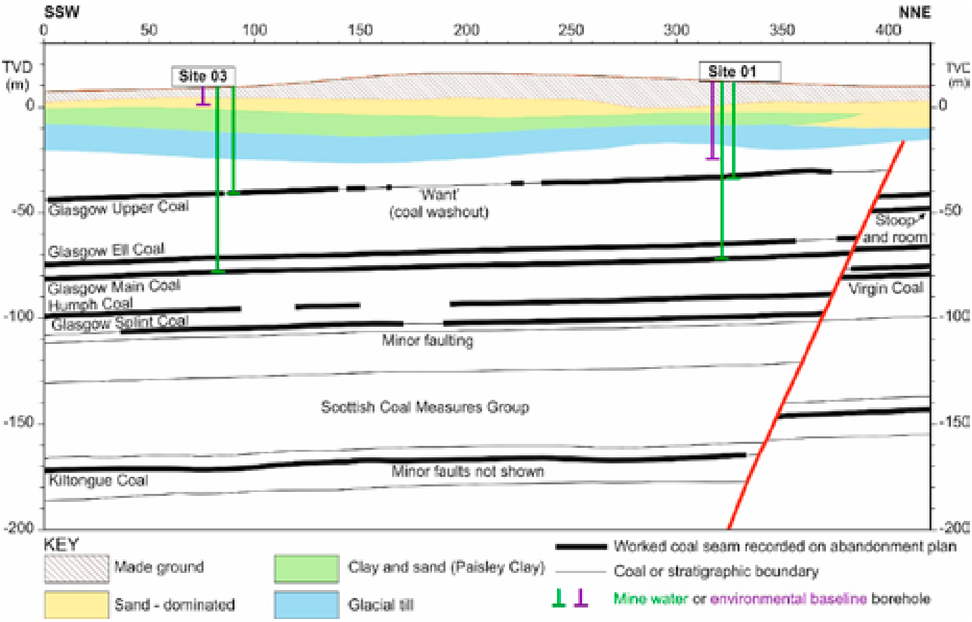

***Figure 3** Cross-section of the geology in the Cuningar Loop area with the planned borehole target depths shown. Note that the thick black lines represent areas recorded on abandonment plans as mine workings. British Geological Survey © UKRI 2019. All Rights Reserved.*

drilling, monitoring and sensing the subsurface.

To conclude

In a few years' time I hope this project will have enabled us to reflect not only on 'how things change' for a BGS geologist's work, or our significantly improved knowledge of 'how things change' in the subsurface environment above and in old coal mines, but because with the results of this national-good science we'll be on the way to changing old coalfield communities with locally sourced, decarbonised heat/heat storage, reinvigorated with local engineering and science expertise.

Further information and references can be found on the BGS website http://www.bgs.ac.uk/research/energy/esios/glasgow/home.html

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