Deep geothermal in the UK

The UK does not have the geothermal resources that are found in volcanic regions. This, coupled with the abundance of offshore gas from the 1980s led to very little exploitation, or interest in UK geothermal. However, times have changed and there is now an increasing requirement to utilise these renewable energy resources. Temperature increases with depth and even in the UK these can reach levels suitable for power generation and as a direct source of renewable heat.

The prospects for power generation are mainly consigned to regions where large masses of high heat producing granites are found (see Figure 1). These granites have slightly raised levels of the radiogenic isotopes of potassium, uranium and thorium, whose radioactive decay leads to a heat anomaly at depth. In Cornwall temperatures of 180 ºC and possibly even 200 ºC are likely at depths of 4.5 to 5 km. Generation of electricity would require fracking of these rocks so that cold water could be introduced down one well, circulated through the engineered reservoir and withdrawn from a production well. Heat would be transferred from the geothermally heated water to a binary fluid with a low boiling point that would then drive a turbine. This type of geothermal system is often referred to as an Engineered Geothermal System (EGS). Two companies are actively pursuing power generation projects in Cornwall with generation capacities of between 3 and 10 MW. With directional drilling it is anticipated that each drill pad could host several EGS's creating a power station of several tens of MW. The northern England granites also have potential for power production; in particular the Weardale granite, where the Eastgate borehole was drilled to intersect a known, mineralised, east-west trending fault (the Slitt Vein). At a depth from surface of 411 m (138 m into the granite) a major fracture zone was intersected and found to have exceptional rates of water flow, the highest yet found in any granite in the UK. Such a discovery shows that water can flow through granite, possibly indicating that fracking may not be required if fracture zones can be targeted by drilling.

Of greater potential is the direct heat use resource. The UK government is extending incentives for the utilisation of renewable heat and deep geothermal heat will be eligible under the Renewable Heat Incentive from 2014. There are three fundamentals required for exploiting deep geothermal heat. The rocks must contain water (or brine) within the pore space between the mineral grains; the pores must be interconnected so that the water can flow through the rock (the rock is permeable) and the rocks must be at a sufficient depth for the temperature to be high enough for the direct use application. The geothermal gradient in the UK has an average value of about 26 ºC/km so at a depth of 1 km temperatures of around 36 ºC would be expected (sufficient for agricultural heating), but depths of 2 – 3 km (temperatures of around 60 - 90 ºC) are needed for district heating. So a borehole extracting water at a rate of 10 l/s at a temperature of 76 ºC and discharging at 28 ºC will have a capacity of $2MW_{(thermal)}$. A group of rocks, the Permo-Triassic sandstones, are known to have favourable porosities and permeabilities and therefore at depth are a potential direct heat use geothermal resource. Their distribution is shown in Figure 2. To date, the only direct heat use project is at Southampton where a legacy borehole from the early 1980s was brought into production in 1987. It exploits the Sherwood sandstone (part of the Permo-Triassic sandstones) in a depth interval of 1725 – 1749 m. The brine is extracted at a temperature of 76 ºC and provides part of the heat to a city centre district heating scheme. The spent brine is expelled to the sea rather than being reinjected back into the sandstone at depth; a procedure that overcomes the need for a second borehole, but has led to a lowering of the water level in the production well over time.

The areal distribution of Permo-Triassic sandstones at depth is limited and does not coincide with most of the main urban centres. Does this mean that deep geothermal heat is only available in a few areas? Possibly not, because water can also flow through fractures in the rock as well as through the pore space. Evidence of this can be found at the two localities where there are warm springs; Bath/Bristol and the Peak District. Here, water flows through fractures in limestone relatively rapidly from depth. The possibility of finding similarly fractured limestone elsewhere is being explored as a potential heat source for district heating. In Manchester, planning permission has now been granted for boreholes that would intersect limestone at 3 km depth. There is also evidence that water may flow laterally along ancient fractures within the crust. The Weardale granite, mentioned above, lies to the west southwest of Newcastle upon Tyne. Warmer water around the granite may migrate eastward along an ancient fault zone known as the Ninety Fathom-Stublick fault zone. This water may then recharge sandstone beneath Newcastle which may have favourable porosities and permeabilities. This has been investigated with the Science Central borehole (see Figure 3) on a redevelopment site in the centre of Newcastle which intersected 377 m of Fell Sandstone below a depth of 1,419 m and recorded a temperature of 73 °C at a depth of 1,767 m, indicating a geothermal gradient of 36 °C/ km. This higher than expected temperature at depth clearly suggests that groundwater may be transporting heat by advection. Investigations are still ongoing to assess whether the Fell Sandstone can provide water flows sufficient for district heating.

At the end of 2011 there was no geothermal electricity generation and only 2.8 MW of installed direct heat use in the UK. This compares to mainland France where there was 1 MW of electricity generation and 345 MW of direct geothermal heat use. There is no fundamental difference in the geology for this discrepancy, although government incentives for geothermal heat and power are higher in France. The UK has had a long love affair with fossil fuels, especially natural gas, that has held back renewables, but perhaps it is now time for a geothermal catch up.

Jon Busby is the Team Leader for Renewables, Energy Storage and Clean Coal at the BGS and BGS is a member of the BritGeothermal research consortium.

Figure 1. Distribution of granite within the crust of the UK. The Cornish and Northern England granites are two regions of high heat producing granites.

Figure 2. Distribution of the Permo-Triassic sandstones at depth displayed from shallow (red) to deep (blue). These rocks are also found in Northern Ireland, but their detailed depth extent is less well known, but do not occur at depth in Scotland.

Figure 3. Drilling of the Science Central borehole in the centre of Newcastle upon Tyne.

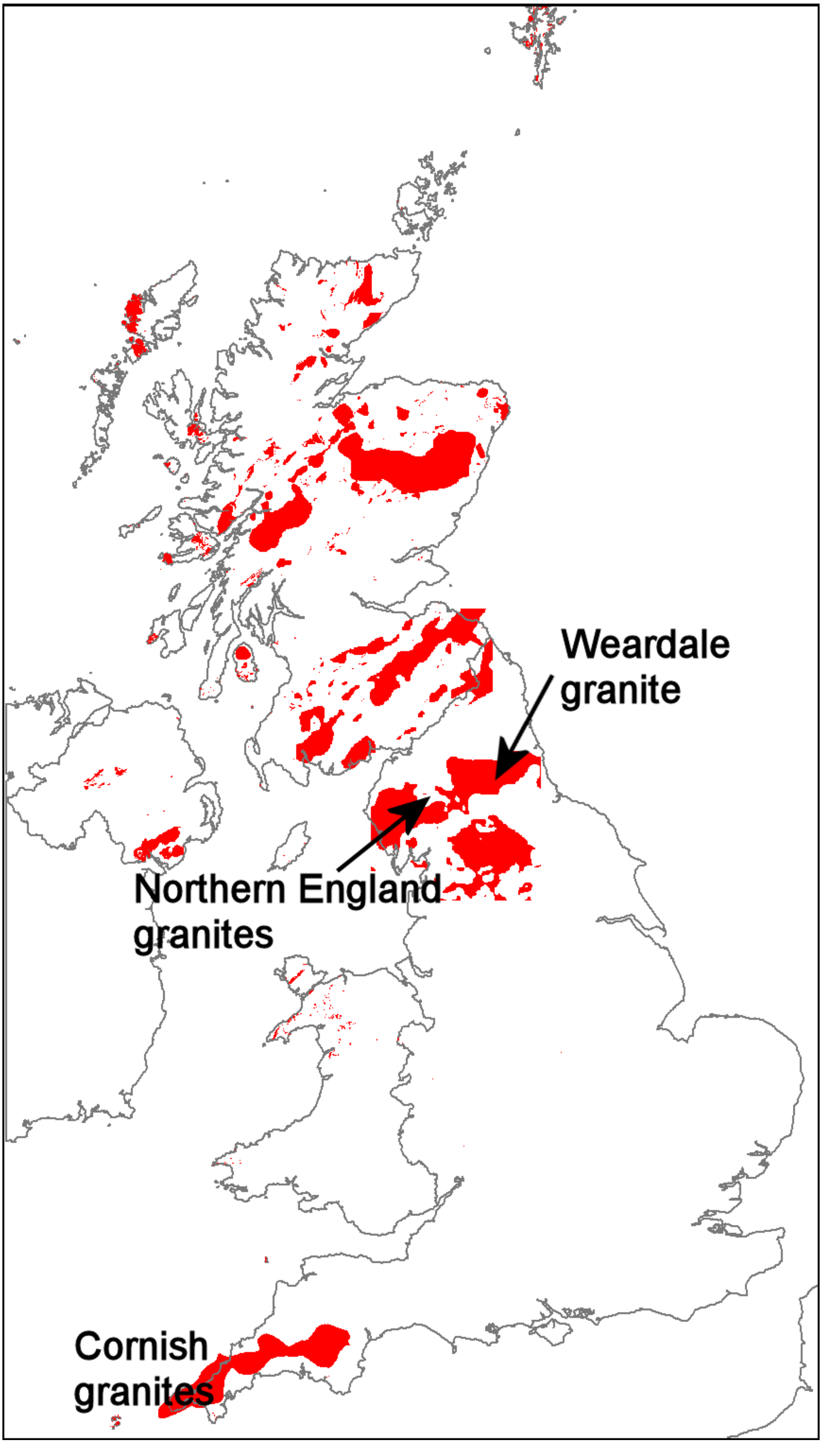
Weardale
granite
Northern England
granites
Cornish
granites

Figure 1

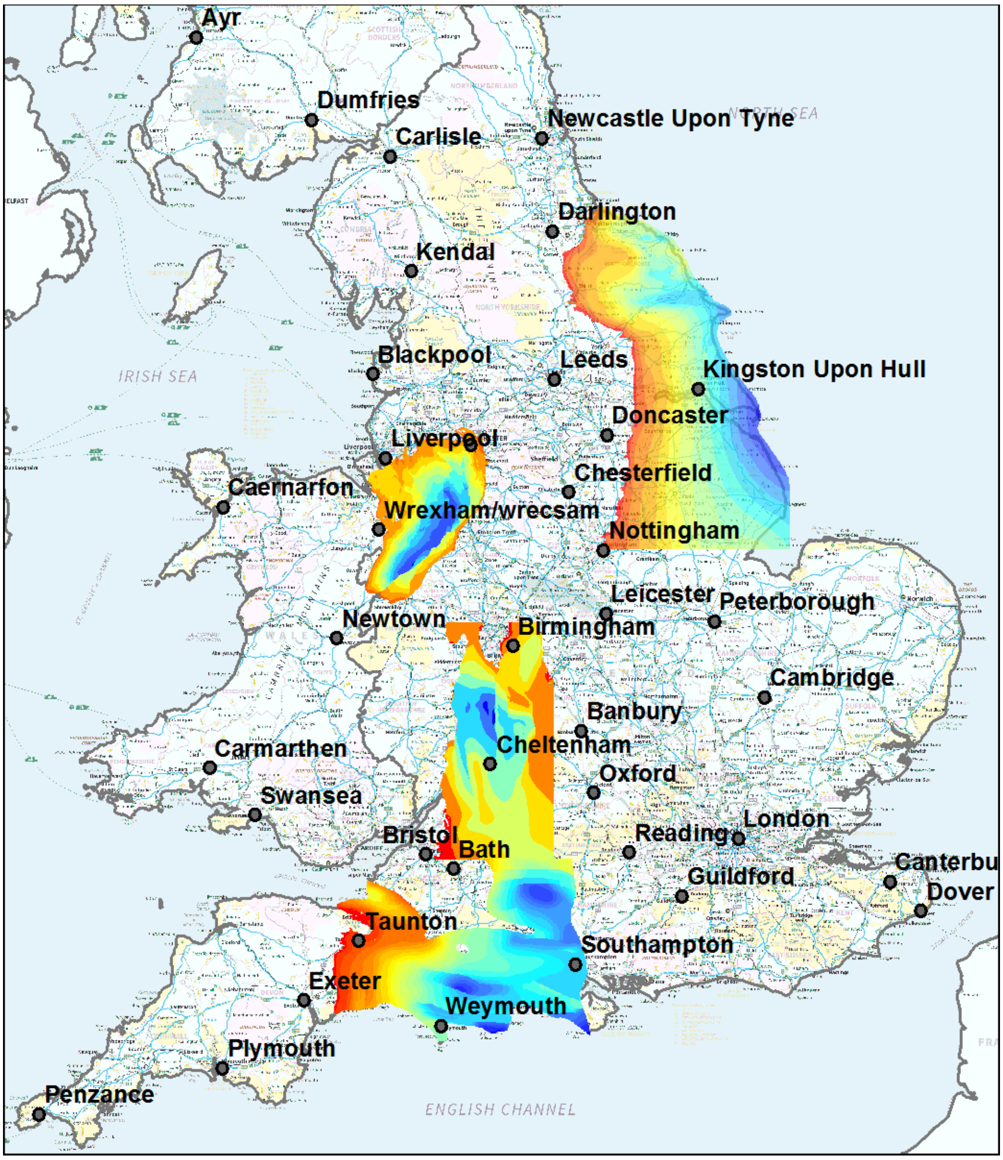
Ayr
Dumfries
Carlisle
Newcastle Upon Tyne
NORTH SEA
Darlington
Kendal
Blackpool
Leeds
Kingston Upon Hull
IRISH SEA
Doncaster
Liverpool
Caernarfon
Chesterfield
Wrexham/wrecsam
Nottingham
Leicester
Peterborough
Newtown
Birmingham
Cambridge
Banbury
Carmarthen
Cheltenham
Oxford
Swansea
London
Bristol
Reading
Bath
Canterbu
Guildford
Dover
Taunton
Southampton
Exeter
Weymouth
Plymouth
Penzance
ENGLISH CHANNEL

Figure 2

Figure 3