ZURICH, SWITZERLAND
6 - 10 OCTOBER 2025

EUROPEAN GEOTHERMAL CONGRESS 2025

Multi-scale thermal property characterisation of a UK Triassic sandstone aquifer with relevance to ATES

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Keywords: Aquifer Thermal Energy Storage, Thermal Conductivity, Geothermal, TRT, Sherwood Sandstone

ABSTRACT

The thermal properties of UK aquifers are important considerations for the effective design of geothermal systems and particularly aquifer thermal energy storage (ATES) systems. We focus on the Triassic Sherwood Sandstone Group (SSG), a legally-protected principal aquifer underlying several major cities in the UK. The bedrock represents a considerable potential commercial shallow heat source/store for ground source heat pump systems, ATES, and deep geothermal plays, and we describe field studies for understanding how subtle variations in rock properties will impact local and regional scale aquifer thermal storage behaviour.

Multi-scale thermal property evaluation of the fluvial Chester Formation of the SSG within a 36x36 m wide by 100m deep rock volume at the UK Geoenergy Observatory (UKGEOS) research facility in Cheshire has been undertaken using core plugs and in situ TRT tests in boreholes. Advanced thermal response tests were conducted in four 100m deep vertical closed loop borehole heat exchangers. The loops and tremie pipes were instrumented with fibre optical cables for distributed temperature sensing (DTS) inside the 40mm OD pipe and on the outside of the 99m long tremie pipe. Digital Temperature Cables (DTC) were also fitted on the outside of the loop and tremie pipes for determination of effective thermal conductivity down the entire well using different deployments.

The field site, located on a prominent UK sandstone aquifer, gives an opportunity to investigate the influence of lithological and mineralogical variations and hydraulically conductive fractures in a rock unit widely considered to be dominated by intergranular flow. Thermo-physical data has been derived from analysis of core plugs and good agreement with in-situ Thermal Response Test (TRT) measurments of thermal conductivity was observed, giving confidence in numerical models assessing the regional potential for thermal storage. However, the results of the TRT tests and downhole logging indicate that fractures may be present and may be a dominant heat transport process operating at certain intervals and this could affect heat losses in ATES systems. The results enhance the site geo-model and support regional-scale heat flow modelling simulations in the UK. The results are also relevant to deep geothermal hot sedimentary aquifer (hydrothermal reservoir) reservoir studies of deep clastic sedimentary aquifers in the UK and elsewhere.

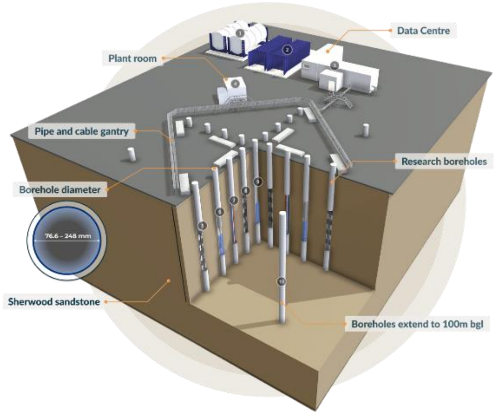

Figure 1: Schematic showing infrastructure at UKGEOS Observatory in Cheshire, UK. BGS © UKRI.

1. INTRODUCTION

The thermal transport properties of UK aquifers are important considerations for the effective design and management of geothermal energy systems, and particularly ATES systems where heat extracted from summer cooling is stored in a warm well and extracted for heating in the winter. The storage efficiency of the ground side of the system is affected by the thermal transport regime in the ground. We focus on improving thermal characterisation of the Triassic Sherwood Sandstone Group (SSG) in the Cheshire Basin. The sandstone is important as it is a principal aquifer underlying several major cities in the UK including Manchester, Liverpool, Birmingham, Nottingham, and Belfast. The aquifer represents a considerable heat source/store for ground source heat pump systems, aquifer thermal energy storage, and deep hot sedimentary aquifer geothermal plays (English et al 2024). Analysis of a combined lab and field-derived dataset of the SSG has improved understanding of how subtle variations in rock properties and groundwater movements will impact aquifer thermal properties and storage behaviour using the newly commissioned UK Geoenergy field research site 'UKGEOS' in Cheshire, located in northwest England, United Kingdom. More information about the network of UKGEOS test sites is found on the project webpages https://www.ukgeos.ac.uk/.

In this paper we report the first test results from heat injection experiments at the site and core characterisation studies which formed part of the UK-government funded UKRI ATESHAC project. More information about the project can be found on the project website https://www.imperial.ac.uk/earth-science/research/research-projects/ateshac/.

2. METHODS

Detailed thermal property evaluation of a 36 x 36m wide by 100m deep rock volume comprising fluvial sandstones of the Chester Formation of the Sherwood Sandstone Group (Lee & Hough 2017) was undertaken using a combination of in situ tests and laboratory analysis of rock core from one of the vertical closed loop borehole heat exchanger wells, labelled yellow triangle TH0422 in Figure 1.

Four ~70 hour long thermal response tests (TRT) with extended monitoring during the recovery period were conducted in four identical 95m deep vertical closed loop borehole heat exchangers in May and June 2024 to measure in-situ thermal properties of the ground. The closed loop boreholes are spaced ~8m apart, installed in the same bedrock formation, and are surrounded by highly instrumented observation wells with the closest wells located 3m away (Figure 2). The sandstone is porous and variably fractured with discontinuities presenting variations in bedrock hydrogeology, macro-porosity and permeability.

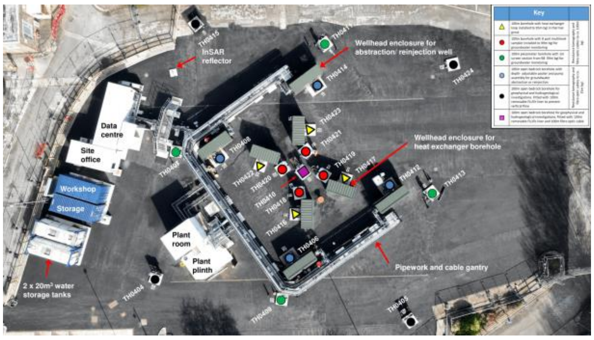

Figure 2: Aerial photo of the test site boreholes and infrastructure at UKGEOS Cheshire, UK. The tested closed loop boreholes with wellhead cabinets are labelled 16, 17, 22, 23. The gantry carries pipe work and data cables back to the plant room and data centre (white buildings). BGS © UKRI.

The geothermal loops are installed into 100m deep 152mm diameter boreholes that were fully backfilled with setting grout (GEOTHERM-X GR®) using a 99.5m long tremie pipe. The boreholes had been installed and commissioned several months previously so had ample time for thermal equilibration. Each loop had fibre optical distributed temperature sensing cables (FO-DTS) pulled through 40mm outside diameter (OD) loop pipe and another tied onto the outside of the tremie pipe, as depicted in Figure 3. The DTS cables on the tremie pipe continue to 99.5m to measure temperature field under the loop U-bend. All multi-mode fibre-optical cables are deployed in double ended configuration with a downhole assembly and connected back to a Silixa Ultima DTS interrogator housed at surface in an air-conditioned temperature-controlled data centre, shown in Figure 2. DTS logging was set to 60 seconds for the TRT test period to maximise data accuracy and provide records every minute in the well cluster (the FO cables are continuously looped servicing 5 wells in four separate clusters). The measurement duration was reduced to 14 seconds (7s x 7s) between successive TRT tests to capture any thermal interference in the wider array (in the other 3 well clusters). This reduced logging reduced resolution from ~0.01°C to ~0.02°C. Digital Temperature Cables (DTC) with nodes crimped every 1m (supplied by RST-Beadedstream in Canada) are also attached onto the outside of both loop pipes, as depicted in Figure 3, with recordings every 3 minutes providing independent distributed temperature sensing data. There are also 99m long electrical resistivity tomography (ERT) cables with electrodes every 1m down each well, as shown in Figure 2.

The advantage of having different sensing technologies in one well is that it allows for comparison of different sensing and analysis approaches for D-TRT (Wilke et al 2020) and thermal plume monitoring but also provides system redundancy in case one of the systems fail during the test or lifetime of the observatory.

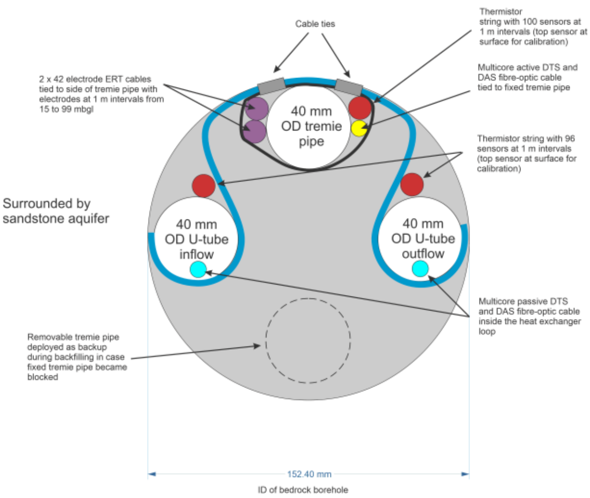

Figure 3: Plan view of borehole heat exchanger design. Thermistor string nodes are spaced at 1m intervals. BGS © UKRI.

The thermal transfer fluid was a water-glycol mix (Coolflow DTX – a non-toxic Ethylene Glycol) with concentration in each loop measured using a water-calibrated refractometer at the end of each test. Glycol concentrations varied ranging from 27-33%. The average circulation rate, controlled by the 18kW capacity TRT rig built by Rock Geotechncial https://www.rockgeotechnical.com/, was 0.57 l/sec.

The nominal thermal input power provided by the electric heaters in the TRT rig were 9kW except TH0423 which had a stepped TRT using 3,6,9 and 12kW over a 7-day period. The details of the borehole heat exchanger wells are given in Table 1. The logging equipment (red Peli case in the silver box in Figure 4) recorded every 1 minute and recorded loop inlet and outlet temperature and circulating pump flowmeter. Following the heating phase, the heaters in the TRT were turned off and the circulating pump continued to circulate the thermal transfer fluid around the system for a 3-4 day recovery period before the rig was moved onto the next well and the testing cycle restarted. The external air temperature was recorded every 15 minutes during the tests using a Solinst Barrologger hung ~2m above ground level within the borehole array area.

Table 1: Borehole and TRT test details

Borehole name	Loop length, m	Nominal input power, kW	^Nominal heating power, W/m
TH0416	95	9	95
TH0417	95	9	95
TH0422*	95	9	95
TH0423	95	3,6,9,12	31-126

* core recovered from TH0422 was tested in the lab
^ the actual heating power delivered was around 90% of the nominal heating power due to system losses.

Figure 4: Photo showing typical test set up using the Rock Geotechnical TRT rig. Taken on 20 May 2024 at well TH0416 by Mike Spence. BGS © UKRI

In addition to the TRTs, 13 of the wells, including the BHEs, were actively heated using copper cables within the hybrid fibre optical cables to undertake Enhanced TRT tests (E-TRT) to further characterise well construction materials (grout and backfill) and evaluate thermal and groundwater flow properties. The heating period was for 3 hours but this was deemed too short for penetrating the formation because the cable is located in grout. However, the active heating test helped map the boundaries of the bentonite, sand and gravel backfill layers in the Multi-level sampling (MLS) groundwater monitoring boreholes and confirmed thermal properties and coverage of the grout. The E-TRT tests will not be further discussed here as the focus of this paper is the conventional TRT and lab test results.

DTS Data extraction

A python script was developed to extract the raw data from the .xml files generated by the DTS interrogator. These where converted to .csv for plotting and interpretation. Files were depth corrected using the supplied Length Along Fibre (LAF) cable mapping data collected during the UKGEOS site commissioning (Silixa's freezer spray test) to provide temperature depth data relative to well tops. The DTS cable for each TRT well sits within daisy-chained cluster of 4 to 5 wells so data extraction for all clusters (red, purple, green, blue) was done accounting for the difference in LAF value in each cluster.

Core plug and grout TC testing

The 102mm diameter rock core recovered from borehole TH0422 was inspected and logged at BGS National Core Repository (NGR) in Keyworth, Nottingham, and a range of lithologies were subsampled providing 108 x 25.4mm (1inch) diameter core plugs. Where possible, two plugs were taken at each depth interval, with one orientated parallel to bedding/lamination fabric and the other perpendicular to bedding in order to study the influence of mineral grain fabrics and mm scale sedimentary structures on thermal conductivity. Samples were then saturated in de-aired distilled water using a vacuum pump and tested in saturated state in 19-20°C lab conditions using the Modified Transient Plane Source (MTPS) method using a CTHERM Trident (Canada) thermal property analyser. Permeability, porosity and bulk density were also measured on the core plugs in BGS Wallingford labs. The equipment was recently calibrated and the sensor tested for conformance prior to any testing using a reference standard ceramic block.

3. RESULTS

Conventional TRT data

In borehole TH0416, the average undisturbed borehole circulation temperature in the 95m deep closed loop borehole heat exchanger (measured by the TRT rig) in the first 30 minutes before the heater was turned on was 12.27 ± 0.25°C. During the heating phase the maximum temperature delivered to the loop inlet was 29.62°C and from the loop outlet was 26.11°C, with a maximum average loop temperature of ~28°C, shown in Figure 5, and an average calculated delivered power of 84 W/m applied to the ground during the heating phase of the test. The delivered power was less than the nominal power of the heater due to system losses despite thermal insulation lagging being applied to the connector pipes (Figure 4). The external air temperature varied between 8°C and 24°C during the heating phase. Assuming an average ground volumetric heat capacity of 2.2MJ/m^3/K the average apparent thermal conductivity of borehole TH0416 was calculated as 3.24W/mK using the Infinite Line Source (ILS) analysis method. The borehole thermal resistance was 0.08 ± 0.01Km/W. The calculated power delivered to the ground decreased progressively during the heating phase from ~8250W at the beginning of heating to ~7750W by the end, as shown in Figure 5. This drop is attributed to the outside air temperature and slight drop in glycol heat capacity as it heats up during the test.

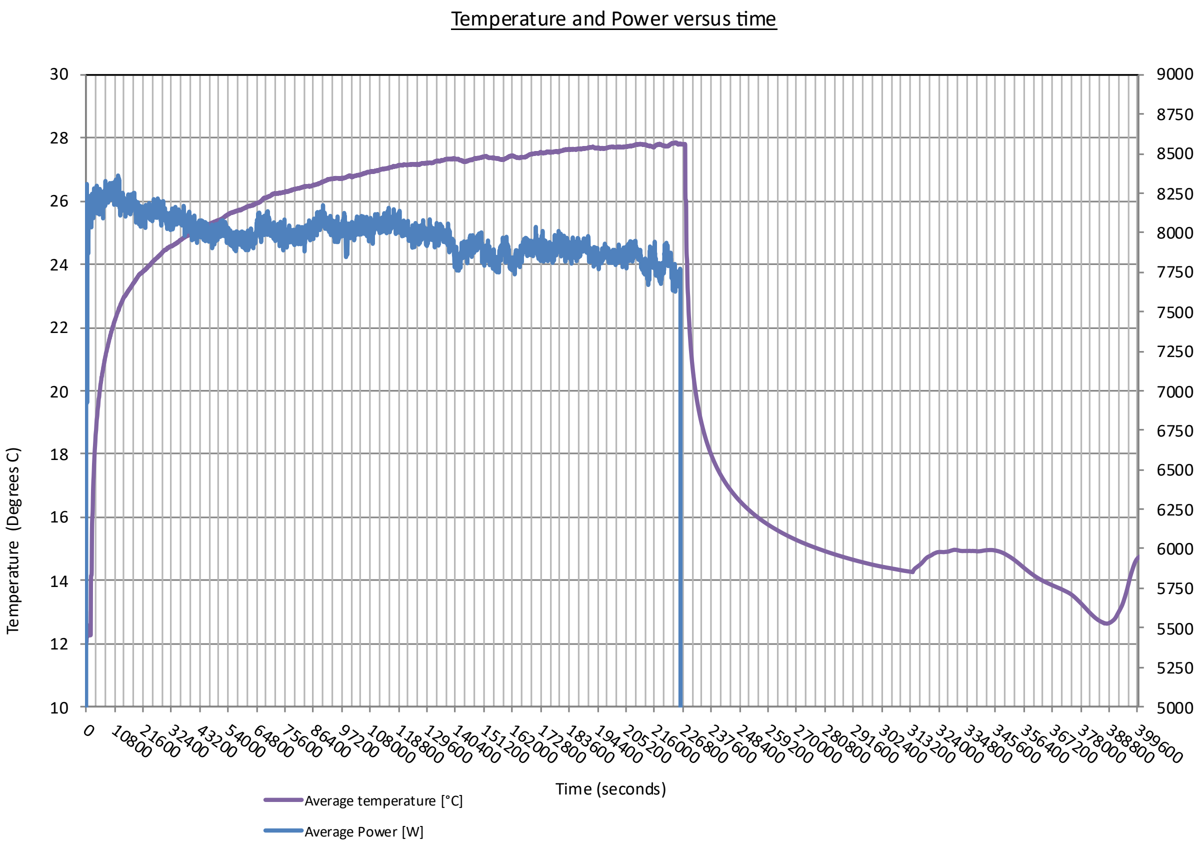

Figure 5: Plot of mean average loop temperature (°C) and calculated input thermal power (W) verses time (seconds) in well TH0416 during the TRT and recovery period. BGS © UKRI.

DTC baseline and heating phase data

The data collected from digital temperature cables attached to the outside of the loop pipes in borehole TH0416 is presented in Figure 6. The upper plot (left hand side) shows undisturbed ground temperature in the morning before the TRT started and the right-hand side curves are the maximum temperatures reached on the outside of the flow and return loops at the peak of heating. The baseline plot (top left) shows the ambient ground temperature was 12.8°C at 13m depth; which corresponds with the depth to the water table and also marks the base of the zone of seasonal temperature fluctuation (ZSF) at this location. The ambient temperature reduces with depth reaching a minimum of 11.0°C at the bottom of the loop, suggesting there is an inverse thermal gradient at this site. In the data from the heating phase, shown on the right-hand side of the plot, there is noticeably more scatter, perhaps suggesting the temperature field in the grout during heating is not even and affected by well construction (grouting thickness and cable location) and formation properties. The spatial variation in temperature on the outside of the inflow loop with depth is illustrated in the DTC data heat map plot below. The maximum temperature reached on the outside of the inlet pipe at the end of the TRT was 26°C whereas the temperature at the bottom of the 95m loop was around 22.5°C. The temperature of the thermal transfer fluid increases slightly in the outlet side suggesting it was picking up heat via conduction through the grout from the warmer inflow pipe, despite outside of the loop pipes being consistently separated by 5cm using Omega EZ-Snaps loop shank spacers placed every 3m. The horizontal stripes in the DTC heat map in Figure 5 indicates vertical variations in effective thermal conductivity likely relating to variations in lithology (mineralogy), porosity, density and the presence of discontinuities such as open and closed fractures/faults and compaction bands. The relatively uniform cooler zone on the inlet pipe between 20-27m suggests the nodes in this zone may be in a different position, possibly rotated around the loop pipe to face outwards or detached from the pipe.

Distributed TRT using DTC data

Using the infinite line source method for analysing heating curves from every 10m depth interval, the mean distributed effective thermal conductivity has been derived and is shown in Figure 7. The mean of all intervals is 3.5W/mK. This is slightly higher than the 3.24W/mK value returned for the conventional TRT analysis on this well. One value of 4W/mK at 95m is affecting the mean value. This is in the lower section of the well where there are relatively well-cemented (calcite) fluvial channel conglomerate facies and this geological attribute of the rock is resulting in an enhanced bulk thermal conductivity in these beds.

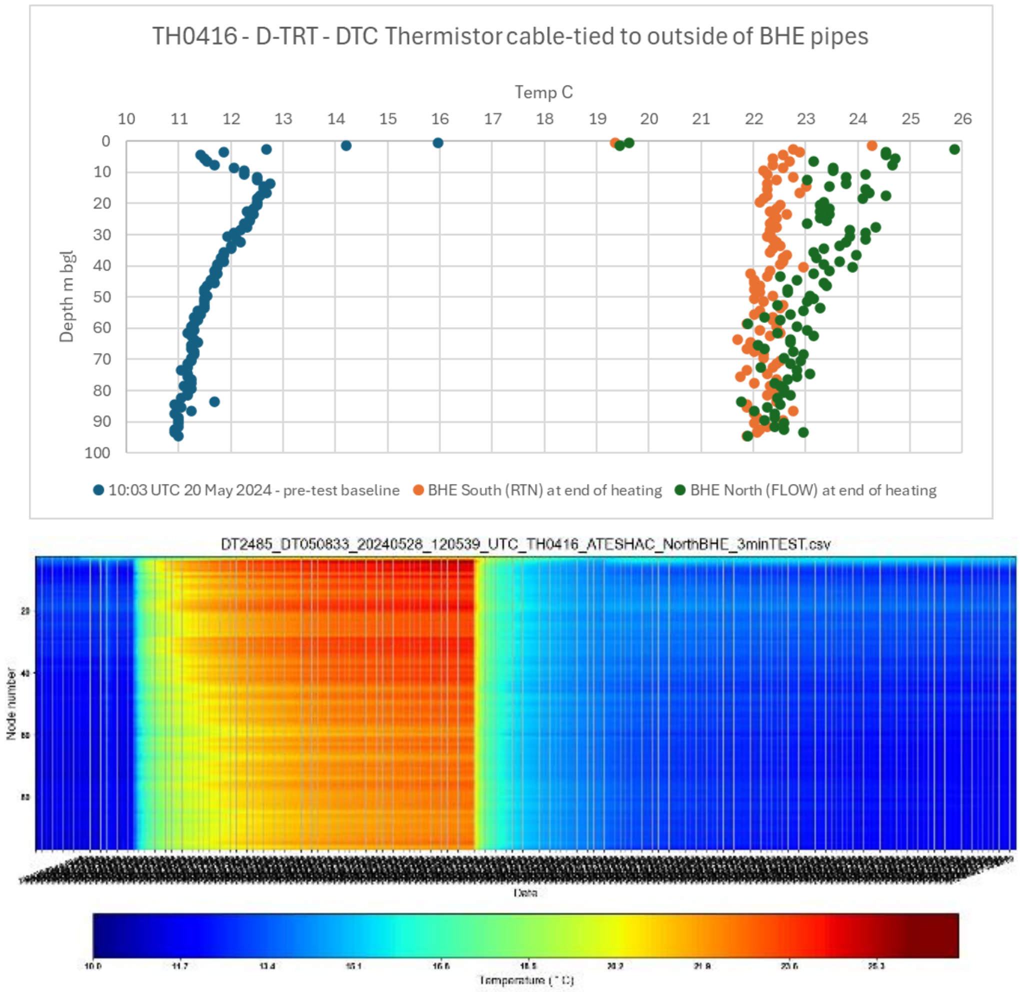

Figure 6: Plot (above) showing undisturbed ground temperature in TH0416 before the TRT started and maximum temperature reached on the outside of the loops measured by digital temperature cables. (below) Heat map of the data from the DTC cable outside of the loop inlet pipe, showing a 1-day pre-test baseline period (blue), 3-day heat injection phase (yellow-red), and 5-day post-test recovery period (light blue cooling to blue). Thermistor nodes are spaced vertically 1m apart down the well. BGS © UKRI.

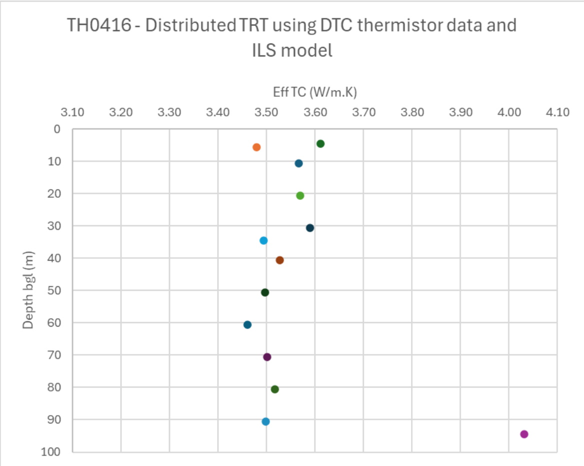

Figure 7: Plot calculated effective conductivity verses depth in TH0416 using Digital Temperature Cable data from outside of loop pipes. BGS © UKRI.

DTS data

The TRT tests all had fibre optical DTS data collected every minute with a spatial resolution of ~0.254m along the fibre and a nominal temperature resolution of ~0.01°C, providing detailed information about fluid thermal changes inside the loop pipe and on the tremie pipe during the baseline, heating and recovery phases.

The plot in Figure 8 shows an example of some DTS monitoring results from the TRT conducted on borehole TH0422. The upper plot shows DTS data collected from the FOC located inside the loop pipe and the lower plot is the DTS data from the sensor cable located on the outside of the grouted tremie pipe, typically located ~3cm away from the loop pipes. The data is of good quality with no data losses. The data plots are clipped to hide the top 5m for presentation clarity as this is affected by daily temperature variations. The pre-heating baseline phase in Figure 8a and 8c shows the undisturbed temperature profile with an inverse thermal gradient that agrees with the profile measured using DTC shown in the adjacent well (TH0416) in Figure 6. The site is near the Mersey River estuary and is in a long-established industrial complex with oil refineries nearby and so this inverse thermal gradient is attributed to the urban heat island effect. It is suspected the natural geothermal gradient here, and in other UK urban areas, will only be encountered below >100m. The temperature profile inside the loop pipe (Figure 8a-b) is smooth whereas the temperature measured on the tremie pipe (Figure 8c-d) shows vertical variation with faster warming behaviour in an upper decalcified 'less thermally conductive zone' between approximately 12-30m (upper aquifer), and a lower 'less conductive zone' between 70-80m suggesting some relatively minor heterogeneity in aquifer thermal transport behaviour with depth. These 'less conductive zones' are shown as areas coloured darker red in Figure 8c, appearing as 'warmer zones' that develop during the heat up phase of the TRT which are indicative of lower thermal conductivity rock horizons. The green and yellow-coloured areas in Figure 8c are zones of relative 'higher thermal conductivity' rock and may indicate well-cemented or mineralogically conductive beds or flowing fractures. The example illustrates the difference in fidelity of distributed temperature sensing information acquired by placing DTC's and DTS cables on the loop pipes verses on the tremie pipe which, because of its outside position and use of separating pipe clips, sits close to the formation and is not so thermally saturated as the cables inside the loop pipes. Cables next to the formation and away from loops seem to reveal more detail of the variations in geology and aquifer properties in both heat up and recovery data and use of low permeability thermally enhanced grout eliminates upwelling effects inside the backfill and the temperature at the tremie pipe near the edge of the grout at the peak of heating is typically 5 to 10°C lower than the temperature inside the loop that peaked at 31°C.

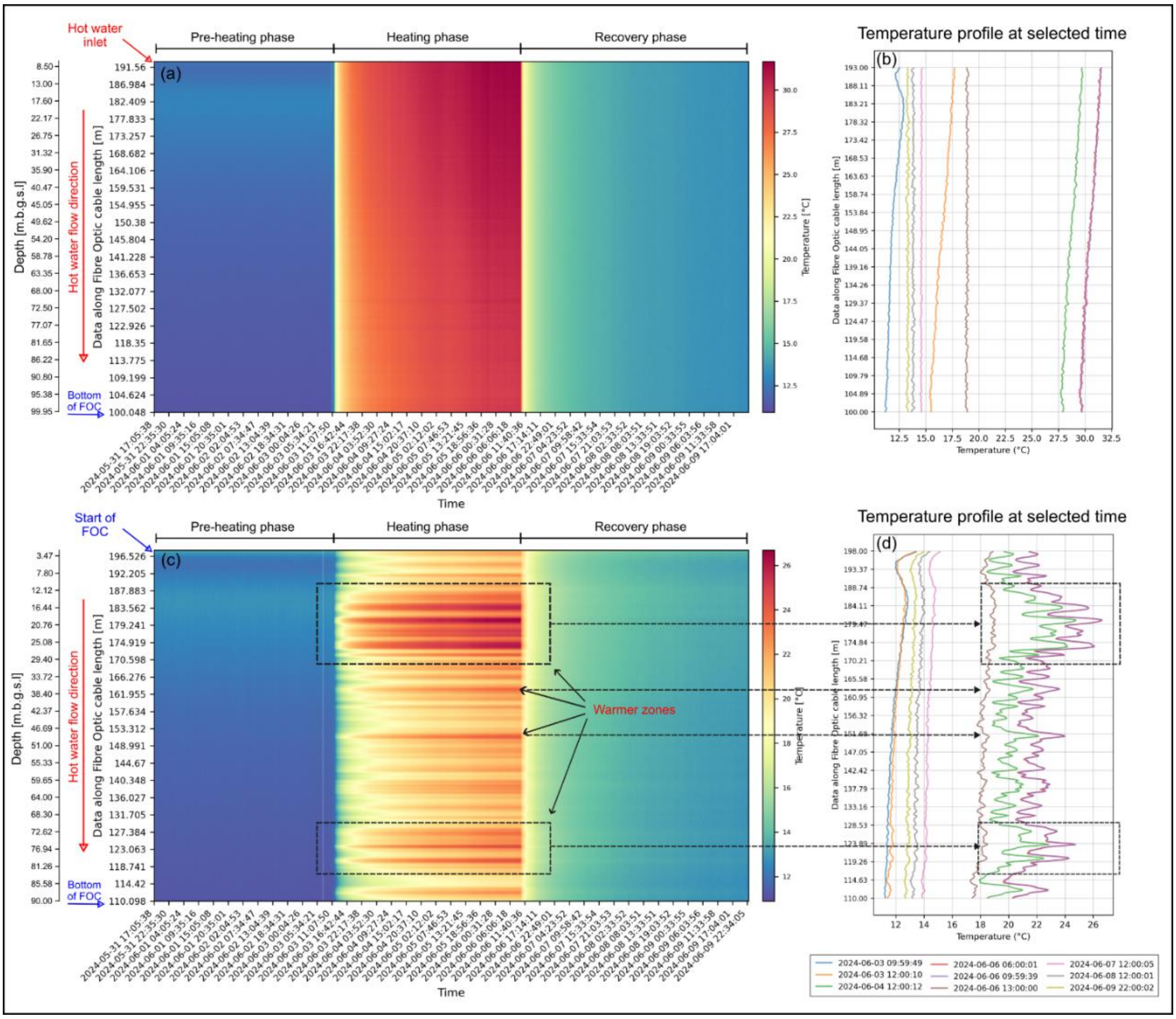

Figure 8: Thermal maps and selected temperature-depth plots of DTS data from inside loop pipe (a-b) and on tremie positions (c-d) in borehole TH0422 before, during and after the TRT. BGS © UKRI.

Core testing results

The physical property measurements on core plugs from well TH0422 are presented in Figure 9, which shows some variation in bulk (saturated) mean matrix thermal conductivity with depth. The range of all 209 values between 0-100m is 2.04-4.44W/mK, and the geometric and arithmetic means are 3.44 W/mK and 3.47W/mK respectively. The porosity and density ranged between 9-27% and bulk density ranged from 2.2 to 2.5Mg/m^3. The is a positive linear relationship between thermal conductivity, density, and a negative-linear relationship between porosity and thermal conductivity, as shown in Figure 10 and Figure 11 respectively. The matrix thermal conductivity generally increases with density, due to finer grain size and increased cement content, and reduces with increasing porosity, due to higher proportion of lower conductivity (~0.6W/m) water filled pore space, but there is some scatter reflecting the variably cemented clastic sedimentary rock material.

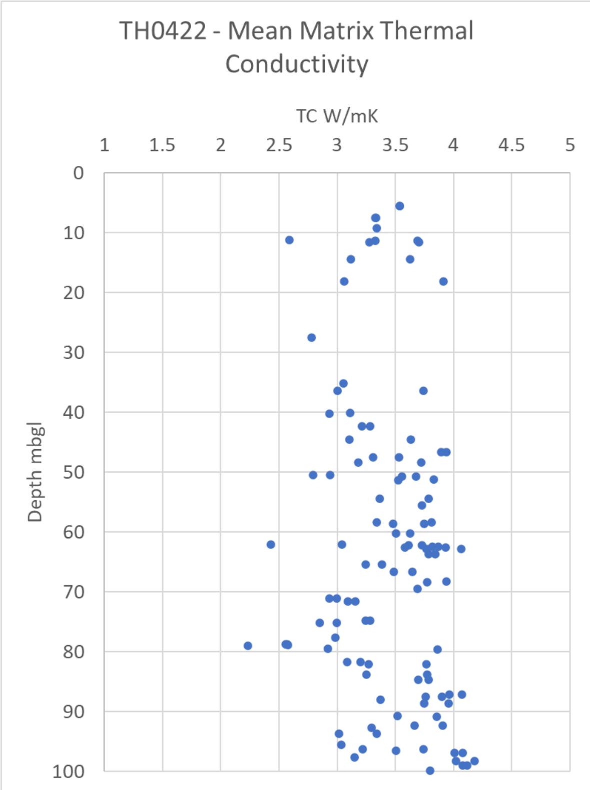

Figure 9: Plot showing bulk average thermal conductivity verses depth measured in lab on Sherwood Sandstone Group (Chester Formation) core plugs from well TH0422. BGS © UKRI.

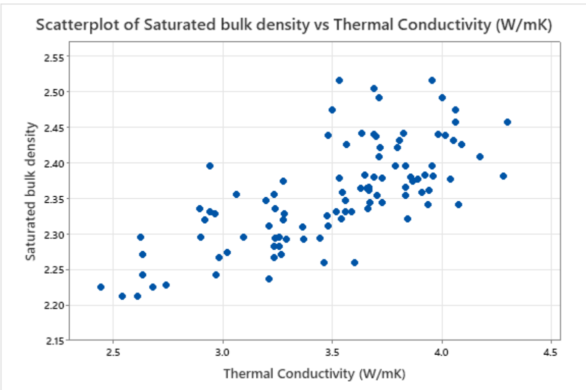

Figure 10: Plot showing relationship between horizontal thermal conductivity verses bulk density measured on core plugs from well TH0422. BGS © UKRI.

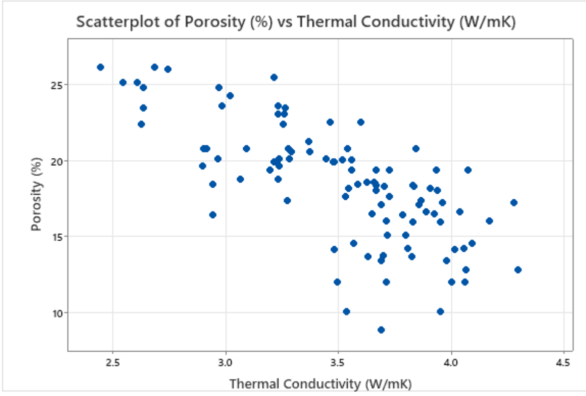

Figure 11: Plot showing relationship between horizontal thermal conductivity verses porosity on Sherwood Sandstone group (Chester Formation) core plugs from well TH0422. BGS © UKRI.

4. DISCUSSION

The results of the distributed TRT tests and core property studies show a that there is some relatively small but measurable variation in thermal conductivity with depth through the Chester Formation of the Sherwood Sandstone Group in the studied 100m thickness interval. The means of the core plugs are 3.44W/mK with variation of ±1W/mK. The core plugs don't allow effects of fractures to be measured and insitu methods including DTS and DTC cable deployments in TRT boreholes are promising but currently expensive techniques for evaluating thermal variations in aquifers and for optimising models that predict thermal plume behaviour. Conductive fractures may cause increased thermal interference between ATES wells and their presence should ideally be identified in any test wells using downhole geophysical well logging and imaging tools so that their impact on a scheme can be considered in the design and well completions. Advanced TRT are also a useful tool for characterising these features, as described herein.

It is noticed that measuring the fluid temperature inside the loops using fibre optical DTS provides closer approximation to the theoretical line source, and good for measurement of borehole thermal resistance, but inside loop placement of the FO cable is not as sensitive to variation in geological formation thermal-physio properties compared to the data from the tremie pipe position. This agrees with the conclusions of Wilke et al 2020. The TC values measured from core plugs shows considerable scatter (Figure 9), and this is not that surprising given the natural variation in porosity and density, and the lab methods are on a different scale and are prone to user errors, and instrumental and analytical errors. However, although the means are slightly higher than the bulk value from the conventional TRT analysis method the core measurments did provide a reasonable 'working' estimate of saturated matrix thermal conductivity. It's likely that the shallow groundwater has tiny gas/air bubbles and so the use of deaired water to saturate samples in the lab may even lead to slight increase the TC values compared to what would be found in nature. The upper 13m of the ground is above the water table and will be partially saturated (and not fully saturated, unlike the core plugs tested) so the saturation state of core samples in this zone and use of the data in that interval will lead to a slight overestimate of integrated bulk values. Further analysis to compare data from all wells is in progress.

The study highlighted the importance of accurate measurement and calculation of input thermal power because the line source equation is very sensitive to this parameter. In this case, the nominal input power of the TRT rig was 9kW provided by 3 x 3kW rated electrical heating elements. The heat flow and temperature meters on the well heads provide independent thermal energy flow data and these suggest the energy delivered to the well was closer to 8kW, and did reduce slightly over the test (Figure 5), probably due to heating up of components and glycol during the test, highlighting the importance of accurate measurement of inlet and outlet temperatures and flow rates, outdoor air temperature, and changes in specific heat capacity of the thermal transfer fluid (glycol/brine). The importance of keeping connector lines as short as possible and good thermal insulation added to the connector lines and exposed tops of loop pipes, especially in colder or variable weather conditions was also noted.

5. CONCLUSIONS

The Distributed Thermal Response Test method has been applied to better characterise and model the thermal properties and behaviour of an important UK sandstone aquifer to evaluate thermal storage behaviour for geothermal systems and UTES/ATES deployment.

Lab based measurements of thermal conductivity using 208 core plugs from a TRT test site returned very slightly higher values compared with to the conventional in-situ TRTs and distributed TRT using digital temperature cables. The values of around 3.4W/mK are higher than the ‘recommended’ value of 2.4W/mK for a sandstone provided in the VDI tables and UK MCS MIS GSHP design reference tables, and this study provides more locally reliable values for the Triassic Chester Formation which can optimise ground loop designs and ATES designs and modelling of heat flow in the region and wider Cheshire Basin. Lab-derived physical property relationships linking thermal conductivity, density and porosity are demonstrated and are potentially useful for predicting aquifer thermal properties based on geophysical well logs, core scanning data, porosity-permeability test data, and for teaching AI models.

The distributed TRTs highlighted zones of higher effective thermal conductivity in the fluvial conglomeratic beds, related to bedrock lithology (calcite cement and conductive quartz clasts), porosity, density, fractures and compaction bands. The extent of fractures in the 4 wells varies, highlighting that natural fracture networks are complex and will be hard to predict in ATES schemes where wells are separated by 10’s or 100’s of meters. From a bulk heat storage perspective these features can be anticipated in such terrains that have undergone burial, uplift and stress relief after glaciation and their importance for underground thermal storage will vary from site to site and even from well to well. Fractures and variations in lithology should ideally be identified in ATES test and production wells using careful downhole geophysical imaging surveys. If there are sites with a combination of closed loop and open loop systems, then collection of D-TRT in the closed loop wells could be useful to inform the aquifer properties in parts of the site that don’t have water wells and the option for downhole geophysics. Similarly, site with existing water wells can be readily studied using distributed temperature sensing techniques to improve optimise closed loop designs in association with regular TRT’s.

The position of the distributed temperature sensing cables in the grouted closed loop well affects fidelity of information that can be collected and there are pros and cons with different arrangements. More detailed information about the formation and vertical aquifer heat transfer variation was captured with the cables located on the tremie pipe. The sensor cables fixed on the outside of the loops also provided reasonable information on formation variability because the fluid is not mixing constantly or shielded by the thermally insulating plastic PE loop pipe in those locations, unlike in the loop pipe. The DTC cables on the outside of the loops provided evidence of thermal short circuiting through the grout during the TRT.

Future analysis will focus on COMSOL numerical modelling of the D-TRTs and further analysis of the DTS data, integration with geological and fracture data, with investigations into the effects of ambient groundwater flow on effective thermal conductivity variations in the wells.

REFERENCES

English K, L., English, J. M., Moscardini,R., Haughton, P. D. W., Raine, R.J., Cooper, M., (2024). Review of Triassic Sherwood Sandstone Group reservoirs of Ireland and Great Britain and their future role in geoenergy applications, Geoenergy, https://www.lyellcollection.org/doi/epub/10.1144/geoenergy2023-042

Lee, J.R., Hough, E. (2017) A Conceptual Geological Model for investigating shallow sub-surface geology, Cheshire Energy Research Field Site. Nottingham, UK, British Geological Survey, 27pp. (OR/17/042) (Unpublished)

Wilke, S., Menberg, K., Steger, H., Blum. P. (2020). Advanced thermal response tests: A review. *Renewable and Sustainable Energy Reviews.*

Volume 119, 109575,ISSN 1364-0321, https://doi.org/10.1016/j.rser.2019.109575.

Acknowledgements

BGS authors publish with the permission of the Executive Director, British Geological Survey.

We would like to thank staff at the BGS NGR core store who facilitated access to borehole materials used in this study. Jason Ngui (BGS) is thanked for programming the DTC data heat map plotting application. Dr Oliver Wakefield (BGS) is thanked for internal review.