ADROK CAN HELP ADVANCE GEOTHERMAL ENERGY

Timing is everything

The geothermal industry is currently experiencing a rapid increase in potential projects. This natural source of energy is a high priority due to its low carbon footprint per kilowatt. Nevertheless, exploration for geothermal targets needs to be met by equally low-carbon, low impact geophysical methods rather than testing via costly, high impact drilling. The industry is also poised to take full advantages of the cutting-edge technologies developed for the oil industry. The timing for geothermal energy exploration couldn't be better. Companies like Adrok are offering another solution to add to the arsenal of tools helping advance the industry and help contribute to an environmentally healthy future.

Adaptation in a changing environment

We don't need to re-invent the wheel, just modify it to suite the purpose. The oil exploration and production industry has been continuously developing technologies for imaging the subsurface for decades, however, with an emphasis on the transition to a low carbon energy sources we explore whether the geothermal industry be utilising cutting edge technologies being "freed up" due to the slowing of the oil exploration industry.

Geothermal exploration already utilises many technologies developed by the oil industry including seismic reflection method for imaging the subsurface geological structures (e.g.), deep drilling technology (e.g.) and down-hole instrumentation. These techniques are vital for assessing the prospectivity of an area or individual borehole for possible energy production. One of the most common measurements is down-hole temperature. Measuring the temperature within in boreholes can be extremely difficult and requires many corrections to account for interruptions such as the introduction of drilling fluids, the cross-contamination of fluids from different levels which may both increase or decrease measurements. Even after drilling is complete, it may be discovered that the temperatures are not be sufficient for any practical application.

A geothermal borehole* can be over 2 kilometers deep and may take months to complete. A plethora of permitting is required and a suitable drill site needs to be located and properly prepared to sustain a prolonged drilling campaign. All of the preparatory and drilling activities lead to expenditures that climbs into the millions of dollars which in turn significantly increases the financial, social and environmental risks associated with drilling. Accordingly, the risks are often so significant that companies, governments and communities may abandon the project thereby missing the possible environmental benefits of utilising geothermal as an energy source. This risk becomes increasingly significant in regional areas for example where geothermal energy may be most beneficial.

*Boreholes are used to either 1) explore for suitable thermal sites and 2) to access high temperature anomalies, i.e. production wells, which are used as sites for energy or heat production.

How are geothermal sites selected?

Regional geophysics, combined with surface measurements, shallow sub-surface measurements, satellite data and other methods are used to select sites. However, the current array of techniques is limited due primarily to primarily to the bi-polar nature of the data resolution. While surface measurements of heat flow can be carried out with sufficient area coverage, the remaining geophysical methods, for example, cover large areas, but the resolution remains very low, particularly if trying to select a small drill site. Techniques such as traditional geological and structural geology, magnetics, time-domain electromagnetics (TEM), gravity methods or magnetotellurics (MT) for example are just a few of the methods that can be used for geothermal exploration. However, magnetotellurics for example, like other resistivity-conductivity methods, relies on measuring the potential presence of water which is often more conductive than the surrounding resistive host rocks. This inferred relationship between enhanced conductivity, water and high temperatures is an indirect method of defining possible hydrothermal targets but the presence of conductive geological layers in the rock mass often triggers false anomalies. For a great overview of current technologies used for exploration the reader is directed to the article located at: https://geothermalcommunities.eu/assets/elearning/2.15.UNU-GTP-SC-10-0401.pdf

Many of the electrical (conductivity-resistivity) based methods cannot be used in built up areas, often where the geothermal energy might be best utilized therefore, there are significant limitations in where many of the existing techniques can be used. The geothermal exploration industry needs a method that can fulfill the void between regional low-resolution geothermal targeting and drilling.

Using pulsed EM technology to fill a current void in the exploration workflow

Low-energy, low-frequency pulsed EM is a relatively new technique currently being used and developed by the oil industry for monitoring the temperature of reservoirs from the surface and without the need for accessing either existing boreholes or by drilling new boreholes. The technology is based on the generation of a polarized, conditioned pulse of EM energy at frequencies of between 1-70MHz. The tool uses a tubular, directional transmitter and parallel receiver antenna to send pulses of EM energy into the ground and then record the time (two-way-travel time) and modified shape of the pulse morphology to measure features in the sub-surface. Being a radar-based technique, the EM pulse is sensitive to the dielectric permittivity and conductivity of materials that it interacts with. When a pulse is transmitted into the ground it is reflected, at least in part, by boundaries between materials with contrasting dielectrics. Water has a very high dielectric permittivity (Er = 80) whereas host rocks including sediments, granites, metamorphic rocks all have permittivity values of <15. This natural difference makes water an ideal target for the pulsed EM. A key to measuring relative temperature changes with depth is that a materials dielectric properties typically change with changing temperature. Accordingly, this characteristic can be utilized to help measure temperature changes with depth.

After many years collaborating with the oil industry and carrying out case studies targeting geothermal sites in New Zealand, Cornwall and Australia, Adrok have developed two ways of measuring the potential temperature of materials at depth. The first relies on the increase in measured dielectrics (relative increase in dielectrics) with depth and the second uses an correlation between one of the measured signals, E-Gamma, and temperature which has been adopted by Adrok as the primary indicator of thermal anomalies. Combined, however, the two techniques provide a good indication of temperature variations at depth. Two examples are provided below, on each of the two different techniques.

Like all geophysical techniques, the technology is constantly evolving, and the current progress and results present a very promising outcome for the geothermal exploration industry. Measuring thermal profiles from the surface and without the limitations of anthropogenic inputs will allow companies and countries to undertake local or even regional pre-drilling confirmation of temperature which in turn will remove some of the almost limitless risks associated with drilling.

How to derive temperature proxy from radiowaves:

- The energy density (ρ) of radiowaves through a layered medium should increase with the absolute temperature in accordance with ***Stefan Boltzmann's Law***:

$$\rho=\sigma T^4 \qquad \sigma = \text{Stefan-Boltzmann constant}$$

- The radiowave Spectral Energy Density Ed(S) is the product of the energy density and the wavelength (λ):

$$Ed(S)=\rho\lambda$$

- Consider the horizontal component α of vector Progressive Wave Direction (PWD) of the ADR beam, this is a function of spectral energy density, more specifically:

$$\alpha=(\rho\lambda\_x)/(Ed(S))$$

Then: $$(Ed(S)\alpha)/\lambda\_x=\rho$$

Therefore: $$\alpha=(\sigma\lambda\_x T^4)/(Ed(S))$$

And, rearranging, it can be seen that the ***temperature T*** can be calculated by:

$$T=\sqrt[4]{((Ed(S)\alpha)/(\sigma\lambda\_x))}$$

Where: α the horizontal component of vector PWD of the ADR beam.

Figure 1. Multiple methods are now used by Adrok to measure relative temperatures at depth beneath the surface. One method is derived from the Stefan-Boltzmans's Law as described above.

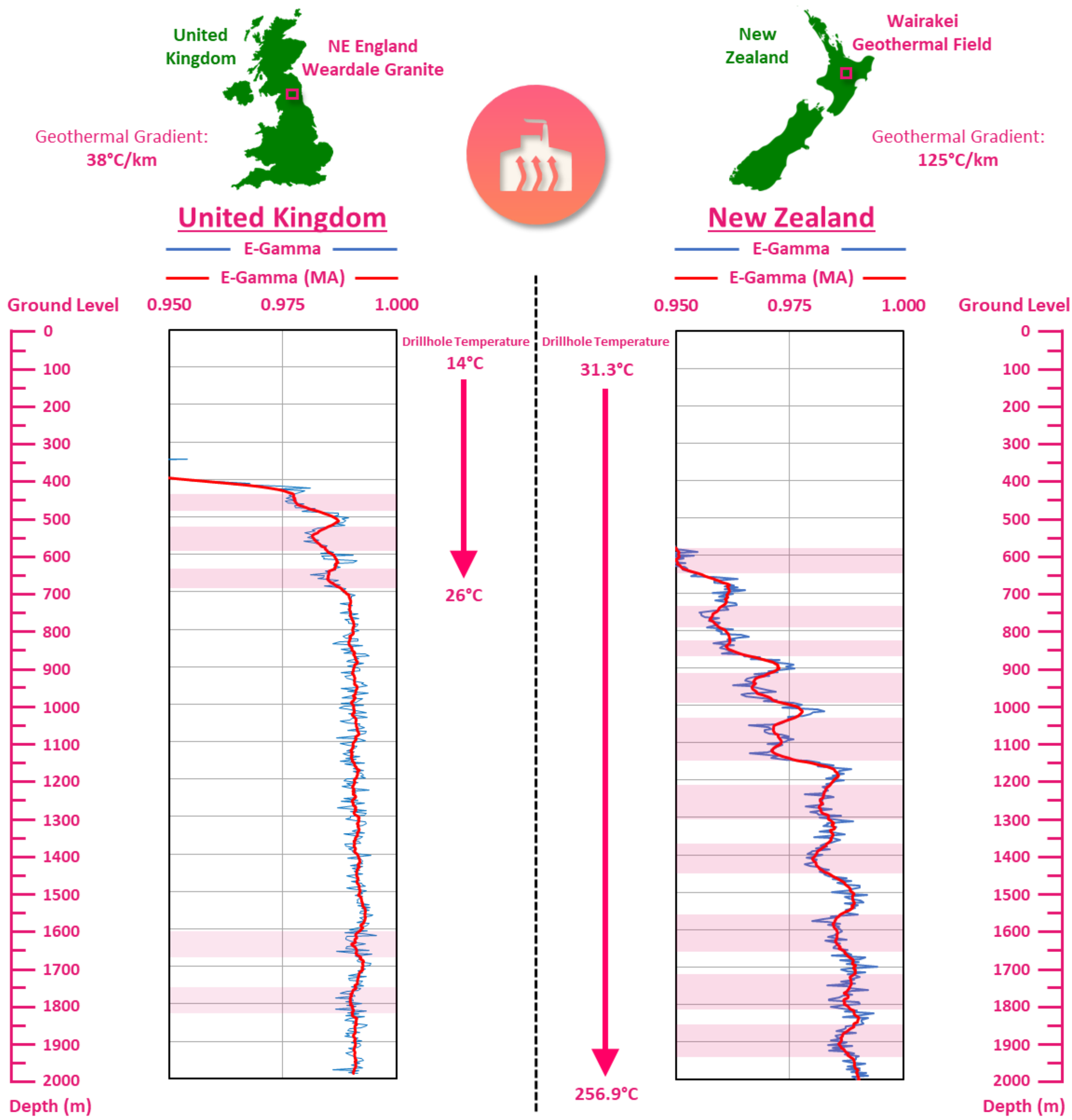
How deep can we look?

Different geophysical techniques can be used to explore different depths of the Earth's crust. TEM surveys at the resolution required for pinpointing drill targets can typically reach 500-1000m, MT can reach kilometers in depth, but the target resolution decreases as the depth increases. Furthermore, both techniques are not suitable for regions with any anthropogenic inputs and can require the setting up of extensive arrays of equipment at the surface which can be disruptive. Adrok's pulsed EM surveys reach over 1000m and have been tested by Greenrock (Perth, Australia) to depths of over 2500m as demonstrated in a case study carried out by Adrok to detect the Wagina siltstone and Kockatea and Caryngina sandstones.

Geothermal targeting and monitoring

The benefits of adopting technologies initially built for solving problems in the oil industry are a means by which the geothermal energy sector can explore with confidence. The ability of geophysics to provide another level of critical information, such as sub-surface thermal measurements, is likely to provide companies with the confidence to commit to drilling. Furthermore, techniques like the pulsed EM method can also be used as a monitor of temperature change from the areas near or surrounding a borehole or geothermal field. Specific sites in a geothermal field can be selected as repeat monitoring stations so that multiple reading per year for example can be used to build a temporal and spatial model of temperature change in a given area. This monitoring can be completed without the need for drilling additional boreholes.

Adrok are a company that's dedicated to ongoing fine tuning of the technique to meet the needs of the geothermal exploration industry. In its current format, the scanner is small, portable, can be used in almost any environment, quick to acquire data (approximately 2-hours per site) and the processing methodologies are already in place to undertake geothermal targeting projects.



Method 1: The differences in the ADR signal from UK to NZ reflects the different geothermal gradients of 38°C/km in NE England's Weardale Granite to 125°C/km in Taupo Volcanic Zone