GEOLOG considers the following points as key to make geothermal activity successful:

**Temperatures · Permeability · Fluids · Cost reduction**

**Scaling prevention and control**

### Temperatures

Evidence of high temperatures can be revealed by the presence of distinctive minerals which form at specific temperatures: the literature provides many examples, and tables are available which relate these minerals directly to formation temperatures. The primary issue with their application is identification, especially when their concentrations are very low. GEOLOG has created an advanced system for XRD data acquisition at well site based on proprietary workflows and, in collaboration with the University of Trento, developed an exclusive software package for XRD data processing. This software is the evolution of the well-known and widely adopted MAUD (Material Analysis by Using Diffraction) software, a Rietveld extended program able to perform combined XRD and XRF analysis which was developed by Trento University.

GEOLOG’s advanced XRD data acquisition system is founded on our extensive experience of collecting data at well site. Geolog has developed and tested its sample preparation techniques, incorporated the use of new, advanced instruments and, by referencing a large collection of international standards, has created the best available system calibration methodology. Furthermore, the capability to acquire low angle data dramatically improves the characterisation and quantification of clay minerals in the field without extensive and complex sample treatments.

Our new and improved proprietary software allows fast identification and quantification of a huge number of minerals, with the combination of XRD and XRF data allowing further optimisation of real time results.

Example of XRD identification of epidote

Example of clay mineral characterization in an untreated samples
Permeability in geothermal systems is often derived from the presence of fractures. GEOLOG has developed and proven an advanced workflow to detect, locate and evaluate the properties of fractures.

This methodology is based on high accuracy delta mud flow measurements, processed using proprietary software. GEOLOG has over time acquired a unique level of experience in the installation and management of mud flowmeters in all types of drilling environments and across multiple different mud types, assuring that the maximum levels of accuracy are consistently achieved. The methodology has been successfully applied in many different lithologies, integrating delta flow data with multiple gas and drilling parameters to provide greater insight into the downhole environment. In particular, integration of this data with the detection of noble gases can deliver further important information regarding downhole fractures. GEOLOG offers wide ranging experience in Helium and Radon detection in real time, in addition Hydrogen and methane can be detected, giving a full spectrum of gas occurrence within the geothermal system and contributing to the overall understanding.

Delta mud flow data (flow out – flow in) can be used not only to detect fractures while drilling, accurately locating them on depth, but can also give significant indications regarding fracture aperture. New software integrating the different parameters has been developed in collaboration with the department of Civil Engineering at Politecnico of Milan.
Use delta flow and drilling parameters to evaluate the presence of fractures

Technical Paper references for fracture detection and evaluation

Application of semi analytical model for drilling mud losses interpretation in fractured formations
6-7 December 2017 | SPE Workshop: Lost circulation: Natural and induced fractures | Dubai, UAE

Quantification of uncertainties of fracture permeability via mud loss information and stochastic inverse modelling
3-6 June 2019 | EAGE Annual Conference | London, England

Stochastic inverse modeling and global sensitivity analysis to assist interpretation of drilling mud losses in fractured formations
September 2019 | Stochastic Environmental Research and Risk Assessment, 33 (2)
The presence of active aquifers implies continuous interactions between fluid and rocks, highlighted not only by the presence of hydrothermal minerals but also by ion exchange processes, inducing anomalous ratios of specific elements in the cuttings. Metasomatic processes and ion exchange can alter the chemical composition of the rock and these can clearly be seen and evaluated by elemental analyses, revealing intervals where fluid flow is occurring or has occurred previously.

GEOLOG has gained abundant experience in the elemental characterization of cuttings and cores at well site using energy dispersive X ray spectrometers (XRF), performing quantitative analyses of major, minor and trace elements from Mg to U, from percentage levels down to ppm, all in real time. XRF data acquisition is calibrated using over 35 international certified standards, using a proprietary methodology. By coupling XRF with XRD data, an improved, more accurate interpretation is made possible, allowing the identification of zones where fluid circulations currently or previously occurred.

Example of major, minor and trace element log
Cost reduction

GEOLOG’s advanced field units serve as a fully equipped lab at well site, able to perform advanced analyses in real time and obtain samples for further, more sophisticated analyses. Expensive lithological wireline logs can be substituted by combined mineralogical and chemical analyses, able to directly identify and quantify specific mineral assemblages rather than providing estimations based on subjective modeling assumptions. GEOLOG’s gas systems allow the controlled extraction of gas from mud with the identification and quantification of multiple components including H₂, He, Rn, CH₄ and CO₂. Additionally, samples may be captured using GEOTube vials for further analyses in the laboratory.

The clear advantages of this approach include real time data, fresh and representative samples, flexible sampling intervals (fine tunable whilst drilling on the basis of varying events and results) and above all, substantial cost savings.

Scaling

GEOLOG’s advanced capabilities in XRD and XRF make a full, quick and accurate quantitative characterisation of possible scale, describing all the occurring phases and the relevant concentrations as well as amorphous material and its concentration. These combined mineralogical and chemical analyses allow a complete description of the sample which may be further extended through the use of thin sections (petrographic microscopy) and Scanning Electron Microscope (SEM) studies for layering and/or spot investigations.

The final deliverable can provide a full characterisation of scale samples or be utilised to monitor the precipitation of a specific phase.