Unlocking Potential of Deep and Supercritical Geothermal Energy Resources Using Machine Learning

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Abstract

Objectives:
Understanding subsurface geology is pivotal for safe exploration and high capacity exploitation of supercritical geothermal resources, particularly in active volcanic areas such as Iceland. IDDP-1 well in Krafla geothermal field was meant to reach a depth of 4-5 km to produce from supercritical conditions. However, an unforeseen magma body was encountered at 2.1 km, leading to cessation of drilling at that depth. Despite IDDP-1 being a high producer with an exceptionally high bottomhole temperature, the intended target depth was not reached. Additionally, cuttings from several depth intervals, specifically beyond 2000 m, were missing. This poses a restriction on understanding the nature of encountered formation, the rock-magma interface and producing a complete lithology log. Furthermore, the critical high temperature conditions impose limitations on the well logging tools that could be used, thereby restricting the amount of collected data.

Procedure:
Unsupervised machine learning algorithms play a crucial role in clustering large data sets into groups of similar characteristics. In the initial phase, the Gamma Ray, Resistivity, Neutron and Caliper row data of IDDP-1 were used to form clusters based on similar data features using Gaussian Mixture Model (GMM). Subsequently statistical data analysis was performed using python scripts. These clusters were then correlated and compared with clustered real time drilling data incorporating Weight on Bit (WOB), Rate of Penetration (ROP), Revolutions per Minute (RPM) and Torque. Finally, the results were validated by comparing them with the available lithology description.

Results and Conclusion:
Well log data and real time drilling data was effectively clustered into broad classes of igneous rock types, including mafic, intermediate and felsic. We also achieved a distinct differentiation between higher porosity and lower porosity mafic rocks. The statistical analysis and correlation with clustered real time drilling data proved instrumental in attributing intervals with missing cuttings to these generalized rock type classifications, thereby enhancing the prediction of the lithological nature of these intervals. This process enabled the regeneration of composite logs, allowing the division of the entire borehole stratigraphy into intervals with similar properties.

Moreover, the algorithm is believed to have accurately identified the transition zone from rock to magma, as this specific interval has been clustered independently. The results obtained will provide valuable support for the next drilling stage by offering insight into the depth and nature of encountered rock types, lithological boundaries, and the rock magma interface. This will be possible to achieve without the need to wait for the cuttings to emerge from the well to the surface, utilizing real time logging and drilling data.