Informing deep geothermal reservoir rock mass properties from drilling data - experience from IDDP-1

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Abstract

During geothermal drilling it is important to know the quality of the rock mass for well completion, mud weight selection, interpreting features of interest, to characterise the subsurface in the absence of core. In deep geothermal drilling, tens to hundreds of meters are drilled without cutting retrieval and, therefore, without insight into the rock mass. Wireline logs are commonly used to interpret the subsurface, however, these data are typically collected after drilling an interval, and do not necessarily provide rock mass information. Despite their increasing development, studies using drilling parameters and logging-while-drilling to interpret the rock mass in high-temperature, deep geothermal environments remain rare. Here we present a method where the drilling parameters from drilling of IDDP-1 are used to assess the quality of the rock mass, with particular focus on its effect on drillability. We use the drilling reports and drilling data to develop and test this method based on recent work into relating drilling (Wyering et al. 2017) and tunnelling boring machine parameters to the rock mass (Gong et al. 2007; Frenzel et al. 2012; Villeneuve 2017) to demonstrate how methods from geotechnical drilling and tunnelling can inform geothermal drilling.

First, we normalize and process the drilling parameters. Penetration rate (PR) and torque (T) are normalized by RPM, whereas weight on bit (WOB) is normalized by drill bit diameter, allowing comparison of values over different intervals of drilling. The drilling parameters are then processed to produce the penetration index (PI), which is the ratio of normalized PR to normalized WOB, and the net advance rate (NAR) which is the drilling speed averaged over 1 m length, including times when PR is 0, but RPM is > 0. Based on previous work regarding interaction of tunnel boring machines with rock masses, we provide interpretations of the rock masses encountered by the drill bit. Key variations in both normalised (PRs, WOBs, Ts) and processed (PI, NAR) drilling parameters are used to interpret the drillability in different rock masses (e.g. poor drillability, blocky ground).

Major variations highlighted on large-scale drilling logs vs depth are combined with the interpretations from drill cuttings to determine the impact of lithology changes on drillability, as well as other indicators of down-hole conditions, such as circulation loss and feed zones, interpreted from flow rate changes. Of particular interest is the link between areas over which the drilling analysis indicates “blocky ground” with circulation loss and feed zones. We show that the PI and NAR combination, along with torque, can provide insight into the locations of fractured rock masses, as confirmation for feed zones that also show increased loss of circulation. Ongoing work is aimed at validating this method with geological characteristics obtained from cuttings, wireline logs and geological models. The development of logging-while-drilling technologies for high-temperature wells also presents the possibility to combine drilling and wireline log data processing for real-time interpretation during drilling.

References

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