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Combining conventional and thermal drilling in order to increase speed and reduce costs of drilling operations to access deep geothermal resources

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The exploitation of deep geothermal resources for energy production relies on finding cost effective solutions to increase the drilling performance in hard rocks. Conventional rotary drilling techniques, based on mechanical rock exportation, result in high rates of drilling tool wearing, causing significant costs. Additionally, rotary drilling results in low drilling speeds in the typically hard crystalline basement rocks targeted for enhanced geothermal energy utilization technologies. Furthermore, even lower overall drilling rates result, when considering tripping times required to exchange worn drill tools. Therefore, alternative drilling techniques, such as hammering, thermal drilling, plasma drilling, and jetting processes are widely investigated in order to provide cost-effective alternatives to conventional drilling methods.

A promising approach, that combines conventional rotary and thermal drilling techniques, is investigated in the present work. Here, the rock material is thermally weakened before being exported by conventional cutters. Heat is locally provided by a flame, which moves over the rock surface, heat-treating the material. Besides reducing the rock strength, an in-depth smoothening effect of the mechanical rock properties is observed due to the thermal treatment. This results in reduced rates of drill bit wearing and higher rates of penetration, which in turn decreases drilling costs significantly, particularly for deep-drilling projects.

Due to the high heating rates, rock-hardening, commonly observed at moderate temperatures, can be avoided. The flame action can be modelled as a localized, high heat transfer coefficient flame treatment, which results in orders of magnitude higher heating rates than conventional oven treatments. Therefore, we analyse rock strength variations after different maximum temperatures, flame-based heating rates, and rock confinement pressures. The results show that flame treatments lead to a monotonous decrease of rock strength with temperature. This is different from oven treatments, where an initial increase of strength is typically observed, followed by a steep decrease upon further (slow) oven-heating. Thus, the weakening of sandstone and granite samples due to flame treatments indicates the feasibility of a combined mechanical-thermal drilling system. These results suggest that the new combined method enables improved rates of penetration in hard rocks while reducing the rate of drill tool wear.

We also present possible implementations of this combined drilling system in the field. From field test results, advantages and limitations of the proposed new technology are presented, with an emphasis on accessing geothermal energy resources in crystalline basement rocks.