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Plasma Pulse Geo-Drilling as a Low-cost Drilling Technology for Deep-geothermal Energy Utilization: Status and Challenges

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Geothermal energy can be a limitless and CO2-free energy resource. However, moderate geothermal temperature gradients of □30 ^{o}C/km in most regions typically require employing so-called "Advanced" or "Enhanced" geothermal systems, called AGS and EGS, respectively, which require reservoirs with temperatures >150 ^{o}C. To access such high temperatures, we need to drill deeper than 5 km, i.e., in hard rock. The costs of drilling to such depths, using traditional rotary drilling, increase exponentially with depth and can be up to 80% of the total geothermal project investment. These high drilling costs can be reduced significantly with contactless drilling technologies (e.g., thermal spallation drilling, laser drilling, microwave drilling, and Plasma Pulse Geo-Drilling), as they avoid the lengthy tripping times associated with drill-bit damage.

PPGD uses high-voltage pulses of a few microseconds duration to fracture the rock, thereby drilling without any mechanical abrasion. Future PPGD costs may be as low as 10% of mechanical rotary drilling costs (**Schiegg et al., 2015**). Our PPGD research addresses two outstanding questions: (1) Understand the fundamental physics of the electric breakdown inside the rock and associated rock fracturing processes, which we investigate numerically (**Ezzat et al., 2022, 2021; Vogler et al., 2020; Walsh and Vogler, 2020**). (2) Evaluate the PPGD performance under deep-wellbore conditions of ~5 km (i.e., high pore and lithostatic pressures, and high temperatures). Our ongoing numerical and experimental studies are expected to provide further insights into the applicability of PPGD for geothermal energy utilization.

First, we numerically model the formation of a plasma in rock pores, which constitutes the onset of rock failure during the PPGD process. These numerical models show the significant effect of the pore characteristics on the PPGD process and give insight into how future PPGD operations should be designed. Second, we conduct PPGD physical experiments, where we employ lithostatic pressures of up to 1500 bar, pore pressures of up to 500 bar, temperatures of up to 80 ^{o}C, and voltages of up to 300 kV. Concluding these experiments with the associated challenges shall demonstrate whether PPGD is efficient at great depths of up to 5 km. Combining our numerical and experimental results allows optimizing future PPGD operations.

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