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Understanding the Eruption Dynamics of CO_2-driven Cold-Water Geyser: Implications on CO_2 Sequestration Processes

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Several cold-water geysers and springs are located adjacent to the Green River in Utah where two major east-west faults, the Little Grand Wash and the Salt Wash Graben faults, trend roughly parallel to each other. Among these springs and geysers is Crystal Geyser, located immediately north of the Little Grand Wash fault and approximately 6 km south of the town of Green River. Anomalously high soil-CO_2 fluxes (>700 g/m2day) have been measured along traverses perpendicular to these two fault zones. In this study, the fluid mechanics of the regularly erupting Crystal Geyser was investigated by instrumenting its conduit with pressure, temperature, pH, EC, and dissolved oxygen sensors, measuring every 1 minute during and between eruptions. Results of these measurements suggest that the time-scale of a single-eruption cycle ranges from 30 to 40 hours and is composed of four successive eruption types with two recharge periods. Current eruption patterns exhibit a bimodal distribution although previous measurements and anecdotal evidence suggests that this pattern was different prior to recent seismic activity. The geyser's eruptions are regular and predictable, and reflect pressure, temperature, EC, pH, and dissolved oxygen changes resulting from Joule-Thomson cooling, endothermic CO_2 exsolution, and exothermic CO_2 dissolution. An additional interesting fact is that the eruption pattern (uni- or bi-modal) and eruption duration of the Crystal Geyser have evolved since the geyser was drilled in 1936. All historical observation before 2004 indicated that the eruption duration was less than 20 minutes. However, in 2005, the duration reached more than 2 hours. Furthermore, our dataset collected in 2010 showed that the geyser eruption has a bimodal pattern but its duration is significantly longer (B-type: 1 hour and D-type: 5 to 7 hours). The seismic events presumably have initiated movement of the Little Grand Wash fault system and disturbed the eruption patterns of the Crystal Geyser. With processes understood from the natural analog study, we investigated the thermal and multiphase CO_2 transport processes with numerical simulation models that include processes of injectivity reduction and potential non-isothermal effects of commercial-scale CO_2 injection. Processes of interest include the spatial CO_2 profile adjacent to the wellbore, injectivity reduction and the potential non-isothermal processes including Joule-Thomson (heating and cooling) effects, exothermic CO_2 dissolution, and heat changes associated with concomitant water vaporization.