在丹麥地熱水儲層中注入加熱的地層水後的地球化學反應

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摘要

克服可再生能源和供給不匹配的其中一種可能的解決方案是在低焓地熱儲層中儲存夏天生產過多的能量。本研究通過注入加熱的地層水後，儲層溫度升高引起的儲層化學溶解和沉澱過程評估了可能對儲層造成破壞的風險。通過 core flooding experiment、岩相分析和地球化學建模相結合，對儲層性能進行評估。丹麥日德蘭半島北部上三疊紀−下侏羅紀 Gassum 地層 (Upper Triassic−Lower Jurassic Gassum Formation in the northern part of Jutland, Denmark),是丹麥最重要的潛在地熱儲層之一，該岩芯樣本在與儲層於地底下時相同環境的條件下進行了岩芯注水實驗，溫度最高達 120°C。在實驗過程中，監測了地層水反應後水中的化學變化。對岩芯樣本進行岩相分析，並在實驗前後將其作為輸入數據，進行了模擬岩芯注水實驗條件的地球化學模型。結果顯示，溫度升高促使了微斜長石的鈉長石化，石英、白雲石/鐵白雲石以及重晶石的溶解，並促進了高嶺土和方解石的沉澱。結果表明，即使是在碳酸鈣較少的儲層中，因為溫度升高可能導致碳酸鈣沉積而引起注入性降低的風險，這一點在任何熱能儲存項目中都應予以考慮。

關鍵字： 高溫含水層熱能儲存、深層含水層熱能儲存、反應性運輸模型、岩芯注水實驗、溶解/沉澱過程。

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Article

Geochemical Reactions upon Injection of Heated Formation Water in a Danish Geothermal Reservoir

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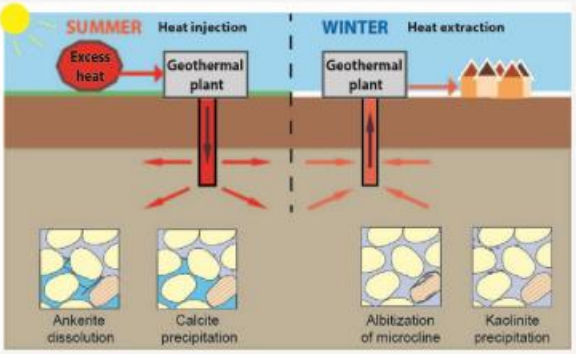
ABSTRACT: One possible solution to overcome the mismatch between the supply and use of available renewable energy resources is to store excess heat in low-enthalpy geothermal reservoirs. In this study, we evaluate the possible risk of damaging the reservoir through chemical dissolution and precipitation processes in the reservoir induced by the increased reservoir temperature upon injection of heated formation water. Evaluation of the reservoir performance is done by a combination of core flooding experiments, petrographic analysis, and geochemical modeling. A sample from the Upper Triassic−Lower Jurassic Gassum Formation in the northern part of Jutland, Denmark, representing one of the most important potential geothermal reservoirs in Denmark, is used in a core flooding experiment at reservoir conditions and elevated temperatures up to 120 °C. During the experiment, chemical changes in the effluent were monitored. Petrographic analysis of the core sample prior to and after the experiment is used as input in a geochemical model simulating the conditions of the core flooding experiment. The results show that the increased temperature induces the albitization of microcline; dissolution of quartz, ferroan dolomite/ankerite, and barite; and precipitation of kaolinite and calcite. The results indicate that the risk of reduced injectivity due to calcium carbonate scaling at elevated temperatures should be considered as part of any thermal energy storage project even in a calcium carbonate poor reservoir.



KEYWORDS: *high-temperature aquifer thermal energy storage, deep aquifer thermal energy storage, reactive transport modeling, flooding experiments, dissolution/precipitation processes*