Numerical Simulation of Injectivity Effects of Mineral Scaling and Clay Swelling in a Fractured Geothermal Reservoir

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RESEARCH OBJECTIVES

A major concern in the development of hot dry rock (HDR) and hot fractured rock (HFR) reservoirs is achieving and maintaining adequate injectivity, while avoiding the development of preferential short-circuiting flow paths. Rock-fluid interactions and associated mineral dissolution and precipitation effects could have a major impact on the long-term performance of these reservoirs.

APPROACH

We used recent European studies as a starting point to explore the chemically induced effects of fluid circulation in geothermal systems. We performed coupled thermal-hydrologic-chemical simulations in which the fractured medium was represented by a one-dimensional MINC model (multiple interacting continua). The non-isothermal multiphase reactive geochemical transport code TOUGHREACT was used for these simulations.

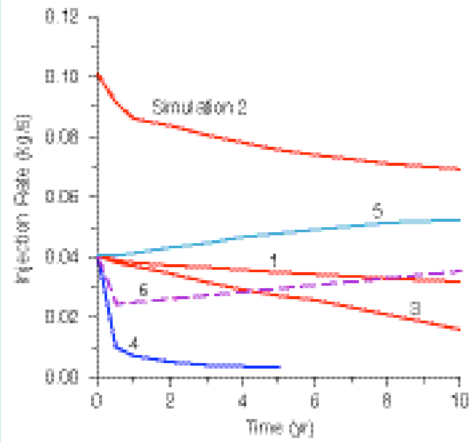

Figure 1. Injection rate of the fracture-matrix column with an area of 1 m^2. Simulation 1—base case; 2—over-pressure; 3—Verma-Pruess; 4—swelling; 5—pH 7; 6—mixing.

ACCOMPLISHMENTS

Injecting produced geothermal brines directly back into the reservoir results in mineral scaling. The reinjected, highly concentrated water from the geothermal reservoir can maintain clay density without swelling, but this limits the availability of water for injection. Mixing the produced geothermal water with large amounts of fresh water (1:4) can cause serious clay swelling when it is reinjected. However, modifying the injection water could avoid mineral scaling and enhance injectivity. Mitigating injection water chemistry could be an efficient way to achieve this objective. In this work, we added alkali to maintain a higher pH and let minerals (mainly calcite and quartz) precipitate out prior to reinjection. Using this modified injection water results in the injection rate gradually increasing, because of continual calcite and quartz dissolution. By mixing the reservoir water with appropriate amounts of fresh water (1:1), together with adding alkali to let minerals precipitate out, we can reduce clay swelling and maintain injectivity. The well configuration and data for mineralogical composition in this study were taken from the European HDR research site, but the results and conclusions should be useful for other HFR reservoirs, because calcite and quartz are commonly present in geothermal systems.

SIGNIFICANCE OF FINDINGS

A detailed, quantitative understanding of processes and mechanisms, as presented in this research, is needed to develop reservoir management tools based on geochemistry. Such a novel approach should result in improvements in reservoir performance.

RELATED PUBLICATIONS

Xu, T, G. Zhang, and K. Pruess, Use of TOUGHREACT to simulate effects of fluid chemistry on injectivity in fractured geothermal reservoirs with high ionic strength fluids. In: Proceedings of the 30th Workshop on Geothermal Reservoir Engineering, Stanford University, California, January 31–February 2, 2005. Berkeley Lab Report LBNL-56532.

Xu, T, and K. Pruess, Numerical simulation of injectivity effects of mineral scaling and clay swelling in a fractured geothermal reservoir. Proceedings of Geothermal Resources Council 2004 Annual Meeting, Palm Springs, California, August 29–September 1, 2004. Berkeley Lab Report LBNL-55113.

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