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Prediction of mass transport in complex fractured reservoirs based on tracer testing

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The life of a geothermal resource may be prolonged by a reinjection process, which can avoid pressure decline and prevent run out of water in a geothermal reservoir. Injection wells should be designed to reduce the cooling of the reservoir by injected water and sustainably utilize the geothermal system. Tracer testing is a standard method for tracing mass transport within a geothermal reservoir and can be a valuable tool in the design and management of production and injection operations. It may be advantageous if we can determine the reinjection conditions such as well location and injection flow rate, based on field tracer data obtained from a pair of exploratory wells. In this study, as a first step toward the development of design of reinjection, we attempt to predict the mass transport between an arbitrary set of wells, based on a tracer test result taken for a certain interval of wells. We employ the fractional advection-dispersion equation (fADE) to characterize the mass transport in fractured and porous media. The aim of this study is to evaluate the applicability of the fADE model in the prediction of mass transport in fractured geothermal reservoirs.

A 3D simulation code for flow analysis (FRACSIM-3D) is utilized to produce numerical data of tracer responses. FRACSIM-3D is based on a fractal fracture network model, and a number of disk-shaped fractures are generated assuming the fractal correlation based on the power-law relationship between the fracture length and the number of fractures. It has been shown that the FRACSIM-3D reproduced highly anomalous behavior of mass transport, which is often observed in field or laboratory tests. Moreover, the anomalous tracer responses produced by FRACSIM-3D was attributable to the fractal nature of fracture networks assumed in the model.

The fADE mathematical model was applied to fit the numerical tracer results simulated by FRACSIM-3D. For comparison, the advection-dispersion equation (ADE) was also used to characterize the tracer responses in addition to the fade. The curve fitting enables us to determine automatically the constitutive parameters in both the mathematical models by using an optimization method. The tracer data obtained for a well interval of 50m were used to determine the constitutive parameters. The determined constitutive parameters were then used in the fADE and ADE models to predict the tracer responses in the case where the well spacing was extended to 80m and the tracer responses predicted by the mathematical models were compared with those calculated using FRACSIM-3D for the well interval of 80m. It was demonstrated that the tracer responses predicted by the fADE model was in reasonable agreement with the numerically obtained data by FRACSIM-3D, while the ADE model produced tracer curves which deviate significantly from the FRACSIM-3D results particularly for long-term behaviors. The present study, which based on the comparison of the mathematical and numerical models, shows that the fADE model provides a useful tool for characterizing the anomalous mass transport behavior in complex fractured reservoirs and possesses a potential to predict the mass transport based on local field data such as tracer response curves.