Geophysical Research Abstracts
Vol. 17, EGU2015-12382, 2015
EGU General Assembly 2015

Numerical simulation of a geothermal reservoir in Tuscany (Italy) with application of "Optimal Experimental Design" for finding optimal slimhole sites

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We study an area of high heat flow, adjacent to the Larderello–Travale and Mt. Amiata geothermal fields in southern Tuscany (Italy) in respect to conductive and advective heat transport in various rock units. We construct a geological three dimensional gridded model, assigned rock properties deduced from logging data in nearby boreholes and rock sample petrophysical lab measurements, and applied numerical simulation technique to resolve the subsurface temperature field and rock units of high fluid flow. We calibrate the model with available temperature depth data from a few shallow and two deep boreholes. We found two rock units (i.e. two depth regions) with permeabilities on the order of $10^{-1}4$ m2 and considerable fluid flow. In the upper regions fluid flow is mainly driven by topography related pressure gradients while in the deeper layer convective heat transport prevails caused by a deep heat source due to a young granitic intrusion.

In a second step we study the problem of finding optimal sites for a slim hole to measure a temperature depth profile for determining the (effective) permeability of a certain rock unit which is not intersected by the slimhole. This question is tackled by methods from optimal experimental design (OED) applied to the numerical simulation model. OED demands the calculation of the Fisher Matrix depending on the slimhole location and the expected permeability of the rock unit in question. An optimization criterion allows finding the optimal locations for a slimhole to minimize the error in determining the permeability of the rock unit. For our study reservoir optimal slimhole locations coincide with regions of high flow rates and large deviations from the mean temperature of the reservoir layer in question.