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The sensitivity of production temperatures and thermal recharge of low-enthalpy geothermal reservoirs to the thermal conductivity of the confining beds

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The exploration and exploitation of low-enthalpy geothermal energy has increased globally within recent decades in the pursuit of sustainable, low carbon emission energy sources. In 2009 funding was dedicated to a national multi-disciplinary research project with the aim of quantifying the thermal properties and temperature distributions of geothermal reservoirs in Denmark and to develop models for utilisation.

The Danish subsurface encompasses low-enthalpy geothermal reservoirs of Triassic, Jurassic, and Cretaceous age with formation temperatures between 40˚C and 80˚C. In previous literature it is shown that the ratio between the circulation rate in doublet well configurations and the vertical thermal conductivity of confining rocks significantly influences the temporal development in production temperatures in low-enthalpy geothermal reservoirs.

We analyse the thermal interplay between a reservoir which is utilised by an injection- and production well, and its confining beds in four conceptual reservoir systems, inspired by the low-enthalpy reservoirs found in Denmark. The analysis is based on state-of-the-art high resolution finite element modelling. Three of the four conceptual reservoirs represent different geological settings in which the confining beds of the reservoir have different thermal conductivities. In the first case, no heat is conducted across the boundaries of the reservoir, which serves merely as a reference. In the three remaining cases, the matrix thermal conductivity of the confining beds is set equal to 1.5, 3 and 4.5 W/m/K. In one additional case study, the anisotropy of the thermal conductivity of the confining beds is increased from 1 (isotropic) to 1.7 (horizontal conductivity is set equal to 1.5 W/m/K). For the considered reservoirs, we calculate the ratio between the accumulated energy that can be attributed conductive heat flow from the confining beds to the reservoir and the accumulated extracted energy from the pumping well.

Given realistic thermal conductivities of the confining beds, the thermal recharge by conductive warming, relative to total extracted energy, varies by up to 20%. The ratio between heat conduction to the reservoir and total extracted heat is 13% higher when tripling the thermal conductivity of the confining beds and the decline in production temperature is reduced by 26% after 500 years. Moreover, the decline in production temperatures roughly doubles when disregarding the conductive warming of the reservoir by the surroundings (i.e. assuming no-flow boundaries). The results demonstrate the important role of heat conduction from the confining rocks to the reservoir, in the lifetime of low-enthalpy geothermal reservoirs.