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Numerical Study of Fluid Loss into a Thief Zone overlying a Geothermal Reservoir

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Injection of cold water into geothermal reservoirs is one of the key processes that determines the success of projects. One of the potential risks is fluid loss into a thief zone during injection. A thief zone is recognized in this paper as a high-permeability layer overlying the main reservoir, separated by a thin sealing layer. Injected fluids can leak into thief zone through the fracture in sealing layer. However, one hypothesis is that pressurization up of the thief zone can prevent further fluid loss. To verify this hypothesis, hydraulic simulation of a geothermal reservoir in the Netherlands with typical geological configuration is performed. The model consists of a 150-m-thick main reservoir, with an overlying 15-m-thick sealing layer. Above the sealing layer is a 15-m-thick thief zone. A pre-existing fracture is assumed to exist in the sealing layer at a close distance to injector. Two different boundary conditions for thief zone, i.e. no flow and fixed pressure that represent boundary sealed by faults and boundary connected with aquifer respectively, are discussed. On the basis of these two boundary conditions, several factors that influence the fluid loss process are studied.

For the thief zone with no-flow boundary, our key conclusions illustrate that once the pressure front reaches an opening in the sealing, fluid loss occurs. However, fluid loss is substantially limited (leakage rate lower than 0.02 m3/h) within one year of operation. The time at which leakage is limited, is controlled by the permeability shock between the thief zone and reservoir, transmissivity of fracture in sealing layer and injection pressure. In addition, only the injection pressure has a significant influence on the total amount of lost fluid, while the permeability shock and fracture conductivity do not influence it. However, more permeable thief zone and more conductive fracture could be helpful to quickly prevent the fluid loss, since the pressurisation up process can be achieved more quickly, and thus prevent the leakage in the early stage, ensuring a stable injection rate in the long term . In contrast, for the thief zone with fixed-pressure boundary, fluid loss does not stop. Instead, it keeps a constant leakage rate, indicating a continuous fluid loss. However, the increase in fluid pressure remains more limited. In this case, a more permeable thief zone, more conductive opening and higher injection pressure increase the leakage rate, yet reduce the elevated pressure.

In conclusion, leakage can be prevented as a result of pressurization up of thief zones sealed by faults, and the only thing to consider in the planning stage is how fast it can be. While for thief zones linked with aquifers, injection plan should be made carefully to avoid induce or promote any fractures in sealing layer, or continuous leakage would occur.