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Natural Convection in a Single Fracture or Permeable Fault

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ABSTRACT

Fractures and faults play a key role in the transport of fluid and heat in geothermal systems. Beyond facilitating large flow rates, these features may also significantly alter the temperature distribution in a reservoir and act as an additional heat source via convection of hot water. Natural, buoyancy driven convection has been shown to occur spontaneously in fractures and permeable faults, bringing hot fluid closer to the surface and significantly increasing the heat flux through the system. By bringing additional heat towards the surface, the depth at which a target temperature is found is greatly reduced, saving time and costs, increasing the likelihood of an economically successful project. This behavior makes reservoirs with strong natural convection a potential target for geothermal exploitation. We investigate the thermal and hydraulic effects of a single, convecting fracture or permeable fault in a sedimentary basin. Our research demonstrates that natural convection in fractures and faults, even when hydraulically disconnected from a reservoir, has strong thermal effects that may indicate the presence of these geologic features. We look at fluid flow patterns around a convecting fracture in a variety of host rocks: impermeable, permeable, and layered media. Additionally, we look at the interaction between fracture/fault convection and natural Rayleigh convection in the permeable host rock itself. A 3D model is presented using a mixed Finite Element and Finite Volume, operator-splitting method within the Complex Systems Modeling Platform, CSMP++. The fracture is modeled as a discrete, lower-dimensional surface and heterogeneous fracture properties are modeled. Realistic water properties are used, calculated as a function of temperature and pressure. By understanding the behavior of in situ faults and fractures, future geothermal projects will be better equipped to find, target, and produce from these reservoirs.