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Determining majors fluid-flow zones in a geothermal sandstone reservoir from thermal conductivity and temperature logs

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A method, based on thermal gradient analysis, is presented for locating hot fluid flow in a rock formation. The method involves determining the thermal gradient from thermal conductivity measurements on core samples and also from borehole temperature logs run in the same borehole. With a heat flow density calculation and thermal conductivity measurements, one can apply Fourier's law to calculate the thermal gradient in a rock system where the heat transfer is assumed to be controlled only by conduction. The thermal gradient calculated from a measured temperature log profile takes into account both the conductive and the convective or advective part due to fluid circulation. On the one hand, if the thermal gradient deduced from temperature logs indicates similar values to the thermal gradient calculated with Fourier's law, the heat transfer is assumed to be controlled solely by conduction in the rock formation and thus involves no relative hot or cold fluid circulation. If, on the other hand, the thermal gradient deduced from the temperature logs indicates higher or lower values than that calculated with Fourier's law, then respectively hot or cold fluid flow could be suspected.

We applied this method to borehole EPS1 (Soultz-sous-Forêts, Upper Rhine Graben) for which temperature logs and core samples from the Buntsandstein are available. Variations between the two determined thermal gradient curves revealed three main hot fluid flow levels alternating with non-flow zones in the sandstone formation. The pattern was then compared against the fracture distribution, and also against sedimentological analyses determined from the borehole cores, in order to determine the driving components of the fluid flows. The flow zones in the Buntsandstein are controlled on the one hand by a macroscopic network with two major fault zones providing a flow path for the deep heat source and on the other hand by a matrix network formed during sedimentary or diagenetic processes within the Playa-lake and Fluvio-aeolian marginal erg facies. At another level in the Buntsandstein sequence, the sedimentary braided river formations may have high matrix permeability, but would not support a macroscopic fluid flow; this is due to their macroscopic sedimentary structure of thick oblique clayey layers that drastically reduce the level's connectivity and thus its permeability.

The proposed method can be used to identify the major fluid-flow levels or structures. Comparing the macroscopic and microscopic data is helpful in determining the relative contribution of the two networks on fluid flow at formation scale.