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Thermal plume in porous media as revealed by streaming potential

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Fluid flow through porous media is a fundamental process to control fluid flow through the crust and the mantle. It has been extensively investigated for long time both in experimental and theoretical approaches but because of experimental limitations fluid dynamical approach has not been conducted enough in laboratory experiments. The main limitation comes from non-transparency of experimental cell, which is composed of solid framework and fluid in the pore space. Non-transparency of solid medium as well as density mismatch make optical investigation through the working cell difficult. Recently nondestructive tomographic methods such as NMR imaging are applied to derive flow filed but it requires large experimental facility and lots of cost. In this presentation we report a trial in combining streaming potential and temperatures to estimate flow field in porous media.

Streaming potential,sometimes called as flow potential occurs when fluid flows through porous/granular material which has ion exchanges with flowing fluid. In the experimental cell of the size of 8x8x20 cm glass beads of homogeneous grain size (0.35 to 4 mm in diameter) are packed and NaCl aqueous solution is used as a working fluid. At the base of the cell we put a small heater(5x3x1 mm) as a localized heat source. Pt electrodes are inserted at several vertical positions above the heater along the center line to measure the induced potential by heating. Temperatures are measured by thermocouples along horizontal line 1cm above the heater and along the vertical centerline.

We measured temporal variations of potential and temperature upon heating with constant power supply to the heater. Systematic variations in the potential were obtained:after small decrease at the initiation large positive increase was observed(the potential signal is measured from the lowest electrode closed to the heater). The amplitude of the initial decrease seems not to depend on the applied power while the succeeding large increase is linearly proportional to the power.

We made numerical simulations to compare both potential and temperature in the corresponding geometry and similar situations as the experiment. We obtained similar behavior which can be interpreted as thermal plume rising above the heater in porous media. Different from laminar thermal plume formulated by Batchelor rising velocity of plume seems to depend linearly on the applied power. This confirms average field formulation of Darcy flow is effective in this permeability range.

Keywords: thermal plume, permeable flow, porous media, streaming potential