Lattice Boltzmann Modeling of Streaming Potential : influence of the fluid-rock interface on the electrolyte conductivity

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ABSTRACT

The lattice Boltzmann method (LBM) is a computational fluid dynamics technique that allows to simulate advection and diffusion phenomena. We focus here on the streaming potential phenomenon by reproducing the mass transport of an electrolyte in a channel, and the electric field generated by the charges displacements. Streaming potentials are characterized by the ratio of the macroscopic potential difference arising from the flow on the pressure difference that generated the flow. This ratio is known under the name of electrokinetic (EK) coefficient, and is supposed to be inversely proportional to the conductivity of the electrolyte, according to the Helmholtz-Smoluchowski equation. The EK coefficient depends on three other parameters that are the permittivity, the viscosity of the electrolyte and the zeta potential, which is the potential of the plane separating the moving fluid from the charges adsorbed at the rock surface.

The LBM approach allows to explore the effects of the ionic distribution within the channel. The simulations show how this ionic distribution makes the bulk electrolyte conductivity differ from the conductivity of the electrolyte measured out of the rock. This difference increases with increasing zeta values, and is quantified through the calculation of an effective conductivity. This effective conductivity is a more precise expression of the bulk fluid conductivity, in the sense that it allows to take into account the effective repartition of the species within the channel, but also the nature of these species (valences, mobilities).

This study also allows to assess the error introduced by the Debye-Hückel approximation in the Helmholtz-Smoluchowski equation. The Debye-Hückel approximation is an expression of the potential within the channel that is valid with the assumption that the potential is inferior to 25mV in absolute value, which is far below the zeta values that are derived experimentally. The simulations provide an insight on the error that is made when the zeta potential is derived from streaming potential measurements without correction.

This model can be further developed for the comprehension of streaming potentials in unsaturated conditions.