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Predicting streaming potentials for various pore size distributions, comparison of numerical and analytical approaches

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Understanding streaming potential generation in porous media is of high interest for hydrological and reservoir studies as it permits to relate water fluxes to measurable electrical potential distributions in geological media. This streaming potential generation results from electrokinetic coupling between water and electrical fluxes due to the presence of an electrical double layer at the interface between the mineral and the pore water. Therefore, the porous medium's pore size is expected to play an important role in this generation. We use in our study 2D pore network simulations to better understand the effect of the pore size distribution upon this electrokinetic mechanism. Our simulations in well-controlled conditions allow us to study in detail the influence of a large permeability range (from 10^{-16} to 3×10^{-10} m^2) for different ionic concentrations (from 10^{-4} to 1 mol L^{-1}). We then use and compare two different approaches that have been used over the last decades to model and interpret the generation of the streaming potential: the classical coupling coefficient approach based on the Helmholtz-Smoluchowski equation and a more recent one based on the effective excess charge density. Our results show that the pore size distribution has a limited influence on the coupling coefficient for ionic concentrations smaller than 10^{-3} mol L^{-1}, while it completely drives the behaviour of the effective excess charge density over several orders of magnitude. Then, we use these simulation results to test a recently proposed analytical model based on a fractal pore size distribution. We show that this model predicts very well the effective excess charge density for all the tested pore size distributions within its intrinsic limitation, that is, for a thin electrical double layer compared to the pore size.