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A theoretical model of streaming potential and zeta potential in rocks

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The Helmholtz-Smoluchowski (HS) equation is commonly used to relate the streaming potential coupling coefficient of porous media to a range of pore fluid parameters and the zeta potential of the rock. We have carried out fundamental theoretical modelling of the streaming potential coupling coefficient as a function of pore fluid salinity, pH and temperature. To do this we have modelled the electrical conductivity, dielectric permittivity and dynamic viscosity of the bulk fluid, calculated the debye screening length, stern plane potential, zeta potential and surface conductance of the rock, and combined them all with parameters that describe the rock microstructure. The resulting theoretical values have been compared with a compilation of 289 streaming potential coupling coefficient measurements and 218 zeta potential measurements obtained experimentally for 9 materials and using data from 27 authors in total. The theoretical model was found to describe well the main features of the data taken either globally or on a sample by sample basis. The low salinity regime was found to be controlled by surface conduction and rock microstructure, and was sensitive to changes in porosity, cementation exponent, formation factor, grain size, pore size and pore throat size as well as specific surface conductivity. The high salinity regime was found to be subject to a zeta potential threshold that allows the streaming potential coupling coefficient to remain significant even as the saturation limit is approached.