Electrokinetic subsurface characterization

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Ferdinand Schoemaker (Delft University of Technology) , D.M.J. Smeulders , Evert Slob

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Email: `F.C.Schoemaker@tudelft.nl`

When a dielectric is immersed in an electrolyte, a surface charge often appears. For example glass immersed in an aqueous solution becomes negatively charged due to the fact that the silane terminals *Si-O-H* located at the surface of the glass become protonated in the presence of an aqueous solution.

When an isolated surface carrying an acquired charge is immersed in an electrolyte, the mobile charge of the liquid forms a so-called 'double layer' near the immersed surface. This double layer consists of 2 layers. The first layer, known as Stern layer, is a molecular film of counter-ions which are bonded to the solid by electrostatic interaction. The second layer is the diffuse layer and results from a statistical equilibrium between thermal and electrical forces. The thickness of this layer λ_d is the Debye-Hückel length which is the characteristic length scale of the problem. The order of magnitude is a few tens of nanometers for a solution of water and salt at 1μ Molarity. In practice, it is difficult to obtain much higher Debye-Hückel lengths.

Electro-osmotic flow is a phenomenon produced in a fluid when an electric field is applied parallel to the surface in the presence of an established double layer. The double layer is moved by Coulomb forces and the rest of the fluid is pulled with it due to viscous forces. The inverse effect is called streaming potential, when an electric field is generated due to fluid flow (caused by a hydraulic gradient). Both effects are of importance for subsurface characterization. In seismic surveys, for example, subsurface waves are generated that induce streaming potentials that are measured at the surface of the earth. Alternatively high voltage sources can be used at the surface to induce subsurface motion that can be detected by geophones at the surface. For these type of measurements dynamic (i.e. frequency-dependent) effects are of importance.

During this research our attention is directed towards the measurement of the frequency-dependency of streaming potential and electro-osmosis. By application of a sinusoidal pressure or current onto a porous, fluid saturated core sample, in a Dynamic Darcy Cell set-up, we are capable of validating the currently applied governing equations (Pride equations). We use the Eulerian model, whereby both fluid and solid are considered as continua, by considering the fluid saturated porous system at a 'macro' scale. The system is described by a double set of conservation equations for both the fluid and the solid (Biot theory), combined with Maxwell theory.

Special attention is paid to the coupling of both electrokinetic effects and their individual components which influence this interaction. The most important ones are the salinity of the fluid and the hydraulic permeability of the rock/soil. Measurements have been performed of the conductivity, as a function of concentration and temperature. A variety of cores is considered, of which also the dynamic permeability has been measured.