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Modelling the frequency dependence of hydraulic flow and streaming potential coupling coefficients in capillary bundles and porous rocks

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The phenomenon of streaming potential has been studied for many years and has extremely diverse applications which encompass life sciences, natural sciences and engineering. Almost all research has been carried out in the DC regime, supported by the well known Helmholtz-Smoluchowski equation, which links the streaming potential coupling coefficient to the zeta potential, the dielectric constant, viscosity and conductivity of the pore fluid, the specific surface conductivity and the characteristic length of the rock microstructure. The aim of this project was to find and develop methods for extending this equation into the AC regime. The equations governing both the hydraulic flow coupling coefficient H(ω) (fluid velocity divided by the difference in fluid pressure) and the streaming potential coupling coefficient C(ω) (difference in potential divided by the difference in fluid pressure) are dispersive and non-linear. Equations for H(ω) and C(ω) in a capillary tube with a circular cross-section have been obtained by the solution of the time-dependent Navier-Stokes equation following Packard‘s method **[1]** and information in Reppert *et al*. **[2]**. The solutions, written in terms of bessel functions, have been built into a Maple code that allows the effect of a bundle of capillaries with a spectrum of different diameters to be modelled. The hydraulic flow coupling coefficient H(ω) for a single diameter capillary can be approximated by a Debye dispersive model, while a Cole and Cole model is more appropriate for a spectrum of different capillary sizes. By contrast the streaming potential coupling coefficient does not fit a Debye or a Cole and Cole model even for a single diameter of capillary. For a spectrum of capillaries, it is always the larger that

control the AC behaviour of both coupling coefficients, with the smaller capillaries rapidly stagnating. Flow in real porous rocks is not unidimensional as in the bundle of capillary tubes. It can be represented by capillary tubes which have holes that allow fluids to flow from one tube to another. We have attempted to extend the model to better represent porous rocks by using a number of different mixing models including the Hashin-Shtrikman upper and lower bounds **[3]**, the modified brick-layer model **[4]** and the modified Archie's Law **[5]**. Unfortunately, comparison of the results with real data is hampered by the lack of available data, a lacuna that we hope to help fill using apparatus described in another presentation at EGU 2008.

References. [1] Packard, R.G., *J.Chem.Phys*. **21**, 303-307, 1953. [2] Reppert, P.M. *et al*., J.Coll.Interf.Sci. 234, 194-203, 2001. [3] Hashin, Z. & Shtrikman, S., J.Appl.Phys. 33, 3125-3131, 1962. [4] Schilling *et al*., Phys.Earth Planet.Int. 103, 17-31, 1997. [5] Glover *et al*., Earth Planet.Sci. Lett. 180, 369-383, 2000.