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Water saturation dependence of streaming potential coupling coefficient and excess charge density in sandstones during drainage and imbibition

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The streaming potential resulting from the flow of water through porous media can be characterised in terms of either the streaming potential coupling coefficient (C), or the density of excess charge transported by the flow of water (Q). These properties are related by

$$C = \frac{Qk_w}{\sigma\mu_w}$$

where k_w is the permeability to water, σ is the rock conductivity and μ_m is the water viscosity. When an immiscible, non-polar phase such as oil or gas is also present in the pore-space, both C and Q are water saturation dependent, but their relationship with saturation is poorly understood. Streaming potential measurements during unsteady-state drainage and imbibition in sandstones saturated with water and undecane have recently been reported (Vinogradov and Jackson, in press). However, the saturation dependence of C and Q cannot be directly obtained from their experimental results. In this paper, we use numerical methods to invert the measured data and report the saturation dependence of C and Q during drainage and, for the first time, imbibition.

We find that C generally decreases with decreasing water saturation while Q generally increases. However, the saturation dependence of both C and Q is different during drainage and imbibition. During drainage, C initially decreases slowly with water saturation, before rapidly decreasing to its minimum value. Even very small rates of water flow, at water saturations close to the assumed 'irreducible' saturation, result in non-zero values of C, because water flow occurs through wetting layers which contain a very high excess charge density. During imbibition, C increases with increasing saturation and, close to the residual non-wetting phase saturation (S_w = 1-S_{nwr}), C exceeds the value observed at saturation (S_w = 1). A number of previous publications have assumed that Q is inversely proportional to water saturation, but we find that this is not the case during either drainage or imbibition.

These results are relevant to the interpretation of streaming potential measurements in oil reservoirs, contaminated aquifers and the vadose zone. They suggest that (i) the behaviour of the multiphase streaming potential coupling coefficient depends upon the phases present and the direction of saturation change, (ii) the excess charge density transported by the flow of water does not scale inversely with water saturation, and (iii) the results of drainage experiments cannot be applied to imbibition.

Vinogradov, J. and Jackson, M.D., Multiphase streaming potential in sandstones saturated with gas/brine and oil/brine during drainage and imbibition, *Geophys. Res. Lett.*, in press.