



Laboratory measurements of the streaming potential coupling coefficient in sandstones saturated with natural and artificial brines at high salinity

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Measurements of streaming potential can be used to monitor subsurface flow using electrodes installed along boreholes. However, the interpretation of the measurements requires an understanding of the streaming potential coupling coefficient, which dictates the magnitude of the streaming potential for a given pressure difference. Previous laboratory measurements of the coupling coefficient in earth materials focussed on crushed and intact rock samples saturated with artificial NaCl and KCl brines of relatively low salinity: salt concentrations were typically lower than average seawater. However, many subsurface brines are significantly more saline.

We have measured the streaming potential coupling coefficient in four different intact sandstone samples saturated with seawater and artificial NaCl brines at concentrations up to 5.3 M/L. We obtain consistent results using three different sets of experimental apparatus. The values we record at low salinity are consistent with those reported previously. As brine salinity increases, the coupling coefficient decreases in magnitude, falling to a value of c. 1.5×10^{-10} V/Pa at 5.3M/L, and remains negative over the entire salinity range. The coupling coefficient measured for seawater is similar to that obtained for NaCl brine of the same ionic strength.

The magnitude of the zeta potential also decreases with increasing salinity, but approaches a constant value of c. 17mV at salinities greater than c. 0.4M/L. This behaviour is not captured by current models of the electrical double layer. We hypothesize that ion interactions cause the reduction in thickness of the diffuse layer at high salinity to be less than predicted by the Poisson-Boltzmann equation, in which it is assumed that the ions are point charges. Moreover, the counter-charge required to balance the mineral surface charge is not accommodated entirely within the Stern layer. Consequently, the diffuse layer does not collapse to zero; rather, some of the counter-charge remains mobile within the diffuse layer, at a maximum concentration which is limited by the size of the hydrated counter-ions. Our hypothesis is supported by the observation that the Debye length is c. 0.5 nm at a salinity of 0.4 M/L, which is comparable with the diameter of a hydrated sodium ion.

Our results suggest that streaming potential measurements may be used to monitor flow in more saline subsurface environments, such as deep saline aquifers and hydrocarbon reservoirs, than previously thought.