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Streaming Potentials in Reservoir Conditions

Jon Saunders, Matthew Jackson, and Murtaza Gulamali
Department of Earth Science and Engineering, Imperial College London, SW7 2AZ, UK (jon.saunders@imperial.ac.uk)

Recent work has shown that streaming potentials measured downhole may be used to identify and characterise fluids moving through the subsurface. Of particular interest is the identification of approaching water during hydrocarbon production and the use of control strategies in response to these measurements in order to improve production efficiency and reduce the quantity of water brought to surface. Such technologies could improve overall recovery, reduce the cost of production in terms of both energy and time and also reduce the immediate impact of production on the environment. A number of important factors have been identified which have an influence on the viability and facility of the method, principally relating to the nature of the streaming potential coupling coefficient which relates the fluid potentials to electrical potentials. Here we examine the the behaviour of the streaming potential coupling coefficient under multiphase conditions, and under conditions of varying temperature and salinity.

Using new insights into the pore-scale distribution of fluids and of electrical charge, we look at the saturation dependence of the streaming potential coupling coefficient, and the variation in the resulting measured potentials in a range of models with differing viscosity regimes. The saturation-dependence of the coupling coefficient is found to be important in determining the resulting streaming potential, in the case where water and oil viscosities are equal and the water front is sharpest as well as in cases with higher oil viscosities and more smoothed out water fronts. The most physically plausible models for the saturation-dependence of the coupling coefficient have the highest values of the relative coupling coefficient at intermediate saturations, and give rise to the largest measured potentials. This is a result of the rarefaction of the water front as it travels through the reservoir, meaning that the saturation fraction at the front is significantly less than 1.

The coupling coefficient is composed of four independent physical parameters and it is through examination of each of these in turn that we build an understanding of the behaviour of the coupling coefficient as a whole under conditions of varying temperature and brine salinity. It is well known that the coupling coefficient (usually) decreases in magnitude with increasing salinity but the effect of temperature is less well understood. By combining the two we can begin to understand how streaming potentials may behave in reservoir conditions. While the zeta potential, dielectric permittivity, conductivity and in particular the fluid viscosity are found to vary with temperature, the overall effect on the coupling coefficient is small, showing about a 10% change between 25 and 75oC, depending on the salinity. This is reflected in the magnitude of signals predicted at the wells during production, where increasing salinity reduces the streaming potential, while increasing temperature has only a small effect.

High salinities, high temperatures and the nature of the saturation-dependent coupling coefficient are among several factors which have previously been seen as obstacles to the viability of using streaming potential methods downhole during hydrocarbon recovery. Here we show that even at high salinity signals remain measurable above the expected noise, that temperature has only a small effect on the measured streaming potential magnitude and that we may expect larger signals than previously thought given a better understanding of the pore-scale physics. Removing these obstacles is a significant step forward in the development of the downhole monitoring method.