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# Experimental study of the water saturation dependence of streaming potential in sandstones during drainage and imbibition

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We report the first measured values of the multiphase streaming potential coupling coefficient in intact sandstone core samples saturated with brine, and either undecane or nitrogen as the second phase, obtained from unsteady-state drainage and imbibition displacement experiments. The displacements are conducted at low rate, with pressure ramping at regular intervals during which the measured pressure and voltage across the sample are used to determine the streaming potential coupling coefficient. The voltage is measured using non-polarizing Ag-AgCl electrodes installed on each face of the sample.

We find that the behaviour of the coupling coefficient at partial saturation is different depending upon whether oil or nitrogen is the second phase, and whether the brine saturation is decreasing during drainage, or increasing during imbibition. When undecane displaces brine, the coupling coefficient initially drops sharply as undecane enters the inlet face of the sample, and then remains approximately constant until undecane is produced at the outlet face of the sample. There is then a slow decrease in the coupling coefficient as the brine saturation decreases towards the irreducible value, but the coupling coefficient remains significantly greater than zero even after pumping several thousand pore volumes of undecane through the sample, during which the change in brine saturation is less than 1%. This behaviour would not be observed in measurements during capillary desaturation, as the non-wetting phase is prevented from flowing out of the sample.

When nitrogen displaces brine, the coupling coefficient falls gradually as the brine saturation decreases, reaching zero (within experimental error) as the brine saturation approaches the irreducible value. During imbibition, the coupling coefficient increases with increasing brine saturation, exceeding the value obtained when the sample is fully saturated with brine as the residual undecane saturation is approached. However, as the residual nitrogen saturation is approached, the coupling coefficient remains less than the value obtained at saturation. We hypothesize that the non-zero coupling observed at low brine saturation in the undecane-brine displacement is associated with the flow of brine within thin wetting layers which are mobilised by the movement of undecane. Similar behaviour is not observed in the nitrogen-brine displacement because of the lower interfacial friction.

These results are relevant to the interpretation of streaming potential measurements in oil reservoirs, contaminated aquifers and the vadose zone. They suggest that the behaviour of the multiphase streaming potential coupling coefficient depends upon the phases present, and the direction of saturation change. The results of drainage experiments cannot be applied to imbibition, and those of air-brine displacements cannot be applied to oil-brine displacements.