Geophysical Research Abstracts,
Vol. 11, EGU2009-7670, 2009
EGU General Assembly 2009

Fluid flow monitoring in hydrocarbon reservoirs using downhole measurements of streaming potential

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Downhole measurements of streaming potential, using permanently installed electrodes, are a promising new technology for hydrocarbon reservoir monitoring, and may also be used to characterize fluid flow in aquifers and during CO2 sequestration. We have used a combination of laboratory experiments and numerical modeling to investigate the behavior of the streaming potential during hydrocarbon production in a range of reservoir environments. We demonstrate that streaming potential signals originate at water-oil and water-gas fronts, and at geological boundaries, where water saturation changes.

As water encroaches on a production well, the streaming potential signal associated with the waterfront reaches the well whilst the front is up to 100m away, so the potential measured at the well starts to change relative to a reference electrode. The encroaching water can therefore be detected at some distance from the well, which contrasts with most other downhole monitoring techniques. Variations in the geometry of the encroaching waterfront may be characterized using an array of electrodes positioned along the well, but an understanding of the local reservoir geology is required to distinguish signals caused by the moving front, from those caused by saturation changes at geological boundaries.

To interpret streaming potential measurements requires knowledge of the streaming potential coupling coefficient during multiphase flow of oil and/or gas, and brine which may be highly saline. We have measured the coupling coefficient in sandstone cores saturated with high salinity brine and find that it decreases with increasing brine salinity, but less rapidly than predicted by extrapolating historical data obtained in the low salinity range. The coupling coefficient is small, but still measurable, even when the brine salinity approaches the saturated concentration limit. We have used a simple bundle-of-capillary-tubes model to predict the variation in streaming potential coupling coefficient with water saturation during multiphase flow, and are currently investigating the validity of these predictions using laboratory measurements.