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Experimental measurements of electrochemical coupling potentials in NaCl-brine saturated sandstone cores

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Measurements of the spontaneous electrical potential (SP) are increasingly being used to characterise and monitor fluid flow in the subsurface. One component of the SP arises from the electrochemical (EC) coupling between gradients in ionic concentration and gradients in electrical potential. The SP anomalies in porous media associated with electrochemical (EC) coupling arise from both diffusion and membrane potentials. Gradients in ionic species concentrations establish diffusion (or liquid junction) potentials; in electrically charged porous media, these gradients in concentration also result in membrane potentials because some of the co-ions are excluded from the electrolyte saturating the pore-space. However, despite their occurrence in many Earth systems, few experimental studies of EC potentials in natural porous media have been reported in the literature, and these provide only a limited number of measurements, over very restricted range of electrolyte salinity, and with few details of the experimental method. The aim of this study is to measure the SP arising from EC coupling in sandstone samples saturated with NaCl-brine over a wide range of salinity values, and to account for electrode effects using a well constrained experimental setup.

The experimental apparatus consists of two reservoirs connected by a horizontal rubber sleeve which is used as the sample holder. Each reservoir is filled with NaCl-brine of a desired salinity and the natural sample is pre-saturated with NaCl-brine of the same salinity as one of the reservoirs. Salinity measurements are performed using conductivity-meters located in the reservoirs and potential measurements are performed using AglAgCl reference electrodes located on each face of the sample in contact with the fluid. To account for the salinity dependence of the reference electrodes, the potential arising from the EC coupling is measured in an additional apparatus which consists of a vertical column filled with NaCl-brine. The top half of the column is filled with NaCl-brine of relatively lower salinity, allowing a stable interface to be formed in the middle of the column.

We report systematic measurements of the EC coupling potentials performed over brine salinities ranging from 5x10-5 to 1 M. The EC potential increases as the salinity difference across the rock sample increases, from 4.5 mV at salinity ratio of 0.5 to 14.5 mV at salinity ratio of 6x10-4. Over the restricted salinity range investigated by Smits (1968), the results are found to be in good agreement.

Smits, L.J.M., 1968, SP log interpretation in shaly sands, SPE Journal, 8(2), 123-136.