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The Effect of Pore Water Velocity on the Spectral Induced Polarization Signature of Porous Media

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Induced polarization (IP) is increasingly applied for hydrological, environmental and agricultural purposes. Interpretation of IP data is based on understanding the relationship between the IP signature and the porous media property of interest. Mechanistic models on the IP phenomenon relay on the Poisson-Nernst-Plank equations, where diffusion and electromigration fluxes are the driving forces of charge transport, and are directly related to IP. However, to our knowledge, the impact of advection flux on IP was not investigated experimentally, and was not considered in any IP model. In this work, we measured the spectral IP (SIP) signature of porous media under varying flow conditions, in addition to developing and solving a model for SIP signature of porous media, which takes flow into consideration. The experimental and the model results demonstrate that as bulk velocity increases, polarization and relaxation time decrease. Using a numerical model, we established that fluid flow near the particle deforms the structure of the electrical double layer (EDL), accounting for the observed decrease in polarization. Using simple physical arguments, we developed a new model for the relaxation time, taking into account the impact of bulk fluid velocity. The model and the measured and synthetic data were found to be in good agreement. Overall, our results demonstrate the sensitivity of the SIP signature to fluid flow, highlighting the need for considering fluid velocity in the interpretation of the SIP signature of porous media, and opening an exciting new direction for noninvasive measurements of fluid flow at the EDL scale.