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5D SIP monitoring of stimulated uranium bio-remediation

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Here, we demonstrate the use of spectral induced polarization (SIP) imaging for monitoring biogeochemical changes accompanying the stimulation of indigenous aquifer microorganisms with the purpose to immobilize uranium in tailings-contaminated groundwater at the Department of Energy's Rifle Integrated Field Research Challenge (IFRC) site near Rifle, Colorado (USA). Measurements have been collected with electrodes placed on the surface and in boreholes along diverse stimulation experiments. The aims of the SIP surveys were (1) to characterize the precipitation of metallic nano-minerals and changes in groundwater geochemistry due to microbial activity; (2) to investigate the distribution of the frequency dependence (e.g., spectral parameters) of the polarization response in an imaging framework, and (3) to evaluate the potential of these images to delineate changes in the hydraulic properties of the aquifer. Careful field procedures provided high quality SIP data from 0.060 to 256 Hz for different periods during the remediation experiment. Data quality was evaluated by means of analysis of the discrepancy between normal and reciprocal measurements. A Cole-Cole model was fitted to pixel values extracted from the inverted images in order to assess changes in the SIP response – particularly in time constant (τ) and chargeability (m) - due to processes accompanying the stimulation of subsurface microbial activity. We observed an important decrease in m and no change in τ correlated with periods characterized by high rates of sulfate-reduction. A significant increase in both τ and m was observed after halting acetate injection, consistent with the accumulation of metallic nano-minerals (e.g., FeS) during biostimulation and the post-injection rebound in aqueous Fe(II).