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Development of geoelectrical monitoring of carbonate dissolution on microfluidic chip

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We miniaturize the low-frequency (<1kHz) geoelectrical acquisition using advanced micro-fabrication technologies to investigate the dissolution of carbonates. With this innovation in the experimental acquisition, we focus on the development of the complex electrical conductivity monitoring with the spectral induced polarization (SIP) method. The interpretation of the SIP signal is based on the development of petrophysical models that relate the complex electrical conductivity to structural, hydrodynamical, and geochemical properties or distributions. State-of-the-art petrophysical models, however, suffer from a limited range of validity and presume too many microscopic mechanisms to define macroscale parameters. Thus, direct observations of the underlying processes coupled with geoelectrical monitoring are keys to deconvolute the signature of the biochemical-physical mechanisms and, then, develop more reliable models. Microfluidic experiments enable direct visualization of flows, reactions, and transport at the pore-scale thanks to transparent micromodels coupled with optical microscopy and high-resolution imaging techniques. Micromodels are a two-dimensional representation of the porous medium, ranging in complexity from single channels to replicas of natural rocks. Cutting-edge micromodels use reactive minerals to investigate the water-mineral interactions. In this work, we propose a new kind of micromodels equipped with four aligned electrodes within the channel for SIP monitoring. First, we study the dissolution of a calcite crystal. From continuous chloride acid injection experiments with a fixed flow rate, we highlight the strong correlation between SIP response and dissolution through electrical signal examination and image analysis. In particular, reactive surface area, liquid phase fraction, surface roughness, porosity, and anisotropy are parameters that strongly influence the SIP response. Besides, the formation of degassed CO2 bubbles, generated by the dissolution under certain hydrodynamic regimes, is a visible source hindering the SIP measurements. Then, we study the dissolution of chalk (Seine-Normandy Basin, France) and mylonitic marble (Alps, Switzerland). The comparison of calcite crystal dissolution with these samples enables studying the impact of adding a porous structure for chalk, an anisotropic combination of minerals for the marble. The unique experimental results obtained from comparing the optical images with the SIP response bring a deeper understanding of the physical interpretation of the complex electrical conductivity.