Geophysical Research Abstracts
Vol. 21, EGU2019-4517, 2019
EGU General Assembly 2019

Direct visualization of colloid transport in fractures of carbonate rocks using fluorescent microscopy

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The leaching and migration of active radionuclides, emanating from radioactive waste disposal sites, poses immense risk to the natural environment in general, and specifically to groundwater reservoirs. Colloid facilitated transport (CFT), in which the contaminant is attached to naturally-occurring mobile colloids, has been identified as a major source for enhanced migration of radioactive species in groundwater. Since many underground repositories of radioactive waste are situated within fractured rock formations, it is crucial to assess the mobility of colloid-borne radionuclides in discrete fractures. More specifically, transport behavior in fractured carbonate rock, which constitutes the local bedrock in the Negev desert in southern Israel, is not well understood. While recent laboratory-scale experiments have shown the significant impact of CFT on contaminant migration, including some of the radionuclides, in natural fractured carbonate rock, the micro-scale origin of this behavior remains largely unknown. In this work, we study two specific questions: (a) what is the distribution of colloids within the fracture, along the flow path; and (b) how this distribution is related to the chemical and mineral heterogeneity of the fracture surface. We use two types of rock samples: a naturally fractured core drilled from the chalk rock, representing a mature and highly heterogeneous fracture surface, and a fresh cut sample from a non-fractured core, representing a more homogeneous and recently formed fracture surface. We develop a novel experimental setup, consisting of a small slab of natural fractured chalk surface, encased in a flow cell under a glass cover, and mounted under a fluorescence microscope. Clay particles labelled with a fluorescent dye are injected into the cell, while the fluorescence intensity of the rock surface is captured using the microscope. This setup allows us to monitor the distribution of labelled clay particles over the fracture surface, with high temporal and spatial resolution. Initial experiments show that fluorescence, hence clay deposition, increases over time during the flow experiment, over a small section of a homogeneous rock surface. Our preliminary results suggest that surface topography and flow pattern impact colloid deposition on the fracture surface.