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Unraveling Salt Precipitation Dynamics in Heterogeneous Porous Media via Time-Lapse Micro-Computed Tomography

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The evaporation of saline water from porous media is a critical global concern, influencing diverse applications such as water management, subsurface energy storage, construction materials, and agriculture. Understanding this process is essential, as it may lead to salt precipitation within pores that can partially or fully block them. This can alter the hydraulic properties of the porous medium, affecting fluid and solute transport. Most studies dealing with salt precipitation during evaporation have focused on homogeneous porous media, with limited attention to heterogeneous systems. This study addresses this gap by investigating vertical textural contrasts in porous media, specifically sand columns with a distinctive vertical interface between fine and coarse sand. Previous studies dealing with evaporation have shown that in such configurations, water migrates from coarse to fine sand, creating an additional evaporation surface at the vertical interface. This potentially leads to subflorescent salt precipitation at the interface, which can significantly impact transport properties. However, previous characterization methods, such as surface imaging, infrared thermography, and low-resolution medical computed tomography, fail to provide direct visual evidence of these processes within the sand matrix. In this study, we aim to bridge this gap by employing time-lapse micro-computed tomography (μ -CT) to provide high-resolution visualization and quantification of water movement and salt distribution during evaporation. The experiments use a heterogeneous column divided into half fine sand (particle size ~ 0.1 mm) next to coarse sand (particle size ~ 1 mm) with a sharp vertical interface. The column was saturated with NaCl solution and underwent evaporative drying at room temperature. μ -CT enabled the characterization of salt distribution on the surface, at the vertical interface, and within the porous media, while mass loss measurements were used to quantify evaporation rates. The spatial and temporal variability of salt precipitation was analyzed to determine its dynamic effects on evaporation and transport processes. Overall, this study enhances the understanding of evaporation and salt precipitation in heterogeneous porous media, offering valuable insights for fields such as soil science, hydrology, and energy storage, where controlling or predicting these processes is crucial.