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Colloid-induced multiphase flow perturbations in porous media

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Colloids in geological porous media such as rocks and soils are relevant for a broad range of environmental applications, such as groundwater remediation. The transport of colloids, ranging from nanometers to micrometers in size, is shaped by pore geometry, surface interactions, flow conditions, and particle properties [1]. In the literature, colloids are widely reported to influence the mobility of contaminants in porous media at the column scale [2], however, the multi-scale mechanisms driving colloid-induced mobilization, from microscopic interfaces to pore networks and field-scale processes, are poorly understood. This study addresses this gap using time-resolved 3D X-ray micro-tomography to investigate colloid transport, pore clogging, and flow modification under transient conditions.

By attaching to fluid interfaces, colloids can reduce capillary forces and aid non-aqueous phase liquids (NAPL) removal, while their deposition can clog pores and alter flow patterns [3]. Here we want to focus on modification in hydrodynamic forces due to pore clogging, which has already been evidenced by microfluidic experiments (as illustrated in figure 1b) [4]. Most of the previous studies at the continuum scale have focused on classical column experiments for colloid transport, missing the complex dynamics at the microscopic level. The existing pore scale studies either lack the third dimension (microfluidic experiments[5]), or in-situ imaging at sufficient spatio-temporal resolution to resolve the flow and transport [2]. To fill these knowledge gaps, this study aims to utilize X-ray microtomography that enables high-resolution, non-destructive imaging at the pore scale to investigate the mechanisms behind colloid-induced pore clogging, which modifies flow and mobilizes trapped NAPL in porous media [6]. Cylindrical samples of porous sintered glass (4 mm diameter, 40 mm length) with average pore throats in the range of 30–70 μm, are mounted in a flow cell (Figure 1a). To achieve our objectives, we conduct single-phase and multiphase flow experiments. We use three types of X-rays attenuating particles of varying sizes and surface properties to represent environmentally relevant colloids. This study is expected to provide insights into the role of colloids in pore clogging, and NAPL mobility.

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