Transport Processes in Permeable Media

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In-depth understanding of the transport of fluids and solute species in permeable (that is, porous and fractured) media is of primary importance for many geological and chemical engineering applications, among which the remediation of aquifers and soils, the subsurface storage of CO_2, the underground storage of radioactive wastes, the fate and transport of non-aqueous phase liquid pollutants, enhanced oil recovery, the development of fuel cells, or the improvement of chemical reactors. The complex geometry of the pores/cavities causes a strong pore scale heterogeneity of the flows. Consequently, even for Stokes flow, the transport and mixing of solutes by liquid phases is often rendered non-Fickian, and chemical reactions occur at intermediate Damköhler numbers for which their kinetics is strongly limited by the mixing of reactants. The heterogeneous spatial distribution of transported solutes can also result in buoyancy-driven coupling of flow and transport. Under multiphase conditions, the flow heterogeneity is further enhanced due to the complex dynamics of the fluid-fluid interfaces, which involves a competition between capillary forces, viscous forces and gravity that can lead to viscous and gravitational instabilities of the interface, depending on the involved viscosity and density ratios. In such situations, the randomness of the pore geometry plays an important role in controling the flow topology. Furthermore, many of the involved fluids, in particular those used in subsurface applications, such as emulsions for enhanced oil recovery (EOR), foams for EOR or subsurface remediation, and bentonite-based drilling muds, are non-Newtonian. Overall the coupled (multiphase) flows, solute transport, and chemical reactions are not easily predicted and upscaled.

One application which examplifies the complexities of the processes at play is the subsurface storage of CO_2. It is now generally considered the only reasonable mid-term method of decreasing the atmospheric concentrations of greenhouse gases and therefore limiting the global warming of the atmosphere. The storage procedure consists in injecting carbon dioxide into a permeable (and hence, porous) formation that is confined by a mostly impermeable formation, the caprock, above it (Fig. 1.a). Carbon dioxide is partially soluble in water (up to 3 wt%), so mixing occurs at the interface, resulting in a mixture that happens to be denser than both the CO_2 and the resident fluid; hence, under certain conditions the dissolution interface destabilizes and a density-driven convection develops (gravitational instability). In addition, for brine, the solubility of CO_2 depends on the concentration of salt in the brine. As a result, four types of CO_2 trapping mechanisms can be distinguished: (i) Static structural/stratigraphic trapping is the trapping of the gas below

the low-permeability cap rock; it is prone to leakage along fractures or boreholes through the cap rock. (ii) Residual trapping is the trapping of disconnected gas bubbles inside cavities of the medium, when the injected gas is displaced by the resident fluid after the injection has stopped. (iii) Solubility trapping occurs when brine mixed with CO_2 (denser than unmixed brine) goes to the bottom of the formation by gravity. (iv) Mineral/chemical trapping occurs when CO_2 is involved into chemical reactions with the host rock and remains bound to it chemically or through physico-chemical forces. As shown in Figure 1.b, the trapping mechanisms act over different time scales in the order given above, the most perennial forms of trapping overtaking structural trapping as time passes.

The objective of the present minicolloque is to bring together scientists from the Physical Sciences, Earth sciences and Engineering interested in advancing our understanding of flow-driven transport processes occurring in permeable (porous and fractured) media. We welcome contributions addressing all aspects of the transport of fluids and solutes in permeable materials, including multiphase flows, viscous/gravitational interface instabilities, density-driven flows, the flow of non-Newtonian fluids, the flow of fluids confined in nanoporous materials, the transport and mixing of solute species, homogeneous and heterogeneous reactions, phase changes in porous media, the flow of fluids confined in nanoporous materials, and the various coupling between any of the above-mentioned. Experimental contributions involving microfluidics, MRI and X-ray tomography, as well as theoretical and numerical studies at the pore scale and/or accounting for the medium's stochasticity, are particularly welcome.

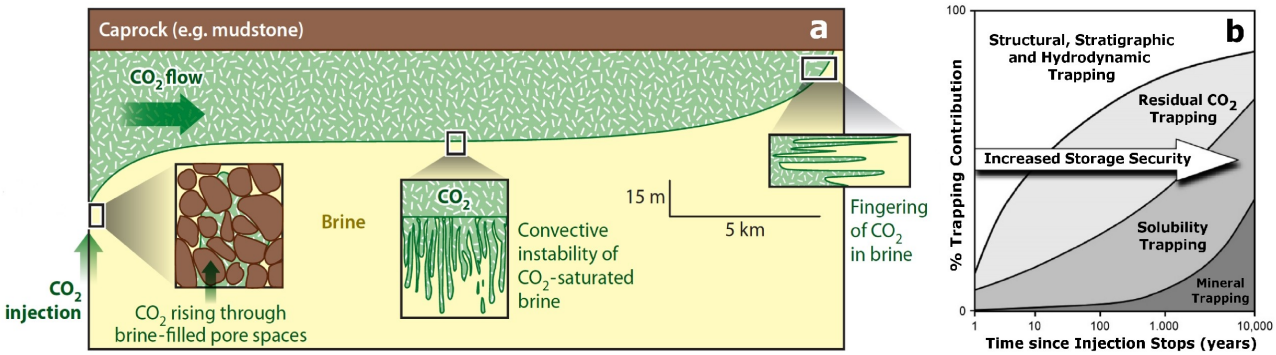

Figure 1 : (a) Phenomenology of CO_2 sequestration in deep aquifers (Huppert et al. [4]). (b) Time evolution of the contributions to trapping of the various trapping mechanisms (adapted from Ref [2]).

Reférences

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