MULTI-SPECIES TRANSPORT AND PH MODELING IN POROUS MEDIA

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Chemical flooding (such as Alkali-Surfactant-Polymer flooding) is an efficient way for enhancing oil production in reservoirs modifying locally fluid properties and reducing surface tension between oil and water. The recovery factor (recovery factor = cumulative oil produced / oil originally in place) can be increased by up to 20% applying chemical flooding. Understanding the coupling between transport and phase properties remains still an important issue at both scales, pore- or reservoir-scale. Alkali, which are widely used in enhanced oil recovery processes, modify significantly the pH of the flowing solution inside porous media and this is of major importance because the modifications of phase properties induced by the injection of polymers depend strongly on the pH.

The objective on this work is to simulate alkali/tracer flooding at pore- and Darcy-scale in real porous media to

(i) compare the simulated results with core experiments (Darcy-scale)

(ii) understand the local phenomena of pH and species concentration on macroscopic flow properties (pore-scale).

The chemical model describing pH evolution involves four distinct acid/base couples (plus water autoprotolysis) and two of them are related to the bicarbonate anion which is amphoteric, *i.e.* it can react both as an acid and a base depending on the pH of the solution. The resulting model, not detailed here, consists in solving a set of two non-linear equations (which the Jacobian is easy to determine) in each cell of the domain.

The flow and transport modeling depends on the scale considered. At the micro-scale, the flow is modeled using the real pore-scale geometry solving Stokes equations whereas at the macro-scale the flow follows Darcy's equation using effective properties (porosity, permeability). Moreover, the transport equations for species are different according to the considered scale. The transport reads at the micro-scale as

$$\frac{\partial X_m}{\partial t} + \mathbf{u}\nabla X_m - D_m \nabla \mathbf{u} = 0$$

with $\mathbf{u}$ the local flow velocity and D_m the molecular diffusion.
At the macro-scale (involving macroscopic effective properties), the transport reads

$$\varepsilon \frac{\partial X_M}{\partial t} + \mathbf{u}_D \nabla X_M - \varepsilon D_M \nabla \mathbf{u}_D = 0$$

with ε the porosity, $\mathbf{u}_D$ the Darcy velocity and D_M the effective dispersion coefficient.

Both micro- and macro- scales solvers have been implemented in foam-extend 4.0. At each time step, pH is computed in each cell solving a non-linear system using a Newton's algorithm. In order to validate implementation and numerical settings, a comparison has been performed using an idealized porous medium (simulation results are illustrated on figure 1 at two different times).

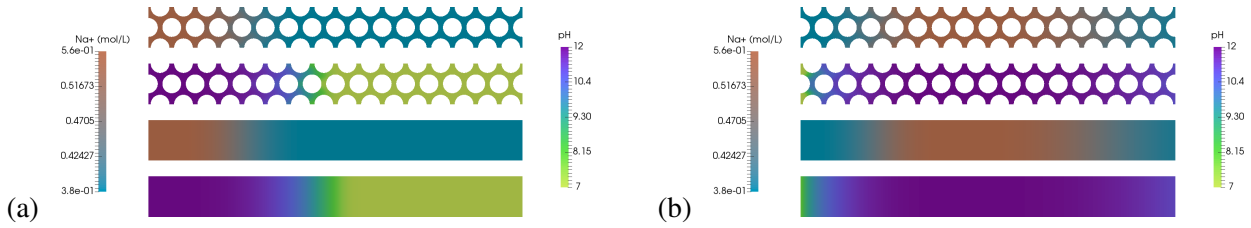

Figure 1: Comparisons of micro- and macro-scales simulations at different times

The macro-scale solver allows direct comparisons with core experiments and measurements and can be used to determine effective dispersion of solute species. These comparisons suggest that the chemical model is well described by this simple model and we also show the benefit of pH measurements for the characterization of the effective dispersion. The micro-scale solver, deployed on small volumes imaged by computed micro-tomography, allows to observe localized phenomena that modify the pH solution as illustrated on figure 2.

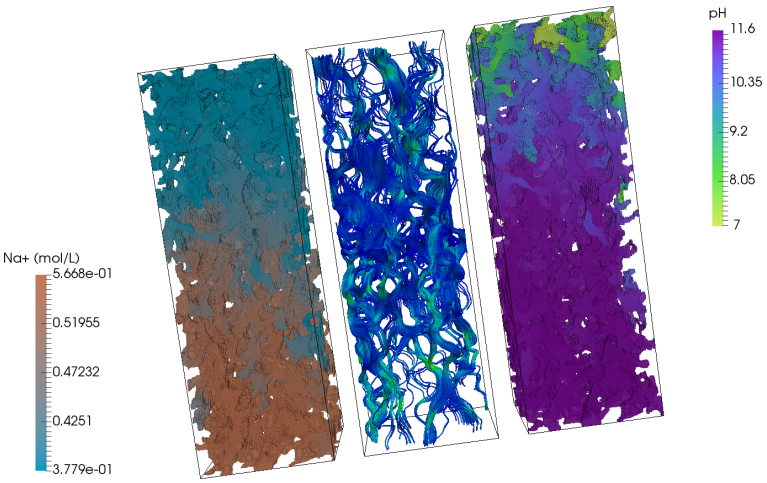

Figure 2: Snapshot of Na^+ concentration and pH computed over a parallelipipedic volume of 3 mm