Salinity Effects in Carbonate Rocks

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1. Introduction

Experimental studies for clastic rocks have shown that low-salinity waterflooding can improve the performance by up to 38%.
The aim of this project is therefore to use core flood studies and numerical simulations for understanding under which conditions low-salinity waterflooding is efficient in carbonate rocks. We will use these results for developing a continuum-scale model for describing the low-salinity effect in carbonates.
For carbonates, imbibition tests show that changing sulfate concentrations have a significant influence on the oil recovery rate (Fig. 1). Therefore, reactive transport of ions during multiphase flow is of outstanding interest (Fig. 2).
Current work focuses on reactive two phase-multicomponent transport where the component transport is described by the advection-diffusion equation

$$\phi\frac{\partial}{\partial t}(C \cdot S_W) = -\nabla \cdot (f_W(S_W)C\mathbf{v}_T - \mathbf{D}S_W\nabla C) + q.$$

Figure 3 shows the injection of a solution with pH=3 into a fractured carbonate aquifer.

We achieved a major speed up in transport calculations by using the fact that in our situation only the chemical equilibrium state is needed.
For simulating two-phase multi-component flow, we use the IMPES approach together with an explicit formulation for component transport (Fig. 4).

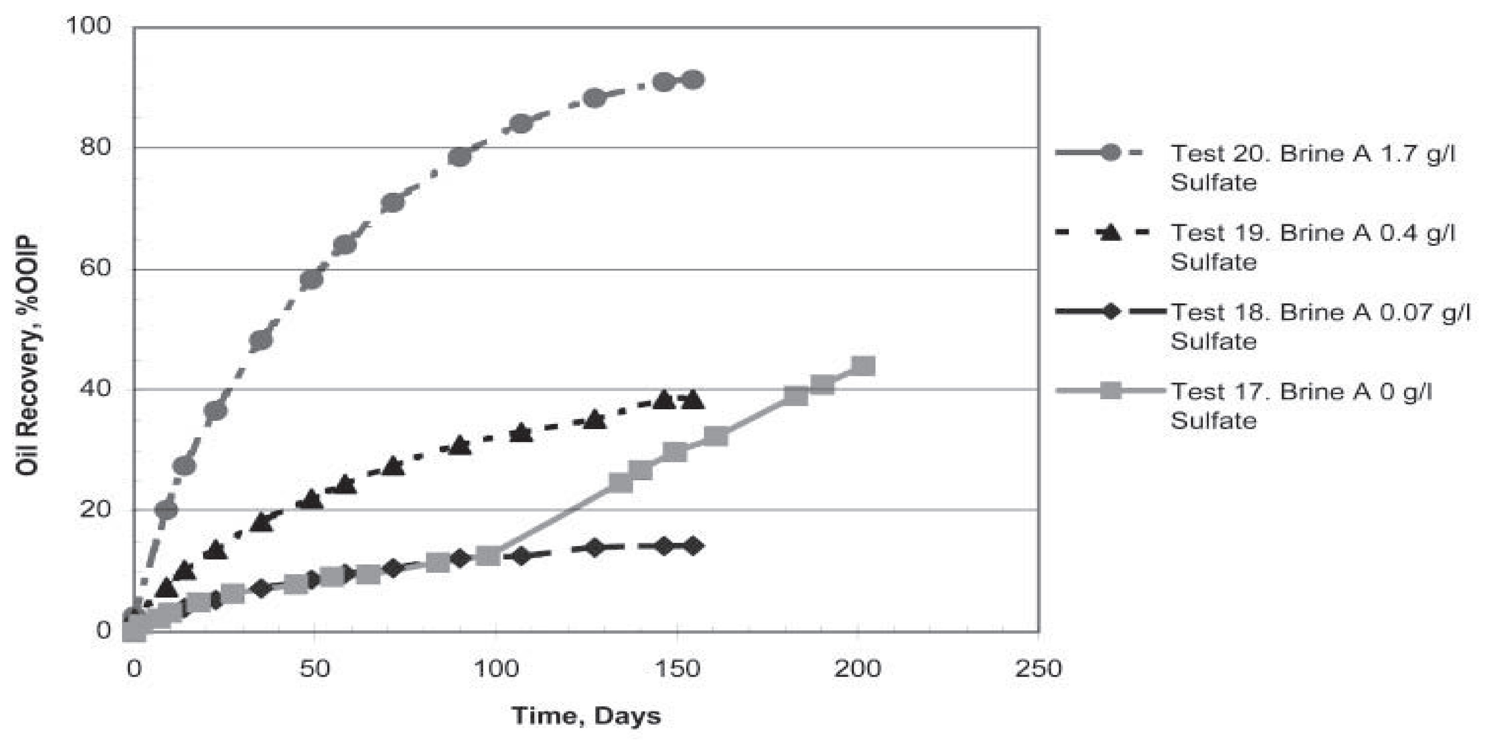


Figure 1. Imbibition tests for chalk; taken from Strand et al., 2003.

2. Reactive transport during muliphase flow

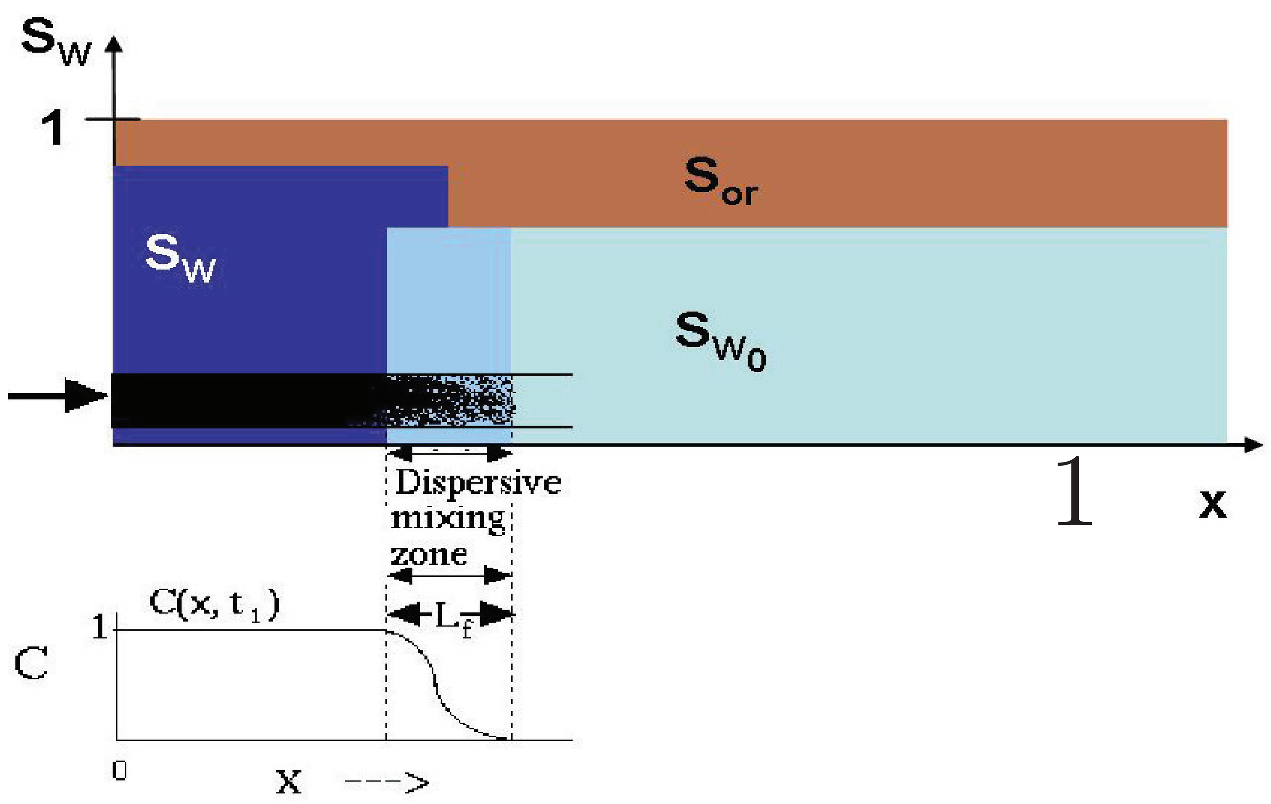


Figure 2. Schematic design of the situation arising during low-salinity waterflooding at the continuum scale. For pore-scale considerations see the poster of Yan Zaretsky.
We have to consider immiscible displacement between the oil and the aqueous phase and advection/dispersion effects for the initial and the injected solution. Additionally to this transport behaviour, chemical reactions have to be taken into account.

3. Simulations of reactive transport

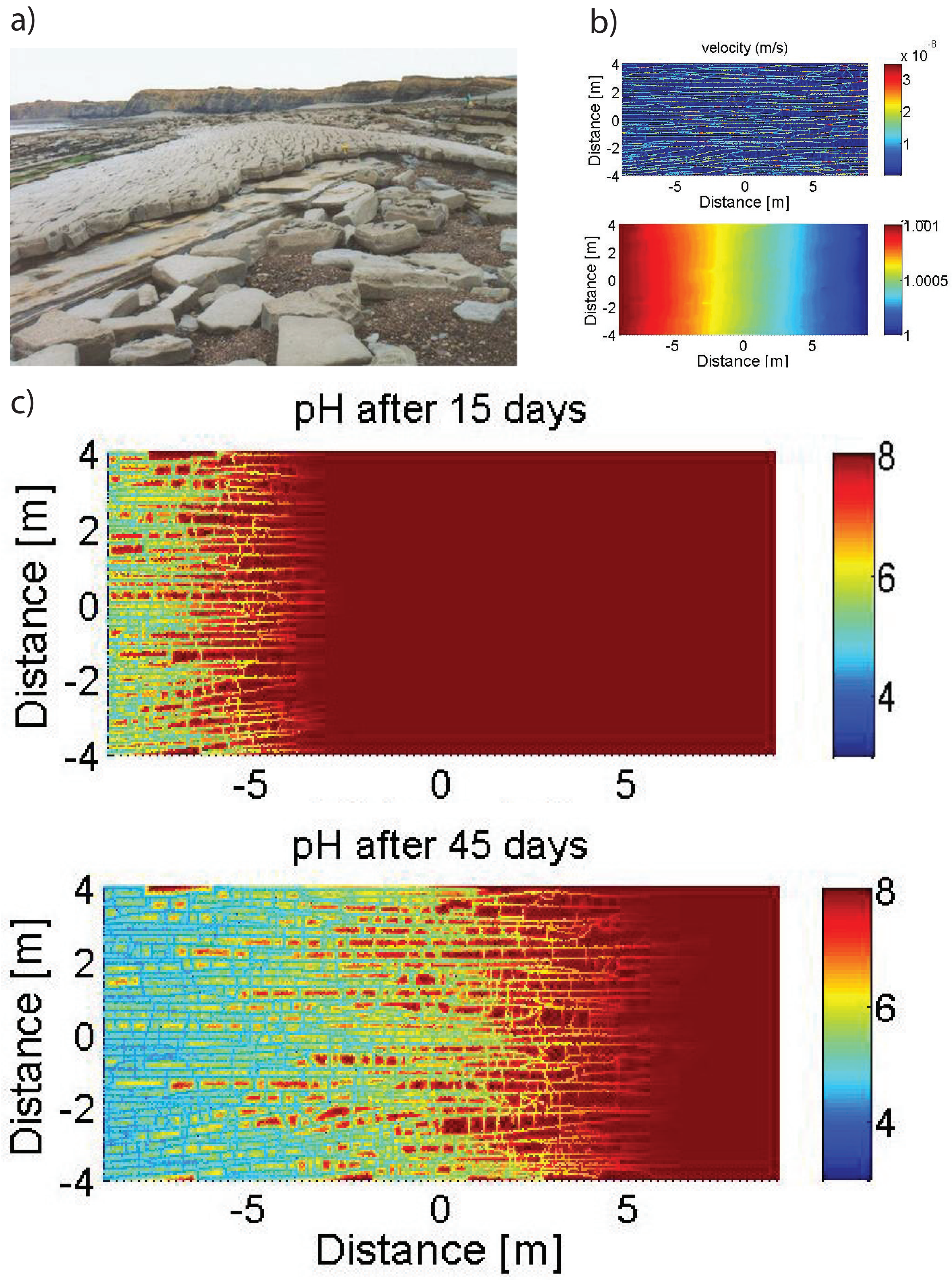
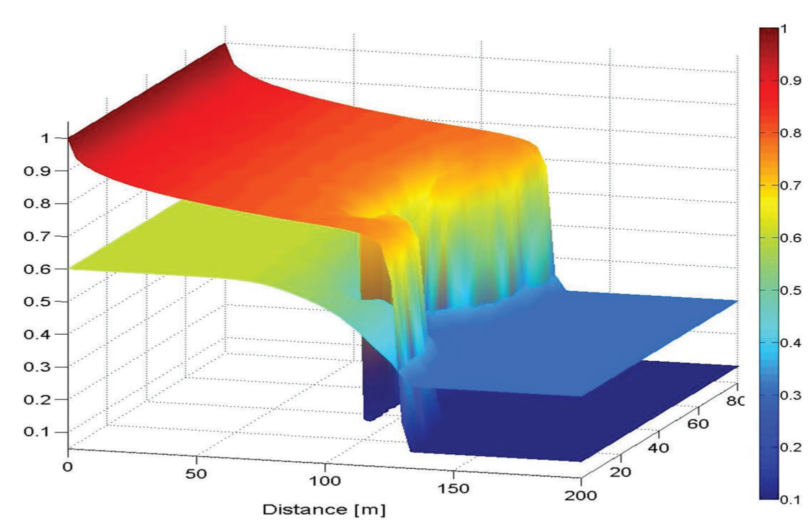


Figure 3. a.) Left: Bristol channel outcrop; fractured limestone with apertures 2mm - 0.2mm. b.) Simulated velocity (top) for a given pressure field (down) through a precise representation of the outcrop. At the left side, fluid with a pH of 3 is injected. Reactive transport calculations are shown for different times (c.)

4. Two-phase multi-component flow

Fig. 4: Simulation of a component travelling within the water-phase around a fault in a two-phase system after 28 days. The higher level is the water-saturation, the lower level the component concentration.



5. Future work

- **Merging of multi-component flow with reactive transport scheme.**
- **Investigation of influence of other ions (e.g. sulfates).**
- **Comparison to both pore-scale simulations (see poster Yan Zaretsky) and core flood experiments.**
- **Development of a continuum-scale model for describing the salinity-effect in carbonates.**