How to displace water in very coarse grained material

(including ugly but harmless grid effects when displacing water with gas)

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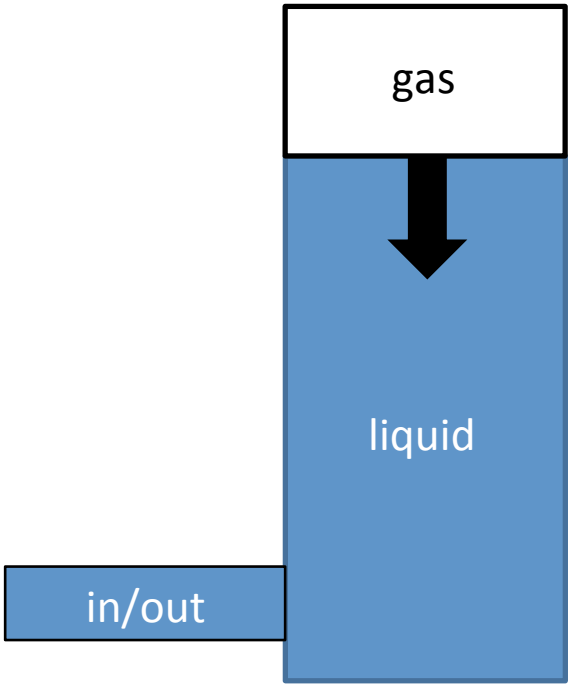
TOUGH Symposium 2015

Setting

Repository cavern filled with
coarse grained material
(no capillary pressures)

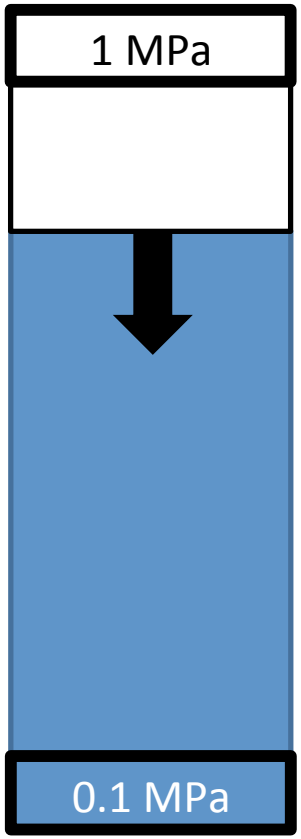
Note: applies also to cavities



After brine has flown into the cavern brine is expelled by gas production and salt creep

Horizontal water table expected

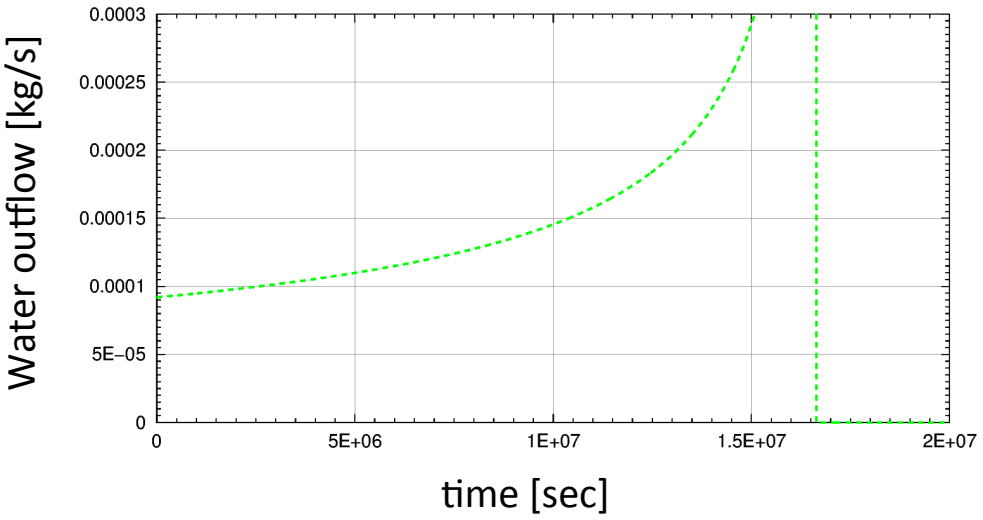
Simple representation of this problem
(no gravity, constant pressure boundary conditions)



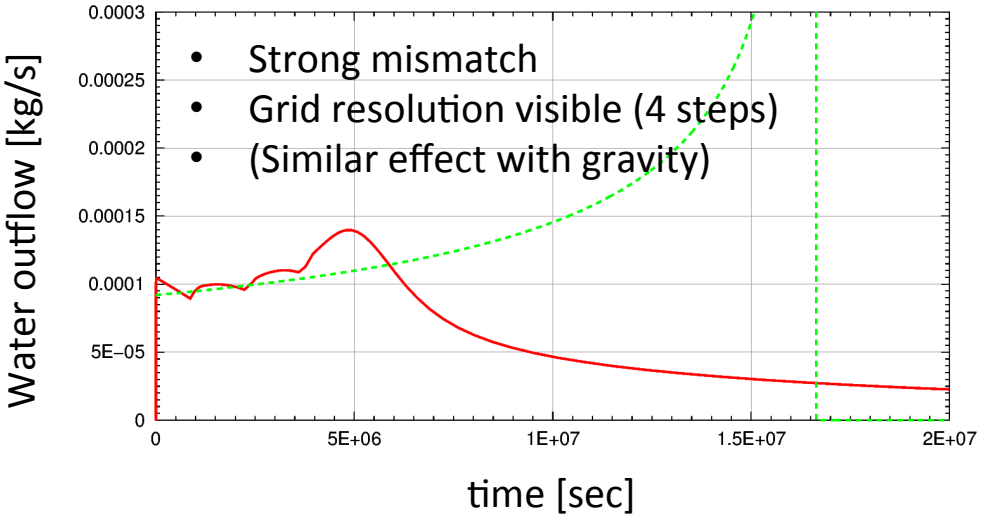
10 m

4 elements only, Corey

Analytical solution (g=0, Pcap=0)



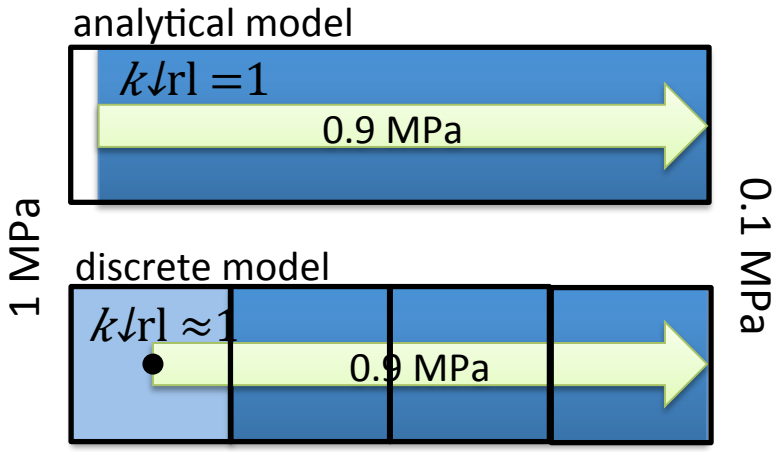
Simulation results



- Strong mismatch
- Grid resolution visible (4 steps)
- (Similar effect with gravity)

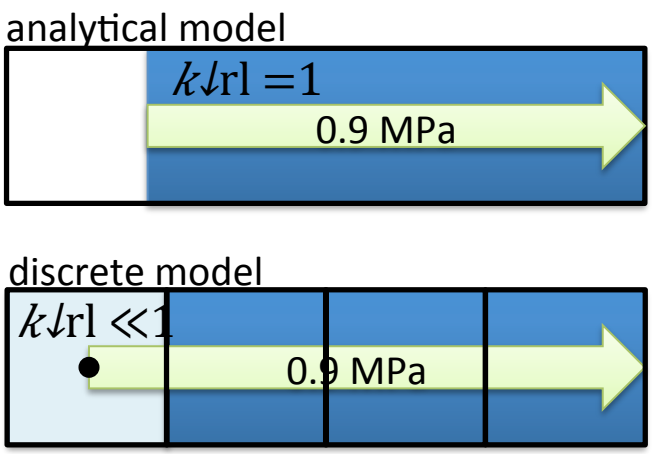
What might cause the steps?

Gas breakthrough phase

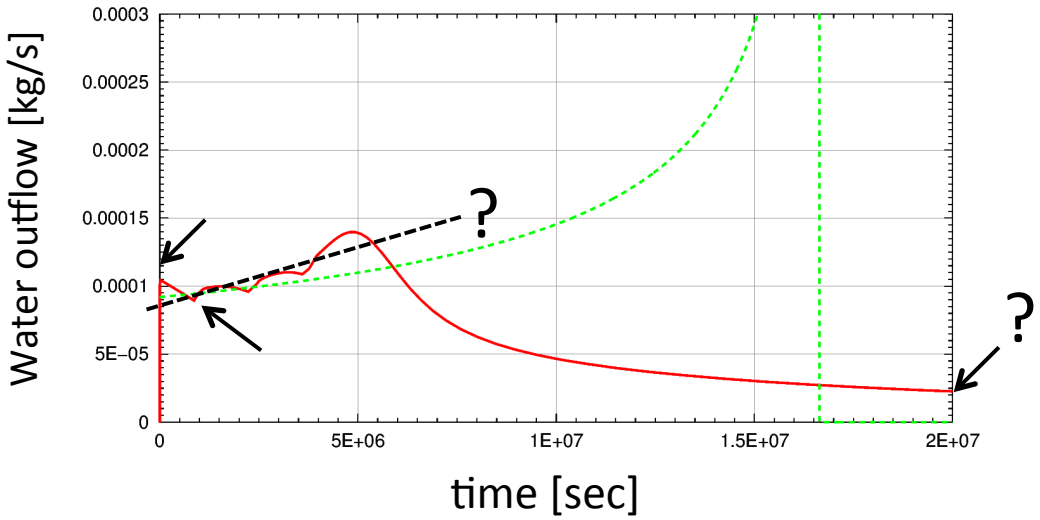


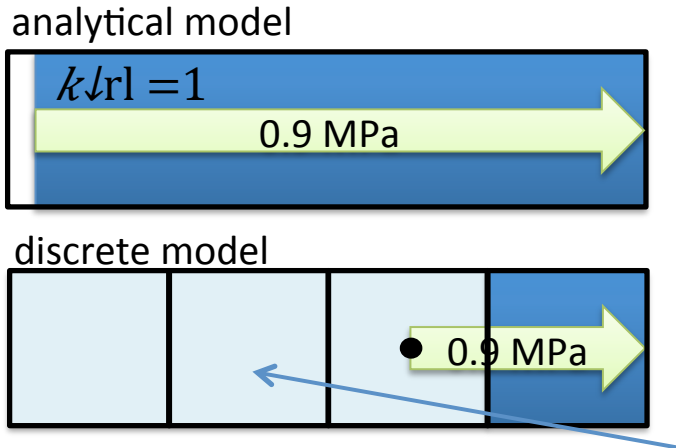
Mobile gas phase carries pressure signal to node
→ Pressure gradient too large
→ **Water outflow too large**

Flushing phase



Pressure gradient too small
Relative liquid permeability too small
→ **Water outflow too small**

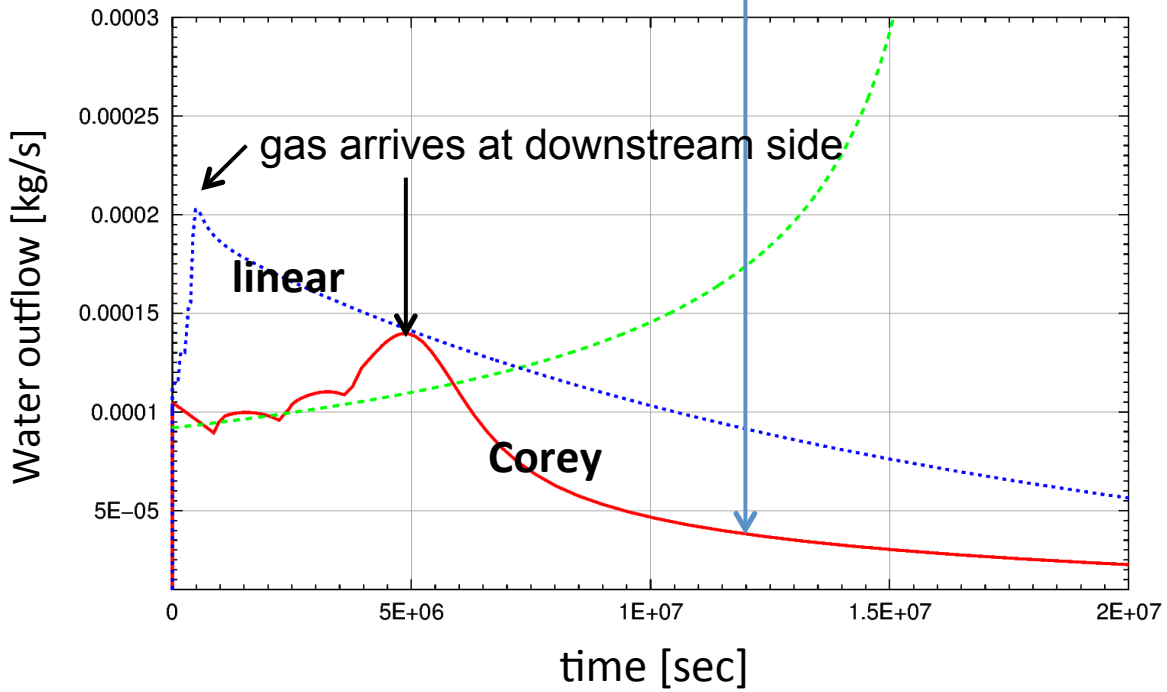




Gas phase front can propagate (upstream weighting)

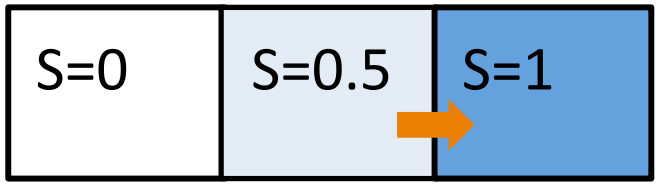
Relative gas permeability controls mobility of phase front

Bypassed water moves slowly
(smaller pressure gradient in gas)

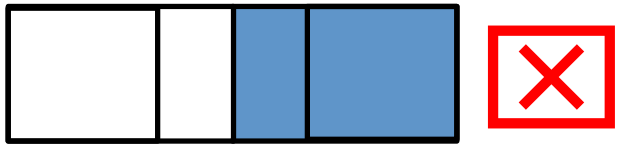


Why is this not correct
for coarse material?

Microscopic interpretation of standard k_r functions

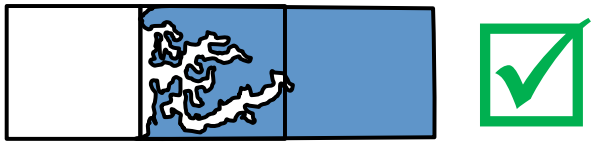


Standard relative permeability functions allow gas flow from second to third element.
What could be an appropriate interpretation on the micro-scale?



stable phase interface
(no gas flow from element 2 to element 3)

- porosity 1 (cavern, tube, vessel, …)
- very coarse grained material (no capillary pressures)
- ~ uniform pore size

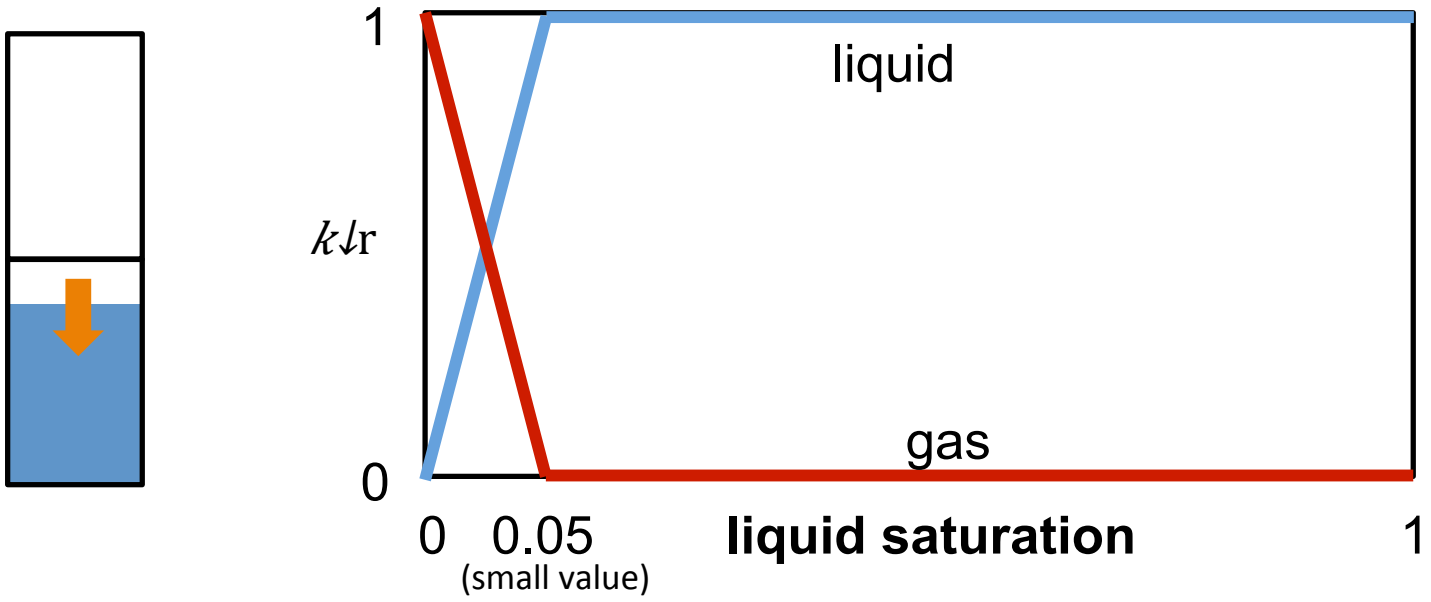


instable phase interface

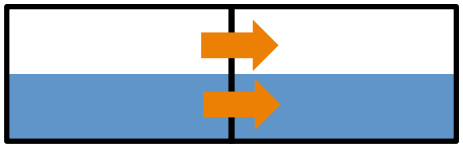
- broad pore size spectrum (water displaced from large pores)
- material inhomogenities
- viscous fingering

Heterogeneous linear relative permeability functions for a stable horizontal water table (use only if gas is located above the water!)

Vertical:



Horizontal: $k_{rl} = S$ and $k_{rg} = 1 - S$ to describe horizontal flow cross section

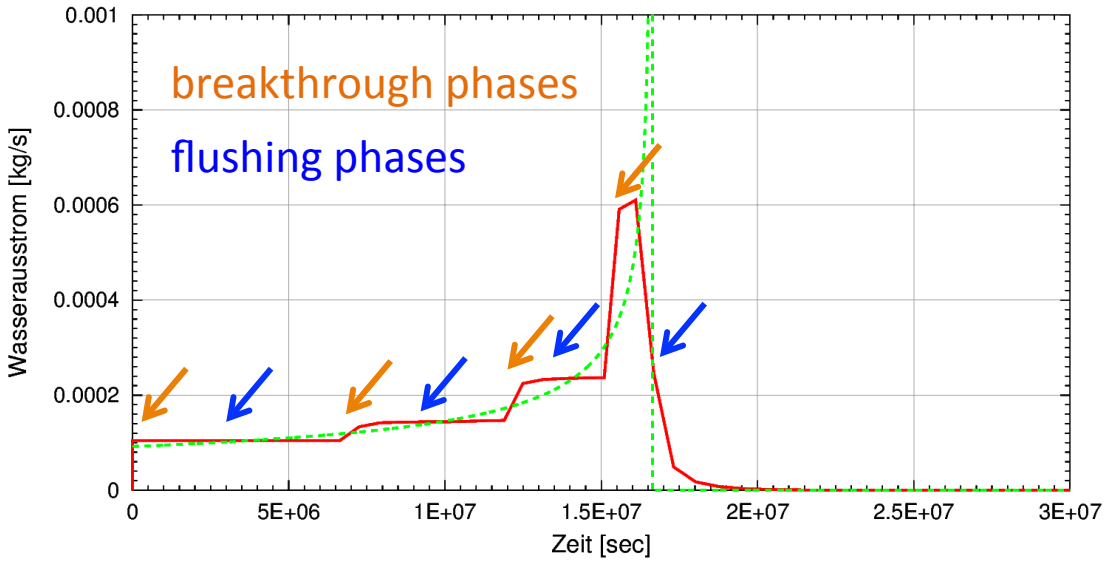


Application

4 elements

Steps still visible

but timing ok



100 elements

(steps probably still there

but small)