Investigating preferential flow dynamics in idealized porous fracture networks via (quasi) 2-D lab experiments

Controls of fracture and matrix properties on flow behavior

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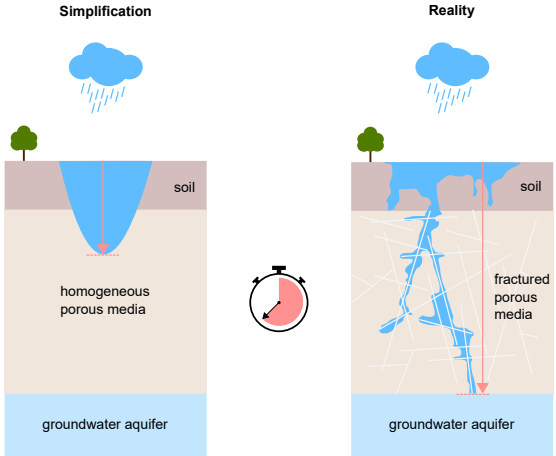
Unsaturated flow in the vadose zone



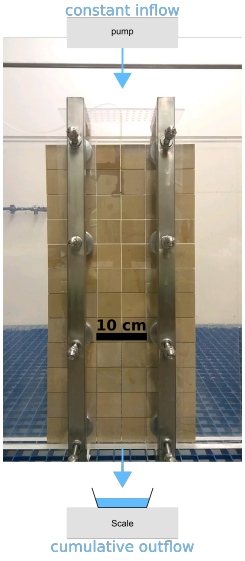
- How can we delineate the control of fractured porous media on flow behavior, especially on the fast preferential flow component, in the vadose zone?

Experimental lab approach: outcrop translation

Outcrop displaying characteristic fracture network features.

Intersection-types:

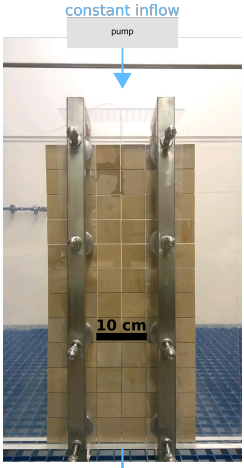
- crossing (X)
- abutting (Y)
- isolating (I)

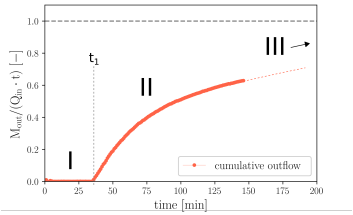


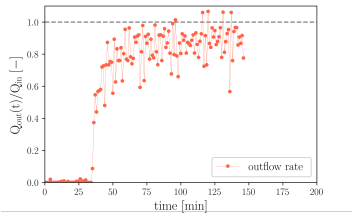
Experiment:

- Simple orthogonal fracture network
- 12 x 6 sandstone slices
- Slice dimension: 5 x 5 x 1 cm
- X-type intersections
- Fracture aperture: 1 mm
- Inflow rates: 0.75 - 3.00 ml/min
- Material used:
  Seeberger sandstone
  (effective porosity = 18.6 %)

Conceptual stages of outflow data

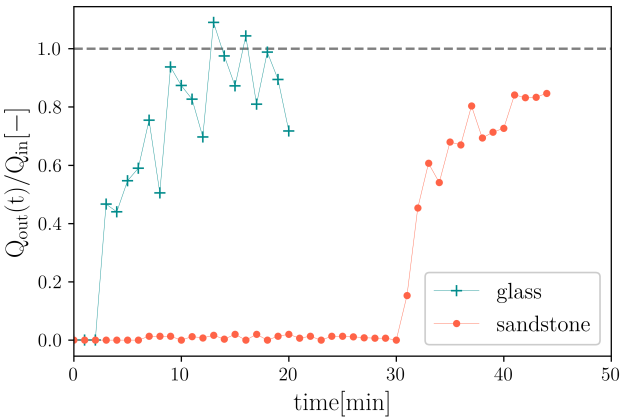






- I Water destributes in the fracture network and pore space
- t_1 First arrival; flow pathway between top and bottom established
- II Pore space adjacent to active fractures mostly reached its saturation limit and outflow dynamics are increasingly controlled by fracture (-network) properties alone
- III: System reaches steady state (outflow = inflow, not the case in this example)

Key control in stage I: matrix imbibiton



Observation:

(1) Arrival time: $t_{1,glass} <<< t_{1,sandstone}$

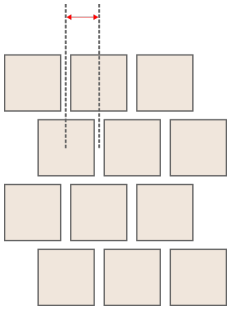
(2) Both show similar outflow pattern

(3) Outflow fluctuations smaller for sandstone

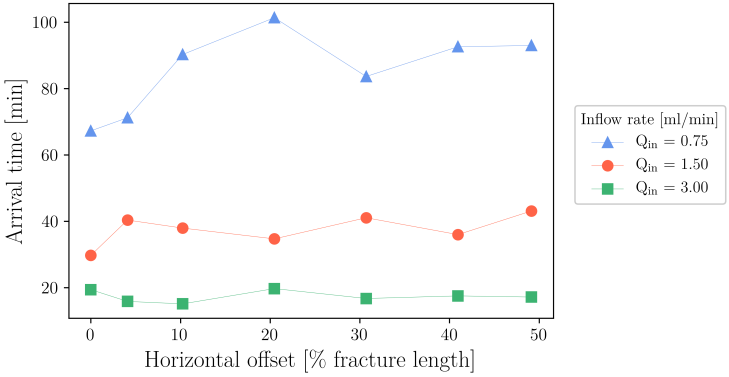
Effect of porous media:

- strongly slowing down fracture flow in stage I
- dampening outflow fluctuations in stage II

Intersection-type and offset: impact on arrival times



Y-type intersection and horizontal offset.

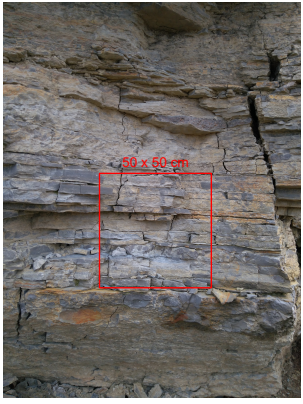


Observation:

- Higher inflow rates result in earlier arrival times
- For a low flow rate a successive increase of the horizontal offset tends to increase arrival times, which is not noticable at higher rates

Conclusion and Outlook

- A sound implementation of the fracture flow retardation by the matrix is crucial when interested in arrival time predictions
- Once a preferential pathway is established between two locations via active fractures, imbibition soon becomes neglectable for flow dynamics
- Y-type intersections and horizontal offsets, which increase the traveling distance between top and bottom of the system (compared to X-type), show no significant correlation with arrival times for higher inflow rates on the scale of observation.
- Further analysis will place emphasis on a physically-based analytical solution for the fracture-matrix interactions in stage I, and, on capturing the fracture network control on the outflow dynamics related to stage II



Percolation experiments in the field at comparable scales in summer/fall 2020.

Questions? Contact me: fruediger@gwdg.de