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Analogue laboratory experiments of preferential flow dynamics in porous fractured media: Importance of fracture intersections and porous matrix imbibition processes

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Infiltration processes in fractured consolidated aquifer systems often exhibit complex gravity-driven flow features and hence tend to develop preferential flow paths along fracture network which contribute to rapid mass fluxes. This behavior is often difficult to model with classical methods such as the Richards equation, as a variety of interacting flow modes, ranging from free-surface flows over droplet and and rivulet flows, control the mass partitioning processes at fracture intersections and within fractures. Here we demonstrate with two different types of laboratory experiments how the complexity of such flows affects the discharge behavior: (1) In order to isolate the mass partitioning process at fracture intersections we use custom-made acrylic cubes to establish a set of vertical fractures (free-surface, bounded by one side only) intersected by horizontal fractures. In order to control the prevailing flow mode we use a multichannel dispenser and set flowrates to critical thresholds for each regime. We then calculate normalized horizontal fracture inflow rates and delineate classical Washburn-type behavior in order to obtain an analytical transfer function for the given system and extended fracture cascades. (2) In order to study the effect of a porous matrix adjacent to the fractures we carried out quasi-2D laboratory experiments of infiltration into complex fracture networks using Seeberger sandstone slices. The system allows to study both the onset of preferential fracture flow dynamics as well as the porous matrix imbibition under dynamics conditions. To study the effect of geometry on discharge dynamics we modify fracture apertures as well as fracture offsets, i.e., the geometry of the fracture intersections. Results show that, despite the complex internal flow dynamics, clear scaling patterns can be observed and the geometrical characteristics are imprinted into the outflow behavior.