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Impact of textural and structural heterogeneity on unsaturated flow and transport through mine waste rock

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In heterogeneous unsaturated conditions, flow paths are not only spatially complex, but may also temporally dynamic, as a function of hydraulic and capillary barriers that form in different places and different times, under a dynamic infiltration regime. We conducted a series of numerical experiments to investigate separately how texture and structure control water and solute distribution. We assume that our material comprises two discrete materials (relatively fine and relatively coarse), which is the case in certain waste rock piles. We generated hypothetical profile structures with multiple point statistics. The simulations were forced with repeated yearly time-series of net infiltration representative of seasonally frozen conditions. The high snowmelt infiltration flux generated patterns of contrasting water content and solute concentration that reflected the textural spatial distribution. In lifts with significant textural contrasts, large hydraulic and capillary barriers were present, and contrasting patterns of flow and solute concentration persisted through the year. When these textural contrasts were smaller, smoothing occurred during the low-infiltration period, such that flowpaths became more uniform. Large amounts of solutes flushed from the lifts, with leaching efficiencies between 70-85%. These results provide increasing evidence of the dominance of matrix flow and leaching in waste rock dumps.