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New methods to determine air-entry values of porous media

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Air-entry into a saturated porous medium occurs at a critical capillary pressure that must be overcome for air invasion. We present new experimental and numerical methods to determine air-entry value, an important parameter separating saturated from unsaturated conditions and useful for modeling flow and transport in porous media. We determined air-entry value experimentally based on evaporation from water saturated media using vertical columns equipped with tensiometers. Initially, the tensiometer measures hydrostatic pressure above its reference depth, however, as soon as evaporation commences, menisci form at the surface and capillary pressure decreases until air invades the surface and drying front forms. Subsequent pressure measurements simply track the drop in water level with the receding drying front superimposed on this initial "jump" associated with air entry. The initial and rather abrupt pressure drop is independent of tensiometer position or column geometry.
Alternatively, we computed the air-entry value based on three-dimensional pore space images deduced from X-ray imaging and from sphere packing models. We have used particle size in the ranges of 0.1 to 0.5 and 0.3 to 0.9 mm scanned with spatial resolution of 11 microns. To relate air-entry value to pore space properties, various geometrical attributes were determined (chord length, distance transform, pore size and connectivity). We found that the mode of pore size distribution (deduced by inserting spherical elements) provides reasonable estimate for air-entry value. Using morphological pore-network models, the process of air invasion was simulated and results were in good agreement with measurements. To predict air-entry values for porous media based on particle size distribution only, a sphere packing algorithm was applied to generate pore scale images. While first results for coarse textured media are in good agreement with measured values, additional comparison with fine textured media must be studied.