Capillarity in Porous Media, on Micro- and Macroscale, Revisited

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In many soil and aquifer systems, one encounters simultaneous movements of two or more immiscible fluids. These systems are modeled using a modified form of Darcy's law, mass or volume balance equations, and an empirical relationship between capillary pressure and saturation. In this lecture, Hassanizadeh will:

- Explain the general understanding that capillary pressure is equal to the difference in pressures of two fluids. At microscale, this difference is given by the Young-Laplace equation, which prescribes an inverse relationship with the mean radius of curvature. At macroscale, the difference in fluid pressures is assumed to be an algebraic empirical function of saturation, as mentioned above.
- Provide a unifying approach to the theory of capillarity based on rational thermodynamics.
- Present alternative definitions of capillary pressure on both micro- and macroscales. In particular, Hassanizadeh will make a clear distinction between capillary pressure and pressure difference of fluids.

- Show that the difference in fluid pressures is a function of boundary conditions and dynamic properties of the system, such as flow rate or dynamic viscosities, based on theoretical, experimental, and computational results.
- Propose that the capillary pressure must be an intrinsic property of the fluids/solid system and independent of dynamics of the system.
- Introduce specific interfacial area (area of fluid/ fluid interfaces per unit volume of porous medium) as a new state variable to account for the fact that capillary pressure is a surface phenomenon and not a volumetric one.
- Present theoretical, experimental, and computational evidences that show the empirical capillary pressure-saturation curve should be replaced with the capillary pressure-saturation-interfacial area surface rooted in thermodynamic theory.