A statistical mechanics framework for porous media flow

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The central problem in the physics of multiphase flow in porous media is to find a proper description of the flow at scales large enough so that the medium may be regarded as a continuum: the scale-up problem. It is the same kind of problem as finding a proper description of fluids at the continuum level when we know that they consist of molecules; a problem that in this case was solved almost two hundred years ago with the introduction of the Navier-Stokes equation. So far, the only workable approach to the multiphase flow scale-up problem has been a set of phenomenological equations that have obvious weaknesses. Attempts at going beyond this relative permeability theory have so far never led to practical applications due to exploding complexity.

Edwin T. Jaynes proposed in the fifties a generalization of statistical mechanics to non-thermal systems based on the information theoretical entropy of Shannon. We have used this approach to construct a description of immiscible two-phase flow in porous media at the continuum scales, which is directly related to the physics at the pore scale, and with a level of complexity that is manageable [1-6]. The approach leads to a thermodynamics-like formalism at the continuum scale with all the relations between variables that ``normal" thermodynamics has to offer.

References

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