Contribution ID: **478** Type: **Poster**

Multiphase micro-continuum models: an hybrid-scale approach

Tuesday, 15 May 2018 17:15 (1h 30m)

Advances in imaging technologies and high-performance computing are making it possible to perform Direct Numerical Simulation (DNS) of flow processes at the pore scale; nevertheless, the restrictions on the physical size of the sample (porous rock) that can be fully resolved using Navier-Stokes-based DNS are quite severe. For samples on the order of a cm 3 , the complexity of the spatial heterogeneity of the pore space precludes Navier-Stokes-based DNS. Even for smaller sizes, some microstructures are below the instrument resolution and are not resolved in the image. To deal with this challenge of having a wide range of length scales -even for 'small' systems, we describe a micro-continuum formalism, based on the Darcy-Brinkman-Stokes (DBS) equation where flow and transport phenomena are governed by Navier-Stokes equations in the resolved regions (voxels containing fluids only) and by Darcy in the unresolved (solid-fluid aggregates) regions [1]. This hybrid-scale modeling framework has been used successfully to compute the flow in a digital sandstone imaged with X-ray microtomography including sub-voxel porosity [2]. The micro-continuum DBS approach has also been used to simulate dissolution phenomena at the pore-scale under single-phase conditions [3].

In this work, the micro-continuum formulation is extended to multiphase flow where two-immiscible fluids share the pore-space involving surface tension force and moving contact lines at the mineral surfaces. The multiphase micro-continuum model is used to investigate multiphase system with reactive transport and is compared with microfluidic experiments.

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Primary authors: SOULAINE, Cyprien (Stanford University); ROMAN, Sophie (Institut des Sciences de la Terre d'Orléans); Prof. TCHELEPI, Hamdi (Stanford University)

Presenter: SOULAINE, Cyprien (Stanford University)

Session Classification: Poster 2

Track Classification: MS 4.18: Coupling multi-physic at the pore-scale: experimental and numerical investigation