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A new multiscale model for flow and transport in unconventional shale oil reservoirs

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ABSTRACT

A new multiscale computational model for two-phase gas/oil flow in a multiporosity shale formation composed of three levels of porosity associated with nano/micro pores and hydraulic fractures is rigorously constructed within the framework of the homogenization procedure in conjunction with the Discrete Fracture Modeling, where fractures are treated as (n-1) interfaces (n=2, 3) immersed in the domain occupied by the matrix. Effective equations are obtained by upscaling the microstructural information of the shale oil formation with matrix composed of three distinct solid phases: the organic matter, constituted by kerogen aggregates containing particles and nanopores with adsorbed gas, and the pyrobitumen network, also containing an organic solid with micropores filled by tight oil and dissolved gas, along with the inorganic solid composed of clay, quartz and calcite, assumed impermeable and free of adsorption. Such distinct solid phases are separated from each other by the network of interparticle pores. Together with the pyrobitumen such a network form the pathways for multiphase flow in the matrix whereas the kerogen aggregates are treated as disconnected inclusions playing the role of storage sites for adsorbed gas. The homogenization of the multiphase flow model of black oil type gives rise to new pressure and saturation equations with effective coefficients strongly correlated with the shale microstructure, volume fractions and total organic content (*TOC*). Constitutive laws for the effective hydraulic conductivity and retardation parameter, which captures adsorption of methane in the nanopores, are numerically reconstructed by solving the local cell problems arising from the homogenization procedure. In particular the partition coefficient is computed from adsorption isotherms rigorously constructed within the framework of the Thermodynamics of confined gases seated on the Density Functional Theory (DFT). The effective equations in the matrix resemble in form of a generalized black oil model coupled with the two-phase flow model posed in the subdomain occupied by the network of hydraulic fractures. A macroscopic model is obtained by averaging the mass conservation equation across the fracture aperture giving rise to reduced balance laws posed in a network of reduced (n-1)-dimension (n=2, 3) supplemented by a source term arising from the jump in the oil/gas fluxes in the shale matrix. The resultant coupled Discrete Fracture/Multiscale model consists of a first attempt at constructing a rigorous correlation between the nature of the macroscopic multiphase flow equations and the local shale-microstructure mainly

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