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A new computational strategy for solving two-phase flow in strongly heterogeneous poroelastic media of evolving scales

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SUMMARY

We develop a new computational methodology for solving two-phase flow in highly heterogeneous porous media incorporating geomechanical coupling subject to uncertainty in the poromechanical parameters. Within the framework of a staggered-in-time coupling algorithm, the numerical method proposed herein relies on a Petrov–Galerkin postprocessing approach projected on the Raviart–Thomas space to compute the Darcy velocity of the mixture in conjunction with a locally conservative higher order finite volume discretization of the nonlinear transport equation for the saturation and an operator splitting procedure based on the difference in the time-scales of transport and geomechanics to compute the effects of transient porosity upon saturation. Notable features of the numerical modeling proposed herein are the local conservation properties inherited by the discrete fluxes that are crucial to correctly capture the fingering patterns arising from the interaction between heterogeneity and nonlinear viscous coupling. Water flooding in a poroelastic formation subject to an overburden is simulated with the geology characterized by multiscale self-similar permeability and Young modulus random fields with power-law covariance structure. Statistical moments of the poromechanical unknowns are computed within the framework of a high-resolution Monte Carlo method. Numerical results illustrate the necessity of adopting locally conservative schemes to obtain reliable predictions of secondary recovery and finger growth in strongly heterogeneous deformable reservoirs. Copyright © 2011 John Wiley & Sons, Ltd.

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KEY WORDS: two-phase flow; poroelasticity; stochastic modeling; heterogeneity; power law covariance; locally conservative numerical schemes; Petrov-Galerkin; finite volume method; Raviart-Thomas; Monte Carlo simulations

1. INTRODUCTION

It is well known that during the exploitation in structurally weak unconsolidated geological formations production-induced pore pressure changes may trigger redistribution of effective stresses in the rock-skeleton-inducing compaction of the medium and the consequent land subsidence. The role of geomechanics in subsurface reservoirs is becoming increasingly important as deeper formations are detected and explored [1, 2]. Accurate predictions of fluid withdrawal in weak rocks require detailed flow simulation and mechanical deformation models demanding precise understanding of the geomechanical factors affecting the hydrodynamics. The interaction between geomechanical response and multiphase flow involves highly complex physics including several coupling mechanisms [3, 4].

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