Geophysical Research Abstracts
Vol. 12, EGU2010-13863, 2010
EGU General Assembly 2010

Velocity dependence of biphasic flow structuration: steady-state and oscillating flow effects

Ken Tore Tallakstad (1), Mihailo Jankov (1), Grunde Løvoll (1), Renaud Toussaint (2), Knut Jørgen Måløy (1), Eirik Grude Flekkøy (1), Jean Schmittbuhl (2), Gerhard Schäfer (3), Yves Méheust (4), and Henning Arendt Knudsen (1)

(2) Institut de Physique du Globe de Strasbourg, CNRS / Universite de Strasbourg, Geophysics, Strasbourg Cedex, France (renaud.toussaint@eost.u-strasbg.fr), (1) Complex, Physics Department, University of Oslo, Norway, (3) Lhyges, CNRS/University of Strasbourg, France, (4) Geosciences Rennes, CNRS/University of Rennes I

We study various types of biphasic flows in quasi-two-dimensional transparent porous models. These flows imply a viscous wetting fluid, and a lowly viscous one. The models are transparent, allowing the displacement process and structure to be monitored in space and time. Three different aspects will be presented: 1. In stationary biphasic flows, we study the relationship between the macroscopic pressure drop (related to relative permeability) and the average flow rate, and how this arises from the cluster size distribution of the lowly viscous fluid [1]. 2. In drainage situations, we study how the geometry of the invader can be explained, and how it gives rise to apparent dynamic capillary effects. We show how these can be explained by viscous effects on evolving geometries of invading fluid [2]. 3. We study the impact of oscillating pressure fields superimposed to a background flow over the flow regimes patterns [3].

Steady-State Two-Phase Flow in Porous Media: Statistics and Transport Properties. First, in stationary flow with a control of the flux of both fluids, we show how the pressure drop depends on the flow rate. We will show that the dynamics is dominated by the interplay between a viscous pressure field from the wetting fluid and bubble transport of a less viscous, nonwetting phase. In contrast with more studied displacement front systems, steady-state flow is in equilibrium, statistically speaking. The corresponding theoretical simplicity allows us to explain a data collapse in the cluster size distribution of lowly viscous fluid in the system, as well as the relation $|\nabla P| \propto \sqrt{Ca}$. This allows to explain so called relative permeability effects by the morphological changes of the cluster size distribution.

Influence of viscous fingering on dynamic saturation-pressure curves in porous media. Next, we study drainage in such models, and investigate the relationship between the pressure field and the morphology of the invading fluid. This allows to model the impact of the saturation changes in the system over the pressure difference between the wetting and non wetting phase. We show that the so-called dynamic effects referred in the hydrology literature of experimentally measured capillary pressure curves might be explained by the combined effect of capillary pressure along the invasion front of the gaseous phase and pressure changes caused by viscous effects. A detailed study of the structure optically followed shows that the geometry of the invader is self-similar with two different behaviors at small and large scales: the structure corresponds to the ones of invasion percolation models at small scales (capillary fingering structures with fractal dimension D=1.83), whereas at large scales, viscous pressure drops dominate over the capillary threshold variations, and the structures are self-similar fingering structures with a fractal dimension corresponding to Dielectric Breakdown Models (variants of the DLA model), with D $\simeq$ 1.5. The cross-over scale is set by the scale at which capillary fluctuations are of the order of the viscous pressure drops. This leads physically to the fact that cross-over scale between the two fingering dimensions, goes like the inverse of the capillary number. This study utilizes these geometrical characteristics of the viscous fingers forming in dynamic drainage, to obtain a meaningfull scaling law for the saturation-pressure curve at finite speed, i.e. the so-called dynamic capillary pressure relations. We thus show how the micromechanical interplay between viscous and capillary forces leads to some pattern formation, which results in a general form of dynamic capillary pressure relations. By combining these detailed informations on the displacement structure with global measures of pressure, saturation and controlling the capillary number Ca, a scaling relation relating pressure, saturation, system size and capillary number is developed. By applying this scaling relation, pressure-saturation curves for a

wide range of capillary numbers can be collapsed.

Effects of pressure oscillations on drainage in an elastic porous medium: The effects of seismic stimulation on the flow of two immiscible fluids in an elastic synthetic porous medium is experimentally investigated. A wetting fluid is slowly evacuated from the medium, while a pressure oscillation is applied on the injected non-wetting fluid. The amplitude and frequency of the pressure oscillations as well as the evacuation speed are kept constant throughout an experiment. The resulting morphology of the invading structure is found to be strongly dependent on the interplay between the amplitude and the frequency of the applied pressure oscillations and the elasticity of the porous medium. Different combinations of these properties yield morphologically similar structures, allowing a classification of structures that is found to depend on a proposed dimensionless number.

[1] Tallakstad, K.T., H.A. Knudsen, T. Ramstad, G. Løvoll, K.J. Måløy, R. Toussaint and E.G. Flekkøy , Steady-state two-phase flow in porous media: statistics and transport properties, Phys. Rev. Lett. 102, 074502 (2009). doi:10.1103/PhysRevLett.102.074502 [2] Løvoll, G., M. Jankov, K.J. Måløy, R. Toussaint, J. Schmittbuhl, G. Schaefer and Y. M´eheust, Influence of viscous fingering on dynamic saturation-pressure curves in porous media, submitted to Transport In Porous Media, (2010) [3] Jankov, M., G. Løvoll, H.A. Knudsen, K.J. Måløy, R. Planet, R. Toussaint and E.G. Flekkøy; Effects of pressure oscillations on drainage in an elastic porous medium, Transport In Porous Media, in press (2010).