Mathematical Geosciences

Mathematical and Numerical Modeling in Porous Media: Applications in Geosciences (Díaz Vera, M.A., Sahay, N., Coronado, M., and Ortiz Tapia, A., Eds.) CRC Press, 2012, ISBN: 978-0-415-66537-7

--Manuscript Draft--

Manuscript Number:	MATG1104
Full Title:	Mathematical and Numerical Modeling in Porous Media: Applications in Geosciences (Díaz Vera, M.A., Sahay, N., Coronado, M., and Ortiz Tapia, A., Eds.) CRC Press, 2012, ISBN: 978-0-415-66537-7
Article Type:	Book Review
Keywords:	
Corresponding Author:	J. Jaime Gómez-Hernández Universitat Politècnica de València Valencia, SPAIN
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Universitat Politècnica de València
Corresponding Author's Secondary Institution:	
First Author:	J. Jaime Gómez-Hernández
First Author Secondary Information:	
Order of Authors:	J. Jaime Gómez-Hernández
Order of Authors Secondary Information:	
Abstract:	

Mathematical and Numerical Modeling in Porous Media: Applications in Geosciences (Díaz Viera, M.A., Sahay, N., Coronado, M., and Ortiz Tapia, A., Eds.) CRC Press, 2012, ISBN: 978-0-415-66537-7

J. Jaime Gómez-Hernández

Research Institute of Water and Environmental Engineering, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain

jgomez@upv.es

http://jgomez.webs.upv.es

The book *Mathematical and Numerical Modeling in Porous Media: Applications in Geosciences* contains selected contributions from two congresses held in Mexico in 2009 and 2010. It is published as volume 6 of the *Multiphysics Modeling* series by CRC Press/Balkema. The papers are organized in four sections under the headings, *Fundamental Concepts*, *Flow and Transport, Statistical and Stochastic Characterization* and *Waves.* This organization is probably the only nexus among the papers, which display large heterogeneity in content, quality and English usage. Regarding the last item, a native English editor should have proofread all papers; there are too many typos left, and too many syntactically incorrect constructions. The reader will encounter very good papers with lengthy and detailed descriptions of the numerical implementation of complex coupled phenomena in porous media; but also bad ones with superficial descriptions of the methods used and difficult to sustain conclusions. All in all, the book lacks the thread that could transform a collection of papers into a reference work on the mathematical and numerical modeling of porous media. The book is written mostly by petroleum engineering, with almost no reference to the work on porous media done in other disciplines, such as hydrogeology; for this reason, the porous media scientist or engineer foreign to the nomenclature used in petroleum engineering may seem lost even though the processes studied are exactly the same they are used to work with.

Section 1 groups three papers on fundamental concepts. The reader is recommended to skip the first chapter on relative permeability. It is not acceptable to publish a paper including symbols without explanation, figures with no labels in the axes, or an appendix full of meaningless equations. The author of this paper claims that he was the first one writing the “true” multiphase equations, but his explanation of simple concepts such as Darcy’s law or the effective permeability associated to a layered media are obscure and difficult to understand.

The second chapter on upscaling and hybrid models goes in great detail in the analysis of reactive transport and how upscaled equations are derived, it presents a phase diagram to establish when the upscaling equations do not hold and proposes a hybrid model in which parts of the domain are modeled at the pore scale and parts are modeled by the upscaled equation using a continuum approach. The text is rigorous, based on papers published by the authors. They end up recognizing that finding out the boundary conditions at the pore scale (that is, the pore geometry) is a tough problem, but even so, they explain how to implement their approach into an existing numerical code.

The third chapter is a nice overview of the formulation of thermoporoelasticity in the context of subsurface fluid flow, it is dense but quite clean, ending with a compact formulation for the dynamic poroelastic phenomenon, which later is demonstrated in a simple 2D example of pumping in a confined aquifer. It is unfortunate that the results shown are somehow controlled by the size and shape of the finite elements used in the discretization.

Section 2 groups five papers about flow and transport in porous media. The fourth chapter presents an optimization method to fit the analytical solution of a tracer test in either a homogeneous reservoir or a fractured one by transforming into Laplace space the data themselves and then doing the fitting there as opposed to doing the optimization in real space. Apparently their approach is almost a replicate of the approach by Roumboustos quoted in the paper. It is of interest only when the analytical solution is available in Laplace space but not in real space; otherwise it is best to perform the optimization in real space.

The fifth chapter describes clearly and with lots of detail the analytical formulation for the coupling of subsurface flow, mass transport and microbial growth, and the implications that the microbial growth will have in the dynamic evolution of both porosity and permeability due to clogging. The numerical solution of the coupled equations is carried out with a commercial program and the authors demonstrate how porosity and permeability change in time as a function of the adsorption/desorption coefficients of the microorganisms.

The sixth chapter arguments on the interest of using tracer tests to characterize underground formations containing conductive faults. The authors propose a very simple conceptual model with an injector well and a producer well at opposite sides of a conductive fault, and analyze the cases in which the fault is open or closed. The conceptual model is too simplistic, but it is amenable to analytical solutions. These solutions are compared with the results obtained from a numerical model, to find a good agreement when fluxes are dominated by the injector-producer pair, and an acceptable agreement when the fluxes are dominated by the fault. The paper lacks a final test against a real tracer test to validate the conceptual model itself.

The seventh chapter presents volume-average equations for in-situ combustion. To the standard multiphase flow state equations preserving mass and momentum, an additional energy conservation equation is coupled aimed to model the temporal evolution of temperature, and thus, the potential combustion of coke. The derivation of the partial differential equations is rigorous, with indication of the hypotheses needed to establish them. A short description of the numerical implementation is included, too. The model is validated against the experimental results obtained in a combustion tube containing a mixture of sand, water and oil, showing a good agreement between numerical predictions and experimental observations.

The eighth paper, the longest one in the book, contains an exhaustive description of the mathematical model of advection-diffusion in porous media in two dimensions considering two phases (oil and gas) and three components (oil, gas and tracer), followed by an exhaustive description of the numerical model used to solve the mathematical model, including the solution method used with the final set of algebraic equations. It is disappointing that after 36 pages of formulae, the validation is limited to one and a half pages and a very simple example. The authors warn the reader that the model is still under validation, specifically in relation with the prediction of tracer concentrations.

Section 3 contains four papers dealing with statistical and stochastic characterization plus a paper difficult to classify in any section. The ninth chapter describes the construction of a 3D geostatistical model of the facies in a given reservoir. The paper reads as a technical report with a good description of the formation and of the data used to construct the model, but the geostatistical part is weaker. The authors use a Gaussian variogram to model a specific facies, when it is well known that Gaussian variograms are not valid for discontinuous variables (unless the authors refer to the variogram of the underlying Gaussian random function that they use later in the truncated Gaussian simulation). There is no information on how the truncated Gaussian simulation is performed, on how the truncation thresholds were chosen, or how the variogram of the underlying random function was defined. The impression of this reviewer is that the authors apply a powerful commercial tool for reservoir characterization without a thorough understanding of the underlying concepts of the methods used.

The tenth chapter presents a non-parametric approach to model the relationship between permeability, shear wave velocity and porosity based on a trivariate copula. The authors demonstrate, using an experimental data set, that permeability predictions from shear velocity and porosity using a trivariate copula are better than from porosity alone using a bivariate copula.

The eleventh chapter starts establishing a non-parametric bivariate copula to model the bivariate dependency between permeability and porosity. The purpose of the paper is unclear to this reviewer, and the implications of using a non-parametric bivariate distribution based on copulas versus other bivariate representations remains unknown.

The twelfth paper presents the steps taken to generate stochastic realizations of a vuggy carbonate media. It starts by a characterization of the porosity of a core fragment by X-ray computed tomography; then, from the porosity distribution derived from the CT image a number of indicator variables are built. From these indicator images, the value of porosity of 18.7% is, somehow arbitrarily selected to define the indicator variable that “best” characterizes the porosity of the sample (Notice that if a different color scale had been used to display porosities in Figure 12.5, a different threshold would have been selected, and notice also, that the indicator image in this figure corresponds to a porosity threshold of 11.9% and not to the one reported.) The simulation of a map of continuous porosity values proceeds in two steps, first use indicator simulation to generate three porosity categories, corresponding to matrix, high porosity halo and vugs (this simulation is performed in two steps), then simulate three images for the porosities, one for each of the three categories, these three images are merged together using the categorical map generated by indicator simulation. Finally, an empirical regression curve is used to derive permeabilities from the simulated porosity values. The paper ends with an analysis of the effect of the matrix proportion in the effective permeability of the core, reproducing well-known results, which are referenced.

The thirteenth chapter presents a stochastic model in two dimensions of the grain distribution in a rock sample using the pluriGaussian method. Only the reader familiar with the pluriGaussian method will be able to follow the contents since the explanation given by the authors is quite incomplete. The paper is, as the authors recognize, a preliminary analysis of the application of the pluriGaussian method to generate categorical maps with three facies; the authors do not enter into the description of the variograms used to generate the two underlying Gaussian random functions, which, at the end, are the responsible of the mismatch between the input variograms and the variograms of the images generated.

The fourteenth chapter is a clear outlier in the book since it discusses metadistances in prime numbers applied to integral equations. This reviewer does not feel capable of writing any comment about it.

Section 4 contains the last two papers, about waves. Again, these two papers fall outside the specialty of this reviewer, who cannot give any critical comment about them. The fifteenth paper analyzes the physical meaning of slow shear waves using a viscosity-extended Biot theory. It starts reviewing the viscosity-extended theory, and continues with the analysis of the conversion scattering mechanism of a fast compressional wave into a slow shear wave in randomly heterogeneous media. The paper ends with a physical interpretation of the slow shear wave conversion scattering process.

The sixteenth and last chapter analyzes the coupling of porosity and saturation waves in porous media. These two types of waves can be coupled, the modeling of such a coupling is important for enhanced oil recovery. The paper presents a detailed description of the governing equations of each wave separately, and then of the coupling, and ends with a numerical illustration.