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Modelling of nonlinear processes in deforming and reacting porous saturated rocks: different regimes for reaction front propagation

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Developing new numerical reactive transport models is essential for predicting and describing natural and technogenic petroleum and geological processes at different scales. Examples of such processes are pore fluid migration in subduction zones, causing seismic and volcanic activity, chemical and thermal enhanced oil recovery activities, etc. New numerical reactive transport models must be validated against analytical or semi-analytical solutions to ensure its correct numerical implementation. In this study, we construct thermo-hydro-chemo-mechanical model which takes into account multi-phase fluid flow in porous matrix associated with inter- and intra-phase chemical reactions with significant temperature and volume effect and treats porosity and permeability evolution. All equations are derived from basic principles of conservation of mass, energy, and momentum and the thermodynamic admissibility of all equations is verified. We solve the proposed system of equations both with a finite difference approach on a staggered grid and characteristic-based Lax-Friedrichs different order schemes to treat the disintegration of discontinuities. Resolving the problem of large discrepancies during the time evolution of coupled physical processes is challenging. For that, we use pseudo-iterations which force slow modes to attenuate quickly. Furthermore, we perform dimensionless analysis of the proposed model which allows us to detect proper dimensionally independent, dimensionally dependent and non-dimensional parameters. A new semi-analytical is derived which is based on a relaxation method of defining the stationary solution of system of partial differential equations, so detection specific regimes for reaction front propagation are possible. As a result, reaction front velocity dependence on Peclet, Damkohler and Lewis nondimensional parameters is obtained.