Parametric sensitivity to gas-entry pressure in 2-phase flow models in a deep geologic disposal of radioactive waste

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TOPIC 03: Fluid (Water, gas) transport and solute migration

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Abstract

After closure of a deep geological disposal (DGD), some gases will be generated through a number of processes. As gas concentration rises, a separate gas phase may be formed. If gas pressure exceeds gas entry pressure, a 2-phase flow may occur, potentially resulting in a decrease of the repository performance [1]. Therefore, a demonstration of the long-term safety of the repository requires a good characterization of hydraulic properties of its host rock and engineered barriers near full water saturation.

A number of studies have focused on air-entry pressure (Pe) as a parameter to correct the classical van Genuchten-Mualem (VGM) model used in unsaturated soil hydrology for water retention and permeability curves [2], [3]. However, numerical simulations with gas-entry pressure effects in 2-phase flows are not available. In this work, a new approach is developed, consistent with experimental measurements of hydraulic properties of clay host rock and clay-based materials. As a first step, the RETC code [4] is modified by implementing a modified VGM model [3] accounting for gas-entry pressure, and by introducing gas permeability in addition to water permeability and water retention curve. All these hydraulic properties are combined in a single objective function. Figure 1 shows the resulting simultaneous fit to data of hydraulic properties of the argillaceous layer of Callovo-Oxfordian (COx) rock which has been chosen by Andra as a possible host-rock for deep geological disposal of intermediate-level long-lived and high-level radioactive wastes in eastern France.

To use this new model with gas-entry pressure parameter, modifications were necessary in the TOUGH2 code [6]. Thus, the capillary pressure is set as primary state variable instead of gas saturation. After numerical verification of the revised version of TOUGH2, the Andra's PGZ1 experiment [7] is modeled (Figure 2). The preliminary results show that a non-zero gas entry pressure leads to considerably higher gas pressures than those simulated by the classical model with Pe=0 while keeping all other materials parameters unchanged.

The optimal fit shown in **Figure 1** indicates that hydraulic properties are sensitive to Pe near full water saturation. **Figure 2** confirms such sensitivity and indicates that in order to predict the fate of gases in DGD a careful estimation of Pe is necessary. Further work includes accounting for the hysteresis effect, and simulations at large space-time scales in the DGD.

References :

[1] Saâdi et al. (2018). A simplified mechanistic for studying the impact of 'Piston Effect' on water displacement in a geep geological repository for radioactive waste.TOUGH Symposium, LBNL.
[2] Ababou (2018).Capillary Flows in Heterogeneous and Random Porous Media 1, ISTE & Wiley.
[3] Vogel et al. (2001). Effect of the shape of the soil hydraulic functions near saturation on variably-saturated flow predictions. Advances in Water Resources 133–44.
[4] Van Genuchten et al. (1991). The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils . Report EPA/600/2-91/065 R. S. Kerr Environ. US.
[5] Gerard P. (2011). Impact du transfert des gaz sur le comportement poro-mécanique des matériaux argileux. PhD thesis, Liège.
[6] Pruess, K., C. Oldenburg, and G. Moridis, TOUGH2 User's Guide, Version 2.0, Report LBNL-43134, Berkeley, Calif., 1999.
[7] ANDRA (2012). Rapport Forge, D5.13.

Figure 1. Optimal simultaneous fit of COx hydraulic properties. The data points are borrowed from Gerard P.(2011) [5]: (a) water retention curve $S_W(h)$; (b) absolute water permeability $K_W(h)$; (c) absolute gas permeability $K_G(h)$. We have chosen to constrain full water saturation and intrinsic permeability to be the same in the two models.

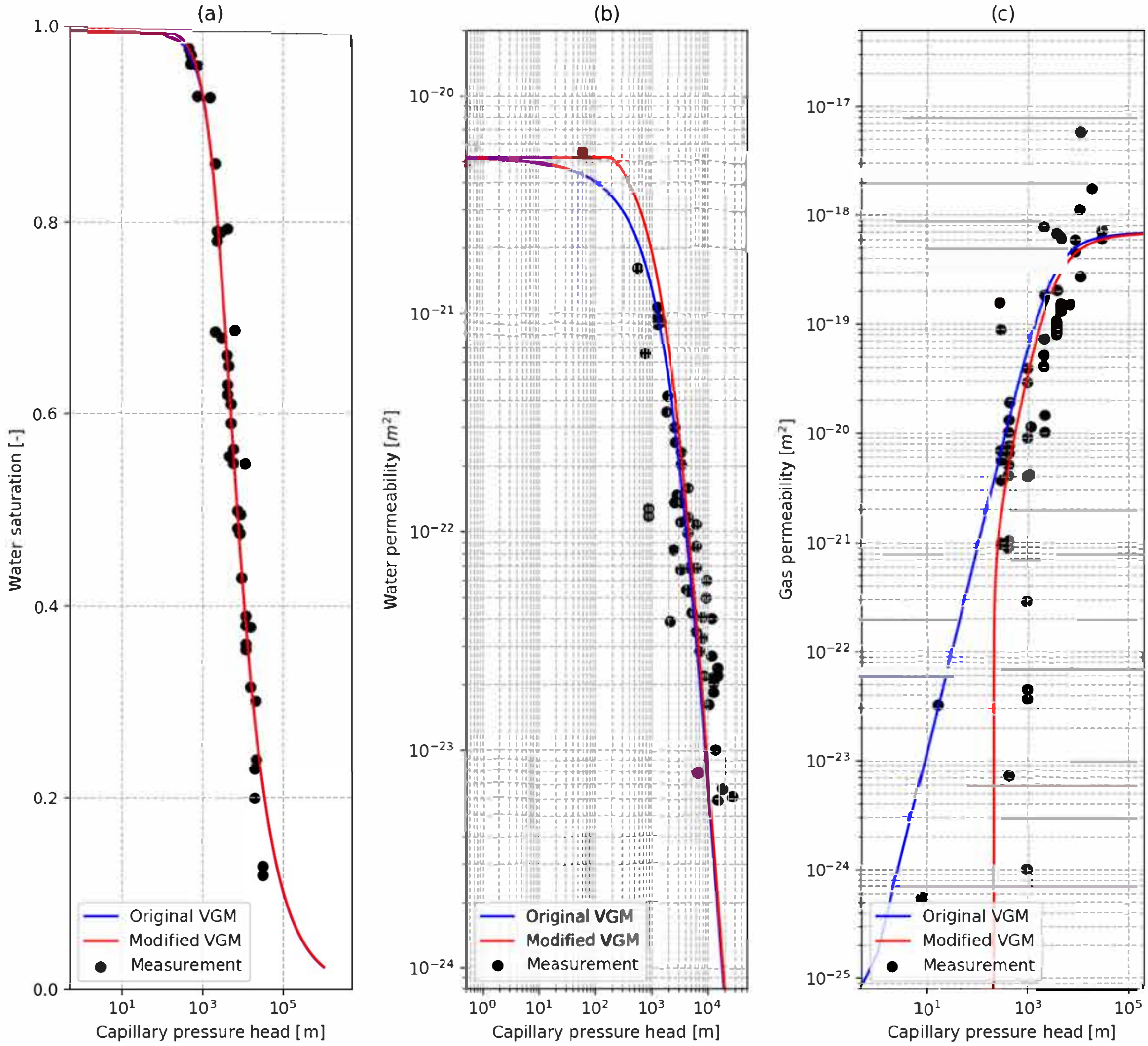

Figure 2. Gas pressures versus time in the Andra's PGZ1 test : Simulated in the present study with unmodified VGM properties (P_e=0), and simulated with modified VGM properties (P_e=1.97 MPa).