Contents

1 Generalization of Darcy’s Law: Non-Darcian Liquid Flow in Low-Permeability Media .................................................. 1
  1.1 Henry Darcy and His Law for Subsurface Fluid Flow .......... 2
  1.2 Relationship Between Water Flow Flux and Hydraulic Gradient in a Capillary Tube .............................................. 6
  1.3 Generalized Darcy’s Law for Water Flow in Low-Permeability Media ................................................................. 9
  1.4 Correlation Between Permeability and the Threshold Gradient ................................................................................. 16
  1.5 Relationship Between Parameter \( \alpha \) and Pore Size Distribution ............................................................................. 20
  1.6 Multidimensional and Anisotropic Cases ............................ 22
  1.7 Case Studies ........................................................................ 24
    1.7.1 Impact of Non-Darcian Flow on Performance of a Shale Repository for High-Level Nuclear Waste ............................. 24
    1.7.2 Influence of Non-Darcian Flow on Observed Relative Permeability ................................................................. 27
    1.7.3 Imbibition of Fracturing Fluids into Shale Matrix and a Methodology to Determine Relevant Parameters ....................... 30
    1.7.4 Non-Darcian Flow and Abnormal Liquid Pressure in Shale Formations .......................................................... 38
  1.8 Concluding Remarks ............................................................ 40
References .................................................................................. 41

2 Generalization of the Darcy-Buckingham Law: Optimality and Water Flow in Unsaturated Media ................................... 45
  2.1 Edgar Buckingham and His Law for Water Flow in Unsaturated Soils ................................................................. 46
3.4 Coupled Hydro-mechanical Processes in a Dual-Continuum System ............................................. 170
3.4.1 Governing Equations .................................................. 173
3.4.2 Constitutive Relationships ........................................... 178
3.4.3 An Application to the In Salah CO₂ Injection Project .................................................. 181
3.5 A Case Study: The Use of the TPHM to Model a Mine-by Test at Mont Terri Site, Switzerland .............. 185
3.5.1 Mine-by (MB) Test at the Mont Terri Site Model and Numerical Model ........................................... 186
3.5.2 Simulated Results and Discussion ........................................ 192
3.6 Concluding Remarks .................................................. 200
References .................................................. 200

4 A Thermodynamic Hypothesis Regarding Optimality Principles for Flow Processes in Geosystems .................... 209
4.1 Two Optimality Principles and Their Inconsistency ........... 210
4.2 A Thermodynamic Hypothesis ........................................ 211
4.3 Consistence Between the Hypothesis and Flow Behavior in Geosystems ........................................ 212
4.3.1 Water Flow in Saturated Porous Media ......................... 212
4.3.2 Water Flow in Unsaturated Porous Media .................... 213
4.3.3 Flow Processes in a River Basin and the Earth-Climate System ........................................ 214
4.3.4 A Further Discussion on the MEP ................................. 217
4.4 Consistence Between the Hypothesis and Darwin’s Evolution Theory ........................................ 219
4.5 Calculation of Inelastic Deformation of Natural Rock .......... 220
4.6 Concluding Remarks ........................................ 222
References ................................................ 223

5 Final Remarks: An “Unfinished” Book ........................ 225
Index ................................................ 227