Contents

Preface *page* ix

1 Introduction 1

2 The governing principles 5
2.1 The physical nature of permeable rocks 5
2.2 Geometrical characteristics 11
2.3 The motion of fluid elements through the medium 13
2.4 Dispersal and diffusion of dissolved species 18
2.5 The transport velocity and the incompressibility condition 22
2.6 Darcy's law 25
2.7 Permeability k 29
2.8 The thermal energy balance 34
2.9 Dissolved species balance 35
2.10 Equations of state 38

3 General flow characteristics: patterns of flow 41
3.1 Stream functions 41
3.2 Natural or intrinsic coordinates 43
3.3 Boundary conditions for flow 45
3.4 Vorticity 47
3.5 Dynamical scaling 53
3.6 Uniqueness and minimum dissipation theorems 59
3.7 Geometrical scaling 61
3.8 Flow patterns near isolated lenses or cracks 67
3.9 Long and multiple lenticular layers 74
3.10 Flow transients 80
3.11 Diffusion-induced flow in fissures or fractures 87

4 General flow characteristics: patterns of reactions 90
4.1 Simple reaction types 90
4.2 The approach to equilibrium at dissolution or reaction boundaries 96
4.3 Isothermal reaction fronts 100
4.4 Gradient reactions 107
4.5 Mixing zones 112

4.6 Mixing and reaction patterns from faults and fractures 115
4.7 Enhancement and destruction of porosity 125
4.8 Isotherm-following reactions 130

5 Instabilities 140
5.1 Rayleigh–Darcy instability 140
5.2 Salinity stabilization 148
5.3 Double-advective, double-diffusive instabilities 152
5.4 Brine invasion beneath hypersaline lagoons by double-diffusive fingering 159
5.5 Stability in the presence of flow 161
5.6 Saffman–Taylor instability 162

6 Pressure-driven flows 166
6.1 Flow in confined aquifers 166
6.2 Flow in unconfined aquifers 176
6.3 Computation of three-dimensional basin-wide flows 182
6.4 Temperature distributions 185
6.5 Mixing zones 201
6.6 Trapping of hydrocarbons 205
6.7 Spatial distributions of mineralization associated with flow 211

7 Thermal convection 220
7.1 The occurrence of thermally driven flows 220
7.2 Submerged banks of slowly varying thickness with small Rayleigh number and scale ratio 223
7.3 Convection and diagenesis in sloping isolated permeable strata 232
7.4 Compact platforms or reefs at low Rayleigh numbers 236
7.5 High Rayleigh number plumes 244
7.6 Flow, temperature, and gradient reaction patterns at intermediate Rayleigh number and scale ratio 252
7.7 Paleoconvection and dolomitization in the Latemar Massif 265

References 271
Index 279