Contents

Introduction 1

1 The Mineralogy of Illite – What is Illite? 3
1.1 Illite Definitions 3
1.1.1 Definitions of the Past 3
1.1.2 Definition Based on XRD Examination 5
1.1.3 Examples of Pure Illites 10
1.1.4 Examples of Illites in Natural Soils, Sediments and Sedimentary Rocks 12
1.1.5 Summary of One-Dimensional Analysis of Natural Minerals by XRD 17
1.2 Definition Based on Chemical Composition 18
1.2.1 Solid Solutions of Illite and Glauconite 18
1.2.2 Charge-Lowering Substitutions 20
1.2.3 The Crystal Structure of Illite and Solid Solution 23
1.2.4 The Theoretical Crystal Structure of Illite 31
1.3 Thermodynamic Stability of Illite 40
1.3.1 The Gibbs Free Energy of Formation of the Illite Phase 40
1.3.2 The Stability Field of the End-Member Illite Phase 45
1.4 The Growth of Illite Crystals 48
1.4.1 Crystal Shapes in Diagenetic Environments 48
1.4.2 Growth Mechanisms of Lath-Shaped Illite Crystals 52
1.4.3 Growth Processes for Plate-Shaped Crystals 56
1.5 A Working Definition of Illite 61

2 The Geology of Illite 63
2.1 Illite in Soils and Weathered Rocks 63
2.1.1 Occurrence of Illite in Soils 63
2.1.2 More Recent Studies 64
2.1.3 Early Formation of Illite in Weathered Granites 68
2.2 Illite in Diagenetic Series 76
2.2.1 Illite Formed During Early Sedimentary or Eodiagenetic Processes 76
2.2.2 The Origin of Illite in Shale Burial Diagenesis 79

2.2.3 Illite Crystallinity 85
2.2.4 Bentonite 97
2.2.5 Sandstones 100
2.3 Illite in Fossil and Active Geothermal Fields and Hydrothermal Alteration Zones 109
2.3.1 Sericite and Illite in Fossil Hydrothermal Systems 109
2.3.2 Instability of Muscovite Relative to Illite 113
2.3.3 Crystallochemical Characteristics of High-Temperature Illites (Sericite) 115
2.3.4 The Smectite-to-Illite Conversion in Geothermal Fields .. 119
2.4 The Illite Age Measurement 122
2.4.1 Fundamental Concepts 122
2.4.2 The K–Ar Apparent Age of Authigenic-Detrital Mineral Mixtures 125
2.4.3 Patterns of K–Ar Accumulation During Illite Growth Processes 129
2.4.4 Diagenesis of Bentonites 136
2.5 Summary 139
2.5.1 What is Illite? 139
2.5.2 Where Does Illite Form? 141

3 Dynamics of the Smectite-to-Illite Transformation 145
3.1 Experimental Studies 145
3.1.1 The Run Products in Whitney and Northrop's Experiments Using Bentonite 146
3.1.2 The Different Possible Interpretations of the Experiments 149
3.2 Kinetics of Experimental Transformations (Natural and Synthetic Starting Materials) 155
3.2.1 Kinetics of Illite Formation Using Synthetic, Chemical Compositions 155
3.2.2 Kinetics Using Natural Smectite Minerals 158
3.3 The Bulk Composition Effect (K_2O) 160
3.3.1 Natural Minerals 160
3.3.2 Multiparameter Kinetics 163
3.3.3 Formation of Muscovite at High KOH Concentrations: Shape and Polymorph 165
3.4 Kinetics of the Smectite-to-Illite Conversion Process in Natural Environments 166
3.4.1 Burial Diagenesis 167
3.4.2 The Dual Reaction Kinetic Model (Velde and Vasseur 1992) 168
3.4.3 Changes in Reaction Kinetics 170
3.5 Success and Failure of the Multiparameter Models 172
3.5.1 The Kinetic Model of Pytte and Reynolds (1989) (Thermal Metamorphism) 172

3.5.2 Drawbacks of Multi-Parameter Kinetic Models 172
3.6 Stability Controls (T, t, μ_x) 174
3.6.1 Comparison of Experimental Models and Natural Systems 174
3.6.2 Kinetic Parameter Values 174
3.6.3 Importance of Mineral Reactions 175
3.7 Summary 176
3.8 Application of Kinetics to K–Ar Dating 176
3.8.1 The Problem for K–Ar Dating of Illite from Shales 176
3.8.2 K–Ar Age and Mass Transfer During Smectite-to-Illite Conversion 178
3.8.3 An Example: The Balazuc Series (Renac 1994) 182

4 Applications **189**
4.1 Exploration and Exploitation of Natural Resources 190
4.1.1 Geothermal Resources 190
4.1.2 Clays and Petroleum 198
4.1.3 Illite Crystallinity and Organic Matter 210
4.1.4 Ore Resources 212
4.2 Environmental Problems 226
4.2.1 Illite and Mixed-Layer Minerals in Soils: Questions of Fertility 226
4.2.2 Some Effects of Agricultural Practice and their Bearing upon the Loss of Illite Content in Soils . 230
4.2.3 Nuclear Waste Barriers – Strategy and Illite Mineralogy 240

Glossary **249**

References **263**

Index **283**