

## **Contents**

	rieface	IX
	Acknowledgements	X
1	The Concept of Metamorphism	1
	1.1 Metamorphic Rocks	4
	1.2 What Do Metamorphic Rocks Look Like?	6
	1.3 Metamorphic Changes	11
	1.4 Factors That Control Metamorphism	13
	1.5 Types and Settings of Metamorphism	21
	1.6 Naming Metamorphic Rocks	24
	Summary	31
	Exercises	32
	Further Reading	32
2	Chemical Equilibrium in Metamorphism	34
	2.1 Equilibrium	35
	2.2 The Phase Rule	36
	2.3 Metamorphic Phase Diagrams	39
	2.4 Metamorphic Reactions and the Phase Rule	42
	2.5 Application of Chemical Equilibrium to Natural Rocks: an	
	Example	46
	2.6 Phase Diagrams for Too Many Components: the Projection	50
	2.7 The Influence of Fluids on Metamorphic Reactions	52
	2.8 The Concept of Buffering	56
	2.9 Practical Limitations to the Application of Chemical Equilibrium	
	to Metamorphic Rocks	58
	Summary	61
	Exercises	62
	Further Reading	63
3	The Pressure–Temperature Conditions of Metamorphism	64
	3.1 Metamorphic Reactions: the Thermodynamic Principles	65
	3.2 Qualitative Relationships: Metamorphic Facies	68
	3.3 Adding Numbers: Quantitative Estimates of Pressure and	
	Temperature	71



## vi Contents

	Summary	90
	Exercises	90
	Further Reading	91
	Software Packages for Geothermometry and Geobarometry	91
4	Metamorphism of Pelitic Rocks	93
	4.1 The AFM Projection	94
	4.2 Metamorphism at Moderate Pressures and Temperatures	96
	4.3 Metamorphism at High Temperatures	111
	4.4 Metamorphism at Low Pressures	117
	4.5 Metamorphism at High Pressures	120
	4.6 Summary: the Effect of Pressure on Metamorphic Zoning	
	Patterns	125
	4.7 Determining <i>P</i> – <i>T</i> Conditions for Metapelite Metamorphism	127
	Summary	129
	Exercises	130
	Further Reading	131
5	Metamorphism of Basic Igneous Rocks	132
	5.1 The Breakdown of Primary Igneous Mineral Assemblages	133
	5.2 The Facies Classification	135
	5.3 Metamorphism at Low Pressures and Temperatures	139
	5.4 Metamorphism at Low to Moderate Pressures	144
	5.5 Metamorphism at High Pressures	150
	5.6 Fluid Flow and Chemical Change During Metamorphism of	
	Basic Rocks	156
	5.7 Determining the $P$ - $T$ Conditions of Metamorphism from	
	Metabasites	159
	Summary	162
	Exercises	163
	Further Reading	163
6	Metamorphism of Limestones – Marbles, Calc-Silicates and	
	Skarns	165
	6.1 Marbles	167
	6.2 Calc-Silicates and Skarns	187
	6.3 Final Considerations	193
	Summary	194
	Exercises	194
	Further Reading	195



		Contents	vii
7	Mineral Growth and Textures in Metamorphic Rocks	196	
	7.1 Crystal Shapes and Alignment	197	
	7.2 How Crystals Grow	199	
	7.3 Crystallisation Textures	209	
	7.4 Disequilibrium Textures	211	
	7.5 Rates and Mechanisms of Metamorphic Mineral Growth	215	
	Summary	222	
	Exercises	222	
	Further Reading	222	
8	Metamorphism Linked to Deformation	224	
	8.1 How Do Rocks and Minerals Deform?	225	
	<ul><li>8.2 Textures Produced by Deformation During Metamorphism</li><li>8.3 Determining the Relative Timing of Metamorphism and</li></ul>	227	
	Deformation	231	
	8.4 Feedbacks Between Deformation and Metamorphism	234	
	Summary	239	
	Exercises	240	
	Further Reading	240	
9	The Duration of Metamorphism	241	
	9.1 Indirect Estimation of Metamorphic Timescales	243	
	9.2 Minerals as Geological Clocks	251	
	9.3 Linking Age to Metamorphic History	257	
	9.4 Timescales of Metamorphism	263	
	Summary	269	
	Exercises	270	
	Further Reading	271	
10	Metamorphism and Tectonics	272	
	10.1 Modern Tectonic Settings and their Metamorphic		
	Implications	273	
	10.2 Linking Facies Series to Tectonic Settings	277	
	10.3 Building Orogens	284	
	10.4 How Do Tectonic Processes Drive Exhumation?	288	
	10.5 Changes in Metamorphism Through Geological		
	Time	289	
	Summary	291	
	Exercises	292	
	Further Reading	292	



## viii Contents

Appendix 1	Glossary of Mineral Names and Abbreviations Used in	
	the Text	294
Appendix 2	Schreinemakers Methods for the Construction of Phase	
	Diagrams	299
Appendix 3	Application of the Phase Rule to Rocks Undergoing	
	Hydrothermal Metamorphism	306
References		308
Index		326