

CONTENTS

Preface	vii
Acknowledgements	x
List of tables	xvi
List of contributors	xviii
1 Carbonatites: nomenclature, average chemical compositions, and element distribution <i>A. R. Woolley & D. R. C. Kempe</i>	1
Abstract	1
1.1 Nomenclature	1
1.2 Average chemical composition	7
Acknowledgements	13
References	13
2 The spatial and temporal distribution of carbonatites <i>A. R. Woolley</i>	15
Abstract	15
2.1 Introduction	15
2.2 Spatial and temporal distribution	16
2.3 Tectonic considerations	31
2.4 Repetition of carbonatite activity	32
2.5 Increase in carbonatite activity with time	
2.6 General features of the temporal and spatial distribution of carbonatites	
Acknowledgements	34
References	34
3 Field relations of carbonatites <i>D. S. Barker</i>	38
Abstract	38
3.1 Introduction	38
3.2 Evidence for carbonatite magmas	39
3.3 Carbonatite lavas	41
3.4 Carbonatite tephra	44
3.5 Carbonatites in small hypabyssal intrusions	47
3.6 Carbonatites in plutons	50
3.7 Carbonatites associated with kimberlites	54
3.8 Metamorphosed carbonatites	
3.9 Hydrothermal dilatant veins and metasomatic replacement bodies associated with carbonatite-bearing plutons	
3.10 Pseudocarbonatites	
3.11 Conclusions	
Acknowledgements	62
References	63
4 Extrusive carbonatites and their significance <i>J. Keller</i>	70
Abstract	70
4.1 Introduction	70
4.2 Carbonatite volcanoes	71
4.3 Volcanological classification of carbonatites	76
4.4 Natrocarbonatites versus calcite carbonatites	77
4.5 Extrusive carbonatites from the Kaiserstuhl	
4.6 Conclusions	
Acknowledgements	86
References	86

5 Carbonatite magma: properties and processes	<i>A. H. Treiman</i>	89
Abstract		89
5.1 Introduction		89
5.2 Composition of carbonatite magma		90
5.3 Structure of carbonatite magmas		90
5.4 Thermochemical properties		91
5.5 Physical properties and processes		96
5.6 Conclusions		101
Acknowledgements		102
References		102
6 Pyrochlore, apatite and amphibole: distinctive minerals in carbonatite		105
<i>D. D. Hogarth</i>		
Abstract		105
6.1 Introduction		105
6.2 Pyrochlore group		109
6.3 Apatite		121
6.4 Amphiboles		132
6.5 Conclusions		140
Acknowledgements		141
References		141
7 Nature of economic mineralization in carbonatites and related rocks		149
<i>A. N. Mariano</i>		
Abstract		149
7.1 Introduction		150
7.2 Rare earth element mineralization		152
7.3 Niobium mineralization		156
7.4 Apatite		160
7.5 Titanium mineralization		162
7.6 Stability of carbonatite minerals in laterites		164
7.7 Vermiculite		166
7.8 Fluorite		167
7.9 Barite		168
7.10 Vanadium		168
7.11 Strontium		169
7.12 Thorium and uranium		169
7.13 Copper		170
7.14 Conclusions		171
Acknowledgements		172
References		172
8 Nature and structural relationships of carbonatites from Southwest and West Tanzania	<i>P. van Straaten</i>	177
Abstract		177
8.1 Introduction		177
8.2 Carbonatites in Tanzania		178
8.3 The carbonatites of southwestern and western Tanzania		179
8.4 Spatial and temporal distribution		192
8.5 Discussion and conclusions		194
Acknowledgements		196
References		197
9 Carbonatites in a continental margin environment – the Canadian Cordillera	<i>J. Pell & T. Höy</i>	200
Abstract		200
9.1 Introduction		200
9.2 Intrusive carbonatites in Palaeozoic rocks, Foreland Belt		202
9.3 Intrusive carbonatites in Late Proterozoic rocks, Omineca Crystalline Belt		205
9.4 Carbonatites associated with		
core complexes, Omineca Crystalline Belt		206
9.5 Chemistry		211
9.6 Tectonic implications		215
9.7 Conclusions		216
Acknowledgements		217
References		217

10 Phalaborwa: a saga of magmatism, metasomatism, and miscibility	S. C. Eriksson	221	
Abstract	221	10.6 Isotopic chemistry	242
10.1 Introduction	222	10.7 Origin of the complex	247
10.2 Geology	222	10.8 Conclusions	248
10.3 Age	230	Acknowledgements	249
10.4 Mineral chemistry	231	References	249
10.5 Whole-rock chemistry	238		
11 Sodium carbonatite extrusions from Oldoinyo Lengai, Tanzania: implications for carbonatite complex genesis	J. B. Dawson	255	
Abstract	255	Acknowledgements	274
11.1 Introduction	255	References	275
11.2 Regional geological setting	256		
11.3 Oldoinyo Lengai, general geology	258		
12 Neodymium and Strontium isotope geochemistry of carbonatites	K. Bell & J. Blenkinsop	278	
Abstract	278	12.5 The source region of carbonatites – lithosphere or asthenosphere?	293
12.1 Introduction	278	12.6 Conclusions	296
12.2 Chemical background	279	Acknowledgements	297
12.3 Strontium and Nd isotope chemistry of carbonatites	281	References	297
12.4 Isotopic constraints on the evolution of carbonatite magmas	290		
13 Stable isotope variations in carbonatites	P. Deines	301	
Abstract	301	and oxygen isotope composition	337
13.1 Introduction	301	13.5 Sulphur	342
13.2 Oxygen	306	13.6 Summary	348
13.3 Carbon	323	Acknowledgements	349
13.4 The relation between carbon		References	350
14 Lead isotope relationships in carbonatites and alkalic complexes: an overview	S.-T. Kwon, G. R. Tilton & M. H. Grünenfelder	360	
Abstract	360	14.5 Evolution models for Canadian complexes	379
14.1 Introduction	361	14.6 Differentiation of U, Th, and Pb in mantle processes	381
14.2 North American alkalic complexes	362	14.7 The source of carbonatites	382
14.3 Bulk Earth Pb isotopic evolution	374	14.8 Concluding statement	383
14.4 $^{206}\text{Pb} : ^{204}\text{Pb} - ^{87}\text{Sr} : ^{86}\text{Sr}$ correlation	375	Acknowledgements	384
		References	384

15 The genesis of carbonatites by immiscibility	<i>B. A. Kjarsgaard & D. L. Hamilton</i>	388	
Abstract	388	15.3 Discussion	398
15.1 Introduction	388	15.4 Summary	403
15.2 Evidence for silicate–carbonate immiscibility	389	Acknowledgements	403
		References	403
16 The behaviour of trace elements in the evolution of carbonatites	<i>D. L. Hamilton, P. Bedson & J. Esson</i>	405	
Abstract	405	16.5 Effect of P on K_D	417
16.1 Introduction	405	16.6 Summary and applications	425
16.2 Methods	406	Acknowledgements	426
16.3 Effect of composition on K_D	411	References	427
16.4 Effect of T on K_D	413		
17 Diversification of carbonatite	<i>M. J. Le Bas</i>	428	
Abstract	428	17.5 Primitive carbonatites	438
17.1 Introduction	428	17.6 Late-stage carbonatites	443
17.2 The choice of carbonatites	430	17.7 Summary	444
17.3 Basic assumptions	432	References	445
17.4 The nephelinite–carbonatite association	432		
18 Upper-mantle enrichment by kimberlitic or carbonatitic magmatism	<i>A. P. Jones</i>	448	
Abstract	448	18.5 South African model	455
18.1 Introduction	448	18.6 Discussion	458
18.2 Mantle metasomatism	449	18.7 Conclusions	460
18.3 Mantle titanate minerals	451	Acknowledgements	461
18.4 Kimberlite signature	453	References	461
19 A model of mantle metasomatism by carbonated alkaline melts: trace-element and isotopic compositions of mantle source regions of carbonatite and other continental igneous rocks	<i>J. K. Meen, J. C. Ayers & E. J. Fregeau</i>	464	
Abstract	464	19.5 Consequences of ijolite–peridotite interaction	478
19.1 Introduction	465	19.6 Examples of materials derived from metasomatic mantle regions	489
19.2 Models of mantle metasomatism	467	19.7 Summary	493
19.3 Phase relations of peridotite– H_2O – CO_2	469	Acknowledgements	495
19.4 Experimental techniques	470	References	495

20 Origin of carbonatites: evidence from phase equilibrium studies	<i>P. J. Wyllie</i>	500	
Abstract	500	low-temperature synthetic carbonatite magmas	514
20.1 Introduction	501	20.5 Immiscibility between silicate and carbonate liquids	520
20.2 Carbonate systems: precipitation of carbonates from melts	503	20.6 The formation of carbonate- rich melts in the mantle	523
20.3 Accessory minerals in synthetic carbonatite magmas	509	20.7 Kimberlites, nephelinites, and carbonatites	532
20.4 Relationships between high- temperature silicate melts and		20.8 The origin of carbonatites	537
		Acknowledgements	540
		References	540
21 Mantle metasomes and the kinship between carbonatites and kimberlites	<i>S. E. Haggerty</i>	546	
Abstract	546	21.5 Kimberlite and carbonatite genesis	553
21.1 Introduction	546	21.6 Conclusions	556
21.2 Carbonate in kimberlites and related rocks	547	Acknowledgements	557
21.3 Metasomatism	549	References	558
21.4 Metasome model	551		
22 Carbonatites, primary melts, and mantle dynamics	<i>D. H. Eggler</i>	561	
Abstract	561	22.4 Mantle dynamics	570
22.1 Introduction	562	22.5 Conclusions	575
22.2 Melting of carbonated peridotite	562	Acknowledgements	576
22.3 Primary melts and carbonatites	566	References	576
		Appendix	579
23 The origin and evolution of carbonatite magmas	<i>J. Gittins</i>	580	
Abstract	580	23.5 Alkalic carbonatite magma as a parental magma	594
23.1 Introduction	581	23.6 Carbonatite lavas and pyroclastics: their bearing on carbonatite magma evolution	594
23.2 Where do carbonatites come from?	582	23.7 Carbonatite fluids and fenitization	597
23.3 Assessment of magma derivation schemes	582	23.8 Epilogue	599
23.4 Carbonatite magma evolution in the crust	589	References	599
Index		601	