VOLCANIC SUCCESSIONS
MODERN AND ANCIENT

A geological approach to processes, products and successions

R. A. F. CAS
Department of Earth Sciences, Monash University

J. V. WRIGHT
Consultant, Sheffield, England

London
ALLEN & UNWIN
Boston Sydney Wellington
# CONTENTS

**PREFACE**
ix

**LIST OF TABLES**
xix

## CHAPTER ONE

_An introduction to facies analysis in volcanic terrains_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>4</td>
</tr>
<tr>
<td>1.2 The facies concept</td>
<td>5</td>
</tr>
<tr>
<td>1.3 Description of facies</td>
<td>6</td>
</tr>
<tr>
<td>1.3.1 Geometry</td>
<td>6</td>
</tr>
<tr>
<td>1.3.2 Lithology</td>
<td>8</td>
</tr>
<tr>
<td>1.3.3 Sedimentary structures</td>
<td>10</td>
</tr>
<tr>
<td>1.3.4 Sedimentary movement patterns</td>
<td>11</td>
</tr>
<tr>
<td>1.3.5 Fossils</td>
<td>11</td>
</tr>
<tr>
<td>1.4 Facies analysis and interpretation</td>
<td>11</td>
</tr>
<tr>
<td>1.5 Summary</td>
<td>12</td>
</tr>
<tr>
<td>1.6 Further reading</td>
<td>12</td>
</tr>
</tbody>
</table>

## CHAPTER TWO

_Some properties of magmas relevant to their physical behaviour_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>15</td>
</tr>
<tr>
<td>2.1 Magmas - an introduction to their diversity and character</td>
<td>15</td>
</tr>
<tr>
<td>2.1.1 Classification</td>
<td>16</td>
</tr>
<tr>
<td>2.1.2 Magmatic associations</td>
<td>19</td>
</tr>
<tr>
<td>2.2 Temperature</td>
<td>19</td>
</tr>
<tr>
<td>2.3 Density</td>
<td>20</td>
</tr>
<tr>
<td>2.4 Viscosity and yield strength</td>
<td>21</td>
</tr>
<tr>
<td>2.5 Factors controlling viscosity in magmas</td>
<td>23</td>
</tr>
<tr>
<td>2.5.1 Pressure</td>
<td>24</td>
</tr>
<tr>
<td>2.5.2 Temperature</td>
<td>24</td>
</tr>
<tr>
<td>2.5.3 Volatile content</td>
<td>24</td>
</tr>
<tr>
<td>2.5.4 Chemical composition</td>
<td>26</td>
</tr>
<tr>
<td>2.5.5 Crystal content</td>
<td>26</td>
</tr>
<tr>
<td>2.5.6 Bubble content</td>
<td>26</td>
</tr>
<tr>
<td>2.6 Strength</td>
<td>27</td>
</tr>
<tr>
<td>2.7 Fluid flow character</td>
<td>27</td>
</tr>
<tr>
<td>2.8 Further reading</td>
<td>30</td>
</tr>
</tbody>
</table>

## CHAPTER THREE

_Volcaniclastic deposits: fragmentation and general characteristics_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial statement</td>
<td>33</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>33</td>
</tr>
<tr>
<td>3.2 Fragmentation due to magmatic explosions</td>
<td>34</td>
</tr>
<tr>
<td>3.2.1 Explosive fragmentation from a sealed, near-surface magma chamber or conduit</td>
<td>35</td>
</tr>
<tr>
<td>3.2.2 Explosive fragmentation of a vesiculating magma erupting from an open vent</td>
<td>36</td>
</tr>
<tr>
<td>3.3 Magma mixing as a means of triggering explosive eruptions</td>
<td>40</td>
</tr>
</tbody>
</table>
CHAPTER TEN

Epiclastic processes in volcanic terrains

11.5.2 'Crystal tuffs' with mixed pyroclastic and epiclastic origins
11.5.3 Crystal-rich volcanioclastics of largely epiclastic origin

CHAPTER TWELVE

Classification of modern and ancient volcanioclastic rocks of pyroclastic and epiclastic origins

Initial statement
12.1 Introduction
12.2 Modern pyroclastic deposits
12.2.1 Genetic classification
12.2.2 Lithological classification

CHAPTER ELEVEN

Crystal-rich volcanioclastics – pyroclastic or epiclastic?

Initial statement
11.1 Introduction
11.2 Three types of ash and tuff
11.3 Possible fragmentation and transportation modes for crystal-rich volcanioclastic deposits

CHAPTER FOURTEEN

Facies models for ancient volcanic successions

Initial statement
14.1 Introduction
14.2 Facies geometry and facies – stratigraphic relationships: factors affecting them in ancient successions
14.3 Factors affecting original lithological characteristics and depositional structures
CONTENTS

14.3.4 Hydraulic fracturing 420
14.3.5 Diagenesis 421
14.3.6 Metamorphism 422
14.3.7 Deformation 422
14.3.8 Relationship between deformation and alteration 422
14.4 Recognition of pumice in the rock record 423
14.5 Facies as diagnostic indicators of palaeoenvironments and palaeoenvironmental conditions 423
14.6 A suggested approach to facies analysis 424
14.7 Facies models – what they represent and their uses 425
14.8 Facies models for volcanic successions 426
14.8.1 Continental basaltic successions 427
14.8.2 Continental stratovolcanoes 427
14.8.3 Continental silicic volcanoes 429
14.8.4 Submarine basaltic rift volcanism 432
14.8.5 Oceanic basaltic seamounts 432
14.8.6 Marine stratovolcanoes 433
14.8.7 Submarine felsic volcanoes and volcanic centres 435
14.8.8 Deep-marine facies derived from shallow marine–subaerial silicic volcanic centres 436
14.8.9 Intraglacial basaltic and rhyolitic volcanism 437
14.8.10 Precambrian volcanism 440
14.9 Summary 441
14.10 Further reading 442

CHAPTER FIFTEEN

Volcanism and tectonic setting 445

Initial statement 445

15.1 An introduction to volcanism in the modern global tectonic framework as a guide to the tectonic settings of ancient volcanic successions 446
15.2 Mid-oceanic ridge volcanism and the geology of the crust and lithosphere 446
15.3 Oceanic back-arc basin, interarc basin, marginal sea spreading volcanism and its geological context 450
15.4 Intraplate oceanic volcanism 452
15.5 Intraplate continental volcanism 452
15.6 Continental rift volcanism 453
15.6.1 Narrow linear rift zones 453
15.6.2 Broad continental rift zones 455
15.7 Young island arc volcanism associated with oceanic trench subduction zones 456
15.8 Microcontinental arc volcanism associated with oceanic trench subduction zones 458
15.9 Continental margin arc volcanism associated with oceanic trench subduction zones 460
15.10 Igneous rock-types as indicators of basement 460
15.11 Volcanism related to regional tectonic regimes and local stress field conditions 462
15.12 Igneous rocks as palaeostress indicators in the crust and lithosphere 465
15.13 An approach to evaluating the tectonic context of ancient successions 466
15.14 Further reading 467

APPENDIX I.

Methods used in studying modern pyroclastic deposits 469

I.1 Physical analysis 469
I.1.1 Thickness 469
I.1.2 Maximum grain size 470
I.1.3 Grain size distribution 471
I.1.4 Proportions of components 474
I.1.5 Crystal content of pumice 475
I.1.6 Density and porosity 476

I.2 Stratigraphic analysis 477

APPENDIX II

Grain size-textural classes of volcaniclastic rocks, some possible origins, and suggested diagnostic characteristics 479

REFERENCES 487

ACKNOWLEDGEMENTS 513

INDEX 519