

# **LATE TRIASSIC VOLCANISM OF THE IPSWICH BASIN**

**Andrew Roach B.App.Sci. (HONS)**

Thesis submitted as a requirement of the  
Doctor of Philosophy degree.

School of Earth Sciences



December, 1997



# MACQUARIE UNIVERSITY

## HIGHER DEGREE THESIS AUTHOR'S CONSENT (DOCTORAL)

This is to certify that I, ANDREW FERGUSON ROACH  
being a candidate for the degree of Doctor of PHILOSOPHY  
am aware of the policy of the University relating to the retention and use  
of higher degree theses as contained in the University's Doctoral Rules  
generally, and in particular Rule 7(7).

In the light of this policy and the policy of the above Rules, I agree to allow  
a copy of my thesis to be deposited in the University Library for consultation,  
loan and photocopying forthwith.

J. J. Ueew  
Signature of Witness

Andrew Roach  
Signature of Candidate

Dated this 13 day of FEBRUARY 1997

The Academic Senate on 24 February '98 resolved that the candidate  
had satisfied requirements for admission to the degree of PhD.  
This thesis represents a major part of the prescribed program of study.

I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution.

  
\_\_\_\_\_  
Andrew Roach

## Acknowledgments

This project was supported by an ARC Special Investigator Award to John Veevers and a Macquarie University Postgraduate Research Award to the author. I thank my supervisors Dick Flood and John Veevers for their assistance and encouragement they provided. I thank, also from Macquarie University, Loc Van Doung for thin sections, Carol Lawson for XRF and XRD analyses, Stirling Shaw for age dating, and Vanessa Bennett for microprobe work. I thank Phil Schmidt and Mark Lackie, CSIRO Rock Magnetism Laboratory, for guidance in AMS work, and Jeff Denton, CSIRO Centre for Isotope Studies, for assistance with the isotope studies. For allowing access to areas in the field I thank: The Royal Australian Army for access to restricted areas in the Canungra Tropical Warfare Centre; the Brisbane City Council and Ipswich City Council for access to quarries and parks; the Queensland Department of Primary Industries for permission to sample in State Forests; the Queensland Transport Department (Maritime Division) and the Queensland National Parks and Wildlife Service for allowing me to sample on Moreton Island; the proprietors of “Thunderbird Park” for access to their land and the “thunder egg” mine; Tricare Ltd. for granting access to, and allowing sampling from, their quarry; The Royal Brisbane Hospital for access to their grounds and disused quarries; the Queensland Police force for permission to sample the cliff face behind the Water Police barracks; and the Department of Mining Engineering at the University of Queensland for access to the University of Queensland Experimental Mine. I also thank the Queensland Department of Mines and Energy for allowing me to sample core material, and particularly Len Cranfield for providing access to their aerial-photo library. I thank Chris Stephens from the University of Queensland for helpful discussion; Al Grenfel and Martin Shaffer from Queensland University of Technology for discussions on, and trips to, the Mount Byron Volcanics; Will Scott of the USGS, Denver, for sending me maps, photographs, and slides of the South Sister Volcano. I thank P. Cawood, C.G. Murray, and J. Smith for detailed comments on the original thesis. I thank Sean, Ray, Jamie, and Mick for giving me a place to stay for the almost perpetual “*two or three weeks more*”, during the last months. I thank my family for providing support and encouragement, and all the people at Robert Menzies College who made my years there enjoyable. And a special thanks to Karen, Meredith, Janice, and Colin for the extra support and encouragement they provided.

# TABLE OF CONTENTS

Acknowledgments .....	iii
Abstract .....	xiv
<b>1: INTRODUCTION .....</b>	<b>1</b>
<b>1.0 Study Area .....</b>	<b>1</b>
<b>1.1 Stratigraphic-tectonic setting of the Ipswich Basin .....</b>	<b>1</b>
<i>1.1.1 Along the Panthalassan margin of Gondwanaland .....</i>	<i>1</i>
<i>1.1.2 Late Triassic Magmatism in Eastern Australia .....</i>	<i>5</i>
<i>1.1.3 The Ipswich Basin .....</i>	<i>5</i>
<i>1.1.4 Clarence-Moreton Basin .....</i>	<i>9</i>
<b>1.2 Nomenclature .....</b>	<b>10</b>
<i>1.2.1 Drill Hole Locations .....</i>	<i>10</i>
<i>1.2.2 Map Grid References .....</i>	<i>10</i>
<i>1.2.3 Internal ignimbrite stratigraphy .....</i>	<i>11</i>
<i>1.2.4 Lava Flows and Domes .....</i>	<i>12</i>
<i>1.2.5 Grain Sizes on Sedimentary Logs .....</i>	<i>13</i>
<b>1.3 Thesis Format .....</b>	<b>13</b>
<b>2: FACIES ANALYSIS AND FLOW DIRECTIONS OF THE LATE TRIASSIC BRISBANE TUFF: AN ANCIENT VALLEY-FILL RHYOLITIC IGNIMBRITE .....</b>	<b>15</b>
<b>2.0 Introduction .....</b>	<b>15</b>
<b>2.1 Geological Framework and Tectonic Setting .....</b>	<b>16</b>
<i>2.1.1 Age of the Brisbane Tuff .....</i>	<i>16</i>
<b>2.2 Distribution .....</b>	<b>16</b>
<b>2.3 Facies Analysis .....</b>	<b>17</b>
<i>2.3.1 Brisbane Tuff: Layer 1 Deposits and Precursory Air-falls .....</i>	<i>18</i>
<i>2.3.2 Layer 2 Deposits .....</i>	<i>20</i>
2.3.2.1 Layer 2b - Dense Lithic Concentration .....	20
2.3.2.2 Layer 2b/c - Pumice Clast Concentration .....	21
2.3.2.3 Dense Lithic Clast Trains .....	22
<i>2.3.3 Possible Layer 3 Deposits .....</i>	<i>22</i>
<i>2.3.4 Distal Air-fall Facies .....</i>	<i>23</i>
<b>2.4 Welding .....</b>	<b>24</b>
<b>2.5 Evidence for Multiple Ignimbrites .....</b>	<b>24</b>

<b>2.6 Evidence of Fumarolic Activity</b>	27
2.6.1 <i>Small Fumaroles</i>	28
2.6.2 <i>Large Fumaroles</i>	30
<b>2.7 Flow Lineation Data</b>	31
2.7.1 <i>Methods</i>	31
2.7.1.1 Grain Orientation Method	31
2.7.1.2 Anisotropy of Magnetic Susceptibility (AMS) Method	32
2.7.2 <i>Grain Orientation Results</i>	33
2.7.2.1 Additional Evidence supporting the Valley Deposition of the main body	33
2.7.3 <i>Anisotropy of Magnetic Susceptibility (AMS)</i>	35
2.8.1 <i>Proximal Facies</i>	38
2.8.2 <i>Ring Dykes, Domes, and Caldera Structures</i>	40
2.8.3 <i>Conclusions</i>	40
<b>2.9 Secondary Flow Features</b>	42
<b>2.10 Discussion and Conclusions</b>	43
<b>3: FACIES AND ERUPTIVE HISTORY OF THE LATE TRIASSIC     CHILLINGHAM VOLCANICS</b>	49
<b>3.0 Introduction</b>	49
<b>3.1 Geological Framework</b>	49
3.1.1 <i>Palaeozoic Basement Rocks</i>	49
3.1.2 <i>Distribution</i>	51
3.1.3 <i>Stratigraphy and Age of the Chillingham Volcanics</i>	51
<b>3.2 Pyroclastic Facies Relationships</b>	53
3.2.1 <i>Ignimbrites</i>	53
3.2.1.1 Dense Lithic Clasts in Ignimbrites	55
3.2.1.2 Internal Ignimbrite Stratigraphy	57
3.2.1.3 Rheomorphism in Ignimbrites	59
3.2.2 <i>Air-fall Tuffs</i>	60
<b>3.3 Lava Flow Facies Relationships</b>	60
3.3.1 <i>Orientation of Flow Fabrics and Dykes</i>	61
3.3.2 <i>Early Lava Effusion Phase</i>	62
3.3.3 <i>Late Lava Effusion Phase</i>	63
3.3.3.1 Lithophysae and Expanded Spherulites	63
<b>3.4 Depositional Environment and Palaeogeography</b>	63
3.4.1 <i>Canungra</i>	63
3.4.2 <i>Numinbah Valley</i>	65
3.4.3 <i>Chillingham and Couchy Creek</i>	69

3.4.4 Rocky Cutting .....	72
3.4.5 Frogs Hollow - Clarrie Hall Dam .....	72
3.4.6 Toolond - Nullun .....	76
3.4.7 Inferred Vents .....	76
<b>3.5 Eruptive History .....</b>	<b>76</b>
3.5.1 Modern Analogues - South Sister Volcano, Oregon .....	80
3.5.2 Modern Analogues - Coso Volcanic Field, California .....	81
<b>3.6 Conclusions .....</b>	<b>82</b>
<b>4: OTHER VOLCANIC ROCK OCCURRENCES .....</b>	<b>88</b>
<b>4.0 Introduction .....</b>	<b>88</b>
<b>4.1 Ipswich Area .....</b>	<b>88</b>
4.1.1 Geological Background .....	88
4.1.2 Mafic Rocks of the Ipswich Area .....	90
4.1.2.1 Weir Basalt .....	90
4.1.2.2 Sugars Basalt .....	90
4.1.2.3 Eruptive History .....	91
4.1.3 Tuff in Mount Crosby Formation .....	94
4.1.4 Hector Tuff .....	97
4.1.4.1 Volcanic Facies .....	97
4.1.4.2 Environments of Deposition and Eruptive History .....	99
<b>4.2 Volcanics on Moreton Island .....</b>	<b>99</b>
4.2.1 Geological background .....	99
4.2.2 Mafic Rocks .....	102
4.2.3 Rhyolites .....	102
4.2.3.1 Facies .....	103
4.2.3.2 Structures .....	103
4.2.3.3 Interpreted Mode of Emplacement .....	104
<b>4.3 Rhyolite on Stradbroke Island .....</b>	<b>104</b>
4.3.1 Geological background .....	104
4.3.2 Rhyolite .....	104
4.3.2.1 Ignimbrite-like Facies .....	106
4.3.2.2 Structure .....	107
4.3.2.3 Interpreted Mode of Emplacement .....	108
<b>4.4 Possible Stratigraphic equivalents in Drill Holes .....</b>	<b>108</b>
4.4.1 QAO "The Overflow" No.1 .....	108
4.4.2 GSQ Ipswich 26 .....	109
4.4.2.1 Subunits A, B, C and D .....	109
4.4.2.2 Subunit E .....	111
4.4.2.3 Subunit F .....	111
4.4.2.4 Subunit G .....	112

4.4.2.5 Interpreted Origin and Significance .....	112
4.4.3 NS 93 .....	115
4.4.4 APS Matjara 1 .....	117
4.4.5 Tamrookum Creek No. 1 .....	120
<b>4.5 Volcanic Rocks at Mount Barney .....</b>	<b>120</b>
<b>4.6 Discussion and Conclusions .....</b>	<b>121</b>
<b>5: GEOCHEMISTRY OF THE VOLCANIC ROCKS OF THE IPSWICH BASIN .....</b>	<b>127</b>
<b>5.0 Introduction .....</b>	<b>127</b>
<b>5.1 Analytical Procedure .....</b>	<b>128</b>
<b>5.2 Major Element Analysis Results .....</b>	<b>128</b>
5.2.1 Brisbane Tuff .....	128
5.2.1.1 Association of high Fe <sub>2</sub> O <sub>3</sub> with welding and pumice .....	130
5.2.2 Chillingham Volcanics .....	131
5.2.2.1 Clarrie Hall Dam sub-suite of the Chillingham Volcanics ..	133
5.2.3 Hector Tuff and Mount Crosby Formation tuff .....	134
5.2.4 Mafic Rocks .....	134
5.2.4.1 Alteration of the Mafic Rocks .....	137
5.2.5 Whole Rock Classification Diagrams .....	141
5.2.5.1 Brisbane Tuff .....	141
5.2.5.2 Chillingham Volcanics .....	142
5.2.5.3 Hector Tuff and Mount Crosby Formation tuff .....	143
5.2.5.4 Mafic Rocks .....	143
5.2.5.5 Plutonic Rocks of the South D'Aguilar Block .....	144
5.2.6 CIPW Normative Chemistry .....	144
<b>5.3 Trace Element Analysis Results .....</b>	<b>147</b>
5.3.1 Trace Element Classification Diagrams .....	150
5.3.1.1 SiO <sub>2</sub> v Zr/TiO <sub>2</sub> .....	151
5.3.1.2 SiO <sub>2</sub> v Nb/Y .....	152
5.3.1.3 Zr/TiO <sub>2</sub> v Nb/Y .....	153
5.3.2 Tectonic Discrimination using High Field Strength Elements .....	155
<b>5.4 Isotope Analysis Results .....</b>	<b>160</b>
<b>5.5 Pyroxene Chemistry .....</b>	<b>165</b>
5.5.1 Ca-Mg-Fe diagram .....	165
5.5.2 SiO <sub>2</sub> v Al <sub>2</sub> O <sub>3</sub> diagram .....	166
5.5.3 Al <sub>2</sub> v TiO <sub>2</sub> diagram .....	166
5.5.4 TiO <sub>2</sub> - MnO - Na <sub>2</sub> O tectonic discriminator of Nisbet and Pearce (1977) .....	167
5.5.5 Factor Analysis .....	168



5.5.6 Conclusions .....	170
<b>5.6 Implications for Tectonic Settings .....</b>	<b>171</b>
5.6.1 Comparison of the Ipswich Basin mafic rocks with those of the South Shetland Islands .....	172
5.6.2 Comparison with Basin and Range Province .....	173
5.6.3 Discussion .....	175
<b>5.7 Conclusions .....</b>	<b>175</b>
<b>6: SYNTHESIS AND CONCLUSIONS .....</b>	<b>177</b>
<b>6.0 Tectonic Setting in the Late Triassic .....</b>	<b>177</b>
<b>6.1 Plutonic Rocks of the D'Aguilar Block .....</b>	<b>179</b>
<b>6.2 Interpreted Geophysical Data .....</b>	<b>179</b>
6.2.1 Magnetic Data .....	179
6.2.1.1 The D'Aguilar Block, Northbrook Block, and Esk Trough ..	180
6.2.1.2 Tertiary Igneous Activity .....	180
6.2.1.3 Anomalies of Uncertain Origin .....	181
6.2.1.4 Ipswich Basin .....	181
6.2.2 Gravity Data .....	186
<b>6.3 Basin Evolution .....</b>	<b>188</b>
6.3.1 West Ipswich Fault .....	190
6.3.2 South Moreton Anticline .....	190
6.3.3 Structure of the Basin .....	192
<b>6.4 Basin Stratigraphy .....</b>	<b>195</b>
6.4.1 Early Volcanic Rocks Present Only In Drill Holes .....	196
6.4.2 Sugars Basalt and Weir Basalt and their Equivalents .....	197
6.4.3 Silicic Volcanism .....	197
6.4.3.1 The Brisbane Tuff .....	197
6.4.3.2 Chillingham Volcanics .....	198
6.4.3.3 Hector Tuff and Mount Crosby Formation .....	199
<b>6.5 Postulated Tectonic Environment Based on Geochemical Studies .....</b>	<b>200</b>
<b>REFERENCES .....</b>	<b>202</b>
<b>Appendix A: Chemical Analyses .....</b>	<b>213</b>
<b>Appendix B: CIPW Normative Data .....</b>	<b>226</b>
<b>Appendix C: Previously Published Chemical Analyses .....</b>	<b>233</b>

**Appendix D: Plagioclase Microprobe Analyses** ..... 235

**Appendix E: Clinopyroxene Microprobe Data** ..... 236

**Appendix F: Anisotropy of Magnetic Susceptibility Data** ..... 240

**Appendix G: Rock Fabric Data** ..... 244

**Appendix H: GCPLLOT** ..... 246

**H.1 Introduction** ..... 246

**H.2 Command Line Usage** ..... 246

**H.3 Graph File Script Language** ..... 247

*H.3.1 Line Comment* ..... 247

*H.3.2 Axis Captions* ..... 248

*H.3.3 Title Caption* ..... 248

*H.3.4 Axis or Box Options* ..... 249

*H.3.5 Default X and Default Y Scaling Factors* ..... 249

*H.3.6 Draw A Vector* ..... 250

*H.3.7 Print Line* ..... 250

*H.3.8 Load File* ..... 251

*H.3.9 Operators* ..... 251

**H.4 Program Listings** ..... 252

**Appendix I: Sample Numbers and Location** ..... 275

**Appendix J: Notes on Techniques used for Palaeo-topographic Reconstruction** 284

**J.1 Topography of the Brisbane Area** ..... 284

**J.2 Ipswich basin Geometry** ..... 285

## LIST OF FIGURES

<b>Figure 1.1</b> Location of detailed maps .....	1
<b>Figure 1.2</b> Time-space diagram along the Panthalassan margin, from South America to New Guinea during the Carboniferous to Jurassic, showing depositional environments .....	3
<b>Figure 1.3</b> Paleo-tectonic/geographic map of the Panthalassan margin .....	4
<b>Figure 1.4</b> a) Distribution of Late Triassic plutonic (boxed numbers), volcanic (circled numbers), and sedimentary rocks (circled numbers), as detailed in Table 1., in central-eastern Australia, and the sub-surface extent of the Ipswich Basin (solid line) .....	5
<b>Figure 1.5</b> Stratigraphic relations in the Carnian Ipswich Basin .....	8
<b>Figure 1.6</b> Major structural elements .....	9
<b>Figure 1.7</b> Location of drill holes discussed in the thesis. ....	10
<b>Figure 1.8</b> The <i>ideal</i> internal stratigraphy of a massive ignimbrite deposit similar to the Brisbane Tuff .....	11
<b>Figure 1.9</b> Structure of an idealised rhyolitic lava showing the relationship of flows and domes .....	12
<b>Figure 2.1</b> Distribution of the Brisbane Tuff and other Triassic igneous rocks of the Brisbane region. ....	17
<b>Figure 2.2</b> Sketch of the contact between the Brisbane Tuff and basement at Kitchener Road (GR: 5022E, 69682N) .....	19
<b>Figure 2.3</b> Stratigraphic column of the Brisbane Tuff in Geological Survey of Queensland drill hole NS15 .....	25
<b>Figure 2.4</b> a) Flow lineations in the Brisbane Tuff determined from rock fabric studies .....	34
<b>Figure 2.5</b> Schematic reconstruction of the Triassic topography over which the Brisbane Tuff flowed .....	35
<b>Figure 2.6</b> Schematic diagram illustrating the steepening of the ignimbrite flows accompanying differential compaction .....	42
<b>Figure 3.1</b> Distribution of the Chillingham Volcanics .....	49
<b>Figure 3.2</b> Correlation between stratigraphic columns for the Chillingham Volcanics .....	51
<b>Figure 3.3</b> Measured section through the Chillingham Volcanics at Canungra. ....	53
<b>Figure 3.4</b> Detailed geology of the Tamborine Mountain area. ....	55
<b>Figure 3.5</b> Detailed geology of the area north from Numinbah Valley. ....	57
<b>Figure 3.6</b> Rose diagrams of flow banding in the Chillingham Volcanics lavas. ....	62
<b>Figure 3.7</b> Composite stratigraphic section through the base of the Chillingham Volcanics at Numinbah Valley. ....	65
<b>Figure 3.8</b> Facies relationship diagram for the Numinbah Valley area. ....	68
<b>Figure 3.9</b> Detailed geology of the Chillingham Volcanics in the Couchy Creek - Chillingham - Rocky Cutting area. ....	70
<b>Figure 3.10</b> Composite stratigraphic section of the Couchy Creek - Chillingham ..	71
<b>Figure 3.11</b> Stratigraphic section though the Chillingham Volcanics at Rocky Cutting .....	73
<b>Figure 3.12</b> Detailed geology of the Clarrie Hall Dam - Toolond area .....	74
<b>Figure 3.13</b> Composite stratigraphic section in the Frogs Hollow - Clarrie Hall Dam area .....	75

<b>Figure 3.14</b> Map illustrating the progressive development of the Chillingham Volcanics .....	78
<b>Figure 3.15</b> Schematic history of the Chillingham Volcanics .....	79
<b>Figure 4.1</b> Geological map of the area north of the city of Ipswich .....	88
<b>Figure 4.2</b> Drill log of GSQ NS 256 .....	91
<b>Figure 4.3</b> Drill log for GSQ NS 295 .....	93
<b>Figure 4.4</b> Drill log of STC 3-4R .....	95
<b>Figure 4.5</b> Measured sections of the Hector Tuff .....	97
<b>Figure 4.6</b> Detailed geology of the northeastern tip of Moreton Island .....	100
<b>Figure 4.7</b> Diagrammatic cross-section through Moreton Island .....	102
<b>Figure 4.8</b> Detailed geology of the northeastern tip of North Stradbroke Island. ...	105
<b>Figure 4.9</b> Drill log of GSQ Ipswich 26 .....	109
<b>Figure 4.10</b> Drill log of GSQ NS 93 Cooneana Estate .....	115
<b>Figure 4.11</b> Drill log of APS Matjara No.1 (offshore southeast of Moreton Island) .....	118
<b>Figure 5.1</b> Variation diagram using $\text{TiO}_2$ and $\text{SiO}_2$ .....	132
<b>Figure 5.2</b> Subdivision of the volcanic rocks into High-K, Medium-K, and Low-K series .....	136
<b>Figure 5.3</b> Composite Harker variation diagrams illustrating the differences between the mafic rocks based on their chalcophile elements, Sr, and MgO .....	136
<b>Figure 5.4</b> AFM diagram of Irvine and Baragar (1971). .....	138
<b>Figure 5.5</b> $\text{TiO}_2$ - $\text{MnO}$ - $\text{P}_2\text{O}_5$ tectonic discrimination diagram of Mullen (1983) ....	139
<b>Figure 5.6</b> $\text{FeO}$ - $\text{MgO}$ - $\text{Al}_2\text{O}_3$ ternary tectonic discrimination diagram of Pearce <i>et al.</i> 's (1977) .....	140
<b>Figure 5.7</b> Total Alkali Silica (TAS) diagram for the volcanic rocks of the Ipswich Basin, and some plutonic rocks of the South D'Aguilar Block .....	141
<b>Figure 5.8</b> Normative plots used for assessing the likely degree of alteration. ....	146
<b>Figure 5.10</b> Harker variation diagrams for trace elements in volcanic and plutonic rocks .....	149
<b>Figure 5.11</b> $\text{SiO}_2$ vs $\text{Zr}/\text{TiO}_2$ classification diagram .....	151
<b>Figure 5.12</b> $\text{SiO}_2$ vs $\text{Nb}/\text{Y}$ classification diagram .....	152
<b>Figure 5.13</b> $\text{Zr}/\text{TiO}_2$ vs $\text{Nb}/\text{Y}$ classification diagram .....	154
<b>Figure 5.14</b> Nb, Y, and Zr ternary tectonic discrimination diagram of Meschede (1986) .....	157
<b>Figure 5.15</b> Zr vs $\text{Zr}/\text{Y}$ tectonic discrimination diagram .....	157
<b>Figure 5.16</b> Nb v Y tectonic discrimination diagram for granites .....	158
<b>Figure 5.17</b> Rb vs Nb + Y tectonic discrimination diagram for granites .....	159
<b>Figure 5.18</b> Ti- Zr-Y ternary tectonic discrimination diagram .....	160
<b>Figure 5.19</b> $\epsilon\text{Nd}$ v- $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for the volcanic rocks of the Ipswich Basin and plutonic rocks of the D'Aguilar block .....	162
<b>Figure 5.20</b> Rb/Sr whole rock radiometric age data .....	164
<b>Figure 5.21</b> Pyroxene classification tetrahedra of Deer <i>et al.</i> (1978) .....	165
<b>Figure 5.22</b> $\text{SiO}_2$ v $\text{Al}_2\text{O}_3$ diagram for clinopyroxenes (Le Bas, 1962), showing classification between sub-alkaline and alkaline pyroxenes .....	166
<b>Figure 5.23</b> $\text{Al}_2$ v $\text{TiO}_2$ diagram fields taken from Le Bas (1962) .....	167
<b>Figure 5.24</b> Pyroxene tectonic discriminator $\text{TiO}_2$ - $\text{MnO}$ - $\text{Na}_2\text{O}$ of Nisbet and Pearce (1977) .....	169
<b>Figure 5.25</b> Plot of discrimination functions $F_1$ v $F_2$ for pyroxene analyses .....	169

<b>Figure 5.26</b> Plate tectonic setting of the South Shetland Islands .....	172
<b>Figure 6.1</b> Schematic distribution of early mafic volcanism, and later silicic volcanism in the Ipswich Basin, and plutonism in the adjacent D'Aguilar Block .....	178
<b>Figure 6.2</b> Medium-wavelength total magnetic-intensity anomalies, filtered to remove wavelengths less than 0.2 degrees (contour interval 20 nT) over the Ipswich Basin .....	181
<b>Figure 6.3</b> Bouguer gravity anomalies (contour interval 20 $\mu\text{m.s}^{-2}$ ) over the Ipswich Basin .....	186
<b>Figure 6.4</b> Progressive development of the Ipswich Basin. ....	189
<b>Figure 6.5</b> Interpreted cross-sections through the Ipswich Basin .....	192
<b>Figure 6.6</b> Interpreted block diagram for the Ipswich Basin .....	193
<b>Figure D.1</b> Feldspar tetrahedra of Deer <i>et al.</i> (1978) showing the compositions of Ipswich Basin plagioclases .....	235
<b>Figure F.1</b> Graph of anisotropy v bulk susceptibility showing the low anisotropy of the samples .....	241
<b>Figure F.2</b> Comparison between the rock fabric method (left) and the AMS method (right) for determining flow direction .....	241
<b>Figure F.3</b> Typical AMS results from sites ARPHD0086-01 and ARPHD0099-01 .....	243

## LIST OF PLATES

<b>Plate 2.1</b> The Brisbane Tuff at the Kangaroo Point Cliffs. ....	44
<b>Plate 2.2</b> Low angle cross bedded ground surge deposits in Layer 1 facies of the Brisbane Tuff at Kitchener Road, Chermside .....	44
<b>Plate 2.3</b> Ground surge and air-fall deposits (Layer 1) above basement at Windsor. .	44
<b>Plate 2.4</b> Charcoal (black specks) in layer 1 faces in a planar bedded ground surge or air-fall tuff, at Chermside .....	45
<b>Plate 2.5</b> Large clasts of Palaeozoic basement rock at the base of layer 2 of the ignimbrite in the Brisbane Tuff at Windsor .....	45
<b>Plate 2.6</b> Flattened pumice clasts in an intensely welded ignimbrite .....	45
<b>Plate 2.7</b> A fossil fumarole from Kangaroo Point, infilled with phenocrysts and granular material. ....	46
<b>Plate 2.8</b> An opal/goethite infilled fossil fumarole from New Farm. ....	46
<b>Plate 2.9</b> A large fossil fumarole in the Kangaroo Point cliffs. ....	46
<b>Plate 2.10</b> Close up of the central vent region of the large fossil fumarole from Kangaroo Point. ....	46
<b>Plate 2.11</b> Horizontal cooling columns signifying a steep valley wall contact .....	47
<b>Plate 2.12</b> Vertical cooling columns typical of the Brisbane Tuff, signifying emplacement over a flat floored valley .....	47
<b>Plate 2.13</b> Poorly welded ignimbrite of the Brisbane Tuff showing relic bubble-wall structures .....	47
<b>Plate 2.14</b> Moderately welded ignimbrite of the Brisbane Tuff showing relic bubble- wall and cusped structures .....	48
<b>Plate 2.15</b> Perlitic cracking in a glassy part of a welded ignimbrite of the Brisbane Tuff .....	48

<b>Plate 2.16</b>	Photomicrograph of a highly welded ignimbrite of the Brisbane Tuff . . .	48
<b>Plate 3.1</b>	Accretionary lapilli tuff within the dominantly epiclastic succession at the base of the Chillingham Volcanics east of Canungra. . . . .	84
<b>Plate 3.2</b>	Pyroclastic Phase 1 at Rocky Cutting (viewed looking south). . . . .	84
<b>Plate 3.3</b>	Vertical section through a thin pumice clast-rich ignimbrite at Numinbah Valley. . . . .	84
<b>Plate 3.4</b>	Near horizontal flow banding in rhyolitic lavas of the Chillingham Volcanics, east of . . . . .	85
<b>Plate 3.5</b>	Close-up of flow bands in Plate 3., showing alternating layers of mm scale flow bands and expanded spherulites . . . . .	85
<b>Plate 3.7</b>	Interbedded epiclastic and pyroclastic sedimentary rocks at the base of the Canungra sequence. . . . .	86
<b>Plate 3.8</b>	Part of a rhyolitic dome at the Clarrie Hall Dam. . . . .	86
<b>Plate 3.9</b>	Perlitic cracking in un-devitrified glass from a rhyolitic dome of the Chillingham Volcanics . . . . .	86
<b>Plate 4.1</b>	Hyaloclastite or Houston’s (1965) “inter-pillow material” from NS 295 .	123
<b>Plate 4.2</b>	An air-fall tuff (top) and ignimbrite (below) of the Hector Tuff in GSQ Ipswich 26 . . . . .	123
<b>Plate 4.3</b>	Steeply inclined flow banding in rhyolitic lavas on Moreton Island . . . .	123
<b>Plate 4.4</b>	Steeply inclined flow banded lava on Moreton Island, truncated and overlain by a crumble breccia of an overlying flow . . . . .	124
<b>Plate 4.5</b>	Close-up of a crumble breccia on Moreton Island . . . . .	124
<b>Plate 4.6</b>	Vugg in a lava filled with hematite and comb quartz . . . . .	124
<b>Plate 4.7</b>	Flow folds in lava, Stradbroke Island . . . . .	125
<b>Plate 4.8</b>	Plan view of a rare spherulitic lava from Deadmans Beach, Stradbroke Island . . . . .	125
<b>Plate 4.9</b>	Close-up view of flow banded rhyolitic lava of subunit E, GSQ Ipswich 26 . . . . .	125
<b>Plate 4.10</b>	Erosive contact between an amygdaloidal (below) and a coarser basaltic-andesite lava flow of subunit F, GSQ Ipswich 26 . . . . .	126

### LIST OF TABLES

<b>Table 1.1</b>	Late Triassic plutonic, volcanic, and sedimentary rocks . . . . .	7
<b>Table 5.1</b>	Average Composition of rhyolitic/felsic rocks of the Ipswich Basin. . . .	129
<b>Table 5.2</b>	Average compositions of mafic rocks of the Ipswich Basin. . . . .	135
<b>Table 5.3</b>	Isotope data for Ipswich Basin volcanic rocks and South D’Aguilar Block plutonic rocks . . . . .	161
<b>Table 5.4</b>	Classification of augites on TiO <sub>2</sub> content . . . . .	167
<b>Table 6.1</b>	Features associated with the magnetic and gravity maps. . . . .	183

## Abstract

The Ipswich Basin, an extensive Late Triassic basin that straddles the Queensland-New South Wales border in eastern Australia, contains a basal sequence of felsic and mafic volcanic rocks, which, together with the Agnes Water Volcanics, Aranbanga Beds, Mount Byron Volcanics, Muncon Volcanics, North Arm Volcanics, and numerous plutons, form a major igneous province. Volcanism in the Ipswich Basin was manifested in an older mafic-dominated (in parts bi-modal) belt on the west, and a younger, silicic belt to the east. An early phase of calc-alkaline rhyolitic lava in the sub-surface is succeeded by exposed basaltic andesite lava flows and air-fall tuffs of the Sugars Basalt and Weir Basalt. Commencing in the westernmost sections, coarse clastic sedimentary rocks were deposited in fans along the West Ipswich Fault. Farther east near Brisbane and south to Mount Warning, extensive rhyolitic volcanism generated the ignimbrites of the Brisbane Tuff, the rhyo-dacitic air-fall tuffs and ignimbrites of the Mount Crosby Formation and Hector Huff, the rhyolitic lavas and pyroclastic rocks of the Chillingham Volcanics, and the isolated exposures of rhyolitic lavas on Moreton and Stradbroke Islands. The Brisbane Tuff is a valley-fill ignimbrite, with minor air-fall tuffs and ground surges, and at Carindale an ignimbrite outflow sheet. The Brisbane Tuff is a single cooling unit of flows continuously emplaced from a single vent. The coeval Chillingham Volcanics extend southward from Brisbane in an 80 km long belt of silicic volcanism. The Chillingham Volcanics follow a cycle of precursory pyroclastic eruptions and subsequent fissure-type lava effusion. In the south and centre, an earlier cycle of pyroclastic rock eruption and lava emplacement in domes also occurs. The northerly strike of vertically oriented zones of flow banding, thought to reflect feeder dykes, parallels the regional strike so the eruptive fissures may be related to deep basin-forming structures.

The chemistry of the Ipswich Basin mafic rocks differs from that of mafic rocks from volcanic-arc or within-plate settings, though sharing features of both. I interpret the “mixed” signature as reflecting the tectonic environment into which the mafic rocks were erupted, namely an area of back-arc extension. Rocks with chemical characteristics similar to the Ipswich Basin mafic rocks are present in the early stages of rifting in the Basin and Range Province of the western United States, the South Shetland Islands, and parts of the Central Andes. Geochemistry is consistent with the postulated tectonic setting of the Ipswich Basin in an area of back-arc extension associated with strike-slip faulting.

Volcanism ceased later in the Late Triassic during the eastward migration of the heat source, and was followed by deposition of the thick coal measures around Ipswich.