



Unravelling the tectonic framework of the Musgrave Province, central Australia

Benjamin P. Wade, B.Sc (Hons)

Geology and Geophysics
School of Earth and Environmental Sciences
The University of Adelaide

This thesis is submitted in fulfilment of the
requirements for the degree of Doctor of Philosophy
in the Faculty of Science, University of Adelaide

September 2006

Table of Contents

List of Figures	v
List of Tables	vii
Abstract	viii
Declaration	x
Acknowledgments	xi
Publications and Conference abstracts	xii
Chapter One - Introduction	1
1.1 Overview and Aims	1
1.2 Outline and Organisation of Thesis	3
Chapter Two - Geological Background	6
2.1 Introduction	6
2.2 Regional Geology	7
2.3 Lithostratigraphy	8
2.3.1 Musgravian Gneiss (ca. 1.60-1.54 Ga)	8
2.3.2 Unnamed cover sequence (ca. 1.40 Ga)	9
2.3.3 Unnamed Orthogneiss (ca. 1.30 Ga)	12
2.3.4 Pitjantjatjara Supersuite (ca. 1.20-1.14 Ga)	12
2.3.5 Giles Event (ca. 1.08-1.04 Ga)	12
2.3.6 Alcurra Dolerite/Unnamed Olivine dykes/Amata Dolerite (ca. 1.08 – 0.82 Ga)	13
2.4 Deformational History of the Musgrave Province	13
2.4.1 D1	14
2.4.2 D2 (Musgrave Orogeny)	14
2.4.3 D3 (Giles Event)	15
2.4.4 D4-5	15
2.4.5 D6-7 (Petermann Orogeny)	16
2.5 Metamorphic Evolution of the Musgrave Province	16
2.5.1 M1/D1	16
2.5.2 M2; Musgrave Orogeny (1.23-1.15 Ga)	17
2.5.3 M3; Giles Event (ca. 1.08-1.06 Ga)	18
2.5.4 M4; Petermann Orogeny (ca. 550 Ma)	18
2.6 Proterozoic Evolution of the Musgrave Province	19
2.7 Conclusion	22
Chapter Three - Evidence for early Mesoproterozoic arc magmatism in the Musgrave Block, central Australia: implications for Proterozoic crustal growth and tectonic reconstructions of Australia.	24
3.1 Introduction	24
3.2 Geological Framework	26
3.3 Analytical Procedure	27
3.4 Geochemistry of the Felsic Gneisses	28
3.4.1 Major elements	28
3.4.2 Trace & Rare Earth Elements	28
3.4.3 Sm-Nd systematics	30
3.5 Origin of the ca. 1.60-1.55 Ga Felsic Rocks	31
3.5.1 Residual Mineral Control on Trace Element Composition	31
3.5.2 Tectono-magmatic affinity	32

3.5.3	Sm-Nd systematics	32
3.6	Petrogenetic and tectonic implications	33
3.7	Proterozoic Tectonic Evolution of the Musgrave Block	33
3.7.1	1.60-1.58 Ga	34
3.7.2	<1.58 Ga	36
3.8	Summary	36
Chapter Four - The Musgrave Province, central Australia; cinching the Belt Supergroup down under?		37
4.1	Introduction	37
4.2	Regional Setting	38
4.3	Sampling and Analytical Methods	39
4.4	Results	40
4.4.1	Major and trace element geochemistry and Sm-Nd isotopic results	40
4.4.2	U-Pb detrital zircon geochronology	41
4.4.2.1	Sample 596	42
4.4.2.2	Sample 563	42
4.4.2.3	Sample 594	42
4.4.2.4	Sample 525	42
4.4.2.5	Sample 476	43
4.4.2.6	Sample 529	43
4.5	Timing of deposition and source characteristics	43
4.6	Belt Basin Correlations	45
4.7	Summary	46
Chapter Five - Petrogenesis of the Kalka, Ewarara, and Gosse Pile layered ultramafic-mafic intrusions, Musgrave Block, Australia: crustal contamination or modified mantle?		47
5.1	Introduction	47
5.2	Geological Framework	48
5.3	Geology of the Intrusions	51
5.3.1	Kalka	51
5.3.2	Ewarara	51
5.3.3	Gosse Pile	51
5.4	Analytical Procedure	51
5.5	Results	52
5.5.1	Whole-rock geochemical variations	52
5.5.1.1	Kalka Intrusion	52
5.5.1.2	Ewarara Intrusion	54
5.5.1.3	Gosse Pile Intrusion	55
5.5.1.4	Country Rock	56
5.5.2	Mineral chemistry	56
5.5.2.1	Major element chemistry	57
5.5.2.2	Trace element chemistry	57
5.5.3	Sm/Nd and Rb/Sr Isotope Data	58
5.5.3.1	Kalka Intrusion	58
5.5.3.2	Ewarara Intrusion	59
5.5.3.3	Gosse Pile Intrusion	60
5.6	Petrogenetic and Tectonic implications	61
5.6.1	Significance of Isotopic and Geochemical variations within the Giles Intrusions	61
5.6.2	Composition of the parental magma	61
5.6.3	Composition of the Contaminant	62
5.6.4	Simple Mixing and AFC Models	63
5.6.5	Contamination in the magma chamber?	65
5.6.6	Petrogenesis of the intrusions	65
5.7	Conclusions	66

Chapter Six - Nd Isotopic and Geochemical Constraints on Provenance of Sedimentary Rocks in the Eastern Officer Basin, Australia: Implications for the Duration of the Intracratonic Petermann Orogeny	67
6.1 Introduction	67
6.2 Geological Framework	69
6.3 Stratigraphic Correlations	69
6.3.1 Callanna Group	70
6.3.2 Sturtian Glacials?	71
6.3.3 Lake Maurice Group	71
6.3.4 Ungoolya Group	71
6.3.5 Marla Group	71
6.3.6 Munda Group	71
6.4 Sampling Methods	72
6.4.1 Sample Selection	72
6.4.2 Analytical Procedures	72
6.5 Petrographic Features: Detrital Modes	72
6.6 Chemical Composition of Sequences	73
6.6.1 Major elements	73
6.6.2 Trace elements	73
6.6.3 Sm-Nd Isotopes	73
6.7 Provenance	74
6.7.1 Source Characterisation	74
6.7.2 Major and Trace element Chemistry	75
6.7.3 Neodymium Isotopes	76
6.8 Implications for the timing of the intracratonic Petermann Orogeny	78
6.9 Conclusions	82
Chapter Seven - Filling the “magmatic gap” of Proterozoic Australia	84
7.1 Introduction	84
7.2 Geology of the Coompana Block	85
7.3 Sampling Methods and Analytical Procedures	86
7.4 Age of the Mallabie 1 Granitic Gneiss	87
7.5 Geochemistry of the Mallabie 1 Granitic Gneiss	88
7.5.1 Major elements	88
7.5.2 Trace & Rare Earth Elements	88
7.5.3 Sm-Nd systematics	91
7.6 Petrogenetic origin of the Mallabie 1 Granitic Gneiss	91
7.6.1 A-type affinity of the granitic gneiss	91
7.6.2 Tectono-magmatic affinity	92
7.6.3 Sm-Nd systematics	93
7.7 Implications for the source of detrital zircons whose age falls within the “Australian magmatic gap”	94
7.8 Summary and conclusions	94
Chapter Eight - The Musgrave Province; terra incognita no longer?	95
8.1 Introduction	95
8.2 ca. 1.60-1.54 Ga Musgravian Gneiss	95
8.2.1 Historical views on crustal formation during the Australian Proterozoic	95
8.2.2 Do the oldest rocks of the Musgrave Province record the amalgamation of Proterozoic Australia?	96
8.3 ca. 1.40 Ga unnamed metasedimentary rocks	98
8.3.1 Where does Australia fit within the supercontinent Rodinia?	98
8.3.2 Does the Musgrave Province contain a vital piercing point in Rodinian reconstructions?	99
8.4 ca. 1.08 Ga Giles Complex	100
8.4.1 Layered intrusions and crust-mantle interaction	100
8.4.2 The Giles Complex; crustal contamination or modified lithospheric mantle?	101
8.5 ca. 0.56 Ga Petermann Orogeny	101

8.5.1	Petermann Orogeny; look in the basin not the mountain belt?	101
8.5.2	When was the initiation of the Petermann Orogeny?	102
8.6	Filling the “Australian magmatic gap”; the Coompana Block	102
8.6.1	Why is the Coompana Block so important?	
8.6.2	What impact does the genesis of the ca. 1.50 granitic gneiss have on reconstruction models?	103
8.7	Conclusions	105
References		118
Appendix One - Geochemistry and Isotopes of ca. 1.60-1.54 Ga Musgravian Gneiss		118
Appendix Two - Geochemistry, isotopic composition, geochronological data, and zircon CL pictures of metasedimentary rocks from the eastern Musgrave Province		123
Appendix Three - Geochemistry and Isotopes on ca. 1.08 Ga Giles Complex		174
Appendix Four - Location, geochemistry and isotopic composition tables of Officer Basin sedimentary rocks		196
Appendix Five - Geochemistry, isotopic composition, CL zircon pictures, and age data of granitic gneiss samples from Mallabie 1		204
Appendix Six - MonAnal v1.0 for Excel: A spreadsheet package for calculating chemical ages, errors and chemical variations of monazite from electron microprobe analyses (excel add-in on cd)		214

List of Figures

1.1	Location map of the Musgrave Province	1
1.2	Map of the Australian Proterozoic	2
1.3	Generalised time-space plot of the lithostratigraphic units of the Musgrave Province	3
1.4	Example photographs of lithological units	4
2.1	Location map of the Musgrave Province within Proterozoic Australia	7
2.2	Simplified geological map of the Musgrave Province	8
2.3	Time-Space plot of the Musgrave Province	9
2.4	TMI image of the Musgrave Province	14
2.5	Photomicrographs of metasedimentary mineral textures	17
2.6	ϵ Nd evolution diagram of Musgrave Province lithologies	19
2.7	Proterozoic reconstruction of amalgamation of Australia	20
2.8	Mid-Mesoproterozoic reconstruction of palaeogeography of Australia	21
3.1	Location map of the Musgrave Province within Proterozoic Australia	25
3.2	Simplified geological map of the Musgrave Province	26
3.3	Outcrop map of the Petermann 1:250k map sheet	27
3.4	Harker variation diagrams	29
3.5	CIPW normative, AFM, and molecular Na-K-Ca diagrams	29
3.6	Chondrite and Primitive Mantle normalised spider plots	30
3.7	Pearce plot	32
3.8	ϵ Nd evolution diagram of felsic magmatic rocks	33
3.9	Reconstruction of the Mesoproterozoic amalgamation of Australia	34
3.10	Cross-section of possible reconstruction outline in Fig. 3.9	35
4.1	SWEAT, AUSWUS, and AUSMEX reconstruction models of Proterozoic Australia	38
4.2	Simplified map of Proterozoic Australia and sample locations	39
4.3	Example CL images of metamorphic and detrital zircons	40
4.4a	La-Th-Ni ternary diagram	41
4.4b	La-Th binary plot	41
4.5	REE plot of samples normalised to Chondrite	41
4.6	ϵ Nd vs age plot of metasediment samples	42
4.7	Detrital zircon histograms of metasediment samples	43
4.8	Pooled SHRIMP and LA-ICPMS age histograms	44
4.9	Possible mid-Mesoproterozoic reconstructions of Australia	46
5.1	Regional geology of the Musgrave Province	48
5.2	Outcrop map of the Kalka, Ewarara, Gosse Pile region	49
5.3	Generalised map of the Kalka intrusion	50
5.4	Generalised map of the Ewarara intrusion	50
5.5	Generalised map of the Gosse Pile intrusion	50
5.6	Major element variation diagrams	53
5.7	Whole rock REE spidergrams	54
5.8	Whole rock trace element spidergrams	55
5.9	Di+Hed+En+Fs quadrilateral of mineral compositions	57
5.10	Mineral separate REE spidergrams	58
5.11	Mineral separate trace element spidergrams	59
5.12	Nd and Sr Isotopic traverses across intrusions	60
5.13	ϵ Nd and ϵ Sr plot of mafic-ultramafic samples	63
5.14	Bulk-mixing calculation diagrams	64
5.15	AFC mixing diagrams	65
6.1	Simplified outcrop map of the Officer Basin	68
6.2	Stratigraphic column of units comprising the Officer Basin	70
6.3	QFL lithological classification diagram	72
6.4	QFL tectonic classification diagram	73
6.5	Major element variation diagrams	74

6.6	REE vs major element variation diagrams	74
6.7	Trace element vs major element variation diagrams	75
6.8	ϵ Nd vs time plot for Officer Basin samples	77
6.9	Grey-scale TMI image of the Musgrave Block	79
6.10	Possible tectonic reconstructions of the Officer Basin at ca. 550 Ma	81
7.1	Tectonic element map of Proterozoic Australia	85
7.2	Solid geology map of the Coompana Block	86
7.3	Photograph of representative core from Mallabie 1	86
7.4	Transmitted light and CL pictures of representative zircons	88
7.5	Conventional U-Pb concordia and $^{207}\text{Pb}/^{206}\text{Pb}$ age histogram	88
7.6	Major element variation diagrams	89
7.7	ASI plot	90
7.8a	CIPW normative ternary plot	90
7.8b	AFM ternary diagram	90
7.9a	Chondrite normalised REE plot	90
7.9b	Primitive Mantle normalised plot	90
7.10	ϵ Nd evolution diagram	91
7.11	Granite classification diagrams	92
7.12	Tectonic discrimination diagrams	93
7.13	Nb-Y-3xGa and Nb-Y-Ce ternary plots	93
8.1a	Reconstrucion of Australia involving an active margin between the NAC and SAC	98
8.1b	Cross-section of line A-B in Figure 7.1a	98
8.2a	Probability density plot of detrital zircon ages from metasedimentary rocks	99
8.2b	Reconstruction diagrams of pre-Rodinia Australia	99
8.3a	ϵ Ndi vs ϵ Sri plot displaying various magma composition and contaminant endmembers	100
8.3b	Example of AFC mixture model involving a picritic source composition and average Musgrave crust as the contaminant	100
8.4a	ϵ Nd vs time plot for units of the Officer Basin	102
8.4b	Possible sediment transport directions during the Petermann Orogeny	102
8.5a	Nb vs 10000xGa/Al and Ga/Al vs Zr+Nb+Ce+Y plots of Whalen et al. (1987)	103
8.5b	Conventional U-Pb concordia diagram	103
8.5c	$^{207}\text{Pb}/^{206}\text{Pb}$ age histogram and probability density curve	103

List of Tables

2.1	Summary of the geological history of the Musgrave Province	10
3.1	Chemical data for ca. 1.60-1.54 Ga felsic rocks	119
3.2	Sm-Nd Isotopic data for ca. 1.60-1.54 Ga felsic rocks	122
4.1	Chemical data for ca. 1.40 Ga metasedimentary rocks	124
4.2	Sm-Nd isotopic data of ca. 1.40 Ga metasedimentary rocks	125
4.3	U-Pb SHRIMP age data	126
	Sample 596 (SHRIMP)	126
	Sample 563 (SHRIMP)	128
4.4	LA-ICPMS age data	130
	Sample 594 (LA-ICPMS)	130
	Sample 525 (LA-ICPMS)	132
	Sample 476 (LA-ICPMS)	134
	Sample 529 (LA-ICPMS)	136
	GJ-1 standard analyses	138
5.1	Chemical data for Giles Complex and country rock	175
5.2	Major and trace element composition of selected clinopyroxenes	188
5.3	Major and trace element composition of selected orthopyroxenes	189
5.4	Major and trace element composition of selected plagioclases	190
5.5	Sm-Nd isotopic data for Giles complex samples and country rock	191
5.6	Mixing component compositions	194
5.7	Mixing models	195
6.1	Summary of lithologies and depositional environment	197
6.2	Sample types and localities	198
6.3	Detrital modes of sandstones and mudstones	199
6.4	Major and trace element data for sedimentary rocks of the Officer Basin	200
6.5	Sm-Nd isotope data for sedimentary rocks of the Officer Basin	203
7.1	Major and trace element data for granitic gneiss of the Coompana Block	205
7.2	U-Pb LA-ICPMS age data	206
7.3	Sm-Nd isotopic data	209
8.1	Summary of the geological history of the Musgrave Province	96

Abstract

The importance of the Musgrave Province in continental reconstructions of Proterozoic Australia is only beginning to be appreciated. The Mesoproterozoic Musgrave Province sits in a geographically central location within Australia and is bounded by older and more isotopically evolved regions including the Gawler Craton of South Australia and Arunta Region of the Northern Territory. Understanding the crustal growth and deformation mechanisms involved in the formation of the Musgrave Province, and also the nature of the basement that separates these tectonic elements, allows for greater insight into defining the timing and processes responsible for the amalgamation of Proterozoic Australia.

The ca. 1.60-1.54 Ga Musgravian Gneiss preserves geochemical and isotopic signatures related to ongoing arc-magmatism in an active margin between the North Australian and South Australian Cratons (NAC and SAC). Characteristic geochemical patterns of the Musgravian Gneiss include negative anomalies in Nb, Ti, and Y, and are accompanied by steep LREE patterns. Also characteristic of the Musgravian Gneiss is its juvenile Nd isotopic composition ($\epsilon_{\text{Nd}1.55}$ values from -1.2 to $+0.9$). The juvenile isotopic signature of the Musgravian Gneiss separates it from the bounding comparatively isotopically evolved terranes of the Arunta Region and Gawler Craton. The geochemical and isotopic signatures of these early Mesoproterozoic felsic rocks have similarities with island arc systems involving residual Ti-bearing minerals and garnet.

Circa 1.40 Ga metasedimentary rocks of the eastern Musgrave Province also record vital evidence for determining Australia's location and fit within a global plate reconstruction context during the late Mesoproterozoic. U-Pb detrital zircon and Sm-Nd isotopic data from these metasedimentary rocks suggests a component of derivation from sources outside of the presently exposed Australian crust. Best fit matches come from rocks originating from eastern Laurentia. Detrital zircon ages range from Palaeoproterozoic to late Mesoproterozoic, constraining the maximum depositional age of the metasediments to approximately 1.40 Ga, similar to that of the Belt Supergroup in western Laurentia. The 1.49-1.36 Ga detrital zircons in the Musgrave metasediments are interpreted to have been derived from the voluminous A-type suites of Laurentia, as this time period represents a "magmatic gap" in Australia, with an extreme paucity of sources this age recognized. The metasedimentary rocks exhibit a range of Nd isotopic signatures, with $\epsilon_{\text{Nd}}(1.4 \text{ Ga})$ values ranging from -5.1 to 0.9 , inconsistent with complete derivation from Australian sources, which are more isotopically evolved. The isotopically juvenile ca. 1.60-1.54 Ga Musgravian Gneiss is also an excellent candidate for the source of the abundant ca. 1.6-1.54 Ga detrital zircons within the lower sequences of the Belt Supergroup. If these interpretations are correct, they support a palaeogeographic reconstruction involving proximity of Australia and Laurentia during the pre-Rodinia Mesoproterozoic. This also increases the prospectivity of the eastern Musgrave Province to host a metamorphosed equivalent of the massive Pb-Zn-Ag Sullivan deposit.

The geochemical and isotopic signatures recorded in mafic-ultramafic rocks can divulge important information regarding the state of the sub continental lithospheric mantle (SCLM). The voluminous cumulate mafic-ultramafic rocks of the ca. 1.08 Ga Giles Complex record geochemical and Nd-Sr isotopic compositions consistent with an enriched parental magma. Traverses across three layered intrusions, the Kalka, Ewarara, and Gosse Pile were geochemically and isotopically analysed. Whole rock samples display variably depleted to enriched LREE patterns when normalised to chondrite ($(\text{La}/\text{Sm})_{\text{N}} = 0.43-4.72$). Clinopyroxene separates display similar depleted to enriched LREE patterns ($(\text{La}/\text{Sm})_{\text{N}} = 0.37-7.33$) relative to a chondritic source. The cumulate rocks display isotopically evolved signatures ($\epsilon_{\text{Nd}} \sim -1.0$ to -5.0 and $\epsilon_{\text{Sr}} \sim -19.0$ to 85.0). Using simple bulk mixing and AFC equations, the Nd-Sr data of the more radiogenic samples can be modelled by addition of $\sim 10\%$ average Musgrave crust to a primitive picritic source, without need for an enriched mantle signature. Shallow decompressional melting of an asthenospheric plume source beneath thinned Musgravian lithosphere is envisaged as a source for the parental picritic magma. A model involving early crustal contamination within feeder zones is favoured, and consequently explorers looking for Ni-Cu-Co sulphides should concentrate on locating these feeder zones.

Few absolute age constraints exist for the timing of the intracratonic Petermann Orogeny of the Musgrave Province. The Petermann Orogeny is responsible for much of the lithospheric architecture we see today within the Musgrave Province, uplifting and exhuming large parts along crustal scale E-W trending fault/shear systems. Isotopic and geochemical analysis of a suite of stratigraphic units within the Neoproterozoic Cambrian Officer Basin to the immediate south indicate the development of a foreland architecture at ca. 600 Ma. An excursion in ϵ_{Nd} values towards increasingly less negative values at this time is interpreted

as representing a large influx of Musgrave derived sediments.

Understanding the nature of the basement separating the SAC from the NAC and WAC is vital in constructing models of the amalgamation of Proterozoic Australia. This region is poorly understood as it is overlain by the thick sedimentary cover of the Officer Basin. However, the Coompana Block is one place where basement is shallow enough to be intersected in drillcore. The previously geochronologically, geochemically, and isotopically uncharacterised granitic gneiss of the Coompana Block represents an important period of within-plate magmatism during a time of relative magmatic quiescence in the Australian Proterozoic. U-Pb LA-ICPMS dating of magmatic zircons provides an age of ca. 1.50 Ga, interpreted as the crystallisation age of the granite protolith. The samples have distinctive A-type chemistry characterised by high contents of Zr, Nb, Y, Ga, LREE with low Mg#, Sr, CaO and HREE. ϵNd values are high with respect to surrounding exposed crust of the Musgrave Province and Gawler Craton, and range from +1.2 to +3.3 at 1.5 Ga. The tectonic environment into which the granite was emplaced is also unclear, however one possibility is emplacement within an extensional environment represented by interlayered basalts and arenaceous sediments of the Coompana Block. Regardless, the granitic gneiss intersected in Mallabie 1 represents magmatic activity during the "Australian magmatic gap" of ca. 1.52-1.35 Ga, and is a possible source for detrital ca. 1.50 zircons found within sedimentary rocks of Tasmania and Antarctica, and metasedimentary rocks of the eastern Musgrave Province.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Benjamin P. Wade

Acknowledgments

First and foremost I would like to sincerely thank my supervisors Karin Barovich and Martin Hand for the opportunity to take on this exciting project within the Musgrave Province, and their support and stimulus throughout made it a thoroughly rewarding experience. I would like to thank the Maths, Chemistry, and Physics Departments for being so boring and antisocial as to railroad me into doing Geology, the result of which has left me indebted to them for life.

Thanks go to Karin for introducing me to the world of geochemistry, and for always being so enthusiastic. Your door was always open, and there was never a word of complaint, even with me continuously knocking on your door near the end with questions about layered intrusions! Also sincere thanks for believing that I could do a Ph.D and offering scholarship support (even though I did get crap third year marks..)

I would also especially like to thank Martin for providing unending ideas and guidance on all things geology related, and for introducing me to the idea that field areas don't just come as powders in plastic jars. His experience and ideas in the field has expanded my knowledge a hundred fold (even if he is a bit obsessed about garnet...).

I am very grateful to the technical and administration staff of the department and Adelaide Microscopy who have helped with many different facets of this project. Especially to David Bruce for all his expertise in the (relatively) clean lab and on the Mass Specs. Angus Netting, John Terlet, and Peter Self are also sincerely thanked for their patience and expertise on the workings of the microprobe, and for all their help in setting up the LA-ICPMS (also for putting up with on-the-spot carbon coating....)

The Musgrave Team - Justin, Ailsa, and Simmo at PIRSA provided invaluable assistance with fieldwork, resources and local knowledge. Many thanks for making the project interesting and fully supporting it. The field would never have been as fun if you guys weren't so easy going (even though I had to put up with Justins obsession with anime, Ailsa's obsession with vegetables and Simmo's obsession with meat). The crazy chats around the fire in the absence of alcohol will be missed.

I also appreciate the help, expertise and feedback of Ian Scrimgeour, Dot Close, and Chris Edgoose on preliminary drafts of manuscripts, as well as providing me with samples from the Mann Ranges.

Thanks to all the other students who have made my Ph.D experience such great fun, especially to Clarky, Swainy and Lachy who made life in CERG tank Mark I a great experience. CERG tank Mark II students Spuz, Rian, Matt and Yee are also thanked for putting up with my loud music for the last year and a half. Justin is particularly thanked for his exchange of ideas on all things geochemical and geochronological (even if he does love the LA-ICPMS a bit too much, and I dare say would like to take it to bed with him), and to Kate for indulging me in my crazy ideas for a store located in Burnside that sells cat clothes. Also thanks must be passed to Kelsey for sharing his vast knowledge of rocks (even though he does have a weird scary obsession with sapphirine and osumilite), and for being the butt of many a practical joke and never once punching me in the face. Thanks to the Murray Bridge boys/girls who made my life outside this thesis considerably more fun than the time spent in front of the computer writing it, even if I never had time to catch up with them.

Finally and most of all thanks to my family who helped me through everything. Thanks to Dad for taking the family on all the trips around Australia which aroused my interest in geology (even if he did throw away all my rock samples I brought back with me telling me they were crap). Thanks to dad also for believing I could do a Ph.D and for providing me with the motivation to finish it. Thanks to Mum for worrying about everything, and for always making sure I was ok through the whole ordeal. Thanks to both Mum and Dad for the financial support throughout my Ph.D, it has made the whole process much less stressful and much more enjoyable. Thanks to Nana and Pappa for always being interested and offering their support. Thanks to Belinda and Michael for reminding me there is life outside a university, and for letting me house-sit their place on numerous occasions so I could indulge in my Antiques Roadshow. Thanks to Jessica for being such an easy-going sister to live with, even if I have to pay for everything.

Good Times!

Publications and Conference abstracts

Peer Reviewed Journal Articles

Wade, B.P., Hand, M. and Barovich, K.M., 2005. Nd isotopic and geochemical constraints on provenance of sedimentary rocks in the eastern Officer Basin, Australia: implications for the duration of the intracratonic Petermann Orogeny. *Journal of the Geological Society*, 162: 513-530.

Wade, B.P., Barovich, K.M., Hand, M., Scrimgeour, I.R. and Close, D.F., 2006. Evidence for early Mesoproterozoic arc magmatism in the Musgrave Block, central Australia: Implications for Proterozoic crustal growth and tectonic reconstructions of Australia. *Journal of Geology*, 114(1): 43-63.

Wade, B.P., Barovich, K. and Hand, M., Maidment, D., 2006. The Musgrave Province, central Australia: cinching the Belt Supergroup down under? *Terra Nova*. In review.

Wade, B.P., Clark, C., Hand, M., 2006. MonAnal v1.0 for Excel: A spreadsheet package for calculating chemical ages, errors and chemical variations of monazite from electron microprobe analyses. *Computers and Geosciences*. In review.

Wade, B.P., Kelsey, D.E., Hand, M., Barovich, K., 2006. The Musgrave Province; Terra Anonymus? *Precambrian Research*. Accepted

Payne, J.L., **Wade, B.P.**, Hand, M., Barovich, K.M., Maidment, D., Netting, A., 2006. On the optimisation and accuracy of LA-ICP-MS for U-Pb monazite geochronology: Applications from the earliest Palaeoproterozoic to Palaeozoic. *Chemical Geology*. In review.

Hand, M., Reid, A., Schwarz, M., Dutch, R., **Wade, B.P.**, 2006. Tectonic Framework for the Evolution of the Gawler Craton. *Economic Geology*. In review.

Conference Abstracts

Wade, B., Hand, M., and Barovich, K., (2001). Geochemical and Nd isotopic constraints on provenance of sediments in the Officer Basin'. In: Storkey, A.C. (ed) 15th Victorian universities earth sciences conference. *Abstracts - Geological Society of Australia*. vol 66, p8.

Wade, B., Hand, M., and Barovich, K., (2002). Neodymium isotopic and geochemical constraints on provenance of sedimentary rocks in the Eastern Officer Basin, Australia: Implications for the duration of the intracratonic Petermann Orogeny'. *16th AGC Geoscience 2002, Volume 72*, Adelaide, Australia.

Wade, B.P., Barovich, K. and Hand, M., 2004. Proterozoic crustal evolution in the Musgrave Block, central Australia: geochemical and isotopic constraints. *17th AGC Conference Vol. 73*, pp. 191. Hobart, Australia.

Wade, B.P., Barovich, K. and Hand, M., 2006. Outcomes of the study on the Cumulate mafic rocks of the Giles Complex, S.A.; Musgrave Province Linkage. *South Australian Resources & Energy Investment Conference*.

Wade, B.P., Barovich, K. and Hand, M., 2005. Towards a tectonic synthesis for the Musgrave Block. In: H.e. al. (Editor), STOMP 2005, Structure, Tectonics and Ore Mineralisation Processes Abstract Volume, pp. 140.

Wade, B.P., Barovich, K. and Hand, M., 2005. Geochemistry and Provenance of a Mesoproterozoic (1.4 Ga) eastern Musgrave Block basin: Buddying up to the Belt-Purcell Basin. In: M.T.D. Wingate and S. Pisarevsky (Editors), Supercontinents and Earth Evolution Symposium, 2005. Geological Society of Australia Inc. Abstracts, pp. 43.

Scrimgeour, I.R., Edgoose, C.J., Close, D.F. and **Wade, B.P.**, 2005. The Musgrave Province; NT's most underexplored terrane. In: T.J. Munson (Editor), Record of abstracts; Annual Geoscience Exploration Seminar (AGES) 2005.

Payne, J.P., **Wade, B.P.**, Hand, M., Barovich, K.M., Clark, C., 2006. Optimising the spatial resolution, fractionation and temporal precision of monazite U-Pb La-ICP-MS geochronology. 16th Annual Goldschmidt Conference. 2006. Melbourne, Australia.

Clark, C., Collins, A.S., **Wade, B.**, Kelsey, D., Payne, J., Santosh, M., Hand, M., 2006. Coupling accessory mineral chemistry and geochronology with calculated phase diagrams: an example from the UHT Palghat Cauvery shear system, southern India. Granulites 2006, Brasilia, Brazil.