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Reworking the Gawler Craton: Metamorphic and geochronologic constraints on Palaeoproterozoic reactivation of the southern Gawler Craton, Australia

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Table of Contents

Abstract	i
Acknowledgements	iii
Publications and Selected Conference Abstracts	v
Declaration	vii
Chapter 1 - Introduction, Reworking the Gawler Craton	1
Thesis Outline	9
References	11
Chapter 2 - In-situ EPMA monazite chemical dating at the University of Adelaide: Setup, procedures, comparisons and application to determining the timing of high-grade deformation and metamorphism in the southern Gawler Craton.	17
2.1 Introduction	17
2.2 Review of EPMA monazite dating theory	19
2.3 Analytical method	21
2.3.1 SX51 operating conditions	22
2.3.2 Elements and standards	22
2.3.3 Peaks, Backgrounds and Interferences	25
2.3.4 Counting Times	28
2.4 Sample Preparation	29
2.5 Data Collection Strategy, Analysis and Reduction	30
2.6 Results of Comparative Study	31
2.6.1 Sample SB17	31
2.6.2 Sample GL4B	31
2.6.3 MAdel Standard	32
2.6.4 Sample 222	32
2.7 Application to an unknown	32
2.7.1 Geological Setting	32
2.7.2 Results	34
2.8 Conclusions	36
Acknowledgements	36
References	37
Appendix 2.1	44
Chapter 3 - High-grade Palaeoproterozoic reworking in the southeastern Gawler Craton, South Australia.	45
3.1 Introduction	45

3.2 Regional Geology	48
3.2.1 Tectonothermal events of the southern Eyre Peninsula	50
3.3 Structural reworking of the Coffin Bay Peninsula	51
3.4 Petrography of the Shear Zones	54
3.4.1 Petrography of the felsic shear zones	54
3.4.2 Petrography of the metabasites	55
3.5 Mineral chemistry	55
3.5.1 Garnet	55
3.5.2 Clinopyroxene	55
3.5.3 Amphibole	56
3.5.4 Mica	56
3.5.5 Feldspar	56
3.5.6 Ilmenite and Titanite	56
3.6 Thermobarometric constraints on metamorphism.	57
3.7 Age constraints on deformation and metamorphism	59
3.7.1 EPMA Monazite Chemical Dating Analytical Techniques	59
3.7.2 SHRIMP Analytical techniques	60
3.7.3 U-Pb Geochronology Results	60
3.7.4 Interpretation of geochronological results	64
3.8 Discussion	67
3.9 Conclusions	69
Acknowledgements	69
References	69
Appendix 3.1	74

Chapter 4 - Tectonothermal evolution of reworked Archaean granulite-facies metapelites in the southern Gawler Craton, Australia. **75**

4.1 Introduction	75
4.2 Geological Setting	77
4.2.1 Tectonothermal Events of the Southern Gawler Craton	79
4.3 Lithology and Structure of Shoal Point	82
4.4 Sample Petrography	84
4.4.1 Assemblage 1	84
4.4.2 Assemblage 2	85
4.4.3 Assemblage 3	87
4.5 Mineral Chemistry	88
4.5.1 Assemblage 1	90
4.5.2 Assemblage 2	90
4.5.3 Assemblage 3	90
4.6 Geochronology	90
4.6.1 Garnet Sm-Nd Geochronology Methods	91
4.6.2 EPMA Monazite Geochronology Methods	91
4.6.3 Geochronological Results	93
4.7 Metamorphic Modelling	96
4.7.1 Effective Bulk Compositions	96
4.7.2 Determining H ₂ O Values	99
4.7.3 Models in the MnNCKFMASH System	99

4.7.4 Models in the NCKFMASHTO System	101
4.8 Discussion	103
4.8.1 Evolution of the Shoal Point Metapelites	103
4.8.2 Tectonic Model for the Development of the southern Kimban Orogeny	105
4.9 Conclusions	107
Acknowledgements	108
References	108
Appendix 4.1	114
Chapter 5 - The tectonothermal evolution of the crustal-scale Kalinjala Shear Zone, southern Gawler Craton, Australia	115
5.1 Introduction	115
5.2 Geological Setting	118
5.3 Existing constraints on the Kimban Orogeny	120
5.4 Structural Development of the Kalinjala Shear Zone	122
5.4.1 Port Neill Section	124
5.4.2 Mine Creek Section	125
5.5 Sample Petrography	128
5.5.1 Port Neill Samples	128
5.5.2 Mine Creek Samples	130
5.6 Mineral Chemistry	130
5.6.1 Port Neill Samples	130
5.6.2 Mine Creek Samples	134
5.7 Age Constraints on Deformation and Metamorphism	134
5.8 Metamorphic Evolution	136
5.8.1 <i>P-T</i> Constraints from the Port Neill Section	136
5.8.2 <i>P-T</i> Constraints from the Mine Creek Section	138
5.8.3 Cooling Rates	140
5.9 Discussion	143
5.9.1 Tectonic Evolution of the Kalinjala Shear Zone	143
5.9.2 Implications for Exhumation during the Kimban Orogeny	147
5.10 Conclusions	147
Acknowledgements	148
References	148
Appendix 5.1	155
Chapter 6 - Retention of Sm-Nd isotopic ages in garnets subjected to high-grade thermal reworking: Implications for diffusion rates of major and rare earth elements and the Sm-Nd closure temperature.	157
6.1 Introduction	157
6.2 Geological setting	158
6.3 Petrography	160
6.4 Analytical methods	161
6.4.1 Monazite	161
6.4.2 Garnet	163
6.5 Results	164

6.5.1 Mineral Chemistry	164
6.5.2 Physical Conditions of Garnet Formation	165
6.5.3 Age of the Sir Isaac Granite	172
6.5.4 Garnet Sm-Nd Geochronology	173
6.6 Discussion	174
6.6.1 Comparison of Major and REE Diffusion Rates in Garnet	174
6.6.2 Closure Temperature of the Sm-Nd System in Garnet	177
6.6.3 The Effect of Zoning on Sm-Nd Age Retention	178
6.7 Conclusions	180
Acknowledgements	180
References	180
Appendix 6.1	186
Chapter 7 - Summary	187
7.1 Introduction	187
7.2 Thesis Summary	187
7.2.1 In-situ EPMA monazite Geochronology as a tool for constraining event timing in reworked assemblages	187
7.2.2 Reworking the southeastern Gawler Craton	188
7.2.3 Reworking the Sleaford Complex	188
7.2.4 Evolution of the Kalinjala Shear Zone	189
7.2.5 Garnet Sm-Nd isotope systematics	190
7.3 Constraints on the Southern Sleafordian Orogeny	190
7.4 The Evolution of the Southern Kimban Orogeny	191
7.5 Future Work	195
References	196
Supplementary Appendix 1 - Cambrian reworking of the southern Australian Proterozoic Curnamona Province: constraints from regional shear-zone systems.	199
Supplementary Appendix 2 - Orogen-parallel flow during continental convergence: Numerical experiments and Archean field examples: COMMENT AND REPLY.	213
Supplementary Appendix 3 - Adelaide Uni EPMA monazite chemical dating procedure.	215

List of Figures

Figure 1.1. Simplified interpreted subsurface geology of the Gawler Craton, South Australia.	2
Figure 1.2. Locations of the major rock units.	3
Figure 1.3. Time-space plot for the Gawler Craton.	6
Figure 2.1. Location and regional geology and TMI image of the southern Gawler Craton.	19
Figure 2.2. Cameca SX51 electron micro-probe.	21
Figure 2.3. WD scans across the U and Th region using a PET crystal.	27
Figure 2.4. WD scans across the Pb region using a PET crystal.	28
Figure 2.5. WD scans across the REE region.	29
Figure 2.6. EPMA geochronological results from the selected comparison samples.	33
Figure 2.7. EPMA monazite geochronological results for the unknown samples from Fishery Bay.	35
Figure 3.1. Simplified interpreted subsurface geology of the Gawler Craton.	46
Figure 3.2. Interpreted sub-surface geology of the Eyre Peninsula.	47
Figure 3.3. Coffin Bay outcrop photos.	48
Figure 3.4. Structural Map of the Coffin Bay Peninsula.	53
Figure 3.5. Sample photomicrographs.	54
Figure 3.6. Quantitative garnet cation profiles.	58
Figure 3.7. Relative probability histograms for EPMA monazite geochronology.	62
Figure 3.8. U-Pb concordia diagrams for titanite and monazite SHRIMP data.	66
Figure 3.9. Temperature – time diagram for the western Eyre Peninsula.	68
Figure 3.10. TMI image of the Eyre Peninsula.	68
Figure 4.1. Simplified interpreted subsurface geology of the Gawler Craton.	76
Figure 4.2. Interpreted sub-surface geology of the southern Eyre Peninsula.	78
Figure 4.3. Time-space plot for the southern Gawler Craton.	79
Figure 4.4. Lithological and structural map of the Shoal Point section.	80
Figure 4.5. Outcrop photos of the Shoal Point units.	83
Figure 4.6. Regional TMI image of the southern Gawler Craton.	85
Figure 4.7. Photomicrographs of the Shoal Point assemblages.	86
Figure 4.8. Representative garnet X-ray maps.	89
Figure 4.9. Garnet Sm-Nd two point isochrons.	93
Figure 4.10. Relative probability distributions for EPMA monazite geochronology.	95
Figure 4.11. <i>T-M</i> pseudosection in the NCKFMASHTO system.	97
Figure 4.12. MnNCKFMASH pseudosection for assemblage 1.	98
Figure 4.13. NCKFMASHTO <i>P-T</i> pseudosection for the whole rock composition from assemblage 2.	100
Figure 4.14. NCKFMASHTO <i>P-T</i> pseudosection for the retrograde aluminous domains within assemblage 2.	101
Figure 4.15. NCKFMASHTO <i>P-T</i> pseudosection for assemblage 3.	102
Figure 4.16. Structural cartoon for the proposed model for the development of the Shoal Point granulites.	106

Figure 5.1. Transpression Model.	116
Figure 5.2. Simplified interpreted subsurface geology of the Gawler Craton.	117
Figure 5.3. Interpreted sub-surface geology of the Eyre Peninsula.	118
Figure 5.4. Summary of Vassallo and Wilson's (2001; 2002) interpreted structural evolution of the southern Eyre Peninsula.	121
Figure 5.5 Structural map of the Port Neill coastline of Oussa (1993).	122
Figure 5.6. Outcrop photos of the Port Neill section.	124
Figure 5.7. Structural and lithological map of the Mine Creek section.	126
Figure 5.8. Mine Creek outcrop photos.	127
Figure 5.9. Photomicrographs from the Port Neill and Mine Creek Sections,	129
Figure 5.10. Major element compositional profiles across selected garnets from the Mine Creek and Port Neill sections.	131
Figure 5.11. EPMA X-ray maps of representative monazites used for EPMA monazite geochronology.	135
Figure 5.12. Relative probability distributions for EPMA monazite geochronology analyses.	137
Figure 5.13. <i>P-T</i> pseudosection for sample Mine Creek MC10.	138
Figure 5.14. <i>P-T</i> pseudosection for sample MC1.	139
Figure 5.15. Modelled cooling rates derived from retrograde X_{Mg} zoning profiles from garnets in contact with biotite.	142
Figure 5.16. Graphical representation of the Kimban Orogeny structures, geochronology and metamorphic evolution.	145
Figure 5.17. Representation of particle flow paths and geothermal gradients.	146
Figure 6.1. Regional interpreted geology of the southern Gawler Craton.	159
Figure 6.2. A/CNK-A/NK plot of samples from the Sir Isaac Granite.	161
Figure 6.3. Photomicrographs of the Sir Isaac Granite.	162
Figure 6.4. Garnet cation and REE traverses for selected samples.	166
Figure 6.5. <i>P-T</i> pseudosection for the peraluminous Sir Isaac granite in the system NCKF-MASH.	172
Figure 6.6. Representative BSE images of targeted monazites.	173
Figure 6.7. U-Pb monazite Concordia diagram for the Sir Isaac granite.	175
Figure 6.8. Graph displaying the deviation of the garnet Sm-Nd ages retrieved from the grains of different sizes from the interpreted crystallisation age of 2414 Ma.	176
Figure 6.9. Arrhenius plot of collected experimental diffusion data for major elements and REE in garnet.	176
Figure 7.1. 1st VD magnetic intensity image of the Gawler Craton with the distribution of Kimban Orogeny metamorphic ages.	192
Figure 7.2. Collection of <i>P-T</i> and geochronology data for the southern Gawler Craton.	194

Abstract

The Gawler Craton in South Australia consists of an Archaean to Palaeoproterozoic core surrounded and intruded by a series of Palaeo- to Mesoproterozoic metasediments and igneous suites. The region has experienced a protracted *c.* 1700 Myr tectonic history from the Archaean through to the Mesoproterozoic, experiencing numerous cycles of deformation, magmatism and basin development. Despite hosting a number of mineral deposits, including the immense Olympic Dam iron oxide-copper-gold deposit, the tectonothermal evolution of the Gawler Craton remains poorly constrained. A significant ambiguity in our current understanding of the geological framework of the Gawler Craton revolves around the timing and spatial distribution of the tectonic events within the craton and their metamorphic evolution. This study addresses some of this ambiguity by unravelling the timing and tectonothermal evolution of the reworked southern Gawler Craton, using a combination of structural and metamorphic analysis, coupled with targeted geochronology. These methods have been applied to three locations representing different lithologies across the southern Gawler Craton.

Putting absolute time into structural and metamorphic analysis is a vital tool for unravelling the development of ancient and modern orogenic systems. Electron Probe Micro-Analysis (EPMA) chemical dating of monazite provides a useful method of obtaining good precision age data from monazite bearing assemblages. This technique was developed at the University of Adelaide in order to constrain the timing of reworked assemblages from the southern Gawler Craton. EPMA measurements carried out on samples of known age, from Palaeoproterozoic to Ordovician, produce ages which are within error of the isotopically determined ages, indicating the validity of the developed setup. This technique, together with SHRIMP monazite and titanite and garnet Sm-Nd geochronology, was used on selected samples from the southern Gawler Craton to determine the timing of high-grade metamorphism and deformation. The results show that the Sleaford Complex records evidence of an early D_1 event during the *c.* 2450 Ma Sleaford Orogeny recorded within structural boudins. The majority of the data indicates that the region underwent subsequent reworking and thorough overprinting during the 1725–1690 Ma Kimban Orogeny.

In the Coffin Bay region, Palaeoproterozoic peraluminous granites of the Dutton Suite are reworked by a series of migmatitic and mylonitic shear zones during the Kimban Orogeny. Peak metamorphic conditions recorded in mafic assemblages indicate conditions of 10 kbar at 730°C. The post-peak evolution is constrained by partial to complete replacement of garnet – clinopyroxene bearing mafic assemblages by hornblende – plagioclase symplectites, which record conditions of *c.* 6 kbar at 700°C, implying a steeply decompressional exhumation path.

The Shoal Point region consists of a series of reworked granulite-facies metapelitic and metaigneous units which belong to the late Archaean Sleaford Complex. Structural evidence indicates three phases of fabric development with D_1 retained within boudins, D_2 consisting of a series upright open to isoclinal folds producing an axial planar fabric and D_3 , a highly planar vertical high-strain fabric which overprints the D_2 fabric. Geochronology constrains the D_1 event to the *c.* 2450 Ma Sleafordian Orogeny while the D_2 the D_3 events are constrained to the 1730–1690 Ma Kimban Orogeny. *P-T* pseudosections constrain the metamorphic conditions for the Sleafordian Orogeny to between 4.5–6 kbar and 750–780 °C. Subsequent Kimban-aged reworking reached peak metamorphic conditions of 8–9 kbar at 820–850 °C during the D_2 event. Followed by near isothermal decompression to metamorphic conditions

<6 kbar and 790–850 °C associated with the development of the D_3 high-strain fabric.

The Pt Neill and Mine Creek regions are located in the core and on the flank of the crustal scale Kalinjala Shear Zone, which forms the main structural element of the poorly exposed Kimban Orogen. Samples record a similar structural development with a dextrally transpressive system resulting in a layer parallel migmatitic gneissic to mylonitic KS_1 fabric which was subsequently deformed and reworked by upright folds and discrete KD_2 east-side-down sub-solidus mylonitic shear zones during east-west compression. Geochronology constrains the timing of deformation and metamorphism to the Kimban Orogeny between 1720 and 1700 Ma. Metamorphic P - T analysis and pseudosections constrain the peak M_1 conditions in the core of the shear zone to 10–11 kbar at *c.* 800 °C reflecting lower crustal conditions at depths of up to 30 km. On the flank of the shear zone the M_1 conditions reached 6–7 kbar at 750 °C followed by sub-solidus reworking during KD_2 at conditions of 3–4 kbar at 600–660 °C, suggesting a maximum burial of <24 km. Cooling rates suggest that the core of the shear zone cooled at rates in excess of 40–80 °C Ma^{-1} while the flank underwent much slower cooling at < 10°C Ma^{-1} . The rapid cooling and inferred decompression in the core of the shear zone reflects rapid burial and exhumation of lower-crustal material into the mid-crust along the Kalinjala Shear Zone. The absence of evidence for extension indicates that differential exhumation and the extrusion of lower-crustal material into the mid-crust was driven by transpression along the shear zone and highlights the role of transpression in creating large variations in vertical exhumation over relatively short lateral extents.

Garnet is a vital mineral for determining constrained P - T - t paths as it can give both the P - T and t information directly. However, estimates of the closure temperature of the Sm-Nd system in garnet vary considerably leading to significant uncertainties in the timing of peak conditions. Five igneous garnets of varying size from an undeformed 2414 ± 6 Ma garnet – cordierite bearing s-type granite from the Coffin Bay region, that were subjected to high-T reworking during the Kimban Orogeny, have been dated to examine their diffusional behaviour in the Sm-Nd system. Garnets were compositionally profiled and then dated. A direct correlation exists between grain size and amount of resetting highlighting the effect of grain size on closure temperature. Major element and REE traverses reveal homogenous major element profiles and relict igneous REE profiles. The retention of REE zoning and homogenisation of major element zoning suggests that diffusion rates of REE's are considerably slower than that of the major cations, in disagreement with recent experimental determinations of the diffusion rates of REE in garnet. The retention of REE zoning and the lack of resetting in the largest grains suggests that Sm-Nd closure temperature in garnet is a function of grain-size, thermal history and REE zoning in garnet.

The findings of this study provide the first temporally constrained tectonothermal model of the evolution of the southern Gawler Craton. The P - T conditions obtained from the earliest D_1 fabric provide the first quantitative constraints on the P - T conditions of the southern Sleafordian Orogeny. The P - T - t evolution determined for the 1725–1690 Ma Kimban Orogeny indicate it developed along a clockwise P - T path, and dominates the structural and metamorphic character of the southern Gawler Craton. The large variations in exhumation over short lateral extents reflect the exhumation of lower crustal rocks during the Kimban Orogeny driven by transpression during the development of a regional transpressional ‘flower structure’.

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Thus, the task is, not so much to see what no one has yet seen; but to think what nobody has yet thought, about that which everybody sees.
-Erwin Schrodinger (1887-1961)

Publications and Selected Conference Abstracts

Journal Articles

Philips, G., Kelsey, D.E., Corvino, A.F. and **Dutch, R.**, In Review. Continental reworking associated with overprinting orogenic events—A chemical (Th+U)—Pb monazite dating and phase equilibria study from the southern Prince Charles Mountains, East Antarctica. *Journal of Petrology*.

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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 made available for loan and photocopying.

Rian A. Dutch