Reworking the Gawler Craton:

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

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

January 2009

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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 °CMa^{-1} while the flank underwent much slower cooling at < 10°CMa^{-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 homogonous 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'.

Acknowledgements

Firstly I would like to thank my supervisors Martin Hand and David Kelsey. They have both provided me with excellent supervision and guidance and their support and stimulus throughout made it a thoroughly rewarding experience. Karin Barovich has also provided invaluable support and assistance.

A huge thankyou goes to Martin for numerous reasons including; for being such a good honours supervisor that I actually wanted to continue working with him on my Ph.D, for providing incredible guidance and always being there (except when he was away) with help and suggestions, for teaching me how to do field work properly, for giving me a new appreciation of metamorphic petrology (I now understand why he uses words like spiffy and sexy when referring to garnets), and most importantly for having faith in me to actually get there in the end.

Honourable mentions need to go to Angus Netting, Peter Self and John Terlet from Adelaide Microscopy. Their massive help and good humour made many long hours (days) in the med. school basement more than just bearable but fun.

David Bruce for all his help (and patience) with garnet Sm-Nd geochronology. Anthony Reid for his significant help and guidance with South Australian geology and his suggestions and improvements to this thesis. Pete Kinny for guidance and expertise with the SHRIMP geochronology done at Curtin University of Technology. David Steel for all his help in getting me up to speed with the ins and outs of setting up EPMA monazite dating and for providing (free of charge) new single element standards.

Thanks goes to all the other past and present CERGers who have made doing a Ph.D so much fun. To Payney (a co-starter and fellow Gawler-ite), Wadey (e-bayer extraordinaire), Lachy and Clarky (CERGers mark I) and Swainy (the bushman from Hahndorf). A huge thanks goes to Mike Szpunar for his assistance with field work and his constant discussions which have made me a better geologist.

A big thankyou needs to go to my family. Especially my Mum and Dad for all the support and assistance that you have given me over the years, I hope I've made you proud. My brothers and sister, Nana and Grumps and Kathy and Wayne, for always being there and giving me such a great family to be a part of. A huge thanks needs to go to my parents in-law, Tom and Anne. Joining your family has been a great experience and I thank you for all your support and assistance over the years.

Outside of Uni life I'd like to thank Allan and Lauren Cadd (and now Imogen) for being such great friends. Also my Ultimate team mates in the Flycatchers and Karma clubs for being such a great bunch of people to play with. I've really enjoyed playing Ulti with you all and haven't minded missing months of Ph.D time going away to play tourneys. My sport has provided a great escape from Uni and most likely kept me sane.

Most importantly I want to thank my beautiful wife Bron. She has been with me right from the start and has provided me with incredible support and motivation, getting me back on track during the slow, tough periods. I kept saying once I had this monkey off my back I'd be less distracted and I hope I can live up to that promise. I really am the luckiest bloke around.

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.

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