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Faculty of Science

School of Physical Science

Department of Earth Sciences

Stratigraphy, Sedimentology, and Geochemistry of the Pandurra Formation

Laura Rollison

Ph.D. Thesis

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Acknowledgements

The journey toward the production of a Doctor of Philosophy thesis begins decades before the first day of the scientific project. For me it began with a strange yellow book in my Grandfather's library titled *Prospecting for Gold* by IL Idriess (1931). I cannot remember how old I was when he gave it to me, but I know I could not read, and it was the black and white sketches that interested me. A book that I forgot until I discovered Trent (my beautiful son) reading it, and I have now retrieved it from the bookcase in Brigitte's (my gorgeous daughter) bedroom. This book and my Grandparents ignited my deep passion for geology.

Ask anyone in the realm of economic geology and they will comment that it gets into your veins, Prospectors with minimal education to Professors who understand the science, it is a passion without an equal. I have worked with both sides of the educational spectrum. Denis O'Meara, a professional Prospector and exploration company creator, was the first person to see my potential as a Geologist. He inspired me to think against the current logic of exploration geology (even drilling backwards) and push the limits of science. Geoff Blackburn, Exploration Manager, made sure that as a female Geologist I knew that my career was going to be difficult (although at times the analogies he used were a little distasteful – we are not in Victorian England!). These two men knew how to get the best out of me, they pushed me and challenged me.

At times I do regret leaving Denis and Geoff for a manganese mine just right of Marble Bar, but it came as a relief to my husband Jason who was wanting me back in Adelaide (at least once every two weeks for a week). When I met Jason he knew I was studying Geology at the University of Adelaide, but I don't quite know whether he understood properly what would happen three years later when I graduated. Through the undulations of university Jason was there for me and continued to be by my side when I decided to fly to Perth for that first geological job interview with Denis. He has supported me through the light and darkness of being a lone female Geologist in a very remote masculine workplace.

As an undergraduate I saw the culture of the people within the University of Adelaide Mawson building, its subterranean academic offices (can't get geologists out of the ground) and its diverse academic views, as strange and conflicting. Andreas Schmidt-Mumm, my Honours supervisor, you were correct about everything. Inspiring academics from my undergraduate years were Andreas, Yvonne Bone, Karin Barovich, Victor Gostin, Patrick James, Ross Both, Martin Hand, Richard Hillis, and John Foden. Whilst working as an exploration/mining geologist in the Yilgarn, Pilbara, and Gawler Cratons or Adelaide Hills or as an environmental geologist with urban contaminated soil and water in Adelaide, I would think about the words of these academics and at times think "I wish I could tell them that they had helped me". I still haven't told them.

So, I was working with a small environmental consultancy in 2010 when I decided that I wanted to be scientifically creative (no more National Environmental Protection Measure (1999) guideline report writing!). Thoughts flickered back to Denis and Geoff. The whole time I had been out in the World there had only been three challenging figures, which included Kevin (Kevin Moriarty, Geologist and exploration company creator), and I realised through mastery of report writing that I was not cut out for rules nor the mindless repetition of environmental consultancy. What would

Denis, Geoff, and Kevin do? Study a Doctor of Philosophy in economic geology (two out of the three have theirs)! So off I went back to the University of Adelaide.

I remember meeting David Giles (my primary supervisor) and working out what I could study. He mentioned the Pandurra Formation, a name which immediately sparked my interest. A couple of years prior I was working for a uranium exploration company and I had used the Pandurra Formation as a target for exploration. So it began. Day one arrived and David suggested a long list of Journal articles on the Precambrian. In the first week I wondered what the Precambrian had to do with mineral dynamics and why on Earth had I signed up for a sedimentology and mineralogy project! What sort of mistake was I making?

Martin Kennedy offered fantastic advice about clay mineralogy and challenged my knowledge. When I asked him where to find information on dickite he replied that the best thing to do was to sit in the Geology section of the Library and start picking up books. A font of practical advice which made me smile and wisdom I have passed onto other students. Caroline Forbes, who initially had absolutely no time to chat to me (whilst waiting for David) but eventually became my secondary supervisor when the project began to drift further into economic geology and geologic time. Caroline has been a surprise supporter of my research and I am very happy to have had her dynamic input (even after her harsh reviews!).

Funding and support for my Doctor of Philosophy was provided from the Deep Exploration Technologies Cooperative Research Centre (DET CRC) and University of Adelaide. John Foden helped iron out the complexity of radiogenic isotope interpretation and the Beda Volcanics. Graham Heinson put his trust in me by allowing me to be a Demonstrator to the "First Years". Richard Hillis allowed me to join the exclusive DET CRC clan and once a year in Hahndorf for one minute I regret the membership.

When it came to sedimentary geology the best advice (outside my supervisory circle) came from Victor Gostin and Kathryn Amos, who both updated me on the presence of the concept of distributive fluvial systems and convinced me to go to talks given by petroleum geology academics. My sedimentary basin knowledge would not have been the same!

Karin Barovich, Alan Collins, and Martin Hand (zircons...zircons...zircons!) have supported me from a distance, offering encouragement and realigning my academic direction. David Bruce helped me to negotiate the windowless radiogenic isotope laboratory, the intricacies of acid digestion of rock, and hours of time sitting in a cold room with a delicate machine. Katie Howard inducted me onto countless machines and showed me the way of the zircon. My safety was constantly looked after by Deb Miller, a very important role! Even when I was sceptical it was fantastic to have time to talk with Joël Brugger and to have him agree so strongly in the origin of the small green spots, maybe I will get to the Syncatron one day to zap them (it's in my list of things to do)! Aoife McFadden helped me to find a way to put siltstone into a micro-CT machine and along with Ben Wade, Angus Netting, Ken Neubauer, and Lyn Waterhouse, assisted me with the wonderful microscopic equipment at Adelaide Microscopy.

I signed up for a challenge and I certainly received it from the wonderful staff at the Department of State Development (South Australia) especially from Tania Wilson, John Keeling, Alan Mauger, Wayne Cowley, Adrian Fabris, and Georgina Gordon. In addition, most of my research would not

have been possible without the staff of Glenside and Thebarton Core Libraries and the thousands of metres of drill core that was lain out for my inspection.

Patrick James opened opportunities to Tutor and Lecture in Geology at the University of South Australia, which I have enjoyed over the last three years and has taught me how to articulate the basics. Helen Alexander and Carolyn Grimes listened to me and urged me to continue the journey and reminded me that despite how I felt then it would be worth it at the end. Jacqueline Balston reminded me that strength, trust, and honesty are the keys to success (thank you for the positive feedback about my lecturing).

The energy and enthusiasm for my Doctor of Philosophy journey shown by David Giles has been amazing. There have been days when minutes before a meeting I have been ready to quit and return to the familiarity and safety of environmental consulting, only to change my mind once we began chatting about the Precambrian or economic geology. David gave me the space and time to make a few of my own rules and forge a sense of true independence with my research (a gift of absolute rarity).

Jason, Trent, and Brigitte were my inspiration to study this Doctor of Philosophy and their unconditional love and support over the years cannot be measured nor forgotten. I am grateful for their acceptance of stored rocks everywhere (house/car) and the time spent looking at outcrops in remote locations. Our trip to Pondanna Out-Station is an unforgettable highlight of my academic journey and a tangible attribute to your understanding! I also did this on behalf of the brilliant ancestral McCarthy women, in particular my Great Aunt Doreen an inspirational scientist who was unable to study a Doctor of Philosophy at the University of Adelaide because of her gender. My parents never understood my interest in Geology but have been the most important support structure for the early evolution of my academic life.

This has been a wonderful and enlightening episode in my life. A Doctor of Philosophy is really all about the people!

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Abstract

Life on Earth during the Mesoproterozoic was challenging with an aggressive low oxygen atmosphere, acidic hydrosphere, intense weathering of the lithosphere, and simple bacteria-plankton biosphere. The research within the following thesis investigates the interaction between the atmosphere, hydrosphere, lithosphere, and biosphere through an assessment of provenance, sedimentology, and characterisation of mineral systems of the Pandurra Formation in southern Australia during the Mesoproterozoic.

The Pandurra Formation preserves evidence of the gradual erosion of the Gawler Range Volcanics and subsequent climate variation of the region. This study characterises the mechanisms for sedimentation of the Pandurra Formation from the rapid lateral and vertical variation that resembles a multi-thread anabranching braided distributive fluvial system. This research identifies seven lithological associations that are not consistent with the existing four-member model.

This investigation reveals that the Pandurra Formation commenced sedimentation soon after 1562 ± 32 Ma. The zircon geochronology of the Pandurra Formation is similar that of the underlying pre-Mesoproterozoic basement geology, and matches with the observed regional geology of the Archean (2560 to 2500 Ma) and late Palaeoproterozoic to early Mesoproterozoic (1900 to 1450 Ma) Gawler Craton. Sm-Nd isotopic geochemistry reveals that the source age of the Pandurra Formation sediments varied with time from Archean dominated to Palaeoproterozoic back to an Archean signature. This research indicates a connection with the Pandurra Formation to the coeval Belt-Purcell Supergroup in North America, but not to the Rocky Cape Group in Tasmania or the East Antarctic Shield during the Mesoproterozoic. The Pandurra Formation represents a series of elevated terrestrial distributive fluvial systems that supplied sediment to the deep water Pritchard Formation from 1470 to 1454 Ma.

Evidence of two fluid flow events at 1211 ± 24 Ma (Vanguard-1) within the Pandurra Formation and at 469 ± 28 Ma (WHD-1) within the overlying Beda Volcanics is described. The spatial and detrital relationship between the Pandurra Formation and Palaeoproterozoic to early Mesoproterozoic IOCG-U enriched basement, indicates the potential to for the sedimentary sequence to host placer (Au and heavy mineral) and remobilised U and/or Cu systems. The Pandurra Formation within Vanguard-1 and numerous other diamond drill cores exhibit kaolinite-dickite and sericite alteration, typical of unconformity U and low temperature epithermal systems. The Beda Volcanics are determined to be prospective for Mississippi Valley-type systems (Pb-Zn-Ba), similar to that in the Adelaide Fold Belt during the waning stages of the ca. 510 to 490 Ma Delamerian Orogeny. The closure age of 1211 ± 24 Ma (Vanguard-1) precludes further hydrothermal activity during the Delamerian Orogeny within the Pandurra Formation.