Sedimentology, Provenance, and Salt-Sediment Interaction in the Ediacaran Pound Subgroup, Flinders Ranges, South Australia

John Waldon Counts
B.Sc., M.Sc.

A thesis submitted for the degree of

Doctor of Philosophy

Australian School of Petroleum

Faculty of Engineering, Computer, and Mathematical Sciences

The University of Adelaide

Adelaide, South Australia

July 2016

Shiny, speckled, red and sandy,

A bonney layer, quite a dandy

Rippled, stippled, grooved and fluted

On bedding plane for inspection suited.

A layer of red and some uniformity

And nicely opposite a fine unconformity.

Poised to announce the most famous of all

The layer of life, standing tall

-Terry Krieg

"Bonney Sandstone"

Contents

Figures and Tables

CHAPTER 5

CHAPTER 6

Appendix

Abstract

Much of our understanding of the sedimentary character and stratigraphic architecture of subsurface sedimentary deposits is derived from field-based studies of similar depositional systems exposed in outcrop. In South Australia, excellent surface exposures in the Neoproterozoic-Cambrian Adelaide Rift Complex provide a unique opportunity to examine a series of clastic sediments deposited in an ancient fluvial-deltaic to deep marine setting. Through extensive field and laboratory work, this study documents the sedimentology, stratigraphy, provenance, facies distribution and salt-sediment interaction of the upper Bonney Sandstone and Billy Springs Formation. These sediments formed part of the margin of the Australian subcontinent during the Ediacaran, a key time in Earth history just prior to the development of multicellular life. Field investigations reveal that the Bonney Sandstone is primarily comprised of sands and shales, often in progradational parasequences that become progressively sand-dominated upward. The formation thickens significantly to the north through the preservation of additional sediments that contain abundant fluvial features, suggesting a northern depocentre in the basin. Zircon data indicate that sediments may be sourced from the distant Musgrave Province and enter the basin from a large deltaic system in the northwest. These results provide substantial new information as to the palaeogeography of South Australia during this time, and are the product of interpretation using multiple lines of evidence and the study of numerous localities.

Throughout the Adelaide Rift Complex, salt diapirs penetrated the basin fill and formed adjacent rim synclines (minibasins) due to withdrawal of underlying salt. Salt-tectonized, passive-margin settings are significant components of hydrocarbon *systems in some of the world's most productive regions, yet these features are rarely exposed in outcrop as they are here. In the far northern Flinders Ranges, the Umberatana Syncline is interpreted as a salt-withdrawal minibasin that formed in a deeper-water setting. The map-view exposure of the structure allows the depositional processes and products in the minibasin interior to be studied in a way not possible elsewhere; deepwater minibasins are very rarely exposed at the surface. Field and petrographic work reveals a mud-dominated minibasin fill containing mass-flow deposits of varying stages of maturity, ranging from clast-bearing convolute-laminated slumps to sandy turbidites. In a more proximal setting, numerous measured sections along the margin of the Mt Frome minibasin clearly show that sediment character is influenced by diapir activity and the shedding of diapir-derived clasts. Lateral facies variability is controlled by growth faulting and diapir topography, with increased abundance of diapiric material near faults and highs, as well as thinning, onlap, and rotation of sediment blocks. These results, as well as those from elsewhere in the basin, are highly applicable to the prediction of reservoir, source, and seal quality in similar geologic settings in the subsurface.*

Declaration

I certify that this work 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 another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works. I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

John Waldon Counts   Date

Acknowledgements

I wish to thank the many people who have supported me personally and professionally throughout this project. First, I would like to thank my spouse Shelagh Jessop for coming with me to Australia and being understanding during the long process of writing this thesis. I would also like to thank my parents, grandparents, and family for their constant support, which has come in many different forms over the years. Third, I would like to thank my academic advisor, Kathryn Amos for many technical comments and helpful discussions, and for supporting my application to come to the University of Adelaide in the first place. Thanks are also due to Peter McCabe, and Bob Dalgarno, who provided much helpful advice over the course of this PhD.

Many other thanks are due to those who contributed to this thesis:

- Bruce Ainsworth, Jim Gehling, Ric Daniel and Vic Gostin for many technical discussions that impacted this work significantly
- My former advisor and excellent field partner Steve Hasiotis
- My fellow PhD candidates, research colleagues, and coauthors- Sara Moron, Tessa Lane, Jess Trainor, Frank Rarity, and Rachel Nanson
- Field assistants Claudia Valenti, Koyejo Oyinloye, and Limeng Liu
- Flinders Ranges landowners Barbara and Warren Fargher (Wirrealpa Station), Edie and Gina Nichol (Maynard's Well Station), and Jenny and Chris Mahoney (Umberatana Station)
- DEWNR for granting scientific research permits to Ikara-Flinders Ranges National Park and Vulkathunha –Gammon Ranges Nathional Park

Funding for this thesis is provided in part by the American Association of Petroleum Geologists Nancy Setzer Murray Memorial Grant and a University of Adelaide International Postgraduate Research Scholarship. I acknowledge the traditional inhabitants of the land on which this research was conducted.