Magnetotelluric monitoring of unconventional resources

A dissertation presented
by
Nigel Rees

In fulfilment of the requirements
for the degree of
Doctor of Philosophy
in the subject of
Geophysics

THE UNIVERSITY
of ADELAIDE

Submitted to the
Department of Earth Sciences,
School of Physical Sciences, Faculty of Sciences

Adelaide, December 2016

CONTENTS

LIST OF FIGURES

ABSTRACT

Magnetotelluric monitoring of unconventional resources

by Nigel Rees

Extraction of unconventional gas involves the movement of fluids at depth. In the case of shale gas, hydraulic fracturing is performed, where fluids are injected into sequences at high pressures resulting in permeable pathways for the trapped gas to escape. Coal seam gas (CSG) extraction involves a process termed depressurisation, where large volumes of groundwater are extracted from coal measures causing a pressure reduction that allows trapped gas to desorb from the coal seams. One of the key questions the industry sector is facing is whether it can effectively monitor movement of fluids and changes in Earth as these unconventional energy resources are being developed. We present two MT monitoring surveys of unconventional energy resource development. The first survey involves an industrial field study conducted in Queensland, Australia, where MT responses indicated the orientation of fluid flow resulting from depressurisation, which can be mapped and directly attributed to spatial and temporal variations in permeability. The second survey involves monitoring deep hydraulic fracturing of a shale gas reservoir in the Cooper Basin, Australia. MT observations indicated increases in bulk conductivity of 20 – 40% in both the temporal and spatial domain, with these changes caused by a combination of both injected fluid permeability and an increase in wider-scale in-situ permeability. Finally the telluric sounding method is introduced as a potential tool for monitoring hydraulic fracturing at depth. The advantage of this method is that it is relatively easy to measure electric fields with many dipoles and multi-channel systems and therefore electric field arrays

could be deployed and left out for continuous monitoring. Additionally, electric field transfer functions are essentially the identity matrix for a 1D Earth no matter what the vertical structure is and therefore monitoring involves plotting deviations relative to the identity matrix.

Thesis Supervisors: Prof. Dr. Graham Heinson, Dr. Stephan Thiel

STATEMENT OF ORIGINALITY

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name 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 in my name 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 Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Signed

Date

ACKNOWLEDGEMENTS

I would like to thank my Ph.D. supervisor Graham Heinson for his tremendous support, encouragement and supervision throughout my candidature. A very special thanks goes to Lars Krieger who has been an invaluable help with writing software as well as exchanging ideas presented throughout this thesis. I am grateful to my secondary supervisor Stephan Thiel for his guidance and advice.

QGC Ltd. and Santos are thanked for providing both financial help and assistance with field data collection. The Australian Geophysical Observing System (AGOS) and AuScope are thanked for all instrumentation used in this project. This research was funded by an Australian postgraduate award from the Australian government.

I wish to thank all my fellow colleagues for providing a friendly and fun work environment. In particular I would like to thank Simon Carter, Dennis Conway and Joseph Rugari for keeping me very entertained throughout my studies. I thank Goran Boren for making the instruments used for field surveys and participating in field work. Chris Matthews is thanked for helping with the logistics of the field surveys.

I thank my family and friends who have supported me throughout. Special thanks to Matt and Raz for ensuring jam sessions happened on a regular basis. Finally, I thank my partner Stephanie whom has given me the most love, encouragement and support through thick and thin.