

**PROGRESSIVE ALBITISATION IN THE “MIGMATITE CREEK”
REGION, WEEKEROO INLIER, CURNAMONA**

Thesis submitted for the degree of
Master of Science
Geology & Geophysics
School of Earth & Environmental Sciences
The University of Adelaide

by

CHENG LIN YANG

July 2008

Supervisors

Dr. Andreas Schmidt Mumm

School of Earth & Environmental Sciences
Geology and Geophysics
The University of Adelaide, Adelaide 5005, South Australia

Dr. Joel Brugger (ARC QEII Fellow)

School of Earth & Environmental Sciences
Geology and Geophysics,
The University of Adelaide, 5000 South Australia, and
South Australian Museum, Adelaide, 5000 South Australia, Australia

Statement of Authenticity

I Cheng Lin Yang declare that this thesis does not contain material which has been accepted to the ward of any other degree and diploma in any university and tertiary institute, and to the best of my knowledge and belief, does not contain 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 in all forms of non-commercial usages e.g. loan and photocopying.

Cheng Lin Yang

ACKNOWLEDGEMENTS

During the Msc candidature, the research has taken me to meet lots of people in Adelaide, Australia, helping and supporting me in many different ways.

- I would like to thank Dr. Baohong Hou and Dr. Weng-Long Zang in PIRSA for references. Without them, this study would not have existed for the application of scholarship and who/what I am.
- I have special thanks to my wife Yun Wu, my parents Tingxing and Shaoxiang, my brother Zhi and my sisters Feng, Bi and Xou, for their support throughout the period of study.
- Special thanks must go to my supervisors Dr. Andreas Schmidt Mumm and Dr. Joel Brugger for their advice and teaching in all aspects of this study, and for their greatly enduring patience and support throughout.
- For preparation of samples, whole rock analyses, electron microprobe analyses and laser ablation inductively coupled plasma spectrometry mass (LA-ICPMS) analyses; I would like to thank John Stanley and Angus Netting in the University of Adelaide.
- Thanks to Dr. Charles Rowland Twidale, Dr. Victor Gostin and Dr. Margaret Cargill for support of “language and illustrations”.
- Thank you all geoscientists and staff in the School of Earth and Environmental Sciences of the University of Adelaide, in the Department of Primary Industries and Resources South Australia and in the Graduate Centre for support in anonymous forms.

Finally, thank all of my friends and study mates in the university and around the world for support in spirit and soul of Geosciences.

ABSTRACT

Albitisation is pervasive and intense in the Curnamona Province. Most FeO-Cu-Au-U-REE deposits are associated with sodic alteration or albitisation (alkaline alteration) worldwide. The minor Cu-Au-U-REE mineralisation occurs in the large albitisation system in the Curnamona Province. Progressive albitisation allows us to demonstrate the mobility of metals linked to mineralisation in the Migmatite Creek, Weekeroo Inliers, Curnamona Province.

Lithological and thematic mapping of albitisation intensities distinguishing low-, medium-, and high- grade albitisation was carried out in the Migmatite Creek area using ArcGIS mapping tools. Progressive albitisation was investigated using whole rock, electron microprobe and Laser Ablation ICPMS analytical methods to establish major, trace and rare earth element variation on a range of scales in bulk samples and individual mineral phases.

Albitisation is structurally controlled by OD_3 antiformal folds and development of a network of breccias creating pathways of fluid flow. Intensities of albitisation decrease from antiformal to synformal fold hinges. Mass balance estimates, using isocons allow a semi-quantitative view of the evolution of fluid and rock compositions and the mobility of elements during progressive albitisation. The evolution of temperature was independently identified by using mineral geothermometers. Mobility of rare earth element (REE) resulted in extreme changes of REE patterns during progressive albitisation. The initial albitisation fluids were identified in the range of hypersaline (approximately 30 wt% equi. NaCl) with the NaCl rich - CO_2 - KCl - $MgCl_2 \pm Al(OH)_x \pm CaCl_2 - H_2O$ was related to regional fluids of metamorphism and migmatisation. 87 % of Eu and 99% of La were removed from psammites to fluids during high intensity albitisation. Most of the siderophile elements, Ni, Co, Cr, Mn and Mo, as well as Zn, Ba and Sr, were removed from unaltered rock to the fluids in the area.

The chemical equilibria of fluid/rock reaction were completely attained between quartz and albite during high–medium intensity albitisation against uncompleted equilibria in low intensity albitisation. New albite +quartz + accessory minerals replaced the original quartz + feldspars + biotite + magnetite assemblages. Progressive albitisation resulted in evolution of fluids and then lead to a secondary stage biotite alteration and a weak quartz alteration (inserted quartz veins). Fe – U – REE elements were extremely removed from all types of lithologies (metasediments and pegmatites and amphibolites) during progressive albitisation. A highly charged, metal fluid was formed during albitisation. Albitisation has great potential as a source process for mineralisation and from its characteristics shows links to the IOCG-REE systems.

TABLE OF CONTENTS

1	INTRODUCTION.....	1
1.1	Background.....	1
1.2	What is albitisation and why is it important?	3
1.3	Basics of Mineral Chemistry and Mineralogy.....	4
1.4	Albitisation: a global overview.....	5
1.4.1	Geological Settings	5
1.4.2	Albitisation and Mineralisation	6
1.4.3	Albitisation Fluids.....	8
1.4.4	Enrichment / Depletion of Elements.....	10
1.4.5	Rare Earth Element (REE) Patterns	11
1.5	Curnamona Geology	12
1.5.1	Stratigraphy.....	12
1.5.2	Structural/Tectonic Evolution.....	12
1.5.3	Metamorphism.....	13
1.5.4	Magmatism	13
1.6	Project Aims.....	15
2	APPROACH AND ANALYTICAL METHODS	16
2.1	Lithological and albitisation gradient mapping	16
2.2	Petrography.....	17
2.3	Whole rock analysis.....	17
2.3.1	X-Ray Fluorescence (XRF).....	17
2.3.2	Whole rock data including REE (ICP-MS).....	17
2.4	Mineral analysis.....	17
2.4.1	Electron Microprobe Analysis.....	17
2.4.2	Laser Ablation ICPM analysis.....	18
2.5	Mass balance calculations.....	19
3	RESULTS	20
3.1	Mapping of Migmatite Creek	20
3.1.1	Albitisation Units	21
3.1.2	Distribution of the Lithological units.....	24
3.1.3	Albitisation gradients in Pegmatites, Amphibolites and Quartz veins.....	24
3.2	Types of Breccias.....	26
3.3	Biotite Alteration and Silicification Alteration.....	27
3.4	Analytical Results	29
3.4.1	Petrography.....	29
3.5	Whole Rock Analysis	37
3.5.1	Whole Rock Compositions.....	37
3.5.2	Whole Rock REE Compositions	41
3.6	Microanalysis of Albitisation Mineralogy	46
3.6.1	Electron Microprobe	46
3.6.1.1	Plagioclase and K-feldspar.....	46
3.6.2	Laser-Ablation-Inductively Coupled Plasma Mass Spectrometry (LAICPMS) analysis	50

3.7 Results of the mass balance estimates	60
4 INTERPRETATION	62
4.1 Changes in Rock compositions	62
4.1.1 Variation of Na ₂ O, K ₂ O and CaO	63
4.1.2 Evolution of compositions	65
4.1.3.2 Breccias and metasediments	66
4.1.3.3 Unalbitised and albitised pegmatites	66
4.1.4 Enrichment/removal of elements	68
4.1.4.1 Albitisation	68
4.1.4.2 Biotite alteration	68
4.1.5 Bulk trace elements variation	72
4.1.6 Fluid evolution during albitisation and related alteration	73
4.1.7 Timing estimates	74
4.2 Mineralogy, Geothermometers and Chemistry	75
4.2.1 Minerals (Feldspar and Micas)	75
4.2.2 Geothermometers	80
4.2.3 REE characteristics of different rock types	81
4.2.4 REE patterns of minerals	84
4.2.5 The influences of albitisation on REE content and variation	85
4.3 Mobility of Elements	86
4.3.1 Siderophile elements and Cu – Pb – Zn (Chalcophile)	86
4.3.2 Ba, U and REE	87
5. CONCLUSIONS AND RECOMMENDATIONS	88
5.1 Conclusions	88
5.1.1 Albitisation System	88
5.1.2 Fluids and Mineralisation	88
5.2 Recommendations	89
6. REFERENCES	89
APPENDIX A: LOCATION OF SAMPLES AND FIELD DESCRIPTION	I
APPENDIX B WHOLE – ROCK CHEMISTRY	II
APPENDIX C MINERAL CHEMISTRY	XI