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**Hydrothermal Processes at the Osborne
Fe-Oxide-Cu-Au deposit, NW Queensland:
Integration of Multiple Micro-analytical Data
Sets to Trace Ore Fluid Sources**

Thesis submitted by

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in April 2007

**for the degree of Doctor of Philosophy
in the School of Earth and Environmental Sciences
James Cook University**

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STATEMENT ON THE CONTRIBUTION OF OTHERS

Financial contributions towards this PhD project have included:

- Project funding from the predictive mineral discovery Cooperative Research Centre (pmd*CRC).
- A Commonwealth Government of Australia International Postgraduate Research Scholarship (IPRS).
- A James Cook University Postgraduate Research Award for Overseas Students.
- A James Cook University, School of Earth Sciences Research Scholarship.
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- pmd*CRC funding for conference and short course attendance.

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- Roger Mustard provided samples from Osborne for this project and raw PIXE and LA-ICP-MS data sets.
- Mark Kendrick provided editorial support for Chapter 3 and trained me in the use of the MAP 215-50 Mass Spectrometer at the University of Melbourne.
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- James Cleverley provided training in the use of HCh modelling software.

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ABSTRACT

The Osborne mine exploits one of several significant iron oxide-copper gold (IOCG) deposits in the eastern part of the Proterozoic Mount Isa Inlier (Cloncurry District) in NW Queensland. Cu-Au bearing sulphides at Osborne are associated with volumes of massive, coarse grained quartz (silicification) which was precipitated both pre- and syn-ore deposition. This extensive quartz is a feature unique to Osborne and make it ideal for a fluid inclusion study. The ore forming fluids were examined by several bulk and microanalytical techniques. The fluid history of the deposit has been evaluated by microscope petrography and the physical conditions under which the fluids were trapped, and their compositions were estimated using microthermometry, laser Raman spectroscopy, proton induced X-ray emission (PIXE) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). The source of the fluids and their salinities were studied using combined noble gas and halogen analysis utilising a neutron activation-mass spectrometric method on bulk samples and PIXE analysis.

Petrographic studies show complex assemblages of fluid inclusions in which both pre- and post-ore depositional ore fluids are identified. Primary multi-solid fluid inclusions (MS), some with a carbon dioxide component (CB), trapped at 340 - >600°C with ultra-high salinity (<64 wt% NaCl equiv.), are correlated with the massive quartz precipitation event. High salinity (17-38 wt% NaCl equiv) pseudosecondary and secondary liquid-vapour ± halite fluid inclusions (LVD) were trapped at 105-292°C and lie on trails that emanate from chalcopyrite and are interpreted to relate to Cu-Au mineralisation and a second phase of quartz deposition. The decrease in temperature and salinity over the period of ore formation is attributed to fluid mixing.

Thermal and mechanical decrepitation of the fluid inclusion populations permitted semi-selective analysis of different fluid inclusion populations and a comparison of the noble gas and halogen composition of the ore fluids with those of the pegmatites. The halogen data for the Osborne deposit indicate multiple sources of salinity suggesting mixing between at least two components; the fluids with the highest values of $\text{Br/Cl} = 3.8 \times 10^{-3}$ and $\text{I/Cl} = 27.4 \times 10^{-6}$ are similar to bittern brine compositions and those with the lowest values of $\text{Br/Cl} = 0.3 \times 10^{-3}$ and $\text{I/Cl} = 2.4 \times 10^{-6}$ are similar to halite dissolution waters. Values for pegmatitic quartz hosted fluids fall within these ranges. The data are consistent with mixing between crustal fluids of diverse origin. $^{40}\text{Ar}/^{36}\text{Ar}$ values of <2000 and ^{36}Ar concentrations of 1- 6 ppb are most similar to sedimentary formation waters but a metamorphic component, derived from devolatilisation reactions during regional metamorphism, can not be excluded. The similar values obtained for samples of pegmatitic quartz support the presence and inclusion of ore fluids at the time of pegmatite anatexis. The moderately high ^{36}Ar concentrations in the ore fluids and their low $^{40}\text{Ar}/^{36}\text{Ar}$ values preclude the involvement of magmatic fluids derived from A-type granites with a deep crust or mantle origin.

Compositional data obtained using PIXE and LA-ICP-MS shows significant compositional variation within single inclusion populations. A two order of magnitude range of Br/Cl ratios ($0.2 - 18 \times 10^{-3}$) correlates with noble gas and halogen data and indicates multiple sources of salinity. Low concentrations of copper in the high salinity ore fluids ($\text{Cu} \ll 150\text{ppm}$) suggest that changes in control factors of copper solubility were important in the formation of the deposit. At temperatures of 600°C , the Osborne ore fluids would be undersaturated with respect to chalcopyrite. Cooling, dilution and

redox changes caused by interaction with host rocks and/or fluid mixing are interpreted to be the main controls on deposition.

Geochemical modelling of the ore forming processes, using HCh, suggests that a redox switch from hematite-stable conditions to magnetite-stable conditions could have triggered chalcopyrite precipitation during rock-buffered fluid mixing. Modelling suggests highest ore grades would be associated with pyrrhotite-bearing assemblages.

Data collected during this study indicate that cooling, dilution and redox changes caused by interaction with host rocks and/or fluid mixing are likely to have been the main controls on deposition at the Osborne deposit. Furthermore, halogen and noble gas data provide strong evidence that magmatic fluids are not a ubiquitous component of IOCG ore forming systems.

TABLE OF CONTENTS

Title Page	<i>i</i>
Statement of Access	<i>ii</i>
Statement of Sources	<i>iii</i>
Statement on the contribution of others	<i>iv</i>
Acknowledgments	<i>v</i>
Abstract	<i>vi</i>
Table of Contents	<i>ix</i>
List of Figures	<i>xiii</i>
List of Tables	<i>xv</i>

1. Introduction

1.1 Thesis rationale	1-1
1.2 Thesis aims	1-5
1.3 Thesis structure	1-5
1.4 Literature review	1-7
<i>1.4.1 Origin of IOCG deposits</i>	1-7
<i>1.4.2 Regional geology</i>	1-10
<i>1.4.3 Cloncurry IOCG deposits</i>	1-17
<i>1.4.4 The Osborne deposit</i>	1-18
<i>1.4.5 Fluid inclusion studies</i>	1-29
<i>1.4.6 Fluid inclusion studies in the Cloncurry district</i>	1-34

2. Ore fluid processes and evolution at the Osborne IOCG deposit; a fluid inclusion study

2.1 Introduction	2-1
2.2 Samples	2-1
2.3 Methodology	2-6
<i>2.3.1 Microthermometry</i>	2-6
<i>2.3.2 Laser Raman Spectroscopy</i>	2-7
<i>2.3.3 Cathodoluminescence</i>	2-9
<i>2.3.4 Phase Volume Calculations</i>	2-9

2.3.5 <i>Microthermometry Background</i>	2-9
2.4 Results	2-13
2.4.1 <i>Classification</i>	2-13
2.4.2 <i>Paragenesis</i>	2-19
2.4.3 <i>Microthermometry and Laser Raman data</i>	2-26
2.5 Discussion	2-37
2.5.1 <i>Pegmatite anatexis and fluids</i>	2-38
2.5.2 <i>Trapping conditions</i>	2-42
2.5.3 <i>Fluid evolution</i>	2-46
2.6 Conclusions	2-50

3. Crustal fluid origins in the Osborne Fe-oxide-Cu-Au deposit, Australia: Evidence from noble gases and halogens

3.1 Introduction	3-1
3.2 Noble gas and halogen methodology	3-2
3.2.1 <i>Introduction</i>	3-2
3.2.2 <i>Analytical equipment</i>	3-3
3.2.3 <i>Sample preparation and loading</i>	3-6
3.2.4 <i>Irradiation monitors</i>	3-7
3.2.5 <i>Sample analysis</i>	3-10
3.2.6 <i>Air calibration and blanks</i>	3-11
3.2.7 <i>Mass spectrometer operation</i>	3-12
3.2.8 <i>Data reduction</i>	3-12
3.2.9 <i>Sample selection</i>	3-14
3.3 Results	3-17
3.3.1 <i>The halogens</i>	3-17
3.3.2 <i>Potassium and radiogenic $^{40}\text{Ar}_R$</i>	3-21
3.3.3 <i>Fluid inclusion argon</i>	3-27
3.3.4 <i>Noble gas non-fractionation</i>	3-31
3.4 Discussion	3-31
3.4.1 <i>Absence of magmatic fluids</i>	3-32

3.4.2 <i>Formation waters versus metamorphic fluids</i>	3-36
3.4.3 <i>Circulation of fluids at mineralisation depths</i>	3-43
3.5 Conclusions	3-47

4. PIXE and LA-ICP-MS constraints on ore fluid compositions at the Osborne IOCG deposit, Mount Isa Inlier, Australia

4.1 Introduction	4-1
4.2 Methods	4-1
4.2.1 <i>PIXE</i>	4-1
4.2.2 <i>LA-ICP-MS</i>	4-8
4.3 Fluid inclusion geochemistry results	4-10
4.3.1 <i>Comparison of micro-analytical methods</i>	4-25
4.4 Discussion	4-30
4.4.1 <i>Fluid compositions</i>	4-30
4.4.2 <i>Compositional similarities between CB brine phases and MS brine phase</i>	4-32
4.4.3 <i>Copper concentrations and solubility in the ore fluids</i>	4-33
4.4.4 <i>Redox controls</i>	4-40
4.4.5 <i>Halogen data and fluid sources</i>	4-43
4.4.6 <i>Reconstruction of a typical fluid inclusion composition</i>	4-47
4.5 Conclusions	4-49

5. Geochemical modelling and interpretation of the formation of the Osborne IOCG deposit

5.1 Introduction	5-1
5.2 Solubility constraints on Cu, Au, Fe and Si, and ore formation	5-2
5.3 Geochemical modelling and discussion	5-7
5.3.1 <i>Geochemical modelling constraints</i>	5-11

5.3.2 <i>Static closed system batch process models</i>	5-13
5.3.3 <i>Fluid mixing models</i>	5-18
5.4 Conclusions	5-31

6. Conclusions and Recommendations

6.1 Osborne Ore Formation	6-1
6.2 Key ingredients for an IOCG deposit	6-2
6.3 Recommendations for future work	6-3

Bibliography

Appendices

- A: Microthermometry**
- B: Phase volumetric calculations**
- C: Laser Raman**
- D: Noble Gas and Halogens**
- E: PIXE**
- F: LA-ICP-MS**
- G: HCh algorithms**
- H: PIXE element map images (on CD)**

LIST OF FIGURES

Chapter 1

1.1	Schematic diagrams illustrating the three models for the origin of fluids in IOCG ore formation.	1-3
1.2	Mount Isa Inlier location map.	1-11
1.3	Simplified geological map of the southern part of the Eastern Fold Belt of the Mt Isa Inlier.	1-12
1.4	Stratigraphic and geochronological framework of the Mt Isa Eastern Fold Belt.	1-14
1.5	3D distribution of ore bodies at the Osborne mine.	1-25
1.6	Plan view of Osborne ore body distribution.	1-26
1.7	Cross-sections through ore bodies.	1-27

Chapter 2

2.1	Polished core samples.	2-4
2.2	Sulphide associations in Osborne Samples.	2-5
2.3	Laser Raman spectra from a CB inclusion in sample Osb40.	2-8
2.4	Fluid inclusion types observed at Osborne Mine.	2-15
2.5	CL image of sample Osb22A.	2-17
2.6	Sample Osb315 under plane polarized light.	2-17
2.7	Schematic diagram showing primary, pseudosecondary and secondary inclusions in a single crystal.	2-21
2.8	Fluid inclusion assemblages in Osborne silica flooding samples.	2-22
2.9	Fluid inclusion relationships in pegmatite samples.	2-23
2.10	Fluid inclusion paragenesis.	2-24
2.11	Schematic representation of fluid inclusion populations, relationships and occurrences in multiple generations of quartz in Osborne ore assemblages.	2-25
2.12	Histograms of vapour and daughter mineral dissolution temperatures.	2-29
2.13	Histogram of homogenisation temperatures.	2-30
2.14	Homogenisation temperature vs salinity.	2-31
2.15	Histograms of fluid inclusion salinities.	2-32
2.16	Final melting temperatures for CO ₂ inclusions.	2-34
2.17	Homogenisation temperatures of CO ₂ inclusions.	2-34
2.18	Comparison of microthermometric behavior of CB and CO ₂ inclusions.	2-35
2.19	Laser Raman determined compositions of carbonic inclusions (CB and CO ₂) within ore and pegmatite samples.	2-36
2.20	Evolution of PT conditions during Osborne ore formation.	2-43
2.21	T-XCO ₂ diagrams for high salinity (35 wt% NaCl) brine-CO ₂ fluids .	2-47

Chapter 3

3.1	MAP-215-50 Extraction line schematic diagram.	3-5
3.2	Br/Cl vs. I/Cl.	3-18
3.3	Br/Cl vs. temperature.	3-20
3.4	Ar-Ar plateau for sample Osb852.	3-22
3.5	Cl/ ³⁶ Ar vs. ⁴⁰ Ar/ ³⁶ Ar.	3-25

3.6	Volatile release during step heating.	3-26
3.7	³⁶ Ar systematics.	3-28
3.8	F ⁸⁴ Kr vs F ¹²⁹ Xe determined by in-vacuo crushing of irradiated and unirradiated samples.	3-30
3.9	Comparison of Osborne and Ernest Henry halogen and noble gas data.	3-40
3.10	Fluid pressure as a function of depth in a sedimentary basin.	3-46

Chapter 4

4.1	Representative PIXE element maps showing CB and MS type inclusions from three samples at Osborne.	4-5
4.2	X-ray spectra for two MS inclusions at Osborne showing true and artificial Cu peaks.	4-6
4.3	X-ray spectra fit for inclusion 15_1_1 with and without As included in the fit.	4-7
4.4	Comparison of selected element ratios in fluid inclusions measured by both PIXE and LA-ICP-MS.	4-13
4.5	Cl vs. metal concentrations in CB and MS inclusions .	4-16
4.6	Correlations between major cation concentrations in inclusions analysed by LA-ICP-MS.	4-17
4.7	Mn/Fe values in CB and MS fluid inclusions.	4-19
4.8	Mn/Fe values vs. major cation concentrations.	4-20
4.9	Br vs. Cl measured by PIXE.	4-23
4.10	K vs. Ca measured by PIXE and LA-ICP-MS in CB and MS inclusions.	4-24
4.11	Comparison of range of Br/Cl values obtained by PIXE and combined noble gas and halogen analysis.	4-26
4.12	PIXE measured K and Ca concentrations vs. inclusion depth.	4-28
4.13	Zn/Ca and Zn/K vs. inclusion depth.	4-29
4.14	Comparison between calculated chalcopyrite solubility and Cu concentrations measured by PIXE and LA-ICP-MS at the Osborne deposit.	4-35

Chapter 5

5.1	Box diagrams for different modelling methodologies used to test hypotheses for the genesis of the Osborne deposit.	5-9
5.2	Dissolved sulphur species in CB fluid during reaction with Western Domain type rocks.	5-10
5.3	Dissolved sulphur species in CB fluid during reaction with Eastern Domain type rocks.	5-17
5.4	Cooling of CB fluid buffered by Western Domain rocks.	5-17
5.5	Flush model of ore fluids reacting with quartz-magnetite host rocks.	5-19
5.6	Fluid mixing and flow through model.	5-20
5.7	Fluid mixing model with additional titration of the reduced fluid phase.	5-24
5.8	Fluid infiltration model with additional titration of reduced fluid.	5-25
5.9	Chalcopyrite and Galena precipitation curves for model 3.	5-26
5.10	Oxygen fugacity vs. sulphide mineral yield for model 2.	5-30

LIST OF TABLES

Chapter 1

- | | | |
|-----|--|------|
| 1.1 | Regional and local Osborne deformation and geological history. | 1-15 |
| 1.2 | Paragenesis of the Osborne ore assemblage. | 1-24 |

Chapter 2

- | | | |
|-----|--|------|
| 2.1 | Samples analysed in this study. | 2-2 |
| 2.2 | Samples and fluid inclusion assemblage descriptions. | 2-3 |
| 2.3 | Correlation of different fluid inclusion populations identified in studies of Osborne. | 2-18 |
| 2.4 | Summary of microthermometric data for all fluid inclusion types. | 2-38 |

Chapter 3

- | | | |
|-----|--|------|
| 3.1 | Irradiation parameters for samples. | 3-10 |
| 3.2 | Nuclide interference reactions. | 3-13 |
| 3.3 | Sample and fluid inclusion assemblage descriptions. | 3-16 |
| 3.4 | Comparison of in-vacuo crush and step heating data. | 3-17 |
| 3.5 | Summary of noble gas and halogen data from stepped heating of samples. | 3-23 |

Chapter 4

- | | | |
|-----|---|------|
| 4.1 | Suite of elements analysed for by LA-ICP-MS. | 4-9 |
| 4.2 | Concentration ranges of selected major and trace elements measured by PIXE in CB and MS inclusions. | 4-11 |
| 4.3 | Concentration ranges of selected major and trace elements measured by LA-ICP-MS in MS and LVD inclusions. | 4-11 |
| 4.4 | Selected element ratios measured by PIXE in CB and MS inclusions. | 4-12 |
| 4.5 | Selected element ratios measured by LA-ICP-MS in MS and LVD inclusions. | 4-12 |
| 4.6 | Inclusions analysed by both PIXE and LA-ICP-MS. | 4-14 |
| 4.7 | Fluid compositions from ore stage and pegmatite sample inclusions. | 4-48 |

Chapter 5

- | | | |
|-----|--|------|
| 5.1 | Fluid and rock compositions used in models. | 5-14 |
| 5.2 | Sulphur saturation limits in the CB-type fluid at 400 and 600°C. | 5-14 |
| 5.3 | Fluid and rock compositions used in rock-buffered fluid mixing models. | 5-23 |