A GEOLOGICAL, GEOCHEMICAL AND METALLOGENIC STUDY
OF THE CHATREE EPITHERMAL DEPOSIT,
PHETCHABUN PROVINCE, CENTRAL THAILAND

by

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A thesis submitted in fulfilment of the requirements for the

degree of Doctor of Philosophy

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University of Tasmania (UTAS), Australia
June, 2013
DECLARATION

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ABSTRACT

The Chatree gold-silver epithermal deposit is located in the central part of the Loei Fold Belt (LFB), which forms an arcuate zone that extends from Laos in the north through central and eastern Thailand into Cambodia in the south. Epithermal gold-silver mineralisation is present as veinlets/veins and stockworks and minor breccia and is hosted in Late Permian volcanlastic and volcanogenic sedimentary rocks. The current (2011) total resource at Chatree is 81 Mt. at 1.2 g/t Au and 10 g/t Ag. The Chatree volcanic complex has a well-defined volcanic stratigraphic sequence comprised of mafic to intermediate units at the base and felsic units at the top. The andesite dominants at the lower parts of the succession and includes plagioclase-hornblende-phyc andesite, plagioclase-hornblende-phyc basaltic andesite, monomictic breccia and overlying mafic-intermediate polymictic breccia facies, followed by fiamme breccia at the top of the succession.

Geochemically, the host volcanic rocks at Chatree comprise two volcanic suites: (a) Volcanic Suite 1 ranging in age from 258.6 to 250 Ma, characterised by low Ti, P, Mg, Zr, Ce and Y with very low LREE basalt to dacite; and (b) Volcanic Suite 2 ranging in age from 250 to 247 Ma, characterised by slightly higher Ti, Zr, Y, Ce, P and LREE andesite to dacite. This host sequence is intruded by two series of dykes: (a) high-Mg and moderate-Ti xenolithic dykes, and (b) high-Ti basaltic to andesitic dykes.

Gold-silver mineralisation is controlled by a geometric combination of structure (faults) and lithology. Lithologically, Au-Ag mineralisation is best developed in volcanic breccia such as mafic-intermediate polymictic breccia, and volcanogenic sedimentary rock and monomictic plagioclase-phyc andesite breccia. Minor mineralisation also is present in coherent rocks (e.g., plagioclase-phyc andesite) and fiamme breccia. Structurally, mineralisation is mainly present in two major structural orientations, namely: N-S to NNW-SSE and NE-SW trending faults. Based on cross-cutting paragenetic relations and mineralogy, the mineralisation at Chatree occurs in 7 stages which can be divided into pre Au-Au mineralisation (Stage 1, 2A, 2B and 3), main Au-Ag mineralisation (Stage 4A, 4B and 4C) and post Au-Ag mineralisation (Stages 5, 6 and 7) stages: Infill Stage 1 – microcrystalline quartz + pyrite; Infill Stage 2 – Quartz-chlorite-sericite-pyrite; (Stage 2A – Quartz-chlorite-sericite-pyrite; Stage 2B – Quartz-sericite ± chlorite-chalcopyrite-pyrite-sphalerite ± galena); Infill Stage 3 – Quartz - carbonate - (K-feldspar) ± carbonate ± sulphide; Infill Stage 4 – quartz + carbonate + chlorite + adularia + sulphide + electrum; (Stage 4A – Quartz-chlorite-adularia ± carbonate-sulphide-electrum; Stage 4B – Quartz ± carbonate-adularia-sulphide-electrum; Stage 4C – Carbonate ± quartz-adularia -sulphide- electrum- argentite - tetrahedrite); Infill Stage 5 – Quartz ± carbonate veins; Infill Stage 6 – quartz ± carbonate veins; and Infill Stage
Quartz-zeolite-carbonate. Four alteration zones were identified, namely:

1. Silicic (quartz-illite-adularia-pyrite),
2. Argillic (Illite-quartz-adularia-chlorite-pyrite),
3. Propylitic (chlorite-calcite-pyrite-epidote), and

Adularia from the main Au-Ag mineralisation Stage 4 was dated by laser incremental-heating \(^{40}\text{Ar}/^{39}\text{Ar}\) analysis, and yields an age of 250 ± 0.8 Ma (Late Permian). The \(^{40}\text{Ar}/^{39}\text{Ar}\) analysis of muscovite from a Au-bearing vein from the nearby (~10 km from Chatree) Khao Phanom Pha gold deposit also yields a similar age of 250 Ma. The minimum age of epithermal mineralisation can be bracketed to be 245–250 Ma by the ages of post-mineralisation dykes which yield LA-ICPMS U-Pb zircon ages of 247–238 Ma. This is further supported by Re-Os dating of molybdenite from sub-economic porphyry-style mineralisation hosted in plagioclase-hornblende diorite porphyry (243 ± 5 Ma) at the ‘N’ Prospect (~1 km south of Chatree), which yields an age of 244 ± 1 Ma (Early Triassic), suggesting it is younger than the Chatree gold-silver epithermal deposit.

Mineral paragenetic studies combined with laser ICPMS analysis (spot analysis and imaging) indicate that at least two generations of pyrite are present in each mineralisation stages. These pyrite generally are characterised by different trace element patterns. Gold is present mostly as stoichiometric substitution in pyrite structure in pre Au-Ag mineralisation stages (Stages 2A, 2B and 3) and wall-rock pyrite. In contrast, Au occurs in the pyrite structure as well as inclusions for the main gold-silver stages (Stages 4A, 4B and 4C). In the pre-Au-Ag mineralisation stages, trace element concentrations generally increase from early Stage 2A to late Stage 3, particularly elements such as Au, Ag, As, Sb, Se and Pb. This temporal trend reflects an increase in metal content of the ore fluid prior to the main gold deposition. Comparison of trace elements in pyrite from the ore zone and various alteration zones in this study indicates that significant trends exist for certain elements such as Tl, Sb and Ag decreasing outwards from the ore zone into the wallrocks. In contrast, Co, Ba and La have values decreasing towards ore zone possibly due to dilution of these elements related to alteration. Other elements such as Pb, Se, K, Rb and Sr show less clear trends. Pyrite tend to have more pronounced trends in many elements particularly in chalcophile elements in comparison to the whole-rock. However, more work need to be done to confirm which of the technique works best at the chatree and more and analyses from regional pyrite distal from the deposit are required for full evolution. The element which has the best potential for use in pyrite chemistry vectoring is Tl and Co. The data from this study shows that this element could be used as a pathfinder for geochemical exploration for similar styles of mineralisation in and around the Chatree area.

The sulphur isotopic values of pyrite from the main gold-silver mineralisation stages (Stages 4A, 4B and 4C) mainly range from 1 to 7 ‰, compatible with a magmatic source. However, some contribution of sulphur derived from other sources such as a biogenic origin is possible, particularly for the data from Q and A lenses which include lighter values (~9 to ~1‰). Oxygen isotope variation of quartz at Chatree shows that the lowest oxygen isotope values are spatially confined to the central parts of the major ore zones, in particular along H and D lenses. Variation in oxygen isotopic values likely is due to an isotopic exchange between the mineralised hydrothermal fluids and wall-rocks where heavy oxygen isotopes were leached out of the propylitic and argillic
alteration zones in the wall rock and were deposited in the outer parts of the main vein system. The combined oxygen and hydrogen isotope data of Chatree plots between meteoric water and magmatic water, indicating a mixture between the magmatic and meteoric water. Lead isotope data indicate that the Pb isotopic model ages of the Chatree Au-Ag epithermal deposit plot around 400 Ma on the model Pb growth curve. As the age of mineralisation at Chatree is known to be Late Permian (ca. 250 Ma), this model Pb age is suggestive of unusually old Pb most likely from Paleozoic sediments.

The mineralisation at Chatree is part of an arc system that was emplaced within the LFB during the Late Permian to Early Triassic. Arc formation commenced with the extruding of basalt and andesite and was followed by rhyolite towards the end of the main phases of volcanic activity. This study suggests that the Chatree Volcanic Complex was emplaced in a shallow marine environment. The initial hydrothermal activity at Chatree appears to have been associated with movement along a NW-SE which caused the N-S to NNE-SSE and NE-SW dilational structures. Circulating ore fluid ascended along the dilational structures. Gold-silver mineralisation was initiated by ground preparation due to rapid cooling of silica-rich fluids that lead to precipitation of microcrystalline quartz early in Stage 1, which sealed in the fractures. Fluid pressure then increased from degassing ore boiling of CO2 and H2S in the fluids and brecciated the seals, allowing mineralising fluids to enter, leading to the precipitation of metals including gold and silver during the main Au-Ag mineralisation stages, particularly in Stages 4B and 4C. Fluid inclusions in quartz during this process contain high homogenisation temperatures ranging from 190 ° to 348 °C with salinities less than 5.6 wt. % NaCl equiv. The metal was probably derived from a fluid reservoir that was significantly enriched in Pb compared to U for a long period of time, as evidenced by the old Pb signature at Chatree. This suggests that Pb and possibly part of the Au were sourced from older basement rocks beneath the deposit as well as magmatic sources. A component of magmatic fluid was possibly involved during ascent of the ore fluids and mixing with circulating dilute meteoric water occurred as indicated by sulphur, oxygen, hydrogen isotope compositions and fluid inclusion data.

After formation, the Chatree deposit was cross-cut by basaltic to andesite dykes at the same time to the emplacement of plagioclase-hornblende diorite porphyry intrusion at N Prospect which has a weak porphyry-style mineralisation. The altered wall-rocks at Chatree deposit was eroded bringing the landscape to its current level represented by Khao Mo hill (A lens). Throughout the Chatree deposit, acidic fluids were produced by breakdown of pyrite in the oxidised zone leaching carbonate; this process also created significant permeability allowing oxidised ground water to react with the ores and form significant supergene gold enrichment.
ACKNOWLEDGEMENTS

I would like to thank my supervisor, Associate Professor Khin Zaw, for providing me with a great project and the opportunity to undertake research and fieldwork at Chatree in Thailand. Khin Zaw has given me motivation, advice, constructive criticism and full logistical support throughout my PhD project at CODES. I would also like to thank my co-supervisor, Dr Sebastien Meffre and Professor Jocelyn McPhie, for their helpful comments and for reviewing drafts of my thesis. This study was undertaken with financial and logistical support from Kingsgate Consolidated Limited, an International Postgraduate Research Scholarships (IPRS) University of Tasmania, the SEG, and CODES-Industry Funded Ore Deposits of Southeast Asia projects.

I would also like to thank Akara Mining Limited and Issara Mining Limited for giving me access to my field areas and for providing logistic support during my field work particularly Phil McIntyre, Ron James, Genesio Circosta, Suphanit Suphananthi and Robert Spears. Previous and present geologists at Chatree mine and exploration including, Weerasak Lanwongsa, Sakawarat Sareerat, Chamrat Sangsrichan, Surachat Nunsamai, Saranya Nuenla-ong, Prakarn Beinkhuntod, Worawong Sirisukprasert and Phuchong Saesuwan helped me during field work. I also thank all local staff at mine and exploration offices for their help and assistance.

Many thanks go to the staff at CODES, University of Tasmania. They include Ross Large, Bruce Gemmell, David Cooke, June Pongratz, Nilar Hlaing, Karin Orth, Garry Davidson, Jacqueline Halpin, Anthony Harris, Zaoshan Chang, Tony Crawford, Sarah Gilbert, Simon Stephens, Andrew McNeill, Helen Thomas, Peter McGoldrick, Katie McGoldrick, Phil Robinson, Wally Herrmann, Ian Little, Peter Cornish, Isabella von Lichtan, Dianne Madden, Christine Higgins, Karen Mollross, Deborah Macklin, Helen Scott, Rose Pongratz, Alexander Cuis and Grace Cumming. Thanks to Christine Cook, Karsten Goemann, Keith Harris and Sandrin Feig at the Central Science Laboratory, to Holly Stein at Colorado State University and to Sue Golding, Paulo Vasconcelos and David Thiede at University of Queensland for helping with my analyses.

My colleagues at CODES provided physical and mental supports during my study. I offer my sincere thanks to Mathieu Ageneau, Basril Mohd Iswadi Basori, Fiona Best, Heidi Pass, Liezl Cuis, Bronto Santoso, Paul Cromie, Weerapan Srichan, Victor Galvan, Ben Jones, Martin Jutzeler, Jeff Steadman, Yungu Lim, Andrea Agangi, Somboon Khositanont and Takayuki Manaka.

Finally, I would like give special thanks to my family in Thailand, who provided mental support for my studies in Hobart. I couldn’t have finished this study at CODES without their kind contribution.
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