Probabilistic and deterministic models of Pb-Zn mineralisation and post-mineralisation megabreccia, in the Lawn Hill Region, Australia

Thesis submitted by

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STATEMENT OF CONTRIBUTIONS

General contributions towards this study included:

- International Postgraduate Research Scholarships (IPRS)
- James Cook University Postgraduate Research Scholarships (JCUPRS)
- Pmd*CRC Top-up Scholarship
- Pmd*CRC educational and training fund

Contributions from others towards this thesis are clearly stated at the forefront of each chapter where applicable. A summary of the major contributions is also provided here:

- **Chapter 4:** Dr. J. G. McLellan – 2D Numerical modelling of the Century deposit and text.

- **Chapter 5:** Dr. J. G. McLellan – 3D Numerical modelling of the Century deposit and text.

- Normal supervisory condition throughout the preparation of the thesis included discussions and proofreading by Prof. N.H.S. Oliver (all thesis), and Dr. J.G. McLellan (Chapters 4, 5).

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Thesis abstract

Quantitative analysis with the aid of numerical and computational modelling has been used to address geological problems since the 1940s. The number of applications developed and used to solve geological problems has increased largely because of the advent of desktop microcomputers. However, despite the introduction of mathematical-computational methods, the observational, inductive approach of Hutton and Wegner remains deep in the geological science.

Qualitative rather than quantitative geology has won in the past because of the naturalistic inclination of geologists - “rather than sit on their desk typing and modelling natural phenomena, they were more interested in exploring the world with the naked eye, spending their time conceptualising models and integrating the data collected in the field”.

With globalisation geologists have broadened their objectives as larger and numerous databases are available. Therefore, rather than collecting their own data, they now have new technologies to retrieve and process large databases. The drawback of this advantage is the lack of data quality verification, which can be a substantial problem. However, a statistical treatment of datasets can be a partial solution to this.

The author as a geologist felt the need of demonstrating that a quantitative-computer based description of a multivariate geological system could lead to a significant improvement of the understanding of such a system.

A line can be drawn to subdivide computational approaches that use inference networks based on physical laws (e.g. Geodynamic modelling) to bound variables, or empirical laws (e.g. Bayesian Probability Analysis) that are not characterised by the nature of the data (such as measures of spatial association). Alternative methods (e.g. Fuzzy Sets, Dempster-Shafer, Neural Networks) have been suggested to treat multivariate data less empirically.

A possible way to improve the quantitative analysis is the simulation of geological parameters (Chapter 4 – 5). The interaction between the geologist and the computer is iterative in this case – multiple simulation leads to a refinement of chosen approximation. Nevertheless, this methodology is often biased and arbitrary. The best approach perhaps remains the validation of computational models comparing therm against the experimental results and observations.

The objective of this thesis was then to apply quantitative/computational tools to different geological scenarios in the Lawn Hill Region, Mount Isa Inlier. Part of this study focused on one of the largest Pb-Zn mineral resources in Australia, the Century zinc deposit. The objective of the first section of this thesis was to discover possible new mineral resources similar to the Century orebody, and comprehend how the mineral deposit formed.

Two case study applications to the Lawn Hill Region at regional and mineral deposit scale (Century deposit) are presented. The first study reflects the need of data

integration in a multivariate system to obtain a statistical estimate of the likelihood of finding a mineral deposit. The concepts of Bayesian reasoning were reviewed and a computer program (coded in Visual Basic) was developed to perform Bayesian modelling. The results were then compared against an expert-driven model to obtain a predictive map for the Lawn Hill Region. The analysis suggested that most of the mineral deposits/prospects are located where knowledge driven models favour the occurrence of SEDEX mineralisation. The data driven model suggests that other Pb-Zn deposits more likely are proximal to the Termite Range fault. Integration of KD and DD models suggests prospectivity for SEDEX-style mineralisation north of the Edith cluster a vein style ore.

The second study involved the quantitative 3D spatial analysis of the Century deposit. The 3D model of the mineral deposit was also combined with a 2D-3D coupled deformational and fluid flow simulation for the mineral deposit. The integration of these modelling tools allowed a better conceptualisation of the variables controlling the spatial distribution of base metals within the mineral deposit. In this case the research effort was directed toward the use of computational tools to solve the classical problem of understanding how the ore deposit formed. The results obtained support (re) mobilisation and a broad scale metal zoning similar to what is observed at Lady Loretta and HYC. Results also illustrated how basin compartmentalisation can control (re)mobilisation, fluid-flow and therefore how a mineral deposit evolves in time. A comparison between the different scale of zoning observed coupled with numerical 2D-3D results outlined that more likely Century is an exhalative system that however experienced later epigenetic introduction of base metals. Modelling results have in

general outlined that classification of geological patterns can be an effective way of discriminating the genesis of an ore deposit. For instance, the textural evolution of a mineral deposit which is derived from a combination of mechanical and chemical processes (the mechano-chemical coupling modelled by Ortoleva, 1994) may represent non-linear behaviour and lead to patterning of the geological system. In this context, the relationships observed and modelled between the evolution of permeability structure and the spatial distribution of mineral grades represent an example of how understanding the dynamics of complex system provides improved interpretations.

The third study, focused on the post-mineralisation Lawn Hill Megabreccia, and explores the variety of patterning of sedimentary textures and deformational features, aimed at differentiating the timing and origin of this brecciation event. The research combined qualitative and quantitative analysis of structural, sedimentary and stable isotopic features at various scales. The results indicate a synsedimentary (Cambrian) origin for the brecciation. However, the study has emphasised that different causative processes (e.g. tectonic, meteorite impacts) may lead to similar patterning.

To conclude, quantitative modelling of the presented geological examples suggests that we need to improve accuracy and numerical descriptions of the system to reveal the timing of formation and how a certain geological process occurred. In other words the loss of data induced by generalisation and oversimplification (often required in computational and quantitative modelling) can reduce the reliability of a predicted answer. Self-organisation and chaos theories (Synergetics) may be a new way to approach and describe the observed patterning of geological events and could be used

to provide better mathematical models to understand ore genesis, discover a mineral deposit or ascertain the origin of a catastrophic event.

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