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

**Thesis submitted by
Leonardo Feltrin, B. Sc. (Hons.), M. Sc.**

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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 them 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.

Table of contents

Chapter 1

<i>Introduction</i>	<i>1-1</i>
1.1. General introduction	1-2
1.2. Application of computer science to geology	1-3
1.3. Aims and objectives	1-5
1.4. Thesis outline	1-6
Chapter 1 Introduction	1-6
Chapter 2 Historic overview and modelling background	1-6
Chapter 3 An integrated knowledge-based and data-driven modelling study of the Lawn Hill Region, Queensland, Australia	1-7
Chapter 4 Testing the structural and geomechanical processes in the formation of the Century Zn-Pb-Ag Deposit	1-7
Chapter 5 Modelling the giant, Zn-Pb-Ag Century deposit, Queensland, Australia	1-8
Chapter 6 Catastrophic mass failure of a Middle Cambrian platform margin, the Lawn Hill Megabreccia, Queensland, Australia	1-8
Chapter 7 Complexity and self-organisation	1-8
Chapter 8 Conclusions	1-9
Appendix A-B	1-9
Appendix C	1-9
Appendix D	1-9
Appendix E	1-9

Chapter 2

<i>Historic overview and modelling background</i>	<i>2-1</i>
2.1 Introduction	2-3
2.2 Historic overview	2-4
2.2.1 From qualitative to quantitative geology	2-4
2.2.2 Regression	2-9
2.2.3 Geostatistics	2-15

2.2.4	Computer simulations	2-23
2.3	Mathematical models and computer software used in the Lawn Hill Region	2-26
2.3.1	Elements of probability	2-27
2.3.1.1	Definition of probability	2-28
2.3.1.2	Addition and multiplication of probability	2-29
2.3.1.3	Distribution, normal distribution and confidence interval	2-31
2.3.1.4	Mathematical expectation and variance	2-37
2.3.2	GoCAD and the DSI algorithm	2-40
2.3.2.1	Topology of an object	2-41
2.3.2.2	Concept of discrete model	2-43
2.3.2.3	Discrete Smooth Interpolation approach	2-45
2.3.2.4	Discrete Smooth Interpolation algorithm	2-49
2.3.3	FLAC (Fast Lagrangian Analysis of Continua)	2-51
2.3.3.1	General description of FLAC	2-52
2.3.3.2	Basics of the finite-difference method to solve differential equations	2-54
2.3.3.3	The Lagrangian description	2-64

Chapter 3

Predictive modelling of prospectivity for Pb-Zn deposits in the Lawn Hill Region, Queensland, Australia 3-1

3.1.	Introduction	3-4
3.2.	Geologic setting	3-7
3.2.1.	Tectonic evolution	3-11
3.2.2.	Style of faulting in the Lawn Hill Region	3-13
3.2.3.	Lawn Hill stratigraphy	3-16
3.3.	Mineral deposits characters and relative conceptual models	3-22
3.3.1.	Deposit classification	3-22
3.3.2.	Conceptual models	3-29
3.3.2.1.	SEDEX and IRISH	3-29
3.3.2.2.	MVTs	3-30
3.4.	Knowledge driven modelling	3-32
3.4.1.	Deformational control on mineralisation	3-33
3.4.1.1.	Stratiform mineralisation	3-34
3.4.1.2.	Regional scale veins and lodes	3-38
3.4.1.3.	End member relationship between stratiform mineralisation and fault related mineralisation	3-42
3.4.2.	Lithological control on mineralisation	3-43
3.4.2.1.	Primary permeability	3-44
3.4.2.2.	Secondary permeability	3-46
3.4.2.3.	Organic content	3-46
3.4.2.4.	Sequence stratigraphic boundaries	3-49
3.4.2.5.	Presence of carbonates and evaporites	3-51
3.4.3.	KD model integration	3-52
3.4.3.1.	Assumption for lithotype-based evidential layers	3-59
3.4.3.2.	Aggregation of evidence	3-61
3.4.3.3.	Interpretation	3-63

3.5. Data driven modelling	3-71
3.5.1. Datasets considered within the model and integration with GIS software	3-72
3.5.2. Phases of Weights of Evidence modelling	3-73
3.5.2.1. Standardization procedure	3-74
3.5.2.2. Classification of spatial evidence	3-75
3.5.2.3. Classification results and ranking	3-80
3.5.2.4. Bayesian analysis	3-87
3.5.2.5. Conditional independence testing	3-90
3.5.3. Uncertainty from missing evidence	3-99
3.6. Pb-Zn mineral potential for the Lawn Hill Region	3-101
3.7. Conclusions	3-113

Chapter 4

<i>Testing the structural and geomechanical processes in the formation of the Century (Zn-Pb-Ag) Deposit</i>	4-1
Abstract	4-3
4.1. Introduction	4-4
4.2. Tectonic evolution of the Mount Isa Block and stratigraphic subdivisions	4-10
4.2.1. The Mount Isa Block	4-10
4.2.2. The Western Fold Belt	4-12
4.2.3. Stratigraphy of the Lawn Hill Formation	4-17
4.3. Century deposit	4-21
4.3.1. Sulphide textures	4-22
4.3.2. Ore zone stratigraphy	4-23
4.4. Introduction to the 3D structural modelling	4-25
4.4.1. GoCAD a 3D geologically optimised CAD package	4-27
4.4.2. Initial steps to construct a 3D model	4-27
4.4.3. Data acquired to construct the 3D model	4-29
4.4.4. 3D model components	4-29
4.4.5. 3D Modelling results	4-30
4.5. Century ore genesis	4-37
4.6. Deformation and Fluid Flow	4-43
4.7. Numerical modelling	4-45
4.7.1. FLAC (Fast Lagrangian Analysis of Continua)	4-45
4.7.2. Sensitivity of Strain Rates	4-46
4.7.3. Conceptual models	4-47
4.7.4. Conceptual Model 1	4-51
4.7.5. Conceptual Model 2	4-53
4.8. Results	4-54
4.8.1. Model 1a (extension, semi-lithified sediments, low permeability shale)	4-54
4.8.2. Model 1b (extension, semi-lithified sediments, high permeability shale)	4-55
4.8.3. Model 2a (contraction, low permeability shale)	4-60
4.8.4. Model 2b (contraction, low permeability shale and sandstone, with overpressure)	4-64

4.8.5. Model 2c (contraction, high permeability shale, low permeability sandstone, with overpressure)	4-68
4.8.6. Model 2d (contraction, high permeability shale, low permeability sandstone, with overpressure and yield permeability)	4-71
4.9. Discussion and conclusions	4-76

Chapter 5

<i>Modelling the giant, Zn-Pb-Ag Century deposit, Queensland, Australia</i>	5-1
Abstract	5-3
5.1. Introduction	5-4
5.2. Geological setting	5-7
5.3. Century 3D structural model and property modelling	5-14
5.3.1. GoCAD and the DSI algorithm	5-14
5.3.2. Modelling approach	5-15
5.3.3. 3D Model visualisation and spatial analysis	5-21
5.3.4. Results	5-22
5.3.4.1. Fault discrimination	5-23
5.3.4.2. Continuity of mineralisation	5-25
5.3.4.3. Evidence of remobilisation	5-30
5.3.4.4. Alteration zoning	5-33
5.4. Century numerical fluid flow simulations	5-37
5.4.1. Introduction	5-37
5.4.2. Conceptual model	5-39
5.4.3. Numerical results	5-41
5.4.4. Control of permeability and hydraulic gradient on fluid flow direction	5-43
5.5. Discussion	5-46
5.5.1. Permeability evolution	5-46
5.5.2. Timing of broad scale zoning	5-47
5.6. Conclusions	5-51

Chapter 6

<i>Catastrophic mass failure of a Middle Cambrian platform margin, the Lawn Hill Megabreccia, Queensland, Australia</i>	6-1
Abstract	6-3
6.1 Introduction	6-4
6.2 Regional geotectonic framework	6-8
6.2.1 From intracratonic to orogenic times	6-8
6.2.2 Stratigraphic evolution of the Centralian Superbasin	6-13
6.3 Georgina Basin	6-16
6.3.1 Introduction	6-16

6.3.2	Main formations Undilla sub-Basin	6-17
6.3.3	Summary	6-20
6.3.4	Folding and brecciation in the Lawn Hill Outlier	6-20
6.4	Deformational and fluidisation related features	6-22
6.4.1	Folding	6-23
6.4.1.1	General description of folds:	6-23
6.4.1.2	Folding patterns	6-24
6.4.1.3	Slump development	6-29
6.4.2	Lawn Hill Megabreccia	6-31
6.4.2.1	Varieties of breccia	6-33
6.4.2.2	Flow breccia CBX	6-38
6.4.2.3	Flow breccia MB	6-41
6.4.2.4	Solution breccia	6-42
6.4.2.5	Collapse breccia	6-43
6.4.2.6	Overprinting relationships	6-44
6.4.3	The control of basement faulting and fracturing on the CBX megabreccia distribution	6-47
6.4.3.1	Importance of spatial analysis in establishing the palaeostress direction	6-47
6.4.3.2	Quantitative estimation of the spatial distribution of dykes	6-52
6.4.4	Post intrusion deformational history	6-57
6.4.4.1	Assessing later deformation and fluid flow	6-57
6.4.4.2	Timing constraints: stylolites, fractures, joints and veins	6-58
6.4.4.3	Carbon and oxygen isotope analyses of hydrothermal phases	6-67
6.5	Discussion and conclusions	6-71
6.5.1	Timing of the megabreccia	6-71
6.5.1.1	Importance of the tectonostratigraphic reconstruction	6-71
6.5.1.2	Paragenesis of deformational features	6-72
6.5.1.3	Palaeogeographic scenario	6-75
6.5.2	Origin of the Lawn Hill Megabreccia - is it the result of an astobleme impact?	6-77

Chapter 7

Complexity and self-organisation	7-1
7.1. Introduction	7-3
7.2. Complexity and self-organisation	7-3
7.2.1. Collection, Multiplicity and Parallelism	7-4
7.2.2. Iteration, Feedback, and Recursion	7-5
7.2.3. Adaptation, Learning and Evolution	7-7
7.2.4. Fractals, attractors and self-organisation	7-7
7.3. Practical applications to the Lawn Hill Region	7-12
7.3.1. The fractal nature of faulting and mineralisation	7-14
7.3.2. The mineral system attractor	7-16

Chapter 8

<i>Conclusions</i>	8-1
8.1 Summary of the thesis conclusions	8-3
8.2 General concluding remarks	8-9

APPENDIX A

A.1. Nodal formulation	A-1
A.2. Theorem of the virtual work	A-3
A.3. The Mohr-Coulomb constitutive model and its relationship to the motion equations	A-7
A.4. Effect of fluid flow in a deforming porous media	A-12

APPENDIX B

B.1. Weights of Evidence formulation	B-2
--------------------------------------	-----

APPENDIX C

C.1. Wofe Modeler	C-2
C.2. Spatial Analyser	C-62

APPENDIX D

D.1. List of Specimens	D-2
------------------------	-----

APPENDIX E

E.1. Digital CD	E-2
-----------------	-----

List of figures

Chapter – 2

Fig. 2.1 Diagram showing a summary of the personalities that influenced the history of science.	2-5
Fig. 2.2 Diagram illustrating the different stages of development of quantitative geology.	2-7
Fig. 2.3 Three of quantification.	2-8

Fig. 2.4 Example of application of polynomial fitting.	2-14
Fig. 2.5 Example of variogram plots.	2-20
Fig. 2.6 Diversification of quantitative applications to geology in the 60s.	2-26
Fig. 2.7 Diagram presenting the concepts of addition and joint probability.	2-31
Fig. 2.8 Probability (P) of finding a set between h_j and h_{j+1} .	2-33
Fig. 2.9 Neighbourhood diagram $N(\alpha)$.	2-42
Fig. 2.10 Examples of objects approximated by a discrete model.	2-43
Fig. 2.11 Finite difference approximation.	2-47
Fig. 2.12 Example of exponential curve and relative intervals of discretization.	2-58
Fig. 2.13 Summary of multi-dimensional grids used to discretise the geological continuum.	2-63

Chapter – 3

Fig. 3.1 Simplified geological map of the Lawn Hill Region	3-9
Fig. 3.2 Aero-photographic view illustrating the structural grain of the Century Area.	3-16
Fig. 3.3 Schematic diagram of the Lawn Hill Platform stratigraphic subdivisions.	3-21
Fig. 3.4 Conceptual model used to generate a data structure.	3-33
Fig. 3.5 Example of Century-style mineralisation and later deformational overprint.	3-37
Fig. 3.6 Breccia-style mineralisation and hydrothermal alteration occurring regionally.	3-41
Fig. 3.7a Diagram illustrating the stratigraphic variation of Pb, Zn, Fe, S, Silica, Carbon, Pb + Zn contents, and Sulphur/Carbon ratio.	3-48
Fig. 3.7b Scatter plot illustrating the correlation between base metals and carbon content (drill core LH412, data from Johnson, 2000).	3-49
Fig. 3.8 Schematic diagram of sequence stratigraphic facies variation in relationship to eustatic oscillations.	3-51
Fig. 3.9 Schematic diagram portraying different phases of expert-driven weighting.	3-60
Fig. 3.10 Summary of lithostratigraphic mineral potential for the Lawn Hill Region.	3-62
Fig. 3.11 Maps of mineral potential derived from KD-modelling compared against known distribution of mineral occurrences.	3-66
Fig. 3.12 Graphic User Interface (GUI) of the WofE modeller, which was used to perform	

Bayesian analysis and testing of CI assumptions (see text).	3-74
Fig. 3.13 Examples of output of contrast analysis and calculated studentised value (C_w) for the contrast measure (C).	3-78
Fig. 3.14 Comparison of conventional contrast approach using constant buffers of 250m interval with Contrast analysis performed using dynamic rescaling based on fuzzy linear functions.	3-79
Fig. 3.15 Histograms obtained from Boolean intersection of multiclass geophysical layers.	3-80
Fig. 3.16 Venn diagrams and schematic plan views representing different conditions of overlap among binary layers.	3-88
Fig. 3.17 Example of χ^2 output of the WofE modeller showing a contingency table in which partial output of the χ^2 analysis can be assessed to allow application of Yates correction if required.	3-97
Fig. 3.18 Diagram portraying Bayesian combination of multiple evidential layers.	3-97
Fig. 3.19 Histogram of 91 pairwise combinations obtained using the WofE modeller (χ^2 tool).	3-104
Fig. 3.20 Output of data driven modelling considering 11 layer (3 rejections) and in case of missing information related to cover sediments.	3-111
Fig. 3. 21 Comparison of integrated KD-DD models.	3-115

Chapter – 4

Fig. 4.1 Location map of the Century deposit and the major subdivisions of the Mount Isa Block and the Northern Australian Zinc Belt.	4-5
Fig. 4.2 Chronostratigraphy for the Mount Isa Block.	4-8
Fig. 4.3 Simplified lithostratigraphic column of the Western Fold Belt displaying the three Superbasins and associated rifting sequences.	4-15
Fig. 4.4 Stratigraphic correlations in the Western Fold Belt displaying the major ore deposits and the age of stratigraphic horizons within the McNamara Group.	4-16
Fig. 4.5 Stratigraphy of the Lawn Hill Platform indicating the relative location of the Century Deposit and stratigraphic ages.	4-17
Fig. 4.6 Stratigraphic columns comparing the various classification schemes for rocks of the upper McNamara Group.	4-20
Fig. 4.7 Stratigraphic summary and description of the Century Deposit.	4-24
Fig. 4.8 Digital Terrain Model (DTM) of the Century deposit and surrounding region.	4-32
Fig. 4.9 Digital Terrain Model (DTM) integrated with 3D structural data, highlighting the Termite Range Fault and the parasitic Prosperity Fault system.	4-33

Fig. 4.10a 3D representation of the thickness variation in Unit 200 of the Century deposit looking south.	4-34
Fig. 4.10b 3D representation of the thickness variation in Unit 200 of the Century deposit looking north.	4-35
Fig. 4.11a 3D representation of the Pb distribution in Unit 200 of the Century deposit looking north.	4-38
Fig. 4.11b 3D representation of the Pb distribution in Unit 200 of the Century deposit looking south.	4-39
Fig. 4.12a 3D representation of the Zn distribution in Unit 200 of the Century deposit looking north.	4-40
Fig. 4.12b 3D representation of the Zn distribution in Unit 200 of the Century deposit looking south.	4-41
Fig. 4.13 Conceptual models representing soft sediments during extensional deformation, and lithified sediments during a later stage of basin evolution.	4-49
Fig. 4.14 Cross section of the Century deposit looking south.	4-50
Fig. 4.15 Pore pressure contours and Darcy fluid flow vectors for Model 1a at 1% extension and magnified plot of the ore zone.	4-56
Fig. 4.16 Model 1a at around 2% extension.	4-57
Fig. 4.17 Plot of pore pressure contours and Darcy fluid flow vectors for Model 1b at 1% extension and magnified plot of the ore zone.	4-58
Fig. 4.18 Plot of pore pressure contours and Darcy fluid flow vectors for Model 1b at 2% extension.	4-59
Fig. 4.19 Early stages of compression for Model 2a.	4-61
Fig. 4.20 Early to late stages of compression for Model 2a.	4-62
Fig. 4.21 Late stage of compression (9%) for Model 2a, plot of volumetric strain (dilation) and Darcy fluid flow vectors.	4-63
Fig. 4.22 Model 2b at commencement of deformation and release of overpressure.	4-65
Fig. 4.23 Model 2b at a) 3% deformation.	4-66
Fig. 4.24 Model 2b at 9% compression.	4-67
Fig. 4.25 Model 2c at 1% deformation.	4-69
Fig. 4.26 Model 2c at a) 1% deformation.	4-70
Fig. 4.27 Model 2d at 3% deformation.	4-73

Fig. 4.28 Model 2d at a) 3% deformation.	4-74
Fig. 4.29 Model 2d at 7% deformation.	4-75
 Chapter – 5	
Fig. 5.1 (a) Main tectonostratigraphic subdivisions of the Mount Isa Inlier, and location of major sediment-hosted Zn-Pb-Ag deposits.	5-7
Fig. 5.2 Mineralised and barren host rocks from the Century sequence illustrate characteristic relationships between mineralisation and deformation related fabrics.	5-9
Fig. 5.3 Mine stratigraphic column (Clifford and Kelso, 2003), showing alternating shale, siltstone intervals and relative total deposit, averaged, concentrations in weight % for Zn-Pb-Mn. Note higher Mn contents of siltstones between the Pb-Zn-rich shales.	5-13
Fig. 5.4 3D structural and property model of the Century deposit.	5-18
Fig. 5.5 S-Grid model conformed to the stratigraphic layers bounding the ore deposit.	5-21
Fig. 5.6 Summary of the GoCAD model components, comprising a surface based structural framework where modelled properties were applied, and an S-grid model representing the 3D spatial distribution of base metals.	5-22
Fig. 5.7 2D map views of base metal concentrations, Mn and thickness distributions over reconstructed surfaces representing mine stratigraphic intervals.	5-29
Fig. 5.8 Summary of figures illustrating the relationship between faulting and mineralisation.	5-31
Fig. 5.9 Diagram portraying examples of GoCAD spatial analysis of adjacent shale and siltstone layers (320-410, 420-430), used to estimate the degree of vertical redistribution of Pb and Zn.	5-32
Fig. 5.10 Results from Fig. 5.9 obtained from correlation analysis, showing the areas where Zn-Pb redistribution occurred.	5-34
Fig. 5.11 Spatial distribution of Zn-Pb-Mn at Century.	5-36
Fig. 5.12 Diagram illustrating the likely effect of faulting and fluid flow in controlling the localisation of remobilisation and mobilisation of base metals during post-sedimentary deformation.	5-38
Fig. 5.13 Conceptual model for syntectonic mineralization of the Century deposit.	5-39
Fig. 5.14 Numerical results for the Century deposit incorporating the main features of the system.	5-42
Fig. 5.15 Plot of pore pressure at around 3% bulk shortening.	5-43
Fig. 5.16 Detail of part of Fig. 5.14b, showing fluid flow vectors in and around shales.	5-45
Fig. 5.17 Schematic diagram illustrating the fluid flow variation during basin evolution,	

and its influence on the type of metal zoning, which represents a constraint for the different ore genetic models. 5-50

Chapter – 6

- Fig. 6.1** Map view of the study area. 6-7
- Fig. 6.2** Simplified stratigraphy from south to north through the Amadeus, Georgina, Wiso and Daly Basins. 6-11
- Fig. 6.3** Crustal transect showing the locus of reactivation during the Petermann and Alice Springs Orogenies. 6-12
- Fig. 6.4** Photographic view and relative structural interpretation of the northern and eastern walls of the Century Mine. 6-25
- Fig. 6.5** Examples of folding patterns observed in the Thornton Limestone. 6-27
- Fig. 6.6** Landscape view of a depositional scar (black outline) truncating highly deformed layers of dolomitic grainstone superposed by flat laying unreformed strata. 6-28
- Fig. 6.7** Conceptual models of slump fold development. 6-30
- Fig. 6.8** Lithostratigraphic classification of the Lawn Hill Outlier. 6-32
- Fig. 6.9** Examples of steep dipping intrusions in Middle Cambrian cover. 6-35
- Fig. 6.10** Examples of interpreted solution/collapse cavities in cherty limestone exposed on the western side of the Century Mine. 6-36
- Fig. 6.11** Breccia typologies observed along mine exposures, and also in drill core and outcrop, in the more internal part of the annulus. 6-37
- Fig. 6.12** Slumping initiation in relatively undeformed beds of the Thornton limestones. 6-40
- Fig. 6.13** Paragenetic chart illustrating the initial phases of basin evolution involving slump/scar development, the formation of different breccia types and their evolution. 6-45
- Fig. 6.14** Mohr diagram of shear stress against effective normal stress, with a composite Griffith-Coulomb failure envelope for intact rock normalised to tensile strength. 6-49
- Fig. 6.15** 3D structural/CBX breccia model of the Century Mine. 6-51
- Fig. 6.16** Stereoplots of fault planes proximal to voxels containing carbonate breccia. 6-54
- Fig. 6.17** Palaeostress directions (eigenvectors/eigenvalues, e_1 , e_2 , e_3) for the dip-classes considered in (a) $D < 30$; (b) $30 < D < 60$; (c) $D > 60$ (Fig. 6.16). 6-55
- Fig. 6.18** Examples of post-intrusion structural features. 6-60
- Fig. 6.19** Stereoplots representing the preferential trend of distribution expressed in %

area for the whole joints dataset.	6-62
Fig. 6.20 Map-view of the northwestern corner of the Century Mine illustrating transects where structural data were collected.	6-64
Fig. 6.21 Scanlines along transect 2 ordered from north to south.	6-66
Fig. 6.22 3D Block diagram representing a summary of the field relationships discussed in the text and presented in previous plates.	6-71
Fig. 6.23 Paragenetic reconstruction of the cross-cutting relationships used to reconstruct the temporal evolution of the sedimentary and tectonic events that contributed to the formation of the Lawn Hill Megabreccia.	6-75
Fig. 6.24 3D Block diagram illustrating the variation of depositional environments across the Lawn Hill Outlier.	6-77
Fig. 6.25 Examples of shatter cones collected in the Gum Hole Plain.	6-80

Chapter – 7

Fig. 7.1 Mandelbrot-set and relative enlargement views of smaller details on the edge of the Cardioid.	7-6
Fig. 7. 2 Bifurcation diagram representing a change from a single state of equilibrium to two stable phases.	7-9
Fig. 7.3 Plots of logistic function for different values of (r).	7-12
Fig. 7.4 Perspective views of the Lorenz attractor in phase space.	7-13
Fig. 7.5 Schematic diagrams representing the basic rules that constrain the mineral system evolution.	7-18
Fig. 7. 6 Diagram summarising distinctive patterns as a function of spatial location within an exhalative system.	7-21

List of tables

Chapter – 3

Table 3.1. Summary of the broad characteristics of SEDEX, IRISH-style and MVT deposits.	3-26
Table 3.2. Weights of evidence and relative variances $s(W)$, Contrast (C), and studentised Contrast C_w for grouped, lithostratigraphic formations outcropping in the	

Lawn Hill Region.	3-81
Table 3.3. Weights (W), contrast (C) and relative studentised values (Cw) for cumulative distances from linear and point patterns.	3-84
Table 3.4. Summary of contrast analyses for considered sub-classes of geophysical datasets.	3-85
Table 3.5. Predictor binary patterns and relative Weights of Evidence, variances and area proportions ranked by contrast (C).	3-87
Table 3.6. Comparison of CI results of chi-square pairwise evaluation against OT and NewOT tests.	3-103
Table 3.7. Omnibus and New-Omnibus test results for multiple combinations of evidential themes.	3-104

Chapter – 4

Table 4.1. Correlation of deformational history in three locations of the Mount Isa Block, including a summary of age dates from several locations.	3-12
Table 4.2 Physical properties for materials, Models 1 and 2.	3-52

Chapter – 5

Table 5.1. Material properties for the geological units used in the numerical models.	5-41
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Chapter – 6

Table 6.1. Bingham axial distributions for sills, oblique dikes, and sub-vertical dikes.	6-56
Table 6.2. Carbon and oxygen isotope analyses of whole rock and veins on the Thornton Limestone and Mesoproterozoic basement.	6-68