GEOSTATISTICAL ASSOCIATION OF AUSTRALASIA

Newsletter 20 December-2003

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Http:// www.gaa.org.au

OVERVIEW FROM THE PRESIDENT

This quarter saw the GAA focus on suggestions for updating the society's website in relation to all matters geostatistical. Preliminary suggestions have included incorporating links to a number of organisations on the GAA site, including to those Australian institutions offering undergraduate and postgraduate courses in geostatistics; companies which offer in-house or public shortcourses; online paper references; sister organisations such as the AusIMM, AIG, Statistical Society etc, online journals. Other planned updates are to include contributions from our Life Members on their careers to date, and where they see geostatistics going in the future and copies of conference posters that relate to geostatistics. Any members who have comments, suggestions or contributions are welcome to email president@gaa.org.au or webmaster@gaa.org.au.

A summary of the Bendigo conference that was co-organised by Dr Simon Dominy, a current GAA committee member, is included inside. GAA Past President Mark Noppe chaired the geostatistical session, and manned a combined GAA/AIG booth that was strategically situated near the coffee bar. The GAA organised a poster display on various aspects of geostatistics, and I would sincerely like to thank all committee members, but particularly Ian Lipton, Mark Noppe, Roussos Dimitrakopolous, Ute Mueller and Alan Miller for their input, comments and corrections. A big thankyou is also due to Snowden Associates, particularly Mark Noppe, Ian Glacken and Jacquie Coombes, who allowed the GAA to use some of their data and various illustrations. Vince Algar of Surpac, Roger Cooper of Placerdome, Steve Hyland of Ravensgate and staff at Medsystems kindly provided various images within, and as background to, the posters. The posters were subsequently borrowed by the AIG for a conference in Perth later that week, but due to venue changes, could not be utilised. A pity, but a great boost for the GAA to have posters that are obviously applicable outside the sometimes arcane geostatistical world.

Finally the GAA is gearing up for its next big challenge, which is supporting the WH Bryan Centre and the AusIMM for the upcoming Orebody Modelling and Risk Uncertainty conference to be held in Perth, 2004. The lineup of attendees is already sterling, and the event promises to be *the* geostatistical event of 2004. A call for papers is included in this edition, and it would be fantastic to see contributions from members. Closing date for abstracts is 27 February 2004.

All the best of the season to members, and hope 2004 is both professionally rewarding and prosperous.

Stella Searston

Contents

Resource Estimation Modeling Techniques – Current Trends in Gold Deposits

During August 2003, Pincock Allen and Holt published the results of a survey into the varieties of modelling techniques used within the mining industry in America. The results make fascinating reading, and my thanks to Raul Borrastero and Leonel Lopex, the authors, and Sandra Prebynski, of PAH publicity for allowing the GAA to reprint the article.

Introduction

Within the last decade, the availability of faster computers and increasingly sophisticated and powerful general mining software packages has made resource estimation a specialized field. This specialization has included many methods that are now commonly applied throughout the industry. The use of statistical and geostatistical analysis techniques have now become common practice and are widely utilized. In addition, general office, mapping and drafting software have allowed explorationists, geologists and engineers to store and process vast amounts of information to aid in the resource estimation process.

In an attempt to find and describe the current trends that are apparent in the exploration and mining industry in regards to the modeling techniques used in the estimation of geologic resources, PAH surveyed information available from public sources such as the Canadian Securities Administrators System for Electronic Document Analysis and Retrieval (SEDAR). Several gold (plus silver and/or base metals) deposits located in a variety of geologic and geographic environments worldwide were studied. The majority of reports reviewed were posted in 2003, a few in 2002, while the oldest report was from February 2001. The findings, detailed on Table 1, show some of the most common parameters and methods currently utilized by the industry when dealing with gold deposit resource estimation.

Modeling Parameters

Each mineral deposit presents unique geologic characteristics, therefore the definition of modeling techniques and parameters must be carefully determined to design the most appropriate geologic model that will effectively represent a specific mineral deposit. The careful and correct interpretation of the deposit's geologic boundaries remains the single most important aspect of any resource estimation. This requires that the geology of the deposit be reasonably delineated allowing for a realistic geologic interpretation. The introduction of modeling software in the early stages of an exploration program helps to capture a more systematic approach to the registry of data that eventually guides the resource modeling process.

It is clear that the majority of companies analyzed utilize computerized methods with varied sophistication to model resources. An exception appears to be in the case of some narrow vein deposits (typically underground mines or exploration projects) where more traditional methods such as manual (or AutoCAD-generated) cross sectional or long-sectional blocking techniques are employed.

Interestingly, several common trends appear to have developed, probably, and at least in part, as a result of cooperation and mobility among professionals, availability of well-regarded and specialized software packages that have become industry standards and the fact that in many cases certain modeling techniques are proving successful at predicting tonnage and grade within generally acceptable limits.

For example, PAH found that among 15 gold deposits checked worldwide (12 epithermal vein, stockwork or disseminated and 3 massive sulfide), 13 used computerized block modeling and grade interpolation techniques (Table 2). Of the 13 using block models, 7 applied geostatistical grade interpolation routines (various kriging methods), whereas the other 6 applied inverse distance interpolation routines.

All of the deposits studied utilized some sort of constraining deposit boundary(s) to limit the extent of the mineralized zone(s) and prevent the projection of grade values into barren or undesirable rock/structural units. This boundary is in many cases (6 out of 15) a geologic boundary that follows veins, rocks or structural controls/domains. In 9 cases, however, the constraining envelope was defined using a grade boundary (typically gold or gold equivalent grade). This grade boundary is usually drawn respecting and following known geologic controls of the mineralization. Again, in the majority of cases, cross-sectional geologic interpretation was used. The cross section spacing was typically in the range of 20 to 35 meters, which roughly coincided with the drill hole grid spacing of the area of interest.

Statistical analysis of exploration and mining data is a standard practice for defining grade groupings. The statistical analysis generally results in defining several parameters such as gold grade capping levels (used in 70% of the deposits reviewed), and grade envelope level definition (used in 9 deposits). Grade capping appears to be the preferred method in dealing with outlying high-grade values that require special consideration, although in two cases a high-grade distance restriction was used instead. In only three of the deposits reviewed it was determined that neither capping nor distance restriction was needed. Whenever grade capping was applied, it was not always clear at what stage of the modeling process it took place (i.e. assay values, composite values and/or block model interpolation stage).

Semivariogram studies are also a standard practice for defining spatial continuity of grade. The variography analysis that was performed in more than 80% of the deposits (13 out of 15) aided in assessing grade continuity along preferred orientations and in defining search distances for grade interpolation and resource categorization parameters (based on distance to sample points). Variography is commonly run separately for geographic areas or for mineral zones/domains.

The distance to sample points for the classification of resources appears to be another item where many deposits have much in common. Ten models used a distance of 5 to 25 meters to define Measured resources. Also in 10 deposits a distance of 20 to 50 meters was used to categorize Indicated resources. The categorization of Inferred resources varied considerably among the deposits reviewed and no real common ground was apparent. It is important to point out that in most deposits, resource categorization may not only be based on distance to sample points but also on many other items such as kriging variance, number of samples within the search distance, indicator probabilities, distance to existing mine workings, etc.

Almost invariably, the resource statements include the utilization of cut off grades, which obviously can vary widely depending upon the mining method (e.g. open pit, underground cut & fill, underground room & pillar, etc.), metallurgical recoveries, processing method, etc. In some cases for open pit projects, resources are stated not only above a certain cutoff grade but also only if they fall within a nominal pit shell that is based on certain economic parameters. This approach tends to restrict the resource tonnage to what might eventually become mineable under favorable economics, etc., instead of simply using a flat cutoff grade applied throughout the deposit. This approach also helps in addressing the stipulation in most guidelines calling for resources to only include material that is "potentially economically viable."

CONCLUSIONS

Despite the fact that unique geologic environments and local conditions must result in a variety of interpretations and resource estimation methods, many gold deposits throughout the world show certain common approaches and application of techniques to estimate mineral resources. The application of some of the most common techniques and parameters can obviously be quite useful for projects in the early stages of exploration, although even advanced stage projects can benefit from knowing and testing successfully applied methods. The models that utilize techniques that have similarities to those of other like projects can be considered standard industry approaches. Those that employ novel or unusual techniques relative to the norm may be considered non-standard and require special scrutiny to validate.

Raul Borrastero, Senior Geologist (raul.borrastero@pincock.com),
Leonel Lopez, C.P.G., Principal Geologist,
Pincock, Allen & Holt

TABLE-1: General Parameters for Deposit Modeling - Review of Several Gold Deposits (Public Source: www.sedar.com)

Project / Mine	Metals	Mine / Process	Geologic Interpretation Base	Drill Hole Grid (meters)	Deposit Boundary(s)	Grade Interpolation Method	Grade Capping	Variography	Search Distances	Resource Classification (Notes: s=samples; h=holes)	Block Model Cell Size
Epithermal - Veining and Stockwork											
Bellavista, Costa Rica	Gold / Silver	Open Pit / Heap Leach	Cross Sections @ 25m	25 X 20	Grade 0.30 gpt Au	Multiple Indicator Kriging	Percentile 97.5^{th}	Yes, for 6 geologic domains	Strike-75m; Dip-50m; Across-25m	Measured=<25m; Indicated=<50-75m Inferred=Over	6X6X6m
Esquel, Argentina	Gold / Silver	Open Pit / CIL Mill	Cross Sections @ 40m	40 X 20 or 40 X 40	Grade Shells 1.50 - 5.0 gpt Au	Inverse Distance to 3^{th}	Gold to 16.5gpt; Silver to 99 g/t	Yes.	Strike-60m; Dip-60m; Across-7.50m	Measured<30m,3s.; Indicated,<30m,2s; Inferred>30m,2s.	5X2X2.5m
Marlin, Guatemala	Gold / Silver	Open Pit & UG / Mill	Cross Sections @ 25m	25 X 50	Grade 0.30 gpt Au	Ordinary Kriging	Gold @ 35 gpt before compositing	Yes, Linear Semi-Variogram	313m in all directions	Measured=25m, 7s/3h; Indicated=50m,4s/2h; Inferred=305m,2s	10X10X7m
Dolores, Mexico	Gold / Silver	Open Pit / Mill	Cross Sections @ 25m	25 X 25	Geologic Controls	Inverse Distance to 5th	Gold-30 gpt; Silver-1000 g/t	Yes; Model: Az. On Strike 330 ; Dip -80.	Strike-150m; Dip-120m; Across-60m	Measured=20X17.5X15m; Indicated=40X35X30m; Inferred=120X90X60m	10X5X3m
Ocampo NE, Mexico	Gold / Silver	Open Pit & UG / Mill	Cross Sections @ 25 - 50m	25 X 60	Geologic Controls	Polygonal Method; Excel spreadsheets	No Capping	No	Half distance between drill holes	Measured<25m & samples on 4 sides: Indicated<50m & samples on =<3 sides; Inferred=100m.	Blocks defined in AutoCAD and geologic interpretation
Pimenton, Chile	Gold / Copper	UG / Mill	Cross Sections @ 10m; 4 Mine Levels @ 40m	Variable by Vein	Geologic and ug mining controls.	Polygonal method.	Gold - 195 gpt	No	Half distance between mine levels	Measured=5m; Indicated=20m; Inferred>40m	Blocks projected between ug levels.
Epithermal, Disseminated and Breccias.											
Alto Chicama, Las Lagunas, Peru	Gold / Silver / Copper	Open Pit / Heap Leach	Cross Sections @ 100m	50 X 100	Grade 0.35 gpt Au	Inverse Distance to the 2^{nd}	Gold-20gpt (99.6%); Silver-100gpt (99.9%)	Yes, Gold Omnidirectional	N60E-50m; S60W-45m; Vertical-20m	Meas=10X10X5m 1s; Indi=30X25X20m 1s, or 60X50X40 min.2s; Infer=90X90X60m min 1s	10X10X5
Marigold, Nevada	Gold / Silver	Open Pit / Heap Leach	Cross Sections @ 30m	30 X 60	Geology & Grade, 0.005 & 0.006 opt	Inverse Distance to 3th	Composited Gold to 0.06 opt	Yes, for anisotropy & range	Strike 200ft; Across-100; Dip-100.	Measured=66ft,min.3s; Indicated=125ft,min. 1s; Inferred=All other blocks.	20X20X20ft & 40X40X40ft
Sam Martin, Honduras	Gold / Silver	Open Pit / Heap Leach	Cross Sections @ 50m	50 X 50	Geology & Grade, 0.35 gpt Au	Ordinary Kriging	No Capping; Hi-Grade distance restriction	Yes, for anisotropy, nugget & range	PrimAxis=137m; Secon=133m; Tertiary=41m	Measured=22m; Indicated=90m; Inferred=All other blocks.	7X7X7m

El Sauzal, Mexico	Gold / Silver	Open Pit / Mill-CIL	Cross Sections @ 50m	50 X 50	Geology & Grade envelope: 0.5 gpt Au	Indicator & Ordinary Kriging	No Capping: Hi-Grade restriction (>25gpt) @ 15m	Yes, for anisotropy & range.	1st.Y=49; X=49; Z=10; 2nd Y=98; X=98; Z=49m	Measured=<25m; Indicated=<50; Inferred>50m	5X5X5m
Segala, Mali, West Africa	Gold.	Open Pit / Mill-Grav.-CIL	Cross Sections @ 25m	30 X 25	Geology & Grade, 0.10 gpt Au	Multiple Indicator Kriging	Capping by 95th and 97.5th percentile	Yes, for each domain, range of grade intervals.	At50th: Strike=30m; Across=25m; Depth=5m	Kriging Run & Kriging Variance:Measured:1, 0.001-0.53; Indicated:1, 0.53-0.63; Inferred:1, >0.63 & 2,3, Any.	5X5X5m
Jerritt Canyon, Nevada	Gold	UG / Mill	Closely Spaced Cross Sections and Plan Views	Tight Spacing typically <50ft	Geology & Grade, 0.15 opt Au	Indicator Kriging	No Capping	Yes, by Mine and Zone	75 ft (measured & indicated); 75-150 ft (Inferred)	Measured=30ft; Indicated=75ft; Inferred> 75ft; & other parameters	15X15X15ft
Volcanogenic, Massive Sulfides											
Casa Berardi, Canada	Gold / Base metals	Open Pit / Mill	Cross Sections @ 20 - 100m	20 X 100	Geology & mineralization controls.	Inverse Distance to 3th	No Capping of outlier High Grade values.	Yes, on small and large intervals.	Range=50m from DH. Strike=Dip componentes.	Inferred=Based on drill density and grade continuity.	10X10X2.5m
LaRonde, Canada	Gold / Silver / Copper	Open Pit & UG / Mill	Cross Sections @ 40m	40 X 40	Geology & mineralization controls.	Polygonal & Inverse Distance	Capping per zone: Au= 17-51gpt; Ag=200-857 g/t	Yes, directional variograms.	Half distance between DH projections.	Polygonal and ID block modeling estimates.	12X12X3m
Tambo Grande, Peru	Gold / Silver / Copper	Open Pit / Mill	Cross Sections @ 35m	35 X 35	Geology & mineralization controls.	Ordinary Kriging	Capping Gold=40 gpt; Silver=3,000 g/t	Yes, spherical range oxides, anisotropic search	1st.Y=40; X=40; Z=5; 2nd Y=75; X=75; Z=25m	Indicated=Blocks within 27m, 2+s from dif. DH; or 1s within 9m.	5X5X2.5m

TABLE 2
General Parameters for Resource Modeling
Review of Several Gold Deposits Worldwide (Public Source: www.sedar.com)

Total Number of Projects/Mines Reviewed		15
Deposit Types	Epithermal (Veins, Stockwork, Disseminated, Breccias)	12
	Massive Sulfide	3
Mine Type	Open Pit Project/Mine	10
	Underground Project/Mine	2
	Combined Open Pit/Underground Project	3
Deposit Boundary Constraints	Geologic/Structural Boundaries	6
	Grade Envelopes (with Geologic Input)	9
Block Model Utilization	Yes	13
	No	2
Grade Interpolation Method	Kriging Techniques	7
	Inverse Distance Techniques	6
Statistical Analysis	Yes	15
High Grade Outliers Treatment	Grade Capping	10
	High Grade Distance Restriction	2
	Not Applied	3
Variogram Analysis	Yes	13
	No	2
Resource Classification (Distance to Nearest Sample)	Measured = 5 to 25 meters (4 used 25m)	10
	Indicated = 20 to 50 meters (4 used 50m)	10
Block Cell Dimensions	Isometric	6
	Non-Isometric	7

DANIE KRIGE HONORARY LIFE MEMBER

Professor Danie Krige has kindly put together for the GAA a brief history of his work, together with some much appreciated comments on the continuing problems of conditional bias in ore block variations.

Career

Born 26 August 1919, matriculated at Monument High School, Krugersdorp, in 1934, (age 15). Graduated as a mining engineer, BSc(Eng.), in 1938, at the University of the Witwatersrand (Wits). Gained an MSc(Eng). Wits, in 1951 and DSc(Eng). Wits, in 1963. I have honorary doctorates from the following: 1981, Pretoria University, 1996, University of South Africa, and 1997, Moscow State Mining University.
From 1942 to 1950, Professor Krige was working at the Government Mining Engineers Department with access to a vast data base of ore statistics from producing mines and from new mines opening up in the Free State and Klerksdorp gold fields. This provided a unique opportunity for research into the application of mathematical statistics to ore valuation; also for the 1951 Masters Thesis, publication of the first two papers (1951/52), and the birth of Geostatistics with the Kriging technique (named after him) as practiced worldwide today.
During the periods 1939-1942 and 1950-1980, Professor Krige worked in the mining industry, specializing mainly in ore valuation, project evaluation, and mining taxation; also in the practical application and development of Geostatistics on producing mines.
From 1980-90 he was the Professor of Mineral Economics at Wits, and subsequently has acted as a Consultant to mining groups and companies.
From 1960 on, Professor Krige has given lectures and courses at international congresses and universities locally and overseas, and has published some 80 papers within South Africa and overseas.

Professor Krige has received a number of prestigious awards, including:

State President: Order of Meritorious Service, Class 1, Gold, 1988.
Gold Medal : South African Academy for Science and Art, 1982.
Two gold Medals: S.A. Institute of Mining and Metallurgy, 1966 and 1980.
The Brigadier Stokes Platinum medal, 1984, i.e. the premier award of the S.A. Institute of Mining and Metallurgy.
The John F.W. Herschel Gold medal, 1988, Royal Society of South Africa.
William Krumbein Medal, 1984, International Association of Mathematical Geology.
Daniel Jackling Award, 1988, American Society of Mining Engineers.

Block Valuations

In reviewing my career and experiences in geostatistics over more than half a century and particularly some of the more recent developments, I am amazed at the growth of the applications and techniques generally including my field of interest, i.e. ore reserve valuations. Much progress has been made, but at the risk of being accused, as has happened frequently in the past, of being obsessed by the problem of misleading attitudes towards conditional biases in ore block valuations, I would again like to state my convictions on this subject concisely and clearly for the future benefit of geostatistics.
Block valuations are performed to enable mine planning and production and financial estimates to be made as reliably as possible, and particularly so where selective mining of individual ore blocks to a cut-off is essential. The short and medium term implications are critically important as well as the longer term considerations. The quality of the estimates must, therefore, be ensured, not only from the global point of view as normally defined by a reliable global tonnage-grade curve, but also in respect of individual blocks in the relatively small local areas covering the short term position. Note that a reliable global tonnage-

grade curve can usually be obtained without any block valuations from an analysis of the point distribution and variogram.

The ideal to be aimed at is thus block valuations which are conditionally unbiased and have an acceptable tonnage-grade curve (i.e. a distribution with an unsmoothed dispersion variance), in respect of both the global and smaller local areas to be mined. This ideal can only be met in the case of perfect valuations. In practice, this is impossible but an acceptable compromise is to do the smoothed block valuations with an adequate search routine, or with SK, and in any case so as to be conditionally unbiased, and to subject them to post-processing to provide unsmoothed and unbiased probability estimates of the tonnage-grade curves globally and locally. Note that repeated simulations when averaged for each block result in smoothed estimates similar to those from Kriging; when correctly and effectively post-processed, via the variability of the individual simulation block estimates as a base, they will also provide probability estimates similar to the Kriged estimates after post-processing.

If practitioners can accept these statements in principle, they will also agree that there is no justification, whatever, for the practice of limiting the data search routine for block estimates so as to approach the required unsmoothed SMU dispersion variance globally; such estimates will be conditionally biased globally and in local areas. The estimates could, thus, lead to bad selective mining decisions for individual blocks particularly in short term planning. I strongly urge the discontinuation of this practice in order to raise the reputation of geostatistics in ensuring ore valuations of quality.

Bendigo conference

Bendigo was co-sponsored by the GAA, and the Committee is very grateful to Mark Noppe who was the GAA representative to the conference, chaired the session on geostatistics, and provided the following report.

The conference attracted some 250 delegates, mostly from Australia, but with representation from South Africa, Tanzania, PNG, Indonesia, Sweden and North America.

Bendigo is a well-established historical town in Central Victoria, about 2 hours drive from Melbourne. Given the travel logistics, the golf day, welcome BBQ, short courses and tours, most delegates were in-place by late Sunday afternoon.

Thirty eight technical talks were presented over two and half days. The final afternoon was an open-session which ended up covering options for enhanced reporting of resource and reserve confidence and the general shortage of skills in the mining industry.

The papers were well presented and technically relevant with many case studies. Question time was generally "quiet", but there was ample time during the breaks to catch-up and the atmosphere was really quite energetic.

The GAA hosted a poster-display and chaired a 4-paper session dedicated to geostatistical applications. All together though there were about 12 papers that referred to geostatistical methods to a greater or lesser degree, from tips on testing the kriging neighbourhood to categorical kriging using indicators to estimate lithology proportions. Noticeably absent were papers on selective grade-tonnage reporting and conditional simulation applications.

The proceedings, available in hard copy and CDROM from the AusIMM, include other papers submitted but not presented at the conference.

The organizing committee, including GAA's Simon Dominy as one of the co-chairs, did a great job, and this will remain an attractive forum for mining geology in the future.

Mark Noppe
26 Nov 2003

ON THE MOVE

Alan Miller has left KCGM for the bright lights of Perth, where he will be working for Golder Associates

Michael Andrews is leaving Newmont to join Snowden Associates

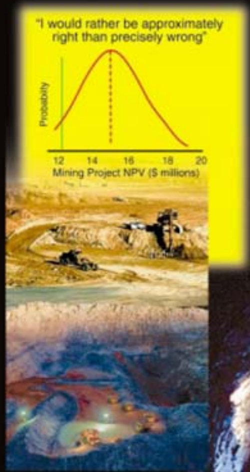
Megan Roberts of SRK, **Adrian Byass** of Siberia Mining Corporation Limited and Peter Chern and Kahan Cervoj have joined the GAA as new members

International Symposium

22-23 November 2004
Hyatt Regency, Perth, WA

Orebody Modelling and Strategic Mine Planning

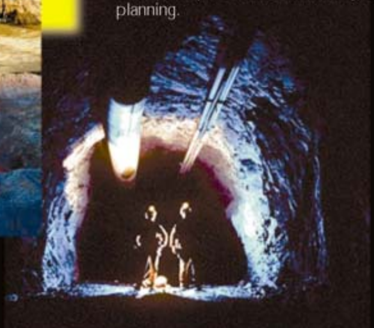
Uncertainty and Risk Management



Call for Papers

Join internationally-recognised practitioners and researchers in the discussion and analysis of traditional and new methods for orebody modelling and mine planning, design optimisation and mining strategies.

Contribute to approaches for managing risk and explore the future possibilities of "harvesting uncertainty" to capture maximum upside while minimising downside in strategic planning.



Internationally recognised participants attending to date:

- Jeff Whittle – *Australia*
- Peter Ravenscroft – *RioTinto, Australia*
- Martin Whitten – *RioTinto, Australia*
- Gavin Yeates – *BHP Billiton, Australia*
- Peter Forrestal – *Xstrata, Australia*
- Olivier Tavchandjian – *INCO, Canada*
- Georges Verly – *Placer Dome, Canada*
- Kadri Dagdalen – *Colorado School of Mines, USA*
- Jean-Michel Rendu – *USA*
- Andre Journel – *Stanford University, USA*
- Wynand Kleingeld – *DeBeers, UK*
- Duncan Campbell – *Anglo American, UK*
- Peter Dowd – *University of Leeds, UK*
- Christian Lantuejoul or Jeal-Paul Chiles – *Paris School of Mines, France*
- Roussos Dimitrakopoulos – *BRC, Australia*

Orebody Modelling and Strategic Mine Planning: Uncertainty and Risk Management is a two-day symposium highlighting the latest advances, technologies, practices and concerns in the field. Key themes will include:

- **From Strategic Planning to Production Management: Risk – The Corporate View**
- **Optimisation in Open Pit Mine Design**
- **Conditional Simulation for Large-Scale Applications**
- **Using Risk in Forecasting Recoverable Reserves**
- **Geological Risk Management through Mine Optimisation**
- **Orebody Uncertainty in Underground Mine Design**
- **Mine Production Scheduling**
- **Strategic Risk Management and Project Valuation**
- **New Advances and Challenges in the fields of Stochastic Modelling and Mining Operations Research**

The symposium will also feature:

- **Case Studies of Strategic Mine Planning in Major Operations**
- **A Forum on Mining Industry Issues and Needs**

A 300 word abstract should be submitted by 27 February 2004 via **email to: conference@ausimm.com.au**

or mail to: **OMMP 2004**
PO Box 931
Palm Beach Qld 4221
Australia

Authors will be sent confirmation of receipt of their abstract. All abstracts and papers will be peer-reviewed and published in a Volume of Proceedings.

Key dates for authors are:

✓ Abstracts submitted	27 February 2004
✓ Author notification of acceptance	19 March 2004
✓ First drafts of papers submitted	11 June 2004
✓ Papers returned to authors for corrections	6 August 2004
✓ Final papers submitted and author registration deadline	1 September 2004

Contact details for further information:

Email: conference@ausimm.com.au
Telephone: (07) 3295 9565
Facsimile: (07) 3295 9566
Mail: PO Box 931, Palm Beach Qld 4221
Website: www.ausimm.com/ommp2004/home.html

This event is being organised with the collaboration and support of the Australasian Institute of Mining and Metallurgy (AusIMM), the Society for Mining, Metallurgy and Exploration Inc. (SME), and the South African Institute of Mining and Metallurgy (SAIMM). The Symposium is an international initiative of the WH Bryan Mining Geology Research Centre (BRC).

Dr Frederik (Frits) Agterberg

During 2004, the Australian statistical community will be fortunate to have the opportunity to attend a number of lectures by distinguished Dutch-Canadian practitioner of the statistical arts, Dr Frederik (Frits) Agterberg. Dr Agterberg is the Distinguished Lecturer of the International Association for Mathematical Geology for 2004, *only the second ever appointee. While dates have still to be confirmed, Dr Agterberg will be presenting in both Perth and Brisbane. The talks will centre around one of the following abbreviated topics, the topic for each venue to be decided prior to Dr Agterberg's visit.*

1. Past and Future of Mathematical Geology.
First half of the 20th century. With the advent of computers, numerical modeling in the geosciences became increasingly accelerated. This includes new methods of 3D geological map-making.
2. Probabilistic Mineral Resource Potential Mapping.
The processing of geo-scientific information for the purpose of estimating probabilities of occurrence for various types of mineral deposits was made easier when Geographic Information Systems became available. Weights-of-Evidence modeling and logistic regression are examples of GIS implementations.
3. Lognormal Distributions and Pareto Tails in Geochemistry and Resource Appraisal.
The lognormal frequency distribution model has seen many successful geo-scientific applications. This includes the modeling of trace element concentration values in bedrock samples and the sizes of ore deposits and oil pools. Multifractal modeling provides new clues on how lognormal distributions can have Pareto tails.
4. Statistical Methods used for the Construction of the 2004 Geological Time Scale.
A newly constructed geological time scale incorporates results of statistical techniques for integrating age determinations with stratigraphic information. Maximum likelihood methods and smoothing splines are used to provide estimates of the ages of stage boundaries and durations.
5. Automated Stratigraphic Correlation.
First and last occurrences of fossils can be sequenced and scaled for the construction of regional stratigraphic zonation columns with incorporation of litho-stratigraphic and seismic information. Land-based sections or exploratory wells can be correlated with one another using the scaled optimum sequence.

Dr Agterberg's shortened CV is included below for general reading, kindly provided by Prof. Roussos Dimitrakopoulos at the W.H. Bryan Centre.

Frederik Pieter (Frits) Agterberg was born in 1936 in Utrecht, the Netherlands. He studied geology and geophysics at Utrecht University obtaining a BSc (1957), MSc (1959) and PhD (1961). These three degrees were obtained "cum laude" (with distinction). After a one-year Wisconsin Alumni Research Foundation postdoctoral fellowship at the University of Wisconsin, he joined the Geological Survey of Canada in 1962, initially as a petrological statistician working on the Canadian contribution to the International Upper Mantle Project.

Later he formed and headed the Geomathematics Section of the Geological Survey of Canada in Ottawa (1971-96). The primary objectives of this group were to develop and apply computer-based geo-scientific data integration techniques for mineral potential mapping; and also to provide mathematical and statistical consulting services to other scientists within the Geological Survey of Canada.

Dr Agterberg has authored or co-authored over 200 scientific publications including the textbook "*Geomathematics: Mathematical Background and Geo-science Applications*" published in 1974 by Elsevier with approximately 10,000 copies sold word-wide, and the monograph "*Automated Stratigraphic Correlation*" (1990). He has edited or co-edited seven other books and special issues in scientific journals.

In 1978 he became the third W.C. Krumbein medallist of the International Association for Mathematical Geology. He won the Best Paper Awards for articles in the international scientific journal "*Computers & Geosciences*" in 1978, 1979 and again in 1982. Other honours include his appointment as Correspondent of the Royal Dutch Academy of Sciences in 1981, and that of Honorary Professor of the China University of Geo-sciences in 1987. A newly discovered fossil was named after him, *Adercotrima agterbergi,* to recognize his contributions to quantitative stratigraphy.

In 2003 he was selected as the second Distinguished Lecturer of the International Association for Mathematical Geology, with his term commencing in January 2004.

Since 1968, Dr Agterberg has been associated with the University of Ottawa where he has taught an undergraduate course on "*Statistics in Geology*" for 25 years, and directed the research of four undergraduate and nine graduate students (7 PhD and 2 MSc). Several of his former students now occupy prominent positions in the mining industry, universities and government organizations in Canada and abroad.

Other academic positions Dr Agterberg has attained, include Distinguished Visiting Research Scientist at the Kansas Geological Survey of the University of Kansas (1969-1970); Adjunct Professor at Syracuse University (1977-1981); Esso Distinguished Lecturer for the Australian Mineral Resource Foundation at the University of Sydney (August - November 1980); and Adjunct Research Professor, Department of Mathematics, Carleton University, Ottawa (1986-1994).

He has been external examiner of 17 PhD and 4 MSc theses at Canadian and foreign universities, mostly in geology departments but also in departments of mining engineering, physics, mineral economics, mathematical statistics, and physical geography.

Dr Agterberg has presented more than 40 short courses worldwide. From 1979 to 1985 he was Leader of the International Geological Correlation Programme's Project on "*Quantitative Stratigraphic Correlation Techniques*". He has served on numerous committees, editorial boards, and councils of national and international organizations.

This has included associate editorships of both the Canadian Journal of Earth Sciences and the Bulletin of the Canadian Institute of Mining and Metallurgy (for geostatistical manuscripts). Recently (1996-2000), he was chair of the Publications Committee of the International Association for Mathematical Geology and the Quantitative Stratigraphy Committee of the International Commission on Stratigraphy that is part of the International Union of Geological Sciences.

In 1996, Dr Agterberg commenced a phased retirement from the Geological Survey of Canada to work as a part-time independent geo-mathematical consultant to industry. He continues to teach and supervise graduate students at the University of Ottawa.

Current positions

1. Emeritus Research Scientist, Geological Survey of Canada
2. Adjunct Professor, Earth Sciences Department, University of Ottawa
3. Member, Ottawa-Carleton Geoscience Center
4. President, Geomathematica Inc., home-based consulting company for industrial applications of mathematics and statistics in the Earth Sciences
5. Vice-President, International Association for Mathematical Geology; duties include organization of joint meetings with professional statisticians, mainly during biannual Sessions of the International Statistical Institute
6. Honorary Professor, China University of Geosciences & Member, Academic Committee, Laboratory of Quantitative Prediction and Exploration Assessment for Mineral Resources, Chinese Ministry Of Land and Resources
7. Associate Editor, Computers & Geosciences
8. Member, Editorial Board, Natural Resources Research.
9. Book Editor, Mathematical Geology.
10. Member Editorial Committee, Earth Science - Journal of China University of Geosciences

Consulting Experience

During full-time employment at the Geological Survey of Canada, statistical and geostatistical consulting services were provided to staff of the Geological Survey of Canada, other

Canadian government organizations and Crown corporations including Canmet, DEVCO, and AECL.

After retirement from full-time employment at Geological Survey of Canada, Dr Agterberg has been consulting to, amongst others, Aber Diamond Corporation (1997-present); Saga Petroleum ASA (1996-1999); Homestake Canada Inc. (2000-2001); Conoco (2001-2002); British Gas (2001-2002) and Shell Oil (2001-2002).

Current activities

During the 2001-2002 winter term, Dr Agterberg taught a geo-mathematics module to graduate students at the Ottawa-Carleton Geoscience Centre. In December 2002, he gave a short course on mineral potential mapping and multifractals in Beijing. Together with Dr Felix Gradstein from the University of Oslo, Dr James Ogg from Purdue University, and others, he is working on the new Standard Geologic Time Scale for the Phanerozoic, Mesozoic and Cenozoic (to be published by Cambridge University Press in 2004). He has organized, or is in the process of organizing, the following meetings:

Recent Developments in Geostatistics: Joint Statistical Meetings, American Statistical Association, August 2002, New York City, U.S.A.

Fractals and Multifractals: Annual Conference of the International Association for Mathematical Geology, September 2002, Berlin, Germany.

Recent Statistical Advances in Geological and Environmental Applications: 54th Session of the International Statistical Institute, August 2003, Berlin, Germany.

Environmental Applications of Mathematical Geology: Joint Statistical Meetings, American Statistical Association, August 2004, Toronto, Canada.

New Applications of Mathematical Statistics in the Earth Sciences: International Geological Congress, August 2004, Florence, Italy.

5TH INTERNATIONAL MINING GEOLOGIST CONFERENCE BENDIGO 17-19 NOVEMBER 2003

The conference attracted some 250 delegates, mostly from Australia, but with representation from South Africa, Tanzania, PNG, Indonesia, Sweden and North America. Bendigo is a well-established historical town in Central Victoria, about 2 hours drive from Melbourne. Given the travel logistics, the golf day, welcome BBQ, short courses and tours, most delegates were in-place by late Sunday afternoon.

Thirty eight technical talks were presented over two and half days. The final afternoon was an open-session which ended up covering options for enhanced reporting of resource and reserve confidence and the general shortage of skills in the mining industry.

The papers were well presented and technically relevant with many case studies. Question time was generally "quiet", but there was ample time during the breaks to catch-up and the atmosphere was really quite energetic.

The GAA hosted a poster-display and chaired a 4-paper session dedicated to geostatistical applications. All together though there were about 12 papers that referred to geostatistical methods to a greater or lesser degree, from tips on testing the kriging neighbourhood to categorical kriging using indicators to estimate lithology proportions. Noticeably absent were papers on selective grade-tonnage reporting and conditional simulation applications.

The proceedings, available in hard copy and CDROM from the AusIMM, include other papers submitted but not presented at the conference.

The organizing committee, including GAA's Simon Domini as one of the co-chairs, did a great job, and this will remain an attractive forum for mining geology in the future.

Mark Noppe
26 Nov 2003

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BOOK REVIEWS

PLURIGAUSSIAN SIMULATIONS IN GEOSCIENCES

By M. Armstrong, A. Galli, G. Le Loc'h et al. 2003, 149pp, ISBN 3-540-42390-7 Springer-Verlag GnbH & Co.KG, Tiergartenstrasse 17, D-69121 Heildelberg, Germany. www.springer.de. Price: Hardcover US$69.95

This volume was produced as an attempt to provide a single, comprehensive guide to the theory and practical applications of truncated and pluriGaussian simulations, and is derived from a set of shortcourse notes developed for pluriGaussian simulation courses run by the Centre de Géostatistique in Fontainebleau, France.

Simulation is rapidly becoming *the* technique for resource estimation. The truncated Gaussian methodology was developed in the late 1980s for simulation of lithotypes in oil reservoirs, while pluriGaussian simulations are an extension of the same method that allow more complex representations of natural patterns.

The book is divided into nine sections, including a comprehensive reference list, and freeware supplied on an accompanying CD-ROM. The first chapter contains an introduction to the methodology, explains the key steps in undertaking a pluriGaussian simulation and outlines the book's setup. The succeeding chapters outline the mathematics related to spatial covariances, variograms and cross variograms; vertical proportions and horizontal non-stationarity; together with a section dealing with thresholds for truncated Gaussian and pluriGaussian methods.

The final theoretical chapter deals with multi-step simulation procedures, and then describes Gibbs sampler methodology and Markov chains in relation to a Gaussian framework. This is followed by a chapter on case studies and practical examples, and finally a section relating to the installation and uses of the supplied freeware; together with a set of exercises.

The sections on the mathematical theory behind the simulation techniques are clearly and concisely presented, and a necessary adjunct to improved understanding of the methodology. Although the examples primarily relate to the oil industry rather than minerals, they are a key asset of the text. The application across to mineral deposits, in particular sediment-hosted deposits, is immediately obvious. In addition, while all illustrations are included within the text, the addition of coloured images to the accompanying CD-ROM means that simulation image clarity is not lost in the effort to keep printing prices down.

The exercises supplied with the CD-ROM are worth the price of the book alone. Each exercise is worked through in Chapter 8, and allows the user to gain familiarity with pluriGaussian simulations through a hands-on approach. The first program, *pluri_demo_simu* lets the user generate simple simulations by choosing two out of 12 pre-programmed images, and then enables the user to vary any of a number of input parameters. For example, there are 36 different rock types that can be selected. The exercises examine the effects of inversion, anisotropy, variations in proportions of facies, variable proportions, and the use of two Gaussian variables.

The second program, *pluri_demo_vario* requires more sophistication on the part of the user, as it primarily deals with the relationship between the indicator variogram and the underlying Gaussian random functions. The program uses the same 36 rock types as the first program. Users can specify the variogram types for two underlying Gaussian random functions, as well as select anisotropies and practical ranges, and, importantly, include a nugget effect when plotting indictor variograms and cross-variograms.

The book is strongly recommended for geostatistics practitioners and simulation novices alike, and is a timely and welcome addition to a rapidly developing field.

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SELF-ORGANISED CRITICALITY IN EARTH SYSTEMS:

By S. Hergarten, 2002, 272pp, Springer-Verlag GnbH & Co.KG, Tiergartenstrasse 17, D-69121 Heildelberg, Germany. www.springer.de Price: Hardcover US$69.95

Earth scientists know too well how difficult it is to predict and understand earth systems and phenomena. The complexity and non-linearity carry problems that have nothing to do with our ability to crunch numbers and solve partial differential equations. The pioneering work of Per Bak, Chao Tang, and Kurt Wiesenfeld showed that many phenomena–landslides, earthquakes, share prices, traffic jams, for example–exhibit *self-organised criticality*, or SOC. Self-organisation is a result of energy dissipation in non-linear dynamic systems. If such a system displays certain scale invariant properties that obey power laws and it fluctuates about a marginal stability, the critical state, it is at SOC. A classic example is the Gutenberg-Richter Law describing the inverse relationship between earthquake magnitude and frequency of occurrence. The recognition that a system is fluctuating about a critical state may not allow us to make more than statistical 'predictions' about that state, but if the system shows SOC, we can–we must–ensure that SOC is built into any model constructed in attempts to understand and explain its physical causes.

Theorists are finding applications in biology and economics most fruitful, and that is where much of the effort is directed. It is early days in the research of SOC in earth systems. Aside from the well-known examples of earthquakes, avalanches, and drainage networks, it applies to climate changes, extinction events, floods, periodicity in sedimentation, volcanic eruptions, and the production, transport, and accumulation of melts. How may it apply to the distribution, in time and space, of ore deposits; of mantle processes; of plate motions? Per Bak, in his book *How Nature Works: The Science of Self-Organized Criticality* (1997, Oxford University Press), suggested that the earth's crust has reached a self-organised critical state. Maybe so, given the abundance of fractals in the natural world, but it will not be surprising if the study of SOC becomes one of the principal branches of the earth sciences.

Stefan Hergarten is a geophysicist at the University of Bonn. The title of his book, *Self-Organized Criticality in Earth Systems*, promises a wide range of SOC in the earth sciences. Disappointingly, the exposition is confined to forest fires, earthquakes, landslides, and drainage networks. These are all covered in other works and well summarised in Donald Turcotte's *Fractals and Chaos in Geology and Geophysics* (2nd edition, 1997, Cambridge University Press).

Of the 272 pages of Hergarten's volume, the first 99 are devoted to the mathematics of fractals, power law distributions, self-affine time series, chaos, and criticality. These are all part of the necessary background to understanding SOC, but the deductive, course-like structure of the book means that SOC is not brought in until the end of Chapter 5. Some early introduction to the central topic would have been helpful, and it does not need to be based on mathematical symbolism for the reader to get a feel for it. From the start, however, the book is rather too abstract for most readers and denser than it needs to be. Mathematics aside, expanding the arguments with physical (read real-world) examples would have been helpful. For instance, the Pareto distribution is introduced on page sixteen (early enough in the book to still have the attention of most readers) as a restricted form of the power law distribution. This leads to a brief discussion of distributions with heavy tails and the conclusion that "these are related to phenomena which may become dangerous." Please explain! Is Hergarten refering to crocodiles with heavy tails? They seem dangerous. This stuff may be common knowledge to statisticians but the rest of us need some help. On the other hand, Hergarten uses the chi-squared distribution to derive expansive equations, resplendent with sigmas majuscule and minuscule, for the slope and intercept of a simple line of best fit. This is not even nice if you can get it and it is hardly germane to developing ideas about SOC. Typically, the mathematics are dazzling rather than enlightening.

From Chapters 6 to 9, Hergarten explores his four chosen examples of earth systems displaying SOC. However, he uses no real forest-fire data; the chapter on earthquakes is mostly on the evaluation of the level of SOC displayed by models of earthquake behaviour; he shows that some landslides in New Zealand did not behave like sandpiles; and the chapter on drainage is confined to idealised systems after failure to obtain scale invariance from a map of Germany's rivers and lakes. Hergarten presumed that the difficulties came from the counting methods and map resolution. He did not consider how physiographic diversity might have been a factor.

So, what to make of a monograph about earth systems that contains the Dirac delta function but nothing about deltas? The book is a letdown. It provides no springboard for earth scientists wishing to know about the applications and research of SOC in their fields. For those who can follow the abstractions, but wish to know more about how they work in the earth sciences, it is just as defeating.

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ASSESSING RISK IN GRADE-TONNAGE CURVES IN A COMPLEX COPPER DEPOSIT, NORTHERN BRAZIL, BASED ON AN EFFICIENT JOINT SIMULATION OF MULTIPLE CORRELATED VARIABLES

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Dr Roussos Dimitrakopoulos, the 2004 GAA president, has kindly allowed the GAA to reprint a paper that was submitted to APCOM in South Africa, during 2003. Due to the size constraints of the newsletter, the abstract is included below, and the full text of the article is posted to the GAA website.

Abstract

Risk quantification in grade-tonnage curves is critical for capital investment in mining projects and can be obtained through geostatistical simulations of orebodies. A practical difficulty may arise in multi-element deposits, as the joint modelling of the related attributes using the traditional co-simulation approaches is computationally intensive and may be impractical for use in the industrial environment. This paper presents the construction of risk-integrating grade-tonnage curves for a complex copper deposit in northern Brazil, by jointly simulating its key geochemical attributes of interest: Cu, Fe and K. The joint conditional simulation of these elements is based on Minimum/Maximum Autocorrelation Factors (MAF). MAF is an approach, based on principal components, that spatially decorrelates the variables involved to non-correlated factors. MAF's spatial decorrelation at any lag distance is the main and critical difference of this approach from the principal component approach attempted in the past. In the MAF approach, the independent factors are individually simulated and back-transformed to the conditional simulations of the correlated deposit attributes that reproduce the cross-correlations of the original variables.

CALENDAR OF EVENTS

2004 FEBRUARY 8-13
17TH AUSTRALIAN GEOLOGICAL CONVENTION. DYNAMIC EARTH: PAST PRESENT FUTURE Hobart, Tasmania. **For Details**: see this issue of TAG or www.17thagc.gsa.org.au

2004 FEBUARY 20
SMEDG/GSA/GEODIVERSITY RESEARCH CENTRE MEETING: A/Prof W. Maier. "Magmatic Ni-Cu-PGE deposits in Southern Africa". Rugby Club, Crane Place off George or Pitt Street, Sydney. **For Details**: www.smedg.org.au

2004 MARCH 17
NSWGSA MEETING: Dr David Cohen, Geochemical exploration in areas of deep cover". Room 456, Biological Sciences Building, UNSW. **For Details:** www.nsw.gsa.org.au

2004 APRIL 18
AMERICAM ASSOCIATION OF PETROLEUM GEOLOGISTS AND SOCIETY FOR SEDIMENTARY GEOLOGY JOINT ANNUAL MEETING AND EXHIBITION, Dallas, Texas. **For Details:** www.aapg.org or convene@aapg.org

2004 MAY 10-12
GREEN PROCESSING. Perth WA **For Details**: www.ausimm.com.au

2004 MAY 17
CANADIAN GEOPHYSICAL UNION AND AMERICAN GEOPHYSICAL UNION JOINT MEETING. Montreal Canada **For Details:** www.agu/org/meetings or meetings@agu.org

2004 MAY 24-25
MINSANDS 5th ANNUAL MEETING Melbourne, Vic. **For Details:** www.ajmonline.com

2004 JUNE 14-16
GOLD DEPOSIT WORKSHOP AT CODES. Hobart, Tas. **For Details:** www.codes.utas.edu.au

2004 AUGUST 20-28
32ND INTERNATIONAL GEOLOGICAL CONGRESS. International Union of Geological Sciences, Fortezza Da Basso, Italy. **For Details**: Chiara Manetti cmanetti@geo.unifi.it Website: www.32igc.org

2004 SEPTEMBER 27 - OCTOBER 1
SEG 2004: PREDICTIVE MINERAL DISCOVERY UNDER COVER, Perth WA **For Details:** www.cgm.wa.edu.au/geoconferences

2004 OCTOBER 18-20
PACRIM 04: HI TECH AND WORLD COMPETITIVE - MINERAL SUCCESS STORIES AROUND THE PACIFIC RIM. Adelaide SA. **For Details:** www.ausimm.com.au