



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
Overview from the President
Resource Estimation Modeling Techniques - Current Trends in Gold Deposits
Danie Krige Honorary Life Member
On The Move
Dr Frederik (Frits) Agterberg
5th International Mining Geologist Conference
Book Reviews
Assessing risks in grade tonnage curves
Calendar of Events
GAA Committee
From The Editor

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 5 th	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 ugm mining controls.	Polygonal method.	Gold - 195 gpt	No	Half distance between mine levels	Measured=5m; Indicated=20m; Inferred>40m	Blocks projected between ugm 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 3 th	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; Seco=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: High 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 components.	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

Support your organisation!
the **Official GAA**
Shirt is here!



Polo shirt - Light Grey Marle
Embroidered on left chest in red, black & white

Shirts are available in 4 sizes, Small, Medium, Large and Extra Large (XL). As the initial print run is small, get in soon to avoid delays!

To order, please send a cheque made payable to the GAA for \$35 (including postage and handling costs), PO Box 1719, West Perth, WA, 6872, and don't forget to include the required shirt size, and a postal address for the shirt!

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-

