



GEOSTATISTICAL ASSOCIATION OF AUSTRALASIA

Newsletter 15

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Contact Addresses: PO Box 1719, West Perth WA, 6872.

[Http:// www.confed.com.au/gaa](http://www.confed.com.au/gaa)

OVERVIEW FROM THE PRESIDENT



Greetings to GAA members from the new committee for 2002/3. Well, mostly the 'old' committee, but with three new members taking on active roles: Stuart Masters, Alan Miller and Simon Dominy. The committee now has a broad geographical spread (Perth, Kalgoorlie, Brisbane and Townsville), which creates greater opportunities for representing members.

The AGM was held in Perth on 22 March, following on from the extremely well attended GAA Symposium on Quantifying Risk and Error. Stella Searston, John Warner and Ian Lipton are to be commended for the time and effort spent in organizing the symposium. The call for JORC revision submissions was highlighted during the symposium, and this is summarised in the newsletter.

The next formal GAA symposium will coincide with the MODSIM 2003 conference in Townsville in July 2003 (see this newsletter). A more informal opportunity for presenting talks is through technical meetings where we encourage members and visitors to talk on relevant topics at whatever time and venue is suitable. Please contact a committee member if you have any ideas in this regard.

We are experiencing some operational difficulties with our website at the moment, but hope to have these resolved soon.

Lastly, if you have a topic of interest to our members we will be happy to consider your letter or article for the newsletter and/or our website.

Mark Noppé

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AGM FEEDBACK

Incoming President's Report

On behalf of the committee, I wish to thank Ian Lipton for his energetic leadership over the past year. I would also like to thank the other members of the committee for their contributions on behalf of the Association.

After having put a few ideas together about how I hoped to see this coming GAA year progress, I decided to review the GAA's primary aims as described on our web-site. Well, the similarity between my points and those already written remind me of just how like-minded we are as a group of professionals!

Rather than use my own words, I decided to remind us all of what our stated goals are, namely:

The GAA is a group promoting and representing the professional interests of geostatisticians by:

1. Increasing community awareness of the role of geostatistics.
2. Assisting the development of quality education and training of practitioners.

How can we achieve this?

By promoting 'Real world geostatistics' or 'Best Practical Practice' in universities, as part of professional development series and by 'educating' management so as to dispel the myth of 'Voodoo Statistics'

One option may be to offer our services as 'mentors' to students and graduate professionals - a practice followed by some AusIMM branches.

3. Maintaining professional standards and ethics among practicing geostatisticians.
And developing standards through forums and sub-committees as discussed at today's symposium.
4. Representing professional geostatisticians to organisations such as the Stock Exchange, Federal and State Governments, other mining bodies, etc.
5. Providing channels for communication and exchange of information within the field of geostatistics throughout the Australasian region.
And also internationally! For example through forums like these, technical talks, workshops and next years MODSIM 2003 July conference in Townsville.

How do we meet these goals? By wanting to and by getting involved! Nothing will get done unless we do it! We currently have over 120 members. Even if you are not on the committee, I encourage you to support the committee and the GAA as a forum for geostatistical ideas and practices.

Mark Noppé
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Outgoing President's report for 2001-2002

The GAA achieved a little revitalization this year.

Five presentations were made during the year:

- Roussos Dimitrakopoulos (WH Bryan Centre, UQ) spoke in Kalgoorlie on the topic of "I'd

rather be approximately right than precisely wrong".

- Michel Dagbert (Geostat Systems International, Canada) spoke in Brisbane on the theme of "Geostatistics around the bend".
- Vaughan Chamberlain, (Anglogold) spoke in Perth on the origins of log-normal kriging.

- Nicolas Bez (Fontainebleau) presented a talk in Perth, titled "A review of the application of geostatistics to fisheries data".
- Simon Dominy, (James Cook University) spoke in Brisbane about the New Bendigo Gold Project.

It was disappointing to note that there were no speakers from the Australian mining industry during the year, however industry was well-represented at the GAA Symposium in March 2002. The symposium was held in Perth on the theme of "Quantifying Risk and Error". Eighty three delegates were rewarded with an excellent range of well-presented papers and an amazing array of unexpected sound-effects..

With assistance from Jennette Binns in Sydney, the GAA published two newsletters via email. Newsletter #15 is planned for April/May 2002.

After a period of some confusion with our membership list, it is finally being brought up to date and most of the overdue membership fees have now been paid. At the last count we had gained nine new members and had three resignations since the start of the year.

During the year, the GAA made contact with the Modelling and Simulation Society of Australia and New Zealand. (MSSANZ),

a society that aims to promote, develop and assist in the study of all areas of modelling and simulation. The MSSANZ has more than 500 members in 50 countries from a wide range of disciplines. The GAA has been invited to convene the geostatistics sessions at the biennial conference of the MSSANZ in Townsville in July 2003. This is an exciting opportunity to interact with researchers and professionals outside the mining industry and the GAA committee has accepted the invitation.

I would like to thank the outgoing committee members for their efforts. They have all contributed to what I believe has been a successful year. I would like to give particular thanks to Mark Noppé, who has been a refreshing source of new ideas and industry contacts; John Warner, who has doggedly addressed the task of sorting out membership details, dead email addresses and unpaid membership fees; and Stella Searston who, in rather difficult circumstances, managed to pull everything together to make the 3rd GAA Symposium happen.

I wish Mark Noppé and his new committee an enthusiastic and successful year ahead.

Ian Lipton
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Conference Roundup

On 22nd March, the GAA held its bi-annual symposium. This year's theme, **Quantifying Risk and Error**, produced a number of case studies, and provoked discussion on what constituted risk and error in a geostatistical sense. The presentations are summarised below, whilst details of the authors and presentation titles are available on the GAA website and in the conference proceedings.

The day commenced with the Keynote Speaker, **Peter Ravenscroft**, of **Rio Tinto Technical Services**, who presented a thought-provoking assessment of risk. Peter considered the elements of risk

analysis to incorporate the identification of risk, risk assessment and then management of the identified risk. Identification of risk was based on two ideas – whether something was likely (rating from certain to rare), and the consequence (insignificant to catastrophic). Risk assessment, in terms of resources, was to identify factors which could impact on the resource, such as tonnage, grade, mining flowsheets and schedules, variability and selectivity. Risk management was then to characterise the risk in terms of manageability, based on the level of information used to calculate the resource (likelihood) and the economic impact (consequence). Peter used the

example of an alluvial diamond deposit to illustrate his discussion, and produced a risk assessment matrix, which will be of interest to any geostatistician.

John Vann of Quantitative Geoscience Pty Ltd then presented an overview of geostatistical simulation for quantifying risk within the mining industry. John described conditional simulations as being regarded as 'equally likely' (equi-probable) images of the mineralisation at a fine scale. In a sense, simulations were thus an attempt at 'sampling the unknown' using constraints, e.g. statistical moments imposed by the data such that in simulation, the requirements of stationarity are stricter than for linear geostatistics (for example, kriging). A brief discussion of the types of applications possible was given together with a summary of some of the possible pitfalls encountered when generating and using geostatistical simulations for application to risk quantification problems in the mining industry.

The first case study of risk assessment was outlined by **Tony Wesson of SRK Consulting Australasia**. Tony's study was based on an example of simulation being used to quantify a resource below an existing mining operation. Raising capital to drill a deeper dislocated portion of an existing orebody could only proceed once the project had attained an indicated resource status. A subjective decision about what level of confidence was sufficient for classification as an Indicated Resource was made, and then, from an exhaustive data set obtained from current mining levels several hundred metres above, a theoretical estimation variance study was carried out to determine the required grid and grid pattern.

Ian Glacken of Snowden Mining Industry Consultants presented a powerpoint study of conditional simulation being used to assist in defining categories for resource classification, by relating confidence intervals to the expected grade of a block. The advantages over purely qualitative and semi-quantitative methods of resource classification were described, including the ability to recognise areas of consistent grade and thus higher confidence, which would not be recognised by an approach such as the use of the grade-independent kriging variance.

That successful mineral exploration requires a clear strategy and well-defined exploration models for the deposit styles being sought was strongly emphasised in the paper presented by **Deborah Lord of SRK Consulting Australasia**. Deb described a method to evaluate risk in exploration, where each area of a project could be assessed in terms of the likelihood or probability of progression to the next exploration stage. Using case studies, she demonstrated practical applications of the method outlined, including risks involved in the exploration process, and summarised the critical success factors that can assist companies to reduce the risks associated with exploration. An interesting point raised, and one not often considered by the exploration industry, was Deb's contention that the maximum value creation and highest risk in exploration occurred at the more advanced exploration stages, particularly after the first mineralised hole was drilled.

The first student paper, presented by **Tuyvet Tran of Edith Cowan University**, introduced an algorithm for the conditional simulation of two-dimensional isotropic random processes using Haar wavelets. Global accuracy of the algorithm was evaluated via two test data sets. The implication of Tuyvet's paper was the potential for the algorithm to considerably speed up estimations, through a significant reduction in computational requirements.

Louis Voortman, of SRK Consulting Australasia, compared a range of grade-tonnage curves that were based on different data sets representing a low-nugget disseminated gold deposit, a high-nugget vein-hosted gold deposit, a lateritic nickel deposit and a sedimentary phosphate deposit. The influence of drillhole spacing, data clustering, missing drillholes, nugget effect and short range structures on the grade-tonnage curves was assessed, and the differences translated to dollar values to show the influence of the estimation method on predicted mining profit.

With a competitive environment both internally and externally for capital and resources, the need to be able to understand and present the risks associated with projects has become

crucial. Management requires tools that will allow a better understanding and ranking of the risks associated with a diverse range of projects that are competing for capital and resources.

Michael Andrew of Newmont Australia used two case studies to illustrate quantification of the risk associated with resource estimation and determination of reserves.

Bill Shaw of Golder Associates presented his "Chain of Mining" methodology, whereby he models the grade control and mining process to determine how sampling, mining selectivity and other issues impact on recoverable resource estimates. The impact of various mining scenarios on tonnes, grade and contained metal in expected products can be quantified and incorporated into feasibility studies using the method. Bill said that the final result was a definitive way of demonstrating the expected risk of various alternative strategies and the optimum strategy based on a cost-benefit analysis.

The second student paper, presented by **Tsz Kei Wong of Curtin University of Technology**, was an assessment of

estimation errors that can occur in financial modelling. Tsz Kei attempted to develop a predictive tool for the behaviour of financial markets in response to specific stimuli in specific situations.

Daniel Guibal of SRK Consulting Australasia was the day's final presenter, with another case study using conditional simulation. Correct characterisation, prediction and management of grade variability was reported to be central to short and long term planning at WMC's Phosphate Hill operation. Grade confidence intervals developed using conditional simulation models were in line with those established using the classic estimation variance approach and more importantly with production experience.

At the end of the talks, **Bill Shaw** convened a discussion on "**What are appropriate measures of reliability for Resource and Reserve estimates and how they are currently used by practitioners?**" It was decided to circularise GAA members later in the year for input into the next round of JORC discussions. (See 'Revision of the JORC Code' article in this newsletter.)

The conference closed with the GAA AGM, followed by a sundowner.

The GAA organising committee would like to thank the day's sponsors, which included:

Symposium Sponsors

Major Sponsors

Snowden Mining Industry Consultants,
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Bateleur Minerals, Data Analysis Australia,
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Mining Geology Research Centre at the
University of Queensland.

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Dr Harry Parker, BFP Consultants,
Quantitative Geoscience and Ravensgate.

Additional conference volumes in CD format can be obtained either by contacting the GAA Secretariat, at P.O. Box 1719, West Perth, WA 6872, or through the GAA website at <http://www.confed.com.au/gaa/>, or by contacting bateleur@omen.net.au. The cost is \$A65 plus postage and handling.

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MODSIM CONFERENCE 2003

From the 14th to 17th July 2003 the Modeling and Simulation Society of Australia and New Zealand will hold their **MODSIM 2003** conference in Townsville, Queensland. Based at the Jupiters Hotel & Casino Complex, attendees will enjoy a tropical setting on the seafront overlooking Magnetic Island. The overall theme of the meeting is the ***Integrative Modelling of Biophysical, Social and Economic Systems for Resource Management Solutions***. The GAA will hold a one-day session during the conference with a theme to be yet decided. It is intended to have a number of keynote speakers to lead the GAA proceedings.

GAA members are encouraged to present a paper, which will be included in the peer reviewed proceedings volume. Abstracts of 300 words are due by 29th November, with acceptance by 20th December 2002. Full papers (up to 6 A4 sides) are due by 28th February 2003 for peer review. All submissions will be via the MODSIM website given below.

Please watch this site for further developments.

Conference website: <http://mssanz.cres.anu.edu.au/modsim2003.html> for registration and submission details.

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REVISION OF THE JORC CODE.

The Joint Ore Reserves Committee (JORC) has commenced a review of the JORC Code. The revision has been deemed desirable because of the substantial developments that have occurred overseas since the last JORC Code revision, with South Africa, Canada, United States and UK/Western Europe all releasing revised reporting codes since 1999. All of these documents have been based on the 1999 JORC Code, and some include clauses that may be an improvement on the JORC Code. JORC has issued a public call for submissions.

The current JORC Code (effective September 1999) can be downloaded from www.jorc.org and the call for submissions is also on that site. Recently Bill Shaw invited GAA members to comment on whether it would now be appropriate to introduce some discussion into the Code regarding quantifying the reliability of resource estimates.

The current version of the Code provides a purely qualitative classification scheme. There are a number of arguments, both for and against, attempting to quantify the accuracy (and precision?) of resource and reserve estimates. These include:

FOR:

- The primary purpose of the Code is to ensure Public Reports best inform investors. It thus appears important that similarly classified estimates have similar "reliability" even if such reliability can only be broadly generalised, rather than quantified.
- Quantification of errors would allow more rigorous financial risk analysis and lead to better decision-making.
- Insistence upon quantification of errors would force some companies to "raise their game".

AGAINST:

- The JORC Code is not currently prescriptive and relies on the Competent Person making decisions about many issues including transparency, materiality and competence (all defined in the Code). Quantification of "expected reliability" presumably requires estimates of tonnes and grades to be made using a method that would allow "errors" to be also estimated. This may make the

Code more prescriptive if such errors are only provided by certain estimation methods.

- Ore reserve estimates depend on a multitude of inputs and assumptions and the risks inherent in many are not quantifiable. Overemphasis on a quantifiable aspect, such as the error in a grade estimate, may inadvertently divert attention away from much more significant but less quantifiable areas of risk.
- Insistence upon quantification of errors would force some companies to use external consultants and hand over their resource and reserve estimates to techniques that their own personnel do not fully understand.

Bill pointed out that "Either way, if the JORC Code discusses this issue it must

get it right. For example it is not very meaningful to suggest that Measured Resources are "within +/- 10%" if such a statement can never be tested or demonstrated. Thus it has been suggested that confidence limits and parcel size must also be stated".

Bill invited GAA members to answer the following questions:

- What are appropriate measures of reliability for Resource and Reserve estimates?
- How do practitioners currently use them?

Submissions can be forwarded through the GAA, or directly to Bill Shaw (wshaw@golder.com.au), or to the JORC Secretary by email (info@jorc.org or to secjorc@gil.com.au) fax to (07) 3279 1565 or post (42 Canowindra Street, Jindalee, Queensland 4074, Australia).

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SAMPLING IN THE NEW BENDIGO GOLDFIELD

A joint GAA – AusIMM (Southern Queensland Branch) technical meeting was held in Brisbane in February. Dr Simon Dominy of the James Cook University presented a fascinating talk on the problems associated with sampling and evaluating the New Bendigo gold resource in Victoria. He was introduced by Mr Mark Noppé.

Since its discovery in 1851, approximately 40 million tonnes of ore for 17 million ounces of gold has been produced from Bendigo. Central Deborah, the last mine operating on the Bendigo goldfield, closed in 1954. WMC took up the lease in 1978 and after a significant exploration effort gave up the lease in 1992. Bendigo Mining NL (BMNL) is the current operator taking up the leases in 1993.

The Geology of the area consists of a turbidite sequence that has been strongly folded with a north-south trace and has undergone low-grade greenschist facies metamorphism with weak alteration around the ore zones.

There were a number of perceived reasons for the closure of the Bendigo mines. First and foremost was that all the economically viable ore had been mined.

Other views were that the grade of the gold reduced at depth and much of the mineralisation was made up of saddle reefs and narrow veins, most of which had been discovered. Similarly, that the old workings were very unstable and would collapse if dewatered. These features have now been shown not to be true. The only remaining challenge to overcome is that of the coarse nature of the gold and its high 'nugget effect'.

Since 1978, the Bendigo Goldfield has been re-investigated in a number of different ways. BMNL set about to analyse all the available data concentrating on the structure of the resource and then adding to the data with drilling and bulk sampling to counter the 'nugget effect'. The investigation found that much of the mineralisation is actually made up of stockworks/spur zones and in-filled faults associated with the deformation zones, very little of the historical production of gold being found within the saddle reefs. This suggested that the potential resource is contained within large orebodies and could be mined using a bulk mining method rather than following the saddle reefs. An indicative study commissioned by BMNL and based

on the available data identified a potentially profitable operation.

There appear to be several structural controls on the reefs that are not yet fully understood. The reefs have one long sub-horizontal dimension and occur in groups with depth as 'ribbons'. The average separation of these ribbons is 250 metres. A 'Ribbon Theory' has been proposed which is based on the reconstruction of the old reefs and workings using Gemcom software. This study has indicated that the project has the potential for a very large gold resource.

BMNL has faced many sampling issues, as the gold is both very coarse and erratically distributed. Sampling results have not been reproducible as expected, but bulk samples in the order of 100 tonnes have shown encouraging signs of reproducibility. BMNL has commenced research to establish suitable sampling methods as alternatives to bulk sampling.

The future plan for the Bendigo Goldfield is to continue drilling and underground development in favourable locations on the Deborah and Sheepshead Lines of Reef. A Ph.D. project will commence at James Cook University in March 2002 on Sampling and Resource Evaluation in the New Bendigo Goldfield. Further sampling studies are planned in the second quarter of 2002. In the fourth quarter of 2002 the S3 Upper target zone will be reached by the Swan Decline where it is expected that a mineable resource will be established and Bendigo will yet again have a new lease to life. Production is planned for the first quarter of 2003.

Dr Dominy was bombarded with questions at a level indicating high interest in the presentation. Ian Lipton proposed a vote of thanks to Dr Dominy.

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Assistant Secretary,
Southern Queensland Branch AusIMM

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GEOSTATISTICS – MODELING SPATIAL UNCERTAINTY **BY JEAN-PAUL CHILÈS AND PIERRE DELFINER**

It is difficult to keep up with the ever-growing number of books dealing with geostatistics or geostatistical applications. Most are of the introductory type, and aim at presenting and adapting the general geostatistical framework to some Scientific Domain, of the type: *Geostatistics and ...Mining, Soil Sciences, Hydrogeology, Petroleum, Fisheries, etc...* This book, *Geostatistics – Modeling Spatial Uncertainty*, by Jean-Paul Chilès and Pierre Delfiner is very different: it covers in depth and in all its generality the Geostatistical Model. Its breadth is enormous, as practically no subject is omitted, from the "Transitive" theory used mainly now for estimating errors in volumes or surfaces, to the latest developments in Simulations.

The book contains the following chapters: Preliminaries. This explains succinctly but clearly the probabilistic background of Geostatistics. It justly emphasises the difficulty of making statistical inferences from unique phenomena. Structural Analysis. The variography is looked at in detail. In particular, the non-stationary case (existence of a drift) is dealt with through a very simple and

illuminating 1D example. Of interest too is the study of the variogram fluctuations, which shows how difficult it can be to evaluate the uncertainty on a fitted variogram model.

Kriging. This chapter covers the theoretical aspects of kriging as well as its practical implementation. An excellent case study about the Channel Tunnel illustrates its application.

Intrinsic Model of Order k . This generalisation of Universal Kriging is treated in depth. It is of particular interest for phenomena showing complex trends at large scale.

Multivariate Methods. Coregionalisations and cokriging and its simplifications (external drift, collocated co-kriging, etc) are well presented here, with examples from geophysical applications.

Nonlinear Methods. This chapter will interest mining people as it deals with the difficult questions associated to recoverable resources, taking into account the support and information effects. Numerous models are described (including indicator and gaussian models), and most importantly, the hypotheses on which they are built and their limitations are lucidly discussed.

Conditional Simulations. Probably the clearest and most comprehensive account of geostatistical simulations can be found here: the numerous available methods are thoroughly explained. The mathematical background is detailed, the examples well chosen. Validation issues are discussed. Scale Effects and Inverse Problems. This chapter looks at particular physical problems mainly from hydrogeology. Upscaling concerns changes of scale from observations known at a small scale to a macro-level phenomenon (Eg: permeability), whereas inverse problem deals with the estimation of the parameters of an equation from the values obtained at a limited number of points.

A very detailed index and a fairly exhaustive and up-to-date list of references (36 pages) complete the text,

Both JP. Chilès and P. Delfiner worked with Prof. Matheron at the Centre de Géostatistique in Fontainebleau (1) where they contributed to many of the developments presented in this splendid book. They have had access to many unpublished notes by Prof. Matheron and this helps to make this book a treasure trove of ideas.

As a consequence of its scope, this is a large book (over 600 pages), not to be read in one go but to be returned to over and over again. Clearly, it is not a beginner's book and it's reading requires sustained attention. It reflects very well the original blend of practice and theory, which defines Geostatistics, as a goal-oriented applied Science. The examples are generally well chosen and interesting. The one given in introduction and showing the pitfalls of automatic interpolation without geological background (Figure 0.1) deserves to become a classic and should be part of any introduction to geostatistics!

This is the book that no professional geostatistician can ignore; it is destined to become the geostatistical reference for many years to come.

Chilès, Jean-Paul and Delfiner, Pierre, 1999: Geostatistics – modeling spatial uncertainty, Wiley Series in Probability and Statistics, John Wiley and Sons, Inc.

*Review by Daniel Guibal, FAusIMM(CP), MMICA, MGAA, Min.Eng.
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(1)JP Chilès just took up the position of head of the Centre of Géostatistique one month ago.

MEMBERSHIP MATTERS

Thank you to all those who have renewed their membership fees for 2001-2002. Your continued support provides the foundation for an interesting program of meetings.

The current fees are:

- Ordinary Member \$35,
- Associate Member \$15,
- Student Member \$5.

If you are unsure of your membership category, please check our web site or email John Warner (rj.warner@bigpond.com).

If you have not already done so, please play your part in the development of geostatistics in the region by becoming a financial member of the GAA. The GAA has a bright future and your committee would like you to be a part of it!

GAA COMMITTEE 2002 – 2003

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