MINERAL RESOURCE AND ORE RESERVE ESTIMATION THE AUSIMM GUIDE TO GOOD PRACTICE MONOGRAPH 23

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The AusIMM is to be congratulated on the excellent result of some five years of collating a series of 79 papers covering, in 9 chapters, the whole spectrum of ore resource and reserve estimation. The overall quality and coverage of the papers provide evidence of the outstanding effort by the Institute in the selection of the papers and in their collation into this monograph. This publication should form an essential part of the reference material for every practitioner, whatever his or her specialisation in this field. The monograph also provides ample proof of an extensive and active Australian community of scientists in the multi-disciplinary field of mineral resource and reserve estimation.

Noteworthy, in particular, is the balance throughout between theory – both orthodox and geostatistical – and practical considerations, such as the quality of data bases and the dictates of common sense in the use of the data and the models.

Without in any way detracting from the overall excellence of the monograph a few fundamental aspects referred to in several papers deserve some corrections and constructive comments.

1. HISTORICAL : (Refer to Monograph p.190, p.254)

Geostatistics originated from the application of the lognormal model and the theory of lognormal kriging was well covered in South African papers in the 1960's and 1970's. Elementary Simple kriging (historical lognormal regression adjustments) was already in use on many gold mines in the 1950's. Routine computerised ore resource estimates were successfully introduced for the first time in the world on a linear Simple kriging basis in the mid 1960's in the large gold mines of the Anglovaal Group. Later this approach spread through the South African industry and Linear Simple or Ordinary kriging are still commonly applied with success wherever correctly used. Lognormal kriging was never practised routinely in this industry due to the problems of avoiding overall biases in the back-transformation process.

2. THE KRIGING VARIANCE AND PROPORTIONAL EFFECT : (refer to Monograph p.195). The Kriging variance is linked directly to the variogram used and the corresponding global mean grade of the data used. For skew distributions (lognormal 2- or 3-parameter, or others close to lognormal), the proportional effect as stressed in David's 1978 text book, must be accommodated and the error distribution, also skew, could be assumed lognormal as a first approximation. The uncertainty of any kriged estimate can then be modeled by adjusting the untransformed kriging variance by the square of the ratio (estimated grade/data mean grade) and transforming the relevant parameters to a lognormal field. Alternatively, the confidence limits can be estimated directly from the Ln-equivalent of the Kriging Variance as percentage deviations relative to the global variogram data mean and these can then be applied to the estimated mean.

3. SMOOTHING AND CONDITIONAL BIASES : (refer to Monograph p.193, pp249/256). These two subjects have received a wide coverage in several papers and deservedly so. If disregarded, smoothing and conditional biases can both result in significant distortions of the grade estimates for individual blocks and for mine sections to be mined sequentially over the mine's life. It is noteworthy that where the data used are significantly less dense than those expected to be available at the final selective mining stage, smoothing will be

i) positive for conditionally unbiased kriged estimates, or
ii) anywhere from positive to negative for orthodox estimates (polygonal, ID, etc); also for kriged estimates where the data search routine is inadequate. Negative smoothing is present when the dispersion variance of the block estimates exceeds the required SMU variance - or even the block variance applicable to perfect block valuations - and this anomalous effect is frequently encountered when the data search routine is too limited.

Estimates under ii) are often conditionally biased and analyses to establish the presence and effects of such biases are essential. Estimates under i) cannot be used directly for mine planning or feasibility studies and have to be post-processed or, as an alternative, a non-linear approach should be used. The remarks in the next paragraph also link up with this discussion.

3. SIMULATION : (refer to Monograph p.194, pp285/292).

This useful technique is covered by a number of papers. However, like all other techniques, it has its own limitations related directly to the density of the data base available. If the data is globally adequate to provide a close estimate of the global mean grade, repeated global simulations can provide a range of equally possible **global** grade patterns and thus also a measure of the **global** uncertainties involved. However, if the data for sections of the ore body, e.g. in the area to be mined in any specific year, are very limited and the mean grade is estimated with wide confidence limits, the simulation estimates for such section(s) could be conditionally biased and could distort the grade pattern over the life of the mine (Krige and Assibey-Bonsu, 2001). The indicated measure of uncertainty or risk for such sections could also be biased. This has recently also been confirmed by the following quote from a paper (Journel et al,2000) on a proposed Spectral Processor aimed at correcting for the smoothing effect of estimators:

> "the covariance reproduction is achieved at a considerable loss of local accuracy… and (of) the conditional unbiasedness of the estimator. We thus confirm that global accuracy (… texture reproduction) and local accuracy are indeed conflicting objectives."

This means that it is impossible to develop any estimator, simulation or otherwise, which can, in the absence of the detailed data which will be available at the actual selection stage, reproduce the SMU grade pattern (with the correct SMU distribution and spatial structure parameters) without introducing local inaccuracies in the form of conditional biases**. This is a fundamental issue not adequately covered in the Monograph.**

5. DENSITY, ALSO CONTENTS vs. GRADES : (refer to Monograph p.193). This factor has also been stressed correctly in several papers. It is essential that, where the density is variable, grades should be weighted by this factor as well as by sample widths in the 2D case. In the 3D case the widths are usually standardised via compositing and then weighting could be confined to density. Effectively, therefore, contents rather than unweighted grades should be used throughout for variogram analyses and in any kriging or orthodox estimation techniques wherever widths and/or densities are variable. This approach will not be affected by any correlation between grade and thickness, whereas the direct use of grade will result in biased estimates if

any such correlation is present. This approach has consistently been applied in the South African mines. Contents essentially measure the mineral concentrations per unit area in the 2-D case, or per unit volume in the 3-D case. Averages or weighted averages (e.g. in kriging) of contents remain unbiased estimates regardless of any correlation between grade and thickness or density. In fact, contents could theoretically be measured directly without a width or density analysis by determining the total mineral content within the actual 2-D area of the sample, or within the actual 3-D volume of the sample. 'Contents' is thus a basic variable and is, in practice only derived from the product of grade, thickness and density because these three variables are determined directly and more conveniently than contents.

References:

Krige D.G. and Assibey-Bonsu, (2001). Valuation of recoverable resources by kriging, direct conditioning or simulation. *Proceedings of the 29th APCOM 2001, Beijing, April, 2001, Balkema.*

Journel A.G.,Kyriakidis P.C.,and Mao S. (2000). Correcting the smoothing effect of estimators : a spectral postprocessor. *Mathematical Geology, Vol. 32, No.7, October 2000. See also discussion in Vol.33, No.6, p.761, August, 2001.*