

# Mineral resource assessment in complex ore deposits based on international standards

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## INTRODUCTION

Geostatistical simulation has been widely used in mineral resource classification of metalliferous deposits based on international standards such as JORC code which is one of the most extensively used around the world for reporting the mineral resources and ore reserves alongside with objectives of the companies (Sadeghi, Madani and Carranza, 2015). However, the modeling process becomes challenging whenever the relationship between the variables of interest is complicated and cumbersome to model. This characteristic sometimes manifests itself in complex spatial and global cross-correlation measures, deeply depending on the formation and genesis of the deposit. The objective then is to generate the models that not only reproduces these significant characteristics, but also, it leads to a better understanding of a mineral resource estimation and successive decision-makings.

In this respect, there are different approaches taking into account the spatial correlation structures, for which can be classified as independent simulation, co-simulation, and factor-based methodologies. In this paper, three techniques: Turning Bands Independent Simulation (TBSIM), Turning Bands Co-Simulation (TBCOSIM) and Projection Pursuit Multivariate Transform (PPMT); from those aforementioned approaches are selected to model two cross-correlated variables (Iron and Aluminum Oxide) belonging to an Iron ore deposit located in Brazil, in order to examine which methodology better reproduces the corresponding complexity in terms of local correlation measure.

By comparisons among the results, it was determined that PPMT outperforms both TBSIM and TBCOSIM for reproducing such an abovementioned complexity. The reason is that these two latter methods which are based on Gaussian assumption, require traditional normal score transformation of the original variables (Emery and Lantuéjoul, 2006). In this context, the complexity in bivariate distribution cannot be effectively preserved after back-transformation. In contrast, PPMT is an algorithm that transforms any complexity nature of correlated variables into uncorrelated factors and then restitutes it after back transformation on the basis of Gaussianizing highly non-Gaussian 1-D projection (Barnett, Manchuk and Deutsch, 2014). Due to the fact that TBSIM does not consider interdependency between co-variables, it could not reproduce the intrinsic correlation between Fe and Al<sub>2</sub>O<sub>3</sub>. On the other hand, the correlation coefficient of the PPMT is almost the same as an original correlation coefficient of 0.85. However, TBCOSIM has a much lower correlation coefficient of 0.57 which can be considered as an unreliable result. As it can be seen from Figure 1, E-type map which is the average of 100 realizations of PPMT shows less content of Iron (Fe) at the center and top of the map, whilst E-type maps of TBSIM and TBCOSIM indicate a higher concentration of iron with little difference between them on the same level. The difference examined between E-type maps of PPMT and other two methodologies occurred because of disability of TBCOSIM and TBSIM to handle with interdependency between co-variables in the deposit.

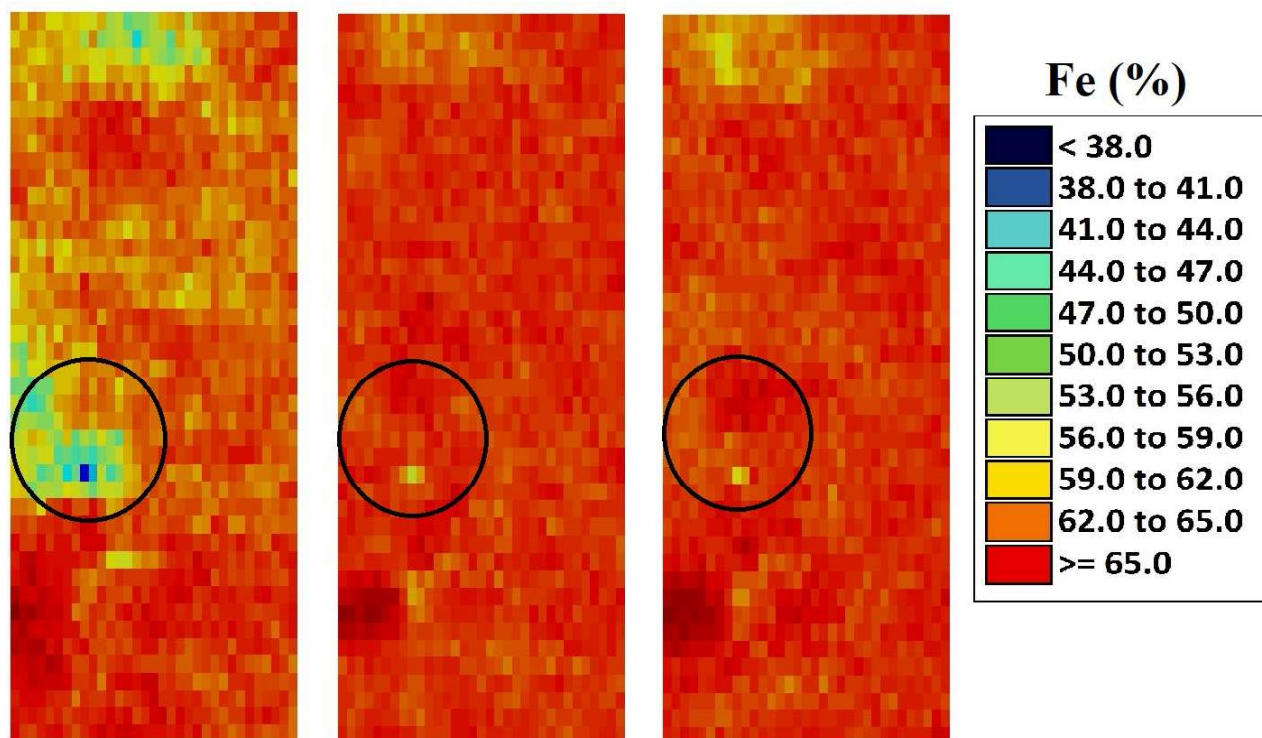


Figure 1 – E-type models of Fe PPMT (left), TBCOSIM (middle) and TBSIM (right) obtained from 100 realizations.

Since the results of PPMT method are more reasonable and satisfying in practice, they are employed to quantify and classify the mineral resources in the underlying Iron deposit based on JORC code into measured, indicated and inferred resources. In this study, resource classification based on uncertainty models is quantified as measured if the block is known within  $\pm 15\%$  (90% of the time); indicated resource if the block is known within  $\pm 15\%$  and  $\pm 30\%$  (90% of the time) and inferred if the block is known more than  $\pm 30\%$  (Rossi and Deutsch, 2014). The outputs for resource classifications are then compared among PPMT, TBSIM, and TBCOSIM. Depending on the cut-off grade of Fe, which were arbitrarily selected as 50 % and 60 %, tonnages of resources are calculated for each method as it presented in Table 1. In both cases, the total tonnage of PPMT was higher than TBCOSIM and TBSIM. The correlation obtained from these three methodologies for Fe and Al<sub>2</sub>O<sub>3</sub> also shows that the PPMT outperforms the two other approaches in terms of global and local correlation reproduction. Comparison of measured mineral resources of each method is very important because the level of confidence in this category is critical for further analysis and planning of a mining project. By comparisons of tonnages for measured resources of mentioned methods, TBSIM provides about 294 Mt ore and TBCOSIM provides approximately 579 Mt ore less than PPMT for the cut-off grade of 50%, respectively. The same differences are observed for the cut-off grade of 60%.

Table 1 Mineral resource classification.

Methods	Measured (Mt)	Indicated (Mt)	Inferred (Mt)	Total tonnage (Mt)
<b>Cut-off grade 50</b>				
TBCOSIM	11035.000	799.680	1043.800	12878.480
TBSIM	11320.000	759.660	854.740	12934.400
PPMT	11614.000	537.730	896.550	13048.280
<b>Cut-off grade 60</b>				
TBCOSIM	10472.000	464.920	975.920	11912.840
TBSIM	10756.000	416.376	799.770	11972.146
PPMT	11046.000	328.340	845.812	12220.152

Application of these methods affects differently not only on the resource estimation but also on the cash flows of the project, Net Present Value (NPV) calculation, geometry of the optimal open-pit and identification of useful blocks. Due to different results mentioned above for each method, it is supported to use PPMT in deposits with complex interdependency between co-variables rather than TBCOSIM and TBSIM which shows not an adequate performance for reproduction of spatial and global correlation.

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