Application of the Truncated Gaussian Simulation Method to the MM deposit at Codelco Norte, Chile

P. CARRASCO[2], P. CARRASCO[2], F. IBARRA[2], G. LE LOC'H[1], R. ROJAS[2], S. SEGURET
[1] *Centre de Géostatistique, Ecole des Mines de Paris,35 rue St Honoré, 77305 Fontainebleau, France*
[2]*: CODELCO, Chile*

Introduction

The MM ore body is a satellite of Chuquicamata porphyry copper deposit in Chile, exploited by Codelco. MM ore body is not yet open to exploitation. Its geology is ore complex than a classical porphyry copper, due to the superimposition of various geological processes, such as the presence of high grade vein type breccias, of variable thickness and of variable continuity.
In this orebody, a huge part of the mineralization of economical value is located in the breccia. The correct modelling of these breccia is then fundamental for the economical valuation of the future mine. Correlations drawn by the geologist usually give very continuous breccia vein, when it is thought that their geometry is more erratic in reality. It has then be decided to use geostatistical modelling to propose another possible model. As the grades are mainly controlled by the rocktypes, it has been proposed to use Truncated Gaussian simulations. As this was the first use of this method in this type of geolgical environment, the work has been done at the Geostatistics Centre at the School of Mines of Paris, where the method was developed, As a close collaboration between the geologists and geostatisticians of CODELCO and the researchers of the Centre de Géostatistique, with the help of the software Isatis

Objectives.

The objectives of this study are the following:

- Test the applicability of the Truncated Gaussian simulation method in a complex mining situation, such as the one located at the Central Zone of the MM deposit.
- Test the capacity of the method to better understand the continuity of the breccia, the stockwork and the low grade mineralization estimation units.
- Study the proportions of the estimation units in EW direction in order to define domains of mining selections.
- Estimate the accuracy and precision of tonnage estimation in relation to the level of information.
- Afterwards, the results of the simulation will be used to study the uncertainty in the amount of metal and the dilution in relation to the capacity of mineral selection and the quality of the grade control practices.

Description of the Geology of MM site

MM orebody is located close to Chuquicamata copper mine, in Chile.
This deposit is a Classic Porphyry with a superimposed High Sulphidation System.
The MM deposit is hosted by an intrusive complex of granodiorite and dacite dykes emplaced in the late Triassic, structurally controlled by the MM Fault. An early stage of alteration-mineralization in the deposit is associated with two Tertiary porphyrytic which developed classic porphyry-style mineralization zoning.

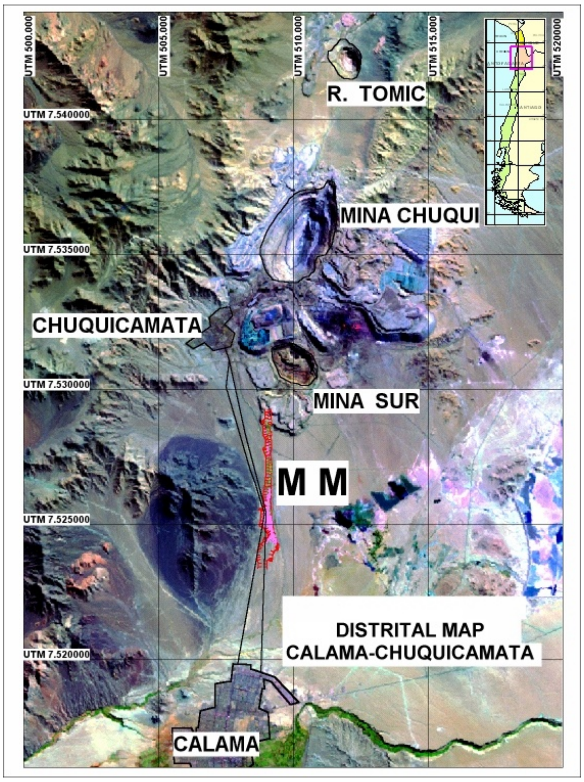
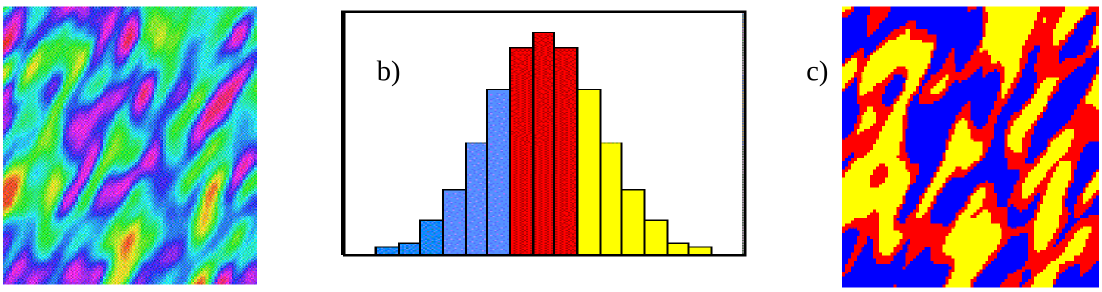


Figure 1. Location map of the MM orebody

The evolution of the MM deposit to a later mineralization stage was triggered by the generation of a gas plume (presumably SO_2) under the porphyry system. The ascent of this plume was channelled through the pre-existing structures. Sulphur contained in hydrothermal fluids was responsible for forming the late high sulphidation mineral assemblages. The late mineralization is contained in magmatic-hydrothermal structurally controlled breccias, which have a 'stockwork' mineralization halo that affects the wall rocks.

The Truncated Gaussian Simulation Method

a)



c)

Figure 2. Principle of the Truncated Gaussian simulation method.
a) Gaussian Random Function. b) Histogram of the Gaussian Random Functions. The thresholds are the limits between the colored areas. c) Rocktypes map.

Truncated Gaussian Simulation method has been first designed to provide stochastic images of sedimentary geology, mostly in fluvio-deltaic environments. The basic principle of the method is to replace the handling of the geological description, poorly designed for calculations, by the handling of a Random Function with a multigaussian distribution, for which geostatistical simulations are used

routinely. The rocktype provided by the simulation depends on the value provided for the Gaussian Random Function. After definition of thresholds, the rocktype is chosen depending between which threshold is the value of the Gaussian Random Function.
The thresholds are given by the proportions of each rocktype. These proportions will vary in space, while the properties of the Gaussian Random Function stay the same (stationnarity).

Application to MM orebody

Usually, Truncated Gaussian Method is used in sedimentary environment. The simulation is performed in a "working simulation grid" after a geometric transformation which flattens one or two chrono-stratigraphic markers. They are represented as Vertical Proportion Curves, drawn along the vertical direction. These curves can vary in space.
In MM orebody, the geometry is completely different, and there is no chrono-stratigraphic marker.
Nevertheless, the geometry of the mineralization is controlled by the MM fault and the network of associated faults and joints. When in a sedimentary environment we draw prportion curves along the vertical, here we have drawn them in direction to the main geological variability, that is EW.
The Western Boundary is given by the MM fault, the other limits define the central area of the orebody.
As it is necessary to know all the boundaries with the same definition as the simulation grid, the MM fault has been estimated by charging with a linear model.
Simulations have been carried out with 6 data sets of increasing sizes, obtained from two drillhole campaigns during 2000 and 2001.

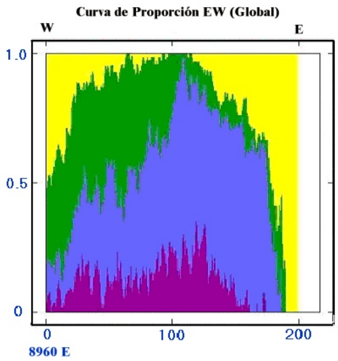


Figure 3. Global East-West Proportion Curves for all data.

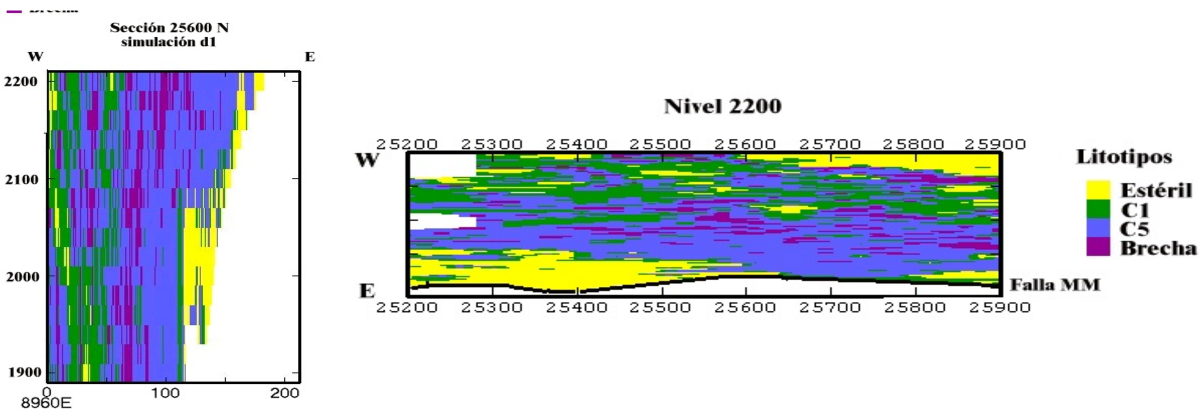


Figure 4. Section 25600 N, simulated with all data. C2000 and C2001.

Figure 3 shows the global proportion curves for the biggest data set (which includes all data). Figure 4 shows cross sections of one simulation for the same data set. This simulation has been performed by using proportions which vary in space.

Volume calculations

The pictures generated by the simulations have been considered as realistic. The geometry of the breccia proposed by the simulations is a lot more irregular than the geometry proposed at first by the geologist.
As a question of economical interest is the volume of high grade breccia, as well as the uncertainty on this volume, about 100 simulations have been carried out with each data set. Mean and standard deviation of the number of simulated breccia blocks have been plotted versus the number of sample used in the data sets.

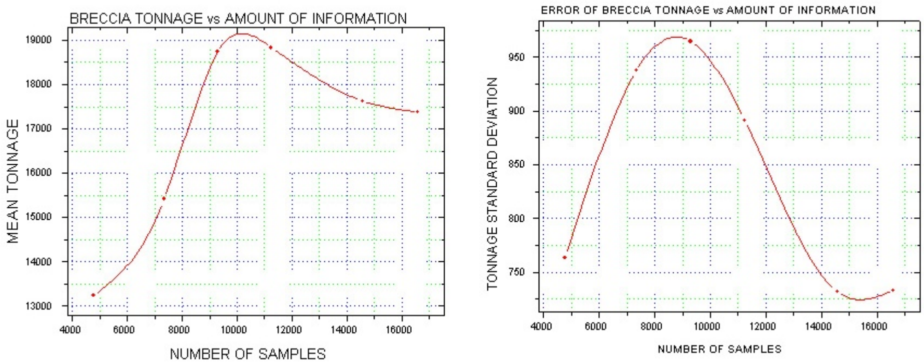


Figure 5. a) Average number of Simulated Breccia Blocks v/s Number of Drillhole Samples. b) standard deviation of the number of Simulated Blocks v/s Number of Drillhole

Conclusion

The use of truncated Gaussian simulation method has provided a geological model for the breccia geometry which, while realistic, is less continuous than the model provided by the correlations given by the geologists. It helps them to understand better the implicit and explicit choices of both modeling, and their consequences.
At the same time, the use of stochastic modeling has allowed us to provide us some statistics for the ore volume, putting in evidence the influence of the density of available information on estimated resources.

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