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MULTIPLE-POINT STATISTICAL SIMULATION IN MODELLING A STRUCTURALLY COMPLEX GEOLOGICAL ENVIRONMENT

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ABSTRACT

An innovative approach to geological modelling and stochastic estimation of a Mineral Resource in a structurally complex gold deposit is presented. An existing Direct Sampling (DS) multiple-point statistics (MPS) algorithm is adopted to produce stochastic models of lithology and gold grade distribution at point support, conditioned to sparse geological and grade data, following a non-parametric multi-variate framework. An ensemble of MPS realisations is upscaled to an open pit mining unit support to obtain an open pit Mineral Resource. A mineable shape optimisation algorithm is used to derive underground stopes for reporting the ore quantity and uncertainty associated with an underground mining method. Comparison is made to understand an inherent increase in uncertainty in mineralised material (tonnage, gold grade and metal quantity) when moving from the open pit to the underground highly selective environment.

The first explicit three dimensional (3D) geological model of the deposit is constructed and a workflow to do it in future proposed. A considerable effort is dedicated to understanding spatial relationships between the variables to derive the exhaustively known ‘true’ model. While modelling finely intercalated folded lithology explicitly with classical methods underperforms even in presence of dense production data, a minimal input from a geologist is envisaged in this approach for a successful model, in a form of an elementary training image and a set of structural measurements of the lithological contact to create a representative potential field of ductile deformation.

A new modelling framework is proposed where (1) a portion of the ‘true’ model is reserved to be used as a training image, while (2) the remaining part serves as a validation tool prior to arriving at a satisfactory ensemble of realisations (3) to be carried forward as a stochastic model for the poorly informed part of the deposit. This approach lends itself to the adaptation of modern developments in artificial intelligence and machine learning. The specialist’s involvement is confined to incorporating understanding of the deposit and its genesis into the explicit ‘prior’ model.

Validation of the algorithm performance showed that complex multivariate relationships are respected during an MPS simulation, such as honouring of the main structural controls, folded geometry of lithological contact, proximity of the

mineralisation to the fold hinge zone affecting the attitude of the shears, distribution of the tenor of mineralisation in relation to the potential field, character of the soft boundary reproduction in the spatial gold grade distribution in relation to the lithological contact boundary, and localisation of ore shoots along the intersection of structural controls (bedding and shearing). The latter is considered of high importance when generating truthful underground mining designs.

Methodological contribution, among others, comprised a finding that reproduction of the gold grade patterns improves when conditioning it to a multiple indicator gold grade variable in a co-simulation mode. The potential field created from the lithological contact served as a non-stationarity descriptor to guide the gold grade simulation, improving it further. For categorical variables (the mineralised domain and lithologies), the proportions reproduction is achieved within 3% deviation from the 'true' model and this approach can be used as-is in future simulations.

The method showed robust performance with sparse data or even in absence of data, provided sufficient understanding of geology and mineralisation in a form of a multi-variate 'true' model exists and the geologist believes the 'true' model is representative of the unknown. As such, the approach yields itself well to in-depth stochastic mining engineering at early stages in a project life when only sparse drilling is available. The stochastic framework allows for an integrated approach to Mineral Resource classification and Mineral Resource and Ore Reserves reporting, with associated geological and geostatistical uncertainty tabulation.

There are other advantages of the proposed workflow such as ability to run it in a reconstructive mode with partial update of the model. Smooth and natural transition between the 'frozen' and new areas with honouring of the spatial structures is allowed, and the definition of non-stationarity is improved continuously.

A list of suggested future enhancements is given with regards to methodology, the improvements to the DS algorithm, and the MPS approach in general.

At the moment of conducting the research, no mentioning could be found in literature with regards to a successful MPS simulation of continuous variables in a context of hard-rock mining for large 3D models.