

**GEOSTATISTICS FOR ORE RESERVE ESTIMATION
AND GRADE CONTROL**
(3 days)

Who should attend : Geologists or mining engineers involved in ore reserve estimation and/or grade control

Summary : Geostatistics is now more than 40 years old. It all started in the Witwatersrand gold mines where Daniel Krige proposed a statistical correction to the traditional way of estimating the average grade of a block of ore to be stoped by the arithmetic mean of a limited number of channels cut in drives, raises and stope faces around the block. Theory was formulated a decade later by Georges Matheron who introduced a tool to analyse the spatial continuity of sample values called "variogram" and an estimation method based on the variogram appropriately called "kriging".

In the following two decades, those tools have been used on a large variety of deposits from fairly regular sedimentary iron ore to highly variable uranium or precious metals occurrences. They have been refined too. The last decade has seen the emergence of more robust ways of analysing the spatial continuity of mineralizations than the plain variogram. Variants of the kriging method have been proposed. Emphasis has been put on the estimation of block recoveries (tonnage and grades above various cut-offs) rather than just a single block grade average. Conditional simulation has been proposed as an alternative to kriging for the production of multiple "stochastic images" of an orebody. Finally, in some selective mining operations with poorly visible ore, geostatistics has proved to be a powerful method of processing grade control data.

The future of geostatistics looks bright. With all the experiments and developments of the last three decades, it has matured as a credible alternative to traditional geometrical ore reserve estimation methods. Other disciplines which use spatially distributed data (oil and gas, environment, hydrology, oceanography, forestry) have started to adopt it.

This three-day course will present the basic concepts of geostatistics and specific applications in ore reserve estimation and grade control. Emphasis is on practical applications, not on theory. In as much as possible, subjects are approached from a real case study drawn from the consulting practice of the instructor. Some microcomputer software will be demonstrated. Participants are encouraged to bring their own data.

For course schedule and pricing please contact Geostat Systems International Inc. at:

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Course outline :**DAY 1 = The first two basic concepts of geostatistics : estimation error and variograms****Estimation error**

Krige's early experiments in Witwatersrand gold mines. Magnitude of estimation errors for a simulated gold deposit. Histogram of errors and error variance. The sample re-use method.

Variograms

Intuitive presentation : the magnitude of estimation errors as a function of grade differences between samples. Practical calculation in 2D and 3D. Variogram features (nugget effect, range and anisotropy). Variograms and geology.

DAY 2 = The next two basic concepts of geostatistics : kriging and simulation**Kriging**

Intuitive presentation : weighting by grade difference = $f(\text{distance})$ rather than just distance. Anatomy of a simple kriging. Variogram modelling prior to kriging. Practical implementation.

Simulation

The classical Monte-Carlo methods to simulate grades with a given histogram. How to introduce spatial dependency and consistency with existing samples in the simulation : turning bands and sequential methods.

DAY 3 = Specific applications in ore reserve estimation and grade control**Nugget effect and sampling error**

Experimental determination of sampling errors with check sample data. Prediction of sampling error : Gy's formula. Nugget effect as a function of sample size.

Dealing with difficult variograms

Compositing. Data transformation (logarithm, indicator). Other measures of grade difference.

Dealing with outlier sample data in precious metal deposits

Statistical analysis of sample data. The lognormal model. Sichel's correction method and lognormal kriging. Indicator kriging.

Precision of reserve estimates

The geostatistical version of the "variance of the mean". Precision as a function of drill hole grid. Getting uncertainties from multiple simulations.

Applying a cut-off to block estimates

Grade variability as a function of sample and block size. Why polygons tend to overestimate grade above cut-off. Why kriging tend to underestimate grade above cut-off and the vanishing tonnes problem. Global corrections. Local corrections with indicator kriging. Assessing dilution from support and information effects via simulations.

Geostatistics with grade control (blast hole) data

How do deal with high blast hole sampling errors. Blast hole kriging. The Similkameen case. Optimising dig lines from multiple conditional simulations.

Instructor

This course is run by Michel Dagbert, who has been associated with Geostat Systems International Inc. since the beginning of operations in Golden (1980) and Montreal (1981). As a senior consultant for Geostat, Michel Dagbert has been responsible for a large number of ore reserve estimation projects for exploration and mining companies throughout the world, most of them involving geostatistics. Major projects include Key Lake, Jabiluka and Kiggavik (uranium), Highvale (coal), Paddington, Waihi, Fenn-Gibb, McBean, Omai, and Kumtor (gold), Maesod, Galmoy, Grevet, Mobrun (base metals), Mifergui-Nimba and Paraburdoo (iron), Lac Tio, Fort-Dauphin, St-Constant and Exshaw (industrial minerals).

Michel Dagbert has taught geostatistics at the Colorado School of Mines, Ecole Polytechnique and UQAC as well as at seminars in Canada, Australia, Colombia, Ivory Coast, Congo, India and China. He is a graduate of the School of Mines in Paris and McGill University. He is also a member of IAMG, CIM and AIME as well as a Professional Engineer in the Province of Quebec.