MULTIVARIATE SIMULATION OF CHANNEL IRON ORE DEPOSITS AT BUNGAROO AND YANDICOOGINA, WESTERN AUSTRALIA

A THESIS SUBMITTED IN THE DEPARTMENT OF EARTH SCIENCES OF THE UNIVERSITY OF QUEENSLAND AND IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF PHILOSOPY
2007

BY
CAMERON MCLAREN WILSON BOYLE
B.SC (HONOURS). – GEOLOGY,
JAMES COOK UNIVERSITY OF NORTH QUEENSLAND,
CERTIFICATE IN THE SCIENCES
UNIVERSITY OF NEW ENGLAND,
POST-GRADUATE CERTIFICATE IN GEOSTATISTICS
EDITH COWAN UNIVERSITY

WH BRYAN MINING GEOLOGY RESEARCH CENTRE
THE UNIVERSITY OF QUEENSLAND

Statement of Originality

The work presented in this thesis, to the best of my knowledge and belief, is original, except as acknowledged in the text, and the material has not been submitted, either in whole or part, for a degree at this or any other university.

Acknowledgements

Assistance from staff members and other students of the WH Bryant Research Centre is gratefully acknowledged. Special thanks apply to the three supervisors: Professor Chris Alford for managing the research project, reading thesis drafts, making available study facilities at UQ and handling university administration; Doctor Shuxing Li for joint supervision and technical input particularly in the fields of conditional simulation, MAF and guidance on running DBMAFSIM; and Professor Roussos Dimitrakopoulos for setting up the research project, as well as direction and advice on course work study and earlier research.

Rio Tinto is thanked for their generous support of this thesis financially, for computing facilities, providing study leave, making available Bungaroo and Yandicoogina data sets and permission to release results.

Abstract

Geostatistical conditional simulation has wide potential applications in the iron ore industry and is the favoured tool to assess variability and risk. Multivariate relationships are important in such simulation, for example between Fe and impurities such as Al_2O_3, SiO_2 and P.

Turning bands has been the main conditional simulation algorithm used in the Western Australian iron ore industry. In this thesis a more recent approach using minimum/maximum autocorrelation factors (MAF) and sequential Gaussian simulation (SGS) are used together and performance comparisons are made with turning bands at Yandicoogina, a channel iron ore deposit (CID) in Western Australia.

MAF-SGS and turning bands algorithms both performed well in simulating Fe, SiO_2, Al_2O_3 and P at Yandicoogina. Extensive checking of simulations showed both approaches could reasonably reproduce multivariate statistics and spatial continuity of composites including means, variances, histograms, quantile-quantile plots, scatter plots and variography in normal scores and data space, as well as in MAF space for the MAF-SGS approach. MAF generated from transformed composites were largely uncorrelated and able to be considered independent for variography and simulation. Later back transformation from MAF space to normal scores space then to data space successfully reintroduced joint relationships seen in the conditioning data.

While the MAF-SGS approach needs additional transformations compared with turning bands, a linear model of coregionalisation and hence the modelling of cross semivariograms is not required. If there are a high number of variables then construction of a linear model of coregionalisation becomes more difficult and the MAF approach may be preferred. In this study four variables were considered and a linear model of coregionalisation could be built. Turning bands transformations are from data space to normal scores space only, with no need to calculate or check any decorrelated factors.

The two main methods currently used in the mining industry for determining optimum drillhole spacing with the use of conditional simulation were compared at the Test Pit area of the Bungaroo channel iron ore deposit, also in Western Australia. The "simulation-simulation" method generates precisions for various drillhole spacing using

two stages of simulation, whereas the "simulation-estimation" approach calculates expected relative errors for different spacings via a simulation stage followed by an estimation step.

Clear differences exist between the relative errors from the simulation-estimation method and the precisions calculated from the simulation-simulation method. The simulation-estimation method appears more insensitive to the grid spacing with only moderate improvements in relative error as the drillhole spacing is tightened. The simulation-simulation method shows more marked improvement in precision with closer spacing and appears more realistic in this study. Al_2O_3 is the main variable to consider at Bungaroo when choosing a suitable drillhole spacing. SiO_2 grades of composites are mainly below the SiO_2 cut off grade for ore whereas the mean Al_2O_3 is grade is quite close to the Al_2O_3 cut off grade for ore. Hence although SiO_2 has higher variability, it is not as critical as Al_2O_3 for determination of drillhole spacing. Fe and P have greater spatial continuity than Al_2O_3 and SiO_2 and do not require such close drillhole spacing. Fifteen percent precision, based on a volume representing a quarter's production and using the simulation-simulation method, may be regarded as acceptable for mine planning purposes. A resource evaluation drilling spacing of 150m along strike and 50m across strike appears appropriate for a precision of less than 15% for a quarterly mining volume in determining Al_2O_3 grade at Bungaroo.

Table of Contents

Table of figures

List of tables