IMPACT: International Journal of Research in Applied, Natural and Social Sciences (IMPACT: IJRANSS)
ISSN(P): 2347-4580; ISSN(E): 2321-8851
Vol. 4, Issue 10, Oct 2016, 151-158

COAL REOSURCES CLASSIFICATION USING VARIOGRAM TO DESCRIBE THE SPATIAL VARIABILITY

IRFAN MARWANZA[1], CHAIRUL NAS[2], AHMAD HELMAN HAMDANI[3] & IYAN HARYANTO[4]

[1, 3, 4] Faculty of Geology, University of Padjadjaran, Bandung, Indonesia

[2]Department of Mining, University of Trisakti, Jakarta, Indonesia

ABSTRACT

Sangatta coal field area is divided into two areas, the western and the eastern zone. Based on the qualitative analysis of geology, west zone is classified in moderate geological conditions and the eastern zone is classified in complex geological conditions.

In this research, using the range of the variogram to calculate distances between drill holes spacing for resource classification. It can be unreliable when a variogram is constructed using few data points, and if there is a high proportion of nugget variance compared to total variance. The variogram may assist in defining distances of continuity between point if observation. There are three categories for classifying the coal resources, depending from the range distance of variogram, by which information points, West Sangatta are separated: Measured: Separated by 116 m of distance from each other. Indicated: Separated from 116.m to256.m of distance from each other. Inferred: Separated from266.m to 528 m of distance from each other. East Sangatta is separated: Measured: Separated by 55 m of distance from each other. Indicated: Separated from 55.m to 110.m of distance from each other. Inferred: Separated from 110.m to 244 m of distance from each other. This variogram has not been calculated across the multiple data. It just takes into account the coal seam thickness. For example, when the variogram is done for another variable, the results are different.

KEYWORDS: Coal, Geological Condition, Variogram

INTRODUCTION

There are several ways in which geostatistics can improve coal seam resource classification and estimation (Larkin, 2011):

- Estimation of coal seam thickness and overburden volumes.
- Estimation of coal seam quality parameters.
- Provision of confidence limits on these estimations.
- Optimization of drilling: determining where to place additional drill holes and determining the minimum drill hole spacing for the classification of resources as measured, indicated or inferred.

Determining the Minimum Drill Hole Spacing for Classification of Resources, Geostatistics can be in two ways to classify resources as measured, indicated or inferred (Larkin, 2011):

- Reading the appropriate distances from the variograms

- “Drilling” the realizations at different drill hole spacings and determining what the maximum “error” would be for each drill hole spacing and then using a maximum acceptable error for each category.

However, for both methods there is no clear guideline on what values should be used as cut offs between categories. Benefits of determine the minimum drill hole spacing for classification of resources are possibility of decreasing drilling costs by using a wider drilling spacing, determine if necessary to increase drilling spacing and determine if increasing drilling spacing is going to provide substantial additional information.

The most obvious factor affecting classification is that of drill hole spacing. In this research, analysis the data density of exploration through construction variogram and classification of resources for coal deposits. The average distance of samples from the block in question is useful if the deposit is isotropic, otherwise, like sample numbers, distance does not reflect spatial relationships adequately. However, the calculation of an ‘anisotropic distance’ corrected for the ratios of the principal orientations of continuity is potentially useful. Inferred material can be screened out beyond the distance equal to the range of influence (where there is no spatial correlation). Measured and Indicated blocks could also be defined according to specified distances determined from the semivariogram (Snowden).

There are three categories of coal resource, namely Measured, Indicated or Inferred reflecting decreasing levels of confidence.

METODOLOGY

GEOSTATISTICAL METHODS

Variograms are used in the first steps of spatial prediction as tools that provide insight into the spatial continuity and structure of a random process. Variogram is one of the significant functions to indicate spatial correlation in observations measured at sample locations. It is commonly represented as a graph that shows the variance in measure with distance between all pairs of sampled locations. Such a graph is helpful to build a mathematical model that describes the variability of the measure with location. Modeling of relationship among sample locations to indicate the variability of the measure with distance of separation is called variogram modeling. It is applied to applications involving estimating the value of a measure at a new location (Vijay Gandhi).

The variogram function was originally defined by Matheron (1963) as half the average squared difference between points separated by a distance *h*. The variogram is calculated as:

$$\gamma_{(h)} = \frac{1}{2N} \sum_{i-1}^{n} (X_i - X_{i+h})^2$$

In the equation above, *h* indicates the distance of separation between a pair or points, *N(h)* is the number of pairs with a maximum difference of *h*, X_i indicates any one of the spatial location, and $X_{(i+h)}$ indicates the value of a measure at location *i*.

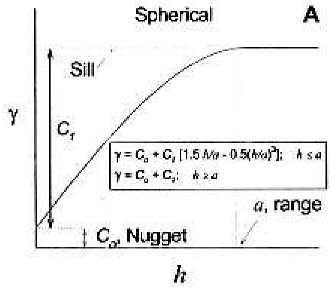

Figure 1: Displays a Theoretical Semivariogram of a Spherical Semi Variance Model, and Points out the Semivariogram Characteristics

Range, sill and nugget are parameters of empirical variogram and related with geostatistics. The range represents a distance beyond which there is little or no autocorrelation among variables.

The nugget represents independent error, measurement error and/or micro scale variation at spatial scales. The nugget effect is seen as a discontinuity at the origin of either the covariance or semivariogram model.

Sill is a parameter of variogram or semivariogram model that represents a value that the semivariogram tends to when distances get very large. Sill of the semivariogram is equal to the variance of the random variable, at large distances, when variables become uncorrelated.

There is not a hard and fast rule to follow for classifying resources using variograms. It is common practice, that some use of 1/3 of the range for the measured and, 2/3 for the indicated and range for inferred, for coal resources. At the end, and this is emphasized in the Coal Guidelines, the competent person will need to take the decision putting together all facts that are available. The use of the omnidirectional variogram to classify resources is equivalent to the use of circles of influence, with the advantage that the chosen distance is supported by geostatistics.

Reading Maximum Resource Category Distances from Variograms (Brett Larkin):

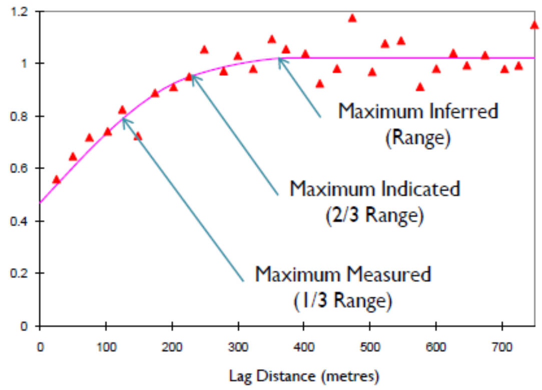

Figure 2: Resource Category Distances from Variograms

CASE STUDY : SANGATTA COAL SEAM

The Sangatta coal seam, which contains high volatile bituminous coal and is the most important seam in the Sangatta Coalfield, was deposited within a Late Middle Miocene fluvial system that occupied the northern Kutei Basin, Indonesia. A study of clastic sedimentology, coal petrology of standard and etched coal samples, thickness and coal quality parameters, integrated with a geostatistical analysis, identified the depositional environment of the seam. The previous study by Nas, 1994, indicated that the coal seam was deposited within the floodplain of a mixed-load fluvio-deltaic system with the rivers flowing southeastward. Local changes in sedimentary facies below and above the Sangatta seam caused variations in the local rates of subsidence and compaction which in turn controlled the peat swamp morphology and coalification pattern. The morphological variations governed hydrologic conditions in the swamp which, in turn, influenced peat accumulation and subsequent geological processes acting on, and within, the peat. These factors also influenced seam thickness, maceral composition and coal quality parameters. The Sangatta seam has an average thickness of 6 m. The coals are characterized by a high vitrinite (average of 9 1 %), low liptinite (average of 3 %), low inertinite (average of 3 %), very low mineral matter (average of 2%) and low sulphur (average of 0.4%).

Sangatta coal field area is divided into two areas, the western and the eastern zone. Based on the analysis of geological, west zone is classified in moderate geological conditions; the conditions of coal sludge sedimentation deposited in more varied conditions and to a certain extent have been changed after the sedimentation and tectonics. Fault and folds are not many, so are faulting and folding the resulting relatively moderate. This group characterized also by low the dip of the seam, thickness and lateral variations and the development of parting, but its distribution is still can be followed up to hundreds of meters.

While the eastern zone is classified in complex geological conditions, the conditions of coal deposited in the system sedimentation complex or resulting in the extensive deformed tectonic, it causes the coal seam thickness vary. The quality of coal is heavily influenced by the changes that occur during the process of sedimentation takes place or at the post-deposition such as division or damage of seam (wash out). Faulting, folding and over tune folding arising by tectonic activity, and its common so coal seams difficult correlated. Strong folding also results coal seam steep. Laterally, spread a coal seam limited and can be followed up to tens of meters

RESULT AND DISCUSSIONS

Statistical Analysis and Geostatistical

Statistical analysis of multiple parameters of coal seam, obtained from field measurements and laboratory work during the exploratory phase of coalfield Sangata conducted to systematically evaluate the spatial variation of each parameter.

West Zone

The data to be analyzed is 426 boreholes. The drill data obtained from the data the thickness of the coal seam, which subsequently made with the histogram graph of statistical zone in the west analysis to obtain the values of the statistical variables.

N	Valid	426
	Missing	0
Mean		6,7933
Std. Error of Mean		0,1386
Median		6,8300
Mode		7,49
Std. Devi tion		2,86116
Variance		8,186
Skewness		-0,025
Std. Error of Skewness		0,118
Kur osis		0,0 2
Std. rror of Kurtosis		0,236
Range		14,14
Minimum		0,40
Maximum		14,54
Sum		2893,96
COV		0,421

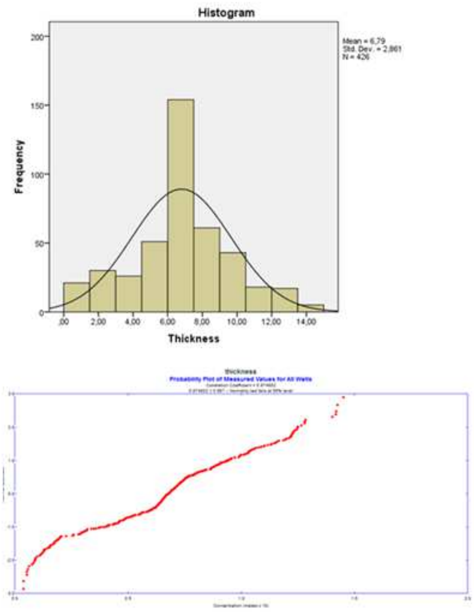

Figure 3: Basic Statistical Analysis for Western Zone

Variogram analysis for variable thickness of the Sangata coal seam using lag distance of 60 m and lag tolerance 30 m, producing Range 528, Sill 1,722 and Nugget Effect 6.97. Variogram models used are spherical.

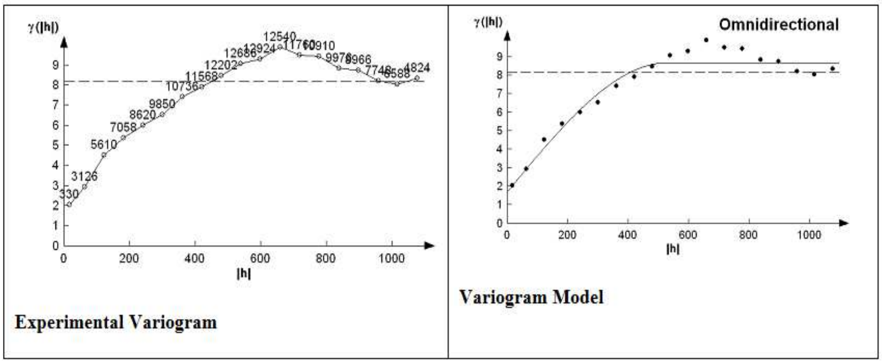

Figure 4: Variogram Analysis for Western Zone

Eastern Zone

The data to be analyzed is 818 boreholes. The drill data obtained from the data the thickness of the coal seam, which subsequently made with the histogram graph of statistical analysis to obtain the values of the statistical variables.

N	Valid	426
	Missing	0
Mean		6,7933
Std. Error of Mean		0,1386
Median		6,8300
Mode		7,49
Std. Devi tion		2,86116
Variance		8,186
Skewness		-0,025
Std. Error of Skewness		0,118
Kur osis		0,0 2
Std. rror of Kurtosis		0,236
Range		14,14
Minimum		0,40
Maximum		14,54
Sum		2893,96
COV		0,421

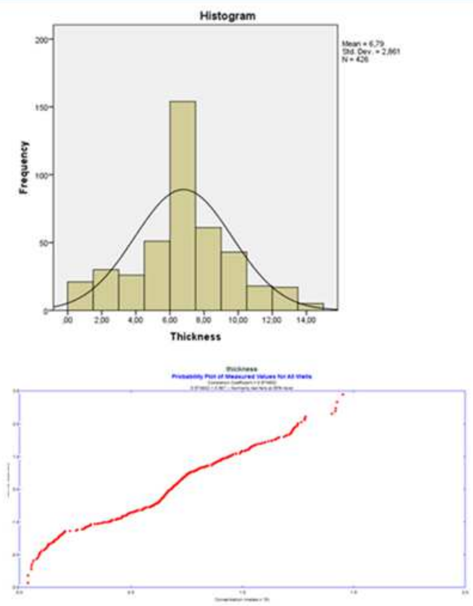

Figure 5: Basic Statistical Analysis for Eastern Zone

Variogram analysis for variable thickness of the Sangata coal seam uses lag distance of 35 m and lag tolerance 25 m, producing Range 211, 2, Sill 3.93 and Nugget Effect 3.854. Variogram models used are spherical.

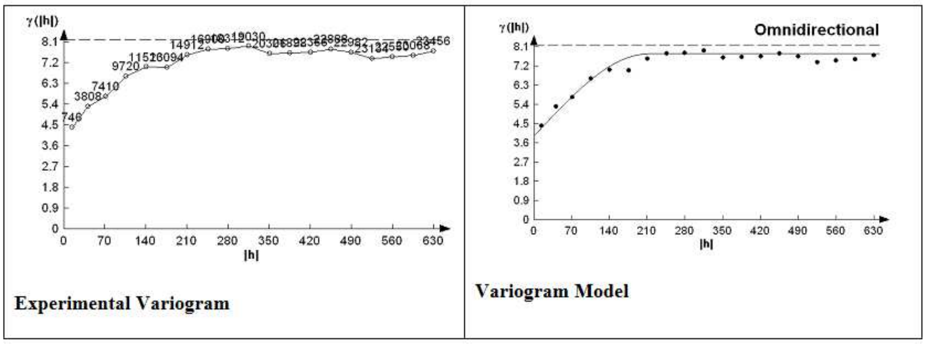

Figure 6: Variogram Analysis for Western Zone

This company determined that the drilling space would be as follows, however will utilise variography to confirm this distances.

Table 1: The Actual Drill Holes Spacing

Location	Distance Between Boreholes
West Zone	60m
East Zone	50m

Classification of Coal Resources

Now if we read the equivalent distance to the resultant number, we find that measured resources will be covered by a distance between boreholes of 100 m (west zone) and 50 m (east zone). This number confirms in principle that the resources for this deposit based on the variable in the measured category.

Table 2: Level of Confidence and Distance between Boreholes from Range of Variogram

Coal Resources Category	Distance Between Boreholes (m)	
	West Zone	East Zone
Measured	116	55
Indicated	266	110
Inferred	528	244

CONCLUSIONS

For the coal measure resources the distance between drill holes in west zone (60m) is shorter than the variogram range (116m). This means that the data is spatially uncorrelated and and can be extended according to the results variogram, but in east zone the distance between drill holes is relatively similar, that means that data is not need to be changed.

The drill hole spacing required for acceptable confidence in a resource estimate, one of them is depends on the geological conditions and range of variogram.

REFERENCES

1. Babish, G. 2000. *Geostatistics without tears*. Ecological Research Division, Saskatchewan (Canada)
2. Blackwell, G. H., 1998, *Relative kriging errors – a basis for mineral resource classification*, Exploration and Mining Geology, Vol. 7, Nos. 1 and 2, p. 99-106.
3. Casley, Z, Bertoli, O, Mawdesley, M, Davies, G, Dunn, and D. 2009*: Benchmarking Estimation Methods for Coal Resource Estimation*. AusIMM 2009 International Mine Geology Conference, Perth.
4. Clark, I. 1982. *Practical Geostatistics*. Applied Science Publishers. London (UK)
5. Davis, J., 1973, *Statistics and Data Analysis in Geology*, Wiley, second edition. 550 pp.
6. Isaaks, E. H., and Srivastava, R. M., 1989, *An Introduction to Applied Geostatistics*, Oxford University Press, New York, 561 pp.
7. Journel, A.G., 1989, *Fundamentals of Geostatistics in Five Lessons*, American Geophysical Union, Washington D.C.
8. Lantuejoul, C, 2002: *Geostatistical Simulation, Models and Algorithms*. Springer-Verlag, Heidelberg.
9. Larkin, B. *When do the Benefits of using Geostatistics for Coal Resource Estimation outweigh the Costs?* Geocheck, Brisbane (Australia)
10. Moore, T.A., Bowe, M. and Nas, C., 2014, *High heat flow effects on a coalbed methane reservoir, East Kalimantan (Borneo), Indonesia*. International Journal of Coal Geology 131, 7-31.
11. Nas, C, 1994. *Spatial Variations in the Thickness and Coal Quality of the Sangatta Seam. Kutai Basin.Kalimantan, Indonesia*.
12. Remy. N, Boucher. A & Wu. J., 2009. *Applied Geostatistics with SGeMS*: A Users' Guide

13. Rivovoirard, J, 1994: *Introduction to Disjunctive Kriging and Non-Linear Geostatistics*. Oxford University Press, Oxford.
14. Silva. D.S.F. and Boisvert. J. B. 2014. *Mineral resource classification: a comparison of new and existing techniques.* The Journal of the Southern African Institute of Mining and Metallurgy
15. Sinclair, A.J., and Blackwell, G.H., 2005. *Applied Mineral Inventory Estimation*. Cambridge University Press.
16. Snowden, V. 1989. Resource Estimation. Professional Development Courses Snowden. Brisbane (Australia)
17. Srivastava, R.M., 2013. *Geostatistics: a toolkit for data analysis, spatial prediction and risk management in the coal industry*. International Journal of Coal Geology (Special Issue on Geostatistics).
18. Tercan A.E and Sohrabian B. 2012. *Multivariate geostatistical simulation of coal quality data by independent components.* Department of Mining Engineering, Hacettepe University, Beytepe, Ankara, Turkey. International Journal of Coal Geology