International Journal of Applied Sciences and Smart Technologies

Volume 5, Issue 2, pages 303–314

p-ISSN 2655-8564, e-ISSN 2685-9432

Resources Estimation of Laterite Nickel Using Ordinary Kriging Method at PT Mahkota Semesta Nikelindo District Wita Pond Morowali District

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(Received 31-07-2023; Revised 10-08-2023; Accepted 28-09-2023)

Abstract

Resources have economic value, form, quality, quantity, grade, geological characteristics, and certain sustainability to be extracted economically. Mineral resources decrease based on the level of geological confidence in the Inferred, Indicated, and Measured categories. This study uses the Ordinary Kriging geostatistical method to assess the potential of nickel laterite resources and the distribution of nickel mineralization levels in the study area. The research methodology was inspired by statistical and geostatistical analysis, starting with univariant statistical analysis, spatial statistics, bivariant statistics, and resource estimation. For later use in determining the distribution of mineralization grades and classifying nickel laterite resources using the Relative Kriging Standard Deviation (RKSD) calculation. This method estimates nickel content in a block whose grade value is unknown. The results of statistical calculations using Ordinary kriging obtained an average grade value of 2.90% Ni. Mineralization data for nickel content in limonite layers with Ni content of 0.5 – 1.3% and saprolite layers with Cut of Grade (COG) Ni, > 1.4 – 3.1% Ni in limonite and saprolite layers are projected in the block model. The estimated tonnage of nickel resources using the OK method is 670,837.83 tonnes. Laterite nickel resource classification results RKSD calculation are classified into measured resources (Measured).

Keywords: nickel laterite, resource estimation, grade, tonnage**.**

1. Introduction

Indonesia is the world's second-largest nickel producer after Russia, contributing around 15% of world nickel production in 2010 [2, 12]. The Eastern Indonesia region, especially in Central Sulawesi, has potential mineral resources in nickel laterite deposits in the Morowali district. Nickel ore deposits found in Morowali are lateritic nickel ore deposits formed from the weathering of ultramafic peridotite, dunite, and serpentinite containing 2.0% Ni; these deposits have profitable potential for mining [7]. The term Laterite is taken from the Latin "later," which means red brick, which was put forward by Buchanan Hamilton

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(1807). Nickel laterite deposits are formed from the weathering of ultramafic parent rocks [5]. Nickel ranks second after manganese, a metal alloy material, where its presence is estimated to be 3% in the earth's core and 0.003% in the earth's crust. Nickel is produced from the recycling of scrap stainless steel and used batteries whose anodes use a nickel alloy [6].

Univariate statistical analysis is an analysis of the description of a variable or a collection of variable populations that describes the characteristics of the data variables from the description values , such as the average value, median, maximum value, minimum value, coefficient of variation, standard deviation, and skewness. The spread of variability of a population can be seen in the value of standard deviation and variance [3]. The coefficient of variation is used as the basis for estimating resources; if the coefficient of variation is equal to or below 1.5, then using the IDW and ordinary kriging methods is good for estimating resources [10]. The principle of using the ordinary kriging method, which is used when the average thickness is unknown, then estimates the thickness value of a block whose thickness value is either vertically or horizontally so that a three-dimensional block model will be obtained. After obtaining the shape of the sediment model, the volume will be calculated so that a resource estimation result will be obtained [11]. In getting the average value as a form of data 2 dimensions and depiction of data distribution Nickel Using required composite assay with the following equation [8]. The variogram is often used as a geostatistical analysis tool by considering the correlation of data to determine the size of the sample points against the space where the sample points are not estimated [4]. In Blackwell's study (1998), if the RKSD value (relative kriging standard deviation) is below 0.3, then it is included in the inferred resource; if the RKSD value is between 0.3 to 0.5, then it is included in the indicated resource; and if the RKSD value is above 0.5 then it is included in the measured resource. The RKSD equation is [1]. There are several methods for estimating resources. In addition to resource estimation using the IDW method, there are also resource estimates using the Kriging and NNP methods. Further research is needed regarding other resource estimation methods [9].

Therefore, the author is interested in researching nickel mining companies; in laterite nickel mining, estimates are needed to determine the number of resources before the

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mining process occurs. Therefore, researchers conduct research by estimating resources using the ordinary kriging method. So that the company has relevant information, it can minimize the factors that cause discrepancies during the mining process.

2. Methods

The data for estimating nickel laterite resources is secondary data obtained from drilling. The data includes drill point codes, location coordinates, laterite nickel thickness, and laterite nickel content. The laterite nickel resource estimation method used the ordinary kriging geostatistical method. This method was chosen because it is considered more thorough than conventional methods.

Ordinary kriging assumes the population mean is constant, but unknown, whereas the variogram of Z(s) is known. This method is a method that provides a Best Linear Unbiased Estimator (BLUE). Ordinary Kriging weights satisfy the unbiased property with Sum, where n is the known number of samples. The usual kriging weight value can be obtained through the following equation:

$$\begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \\ m \end{pmatrix} = \begin{pmatrix} \gamma(s_1,s_1) & \gamma(s_1,s_2) & \cdots & \gamma(s_1,s_n) & 1 \\ \gamma(s_2,s_1) & \gamma(s_2,s_2) & \cdots & \gamma(s_2,s_n) & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \gamma(s_n,s_1) & \gamma(s_n,s_2) & \cdots & \gamma(s_n,s_n) & 1 \\ 1 & 1 & \cdots & 1 & 0 \end{pmatrix}^{-1} \begin{pmatrix} \gamma(s_1,s_0) \\ \gamma(s_2,s_0) \\ \vdots \\ \gamma(s_n,s_0) \\ 1 \end{pmatrix}$$

The additional parameter m is the Lagrange multiplier used to minimize the kriging error. The following equation can obtain ordinary kriging interpolation:

$$Z(S_0)=\lambda^T.Z$$

and the kriging error variance $var(\varepsilon(S_0))$ can be obtained from the equation:

$$var(\varepsilon(s_0)) = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \\ m \end{pmatrix}^T \begin{pmatrix} \gamma(s_1,s_0) \\ \gamma(s_2,s_0) \\ \vdots \\ \gamma(s_n,s_0) \\ 1 \end{pmatrix}$$

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3. Result and discussion

Drill spread

Exploration drilling carried out at PT Mahkota Semesta Nikelindo resulted in an irregular distribution of drill points with a total of 56 drill points with an average information retrieval or drilling spacing of 25 meters which is detailed information retrieval and is included in measured resources as explained in SNI 2019 regarding reporting of exploration, mineral resources and reserves that measured resources are not more than 50 meters in gathering information. The map can be seen in Figure 1 below.

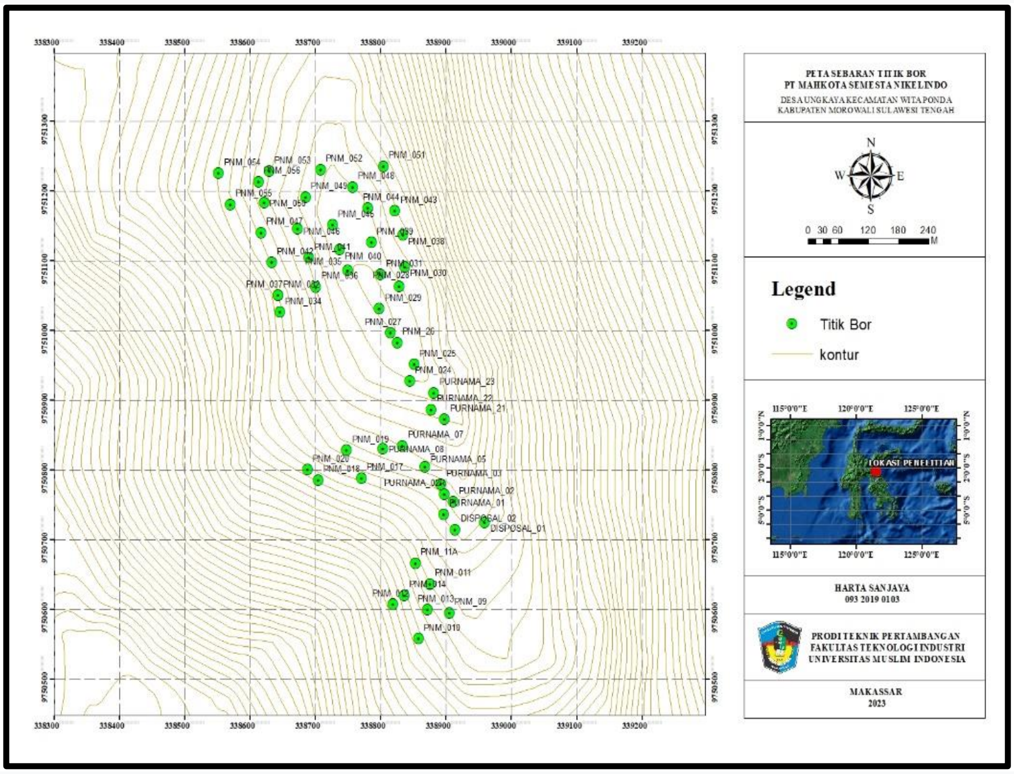

Figure 1. Drill point distribution map

Univariant Statistics

Descriptive statistics describes a mathematical distribution to determine the mean value and the difference between each value and the mean. The values that appear when statistical analysis is carried out are the mean, variance, standard deviation, and coefficient of variation, and the Geometry Mean values become parameters in the formation of distribution graphs in the form of histograms. The histogram graph that appears is a depiction

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of the distribution of data which intends to provide an overall picture of the shape of the distribution and make it easier to identify data errors. The histogram that appears is an outlier histogram, which means there is still a possibility of data errors, so a cutlier is needed to eliminate these errors so that errors do not occur when carrying out spatial statistical analysis. Limiting the margin of error that may occur with the following equation is necessary.

Confidence interval

$$95\% = \overline{x} + 2S$$

Statistical results can be seen in Figure 2 histogram of Ni content composite downhole data.

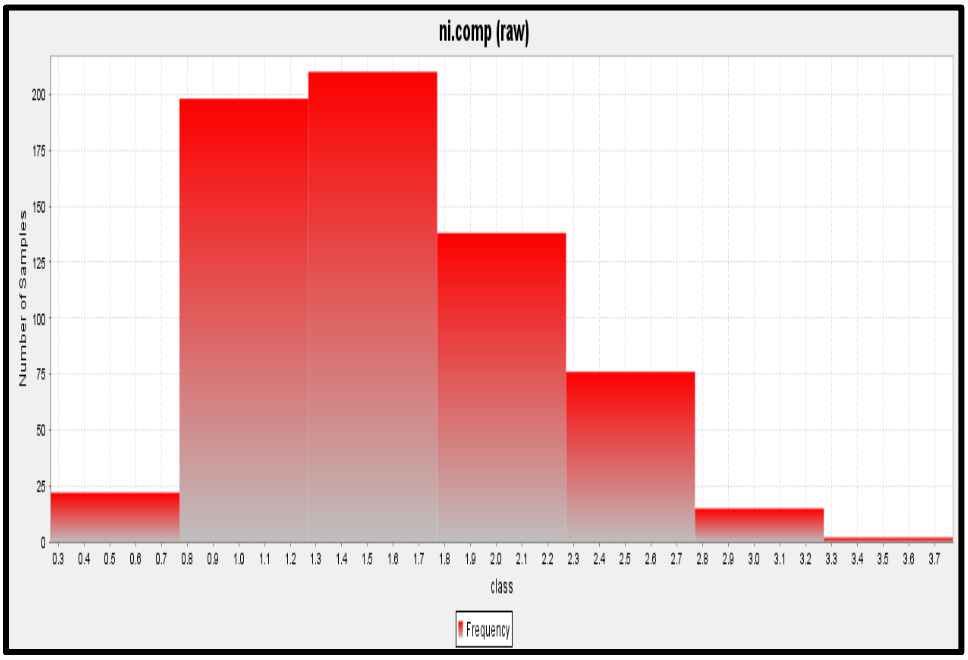

Figure 2. Histogram of composite downhole data for Ni content

The results of the descriptive statistical analysis in Table 1 are descriptive statistics with several samples, variance, mean, and coefficient of variance, where these values will become parameter values in resource estimation. The skewness value is the data symmetry value, where 0 (zero) is the data symmetrical value. Table 1. has a skewness value that is still good because it is not too far from the number 0 (zero), and the difference between the mean and the median is not too far or even close. Hence, the possibility of error is relatively small.

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Table 1. Statistical report on composite downhole data for Ni content

Parameter	Sampel composite cut
Number of Data	661
Mean	1.605174
Median	1.500000
Geometri mean	1.508518
Minimum	0.270000
Maximum	3.500000
Stdt Dev	0.548176
Variance	0.300497
Coefficien of variation	0.341506

Spatial Statistics Analysis

In the variogram analysis, horizontal and vertical variogram fittings will be carried out to find bearing, plunge and dip values. From the results of bearing, plunge, and dip, major, semi-major and minor values will be obtained in determining ellipsoid anisotropy in the distribution of lateritic nickel deposit levels, besides that it can also determine the potential of the distribution direction of nickel laterite based on the variogram maps formed. In the experimental semivariogram calculation, data from MS Excel is required which includes the sample code or drill point code, sample coordinate points and nickel content. The experimental semivariogram is calculated from four directions, namely: 0^o, 45^o, 90^o and 135^o. Structural analysis or matching between data patterns in experimental semi-variogram models and theoretical semi-variogram models. The selection of this variogram model will then greatly determine the results of the estimation process in correcting and interpreting the value of a variable. Structural analysis also obtained a shape that shows elliptical geometric anisotropy for nickel content with the direction used, namely N 0^o E.

Figure 3 shows the value of the variogram model of the formed Omnidirectional variogram which produces a sill value of 0.622430, a nugget of 0.357796 and a range value of 47 m.

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p-ISSN 2655-8564, e-ISSN 2685-9432

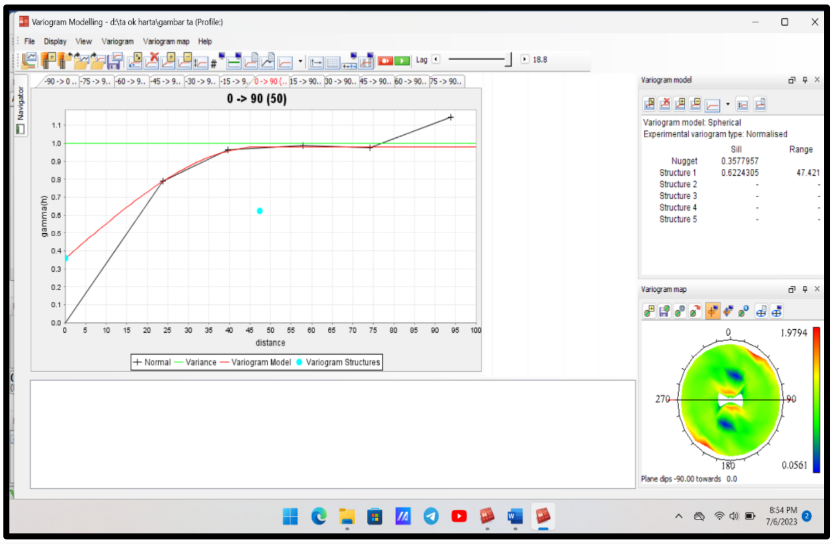

Figure 3. Variogram models

Resource modeling and estimation

In estimating resources, the data is first made into a block model where the creation of this block model is intended so that the data that has been estimated with the determination of the drill point can be estimated by making small blocks of a predetermined size from the company to show the content of a metal such as Ni, Fe, and others. The block modeling made is adjusted to the drill point spacing of 25 m so that the size of the block model will match the drill point spacing. The making of the block model is adjusted to the distribution of mineral deposits. The maximum user block size is 10 meters long, 10 meters wide, and 5 meters thick, while the minimum Sub Block Size is 5 meters long, 5 meters wide, and 1 meter thick.

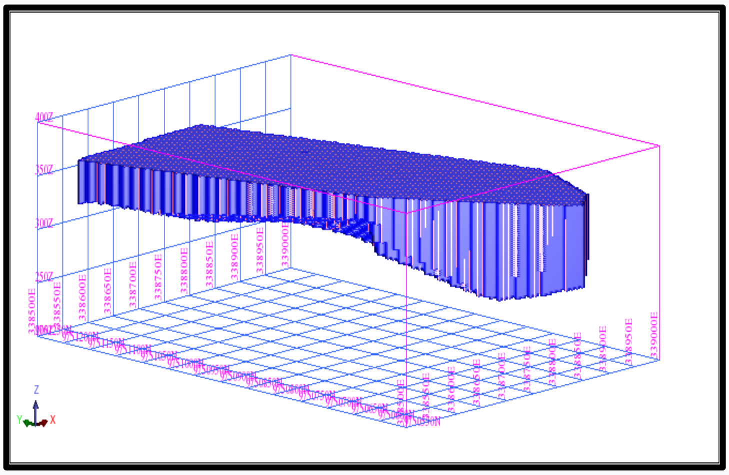

Figure 4. Block model of the saprolite and limonite layer

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Making block models for saprolite and limonite layers with a Cut off Grade (CoG) value of > 1.4% Ni is carried out with a Minimum % of the sample to be included, namely 75 m, Maximum Search radius, which is 50 m, and the Power used is 2, the greater the power used, the greater the volume generated to obtain data on total laterite nickel resources. The basic concept of making the block model itself is based on the drill point spacing in the field, which, as shown in Figure 4, shows the block size that matches the drill point spacing in the field, in this case, the block size is ¼ of the drill point spacing.

In mining at PT Mahkota Semesta Nikelindo itself, it has a cut of grade, which is 1.4% taken from the company's recommended COG, while the recommended density for OB or levels below COG is 1 kg/m3 and for ore, which is 1.55 tonnes. The tonnage will later be obtained, which is the result of the equation of

$$\text{Tonnage} = \text{volume} \times \text{density}$$

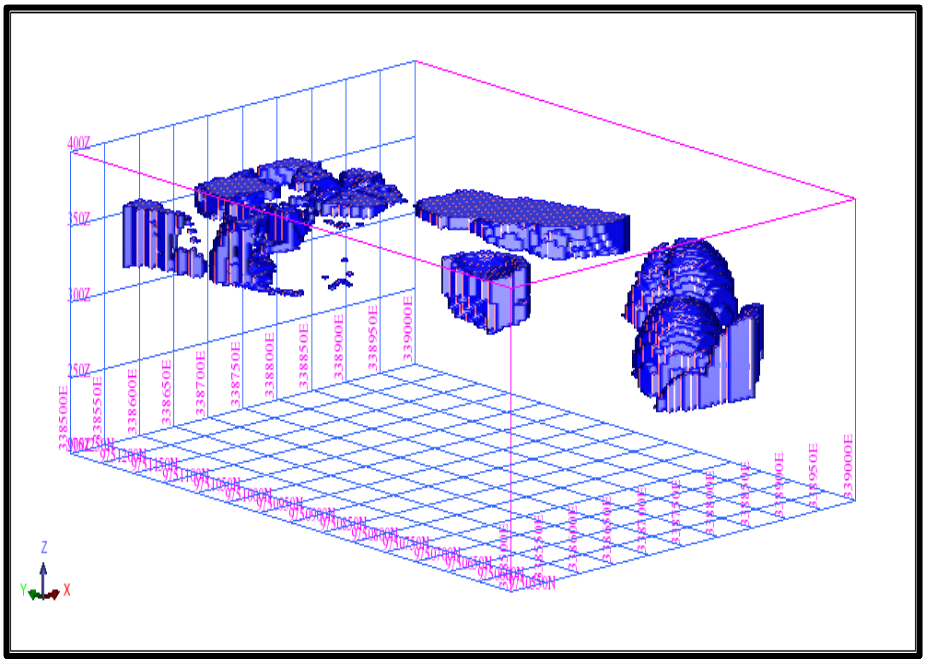

Figure 5. Block model OK saprolite layer COG >1.4

The calculation results using the Ordinary Kriging method can be seen in the Table below:

Table 2. The estimation results of ordinary kriging resources

Lithology	Volume (m^3)	Tonnage (ton)	Ni (%)
Limonit 0.5 – 1.3%	232.880,0	256.928,7	1.12
Saprolit 1.4 – 3.1%	832.772,5	145.657.47	1.78
Grand Total	**113.619,575**	**402.586,17**	**2.90**

From the results of resource estimation using the Ordinary Krigin method in this study, a volume of 832,772.50 was obtained with a resource tonnage of 145,657.470 tons and an average grade of nickel laterite of 2.90 % Ni.

Resource classification with RKSD

From the results of resource estimation using the Ordinary Krigin method in this study, a volume of 832,772.50 was obtained with a resource tonnage of 145,657.470 tons and an average grade of nickel laterite of 1.78% Ni.

Table 3. Statistical results of resource classification with RKSD

Parameter	Saprolite
Number of Data	333109
Mean	1.749067
Minimum	1.395005
Maximum	2.675809
Stdt Dev	0.224451
Variance	0.050378
Skewness (se)	0.621483
Kurtosis (se)	3.086359
Standard error	0.084569

The results of this estimate can be used as a reference for information on the amount of resources and 3D models of mineral deposits. This information can be used for mine planning.

4. Conclusions and suggestion

Conclusion

The conclusions of this study are:

Resources using the Ordinary Kriging method with Cut of Grade (CoG) > 0.5 - 1.3% totaling 256,928.7 tonnes, (CoG) 1.8 - 2.1% totaling 521,794.80 tonnes, (CoG) > 2.1 - 3.0% totaling 132,228.00 tonnes, with a total of 145,657.47 tonnes and an average grade of Ni 1.45 %. Classification of nickel laterite resources based on RKSD (Relative Kriging Standard Deviation) with a resource mean value of 1.749% Ni and a standard deviation of 0.224, categorized as a measured resource.

Suggestion

To maximize research, the authors suggest using the NNP estimation process or other assessment processes, then conducting statistical analysis with several references in statistical software, then comparing the Ordinary Kriging estimation process that has been carried out. So that the data obtained can be more accurate and can be used in modeling software as well as a reference for determining the classification of nickel laterite resources based on RKSD (Relative Kriging Standard Deviation) calculations.

Acknowledgements

The author thanks the academic community of the mining engineering study program at the Indonesian Muslim University who have provided a lot of help and support, the author also thanks the company PT Mahkota Semesta Nikelindo which is right in Morowali, Central Sulawesi for taking the time to guide us in the field and help us in carrying out our final project.

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