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Estimation of Laterite Nickel Resources Using Ordinary Kriging Method in The Garuda Block PT Ceria Nugraha Indotama Southeast Sulawesi

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ABSTRACT

Assessing nickel resources before mining is crucial. Ordinary kriging, based on spatial relationships, is key in this estimation process. This study aims to quantify nickel resources using ordinary kriging and classify them into limonite and saprolite with a CoG of 1.5%. Employing statistical and geostatistical methods, it ensures reliability. Criteria such as a coefficient of variation below 1.5 and a sill-nugget difference under 50% favor ordinary kriging. The methodology involves univariate statistical analysis, spatial statistics, resource estimation, and classification based on RKSD. In the limonite zone, nickel content exceeds 1.5% CoG, with a variation coefficient of 0.184 and a 38% sill-nugget effect. Strong correlation (0.8085) and low RMSE (0.5537) indicate minimal data errors. In the saprolite zone, nickel content meets the 1.5% CoG, with a variation coefficient of 0.3893 and a 22% sill-nugget effect. The correlation coefficient (0.6581) and RMSE (0.4422) suggest low data errors. Ordinary kriging estimates total resources at 610,668 tons with an average nickel content of 1.60%. This comprehensive approach ensures accurate resource assessment for effective mining planning.

1. INTRODUCTION

Nickel laterite is the presence of minerals or deposits on the earth's surface that have economic value, because in the present and in the future the need for nickel will be higher. [1]. The term Laterite from Latin means red brick [2]. 72% of the world's total nickel reserves are laterite nickel and 42% of new nickel reserves are in production [3].

Reserve calculation is one of the cornerstones and most important things in exploration. It means calculating from resources to reserves [4]. When estimating resources and reserves by determining the quantity of a deposit that has economic value to be mined [5].

Resource estimation has an important role in determining the quantity and quality of a deposit [6]. In the principle of calculating reserves, it determines the dimensions of a deposit. The calculation of reserves also requires parameters in the form of, content, block thickness, and others [7].

Estimation using the ordinary kriging method is B.L.U.E. (best linear unbiased estimator) because it produces an unbiased estimation [8]. The results of modeling and resource calculations in the exploration phase will be used for evaluation, if a mining activity is feasible or not carried out [9].

Variogram aims to see the distance and direction of distribution in deposits by looking at the value of variance and data pairs that have the longest range and the direction of greatest influence [10.]

Kriging is a spatial estimation technique that provides unbiased estimation with minimal mean error. This estimation method not only obtains riging estimation results, but also obtains rigging variance results as a measure of reliability and uncertainty values [11]. The principle of estimating Ordinary Kriging is to weight the reverse distance drill point based on the nearest sample and the relationship between the location of the sample weight by adding variogram elements to obtain the value of the nugget, sill, range parameters. And look at the anisotropy factor.

Mining activities will not be able to be carried out when resources are not yet known and it is better when the distribution of deposits, the quality and quantity of deposits can be known so that mining activities to investment can be structured. By estimating nickel resources using the ordinary kriging method that considers the distance between data and spatial conditions or the direction of data continuity, can determine the average content, and the amount of nickel tonnage. Based on this, the author conducted this study to estimate nickel laterite resources using the ordinary kriging method in the Garuda block of PT Ceria Nugraha Indotama, Southeast Sulawesi.

The Wolo region has many fractures filled with secondary minerals such as garnierite, chrysoprase, asbestos, and chalcedony (silica). Rock assemblages from island arcs, priorities, and small continental masses are washed away by subduction, collisions, and other tectonic processes [12]. The geological structure found in the Wolo region consists of documented shear faults, descending faults, cracks found almost all in inward-facing complex rocks and ultramafic rocks, and fold shapes thought to have formed since the Mesozoic [13].

The process of laterization comes from the weathering process of ultrabasic rocks, which are composed of harzburgite rocks. These rocks are rich in olivine, pyroxene, magnesium silicate and iron. These minerals are not unstable and susceptible to weathering. Weathering processions show that these rocks contain mostly olivine, pyroxene, magnesium silicate minerals, and typically contain 0.30% nickel in ultrabasic rocks (peridotite, dunnite, serpentinite) these rocks are particularly susceptible to laterite weathering [14].

The purpose of this study is to determine the amount of nickel resources and classify nickel resources in the limonite and saprolite zones using RKSD with a CoG of 1.5%.

2. METHODOLOGY

In this study, calculate or estimate the amount of nikell lateritt resources using the methode ordinaryy krigingy (OK). As for the implementation of research, there are several stages carried out in conducting research, namely:

- Literature study
- Primary and secondary data collection
- Data processing and analysis
- Research results

Literature studies are carried out during pre-research and post-research. At this stage, study the literature and collect various sources of information that have a relationship with resource estimates. The data collected is in the form of primary data and secondary data that has been collected from the research location, then in the end to be processed and analyzed.

The data processing in this study uses the ordinary kriging (OK) method. Import database, zone thickness and depth, composite downhole, block model, univariate statistical analysis, and spatial statistics Using X software. In processing the data, data is needed including:

- Geological data, which is in the form of lithological data, and mineralization limits for estimating certain levels.
- Data assay, which is the result of nickel content analysis per drill point depth.
- Collar data is the coordinate and elevation data of the drill point.
- Survey data, which is data on the total depth of the drill point.
- Topographic data, namely DTM data on the contour of the earth's surface appearance.
- The COG value is the minimum nickel grade that is economically valuable to be mined.

Then, from the data above, the results of laterite nickel resource estimation were obtained and processed with the help of Microsoft excel.

3. RESULT AND DISCUSSION

3.1 Drill point spread

In exploration drilling in the Garuda block, PT CNI produces a regular distribution of drill points with several drill points of 116 points and an average information collection or drilling space of 50 meters which is a detailed information collection and is included in measurable resources as explained in SNI 2011 concerning reporting exploration, resources and mineral reserves that measured resources are no more than 50 meters in collecting information.

3.2 Composite downhole

Before analyzing and looking for the number of resources, it is necessary to correlate the attributes and values entered in the drill data, which has previously imported the database before becoming a 3-dimensional drill bar. Then, perform a downhole composite with a composite length per 1 meter and a minimum sample of 75% in Mining Software. The databases are Assay, Collar, Survey and Lithology.

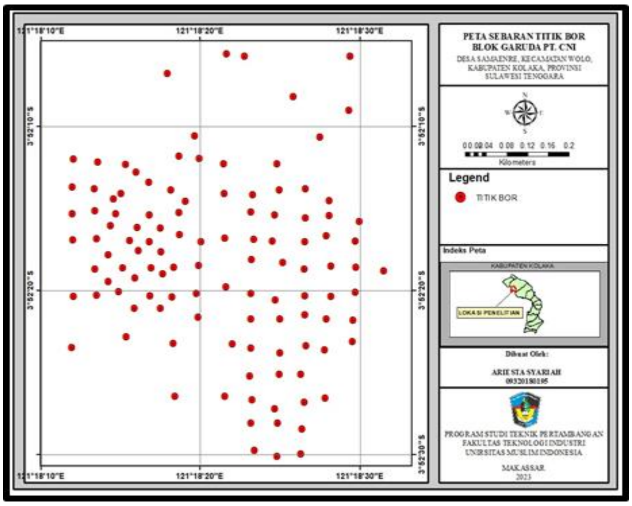

Figure 2. Spread the drill point.

3.3 Analysis of statistics univariate

Descriptive statistics is used to describe a mathematical distribution to determine the average value and the difference between each value and the mean. It is necessary to cutlier the histogram to cut or eliminate the error value by doing top cut and bottom cut. To find out the value of errors that are likely to occur, the confidence interval equation is entered.

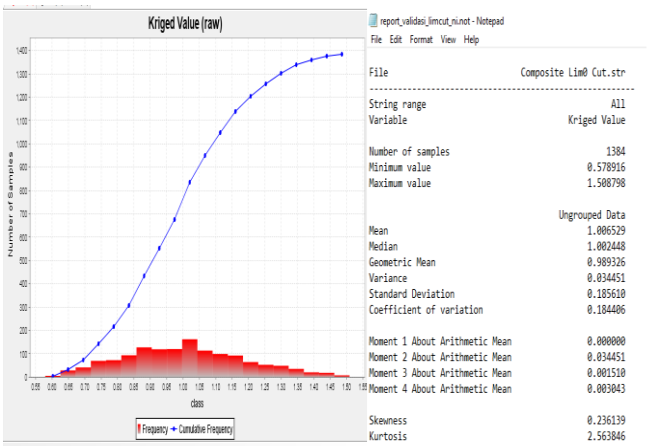

Figure 3. Histogram statistik cutlier limonite

After estimating the limit of possible errors with the equation Confidence interval 95%. So, Confidence interval 95%.

$$\text{Top cut / bottom cut } = \bar{x} \pm (1.96 \times SD) \qquad (1)$$

Limonite = 1,202 ± 1,96 × 0,478
= 2,138 (top cut)
= 0,265 (bottom cut)

Saprolite = 1,015 ± 1,96 × 0,301
= 1,605 (top cut)
= 0,424 (bottom cut)

In figure (3) is the result of descriptive statistics on the cutlier histogram, where the coefficient of variation is 0.184 which means that the use of kriging is good for estimating resources because the coefficient of variation is below 1.5. It is known that the value of the coefficient of variation is low where the value is below 1.5, so the distribution of data owned has a small degree of heterogeneity. So why use kriging. It would be better, if used to estimate resources in the limonite zone.

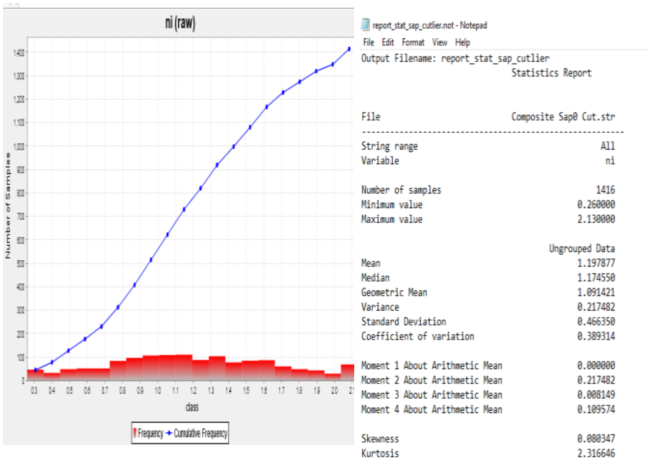

Figure 4. Histogram statistic cutlier saprolite

In figure (4) is the result of descriptive statistics on the cutlier histogram, where the coefficient of variation is 0.389 which means that the use of kriging is good for estimating resources because the coefficient of variation is below 1.5. It is known that the value of the coefficient of variation is low where the value is below 1.5, so the distribution of data owned has a small degree of heterogeneity. So that the use of kriging will be better if it is used in estimating resources in the saprolite zone.

3.4 Spatial statistical analysis

In variogram analysis, horizontal variogram fittings and vertical variograms will be carried out in finding bearing, plunge and dip values. From the results of bearings, plunges and dips will be obtained major, semi-major and minor values in knowing the anisotropy ellipsoid.

Make Haster and John Marek (2001), explaining that if the difference between the nugget and the sill is > 50% then the kriging method does not produce an accurate assessment and it is better to use IDW, if the nugget is close to the sill then the kriging estimate is the same as ordinary arithmetic so it is better to use polygons.

In figure (5) The variogram value of the model variogram formed produces a sill value of 0.48 nuggets, which is 0.1, and a range value of 153. The difference between sill and nugget is 38% so that the use of ordinary kriging method is good for interpreting resources.

3.5 Cross validation

Cross validation is a bivariate statistical analysis phase used to analyze the distribution of two different data sets in the same location. A commonly used bivariate statistic is (scatterplot), which plots two variables on an x-y graph plot. The estimated variables are actual data and spatial data.

The correlation value for the coefficient (r) is in the range of -1 ≤ r ≤ 1, indicating that the value of the correlation coefficient close to 1 or -1 indicates a stronger relationship between the variables and vice versa. At 0 (zero), there is no correlation between variables and RMSE is the value used to determine the rate or degree of error. The smaller the RMSE value (close to zero), the more accurate the prediction value gets.

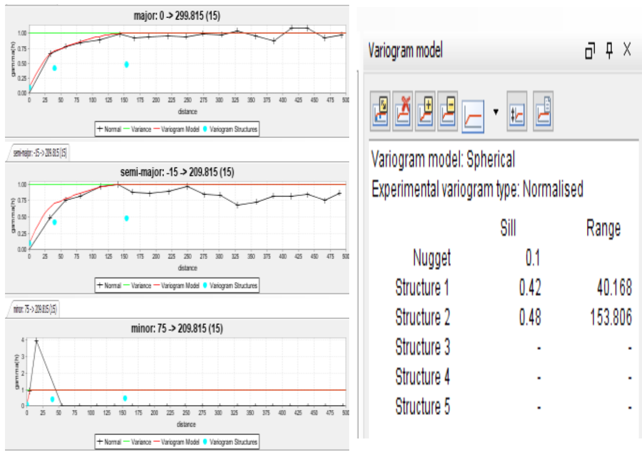

Figure 5. Variogram anisotropy ellipse limonite

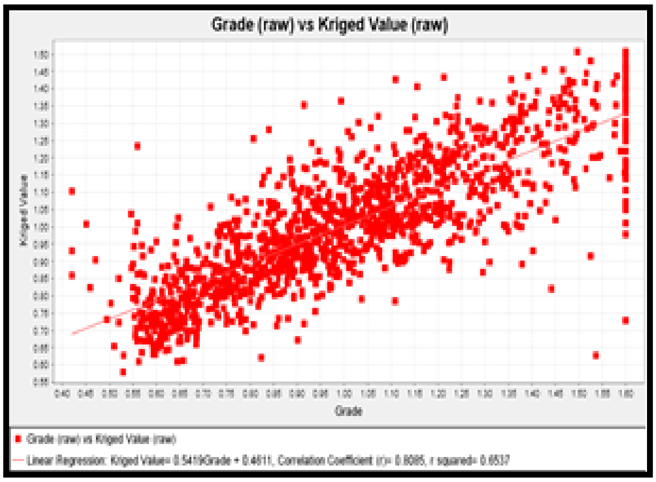

Figure 6. Cross validation limonite

In figure (6) showing the Correlations coefficient of the limonite zone, which is 0.8085 which means that the relationship between different variables has a very strong correlation so that the distribution of data from the results of spatial statistical analysis is good and the RMSE of 0.6537 means that the results obtained are accurate because the RMSE value is almost close to 0 (zero).

In figure (7) is a cross validation saprolite image, the Correlation coefficient of the saprolite zone, which is 0.6550, means that the relationship between different variables has a strong relationship so that the distribution of data from the results of spatial statistical analysis is good and the RMSE is

0.4422 which means that the results obtained are accurate because the RMSE value is almost close to 0 (zero).

3.6 Resource Modeling

After all parameters have been obtained values, a representation of resource modeling is carried out before estimating the amounts of resources. The estimation radius is taken from the range value. For block size is taken from 1/4 of the average spacing of the 50 m drill point which is 12.5 m, for vertical which is 1 m taken from the drilling run. In mining, the Garuda block has a cut of grade of 1.5% taken from the company's recommended CoG, while the density is recommended for the limonite zone of 1.68 m^3 and the saprolite zone of 1.72 m^3.

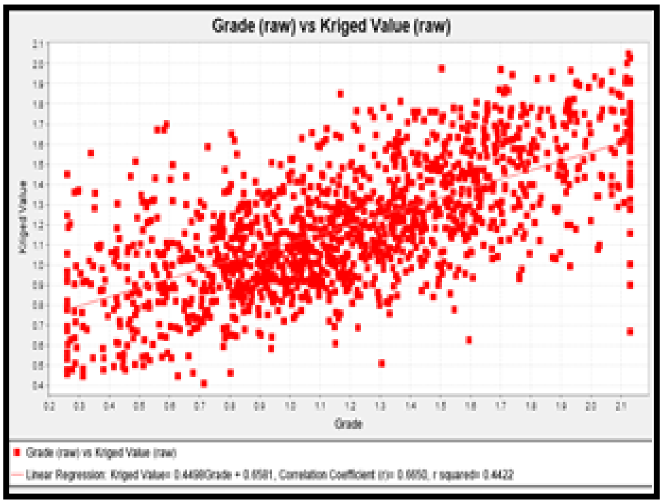

Figure 7. Cross validation saprolite

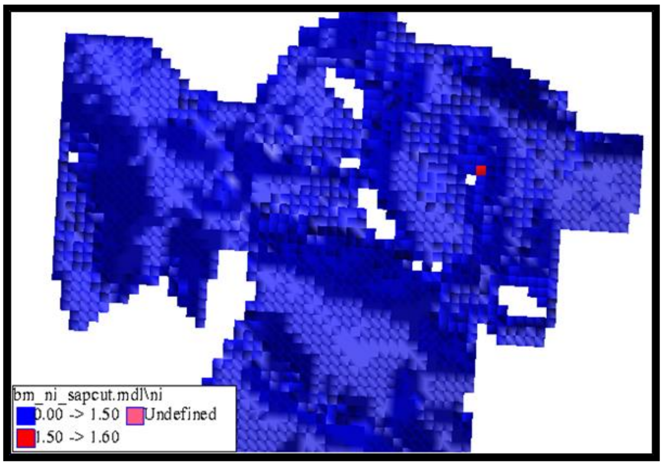

Figure 8. Limonite resource block model

In Figure (8), namely limonite resource modeling, the color in the model block is the difference in interval levels and the coloring of the levels can be seen in the limonite resource modeling drawing.

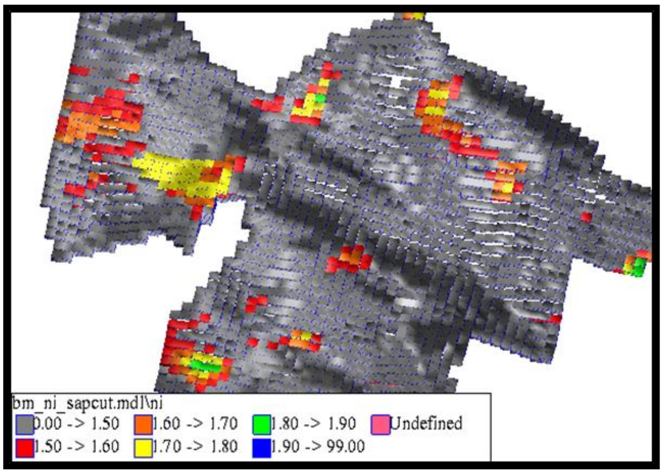

Figure 9. Saprolite resource block model

In Figure (9), namely saprolite resource modeling, the color in the model block is the difference in interval levels and the coloring of the levels can be seen in the saprolite resource modeling image.

3.7 Amount of Nickel Resources

Table 1. Results of estimated CoG resources 1.5% Ni

CoG	Volume	Tones	Ni
0	2,328,908	3,912,563	0.98
1	1,063,908	1,787,363	1.11
1.1	486,408	817,163	1.19
1.2	154,845	260,138	1.28
1.3	51,095	85,838	1.37
1.4	16,407	27,563	1.47
1.5	5,001	8,400	1.55
1.6	1,563	2,625	1.6

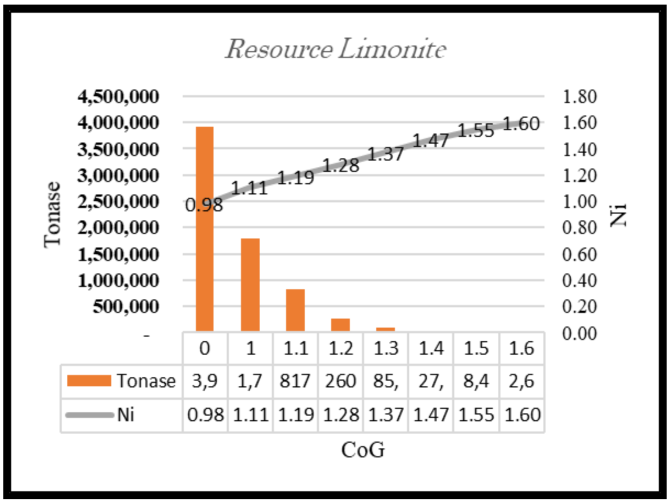

Figure 10. Graph of limonite resources CoG 1.5%

After knowing the modeling picture, then estimate resources by reporting excel format model blocks. Based on table 1, results were obtained in the form of tonnage 8,400 / ton and Ni content of 1.55% with CoG 1.5% in limonite.

Table 2. Results of estimated CoG resources 1.5% Ni Saprolite

CoG	Volume	Tones	Ni
0	2,441,252	419,850	1.2
1	1,892,033	3,254,294	1.29
1.1	1,550,002	2,666,000	1.35
1.2	1,144,533	1,968,594	1.42
1.3	820,783	1,411,744	1.49
1.4	569,220	979,056	1.55
1.5	350,157	602,268	1.61
1.6	182,188	313,362	1.68
1.7	75,313	129,537	1.74
1.8	5,313	9,137	1.85
1.9	469	806	1.9

After knowing the modeling picture, then estimate resources by reporting excel format model blocks. Based on table 4.2 obtained results in the form of, tonnage 602.268 / ton and Ni content 1.61% with CoG 1.5% in saprolite.

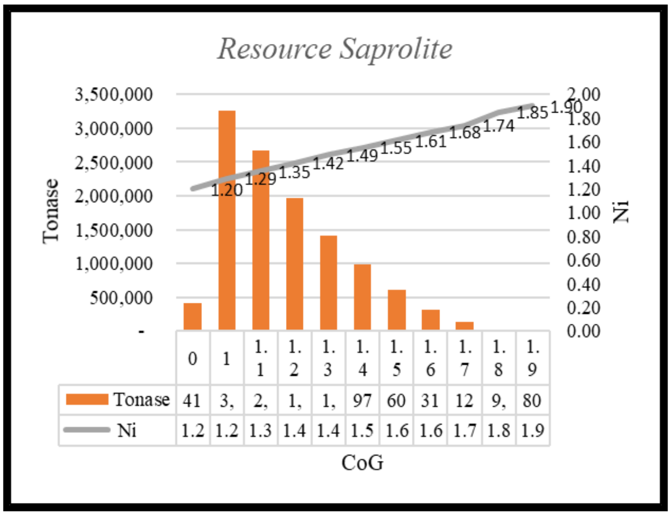

Figure 11. Graph of saprolite CoG 1.5% resources

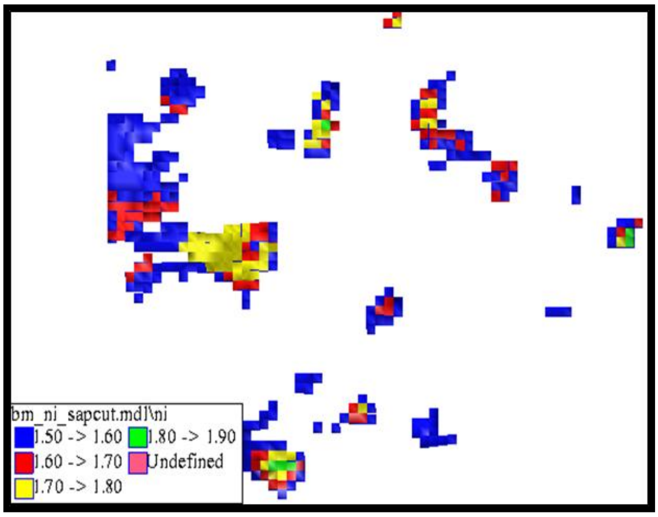

Figure 12. 1.5% CoG resource modeling

Figure 12 is a resource modeling based on the 1.5% CoG constraint that has been determined.

Table 3. Total resources Ni Garuda block

Lithology	Density	Tones	Ni
Limonite	1,68	8,400	1.55
Saprolite	1,72	602,268	1.61
Total		610,668	1.6

So, the total resources of Ni block Garuda CoG 1.5% can be seen in table 3 where the tonnage is 610,668/ton and the average content is 1.60%.

3.8 RKSD Resource Classification

RKSD is a relative kriging standard deviation that calculates the relative error of the estimate, the RKSD calculation parameter requires the standard deviation of the estimated value and the estimated rate. In Blackwell's research (1998), if the RKSD value (relative kriging standard deviation) is below 0.3 then it is included in the measured resource, if the RKSD value is between 0.3 to 0.5 then it is included in the designated resource, and if the RKSD value is above 0.5 it is included in the estimated resource. The RKSD equation is [15].

$$RKSD = 1.96 \cdot \left(\frac{\sigma E}{Z*}\right) \quad (2)$$

Information.
σE = Standard deviation
Z∗ = Estimated rate

Table 4. Resource classification using RKSD.

Lithology	Deviation standard	Estimation content	RKSD	Classification
Limonite	0.157079	1.55	0.19	Measured
Saprolite	0.191361	1.61	0.23	Measured

After conducting descriptive statistical analysis on the constraints of limonite and saprolite. Table 4 shows that limonite and saprolite zones with a CoG of 1.5% are classified as measurable resources because the RKSD value is below 0.3.

4. CONCLUSION

Based on the research conducted, it can be concluded that, the amount of nickel resources with CoG 1.5% obtained estimated results, tonnage 610.668 / ton and an average grade of Ni 1.60%. The classification of resources in the limonite and saprolite zones is classified into measured resources based on relative kriging standard deviation.

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