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Mapping the Distribution of Lead and Zinc In Skarn Deposit

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ABSTRACT

In Magmatic belts formed mineralization in West Java, and most of that are epithermal deposits and porphyry deposits bearing with Cu, Au, Pb or Zn. Lately, there are indication of Pb-Zn mineralization in Cihaur area, and it is a new economic discovery for Pb-Zn skarn deposit in Java Island. Geostatistics offers the ways of describing and modeling the spatial continuities of the regionalized variables and allows to integrate the inferred continuity parameters into the regression techniques used for their spatial interpolations. The experimental variogram for ordinary kriging in the horizontal direction utilized an azimuth of 135°. The fitting results of the experimental variogram for the Pb-Zn assay indicated a spherical variogram model type. The distribution map of Pb-Zn grades indicates clear mineralization zonation classified into low grade (3% – 6%), medium grade (6% – 9%), and high grade (>9%).

INTRODUCTION

Indonesia is an archipelagic country that surrounded by Ring of Fire. In addition, located at Indo-Australia plate, Eurasian plate and Pacific plate that causes high frequency of magmatic activity in Indonesia. Java Island, especially West Java has two magmatic belts, from Cenozoic magmatic belts and late Miocene-Pliocene magmatic belts (Zheng et al., (2017). Magmatic belts formed mineralization in West Java, and most of that are epithermal deposits and porphyry deposits bearing with Cu, Au, Pb or Zn. Lately, there are indication of Pb-Zn mineralization in Cihaur area, and it is a new economic discovery for Pb-Zn skarn deposit in Java Island. This research area is in Cihaur, Simpenan, Sukabumi, West Java. Based on subsurface data, skarn Pb-Zn deposit is mainly hosted by limestone, but some part of them associated with volcanics rocks (Arsah et al., 2023).

Base metal minerals found in this area are galena and sphalerite with an abundance of pyrite around it. Galena has the characteristic form of triangular pits textures with a cloudy gray color and has associated with the minerals pyrite and sphalerite. Sphalerite is identified by dark gray color with anhedral shape and isotropic. Some gaps in sphalerite were found to have been filled by native minerals like gold and silver. Galena and sphalerite are known as the carrier of valuable base metals. Galena (PbS) is the main Pb-carrier mineral in the research area, while sphalerite (ZnS) is the main Zn-carrier mineral (Laksana et al., 2023).

One of the main factors to consider when evaluating a deposit is its concentration condition (Amir et al., 2022). To determine the characteristics of laterite deposits, a systematic drilling exploration stage and grade analysis are required. These results are then visualized as a map model with the help of specialized

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software (Rahman A. et al., 2015). Therefore, this research was conducted to analyze the distribution of Pb-Zn based on grade mapping derived from drilling data. Mapping the distribution of Pb-Zn in skarn deposit is crucial for optimizing exploration in the Cibujang Project area. This allows drilling activities to be focused on the most prospective zones within the project area. Additionally, such mapping supports the development of efficient mine designs, maximizing the extraction of high value ore while minimizing waste.

METHODOLOGY

Geostatistics offers the ways of describing and modeling the spatial continuities of the regionalized variables and allows to integrate the inferred continuity parameters into the regression techniques used for their spatial interpolations. Applications of the geostatistical techniques in mining industry is cery broad and ranges from estimation of the mineral resources to assessment of the model uncertainty, quantification of the risks and determining the optimal drilling and sampling grids (Abzalov,2016).

Data Colletion

This research uses samples from the results of drilling in the Cibujang project, with data collection and processing conducted following the standards of SNI 4726:2019 and KCMI 2017 :

1. Assay data is grade sample of drilling results.
2. Collar data is coordinate and elevation data from drilling point.
3. Lithology is drilling point distribution data.
4. Survey is the total drilling depht data.

Data Processing and Data Analysis

The stages carried out in data processing in this research are as follows:

1. Combining data assay, collar, lithology and survey menggunakan microsorf excel then save file in the form of *.csv.
2. Contructing the ore body base on the upper and lower grade boundaries at each drill hole, then correlating them with one another.
3. Creating a block model base on the ore body with dimensions of 7,5 x 7,5 x 1 m.
4. Interpolation with kriging method using micromine software with variable levels of Pb and Zn. Variogram and kriging equations used in weighthing are as follows (Isaak dan Srivastava, 1989) :

$$y(h) = \frac{1}{2n(h)} \sum_{i=1}^{N(h)} [Z(x_i + h) - Z\,(X_i)]^2 \quad (1)$$

To calculate the value of the estimated point, the following formula :

$$Z^* = \sum_{i=1}^{n} W_i . Z(\,x_i) \quad (2)$$

Keterangan :

$\gamma(h)$: estimated or expeirmental semivariogram

$n(h)$: number of pairs h units apart

$Z(x_i)$: observation at site xi

$Z(x_{i+h})$: value on location (x_{i+h})

h : vector that expresses the distance between to points

Z^* : estimated value

W_i : sample weight, where $\sum_{i=1}^{n} W = 1$

$Z\,(x_i)$: sample rate

RESULT

Ore Body and Block Model

An ore body model is a method used to constrain the estimation of Pb-Zn resources within a specific population in the study area. This approach ensures that grade estimation does not involve excessive extrapolation beyond the boundaries of mineralization. The dimensions of the block model are crucial in three-dimensional (3D) estimation. This is because the block-shaped structure is designed to represent the mineral deposits at specific locations accurately.

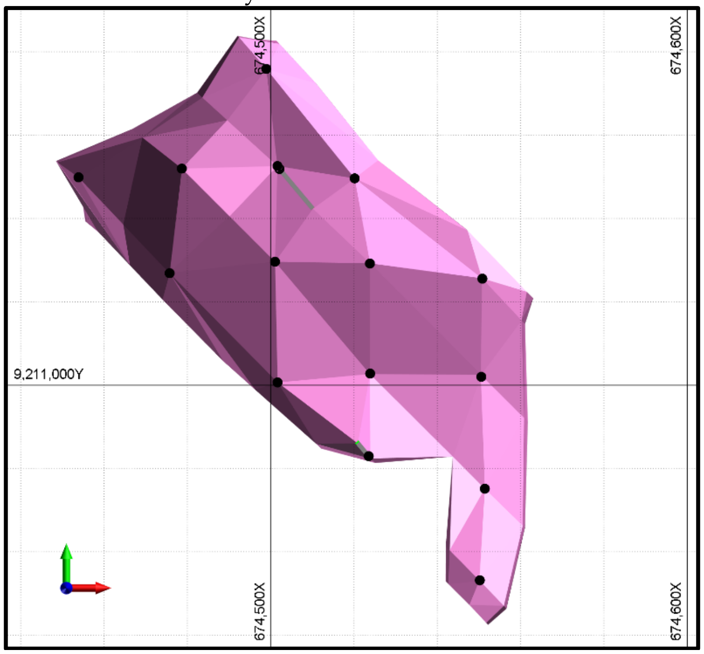

Figure 1. Ore Body

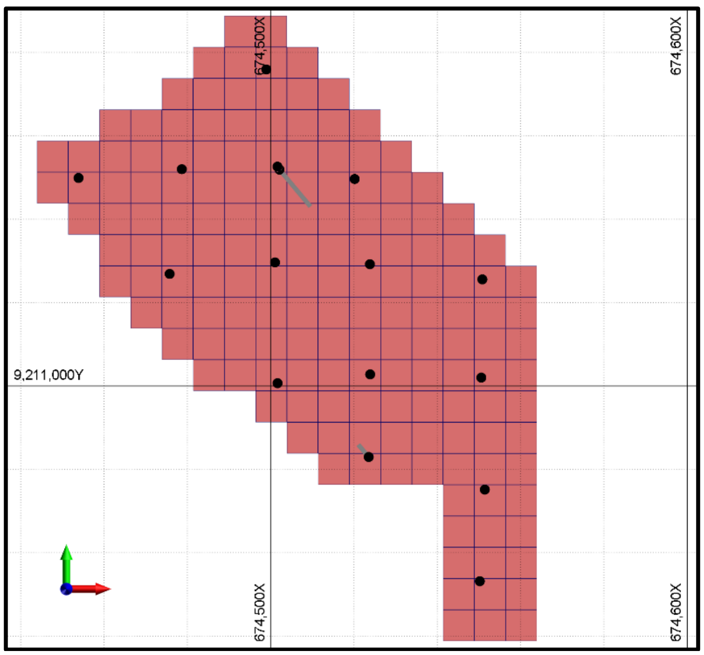

Figure 2. Block Model

Variogram

A variogram study using the ordinary kriging method was conducted with Pb-Zn assay data from the study area. The experimental variogram for ordinary kriging in the horizontal direction utilized an azimuth of 135°. The fitting results of the experimental variogram for the Pb-Zn assay indicated a spherical variogram model type.

Table 1. Variogram fitting result parameters

Nugget	Partial sill	Range	Azimuth
0.10	0.90	56	135

Ordinary Kriging

Estimation using the OK technique was carried out using the pb-zn assay database with The amount of data used in the estimation is a maximum of 16 drill point data, as well as a search area of 56 m corresponds to the range value of the selected variogram, namely spherical. InIn this research, the interpolation process was carried out using the kriging method with a variogramspherical anisotropy, and in its calculations using equations (1) and (2). Figure 1 shows the spatial distribution of Pb and Zn grades.

Table 2. Grade and tonnage

Grade	Tonnage
3-6	10.440
6-9	98.640
>9	338.940

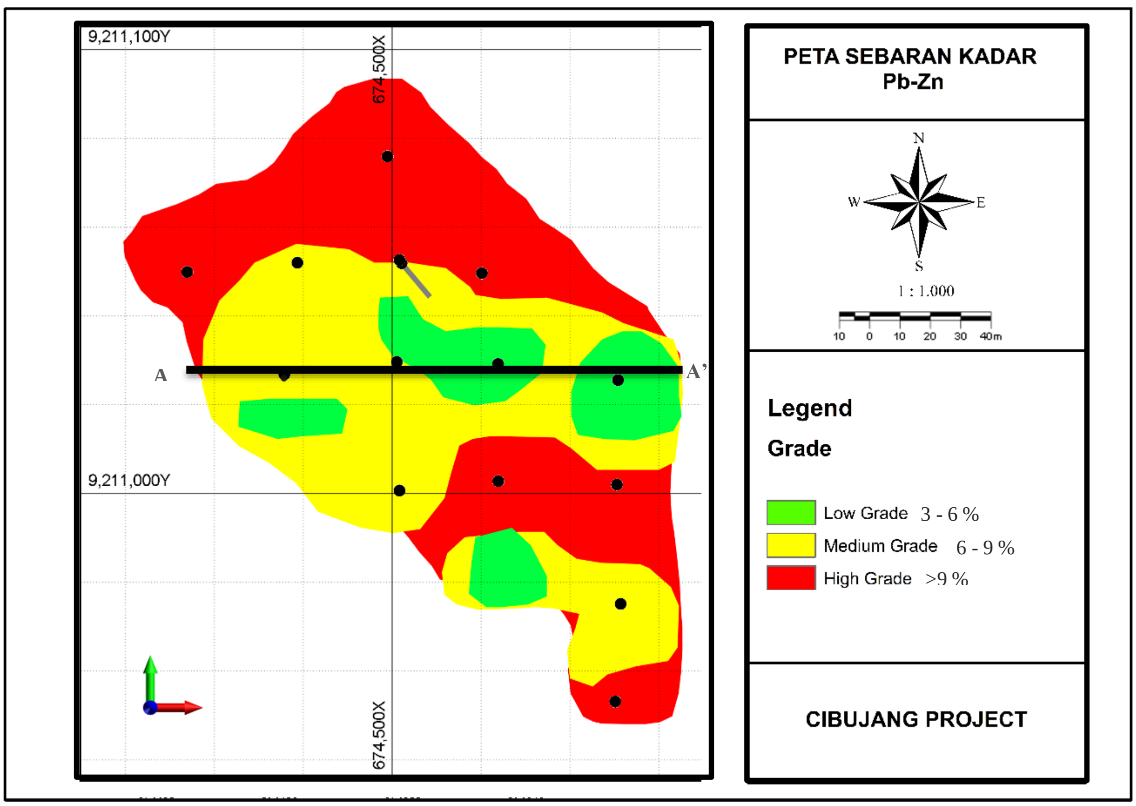

Figure 3. Distribution map of Pb-Zn grades

Low-Grade Distribution (3% – 6%) The map with green shading shows the distribution of low-grade

Pb-Zn, concentrated in the central to southeastern parts and some areas in the southwest. This distribution also mixes with the yellow zones (medium grade) in certain locations, indicating a transition between the outer alteration zone and areas with more intense mineralization. The wide extent of the low-grade distribution suggests potential additional exploration to understand the alteration zonation in the skarn deposit system.

Medium-Grade Distribution (6% – 9%) The map with yellow shading highlights the distribution of medium-grade Pb-Zn, which dominates the study area, particularly in the central, northwestern, and northeastern parts. This grade covers a larger area compared to the low- and high-grade zones, representing a major transition zone where Pb-Zn mineralization occurs with moderate intensity. The consistent pattern of medium-grade distribution indicates stable mineralization across the region, making it a key target for further exploration.

High-Grade Distribution (>9%) The map with red shading reveals that high-grade Pb-Zn is distributed relatively evenly across most of the study area, with dominance in the central to southern regions. This broad distribution suggests widespread intense mineralization, likely associated with hydrothermal processes or geological structures that facilitated the dispersion of metal-bearing fluids across a wide area. The widespread high-grade zones emphasize the significant economic potential for mining development and should be prioritized for exploration and mine planning.

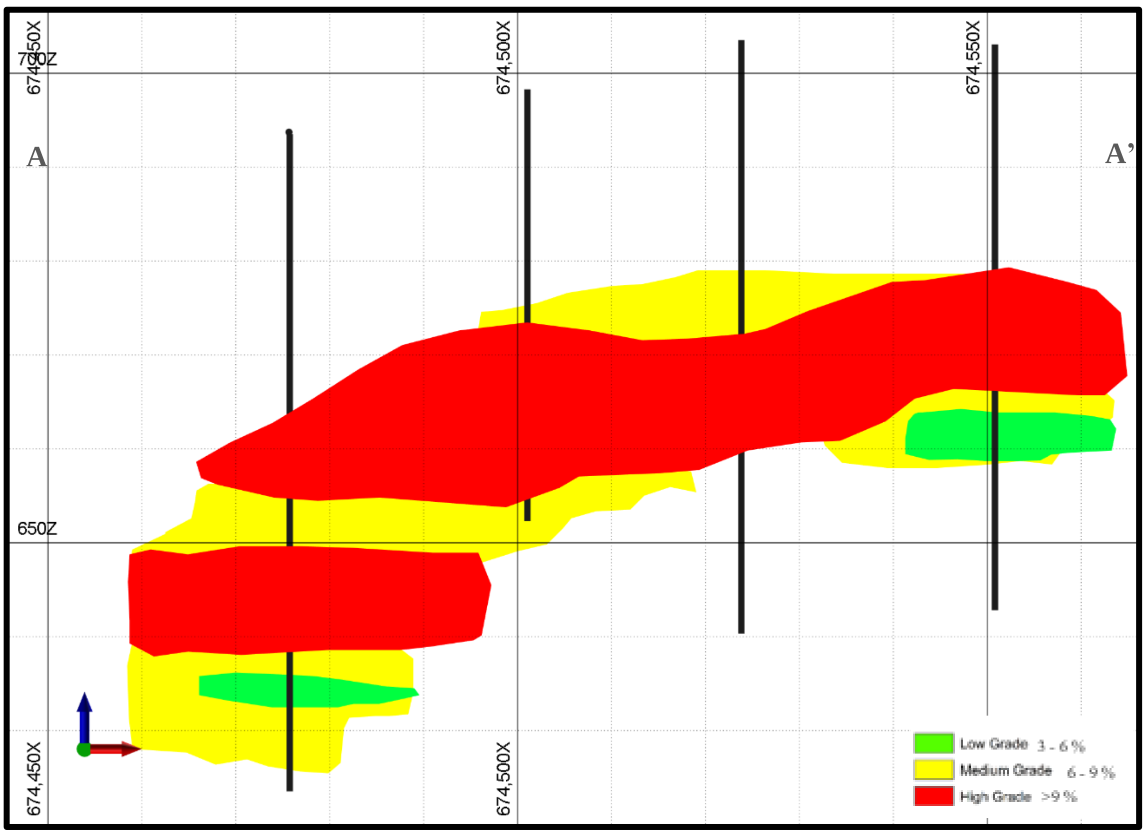

Figure 4. Section A – A'

Low-Grade Distribution (3% – 6%) The green zones represent low-grade Pb-Zn mineralization and are observed in the lower portions of the section, particularly concentrated near the southwestern and southeastern edges of the cross-section. These areas indicate zones of minimal mineralization intensity, likely corresponding to the outer alteration zones where hydrothermal activity was weaker. The presence of low-grade zones interspersed with medium-grade areas suggests a gradual transition in mineralization intensity.

Medium-Grade Distribution (6% – 9%) The yellow zones, representing medium-grade mineralization, are relatively consistent along the cross-section and are more prominent in the upper and middle portions of the section. These areas appear to act as transition zones between the low- and high-grade zones, reflecting moderate mineralization intensity. This distribution pattern suggests an environment of ongoing metasomatic processes with sufficient but not intense hydrothermal fluid flow. The medium-grade zones are widespread and form the majority of the observed mineralized areas.

High-Grade Distribution (>9%) The red zones, indicating high-grade Pb-Zn mineralization, dominate the central part of the cross-section and extend horizontally across the majority of the section. These areas are concentrated in regions closer to structural features (represented by the vertical black lines), suggesting that faults or fractures acted as pathways for hydrothermal fluids. The high-grade zones reflect intense mineralization processes and are likely associated with areas of significant fluid accumulation and favorable permeability conditions. These zones are critical targets for future drilling and mining operations due to their high economic value.

CONCLUSION

The distribution map of Pb-Zn grades indicates clear mineralization zonation classified into low grade (3% – 6%), medium grade (6% – 9%), and high grade (>9%). Low-grade Pb-Zn dominates the southeastern, southwestern, and some central areas, reflecting outer alteration zones with lower mineralization intensity. Medium-grade Pb-Zn is widely distributed, particularly in the central, northwestern, and northeastern regions, representing the main transition zone with stable mineralization. High-grade Pb-Zn is relatively evenly distributed across the study area, with notable dominance in the central and southern parts, indicating widespread intense mineralization with significant economic potential.

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