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RESEARCH ARTICLE

Rock Formation Acid Mine Drainage in Epithermal Gold Mineralization, Pandeglang, Banten Province

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Abstract

Mine acid water is acidic water and contains iron and sulfate, which is formed under natural conditions when geological strata containing pyrites are exposed to an oxidizing atmosphere or environment. One of the impacts of the mineralization zone where there is a mining process is the potential for the formation of acid mine drainage, especially in the Cibaliung gold mineralization area and its surroundings, Pandeglang Regency, Banten Province. Acid-forming sulfide minerals include pyrite (FeS2), headquarters (FeS2), picoliters (FexSx), calcocytes (CuS), covellite (CuS), chalcopyrite (CuFeS2), molybdenite (MoS), mulenite (NiS), chalocytes (CuS), covellite (CuS), chalcopyrite (CuFeS2), molybdenite (MoS), mulenite (NiS), chalocytes (CuS), covellite (CuS), chalcopyrite (CuFeS2), molybdenite (MoS), mulenite (NiS), galena (PbS)) and sphalerite (ZnS). Of all these minerals, pyrite is the most dominant sulfide in acid formation.

Alkaline mine water (alkaline mine drainage) is mine water that has an acidity level (pH) of 6 or more, containing alkalinity but still containing dissolved metals that can produce acids. The quality of mine water, acid or alkali, depends on the presence or absence of acid mineral content (sulfides) and alkaline materials in the geological strata.

Acid water formation tends to be more intensive in mining areas. This can be prevented by avoiding exposure to sulfide-containing materials in the free air. Acid-forming sulfide minerals include pyrite (FeS2), headquarters (FeS2), picoliters (FexSx), calcocytes (CuS), covellite (CuS), chalcopyrite (CuFeS2), molybdenite (MoS), mulenite (NiS), chalocytes (CuS), covellite (CuS), chalcopyrite (CuFeS2), molybdenite (MoS), mulenite (NiS), chalocytes (CuS), covellite (CuS), chalcopyrite (CuFeS2), molybdenite (MoS), mulenite (NiS), galena (PbS)) and sphalerite (ZnS). Of all these minerals, pyrite is the most dominant sulfide in acid formation. Formation of potential acidic water also occurs in tailings which are residues/processing residues containing sulfide minerals. The formation of acid mine drainage does not always develop in every sulfide-ore mining. In certain types of ore deposits, there are neutralizing agents which prevent the formation of acid mine drainage.

Keywords: Acid Mine Drainage, Ephitermal gold, Sulphide Minerals, Source Rock, Cibaliung.

1. Introduction

AAT is formed as a result of oxidation of certain sulfide minerals contained in rocks, which react with oxygen in the air in an aqueous environment (Sayoga, 2007). In the initial stages of acid mine drainage is the presence of water in a green mining pit. As a result of these mining activities, can potentially produce acid mine drainage it is necessary to consider how the impact on the surrounding community.

Control of acid mine drainage is something that needs to be done during mining activities and after mining activities end, because Acid Mine Water (AAT) can cause a decrease in the quality of water, surface water, and groundwater, in addition, if flowed into the river will have an impact on the community stay along the river and will disturb the biota that lives on land as well as the biota in the waters. Acid Mine Water (AAT) can reduce water pH from public waters so that it will kill aquatic biota.

Alkaline mine water (alkaline mine drainage) is mine water that has an acidity level (pH) of 6 or more, containing alkalinity but still containing dissolved metals that can produce acids. The quality of mine water, acid or alkali, depends on the presence or absence of acid mineral content (sulfides) and alkaline materials in the geological strata. It generally contains a lot of sulfides and contains little alkaline material that tends to form acid mine water. Conversely, materials that contain a lot of alkalies, even though they contain sulfide material with a lot of concentration, often produce alkaline water (net machine water).

2. System and Characteristics of Epithermal Deposits

Epithermal ore deposits are deposits formed in near-surface hydrothermal environments that have relatively low temperatures and pressures and are associated with sub-aerial calc-alkali magmatism.

These deposits are often found in volcanic products (volcanic sediments).

Epithermal gold deposits are highly variable in shape, from thin quartz veins to large disseminated deposited deposits, and occur in different geological environments.

3. Cibaliung Gold Mineralization Zone

The research locations are generally located in Cibaliung and surrounding areas, Kec. Cimanggu, Kab. Pandeglang, Banten Province, in particular, includes the PT Cibaliung Resource Concession which belongs to the dome and collections in the central depressive zone, West Java. The dome and the central depressive zone are mountainous regions that show dome forms. This zone is controlled by structure and lithology (Figure 1.) (Nasrudin, 2017).

There is a striking difference in structure direction between the structures in Banten Block, which is dominated by the north-south direction and Javanese structures which are dominated east-west (Nasrudin, 2018).

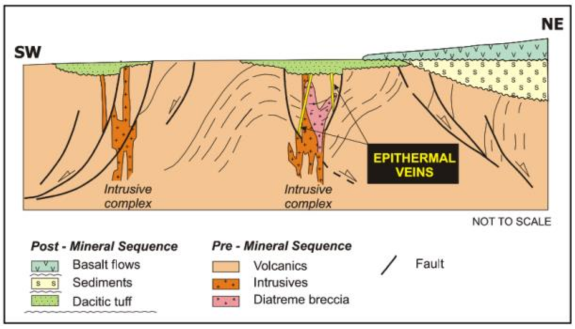

Fig 1. Schematic Cross Section Scheme of Study Area (Anonymous (c), 2004)

Mineralized zones in the concession area of PT CibaliungSumberdaya in particular, are divided into several lithology / rocks including ANDS (andesite), BRAN (basalt to andesite breccia hyaloclastite, flow, epiclastite), PAND (porphyritic andesite), VEIN (andesite), BRAN (basalt to andesite breccia hyaloclastite, flow, epiclastite), PAND (porphyritic andesite), VEIN (andesite), BRAN (basalt to andesite breccia hyaloclastite, flow, epiclastite), PAND (porphyritic andesite), VEIN (quartz vein), VNBR (breccia vein), DBSL (basalt dike) and others. For this study the focus is on lithology BRAN, VEIN and VNBR, this determination is seen based on the relatively dominant distribution of levels present in these 3 lithologies.

The results of laboratory analysis of the levels of sediment both for primary minerals and associated minerals showed the presence of 5 associated minerals, namely silver (Ag), copper (Cu), Galena (pb), Zinc (Zn), and Arsenic (As).

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In this area, mineralization is found in the form of veins called Vein Cibitung and Vein Cikoneng, both of which are characterized by quartz-sericite and adularia. The alteration zoning can be divided into silicic (dominant quartz), propylic (chlorite, epidote, carbonate, and quartz) and argillic (illite and smectite). The main metal minerals are electrum, pyrite, chalcopyrite, sphalerite, and galena, as well as other minerals in the form of tetrahedrite, argentite, polybasite and bornite, and hessite and stromeyet in small amounts.

4. Regional Stratigraphy

Stratigraphy in the study area from old to young can be grouped into four rock units Sudana, et al (1992), namely: Honje lava units (Late Miocene / 11.4 mya), Honje breccia units (Late Miocene), Cipacar tuff units (Pliocene units) Early / 4.9 mya), and alluvial deposits (Holocene - Resen) (Nasrudin, 2018).

The Cibaliung mineralization complex is found in the igneous rock complex called the Honje Formation, which is connected to the Bayah Dome by a low back of Plio-Pleistocene sedimentary rock. The Honje Formation itself is in the Late Miocene age and is dominated by igneous rocks composed of basaltic to andesitic compositions, as well as volcanic breccias that interact with sedimentary rocks.

This formation is then covered unconformably by the Cibaliung Formation which is dominated by a tactical composition (Angeles, et al (2002) in Rosana (2009)) (Figure 2).

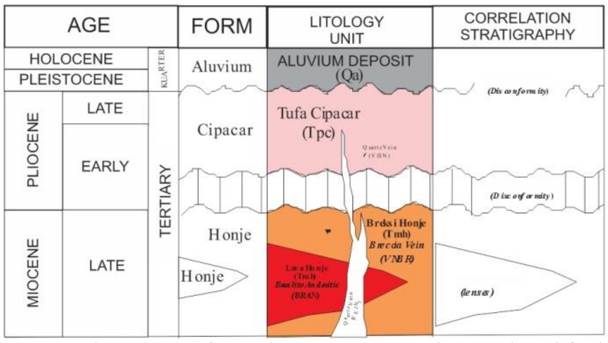

Fig 2. Rock Stratigraphic Columns at Research Sites (Modified Setiawan (2014) and Sudana, et al (1992) in Nasrudin, 2018)

5. Types of Mine Water

The type of mine water is the result of a chemical reaction that produces various species of chemical compounds that naturally degrade and result in the discovery of various types or forms of these mineral water compounds. According to Skousen and Ziemkiewicz (1996) in Said, 2014 mining water can be grouped into 5 types namely:

Mining Water Type 1
Mining Water Type 2
Mining Water Type 3
Mining Water Type 4
Mining Water Type 5

Among the types of mine water above there is the possibility of a transition type so that the appropriate data collection and analysis of metal concentrations, water pH, and oxygen status need to be done to determine the type or characteristics of mine water.

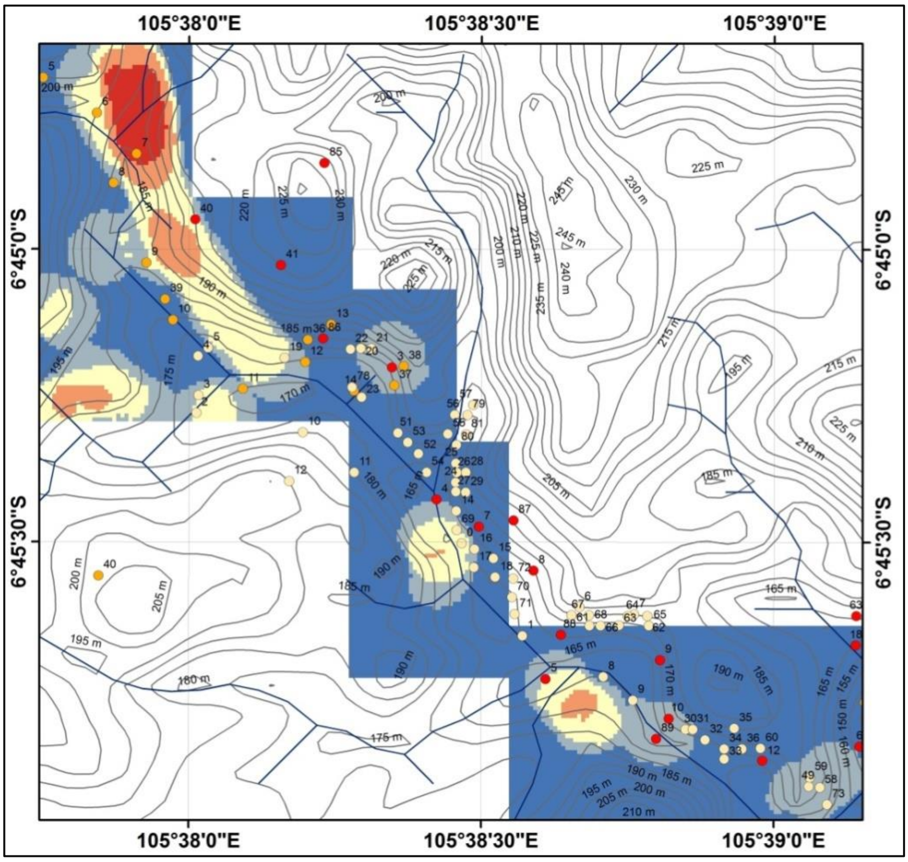

Fig 3. Vein density Zone of gold mineralization in te area of Mangku Alam, Cimanggu, Pandeglang Banten

6. Reaction Formation of Acid Mine Water

6.1 Stages of the Establishment of Mine Acid Water

Stages of the reaction process of acid mine drainage.

Phase I:

$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$

Pyrite + Oxygen + Water → Ferrous Iron + Sulfate + Acid

The first reaction is the weathering reaction of pyrite (pyrite) accompanied by an oxidation process. Sulfur is oxidized to sulfate and iron-ferrous is released.

Phase II:

$Fe^{2+} + ¼\ O_2 + H^+ \rightarrow Fe^{3+} + ½\ H_2O$

Ferrous Iron + Oxygen + Acidity → Ferric Iron + Water

The second reaction is the conversion from ferrous to ferrous ferrous materials which consume one mole of acidity. Slow reaction rate at pH <5 and abiotic conditions. Thiobacillus bacteria will accelerate the oxidation process. Thiobacillusferrooxidans is a gram-negative, acidophilic, autotrophic bacterium capable of using iron or various reduced sulfur compounds as an energy source (Vishniac in Wijayanti, 2002).

This microorganism has shown its great role in producing acid mine drainage. These microorganisms are also able to oxidize ferrous ions in ferrous form into ferries.

Phase III :

$Fe^{3+} + 3H_2O \rightarrow Fe\,(OH)_3 + 3H^+$

Ferric Iron + Water → Ferric Hydroxide (yellowboy) + Acid

The third reaction is the hydrolysis of iron. Hydrolysis is a reaction that separates water molecules. Three moles of acidity is produced from this reaction. The formation of ferric hydroxide precipitation depends on pH, ie more at pH above 3.5.

Phase IV :

$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$

Pyrite + Ferric Iron + Water → Ferrous Iron + Sulfate + Acid

The fourth reaction is the continued oxidation of pyrite by ferric iron. This is a propagation reaction that takes place very quickly and will stop if the pyrite or ferric iron runs out. The oxidizing agent in this reaction is iron-ferry.

6.2 Characteristics of Differences in Rock Formation on the Potential or Absence of Acid Mine Water.

6.2.1 Based on Average Comparison Test

In each lithology can indicate the presence or absence of differences in the value of gold content (Au) as the main mineral, so it is necessary to know whether there are differences or similarities in lithology differences or there are other factors that influence it, a quantitative analysis based on the values of the levels of the main minerals and associated minerals based on drilling assay data.

Comparative test analysis of 3 average vectors that can be used to see whether there are differences in mineral content (Au, Ag, Cu, Pb, Zn, and As) in the Breccia to Andesitic (BRAN), Quartz Vein (VEIN) and Breccia mineralized zones Vein (VNBR) is a Multivariate Analysis of Variance (Manova). For this reason, it is necessary to conduct a multivariate normality test of the data.

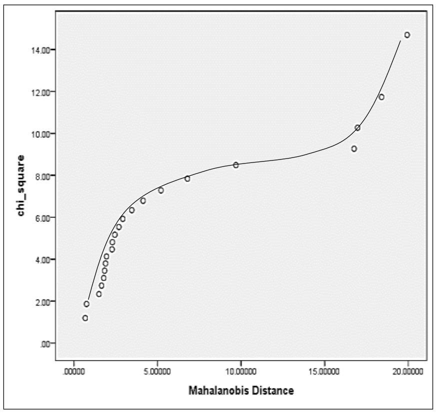

Fig 4. Plot graph between Square Distance (dj2) and the quantile value of the Chi-Square distribution of each dj2 in the BRAN Zone.

Based on the picture above, the points on the scatterplot have a pattern that tends to be exponential, so it can be said that the BRAN Zone data is not normally distributed multivariate. Next, the correlation analysis between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution is hypothesized as follows.

H0: There is no relationship between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution (Data not normally distributed multivariate)

H1: There is a relationship between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution (multivariate normally distributed data)

Table 1. Multivariate Normality Test for the BRAN Zone Data

Mineralization Zone	R	*p-value*	Result
BRAN	0,923	0,000	**There is a Correlation**

Based on table 2. above it appears that the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution have a strong relationship. So it can be concluded that the BRAN Zone data has a multivariate normal distribution.

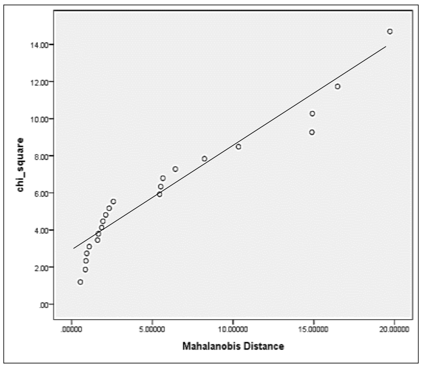

Fig 5. Plot graph between Square Distance (dj2) and the quantile value of the Chi-Square distribution of each dj2 in the VEIN Zone

Next, the correlation analysis between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution is hypothesized as follows.

H0: There is no relationship between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution (Data not normally distributed multivariate)

H1: There is a relationship between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution (multivariate normally distributed data)

The test results (Table 2.) show that the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution have a strong relationship, so it can be concluded that the VEIN Zone data has a multivariate normal distribution.

Table 2. VEIN Zone Data Multivariate Normality Test

Mineralization Zone	R	*p-value*	Result
VEIN	0,962	0,000	**There is a Correlation**

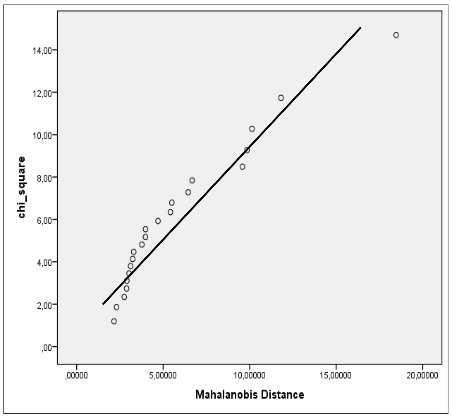

Fig 6. Plot graph between Square Distance (dj2) and the quantile value of the Chi-Square distribution of each dj2 in the VNBR Zone.

Next, the correlation analysis between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution is hypothesized as follows.

H0: There is no relationship between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution (Data not normally distributed multivariate)

H1: There is a relationship between the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution (multivariate normally distributed data)

Based on (Table 5.4) above it can be seen that the value of Square Distance (dj2) and the quantile value of the Chi-Square distribution have a strong relationship, so it can be concluded that the VNBR Zone data has a multivariate normal distribution.

Tabel 3. Data Zone of multivariate normality test VNBR

Mineralization Zone	r	*p-value*	Result
VNBR	0,962	0,000	**There is a Correlation**

Based on the results of testing multivariate normality assumptions in each mineralized zone, it can be concluded that the assumption of multivariate normality is fulfilled. Therefore, the comparison test analysis of 3 average vectors used is Multivariate Analysis of Variance (Manova).

6.3 Manova Average Comparison Test

Hypothesis testing was carried out with a significance level (α) of 5% to determine the ratio of mineral content (Au, Ag, Cu, Pb, Zn, and As) in the Breccia to Andesitic (BRAN), Quartz Vein (VEIN) and Breccia Vein mineralized zones. (VNBR) with the hypothesis formulation as follows .H0: There were no significant (significant) differences between mineral levels (Au, Ag, Cu, Pb, Zn, and As) in the Breccia to Andesitic (BRAN), Quartz Vein (VEIN) and Breccia Vein (VNBR) mineralized zones.

H1: There is a significant (significant) difference between mineral content (Au, Ag, Cu, Pb, Zn, and As) in the Breccia to Andesitic (BRAN), Quartz Vein (VEIN), and Breccia Vein (VNBR) mineralized zones.

Test criteria: Reject H0 if p-value ≤ 0.05, accept in other cases.

Based on (Table 4.) it can be seen that by using the Wilks' Lambda test statistic obtained a p-value of 0,000 <0.05, then H0 is rejected.

Table 4. Comparison Test of Average Manova

Zona	Statistical Test	F Count	*p-value*	Adjective
BRAN, VEIN, dan VNBR	*Wilks' Lambda*	6,212	0,000	**H_0Reject**

So it can be concluded that there are significant (significant) differences between mineral content (Au, Ag, Cu, Pb, Zn, and As) in the Breccia to Andesitic (BRAN), Quartz Vein (VEIN), and Breccia Vein (VNBR) mineralized zones. Furthermore, to find out which mineralized zones have different levels of minerals (Au, Ag, Cu, Pb, Zn, and As), further testing is done using T2 Hotelling.

The content of a precipitate indicates the presence of an element in the mineralized zone, where the presence of Cu, Pb, Zn and As in mineralization which could be the potential for acid mine formation in a sulfide mineralized zone.

6.4 Conclusion

There is a significant (significant) difference between mineral levels (Au, Ag, Cu, Pb, Zn, and As) in the Breccia to Andesitic (BRAN), Quartz Vein (VEIN) and Breccia Vein (VNBR) mineralized zones. Furthermore, to find out which mineralized zones have different levels of minerals (Au, Ag, Cu, Pb, Zn, and As). The content of a precipitate indicates the presence of an element in the mineralized zone, where the presence of Cu, Pb, Zn and As in mineralization which could be the potential for acid mine formation in a sulfide mineralized zone.

Mineralization which could be a potential formation of acid mine drainage in a zone of sulfide mineralization. Many parameters inside rocks and host rock to make occurrence about Mine Water Drainage. The statistical method can be to get a solution to a correlation between parameter in rocks and ore.

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