Description of the composition of gold to silver minerals in the rock containing gold

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Abstract. This study aimed to determine the composition of gold to silver minerals in rocks originating from Dongi-Dongi at 2 stations and to determine the composition of gold to silver minerals in rocks fixed to definite proportion. This study used secondary data, which were the result of rock analysis from Dongi-Dongi. The analysis showed that the gold composition from the three samples at Station 1 ranged from 0.01 to 0.99%, and the composition of silver ranged from 0.02 to 1.46%. While the composition of gold at Station 2 ranged from 0.01 to 2.55%, and the composition of silver ranged from 0.07 to 3.02%. The results of the similarity analysis test of two variances and more than two variances showed that the composition of gold to silver has the same ratio in each sample, with $F_{\text{count}} < F_{\text{table}}$, then $H_0$ is accepted. Therefore, it can be concluded that the ratio of gold to silver in each sample is the same, and follows the Law of Definite Proportion as stated by Proust that a chemical compound consists of elements with a mass ratio always remains the same. In other words, each sample or compound has a fixed composition of elements

1. Introduction

Indonesia is an archipelago country that has abundant natural resource potential, both natural and non-biological natural resources. This is because, geologically, Indonesia is an area with many ancient mountains or hills. In addition to fertile soil, mountains and hills in Indonesia also produce much gold, silver, copper, iron, and other metal mineral deposits [1].

Minerals are defined as naturally occurring inorganic solids, which consist of chemical elements in certain ratios, where the atoms in them are arranged in a systematic pattern. The presence of minerals is generally found in areas with heavy terrain, high and steep mountains, and heavily forested [2]. Furthermore, minerals found all around us and can form as rock, soil, or sand deposited on the riverbed [3].

Rocks are solid objects that are naturally formed and composed of minerals or mineraloids. These elements are arranged into a single unit so that in the rock, it does not limit to one element, but there are many elements contained in the rocks. This rock is divided into three parts which are distinguished based
on its formation process namely igneous rocks, sedimentary rocks, and metamorphic rocks [4]. Rocks found in the earth's crust contain various kinds of minerals that are useful for humans such as gold, copper, silver, and others.

Gold is a precious metal that is widely used and has an important role in human life. Gold is included in the group of precious metals because of its presence on earth which is rare and has certain specific properties [5]. Gold is a metal that is soft, malleable and hardness ranges from 2.5 - 3 on the Mohs’ Scale [6], and its density depends on the type and content of other metals that combine with it [7]. Some gold ores have been known to contain several other metals in various amounts [8].

Gold-bearing minerals are usually associated with gangue minerals. These associated minerals are generally quartz, carbonate, tourmaline, fluor spar, and small amounts of non-metallic minerals. In the gold ore, there are usually various sulfide minerals such as pyrite, galena, arsenopyrite, chalcopyrite, covellite, and calcocites [9]. Gold-bearing minerals are also associated with oxidized sulfide deposits. Gold-bearing minerals consist of native gold, telluride gold, and a number of alloys of gold compounds with sulfur, antimony, and selenium elements [7]. Gold is often obtained in the form of telluride (AuTe$_2$) and sylvanite (AuAgTe$_4$) mineral compounds [10].

Separation of gold from rocks in nature is an interesting study because gold is a precious metal with a high economic value [11]. The economic potential can be seen from the mining activities on a large scale and its achievement on the national distribution with high selling prices. Until recently, the gold economy is considered as a significant foreign exchange earner on the globe [12].

Mining is one of the livelihoods of the Indonesian population. Mining is carried out by humans by digging, taking, and processing natural resources contained in the bowels of the earth to meet some human needs [13]. Traditional and small-scale gold mining known as ASGM (Artisanal and Small Scale Gold Mining) is a side job done by the community with the main livelihood as farmers to improve their standard of living and generally happens in rural areas [14].

One of the provinces in Indonesia which has the potential of rich natural resources, minerals, and energy is Central Sulawesi. Some areas in Central Sulawesi that have gold potential are Palu City and Donggala Regency where there are several places such as Poboya, Watutempe, Watutela, and Balaesang. In addition, there are also in Parigi Moutong District, Sausu District, Buol Regency, Toli-Toli Regency, and Poso Regency. This can be seen by the existence of traditional miners in the area.

However, some areas still carry out mining activities illegally or without permission from the local government. This clearly violates the legal provisions because according to Law Number 4 the year 2009 concerning Mineral and Coal Mining, mining can operate on the condition that it has a Mining Business License (IUP) [15].

Dongi-Dongi is one of the areas where people conduct illegal mining activities. So that, the Central Sulawesi Regional Police anticipated this case directly. To prove the existence of gold at the mining site, the rocks contained in Dongi-Dongi the analyzed by PT. Sucofindo to find the gold content contained in these rocks. Besides the element of gold, there are other elements such as silver, copper, zinc, lead, and iron. The composition of elements contained in a rock has a fixed mass ratio.

In 1799 Joseph Louis Proust discovered an important property of compounds called the constant proportion law. Based on his research on various compounds, Proust concluded that the mass ratio of the elements in a compound was certain and fixed. The same compound, which comes from different regions or is made in different ways, has the same or permanent composition. This can be proven in an experiment on the salt analysis (NaCl) from various regions, namely Indramayu and Madura. The results of the salt analysis show that the mass of Na and Cl elements in the two regions has a fixed mass ratio of 1:1.54 [16].

The purpose of this study is to describe the composition of gold and silver minerals in gold-containing rocks.
2. Method

The type of research used in this study is descriptive research. The source of the data is secondary data which is the result of rock content analysis from Dongi-Dongi, obtained from the Central Sulawesi Regional Police Directorate of Special Criminal Investigation.

The population of this research is data of gold and silver content in rocks originating from Dongi-Dongi at 2 stations. While the sample used is the entire population, the data used as samples are grouped into 3 parts.

2.1. Data analysis

The data analysis used in research is two variance similarity test and similarity test for more than two variances (Bartlett’s test).

2.2. Gold and silver mineral composition in rocks

The composition is the ratio between a substance and the whole mixture. The percentage of composition is the percentage of the mass of each element contained in a compound. The percentage of this composition is obtained by dividing the mass of each element in 1 mole of the compound by the molar mass of the compound multiplied by 100 percent. Mathematically, the percent composition of an element in a compound can be written as [17]:

\[
\text{The percentage of an element composition} = \frac{n \times \text{element molar mass}}{\text{compound molar mass}} \times 100\%
\]

2.3. Test for the Equality of Two Variances (F-Test)

The F-test is used in this study to determine whether the composition of gold and silver in rocks has the same ratio in each sample. The F test formula is as follows:

\[
F_{\text{count}} = \frac{\text{The largest variance}}{\text{The smallest variance}}
\]

In this research, the variance is the ratio of gold to silver in each sample. To test whether the two variants are homogeneous or not, then the $F_{\text{count}}$ is compared with the $F_{\text{table}}$. On condition that $F_{\text{count}} < F_{\text{table}}$, then $H_0$ is accepted, and means that both groups have the same or homogeneous variants. On the other hand, on condition that $F_{\text{count}} > F_{\text{table}}$, then $H_0$ is rejected or $H_a$ is accepted [18].

2.4. Test for the equality of more than two variances (Bartlett’s Test)

The Bartlett test is also used to find out whether the composition of gold and silver in rocks has the same or homogenous. The formula of the Bartlett’s test is:

\[
\chi^2_{\text{count}} = (\ln 10)\{B - \Sigma(n-1) \log s_i^2\}
\]

With the test criteria that if $X^2_{\text{count}} < X^2_{\text{table}}$, for the significance level of $\alpha = 0.05$ and df=k-1 then the data are homogenously distributed [19].

3. Result and Discussion

3.1. Data Description

The Rock data that was analyzed in this study are from Dongi-Dongi, Poso Regency. Several locations in the Dongi-Dongi Lore Lindu National Park were rock samples taken for the analysis. Thus, from the results of the analysis 2 data groups were obtained, namely Station 1 and Station 2. Each group consisted of 3 samples. The sample is the sampling location. At each location there are several rock picking points. The chemical elements analyzed in this study are Gold (Au) and Silver (Ag).

3.2. Gold and silver mineral composition in rocks

In this study the first procedure performed was analyzing the composition of gold and silver minerals in rocks. To determine the composition, the concentration data of each element that has been known is
processed by calculating the percentage of gold and silver minerals in each sample that has been determined. Hence, the results of the percentage of gold and silver minerals are obtained as depicted in Tables 1 and 2.

Table 1. The Percentage of Gold and Silver Mineral Composition in Station 1

| No | X1  | X2  | X3  |
|----|-----|-----|-----|
|    | Au(%) | Ag(%) | Au(%) | Ag(%) | Au(%) | Ag(%) |
| 1  | 0.73  | 0.56  | 0.28  | 0.24  | 0.11  | 0.12  |
| 2  | 0.95  | 1.46  | 0.5   | 0.34  | 0.13  | 0.19  |
| 3  | 0.83  | 0.96  | 0.39  | 0.59  | 0.04  | 0.09  |
| 4  | 0.77  | 0.62  | 0.35  | 0.3   | 0.06  | 0.02  | 0.02  |
| 5  | 0.99  | 0.44  | 0.26  | 0.15  | 0.02  | 0.02  |
| 6  | 0.91  | 0.59  | 0.59  | 0.49  | 0.02  | 0.05  |
| 7  | 0.01  |       |       |       | 0.04  |       |
| 8  |       | 0.06  |       |       | 0.06  |       |
| 9  |       | 0.02  |       |       | 0.16  |       |
| Σ  | 5.18  | 4.63  | 2.37  | 2.11  | 0.47  | 1.35  |
| x  | 0.86  | 0.77  | 0.40  | 0.35  | 0.05  | 0.15  |

Based on Table 1, the gold and silver mineral composition for Station 1 consists of 3 samples, namely Sample I for X1, sample II for X2 and sample III for X3. The three samples have a gold composition with percentage values ranging from 0.01% - 0.99% while the silver composition of the three samples has a percentage value of 0.02% - 1.46%. So, the average value of gold and silver for sample I is 0.86% and 0.77%, sample II is 0.40% and 0.35%, and for sample III is 0.05% and 0.15%. From the average value it can be seen that in sample I and II the composition of gold has a higher percentage value compared to the composition of silver, while in sample III the composition of gold has a percentage value lower than the composition of silver. These data can be seen in Figure 1.

![Figure 1. The Graph of Gold and Silver Mineral Composition in Station 1](image)

Table 2. The Percentage of Gold and Silver Mineral Composition in Station 2

| No | X1  | X2  | X3  |
|----|-----|-----|-----|
|    | Au(%) | Ag(%) | Au(%) | Ag(%) | Au(%) | Ag(%) |
| 1  | 2.55  | 1.75  | 0.22  | 0.32  | 0.18  | 0.83  |
| 2  | 2.33  | 2.12  | 0.5   | 0.44  | 0.14  | 0.14  |
| 3  | 2.36  | 2.06  | 1.2   | 0.68  | 0.05  | 0.07  |
| 4  | 1.53  | 3.02  | 1.25  | 2.94  | 0.01  | 0.06  |
From Table 2, it can be seen that the results of the composition of gold and silver for the three samples that have a gold composition with a percentage value ranging from 0.01% - 2.55% while the composition of silver has a percentage value between 0.07% - 3.02%. The average value of the composition of gold the three samples were 2.16%, 0.87% and 0.08%. While the average value of the composition of silver of the three samples is 2.01%, 1.03% and 0.21%. Based on the average value, it can be seen that in sample I gold has a composition that is higher than the composition of silver. Furthermore, sample II and III silver have a higher composition than gold. The data are shown in Figure 2.

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|    | X1  | X2  | X3  |
|----|-----|-----|-----|
| 1  | 1.30| 1.17| 0.92|
| 2  | 0.65| 1.47| 0.68|
| 3  | 0.86| 0.66| 0.44|
| 4  | 1.24| 1.17| 0.10|
| 5  | 2.25| 1.73| 1.00|
| 6  | 1.54| 1.20| 0.40|
| 7  |     |     | 0.25|

3.3. The ratio of gold to silver in rocks
The second step taken in this study is to determine the ratio of gold to silver in rocks. The way to determine the ratio of gold to silver is the composition of gold minerals divided by the composition of silver minerals, so that the ratio of gold to silver is obtained in each sample as described in Table 3.

Table 3. Results of Calculation of the Golden to Silver Ratio at Station 1
Based on Table 3 the composition of gold to silver minerals for Station 1 has a ratio that is in sample I range from 0.65 to 2.25, sample II ranges from 0.66 to 1.73 and sample III ranges from 0.10 to 1.00. Then the three samples have an average ratio value in a row that is 1.31, 1.23 and 0.55. Analyzing the average value, it can be concluded that the composition of gold to silver in sample I has a higher ratio than sample II and sample III.

The ratio of the composition of gold to silver at station 2, namely in sample I ranged from 0.51-1.63, sample II ranged from 0.43-1.76 and sample III ranged from 0.17-1.00. The average value of each sample is 1.15, 1.11, and 0.55, respectively. Based on the average value, it can be seen that sample I has a higher ratio than sample II and III, as shown in Table 4.

| No | X1  | X2  | X3  |
|----|-----|-----|-----|
| 1  | 1.46| 0.69| 0.22|
| 2  | 1.10| 1.14| 1.00|
| 3  | 1.15| 1.76| 0.71|
| 4  | 0.51| 0.43| 0.17|
| 5  | 1.63| 1.52| 0.78|
| 6  | 1.09|    | 0.43|
|    | \(\sum\) | 6.93| 5.53| 3.30|
|    | \(\bar{x}\) | 1.15| 1.11| 0.55|

3.4. Test for the equality of two variances

The similarity test of two variants is used to find out whether the two groups have differences in variance or not. A population is said to be no difference on condition that \(F_{\text{count}} < F_{\text{table}}\).

Based on the information gained about the ratio of gold to silver mineral, the next step is to analyze the data using the two-variance similarity test. So, this test can determine whether the composition of gold to silver in each sample has the same or different ratio. The similarity test results of the two variances can be seen in Table 5.

| No | Sample    | \(F_{\text{count}}\) | \(F_{\text{table}}\) | Result  |
|----|-----------|-----------------------|----------------------|---------|
| 1  | I and II  | 2.25                  | 5.05                 | Homogenous |
| 2  | II and III | 1.08                  | 4.82                 | Homogenous |
| 3  | I and III | 2.07                  | 3.69                 | Homogenous |

According to the table 5, the result of the equality test is that for the significance level of \(\alpha = 5\%\), from the sample I and II, the variances gained are 0.27 and 0.12 respectively so that the result of equality test of the two variances is \(F_{\text{count}} = 0.27/0.12 = 2.25\) and \(F_{(0.05)(5,5)} = 5.05\). From the sample II and III, the variances gained are 0.12 and 0.13 respectively so that the result of equality test of the two variances is \(F_{\text{count}} = 0.13/0.12 = 1.08\) and \(F_{(0.05)(5,8)} = 4.82\). On the other hand, from the sample I and III, the variances gained are 0.27 and 0.13 respectively so that the result of equality test of the two variances is \(F_{\text{count}} = 0.27/0.13 = 2.07\) dan \(F_{(0.05)(5,8)} = 3.69\). The value of
\( \text{F}_{\text{count}} < \text{F}_{\text{table}} \), it can be concluded that the ratio of gold to silver on each sample is the same or homogenous.

**Table 6.** The result of the equality test for two variances for station 2

| No | Sample       | \( \text{F}_{\text{count}} \) | \( \text{F}_{\text{table}} \) | Result     |
|----|--------------|-------------------------------|------------------------------|------------|
| 1  | I and II     | 2.21                          | 5.19                         | Homogenous |
| 2  | II and III   | 3.1                           | 5.19                         | Homogenous |
| 3  | I and III    | 1.4                           | 5.05                         | Homogenous |

According to the table 6, the result of the equality test is that for the significance level of \( \alpha = 5\% \), from the sample I and II, the variances gained are 0.14 and 0.31 respectively so that the result of equality test of the two variances is \( \text{F}_{\text{count}} = 0.31/0.14 = 2.21 \) and \( \text{F}_{(0.05)(5,4)} = 5.19 \). From the sample II and III, the variances gained are 0.31 and 0.10 respectively so that the result of equality test of the two variances is \( \text{F}_{\text{count}} = 0.31/0.10 = 3.1 \) and \( \text{F}_{(0.05)(4,5)} = 5.19 \). On the other hand, from the sample I and III, the variances gained are 0.14 and 0.10 respectively so that the result of equality test of the two variances is \( \text{F}_{\text{count}} = 0.14/0.10 = 1.4 \) and \( \text{F}_{(0.05)(5,5)} = 5.05 \). The value of \( \text{F}_{\text{count}} < \text{F}_{\text{table}} \), it can be concluded that \( \text{H}_0 \) is accepted or the ratio of gold to silver on each sample is the same or homogenous.

### 3.5. Test for the equality of more than two variances (Bartlett’s Test)

Bartlett’s test is also used to determine whether the population has the same variance or not. A population is said to be no difference if \( \text{F}_{\text{count}} < \text{F}_{\text{table}} \). Bartlett’s test is used for data on more than two variances.

In this test using 6 samples, taken from groups I and II that have been analyzed previously using the two-variance similarity test. So, the results of the Bartlett test can be seen in Table 7.

**Table 7.** The Result of Bartlett’s Test

| Sample | Df | 1/df | \( S_i^2 \) | \( \log S_i^2 \) | df \( \log S_i^2 \) |
|--------|----|------|-------------|-----------------|-----------------|
| 1      | 5  | 0.2  | 0.27        | -0.56           | -2.8            |
| 2      | 5  | 0.2  | 0.12        | -0.92           | -4.6            |
| 3      | 8  | 0.125| 0.13        | -0.88           | -7.04           |
| 4      | 5  | 0.2  | 0.14        | -0.85           | -4.25           |
| 5      | 4  | 0.25 | 0.31        | -0.5            | -2              |
| 6      | 5  | 0.2  | 0.1         | -1              | -5              |
| Total  | 32 | 1.175| 1.07        | -4.71           | -25.69          |

Based on table 7, the calculation results are obtained with a combined variance value of 0.16, and the combined variance logarithm price \( \text{Log} \ S^2 \) = -0.79. so that the value of \( B = -25.28 \) is obtained. From the B value, the value of \( x^2 \text{count} = 0.94 \) is obtained, with the value of \( x^2 \text{table} = 11.1 \) for the significance level of 5\% and degrees of freedom (df) = 5. The value of \( x^2 \text{count} < x^2 \text{table} \) then \( \text{H}_0 \) is accepted. Therefore, it can be concluded that the six populations come from homogeneous or equal variance. That way all samples that have been tested have the same composition of gold and silver.

### 4. Conclusion

Based on the research results the composition of gold and silver in rocks originating from Dongi-Dongi in various places, namely the composition of gold at station 1 of the three samples ranged from 0.01 to 0.99\%, and the composition of silver ranged from 0.02-1.46\%. In addition, the composition of gold at station 2 of the three samples ranged from 0.01 to 2.55\%, and the composition of silver had a percentage value ranging from 0.07-3.02\%. From the results of the analysis of the similarity test of two variances and more than two variances shows that the composition of gold to silver has the same ratio in each
sample, which is marked with $F_{\text{count}} < F_{\text{table}}$, $H_0$ is accepted so it can be concluded that the ratio of gold to silver in each sample is the same or homogenous. Thus, the composition of gold and silver in the rock applies the constant proportion law. As stated by Proust that a chemical compound consists of elements with a mass ratio that always remains the same. In other words, each sample or compound has a fixed or equal composition of elements.

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