Study of Alteration Geochemistry and Mineralization in the Jawara Field, Jember Regency, East Java Province

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Abstract. The Jawara Field in Jember Regency is a location where it is indicated that there are precious metal deposits in the form of porphyry type Gold and Copper. In this study, the focus is more on the search for metal mineral deposits related to the elements of Gold (Au) and Copper (Cu), namely the metal mineral chalcopyrite (CuFeS2) as the main carrier minerals for Au, Cu, Ag, as impurities. The results of alteration products in the form of weathered minerals are also the focus of research. The analysis used to detect metallic element content and the presence of metallic and non-metallic minerals is by petrographic analysis, mineragraphy analysis, sediment grain analysis and geochemical analysis. Based on the results of the mineragraphy analysis, it was proven that the metal mineral chalcopyrite was found in the JAFA 6 BPS sample which is a carrier mineral for the metallic copper element and silver was also found in JAFA 2 ALT. In addition, the results of the sediment grain analysis also found metal mineral grains and metal elements, namely copper and iron elements in all JAFA samples. The results of petrographic analysis show that the weathered minerals in the form of kaolinite, alunite, and smectite are products of hydrothermal alteration activities. Based on these results, the research area is divided into 3 alteration zones, namely potassic, propylitic, and argillic alteration zones. The results of the geochemical analysis showed that the highest levels of copper were found in JAFA 5 as much as 13.9 ppm and the highest levels of iron in JAFA 6 were 390.8 ppm. From the results of the analysis, it can be concluded that it is true that there are metal mineral deposits and metal elements in the form of sediment grains and porphyry-type Au and Cu elements.

1. Introduction
Along with the times, the need for information regarding the prospect of mining materials is very necessary to support the sustainability of mining activities and academic activities, namely research. Exploration of minerals is carried out as an initial activity in digging various information data regarding deposits of mining minerals. There is potential for minerals based on information from previous research that in Jember Regency there is a potential for porphyry type Au, Cu ore deposits. There are many things must be done in mapping and determining the results to be obtained from an area of mineral deposits, one of which is the study of geochemical alteration. This activity is considered quite easy to dig up information and can prove that there are deposits of minerals, especially in deposits of porphyry type Au and Cu elements. Where in this study aims to find a variety
of rocks, minerals, and metals related to the elements Au, Cu, and map the alteration zones that occur at that location.

The purpose and objective of this research are to study and describe the presence of minerals and metal elements as well as to determine the distribution of metal content and alteration zones of weathered minerals in the study area. In addition, the geomorphological conditions of the research area are also important for assessment.

This research was conducted in the Jawara Field, Jember Regency, East Java Province. Administratively, Jember Regency is part of East Java Province, located ± 200 km to the east of Surabaya. Geographically, it is located at 1130 15’ 47” to 1 140 02’ 35” East Longitude and T 58’ 06” to 80 26’ 33’ 44” South Latitude. [1].

The administrative boundaries of Jember Regency are as follows:
1. To the North: Bondowoso and Probolinggo.
2. To the East: Banyuwangi.
3. To the West: Lumajang.
4. To the South: The Indonesian Ocean.

Where in this Jawara Field it is indicated that there is a porphyry type of Au, Cu ore deposits originating from several volcanic intrusions in the past which are now sedimented until the cones have disappeared from the mountain.

Figure 1. Research area achievement map

2. Geological settings
Tectonically, the Southern Mountain Zone of Java is a magmatic arc formed from the subduction of the Indian-Australian Plate and the Asian Plate during the Late Oligocene - Early Miocene. The magmatic arc stretches from west to east along the island of Java.

The rock arrangement of the Eastern Southern Mountain Zone, especially in Sheet Jember, Java from oldest to youngest is the Merubetiri Formation, Batuampar Formation, Sukamade Formation, Granodiorite Breakthrough Rock, Dioarite, Dacite, Puger Formation; My Mandi Formation; Argopuro Formation, Bagor Formation, Kalibaru Formation, Raung Volcanic Rocks and Quaternary Alluvial Deposits [2]. There are three rock formations in the study area: [3]
a. Batuampar Formation
The Batuampar Formation is characterized by alternating sandstone and claystone with intercalations of tuff, breccia, and conglomerate and is generally well layered. The distribution of this formation is in the middle, southeast, and east around the north and east slopes of Mount Merubetiri and several hills in the southwest. The best outcrops are along the Batuampar River. This formation is thought to be of Late Oligocene-the early Middle Miocene age. Thickness is estimated not more than 500 m. This formation was deposited in an open shallow marine environment and intermingled with the Merubetiri Formation.

b. Intrusive Rock
Dacite, diorite, granodiorite are rocks that are influenced by breakthroughs, generally from Oligo-Miocene to early Miocene, especially the Mandalika Formation, while not at all in the Middle Miocene. The breakthrough is estimated to have taken place at the end of the Early Miocene, which is before the sedimentation of the limestones of the Wonosari Formation. Diorite and dacite breakthroughs generally take the form of stocks. This Oligo-Miocene breakthrough rock can be compared to the Besole Formation.

c. Alluvium
The alluvium unit consists of mud, sand, gravel, and boulders resulting from river deposition. Spatial Volcanic Rocks, Argopuro Fan Deposits, and Alluvium are deposited which are bounded by erosion fields. The Holocene age is appropriate for these three deposits.

Figure 2. Geological Map of the Jawara Field modified from the Jember map sheet [4]

3. Methodology

3.1. Methods
The preparation stage is carried out by studying theories from the literature related to geochemical exploration, hydrothermal alteration, types of metal deposits. In addition, the need for tools for research is also needed such as GPS, Compass, Geological Hammer, Pan, and Sample Bags.

The field research phase includes two ways to be carried out by direct observation; rock sampling with chip sampling and stream sediment methods. Rock samples taken can be in the form of fresh rock, as well as scale samples from direct outcrops as well as water and sand obtained from sediment streams in rivers. Then, laboratory analysis is carried out, namely the activity of analyzing samples obtained from the results of exploration and sampling in the field. The analyzes to be carried out are petrographic analysis, mineragraphy analysis, sediment grain analysis, and geochemical analysis.
3.2. Materials
The data collection process was carried out in the Jawara Field, Jember Regency, East Java Province. Field data collection is carried out at certain locations that have been mapped through the research route. There are four sampling locations, namely JAFA 1, JAFA 2, JAFA 5, JAFA 6, and one literature sample from other locations.

![Research geological trajectory map](image)

**Figure 3.** Research geological trajectory map

3.3. Geomorphological Observations
By observing the morphology of the research area, the shape of rivers, valleys, mountains, and others that support the making of geomorphological maps.

![Geomorphological observations](image)

**Figure 4.** Geomorphological observations

3.4. Stream Sediment
By taking the fraction of sand-sized sediment, silt-clay by holding the fraction using a sample bag until the appropriate sample is obtained. The purpose of this method is to capture metal grains and metal-carrying minerals in the form of fine grains.
3.5. Chip Sampling
By collecting rock chips that are broken through a path (with a width of 15 cm) that cuts through the mineralized zone using a hammer or chisel. Sampling was carried out at each location point and samples were considered suitable and prospects for analysis were taken.

The samples taken in each method used are a minimum of 5 to 10 samples. With the realization for laboratory analysis, a total of 9 samples were used for petrographic analysis, 8 samples for mineragraphy analysis, and 4 samples for sediment and geochemical grain analysis.

The sample that will be used for the previous analysis will be prepared first. For petrographic analysis samples, preparations were made, namely, thin incisions were made by special agencies, for mineragraphy analysis preparations were made, namely made into polished incisions by researchers, for sediment grain analysis samples, preparations were carried out, namely separating coarse and large grains to obtain silt clay, and for geochemical analysis, the metal element grains are separated from the sediment grain analysis which will be weighted to determine the metal element content.

4. Result

4.1. Geomorphological Mapping
Mapping was carried out at the research location with a 1:50,000 scale map with an emphasis on the types of geomorphological units, landforms, river flow patterns, and land use. Based on the results of research on the geomorphology of the study area, the results obtained (figure 7 and table 1):

1. Geomorphological Unit
   a. Anoman Mountain Structural Unit
   b. Gundil Highlands Unit
   c. Sanen Mountain Structural Unit
   d. Maskumambang Mountains Structural Plain
   e. Alluvial Lowlands
Jawara District is generally an area of hills and alluvial plains which are dominated by dense and loose contour patterns. The flow pattern is dendritic with the lithology of alternating sandstone, claystone, and tuff with a folded structure that forms valleys and ridges. The movement of the Eurasian and Indies-Australian tectonic plates causes the formation of high and low morphology [5].

![Jawara field geomorphological map](image)

**Figure 7.** Jawara field geomorphological map

| Table 1. Geomorphological Observation and Analysis Results |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Unit Morphology | Anoman Mountain Structural Unit | Gundil Highlands Unit | Sanen Mountain Structural Unit | Maskumbang Mountains Structural Unit | Alluvial Lowlands |
| Colour | The spreading | 15% | 10% | 30% | 25% | 20% |
| Highest Point | 800 mdpl | 450 mdpl | 950 mdpl | 850 mdpl | 50 mdpl |
| Lowest Point | 175 mdpl | 100 mdpl | 125 mdpl | 75 mdpl | 25 mdpl |
| Height Difference | 675 mdpl | 350 mdpl | 825 mdpl | 775 mdpl | 25 mdpl |
| Flow Pattern | Radial | Radial | Rectangular | Dendritic | Dendritic |
| Valley Shape | U | V | V | V | V |
| Compiling Lithology | Alternating Sandstone and Claystone, Conglomerate, Andesite, Volcanic Breccia | Volcano Breccia and Tuff Breccia | Sandstone, Claystone, Breccia, Conglomerate, Andesite Breccia | Limestone, Sandstone, Claystone, Tufan, Napal | Gravel, Gravel, Sand and Mud |
| Endogenic Process Structure | Appointment, Frustration Fault | Appointment Fault | Appointment, Frustration Sliding Fault | Fault | Appointment |
| Usage | Plantation, Forest | Rice Fields, Farms | Forest | Plantations, Rice Fields | Settlement, Plantation |
2. River Flow Pattern
At the research location, precisely in the JAFA 1, 2, 5, and 6 areas, the drainage pattern is dendritic, which is a river flow pattern whose flow pattern is branched like tree branches (figure 8). Dendritic flow patterns are generally controlled by a complex or homogeneous rock lithology. This kind of flow pattern may have a river texture/density which is controlled by the type of rock depending on whether or not the rock is resistant to erosion [6].

![Figure 8. River flow pattern map](image)

4.2. Laboratory Analysis
Laboratory analysis in this research was carried out at the Mining Engineering laboratory and the Geological Engineering laboratory at the Adhi Tama Institute of Technology Surabaya. Divided into three analyzes carried out namely petrographic analysis, mineragraphy analysis, and analysis of sediment grains which have their respective analytical functions. The purpose of this analysis is to obtain results from a collection of minerals, metals, elements obtained from rock sampling, and sedimentary deposits during exploration in the field.

1. Petrographic Analysis
Based on the results of the petrographic analysis, the variety of minerals from each rock sample is obtained as shown in the image below.

![Figure 9. The results of the 20-micron scale petrographic analysis](image)
Figure 10. The results of the 20-micron scale petrographic analysis

Based on the results of the microscopic petrographic analysis with a scale of 20 microns, various minerals are obtained, both primary, secondary, and accessory minerals. In this case, JAFA can be grouped into five groups, namely:

a) JAFA 1
Whereat the JAFA 1 location there are primary minerals in the form of small veined quartz, hornblende, and opaque minerals. There is one secondary and accessory mineral, namely alunite and hematite. Of the minerals identified, only quartz and hematite dominate the JAFA 1 sample.

b) JAFA 2
In JAFA 2 there are feldspar, plagioclase, opaque, and olivine minerals as the main minerals. Meanwhile, smectite and biotite are secondary minerals that have undergone an alteration process from their original minerals.

c) JAFA 5
In JAFA 5 there is 1 sample with a lot of mineral analysis results, namely olivine, opaque, feldspar, pyroxene, muscovite, and chlorite as the main/primary minerals. While smectite, kaolinite, and adularia are included in the secondary minerals.

d) JAFA 6
There are four types of rock samples that were analyzed petrographically at JAFA 6 as shown in the picture. Based on the analysis results obtained several minerals, namely: feldspar, opaque, quartz, augite, hornblende as the main minerals. Secondary minerals are kaolinite, smectite, alunite, and biotite. For accessory minerals, there is only one type, namely hematite.

e) JAFA L
In JAFA L there are feldspar, pyroxene, opaque, amphibole, olivine, and quartz minerals as primary minerals. Alunite, biotite, kaolinite, and smectite minerals are secondary minerals. JAFA is a literature sample obtained from the results of previous studies.

Based on the results of the analysis, it shows the suitability of the characteristics of the minerals contained in the sample rock according to the literature (Anonymous, 2016) Such as quartz, hornblende, augite, feldspar, pyroxene, muscovite, and opaque minerals which are characterized by
their color, relief, blackness, and crystal form. As for clay minerals or products from hydrothermal alteration such as smectite, alunite, kaolinite, refer to the literature (Titisari et al., 2019) [7] and (Corbett G. J., 1996) [8].

2. Mineragraphy Analysis

The results of microscopic observations using a polished polarizing microscope with samples that have been prepared into polished incisions show that (figures 11 and 12) a variety of metallic, non-metallic, and metallic minerals from several rock samples are shown in table 2.

![Figure 11. The results of the 20 micron scale mineragraphy analysis](image1)

![Figure 12. The results of the 20-micron scale mineragraphy analysis](image2)

From the observations in the table, there are chalcopyrite and pyrite metal minerals as associations of copper, gold, iron, and silver metallic elements. There are elements of copper, silver, and iron. In addition, other minerals are also present in the sample rock. In the identification of the characteristics
of metal and mineral elements, there is conformity with the mineragraphy analysis research conducted by [9] and [10].

3. Sediment Grain Analysis
Based on the results of observations of grains of sediment deposits using a polished polarization microscope, the results obtained are the presence of grains of metal elements in the form of copper and iron elements. In addition, other grains in the form of non-metallic minerals such as feldspar, quartz, and clay are also quite a lot present in the sediment grain samples. Copper and iron metal elements were obtained from all JAFA samples (picture).

![Figure 13. The results of the analysis of sediment grains on a scale of 20 micron](image)

4. Alteration Zone
Based on the results of microscopic observations carried out with petrographic mineral descriptions in all rock samples, secondary mineral associations were found in the research area, namely in the Jawara field at JAFA 1, 2, 5, and 6 locations divided into 3 alteration zones based on the alteration zone table [8] namely the argillic zone with mineral associations (kaolinite, smectite, alunite, quartz), the prophylitic zone with mineral associations (chlorite, hornblende, quartz), and the potassic zone with mineral associations (hematite, feldspar, biotite, quartz). The conceptual model was inspired from [13] and [15] which explained about the magmatic effect to surrounding rock.

![Figure 14. Zone alteration map](image)
The argillic alteration zone has an area of 25% of the total study area. The rock unit undergoing argillic alteration is the granodiorite unit. The level of alteration is strong because there is little visible primary mineral rock. Based on the results of petrographic analysis, the alteration minerals associated with the argillic zone are obtained in the form of kaolinite, smectite, alunite, and quartz. As in Alunite minerals that are present in a geothermal system due to the potassium fixation process at low pH conditions and high sulfate activity at low temperatures [11]. Based on the mineral formation temperature table (Hedenquist et al., 1995), this zone is formed at a temperature of 170-200 °C and the pH of the fluid is close to neutral.

![Figure 15. Temperature range of alteration minerals in the Argillic Zone](image)

The prophylitic alteration zone has an area of 15% of the total research area. The rock unit undergoing prophylitic alteration is the Diorite unit. The level of alteration is quite strong because not so many primary minerals are present. Based on the results of petrographic analysis, obtained alteration minerals associated with the prophylitic zone in the form of chlorite, hornblende, quartz. As in the chlorite minerals that are present, partially to completely replace plagioclase minerals, volcanic glass, and fill cavities and veins [11]. Based on the mineral formation temperature table, this zone is formed at a temperature of 200-300 °C and the pH of the fluid is acidic.

![Figure 16. Temperature range of alteration minerals in the Prophylitic Zone](image)

The potassic alteration zone has an area of 10% of the total research area. The rock unit undergoing potassic alteration is the granodiorite unit. Based on the results of petrographic analysis, obtained alteration minerals associated with the potassic zone in the form of hematite, feldspar, biotite, quartz. Based on the mineral formation temperature table, this zone is formed at a temperature of 270-300 °C and the pH of the fluid is acidic.
Figure 17. Temperature range of alteration minerals in the Potassic Zone

The type of ore mineral deposit in the study area is a porphyry deposit type. This is evidenced by the presence of several main characteristics of the type of porphyry deposit according to [12] and proves that the area belongs to the type of mineral resulting from Low Sulfidation (low sulfidation), namely the presence of small veins or mineral veinlets, namely small and branching quartz veins on the surface until JAFA 1 Rijang. In addition, claystone outcrops are resulting from the alteration of hydrothermal breccias at JAFA 5 ALT. In addition, the presence of metallic Ag/silver minerals in the JAFA 2 ALT mineragraphy sample indicates metallic minerals resulting from low sulfidation products. And the presence of metallic Cu/copper minerals in all samples of sediment grains is a marker of the porphyry type of sediment product. In addition, the porphyry deposit type is characterized by the presence of potassic and prophylitic alteration zones.

5. Geochemical Analysis

This analysis is focused on the analysis of iron and copper metal elements in ppm units. Observations were made using a polished polarizing microscope and to determine the weight of the metal elements using an Ohaus PA224 digital scale. After the metal weight results are obtained in units (gr/kg) then it is converted into units (ppm) with the following formula:

\[ 1 \text{ gram} = \frac{1}{1000} \text{ kg} \]

\[ 1 \text{ ppm} = 0.001 \text{ g/kg} \]

\[ 1 \text{ gram/kg} = 1000 \text{ ppm} \]

Based on the results of observations and calculations obtained the results of metal content in each sample (Table 2). These results indicate that the highest levels of copper are found in the JAFA 5 sediment sample and the highest levels of iron are in JAFA 6 sediments.

Table 2. Geochemical analysis grade results

| No | Sample Code | Metal Type | Sample Bag Weight (gr) | Metal Content (gr/kg) | Metal Content (ppm) |
|----|-------------|------------|------------------------|-----------------------|---------------------|
| 1  | JAFA 1 SEDIMENT | IRON (Fe) | 0.3899 | 0.0768 | 7.68 |
| 2  | JAFA 2 SEDIMENT | COPPER (Cu) | 0.3899 | 0.0014 | 1.4 |
| 3  | JAFA 3 SEDIMENT | IRON (Fe) | 0.3899 | 0.0272 | 2.72 |
| 4  | JAFA 4 SEDIMENT | COPPER (Cu) | 0.3899 | 0.0002 | 0.2 |
| 5  | JAFA 5 SEDIMENT | IRON (Fe) | 1.2047 | 0.3677 | 367.7 |
| 6  | JAFA 6 SEDIMENT | COPPER (Cu) | 0.3899 | 0.0139 | 13.9 |
| 7  | JAFA 7 SEDIMENT | IRON (Fe) | 0.3899 | 0.3908 | 390.8 |
| 8  | JAFA 8 SEDIMENT | COPPER (Cu) | 1.2047 | 0.0014 | 1.4 |

The assay value from the geochemical analysis was then computerized using ArcMap/ArcGIS 10.6 software to determine the extent of distribution of metal elements. Processing is done by estimating
the spatial distribution of levels using the kriging interpolation method. The results are then presented in the form of a map as shown in Figure 18.

![Figure 18. The results of interpolation of copper content using the kriging method](image)

Figure 18. The results of interpolation of copper content using the kriging method

In Figure 5, it is an interpolation for the content of Cu elements. The results above show that the area of kriging land is divided into 3 grades of color, namely at levels 0-3 with dark green, 3-7 in light green, and 7-10 in light orange. Levels of 0-3 ppm indicate a fairly wide distribution area such as levels of 3-7, while levels of 7-10 ppm occupy a little of the total kriging area. On the other hand, the 10-13 ppm red color previously obtained from JAFA 5 did not appear. This means that the distribution of levels is more dominant in the middle area, namely the level value of 3-7 ppm which is obtained from the average level of 4.22 ppm. In addition, the elevation factor at the research site, namely the high elevation that divides the eastern and western regions in the kriging area, causes the level distribution to be unreadable with a value of 10-13 ppm.

![Figure 19. The results of interpolation of Iron content using the kriging method](image)

Figure 19. The results of interpolation of Iron content using the kriging method
Based on the interpretation in Figure 19. It shows that the kriging area is divided into 4 parts of the color content or is divided almost evenly for the reading of the grade. However, the first green area shows the most dominant color at levels of 2-99 ppm and also in the red area with levels of 293-390 ppm. This proves that in that area there are indeed many Fe metal elements, namely in JAFA 6 with a content of 390 ppm. The presence of a large amount of Fe content in the JAFA 6 area is due to the location being the location of deposition of the transport of iron sand from a higher location or above it, namely JAFA 5.

5. Conclusions
Based on the results of geomorphological observations in the Jawara Field, it is divided into 5 geomorphological units, namely the Mount Anoman Structural Unit, the Gundil Highlands Unit, the Sanen Mountains Structural Unit, the Maskumambang Mountains Structural Unit, and the Alluvial Lowlands. The river flow pattern at the research site is dendritic.

Mineragraphy analysis results show the presence of chalcopyrite and pyrite metal minerals as carrier minerals for copper, gold, and iron metals. And also, the presence of iron and copper metal elements. There are 3 hydrothermal alteration zones from the petrographic analysis, namely the argillic zone with mineral associations (kaolinite, smectite, alunite, quartz), propylitic zone with mineral associations (chlorite, hornblende, quartz), and potassic zone with mineral associations (hematite, feldspar, biotite, quartz).

Based on the results of observations and calculations on geochemical analysis, it was found that the highest levels of copper were found in the JAFA 5 sample with a concentration of 13.9 ppm. Meanwhile, the highest levels of iron in the JAFA 6 sample were 390.8 ppm.

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