Study of Hydrothermal Alteration and Mineralization in the Lahbako Field, Jember Regency, East Java Province

F R Widiatmoko1,2, A S Sari1, J A N Ramadhanty1, R H K Putri1
1 Faculty of Mineral and Marine Technology - Institut Teknologi Adhi Tama Surabaya (ITATS), Indonesia
2 Department of Natural Resources and Environmental Studies – National Dong Hwa University (NDHU), Hualien, Taiwan, R.O.C.
widiatmokogeo@gmail.com

Abstract. Administratively, the research location is in Lahbako Field, Jember Regency, East Java Province. This study discusses the geological characteristics, hydrothermal alteration, and mineralization in the study area. The method used is field data collection by mapping and laboratory analysis in the form of petrographic analysis and mineragraphic analysis. The research area is divided into three geomorphology units, namely a unit with steep hills, a unit with undulating hills, and a unit with sloping plains. The stratigraphy of the study area is divided into five rock units, while the order of rock units from oldest to youngest is the volcanic Breccia unit, the intercalated Sandstone, and Claystone unit with Tuff insertion, the Diorite Intrusion Unit, the Granodiorite Intrusion Unit, and the youngest unit, namely Alluvium Unit. The research area has a high straightness density value and a straight lineage pattern that tends to be dense. The area with high lineament density is assumed to be the area with the best prospect of alteration and mineralization because the lineament reflects the geological structure which is the path of hydrothermal fluid passage that causes alteration and mineralization. Based on petrographic analysis, the research area has undergone alteration with the type of Philic alteration (Chlorite-Quartz-Feldspar), Prophilic Alteration (Chlorite-Quartz-Feldspar) Feldspar-Quartz-Epidote) and Argillic Alteration (Alunite-Quartz-Biotite). The study area is indicated as an area with high sulfide epithermal mineral deposits where the indication is based on the discovery of vein textures in the form of Vuggy Quartz and ore minerals in the form of Silver, Copper, and Iron in mineragraphic analysis.

1. Introduction
Jember Regency, East Java Province is an area part of an ancient volcano that has the potential to form mineralization processes and hydrothermal alteration. In addition, previous research in the Mumbulsari area, Tempurejo District, Jember Regency has found ore deposits in the form of vuggy quartz, with base metals in the form of pyrite and magnetite minerals and minerals due to the oxidation process consisting of goethite and Hematite minerals (S, Daniz Dyas 2018). And in the Andongrejo area, Tempurejo District, Jember Regency, an alteration mineral in the form of kaolinite was also found [1]. Therefore, it is necessary to do a detailed mapping of the research area to know the geological conditions of the research area starting from the morphology, stratigraphy, and lineament patterns of the research area as well as conducting further studies in the form of hydrothermal alteration and mineralization studies in the research area to know the potential of metal deposits and also models. the distribution of the hydrothermal alteration zone that occurs in the area.
2. Geological settings
Based on its tectonics, 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. This magmatic arc stretches from west to east along the island of Java.

Based on physiography, the southern part of Jember is included in the Southern Mountain Zone of Java Island. This zone consists of hills remaining from the Eocene-Miocene volcanic arc consisting of volcanic deposits, siliciclastic sediments, volcaniclastics, and carbonates with an almost uniform slope to the south [2]. This zone is not continuous and consists of three isolated parts. Its territory extends from the southern coast of East Java and Wonosari to the easternmost tip of Java Island. In general, this zone consists of alluvial covered volcanic rock and limestone [2].

The rock structure of the Eastern Southern Mountain Zone, especially in Sheet Jember, Java, from oldest to youngest are Merubetiri Formation, Batuampar Formation, Sukamade Formation, Granodiorite Breakthrough Rock, Diorite, Dacite, Puger Formation; Mandiku Formation; Argopuro Formation, Bagor Formation, Kalibaru Formation, Raung Volcanic Rock and Quaternary Alluvial Deposits [3].

3. Methodology

3.2. Methods
In achieving the research objectives, the selected research methods include field research (geological mapping and rock sampling) and laboratory (petrographic and mineragraphic analysis). Laboratory research was conducted at the Laboratory of the Adhi Tama Institute of Technology Surabaya using a polarizing microscope and binoculars.

The data collection process begins with geological mapping starting from geomorphology observations, river flow patterns, stratigraphic observations, and analysis of the lineament patterns of the research area. Next is laboratory analysis.

3.2. Materials
Geological mapping of the research area was carried out at 4 stations of the research track, while the 4 stations were located at JAFA 1, JAFA 2, JAFA 3, and JAFA 4.

![Figure 1. Research geological trajectory map](image-url)
and JAFA K. followed by the preparation of samples according to the needs in laboratory analysis. Sample preparation was carried out to facilitate the stages of laboratory analysis. For petrographic analysis, sample preparation was carried out by making a thin incision on the rock sample. Whereas in mineragraphic analysis, the required rock samples are in the form of rock samples that have been prepared into polished incisions.

4. Result

4.1. Geology of Research Area
To find out the geological condition of an area, the geological mapping must be carried out. Geological mapping of an area is a field research activity that applies all aspects of geological science to actual conditions. The geological mapping carried out in the Lahbako field, Jember Regency includes geomorphology conditions, river flow patterns, as well as straightness and density patterns, and stratigraphy of the research area.

4.1.1. Geomorphological of Research Area
In classifying the geomorphology units of the Lahbako field, the authors use 3 aspects of the approach, namely aspects of morphography, morphometry, and morphogenesis, and use a descriptive classification on relief, height, slope value according to Van Zuidam, 1983. Based on these three aspects and classifications, the geomorphology of the research area is divided into 3 units:

a. Unit Hills with Steep Slopes
This unit is located in the eastern part of the study area which is marked in red on the geomorphology map with an area of 30% of the research area. This geomorphology unit is located at an altitude of 500 meters above sea level and is at a slope of 21 – 70 or 23–42°. Based on the geomorphology classification, this unit has a morphology appearance in the form of mountains with a branching river flow pattern resembling a tree structure or commonly referred to as a dendritic river flow pattern, the ridge pattern in this unit is a curved/circular pattern, this can be seen from the density of contour lines. dense enough to be interpreted as the result of a fault.

The morphogenesis that controls the development of this unit is the process of magma movement on the earth's surface (volcanism) in the form of intrusions, joints, and faults so that the landform of this unit is volcanic [4]

![Figure 2. Unit Hills with steep slopes](image)

b. Corrugated Hills Unit
These corrugated hills unit is located in the center and spreads about 50% of the research area and this unit is marked in green on the geomorphology map. This geomorphology unit is located at an altitude of 200 meters above sea level and is on a slope of 21-70% or 23-42°.
Based on the geomorphology classification, this unit has a morphology appearance in the form of hills with a branching river flow pattern that resembles a tree structure or commonly referred to as a dendritic river flow pattern, the ridge pattern in this unit is a curved/circular pattern, this can be seen from the density of the contour lines, close enough to be interpreted as the result of a fault. The morphogenesis that controls the development of this unit is the tectonic process in the form of uplift, folding, and faulting so that the landform of this unit is structural [4].

![Figure 3. Corrugated hills unit](image)

c. Sloping Plain Unit
This geomorphology unit occupies an area of 20% of the research area, spread over the northern and eastern parts of the study area. This sloping land unit is marked in brown on the geomorphology map. This unit has an elevation between 25 masl to 100 masl. This unit belongs to the class of sloping slopes with a value of 8-13%.

The morphography appearance of this unit is a plain with a river flow pattern that dominates is a dendritic flow pattern. The morphogenesis that controls the development of this unit is weathering and erosion of both air and water where many rocks have gone through the process of disintegration into the soil so that this unit is included in the form of Denudational land origin.

![Figure 4. Sloping plain unit](image)
Table 1. Geomorphology observation and analysis results

| Geomorphology Unit | Unit Hills with Steep Slopes | Corrugated Hills Unit | Sloping Plain Unit |
|--------------------|------------------------------|-----------------------|--------------------|
| Spread Area (%)    | ± 30                         | ±50                   | ±20                |
| H (m)              | 875 – 375                    | 375 – 100             | 100 – 25           |
| ΔH (m)             | 500                          | 200                   | 75                 |
| Slope (%)          | ± 21 – 70                    | ± 14 – 20             | ± 8 – 13           |
| Relief              | Hills                        | Hills                 | Plains             |
| River Flow Pattern | Dendritic                    | Dendritic             | Dendritic          |
| Ridge Pattern      | Circular                     | Circular              | -                  |
| Landform           | Magmatic                     | Structural            | Denudational       |
| Morphogenesis      | Magma Movement               | Tectonic Process      | -                  |
| Erosion            | Erosion                      | Erosion               | Erosion            |

Figure 5. Lahbako field geomorphology map

4.1.2. River Flow Pattern
The direction of river flow in the study area generally has a dominant flow direction from south to north. Based on observations of flow patterns in the field and on topographic maps, it can be concluded that the river flow pattern formed in the research area is a dendritic flow pattern where this flow pattern has river branches that resemble tree structures.

The flow pattern in the Lahbako field is a collection of a flow network that is influenced or not by rainfall and is influenced by certain patterns, both rock structures and natural morphology structures of the river. The geological structures that influence are active and passive tectonics. The influence of geological structures includes faults, joints, folds, and volcanic activities that result in river erosion.
4.1.3 Stratigraphy of Research Area

Based on the results of measurements and observations of lithological characteristics revealed in the field and their comparison to regional stratigraphy, the study area can be divided into four rock units, in order from oldest to youngest, as follows:

Table 2. Lahbako filed stratigraphy column

| Era      | Period       | Rock Unit                              | Lithology                        |
|----------|--------------|----------------------------------------|----------------------------------|
| Tertiary | Early Miocene| Volcanic Breccia Unit                  | Alluvium                         |
|          | Middle Miocene| Alternating Unit of Sandstone and Claystone Containing Tuff | Tuff                            |
|          | Latest Miocene| Lahbako Breccia Unit                   | Sandstone                        |
|          | Pliocene     | Lahbako Breccia Unit                   | Claystone                        |
|          | Holocene     | Lahbako Breccia Unit                   | Basalt                           |

a. Volcanic Breccia Unit

The volcanic breccia unit is the oldest rock unit in the study area. The distribution of rock units covers 35% of the research area. This unit occupies the southern part of the study area. This Volcanic Breccia unit was formed in the tertiary era in the Oligocene period or about 34 million years ago [5]. Volcanic breccia units are characterized by a brownish-gray color, characterized by sub-angular rock fragments with the size of coarse sand to chunks. This unit fragment consists of chert, diorite, basalt, tuff, and sandstone with a matrix consisting of coarse sand, as well as iron oxide cement. Based on the Geological Sheet Map of Jember, East Java, this unit belongs to the Ampar Rock (Tomb) formation.

b. Alternating Unit of Sandstone and Claystone Containing Tuff

The distribution of this rock unit occupies an area of 35% of the study area. The units of alternating new sand and claystone with tuff inserts are scattered in the center of the study area. The age of this rock unit is in the form of Early Miocene Tertiary or about 23 million years ago [5]. This rock unit is
characterized by non-carbonate clay rocks that are greenish. In addition, there is sandstone with a brownish ash color and is characterized by sub-rounded rock fragments of medium to fine sand size. This sandstone fragment consists of quartz, feldspar, lithic, silica cement. The sandstone in this unit is classified as moderate sorting, good permeability, and good porosity. Based on the Geological Sheet Map of Jember, East Java, this rock unit belongs to the Batu Ampar (Tomb) formation.

c. **Diorite Rock Intrusion Unit**
Diorite is an old intrusive rock in the study area. This rock unit has an area of 5% of the study area and occupies the eastern part of the study area. This rock unit was formed in the tertiary era in the middle Miocene period. Diorite intrusion units are characterized by blackish gray and greenish-gray. The massive structure has a texture of the degree of crystallization in the form of holocrystalline. Granularity or pheneric grain size and anhedral crystal form. Based on the Geological Sheet Map of Jember, East Java, this rock unit belongs to the Intrusion Rock (Tmi) formation.

d. **Granodiorite Intrusion Unit**
Granodiorite intrusion unit is a young intrusive rock in the study area. This rock unit occupies about 5% of the study area and is located in the southern part of the study area. Granodiorite rocks are characterized by a dark gray color with white patches. A massive structure with a degree of crystallinity in the form of holocrystalline. Fine pheneric granularity – medium pheneric and subhedral crystal form. Based on the Geological Sheet Map of Jember, East Java, this rock unit belongs to the Intrusion Rock (Tmi) formation.

e. **Alluvium Rock Unit**
The naming of this unit is based on the alluvial deposits found in the research field. This sediment unit occupies an area of 10% of the research area. And the distribution of this unit is in the northwest part of the research area. On the geological map, this unit is marked in gray. Alluvial deposit units are thought to have formed since the Quaternary period in the Holocene period. The alluvial sediment unit is composed of material, the size of the texture is sand, gravel, gravel, and boulders.

![Figure 7. Lahbako field geological map](image)

**4.1.4 Lineaments and density pattern**
Identification of the geological structure of the research area is carried out by observing the density and lineament patterns from the DEM map. The results of the lineament analysis of the research area are as follow:
8

Figure 8. Lineaments patterns of Lahbako field (left), Map of the density distribution of the geological structure of the research area (Right)

From the two figures above (Figures 9) it can be seen that the study area is an area with a high straightness density which is indicated by the straightness pattern that tends to be denser. The straightness pattern that has been detected is also analysed using a rosette diagram where this rosette diagram is used to show the direction of the geological structure of the study area. The results of the diagram show that the dominant direction of the geological structure in the research area is Northeast – Southwest with a pattern length of about 309 kilometres.

The area with high lineament density is assumed to be an area with the intensive prospect of alteration and mineralization because the lineament itself reflects the geological structure which is the path of the passage of hydrothermal fluids that cause alteration and mineralization. The hydrothermal fluid solution will fill the fractures in the rock to form ore mineral deposits. Rock fractures are formed as a result of plate interactions.

Based on the straightness data on the Rosset diagram, it shows that the direction of the main fracture is from north to south so that based on the simple shear theory, it states that the direction of origin of the main fracture opening is the direction of origin of the main force [6]. In the tectonic setting of the island of Java, it is stated that the main direction of the formation of the island of Java comes from the north-south direction as a product of the collision of the Eurasian-Indian-Australian plate [6]. The main force direction in the study area is relatively derived from the Eurasian subduction tectonic process with the Australian Indies from the Palaeocene age [7].

4.2. Alteration and Mineralization

4.2.1 Research area alteration

In determining the type of alteration of the research area, conduct petrographic analysis to determine the mineral composition of rock samples obtained from the field. This analysis was carried out on 6 rock samples in the study area that had been prepared into thin incisions and coded as JAFA K, JAFA 1 Rijang, JAFA 2 ALT, JAFA 3, JAFA 4 ALT, and JAFA 4 INT II. This petrographic analysis was carried out using a polarizing microscope. From the petrographic analysis conducted on several rock sections, it is known that there are several mineral alterations including, quartz, epidote, feldspar, chlorite, biotite, and alunite. From the alteration mineral data obtained from the petrographic analysis, the research area is divided into 3 types of alteration:

a. Philik alteration type

This type of alteration has an area of 10% of the study area and spreads in the southeastern part of the study area. This type of alteration is characterized by the presence of chlorite minerals in rock samples JAFA 4 INT 2.
With reference to the table of alteration assemblages and mineral assemblages in the hydrothermal system [8]. The assemblage of alteration minerals in this type of propylitic alteration is Feldspar-Quartz-Epidot. From this set of alteration minerals, it shows that its formation is at a pH close to neutral and the temperature range of its formation ranges from 250°C - 290°C.

**Table 3. Mineral alteration temperature range in the philik zone**

| Alteration Minerals | Temperature (°C) |
|--------------------|-----------------|
| Chlorite           | 200 250 300 350 |
| Quartz             | 200 250 300 350 |
| Feldspar           | 200 250 300 350 |

Temperature Range: 180°C - 290°C.

**b. Propylitic alteration type**

The propylitic alteration type occupies 25% of the research area. This type of alteration is characterized by rocks that are brownish-gray in color and some are greenish-gray in colour. Determination of the type of propylitic alteration is based on the results of the petrographic analysis of the discovery of epidote minerals in rock samples with sample code JAFA 4 ALT.

Concerning the table of alteration assemblages and mineral assemblages in the hydrothermal system (Corbett G.J. and Leach, 1996). The assemblage of alteration minerals in this type of propylitic...
alteration is Feldspar-Quartz-Epidote. This set of alteration minerals, it shows that its formation is at a pH close to neutral and the temperature range of its formation ranges from 250°C - 290°C.

| Alteration Minerals | Temperature (°C) |
|---------------------|-----------------|
| Feldspar            | 250             |
| Quartz              | 250             |
| Epidote             | 250             |

Temperature Range: 250°C - 290°C.

Table 4. Mineral alteration temperature range in the propylitic zone

c. Argillic alteration type

Argillic alteration type is an alteration type that has an area of 55% of the total area of the study area. The determination of this type of alteration is based on the results of alteration minerals obtained from petrographic analysis which are then classified according to the table of alteration assemblages and mineral assemblages in the hydrothermal system.

Based on the mineral composition obtained from several rock samples concerning the table of alteration assemblages and mineral assemblages in the hydrothermal system, it can be concluded that the Argillic alteration type in the study area has an alteration mineral assemblage in the form of...
Feldspar-Quartz-Biotite [8]. This set of alteration minerals, it shows that its formation is at a pH close to neutral and the temperature range of its formation is 280°C - 310°C.

**Table 5.** Mineral alteration temperature range in the propylitic zone

| Alteration Minerals | Temperature (°C) |
|---------------------|------------------|
| Alunite             | 50               |
| Quartz              | 100              |
| Biotite             | 150              |
|                     | 200              |
|                     | 250              |
|                     | 300              |
|                     | 350              |
| Temperature Range: 280°C - 310°C |

**Figure 15.** Lahbako field alteration distribution map

4.3. *Mineralization of The Research Area*

Mineralization studies are carried out by conducting mineragraphic analysis on several rock samples. The samples used in the mineragraphic analysis were rock samples that had been prepared into polished incisions and then mineragraphic analysis was performed using a binocular microscope to determine the presence of metallic minerals in the polished incisions of each rock sample.

Based on mineragraphic analysis of several polished incisions, the ore minerals found were copper, silver, and iron (Figure 16). In addition, veins were also found in the polished incision sample with the code JAFA 1 RIJANG. The characteristic texture of the veins found is in the form of vuggy quartz which has a grayish-white appearance (Figure 17).

**Table 6.** Mineralization characteristic of the epithermal high sulfidation deposit type in the study area

| Rock intrusion          | Diorite and Granodiorite |
|-------------------------|--------------------------|
| Host Rock               | Diorite                  |
| Wall Rock               | Breccia, Claystone, Sandstone |
| Alteration Type         | Phyllic, Propylitic, Argillic |
| Altered Minerals        | Chlorite, quartz, feldspar, epidote, alunite and biotite |
| Metal Minerals          | Ag, Cu                   |
| Vein Texture            | Vuggy Quartz             |
| Mineralization Control  | Geological structure     |
5. Conclusions
Based on the results of field investigations and supported by laboratory analysis in Lahbako Field, Jember Regency, it is concluded that contain 3 kind of morphological units; the steep slope hill unit, the corrugated hill unit, the sloping ground unit. The research area has river with the dendritic pattern. The stratigraphy of the research area has 5 kind of rock unit; the volcanic breccia unit, the sandstone –
claystone unit with the tuff insertions, the diorite rock intrusion unit, the granodiorite rock intrusion unit, and the alluvium unit. The study area has high lineament density around the alteration area with the dominated lineament on NE-SW. The study area has 3 alteration type; Feldspar-Quartz-Biotite argillic alteration type, Feldspar-Quartz-Epidote propylitic alteration type, Chlorite-Quartz-Feldspar phillic alteration type. The study area concluded as the type of high sulfidation epithermal deposit that indicated with the vuggy vein, the economic deposit has presented copper, silver, and iron through mineragraphic analysis.

6. References
[1] H. Salwey, “Estimasi Cadangan Dan Studi Geokimia Kaolin Desa Andongrejo, Kec. Tempurejo, Kab. Jember Jawa Timur,” Pros. Semin. Teknol. Kebumian dan Kelaut., 2020.
[2] R. W. Van Bemmelen, “The Geology of Indonesia. General Geology of Indonesia and Adjacent Archipelagoes,” Government Printing Office, The Hague. 1949, doi: 10.1109/VR.2018.8447558.
[3] I. A. P. Musa Isona Derebi, Djauhari Noor, “GEOLOGI DAERAH MULYOREJO DAN SEKITARNYA KECAMATAN SILO, KABUPATEN JEMBER, JAWA TIMUR,” Semin. Nas., pp. 1–12, 2006.
[4] R. A. Van Zuidam, “Aerial photo-interpretation in terrain analysis and geomorphologic mapping.,” Aer. photo-interpretation terrain Anal. Geomorph. mapping., 1986, doi: 10.2307/634926.
[5] T. Sapei, A. H. Suganda, K. A. S. Astadiredja, and Suharsono, “Geological Map of The Jember Quadrangle, Jawa,” Bandung, Indonesia, 1992.
[6] W. R. Buck, F. Martinez, M. S. Steckler, and J. R. Cochran, “Thermal consequences of lithospheric extension: Pure and simple,” Tectonics, 1988, doi: 10.1029/TC007i002p00213.
[7] R. Soeria-Atmadja, R. C. Maury, H. Bellon, H. Pringgoprawiro, M. Polve, and B. Priadi, “Tertiary magmatic belts in Java,” J. Southeast Asian Earth Sci., 1994, doi: 10.1016/0743-9547(94)90062-0.
[8] L. T. M. Corbett G. J., “SW Pacific Gold-Copper System (Structure, Alteration, and Mineralization),” 1996.
[9] F. R. Widiatmoko et al., “Possibility of geothermal offshore in Sangihe archipelago, northern part of Sulawesi, Indonesia,” 2021, doi: 10.1088/1757-899X/1010/1/012004.
[10] F. R. Widiatmoko, R. H. K. Putri, and H. L. Sunan, “The Relation of Fault Fracture Density with the Residual Gravity; case study in Muria,” J. Earth Mar. Technol., 2021, doi: 10.31284/j.jemt.2021.v1i2.1743.
[11] F. R. Widiatmoko, M. N. Hadi, D. Kusnadi, S. Iswahyudi, and F. Fadlin, “The conceptual model of Wae Sano Geothermal field based on geology and geochemistry data,” J. Earth Mar. Technol., 2020, doi: 10.31284/j.jemt.2020.v1i1.1189.