



## Characteristics of Epithermal Mineralization in Block Jalur 7 Bolaang Mongondow Regency, North Sulawesi

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### ABSTRACTS

Indonesia has the potential as an area containing large reserves of gold and sulfide minerals. One of the areas with the potential to produce gold is Bolaang Mongondow Regency, North Sulawesi Province. This study aims to identify the characteristics of epithermal deposition mineralization, including texture and the presence of mineralization, to determine its paragenesis. The analysis methods used are petrography, mineralogy, and X-ray Diffraction (XRD). As many as six samples in the test well are described megascopically and polarization microscopically, which have been ground into clay-sized fractions and analyzed using the X-ray Diffraction (XRD) method to detect clay minerals and other altered mineral associations. The quartz texture present at the research location based on megascopic observations is generally dominated by saccharoidal, vuggy, mold, banded, and chalcedonic textures. The identified minerals are generally dominated by base metal minerals, with paragenesis in sequence being pyrite, chalcopyrite, galena, hematite, ilmenite, and geothite. Alterations in the research area are in the form of Argillic, Silicic, Silica-Carbonate, and propylitic zones. The study's results concluded that the type of mineralization in Bolaang Mongondow Regency, North Sulawesi, is of the low-sulfidation epithermal type.

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### INTRODUCTION

The Bolaang Mongondow area is located in the central part of the northern arm of Sulawesi, which is generally composed of a Neogene magmatic arc with great potential to contain economic minerals. Therefore, it is necessary to research the potential of these mineral resources. Previous research concluded that the research area contains medium to high sulfidation epithermal Au-Ag mineralization types. Several earlier studies have been conducted around the research location in the Bolaang Mongondow Regency, including an inventory and evaluation of metal minerals by the Geological Resources Center in Lolayan District, research on epithermal deposits, and detailed descriptions of the geology and high-sulfide gold mineralization systems in Lolayan District. Based on data and information from previous researchers, further research was conducted with the aim of determining the characteristics of gold ore deposit mineralization as well as the content of associated minerals and types of deposits formed in the research area (Craig, 1994; Harjanto, 2016).

Mineralization has a very close relationship with hydrothermal alteration, as certain types of mineralization are characterized by the presence of typical hydrothermal alteration as their hallmark. Certain mineral deposits will describe a specific type of alteration mineral. In the exploration of ore mineral deposits, it is crucial to understand mineralogy. Detailed mineralogical studies are needed to determine the presence of mineral carriers in an area (Guilbert, 1986; Maulana, 2017).

The metal deposits found in the research area are associated with hydrothermal processes associated with Quaternary active volcanic activity. In hydrothermal veins, quartz is the dominant mineral and is typical of hydrothermal system deposits. Thus, the characteristics of the quartz can be known to determine the differences in hydrothermal conditions and the presence of mineralization in an





area. In hydrothermal veins, quartz as an accompanying mineral has several typical appearances, commonly referred to as quartz texture, which can be used as an indicator of the boiling process in an epithermal environment, and there is a positive correlation between metal mineralization and indications of quartz texture (Dong, et al, 1995).

This research aims to further elucidate the characteristics of epithermal deposits based on quartz texture and the type of mineralization identified through mineragraphic studies, thereby enabling the identification of the deposit type in the area with certainty.

## **METHODS**

To determine the mineralization of the research area, both megascopic and microscopic observation methods were employed. Both approaches aim to identify the ore minerals present in the rocks and analyze their texture. The samples obtained came from 6 test wells. They were then ground into clay-sized fractions and analyzed using the X-ray Diffraction (XRD) method to detect clay minerals and other altered mineral associations.

### **Megascopic Observation**

In this study, megascopic observations were made on samples obtained from test wells. The information obtained from macroscopic observations is used to identify the physical properties of rocks, rock textures, and the presence of mineral ores, which will later be compared with the texture of veins and the results of polished thin-section observations under a reflected light microscope.

### **Mineragraphy Observation**

Mineragraphy observations are conducted to identify ore minerals in polished thin-section samples using a BX41-type microscope and NPL 107 B. The observations of ore minerals are based on the physical properties of the minerals and their optical characteristics.

### **X-ray Diffraction Analysis**

The X-ray Diffraction (XRD) testing was performed using a Shimadzu XRD-7000L type instrument. The sample was meticulously prepared, ensuring a clay size of 200 mesh. The X-ray Diffraction (XRD) analysis was conducted to determine the presence of altered minerals, especially clay minerals. This mineral set cannot be observed through macroscopic or microscopic analysis.

### **Figures and tables**

Figures or graphs (Figure 1) are numbered and sorted by numbers. The image name is placed below the image and is one single space away from the image. Write the name of the image using 10pt font size, bold. When using captions, use 10pt font, not aggressive. The distance between image names and paragraphs is one single space, and paragraphs with images are one. If the image is a modification of another author, the source must be written after the image's description. However, if the image is the actual result of the article itself, then there is no need to write it down.

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## **RESULTS AND DISCUSSION**

### **Observed Vein Textures in Macroscopic Observations**

Based on the results of macroscopic observations, the quartz rock samples are generally dominated by saccharoidal, vuggy, mold, banded, and chalcedonic textures. The identified textures include:

#### **Saccharoidal Texture**

The saccharoidal texture has two distinct compositions, namely calcite and quartz. A saccharoidal texture with a calcite composition occurs because existing conditions are more likely to allow calcite precipitation than quartz (Figure 1a). The saccharoidal texture observed in vein samples has two distinct compositions: calcite and quartz. Meanwhile, the saccharoidal texture with quartz mineral composition shows that the hydrothermal solution that passes through the saccharoidal texture dissolves the quartz mineral and is replaced by calcite.

#### **Vuggy Texture**

Megascopically, it is characterized by the presence of a vuggy form in igneous rocks caused by the presence of a hydrothermal solution that allows vuggy silica to occur (Figures 1b and 1d).

#### **Mold Texture**

This texture exhibits traces of dissolution or replacement (Figure 1c) of minerals that are readily dissolved in quartz.



## Banded Texture

Megascopically, the banded texture is characterized by the presence of a dark gray sulfide layer (Figure 1e). This sulfide layer has a very fine to coarse grain size and mainly consists of varying sulfide minerals. The sulfide minerals observed in this texture include galena, pyrite, and chalcopyrite.

## Chalcedonic Texture

This texture is characterized by quartz minerals that exhibit a fatty sheen, indicating silica formation at low temperatures (Figure 1f). Generally, it is located at shallow depths above the up-flow zone and may overlap the mineralized area.

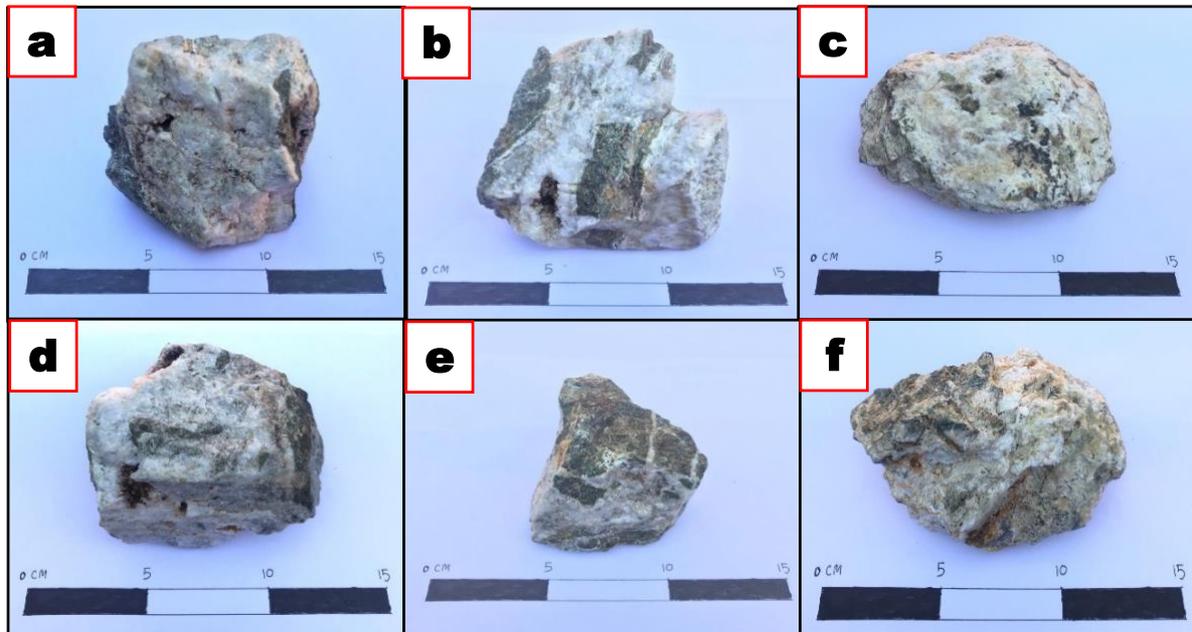


Figure 1. (a) saccharoidal vein texture, (b) vuggy vein texture, (c) mold vein texture, (d) vuggy vein texture, (e) banded vein texture, (f) chalcedonic vein texture.

## Minerals Identified by Reflection Microscope

Microscopic observations were conducted on polished section samples from test wells. In this observation, the presence of metal minerals and their textures can be identified, such as replacement, intergrowth, open space filling, and other mineral textures (Isyqi, 2016). Minerals identified in polished section observations are described as follows:

### Magnesite (MgO)

Magnesite is present in anhedral-subhedral form and is associated with other sulfide minerals. The results of observations on magnesite minerals reveal a brownish-white color with a resinous luster, characterized by an intergrowth texture with chalcopyrite, siderite, and geotite minerals.

### Ilmenite (FeO<sub>3</sub>Ti)

The ilmenite found has a blackish-gray color and metallic luster. The open space filling texture occurs due to the presence of other minerals that fill the pores or fractures in previously formed minerals.

### Hematite (Fe<sub>2</sub>O<sub>3</sub>)

The hematite found in the observation results is blackish red, exhibiting an anhedral to subhedral form and a submetallic luster. Replacement texture is the dominant texture observed in ore minerals. Overall, replacement texture can be used as a reference to determine which minerals were formed first. According to the replacement results, irregular boundaries between minerals will form.

### Gold (Au)

Gold is found as native gold (Au) and is also included in chalcopyrite. Ore minerals associated with low-sulfidation epithermal gold deposits include pyrite, chalcopyrite, siderite, and magnesite.

### Geotite (FeO<sub>2</sub>)

Geotite is found in an anhedral-subhedral form, with an intergrowth texture of chalcopyrite, siderite, magnesite, and hematite minerals.

### Pyrite (FeS<sub>2</sub>)

Pyrite is commonly found at all stages of mineralization and generally occurs in subhedral-euhedral form. Pyrite minerals are sometimes found in intergrowth form with chalcopyrite minerals.



### Galena (PbS)

Galena is typically associated with sulfide minerals, including sphalerite, chalcopyrite, and pyrite. Observation results reveal a grayish-white appearance of triangular pits, attributed to the three-way cleavage of galena minerals and their intergrowth texture with other minerals. The galena found is generally cubic.

### Chalcopyrite (CuFeS<sub>2</sub>)

The shape of the chalcopyrite found is irregular with intergrowth/coexisting texture with sphalerite, pyrite, and galena, indicating that these minerals were formed together. In addition, chalcopyrite is a trace mineral that is often found as an inclusion or replacement within other minerals. Chalcopyrite is relatively abundant in the research samples.

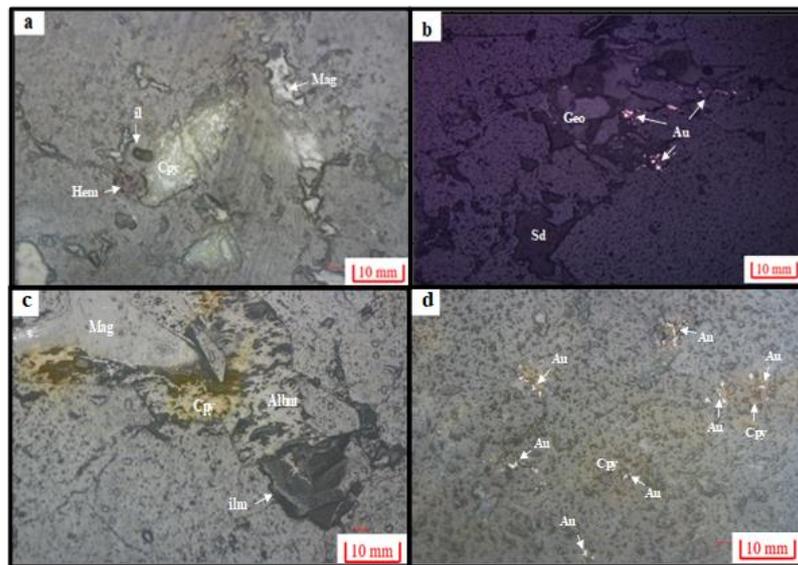


Figure 2. Photomicrographs showing the minerals (a) hem = hematite, il = ilmenite, mag = magnesite, cpy = chalcopyrite; (b) geo = geotite, sd = siderite, Au = gold; (c) alb = alabandite (d) Au = gold, cpy = chalcopyrite

### Hydrothermal alteration in the research area

Hydrothermal alteration is a change in the mineral composition of a rock due to the interaction between hydrothermal solutions and the rock. The alteration process causes primary minerals to change into secondary minerals, which are then referred to as altered minerals. Hydrothermal alteration is a complex process because there are changes in mineralogy, chemistry, and texture due to the interaction of hydrothermal solutions with the side rocks (wall rocks) that they pass through under certain physical-chemical conditions (Pirajno, 2009).

The results of macroscopic, microscopic, and X-ray Diffraction (XRD) observations show that in the research area, the hydrothermal alteration is divided into Argillic, Silica, Silica-Carbonate, and propylitic zones (Morrison, 1990; Thompson, et al. 1996).

#### Argillic Zone

The type of alteration is characterized by the presence of secondary minerals, such as clay minerals, which are quite intensive. The observed rock samples were whitish gray, indicating argillic alteration; some minerals, such as oxidized iron minerals, were reddish brown. This type of alteration is characterized by the presence of key minerals such as montmorillonite and kaolinite with accessory minerals in the form of calcite, quartz, and dolomite. The temperature of formation of alteration minerals ranges from 100 ° to 300 °C, with low salinity and an acid-neutral pH. This indicates that the type of deposit in the research area is a low-sulfidation epithermal deposit.

#### Silicic Zone

The silicic type is characterized by the key mineral quartz, with accessory minerals pyrite and hematite. Intense alteration is often at the top of the porphyry system but also forms a sheath around pyrite-rich veins that cut other types of alteration. Extensive replacement of rocks with silica minerals occurs in some epithermal and geothermal systems, as wall rock changes around fractures and veins or in permeable zones, typically at relatively shallow depths. It also forms a blanket-like replacement zone in the water table below advanced argillic alteration heated by steam.

#### Silica-Carbonate Zone





The results of the observations on the samples are dominated by quartz and calcite, along with several accessory minerals. Based on the key minerals, this unit is classified as a silica-carbonate type. The silica-carbonate type is formed from the replacement of ultrabasic rocks in the shallow (low-temperature) part of the geothermal system.

Propylitic Zone

The propylitic type in this sample is generally dominated by the presence of calcite, montmorillonite, and pyrite minerals. Most of these samples are composed of quartz and form veins that contain sulfide minerals, such as pyrite. The estimated temperature for the formation of alteration minerals is between 200-300°C, at a pH approaching neutrality, with varying salinity, typically found in zones with low permeability.

Table 1. Results of mineral analysis by X-ray diffraction

| Kode Sampel | Mineral Teridentifikasi | Zona Alterasi    |
|-------------|-------------------------|------------------|
| SU1-01      | Montmorillonite         | Argillic         |
|             | Kaolinite               |                  |
|             | Quartz                  |                  |
|             | Calcite                 |                  |
| SU1-02      | Quartz                  | Silicate         |
|             | Hematite                |                  |
|             | Pyrite                  |                  |
| SU1-03      | Montmorillonite         | Argillic         |
|             | Kaolinite               |                  |
|             | Calcite                 |                  |
|             | Quartz                  |                  |
| SU2-01      | Quartz                  | Silica-Carbonate |
|             | Calcite                 |                  |
| SU2-02      | Montmorillonite         | Argillic         |
|             | Kaolinite               |                  |
|             | Calcite                 |                  |
|             | Quartz                  |                  |
| SU2-03      | Montmorillonite         | Propylitic       |
|             | Kaolinite               |                  |
|             | Calcite                 |                  |
|             | Pyrite                  |                  |

Mineral Paragenesis

According to the research results, certain minerals can determine the paragenesis of ore minerals. Therefore, first, identify the type of ore minerals present and the texture that is observed. Then, the paragenesis analysis follows the method described by Craig and Vaughan (1994).

The sulfide minerals present, based on the results of mineragraphic analysis, are pyrite, chalcopyrite, galena, and a small portion of iron oxide and hydroxide minerals, such as hematite, ilmenite, and goetite.

Table 2. Paragenesis or time sequence of mineral deposition

| Identified Minerals | Beginning | End | Supergene Enrichment |
|---------------------|-----------|-----|----------------------|
| Pyrite              | —————     |     |                      |
| Chalcopyrite        | —————     |     |                      |
| Galena              | —————     |     |                      |
| Hematite            |           |     | —————                |
| Ilmenite            |           |     | —————                |





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## Geotite

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Based on the characteristics obtained from both macroscopic and microscopic observations as well as X-ray Diffraction (XRD) analysis such as the appearance of quartz textures, namely saccharoidal, vuggy, mold, cockade, chalcedonic and the abundance of base metal minerals such as pyrite, chalcocopyrite, galena, hematite, ilmenite, geotite and the presence of alteration types in the form of Argillic, Silicic, Silica-Carbonate, propylitic zones, it can be concluded that the type of mineralization in the Arinem prospect is a low sulfidation epithermal type (Zhou et al, m 2018).

### CONCLUSION

1. The quartz texture present at the research location, based on megascopic observations, is generally dominated by saccharoidal, vuggy, mold, cockade, and chalcedonic textures.
2. The identified ore minerals are generally dominated by base metal minerals, with the paragenesis sequence being pyrite, chalcocopyrite, galena, hematite, ilmenite, and geotite.
3. From the results of observations of quartz textures in rock samples, the presence of sulfide minerals (pyrite, chalcocopyrite, and galena), as well as ore textures and the presence of dominant alteration minerals, indicates that the deposits in Block Jalur 7 Bolaang Mongondow Regency, North Sulawesi, are low-sulfidation epithermal types.

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