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Temperature f Gold Mineralization In Tugurejo Area and Its Surrounding, Slahung Subdistrict, Ponorogo District, East Java Province, Indonesia

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ABSTRACT

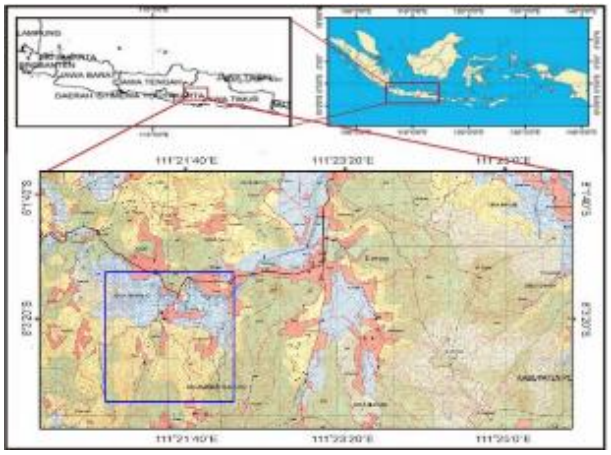
Our research was conducted in Tugurejo Area and its surrounding, Slahung District, Ponorogo Regency, East Java, Indonesia. It consists of 2 informal lithostratigraphic units, that are the Watupatok Formation lava unit and the Watupatok Formation breccia unit. Tugurejo area and its surrounding is an area of alteration and mineralization, such as gold, copper and zinc (Purwanto, et al., 2021). The geological structures of the research site are predominantly joints filled with quartz veins and faults in the direction of NE-SW, NW-SE and E-W. The hydrothermal alterations formed in the research site were grouped into three alteration types, which are silica type (defined by Pyrite ± Quartz), argillic type (defined by Smectite ± Kaolinite ± Quartz ± Pyrite ± Albite), and propylitic (identified by Chlorite ± Albite ± Quartz ± Dolomite ± Pyrite ± Smectite ± Illite minerals). The mineralizations encountered at the research site are Pyrite (FeS2), Chalcopyrite (CuFeS2), Sphalerite (ZnS). Previous research showed that the area and its vicinity has Epithermal Low Sulfidation deposit type and Intermediate Sulfidation which generally could be identified in the quartz veins (Purwanto, et al,2021). This research is a continuation of the previous one in order to know the temperature of mineralization and alteration zone, as well as lithology and geological structure in research area. The general method of this research is surface mapping, and the temperature data was obtain by fluid inclusion analysis of the quartz vein samples acquired in the area. There are 2 samples of quartz to be analyzed and interpreted to represent the temperature of mineralization in the area. Based on the analysis result, we conclude that the temperature of mineralization in the research area is between 263°C – 312°C with salinity 5.13 – 6.13 wt% NaCl and 273 – 300^{O}C, with salinity 3,16 - 4,24 %WT

Keywords: sulfidation, alteration, mineralization, quartz, fluid inclusion

INTRODUCTION

The southern part of East Java, particularly Tugurejo area and its sourronding is mainly comprised of volcanic rock, which is considered accountable for the formation of ore mineral deposit. Tugurejo area and its neighborhood is an area of alteration and mineralization, among them are gold, copper and zinc (Purwanto, et.al., 2021). The lithology units resulted from ancient volcanism, such as volcanic sediment and intrusion, as well as other geological processes had compensated the formation of ore deposit. Geological structure controlling the ore deposit potential was also identified in the research area.

Previous study had pointed that the area is Epithermal Low Sulfidation deposit type, generally manifested in the quartz veins (Arifudin Idrus at al, 2017 & Purwanto, et.al.,2021). This research, as a follow-up of the previous study, was conducted to learn the temperature of mineralization and alteration zones, as well as lithology and structures in the area. The general method was geological surface mapping, and fluid inclusion analysis was performed to quartz



samples from the area of interest in order to estimate the temperature. There were 2 samples of quartz veins, eligible for the analysis and were interpreted to reflect the temperature of mineralization presented in the area. The result showed that the temperature of mineralization area is between 263°C - 312°C with salinity 5.13 – 6.13 wt% NaCl and 273 – 300^{O}C, with salinity 3,16 - 4,24 %WT.

RESEARCH OBJECTIVE

The objective of this research is to study the temperature of alteration and mineralization as well as lithology and its geological structures, particularly in order to collect detailed data of the temperature of ore mineral in research area.

Figure 1. The research site is in the Tugurejo area and its sourrounding, Slahung District, Ponorogo Regency, East Java Province.

METHODOLOGY

This research is a part of research series on alteration and mineralization related to controlling geological structure of the research site. It was conducted by geological mapping focusing on data of joints and faults in the vicinity of alteration and of which the appertures are filled with quartz veins containing minerals such as pyrite, chalcopyrite, galena, sphalerite, and other minerals which could not be seen megascopically. Furthermore, the information of joints and faults orientation were recorded and analyzed, to define whether the alterations and mineralizations of the site were controlled by geological structures. Analysis was conducted on the geological structures, mineralography, alterations and minerals using X-Ray Diffraction (XRD), Atomic Absorption Spectrophotometry (AAS) and Fluid Inclusion.

GEOLOGICAL SETTING OF THE STUDY AREA

The lava units in the area were found in the river valleys and roadsides, occupying an area of 57% from the total research area. Megascopic description on the andesite lithology in the field exhibited gray to blackish gray of fresh colour, light gray to brown for weathered color, a massive structure, columnar joints, and sheeting joints. The primary mineral compositions are hornblende, biotite, plagioclase, k-feldspar, quartz, and glass. The site underwent weak to unaltered hydrothermal alterations and there were veins filled with pyrite, chalcopyrite, and sphalerite mineralization found in several observation sites. This unit is in the age of Late Oligocene-Early Miocene (Samodra et al., 1992) and the stratigraphic relationship of this unit with the Watupatok Formation Breccia Unit is interfingering.

The breccia unit occupies around 43% of the research area, where the characteristics of this unit in the site are having gray as fresh colour and cream on weathered colour, having massive structures, gravel-fine sand grain size, poorly sorted, angular roundness and open packing. It has fragments of tuff, lithic, feldspar and matrices of tuff, while the cement is silica. The unit experienced strong hydrothermal alteration to unaltered and there were veins with mineralizations of galena, chalcopyrite, and sphalerite found in some observation locations. The age of this unit is around the Late Oligocene-Early Miocene (Samodra et al., 1992). The stratigraphic relationship of breccia unit with the Watupatok Formation Lava Unit is interfingering.

The geological structures developed in study area are dextral strike-slip fault in northwest – southeast direction (N330^{0}E) as the main fault controlling mineralization in this area, and also dextral strike-slip fault in N 030^{0} E direction. Mineral bearing veins were found in quartz veins filling the shear joints in N330^{o}E direction and extension joints in N 005^{0}-005^{0} E direction. These quartz veins containing mineral were sampled to be analyzed in term of temperature, using the analysis of fluid inclusion.

ALTERATION

Hydrothermal alteration is a complex process involving changes in terms of mineralogy, texture,

and chemical composition of rocks. This process is a result of interaction between hydrothermal fluid and the rocks it passes through, in a specific physical and chemical condition (Pirajno, 1992). Alteration zone has distinctive characteristics and patterns to be identified with. The zonation pattern begins from the nearest zone to the ore deposit.

The result of megascopic and petrographic observation on several samples of altered rocks in the field indicated three alteration zones;

1. Silicic type (indicated by quartz mineral)
2. Argillic type (indicated by kaolinite and sericite mineral)
3. Propylitic type (indicated by albite, chlorite, ±epidote, ±sericite, mineral)

Silicic Type

Silicic alteration type was indicated by a group of silicic mineral (SiO_2), such as quartz. The alteration only occupied a small area that is 5% of the whole area of interest and is commonly found in epithermal mineralization system. The silicic alteration found in the study area had exposed to strong alteration process and could be found in dacite and andesite lava. It was formed in the earliest phase at volatile rich condition. After fluid rich phase, this alteration was exposed to leaching and became vuggy, and it could even be having brecciated which would open space for deposition of metals brought by hydrothermal fluid. This alteration spreading pattern was influenced by structures developed in the area.

Argillic Type

Argillic alteration is indicated by the presence of clay mineral aggregate build upon kaolinite and sericite. In the field, this alteration was generally manifested in white color. Argillic alteration was formed in the final phase when volatile rich hydrothermal fluid seeped out through the cracks during post – magmatic in pH of 4 – 5 and relatively low temperature of 200 - 250˚C (Corbett and Leach, 1997). The pattern of argillic alteration spreading was controlled by geological structures developed in the study area and it covers about 20% of the area.

Propylitic Type

The propylitic alteration is indicated by the presence of albite and chlorite mineral that partially substitute pyroxene in andesite and epidote rocks. This propylitic alteration was categorized in weak up to strong alteration. The field manifestation of this alteration still had the texture of its origin rock, but started to have the green color of chlorite mineral on certain places and there were spots that had been strongly altered and had strong green color. The spreading pattern of propylitic alteration in the area was controlled by geological structure developed there and it was about 75% of the study area. It occurred in the early stage of alteration at high temperature so it was found on almost all over the study area.

MINERALIZATION

The mineralization occurred in research area was relatively associated to quartz veins (or veinlets) in texture of banded, chloroform, vuggy and quartz breccia, and sheared often filled with quartz breccia in relatively northwest – southeast direction that were found in sandstone and andesite-basalt lava. The mineralization veins were the result of the filling process of hydrothermal fluid along with shear joint formation. Based on mineralography analysis and its presence in the field, the ore mineralization in study area were primary metal elements in the form of silver (Ag) copper (Cu) and zinc (Zn) and other secondary metal minerals, such as: pyrite (FeS_2), chalcopyrite ($CuFeS_2$), magnetite (Fe_3O_4), Sphalerite (ZnS), gold (Au).

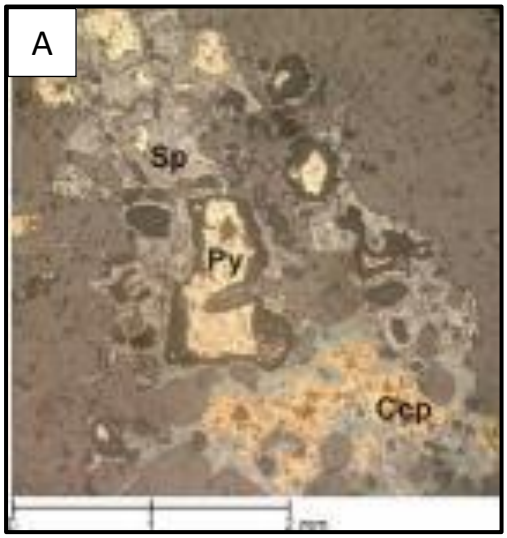
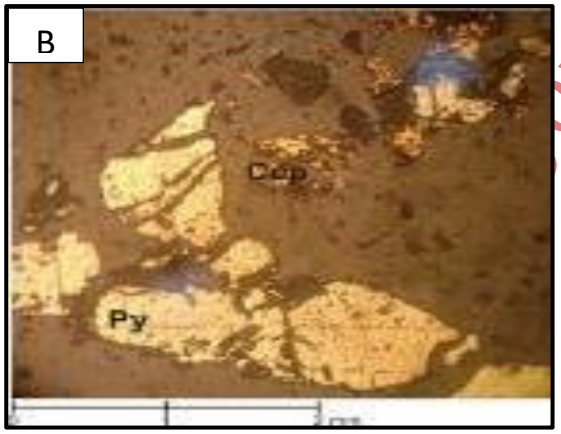


Figure 2. The presence of Silicic alteration (A), Argillic alteration (B) and Propylitic alteration on Andesite rock (C).

The texture of quartz veins found in the area were brecciated quartz, (chalcopyrite, sphalerite), bended quartz (comb structure and it contains pyrite, chalcopyrite), and quartz vein (malachite).



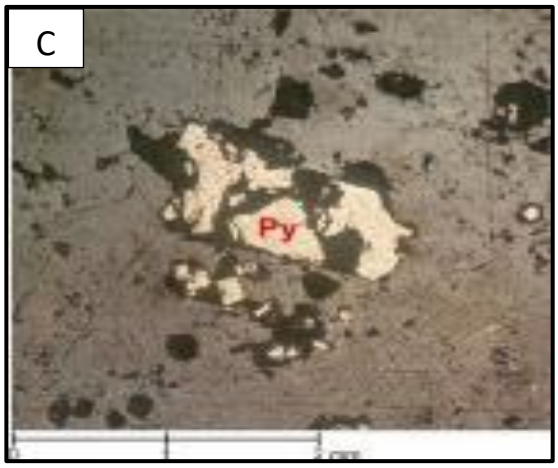


Figure 3. Samples of mineralgraphy from Quartz Vein, Chalcopyrite, Pyrite, Sphalerite (A), Pyrite, Chalcopyrite (B), Pyrite (C).

FLUID INCLUSION

Fluid inclusion is a temperature measurement on the fluid trapped inside a mineral, in this case is quartz vein, during its formation. The method was performed on thin incision preparation. In this research, temperature was estimated on the quartz vein samples from 2 (two) observation locations in research area. The percentage of pressure and density of the fluid were calculated, in order to estimate the pressure, density, paleosurface depth, model and environment of mineralization. Salinity estimation was based on the assumption that the fluid was mainly composed of Na+ and Cl-, in terms of the equivalent weight total percentage of NaCl (Potter, 1978).

LEMBAR MIKROTERMOMETRI INKLUSI FLUIDA

No Sampel	UPN Veteran Yogyakarta	Lokasi	-
Kode Sampel	LP 09	Koordinat	-
Tanggal	1 April 2021	Tipe Batuan	Urat Kuarsa

Rata-rata Th:	Rata- rata Tm:	Rata - rata % wt NaCl:
263°C - 312°C	(-3.1)°C - (-3.8)°C	5.13 - 6.13

No	Ukuran [µm]	Th (°C)	Tm (°C)	% Wt NaCl	Fase
1	16.81	278	-3.5	5.71	Liquid + Vapour
2	27.67	307	-3.7	5.99	Liquid + Vapour
3	8.7	312	-3.8	6.13	Liquid + Vapour
4	20.14	270	-3.3	5.42	Liquid + Vapour
5	21.98	271	3.3	5.42	Liquid + Vapour
6	19.47	263	-3.1	5.13	Liquid + Vapour
7					
8					
9					
10					

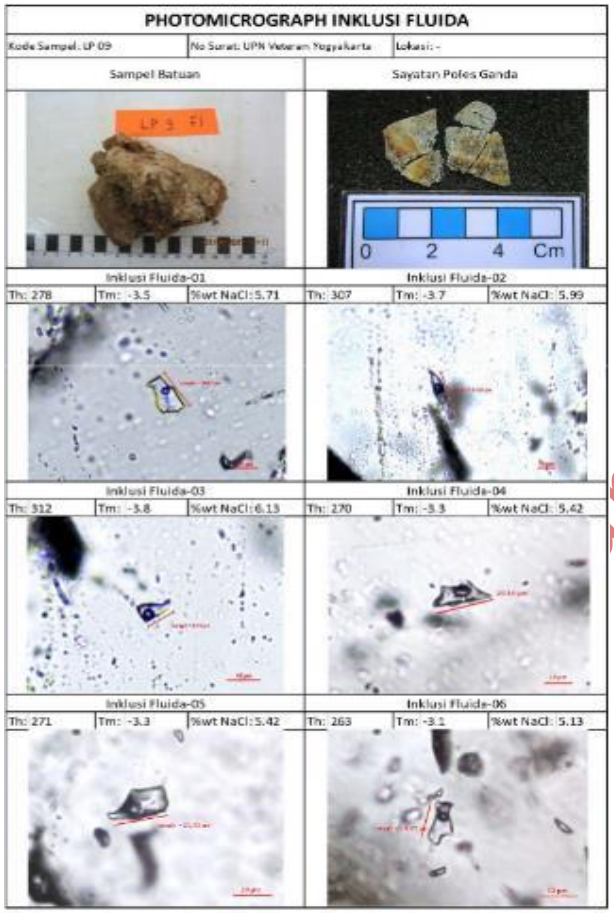


Fig
(B)

Fluid Inclusion Analysis of sample LP 09

The sample with code LP 09, based on the fluid inclusion measurement, by combining the values of Th (homogenization temperature), Tm (melting temperature) and salinity, is a silicified rocks containing quartz veins and oxide contaminated. The silicified part is milky white in color, having many fine fractures due to

Figure 5. The result of Fluid Inclusion analysis of sample LP 09

deformation and oxide contamination. The quartz vein is composed of quartz anhedral, partly granular, sheeted, partly clear, containing many older generation of quartz mineral detritus. The fluid inclusion of the silicified rock is generally damaged. Fluid inclusion inside quartz vein is sparse, they are in various size, shape, type and generation. The size is generally between fine to medium (8,7 -27,67 µm), the shapes are anhedral and subhedral, some are necking down and partly damaged. The fluid inclusion is found to be unevenly spread, sometimes isolated (primer) and planar oriented (secondary).

The result of microthermometry measurement of sample LP09 showed values of Th is between 263 – 312^{O}C, and Tm is between (-3,01)^{O}C – (-3,08)^{O}C, and the calculation had estimated the percentage of NaCl to be equivalent of 5,13 - 6,13 %WT

Fluid inclusion analysis of sample LP 10

Based on the analysis, the quartz vein sample is chalcedonic and microsilica silicified rock which is

mostly milky white, containing a lot of altered mineral fragment of mica, sericite, clay, very fine mineral inclusion, opaque and the inclusion in general is damaged. The crystal of quartz vein is generally transparent but many impurities such as granules and fibers of altered mineral and amorphous were found. The quartz is opaque, anhedral, sheeted, having many fine fractures and damaged inclusions. The quartz veinlets are transparent, sheeted, drusy, some have crustiform texture, granular crystal.

Many fluid inclusions were found and most of them are single phase rich of water, some are rich of gas, the dimension is generally very fine, the shape is anhedral to subhedral, many are necking down and damaged, they are randomly spread all over. Fluid inclusion inside quartz vein is sparse, they were found in various size, shape, type and generation. Generally it has very fine up to medium size (9,56 - 35,24 µm), anhedral and subhedral, some are necking down and partly damaged. The fluid inclusion is unevenly spread, some are isolated (primary) and others are planar oriented (secondary).

The microthermometry measurement result of sample LP10 showed values of Th is between 273 – 300^{O}C, and Tm is between (-1,9)^{O}C – (-2,6)^{O}C, and the calculation result had estimated the percentage of NaCl to be equivalent of 3,16 - 4,24 %WT

Based on fluid inclusion analysis of those 2 (two) quartz vein samples, we interpreted that alteration and mineralization in the research area occur at temperature between 273^{O}C – 300^{O}C

DISCUSSION

The location of our research is an area of local gold mining that had been closed down, where the presence of gold is much related to chalcopyrite and sphalerite and few secondary minerals such as malachite.

The research area have been categorized by researchers as low sulfidation type deposit, due to the presence of sphalerite, as it unevenly spread in the location of alteration and mineralization zone. Sphaleriteis considered as an indication of low sulfidation deposit type near a fault zone with higher temperature.

LEMBAR MIKROTERMOMETRI INKLUSI FLUIDA

No Sampel	UPN Veteran Yogyakarta	Lokasi	-
Kode Sampel	LP 10	Koordinat	-
Tanggal	1 April 2021	Tipe Batuan	Urat Kuarsa

Rata-rata Th:	Rata- rata Tm:	Rata - rata % wt NaCl:
273°C - 300°C	(-1.7)°C - (-2.4)°C	3.16 - 4.24

No	Ukuran (µm)	Th (°C)	Tm (°C)	% Wt NaCl	Fase
1	9.56	300	-2.6	4.24	Liquid + Vapour
2	11.23	292	-2.4	3.94	Liquid + Vapour
3	27.8	290	-2.1	3.48	Liquid + Vapour
4	35.24	273	-1.9	3.16	Liquid + Vapour
5					
6					
7					
8					
9					
10					

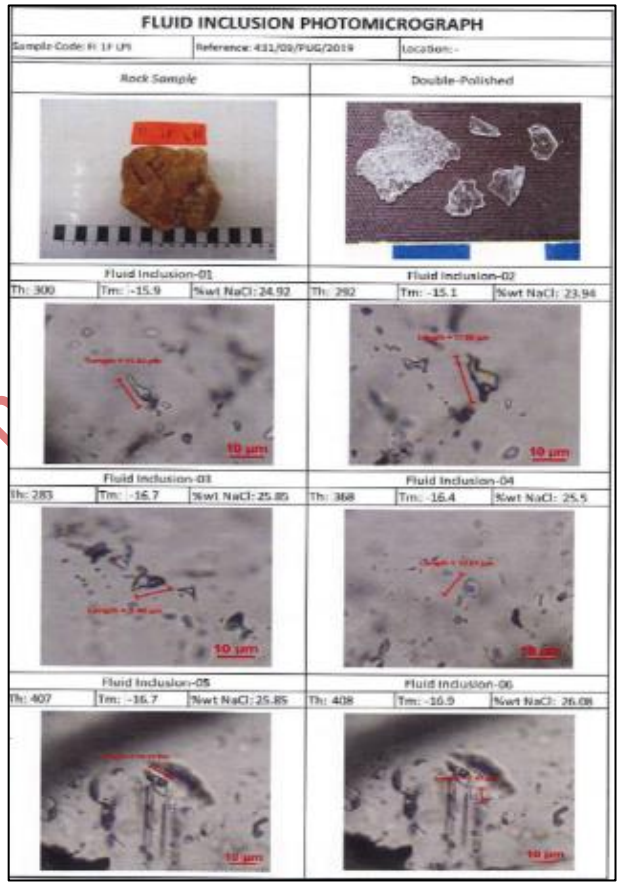


Figure 6. Fluid inclusion analysis result of sample LP 10

Later on in this research, we found an abundant of sphalerite along with pyrite, chalcopyrite on the fault zone, quartz brecciated, and secondary mineral of malachite.

There are existences of silicic, argillic and propylitic alteration in research area where we could find carrier of gold, silver and zinc ore mineral, such as chalcopyrite, sphalerite galena and pyrite. Based on the classification made by White (2009) or Silitoe

(2015), the epithermal deposit of our study area then can be classified as Intermediate Sulfidation with the presence of sphalerite particularly in some locations near the fault zone and quartz brecciated. While the area itself is generally an Epithermal Low Sulfidation type deposit.

The determination of deposit type is based on not only mineral presence, quartz texture and geological structures, but the temperature during mineral formation is also very important. In that case we had taken quartz vein samples in order to analyze the fluid trapped during vein formation and to interpret the minerals formed. Based on the fluid inclusion analysis result, it showed that the temperature is between 263 – 312^{O}C of which there is a possibility of Epithermal Low Sulfidation deposit type, in the area at the temperature is between 273 – 300^{O}C of which there is a possibility of Intermediate Sulfidation deposit type.

CONCLUSION

The Tugurejo area is a region with the potential of ore mineral reserves inside quartz vein system. The presence of quartz vein as a result of hydrothermal activity can be found in shear joint controlled by dextral strike-slip as the main fault. The alteration had developed following fault zone from the main zone to the outmost part, that are Silicic Alteration, Argillic Alteration and Propylitic Alteration, respectively. There are carrier of ore mineral found in chalcopyrite and sphalerite, and secondary mineral such as malachite. The analysis result of fluid inclusion in the area showed that the temperature is between 263 – 312^{O}C which could be classified as Epithermal Low Sulfidation, while some areas near fault zone and quartz brecciated area showed that the temperature is between 273 – 300^{O}C which could be classified as Epithermal Intermediate Sulfidation.

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