https://doi.org/10.1051/e3sconf/202132504008

Mineralogy of hydrothermal breccia cement of Humpa Leu East porphyry copper-gold prospect, Sumbawa Island, Indonesia

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Abstract. Indonesia is a country that has several world-class copper-gold deposits, particularly in eastern Sunda arc. The Hu'u complex has several prospects in the surface as lithocap of extensive epithermal style alteration, but some were detected associated with porphyry beneath the surface. The study focuses on hydrothermal breccia cement as a factor influencing the porphyry system in the Hu'u district. The methods used is mineralogical analysis with petrography and μ-XRF elemental mapping on hydrothermal breccia samples. The Hu'u district is interpreted as a paleo-volcano; a member of the Old Volcanics Rocks Formation. The Humpa Leu East lithology consists of pre-volcanics unit (lava and pyroclastics), diorite, andesite-μ-diorite, and tonalitic intrusion at the depth. Hydrothermal alteration evolved from tonalite body to outward, consist of potassic, inner propyllitic and overprinted by phyllic and advanced argillic. Several phases of hydrothermal activities occur in this system, including the hydrothermal breccia phase associated with complex fluids. The hydrothermal cement of Humpa Leu East porphyry at least have three phases of mineralogical assemblages and possibly influencing the mineralization. The mineralogical assemblage of hydrothermal cement in HLE consists of quartz-feldspar-plagioclase-biotite as a high-temperature phase; then followed by epidote-sericite-chlorites-anhydrite-carbonates in medium temperature; there are aluminum-rich clay minerals interpreted as gibbsite. Mineralization occurs in three phases including chalcopyrite-magnetite, bornite-chalcopyrite and chalcopyrite-sphalerite phases. The occurrences of chalcopyrite at all phases indicate the stability of intermediate sulfidation proses in Humpa Leu and as a possible factor to answer the abundant copper in the Hu'u hydrothermal fluid system
Keywords: porphyry, gold, copper, mineralogy, μ-XRF, Indonesia

1 Introduction

Indonesia is a country that has several world-class copper-gold deposits such as Batu Hijau, Martabe, Grasberg - Ertsberg, and the discovery of Onto Copper-Gold Deposits in Hu'u Complex in 2013 [1]. The mineralization emplaced on the Tertiary or Oligocene to Pleistocene magmatic – volcanic belt of Sunda-Banda arc, especially at the eastern side [2,3]. The deposits classify as world-class with more than > 5 million ounces gold equivalent, which is dominantly associated with porphyry-epithermal type.

Hu'u complex has several prospects in the surface as low to medium metal's grade lithocap of large epithermal style alteration, but some were detected associated with porphyry beneath the surface. In 2013, the exploration team succeeded in obtaining a large deposit in a very large hydrothermal alteration complex. The Humpa Leu East (HLE) is located in Sumbawa Island, administratively lies on Hu'u sub-district, Dompu district, Nusa Tenggara Barat province, Indonesia (Fig. 1). The Humpa Leu (East) prospect has 257 Mt resources potential with a grade at 0.2% Cu and 0.2 g/t Au [4].

The regional geology of Hu'u consists of a Tertiary volcanic unit [5,6] in the outer volcanic complex, with magmatism still active. The latest research in Hu'u complex was done by Burrows et al. (2020) and reporting that the U-Pb zircon age for the andesite that caps the volcano-sedimentary host rocks provides a maximum age of 0.838 ± 0.039 Ma, with a slightly younger porphyry zircon crystallization age of 0.688 ± 0.053 Ma. The mineralization in this 'young' ages to be interested in exploration, and the character of deposits in Hu'u still open up opportunities for new discovery in this belt or Pleistocene ages volcanism or magmatism.

The mineralization of precious metals is mainly affected by the fluids as the metals carrier agent in this system. Therefore, the mineralogical study of hydrothermal breccia in the porphyry system can be used to interpret the hydrothermal fluids system [7]. μ-XRF is used in many applications working with multiple material types, including examining minerals to determine the element distribution in geological samples [8,9,10]. This study is focused on mineralogical analysis

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in hydrothermal breccia cement using μ-XRF, which aims to determine the character and paragenesis of hydrothermal system in HLE.

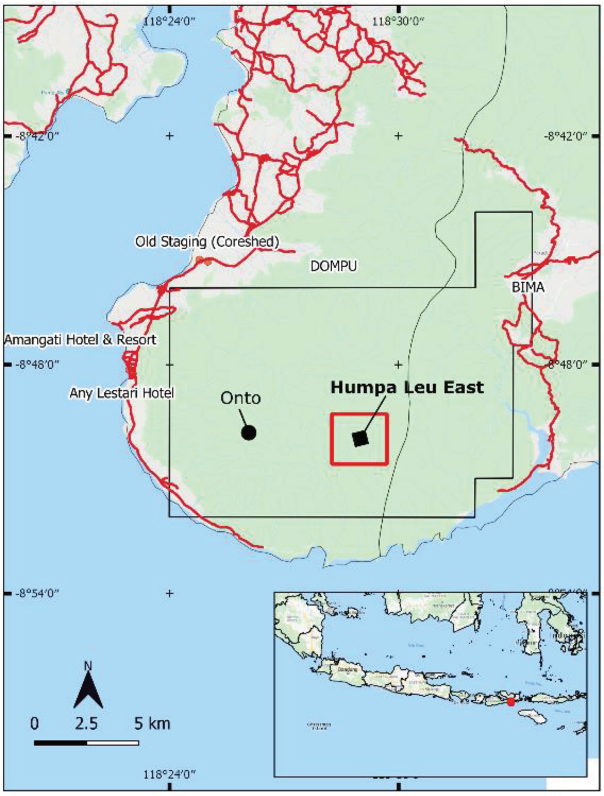

Fig. 1. Location of the study area.

2 Methods

The research uses several steps to interpret geological framework from surface alteration and lithological map and then subsurface from drill core analyses and interpretation. Then, the research materials are focused on hydrothermal breccia samples, then analysed by the petrographic method by polarizing microscope and elemental analysis by μ-XRF. Total samples analysed is two sample from two zone of breccia, then analysed of elemental distribution, mineral chemistry from pint analysis, and quantitative analysis with AMICS software. The μ-XRF analysis uses M4-Tornado Bruker unit at Centre for Nuclear Minerals Technology National, Nuclear Energy Agency (BATAN) laboratory, Jakarta, Indonesia. The spectrometer was equipped with an X-ray tube and a vacuum pump and was operated at 50-kV voltage and 600-μA current. Finally, we use AMICS software for quantitative mineralogical analysis from μ-XRF data to increase confidence about mineral distribution and petrogenesis.

3 Results

3.1 Geology of Humpa Leu East

Humpa leu East is part of the Hu'u volcanic system with typical lithology as volcanic product, lava, pyroclastic and diatremes, and spotted subvolcanic intrusion. The lithology of Humpa Leu East consists of andesitic domes, pre-volcanic unit (lava and pyroclastics), diorite, μ-diorite, andesite subvolcanic intrusion, and tonalitic intrusion at the depth (Fig 2). The lithological unit in surface is seen as interfingering of lava and pyroclastics; in lower elevation such as rivers or valleys, the dioritic rock can be seen. Tonalitic intrusion or quartz diorite was founded by deep drilling at >100 m from the surface. The top of tonalitic intrusive rock only occurs in elevation 200 m above sea level (m.asl) to the depth that's characterized pencil-like intrusive caused by the width of the intrusive body about 100-150 m narrow to depth. Otherwise, It's can be similar types Onto deposits but different in size that's as a big intrusive body width of about 1-1.3 km and still bigger to depth.

The Humpa Leu prospect is the clear porphyry type prospect in this district with more deep drilling. The Humpa Leu (East) prospect has 257 Mt of resources potential with a grade at 0.2% Cu and 0.2 g/t Au [4]. Hydrothermal alteration evolved from tonalite body to outward, consist of biotite-feldspar-sericite-magnetite-chalcopyrite-bornite±digenite (potassic) and epidote-actinolite-chlorite-magnetite-chalcopyrite (inner propyllitic) and overprinted by sericite-illite-kaolinite-chalcopyrite-pyrite±sphalerite (phyllic) and alunite-dickite-pyrite-chalcopyrite (advanced argillic). The mineralization is controlled by disseminating chalcopyrites and other copper-sulfides, quartz–anhydrite veins, and hydrothermal breccia. The texture of mineralization is associated with quartz veins stockwork, parallel pseudobands, and cement in hydrothermal breccia. In this research, we try to characterize the cement of hydrothermal as the mineralization trigger in this system

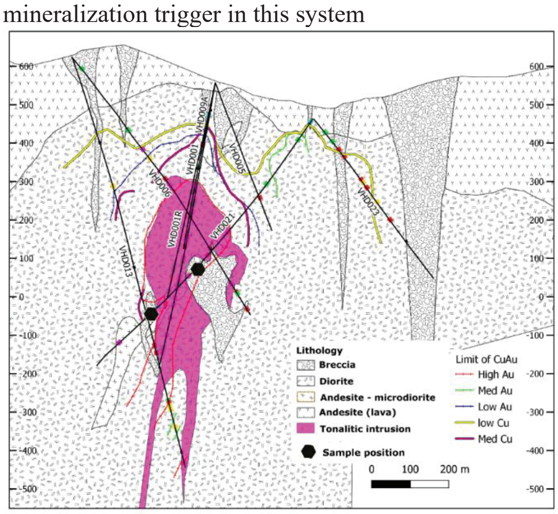

Fig 2. Interpretation of east-west section geological model of Humpa Leu East and the sample described in this study.

3.2 Hydrothermal Breccia

Several phases of hydrothermal occur in this system, including the hydrothermal breccia phase associated with complex fluids. The samples of hydrothermal breccia were taken from about 500 m from the surface or at -100 to 100 m above sea level. The hydrothermal breccia mineralogy is associated with potassic type mineralogy, commonly consisting of feldspar, quartz, biotite, and magnetite. In addition, HLE hydrothermal breccia characters are encountering high-temperature hydrous silicates, retrograde silicates, and sulfate minerals.

The hydrothermal cement of Humpa Leu East porphyry at least has three phases of mineralogical assemblages and possibly influencing the mineralization. A mineralogical assemblage of hydrothermal cement in HLE consists of quartz-feldspar-plagioclase-biotite-magnetite as high-temperature phase; then followed by epidote-sericite-chlorites-anhydrite-carbonates in medium temperature, and there are aluminum-rich clay minerals interpreted as gibbsite. All three phases are associated with copper sulfide that is chalcopyrite-bornite, chalcopyrite-magnetite, and chalcopyrite-sphalerites. Those minerals can describe clearly in petrographic analysis and reinforcement by elemental mapping analysis and quantitative mineralogical analysis from µ--XRF scanned data (Fig 3).

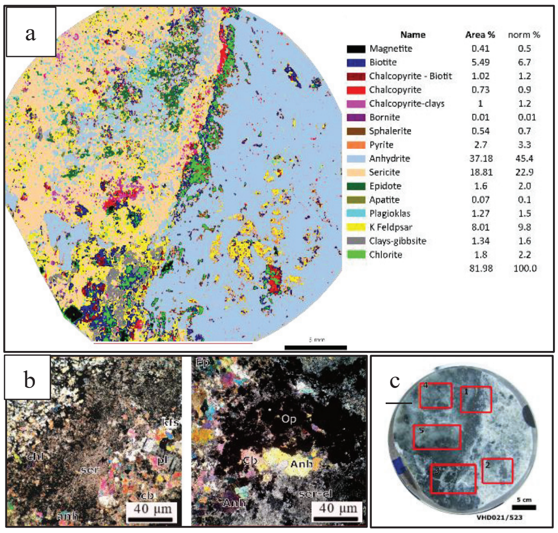

Fig 3. Mineralogical analysis of cement hydrothermal of sample VHD021/523. (a) A quantitative mineralogy from µ--XRF data shows two dominant variation consist of calcium sulfate group in right side, silicate groups in left side, and also clays in bottom (b) petrographic analysis shows cement mineral, consist of quartz (qz), K Feldspar (kfs), plagioclase (pl), sericite (ser), anhydrite (anh), epidote (ep), carbonate (cb), chlorite (chl), clays (cl), an opaque (op), (d) polish section for µ--XRF analysis and box position of detailed µ--XRF analysis.

3.3 Mineralogical phase

The observed hydrothermal breccias showed the presence of two main components in the hydrothermal solution or fluids. The initial component is siliceous fluids that produce silicate mineral groups such as quartz-feldspar-biotite and the dissemination of copper minerals such as chalcopyrite and bornite. The second component is calcium-rich sulfate and less carbonate, which produces the minerals, anhydrite and a little carbonate, and gypsum. The mineralization formed due to contact of the solution phases shows the oriented distribution of Fe-Mg-rich silicates minerals such as biotite-phlogopite-chlorite and the formation of chalcopyrite-magnetite and sphalerite mineralization. This contact phase shows the existence of an intermediate sulfidation state mechanism in the porphyry system.

3.3.1 Chalcopyrite-magnetite

Chalcopyrite is a mineral present from the late-magmatic phase, early phase, to late or epithermal phase in the Humpa Leu porphyry system. Chalcopyrite shows chemical formula $Cu_{1-1.2}Fe_{1-3.6}S_{1-1.6}$, and in the some case associated with bornite with formula $Cu_{3.6-6}Fe_{1-8.8}S_{1-3.6}$ (some detected as mix formula with chalcopyrite). The iron oxide minerals occur as hematite-magnetite-pyrrhotite, commonly occurring in the early phase as a massive veinlet and disseminates associated with quartz vein, followed by chalcopyrite. In hydrothermal breccia, magnetite occurs as disseminated and accumulate mineral with chalcopyrite and some pyrite. The magnetite extensively grows in the silicates phase with other sulfides, less abundant in the anhydrite phase. The silicates gathered as cement include quartz, sericite-feldspar, biotite, epidote, chlorite, and clays (Fig 4).

Meanwhile, copper (Cu) disseminates strongly in the silicates phase due to chalcopyrites and possibly of bornite minerals. The analysis of ferrous oxide mineral shows a variation of Fe element with formula $Fe_{0.8-1.6}O_{0.8-3}$ as a description of presence iron-hematite-magnetite, but still dominantly by magnetite type. The magnetite contains several anomalies of the element, such as 0.06 – 0.25% Cu, 0.03-0.57 % Zn that occurs if sulfur presents.

The silicate cement in the siliceous phase occurs to envelop the metal minerals in irregular to pseudo bands pattern, in sharp contact with the anhydrite phase. From elemental mapping analysis, the copper (Cu) occurs in associated with feldspar-sericite minerals; also the magnetite but more closely associated with biotite-quartz. Moreover, it all showed high aluminum and potassium anomaly in spot analysis due to copper target.

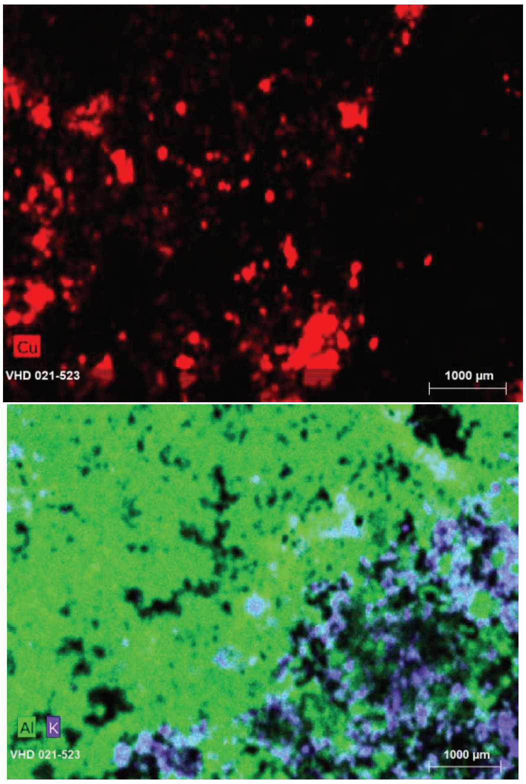

Fig. 4. The siliceous phase of cement breccia from sample VHD021/523 *(at position 3 of Fig 3c),* shows the distribution of copper minerals and related to Aluminum-potassium minerals cement. (picture analysis at position 4 of Fig 3c),

3.3.2 Bornite-chalcopyrite

As has been explained in the previous paragraph, bornite may be present simultaneously as chalcopyrite. The presence of bornite in the HLE porphyry system is difficult to find because it has a very fine size grain (<20 µ-ns). In hydrothermal cement, bornites disseminated associated with chalcopyrite and surrounded by silicate minerals, namely biotite-chlorite and sericite (Fig 5). As shown in Figure 3, it can be seen that the bornite is only present 0.01% in the sample; it shows that the hydrothermal breccia is part of the transition from high to intermediate sulfidation stage. It is strengthened by occurrences of retrograde minerals caused by a decrease in temperature, such as chlorite-sericite-clays.

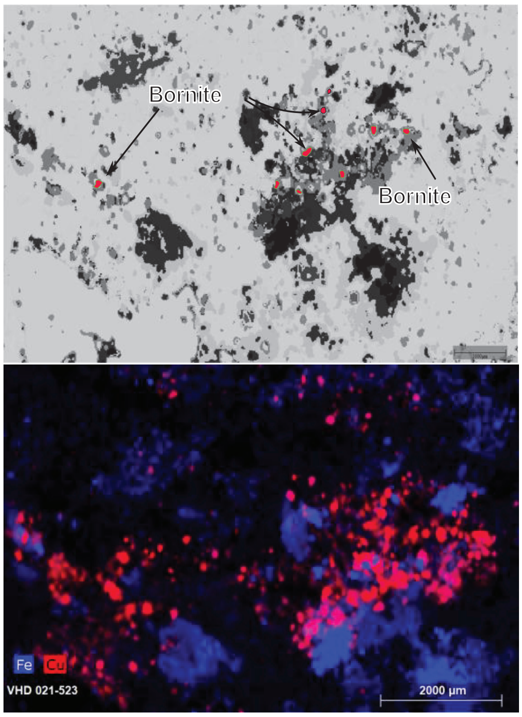

Fig 5. Distribution of bornite that's associated with chacopyrite and feldspar. Table of point analysis shows object 1 as bornite with empirical formula as $Cu_{3.6}FeS_2$, and the other was mix with feldspar minerals. (picture analysis at position 5 of Fig 3c)

3.3.3 Chalcopyrite-sphalerite

One of the characteristics of porphyry mineralization in HLE is the occurrence of sphalerite, together with chalcopyrite in the porphyry phase and especially in the epithermal phase. In the hydrothermal breccias, sphalerite is associated with chalcopyrite, mainly at the contact margin between the siliceous and calcium sulfate stage. Sphalerite occurs associates with the distribution pattern of chalcopyrite-biotite-chlorite (fig 6) and chalcopyrite-magnetite (Fig 7). The occurrence of sphalerites indicates intermediate sulfidation state condition during the hydrothermal process, influence the grade of gold (Au) in several phases.

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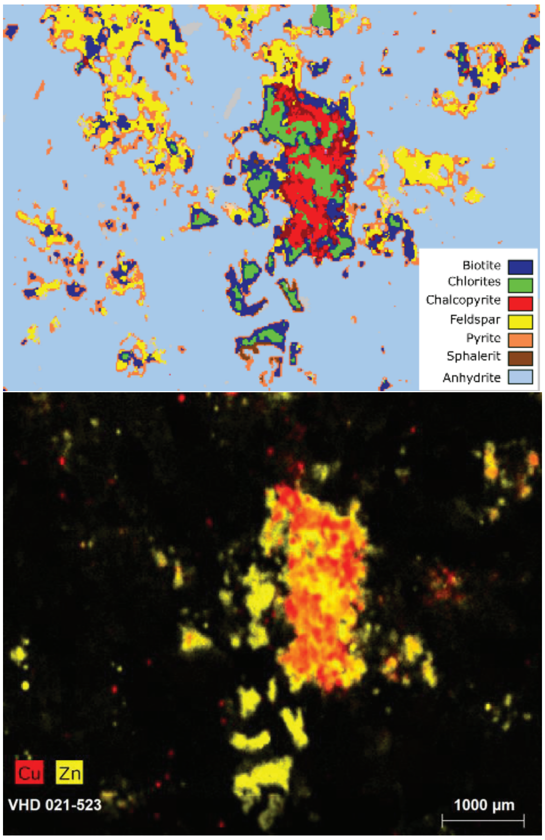

Fig 6. Distribution and association of chalcopyrite-sphalerite that's associated with biotite-chlorite-feldspar (picture analysis at position 2 of Fig 3c)

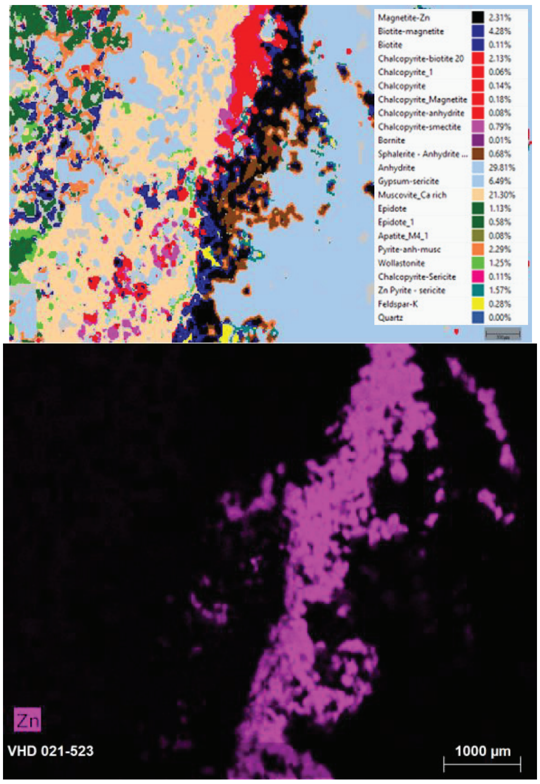

Fig 7. Distribution and association of chalcopyrite-magnetite-sphalerite that's associated with biotite-chlorite-feldspar-sericite-epidote-anhydrite in contact of siliceous phase and sulfate phase (picture analysis at position 1 of Fig 3c)

4 Interpretation & Discussion

The condition of Hydrothermal breccia shows the complexity of the temperature formed in the porphyry system in HLE. In this one event, the change conditions prove an immediate process of mixing meteoric and magmatic water and causing mineralization by the redox system process. The initial process is represented by the presence of chalcopyrite-magnetite or hematite, followed by chalcopyrite-bornite and then chalcopyrite-sphalerite. The occurrences of chalcopyrites at all phase indicate the stability of intermediate sulfidation proses in Humpa Leu and as a possible factor to answer the abundant copper in the Hu'u hydrothermal fluid system.

This study is a part of PhD study results of the first author at the Geological Engineering Department at Universitas Gadjah Mada. We thank to all geologists of PT. Sumbawa Timur Mining, Mr. Yulindra, Mr. Kristison, Mr. Nurtyas, Mr. Nurhadi wibowo and Mr. Doughlas. Special thanks to the management of Institut Teknologi Nasional Yogyakarta for the powerful support to us.

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