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Comparative Study of Gajah and Ijo Volcano Mineralization in Kulon Progo Dome based on Textural and Mineralogical Characteristics

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Abstract

Gajah Volcano and Ijo Volcano are two tertiary volcanoes located in the Kulon Progo Dome area, Yogyakarta. Gajah Volcano is located in the middle of the Kulon Progo Dome which is the oldest in the complex and belongs to Early Oligocene volcanism period (± 29 mya). On the other hand, Ijo Volcano is a product of younger volcanism period, occurred in the Late Oligocene (± 25 mya). The tectonic deformation occurred during the Late Oligocene-Early Miocene led to the formation of geological structures like faults and joints, which also serve as pathway for acid-intermediate intrusion rocks. The intrusions are associated with hydrothermal alteration and ore mineralization in both volcanoes. There has been no research comparing the characteristics of hydrothermal deposits that formed on Gajah Volcano and Ijo Volcano. This will be the main objective of this research. The research was carried out at two mineralization prospect locations representing each volcano, namely the Kaligono area (Gajah Volcano) and the Hargorojo area (Ijo Volcano). The results were obtained from geological and alteration mapping as well as representative rocks/veins sampling. Petrology, petrography, mineragra- phy, and XRD analyzes conducted on altered rock and vein samples from the two prospects indicated some differences. Kaligono prospect area (Gajah Volcano) consists various of alteration types ie. phylic (quartz-sericite-illite-pyrite), propylitic (chlorite-calcite-pyrite±epi- dote±actinolite), and argillic (illite-smectite-kaolinite±quartz). The mineralized veins found on Gajah Volcano show vein swarm, brecciated, stockwork, and massive vein structure with massive vein textures. The veins in Kaligono show NE-SW and NW-SE trends and hosted by Andesite, Dacite, and Andesite Lava. Gangue minerals that are found in the vein samples are quartz, illite, iron oxide, pyrite, and carbonate minerals. The ore minerals consist of magnetite, chalcopyrite, and sphalerite. Meanwhile in Hargorojo prospect area (Ijo Volcano), the types of alteration found including phylic (quartz-sericite-pyrite), propylitic (pyrite-calcite±ch- lorite), and argillic (illite-smectite-kaolinite-quartz). The mineralized veins found on Ijo Volcano have a massive vein structure, brecciation, and stockwork with comb, drussy, and massive vein textures. The veins have NNE-SSW and E-W trend and hosted by Andesite and Dacite. The gangue minerals are carbonate minerals, oxide minerals, pyrite, barite, quartz and chalcedony. The ore minerals include chalcopyrite, silver, galena, and sphalerite. Based on the vein characteristics of Kaligono prospect, such as a complex stockwork structure, hydrothermal breccia, and massive vein texture, which contain high temperature hydrothermal minerals, ie. epidote, actinolite, and magnetite, maybe indicate this deposit is controlled by deep structure related to the porphyry miner alization. Whereas in the Hargorojo prospect shows the typical textures of shallow epithermal system (open space filling), such as comb and drussy, which contain lower temperature hydrothermal minerals, such as chalcedony, silver, and galena. Based on textural and mineralogical characteristics, Kaligono prospect suggests that the alteration and mineralization takes place deeper or closer to the magmatic source. On the other hand, Hargorojo prospect suggests the alteration and mineralization process relatively far from the source.

Keywords: Volcano, Mineralization, Mineralogy, Petrology, Characterization, Kulonprogo

INTRODUCTION

The Kulon Progo dome is a morphology formed from a line of Tertiary volcanoes on the island of Java. Mount Gajah and Mount Ijo are two Tertiary volcanoes located in the Kubah Kulon Progo area which includes two provinces, namely Yogyakarta-Central Java (Figure 1). Mount Gajah is located in the middle of Kulon Progo Dome and is the oldest mountain in the Kulon Progo Dome line and is a product of Early Oligocene (± 29 M) volcanism. Meanwhile, Mount Ijo is a volcano that is younger than Mount Gajah and is a product of the Late Oligocene volcanic period (± 25 Mya) (Widagdo et al., 2018). Tectonic deformations that occurred during the Late Oligocene to the Early Miocene causes the formation of geological structures such as burrows and faults, as well as a pathway for medium-acid rocks to intrude. The intrusion of rocks is an influencing factor for the hydrothermal alteration process and mineralization that occurs in the two mountains (Harjanto, 2011). There is no studies that have tried to compare the characteristics of the hydrothermal deposits formed on Mount Gajah and Mount Ijo based on mineralogical and textural aspects, so this will be the main objective of this research.

Figure 1. Location of research area.

Geological and Volcanism Background

Based on the Regional Geological Map of the Yogyakarta Sheet by Rahardjo et al. (1995), the Kulon Progo Dome is an area composed of four Tertiary sedimentary rock formations, breakthrough rocks, and several deposits. The four rock formations, from old to young, are the Nanggulan Formation, the Kebo Butak Formation, the Sentolo Formation, and the Jonggrangan Formation. The research area is composed of the Old Andesite Formation (OAF) from the late Oligocene to the Early Miocene. The arrangement of this formation consists of andesite breccias, tuffs, and andesite lava flow inserts. Also, the Jonggrangan formation that was present was not aligned above the OAF Formation. This formation is composed of limestone sandstones with lignite inserts, layered limestones, and coral limestones. Besides, there are intrusion rocks that are present in the Kulon Progo Mountains consisting of intrusion andesite and intrusion dacite. Andesite is an intrusion rock that intrudes to the Kebobutak Formation and is thought to have a Miocene age. Similar to andesite, dacite is an intrusion rock which is estimated to have a Late Miocene – Quaternary age Miocene (Harjanto, 2011). The dacite and andesite intrusion rocks in the study area are intruded to be the host rock of the mineralization process formed in the southwestern part of the Kulon Progo Dome. The presence of dacite intrusion in the research area, namely in the Bagelen District and Kaligesing District was a consideration for the choice of these two areas as a location that could represent the mineralization that occurred in the southwestern part of the Kulon Progo Dome. The research area of the Kaligono prospect has an area of 2.5 x 2.8 km^2, while the research area of the Hargorojo prospect has an area of 1.8 x 2 km^2 (see Figure 2).

The regional volcanism in the study area was divided by time of occurrence into four volcanic periods by Widagdo et al. (2018) namely the Late Eocene volcanic period, the Early Oligocene volcanic period, the Late Oligocene volcanic period, and the Late Miocene volcanism period . The Late Eocene volcanic period is pre-gajah volcanism. The Early Oligocene volcanic period formed Gajah Volcano. The Late Oligocene volcanic period produced Ijo Volcano. The Late Miocene volcanic period activated magmatism which stopped after the Late Oligocene at the Kulon Progo Dome and formed Menoreh Volcano.

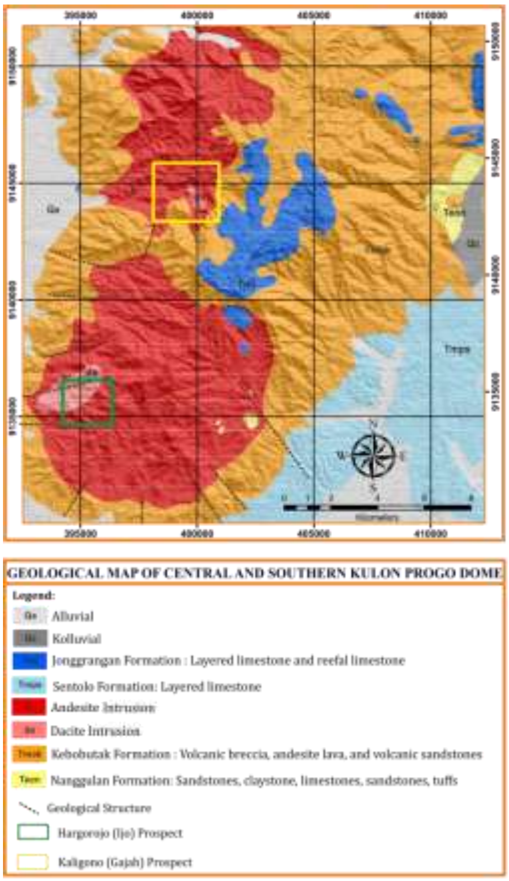


Figure 2. Geological map of the central and southern Kulon Progo Dome. Formation division based on the Regional Geological Map of the Yogyakarta Sheet by Rahardjo et al (1995).

METHODOLOGY

The stages of the research carried out into the preliminary stage, the stage of work and field data collection, the stage of laboratory work, the stage of integration of analysis and interpretation results, and the stage of concluding.

During the work and field data collection stages, samples of fresh rock were taken, samples of altered rocks, and samples of mineralized veins. It is also carried out recording and measuring the direction and dimensions of mineralized veins.

In the laboratory work stage, an analysis of the sample data of fresh rock, altered rock, and mineralized veins is carried out in the laboratory by first selecting and preparing samples. Mineralogical and textural analyzes were carried out by petrographic observations, ore microscopy and mineralogical analysis using X-Ray Diffraction (XRD). Samples of rocks and veins from the Kaligono prospect analyzed were 31 petrographic thin sections,15 ore microscopy polishing sections, 2 samples of argillic altered rock, and 2 samples of silica veins for XRD analysis. The samples of rocks and veins from the Hargorojo prospect were analyzed as many as 20 thin petrographic section, 7 ore microscopy polishing section, and 4 samples of argillic altered rock and 1 sample of barite minerals for XRD analysis.

RESULTS AND DISCUSSION

Field Observation

Field observations were carried out at two research locations in Purworejo Regency, Central Java Province, namely the Kaligono area, Kaligesing District, and the Hargorojo area, Bagelen District. The research area is composed..of..Old..Andesite..Formations, An-desite Intrusive Rocks, and Dacite Intrusive Rocks. The rocks that comprise the study area have undergone many hydrothermal alterations, such as argillic alteration, phyllic alteration, and propylitic alteration.

The Kaligono area is composed of dacite intrusion, andesite lava, and andesite intrusion. Andesite lava is intruded by andesite and dacite at several locations, especially along with the main river flow in the Kaligono area. Besides, there are also diatreme breccia (Figure 3.A) produced by magmatic-hydrothermal processes that are present at the Gajah Volcano. The geological structure that develops in this area is in the form of shear faults and has trend northeast-southwest and southeast-northwest directions, which can be found in the main rivers.

Andesite porphyry, andesite lava, and dacite rocks in the Kaligono area undergo propylitic and phyllic alteration (Figure 3.C and D) as indicated by the presence of epidote, chlorite, and actinolite in hand specimen samples. An extension stump is found in this area and its direction is measured.

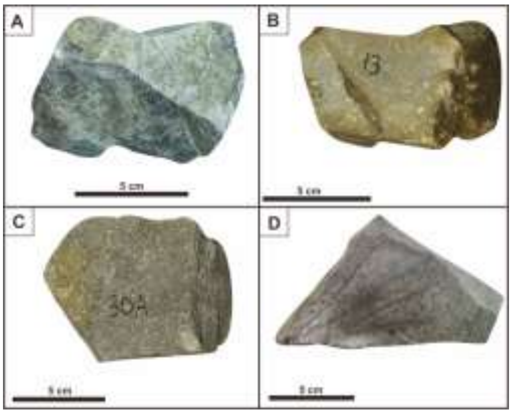


Figure 3. Hand specimen of rocks found in the kaligono prospect (A) Diatreme breccia fragments undergoing propylitic alteration, (B) Andesite lava undergoing propylitic alteration, (C) Andesite porphyry undergoing propylitic alteration, and (D) Dacite undergoing phyllic alteration.

Several places in the main Kaligono river contain rocks that have undergone phyllic alteration, which is characterized by the presence of silica, clay minerals, sericite, and pyrite. Rocks that have undergone phyllic alteration at this location are associated with massive textured veins filled with silica and clay minerals. Also, rocks with argillic alteration are found in locations that have a secondary..structures such as joints and characterized by the presence of clay and silica minerals. The argillic alteration rocks also has a stockwork structure.

The hydrothermal veins that fill altered rocks have a massive texture with a composition of silica, carbonate minerals, and ore minerals, such as pyrite. The hydrothermal vein direction measurements carried out in the Kaligono area show trend northeast-southwest and southeast-northwest directions.

The Hargorojo area is located on Ijo Volcano and is composed by andesite and dacite intrusion rocks. Dacite is found in the northwest of the research area at Hargorojo while andesite is found in the southeast of the study area. Rocks in the Hargorojo area experience phyllic, argillic, and propylitic alteration. Dacite with phyllic alteration and infiltrated by silica-clay-pyrite vein found in the main river in Hargorojo Village (Figure 4.B). The geological structure found in the Hargorojo area is joints and shear faults that are predominantly northeast-southwest and southeast-northwest.

Dacite rocks found in Hargorojo Village have also undergone argillic alteration as indicated by clay and silica minerals. Barite veins are also found on the main river in Hargorojo Village with dacitic host-rock (Figure 4.A). In the southern part of Hargorojo Village, andesite rocks have undergone argillic alteration, these rocks are associated with silica veins with vuggy structures (Figure 4.C). Rocks with propylitic alteration are found in areas with relatively dense contours, some rocks with moderate alteration (25-75% of the minerals undergo alteration). Rocks that undergo propylitic alteration are composed of chlorite, calcite, and pyrite (Figure 4.D).

Figure 4. Field features of the Hargorojo prospect. (A) Barite veins (indicated by yellow lines) filling the rock fractures exposed to the main river. West facing camera. (B) Dacite rock outcrop relatively fresh. West facing camera. (C) Extension joints filled with veins with a massive structure with a secondary mineral composition (clay minerals, secondary quartz) in phyllic altered dacite rocks. Camera facing east. (D) Rock propylitic altered dacit which undergoes expansion in the body of the outcrop. West facing camera.

Petrological and Petrographic Analysis

Petrological and petrographic analyzes were performed on fresh rock samples, altered rocks, and hydrothermal veins with a total of 52 samples. The petrological analysis is carried out for rock texture, as well as mineral abundance which will be used in determining rock names; however, this analysis will be detailed using petrographic analysis. The petrographic analysis was performed by looking at thin section of rock using an Olympus polarizing microscope with a camera that connected to a computer.

Petrological and petrographic observations made on existing rocks in the Kaligono area show that there are three types of rock, namely dacite intrusion, andesite lava, and andesite intrusion. Lava and andesite intrusion are differentiated through petrographic observations, andesite lava will show trachytic texture or flow while andesite intrusion will not. The analyzed rock shows that the rock has undergone hydrothermal alteration as indicated by alteration minerals, such as clay and silica minerals, and hydrothermal veins.

Based on petrographic observations, the rocks have undergone moderate-strong alteration, the alterations formed are divided into three types, including phyllic (which is characterized by the presence of secondary quartz, sericite, and dominant pyrite), propylitic (characterized by pyrite minerals, chlorite, calcite, epidote, and actinolite), and argillic (illite, smectite, kaolinite, and silica). Vein textures that can be observed on petrographic observations include massive and stockwork with a composition of secondary quartz minerals, illite, iron oxide, pyrite, and calcite (Figure 5).

The Hargorojo prospect has quite different rock and vein characteristics from the Kaligono area Petrological and petrographic observations carried out in the Hargorojo area show that the area is composed of two types of rock, namely andesite intrusion and dacite intrusion. The percentage of the amount of quartz and feldspar in the rock is a distinguish feature between andesite and dacite, dacite will have a greater percentage of quartz than andesite.

The rock samples from the Hargorojo prospect show that the rocks have undergone hydrothermal alteration as indicated by alteration minerals, such as clay and silica minerals, as well as the presence of hydrothermal veins. Based on petrographic observations, rocks have undergone moderate-to very strong alteration, the alteration formed is divided into three types, including phyllic (which is characterized by the presence of dominant secondary quartz, sericite, and pyrite), propylitic (characterized by pyrite, chlorite, and calcite), and argillic (illite, smectite, kaolinite, and silica). Vein textures that can be observed on petrographic observations, such as massive, drussy, and comb with the mineral composition of secondary quartz, chalcedony, barite, illite, iron oxide, pyrite, and calcite (Figure 6).

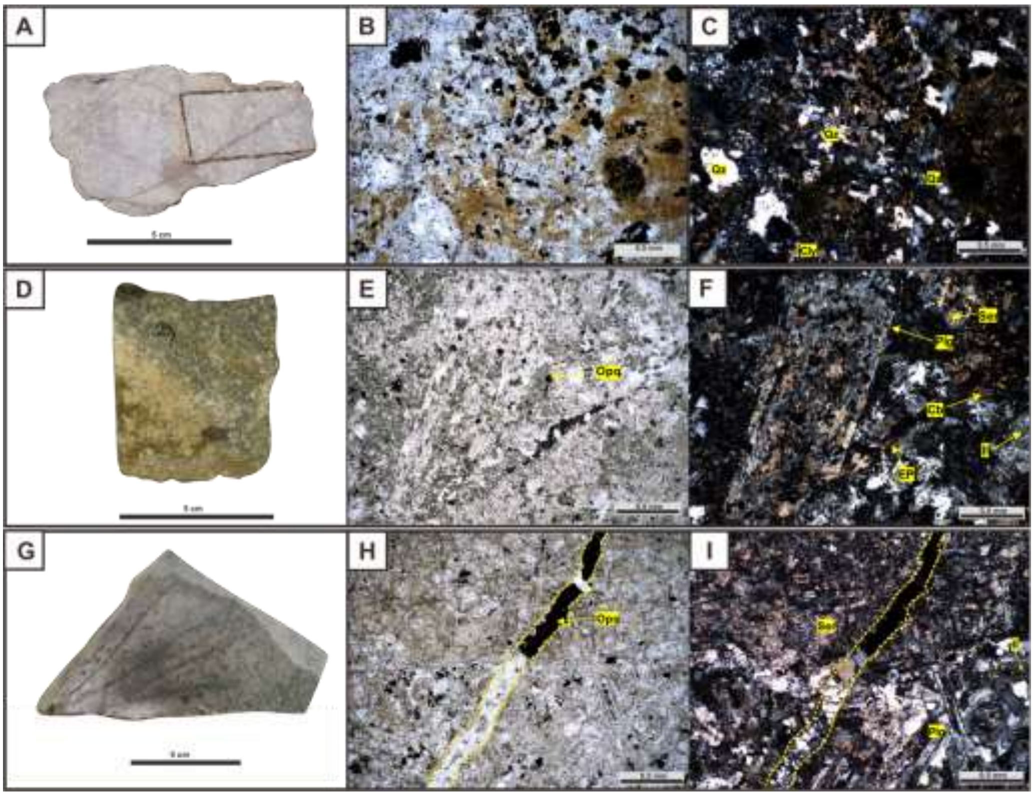


Figure 5. Altered rock samples from the Kaligono prospect consisting of rock slabs (A,D,G), PPL petrographic features (BEH), and XPL petrographic features (C,F,H) consisting of (A) Dacite which undergoes argillic alteration with a very strong degree and pervasive alteration, and there is the presence of oxide veinlets. (D) Propylitic altered andesite with moderate degree and selective alteration. (G) Phyllic altered dacite with a strong degree and pervasive alteration shows silica+pyrite vein. (Opq: opaque minerals, Ser: sericite, Plg: plagioclase, Il: illite/smectite, Cb: carbonate minerals, Qz: quartz, Ep: epidote, Cly: clay minerals).

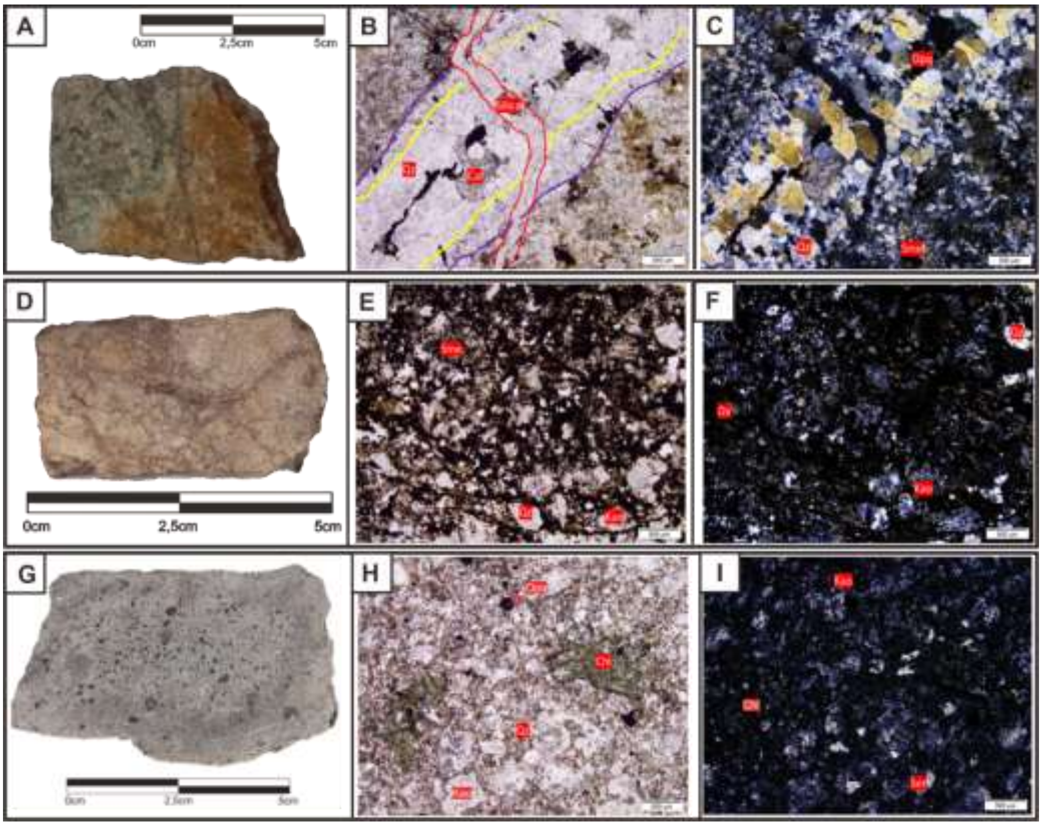


Figure 6. Altered rock samples from the Hargorojo prospect consisting of rock slabs (A,D,G), PPL petrographic features (BEH), and XPL petrographic features (C,F,H) consisting of (A) Phyllic altered dacite with a strong degree of alteration. (D) Andesite which undergoes argillic alteration with a very strong degree of alteration, and there is the presence of silica veins with a massive texture with a vuggy structure. (G) Propylitic altered andesite with low alteration degree. (Kao: kaolinite, Qz: quartz, Ch: chlorite, Ser: sericite, Opq: opaque minerals, Sme: smectie).

Mineragraphy Analysis

Mineragraphic observations are intended to see opaque minerals or ore minerals that cannot be observed on petrography. Mineragraphic observations were carried out with the Leica ore microscope on 22 samples. Ore mineral density is generally contained in veins although it can also be found inside the rock. In addition to the mineral ore that fills the veins, there are gangue minerals in the vein body that can be identified by mineragraphy and petrographic observations in general. Mineragraphic observations can also be intended to determine the relationship between ore minerals and the special texture of ore minerals.

The Kaligono area has the characteristics of ore minerals that are formed at medium-high temperatures, such as magnetite, chalcopyrite, and sphalerite (Figure 7). Besides, there are other metal minerals, such as pyrite and hematite. Pyrite is widely formed disseminated in the side rock and some accumulate in the silica veins that fill the rock.

The Hargorojo area has different ore minerals from the Kaligono area. Ore minerals formed in the Hargorojo area include chalcopyrite, silver, galena, and sphalerite. Also, there are other metal minerals, such as pyrite and hematite. Galena can be observed from the presence of triangular pits. Silver was found to be relatively small in size with bright white color and a higher reflectance than pyrite (Figure 9). Pyrite is widely formed (disseminated) in the side rock and some accumulate in the silica veins that fill the rock.

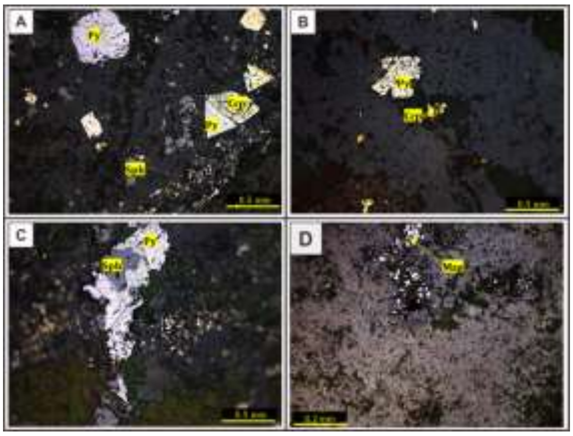


Figure 7. Appearance of several ore minerals in altered rock samples from the Kaligono area. (py: pyrite, mag: magnetite, ccp: chalcopyrite).

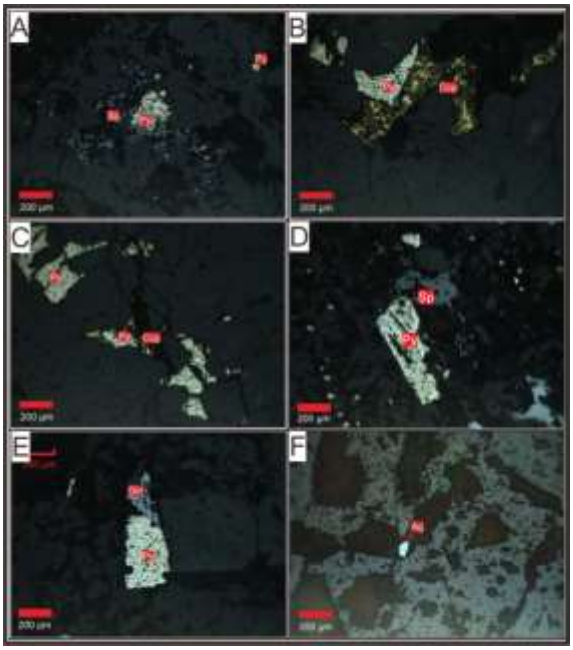


Figure 8. Appearance of several ore minerals in altered rock samples from the Hargorojo area. (py: pyrite, gln: galena, ccp: chalcopyrite).

X-Ray Diffraction Analysis

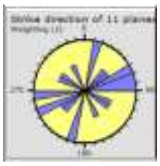
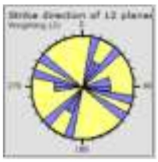
X-Ray Diffraction (XRD) observations were made on argillic altered rocks and hydrothermal veins in the study area. XRD analysis includes bulk analysis, analysis of clay air-dried, ethylene glycol, and heated 550℃. These observations are intended to identify minerals that are difficult to observe on microscopic observations.

Minerals that can be identified and commonly present on the argillic altered rocks in Hargorojo prospect including minerals such as illite, smectite, chlorite, goethite, hematite, lepidocrocite, montmorillonite, interlayered illite-smectite, quartz, and pyrite. Whereas in the Kaligono prospect that is present as gangue minerals, among others, illite, margarite, interlayered illite-mica, quartz, chrystobalite, goethite, hematite, calcite, dolomite, pyrite, epidote, and chamosite. The types of mineralized clay formed by hydrothermal alteration are smectite (Montmorillonite), kaolinite, dickite, halloysite, and illite.

Hydrothermal Veins

Hydrothermal veins fill rock fractures and deposit minerals economically. Besides, veins can also indicate the direction of the tectonic force acting on an area. The characteristics of hydrothermal veins, such as texture and mineralogy, can characterize different formation processes. Kaligono and Hargorojo areas have hydrothermal veins that have different characteristics. Details can be seen in Table 1.

Tabel 1. Comparison table of hydrothermal veins from Kaligono and Hargorojo prospects.

Location	Dimension	Structure	Texture	Gangue	Ore	Direction
Kaligono (Gajah)	<0.5-10 cm	Massive, brecciated, stockwork, vein swarm.	Massive	Secondary quartz, carbonates, clay minerals, pyrite, hematite.	Magnetite, chalcopyrite, sphalerite.	NE-SW, NE-SE 
Hargorojo (Ijo)	<0.5-30 cm	Massive, intersecting, stockwork, vuggy	Massive, comb, Drussy.	Secondary quartz, chalcedony, barite, illite, ferro-oxide, pyrite.	Chalcopyrite, silcer, galena, sphalerite.	NE-SW, NE-SE 

Discussion

The results of data analysis taken from the Kaligono and Hargorojo areas, such as the texture of veins and mineral assemblages in altered rocks, indicate that two areas belong to the type of epithermal deposits. Epithermal deposits generally form closer to the surface characterized by the presence of chalcedony, calcite, and hydrothermal breccias with commonly formed ore associations such as gold, silver, copper, and lead (Hedenquist & Arribas, 2017).

Texture and mineralogical data indicate that the Kaligono and Hargorojo areas specifically belong to low sulfidation epithermal deposits. According to John et al. (2018), low sulfidation epithermal (adularia-sericite) are associated with veins and are composed of alteration minerals that have a pH approaching neutral, such as quartz ± calcite ± adularia ± illite. The distribution of low sulfidation deposits is largely controlled by the geological structure. Most of the mineral metals in the low-sulfidation epithermal are found in cavity-filling veins or small vein stockworks (White et al., 1995).

The Kaligono and Hargorojo areas which are low sulfidation epithermal deposits have several different characteristics of the sediment formed, including the vein structure and texture formed and the composition of alteration minerals and ores. The Kaligono area has a more dominant breccia and stockwork structure than the Hargorojo area. Meanwhile, the vein texture in the Hargorojo area is mostly comb and drussy, while in the Kaligono area there are more massive textures. In the Kaligono area, there are many epidote and actinolite, while the Hargorojo, clay minerals are dominantly formed.

CONCLUSION

The Kaligono and Hargorojo areas are categorized as low-sulfidation epithermal deposits based on the texture and mineralogy of veins and altered rocks found in both places. However, there are some differences in vein texture and rock mineralogy which indicate a different characteristic of the low-sulfidation epithermal deposits formed. The vein characteristic of the Kaligono area is characterized by a complex stockwork structure, hydrothermal breccias, and massive vein texture containing high-temperature hydrothermal minerals, namely. epidote, actinolite, and magnetite, show that Kaligono

Deposits are controlled by deep structures, and maybe associated with porphyry mineralization. Meanwhile, the Hargorojo area shows typical open space-filling vein textures, such as comb and drussy, which contain hydrothermal minerals at lower temperatures, such as chalcedony, silver, and galena. Based on texture and mineralogical characteristics, the Kaligono area shows that alteration and mineralization occur closer to the magmatic source. On the other hand, the Hargorojo area shows a process of alteration and mineralization which is relatively far from the source.

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