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Host rock petrology, hydrothermal alteration characteristics & ore mineralogy of porphyry copper-gold deposit, Brambang, Lombok, West Nusa Tenggara Indonesia

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ABSTRACT

Several world-class porphyry copper–gold deposits/prospects have been discovered in the eastern Sunda arc. One copper–gold prospect area is located at Brambang, Sekotong District, West Lombok Regency, West Nusa Tenggara Province, Indonesia This study is aimed to understand a preliminary geological framework, which characterizes the Brambang deposit in terms of the host rock, hydrothermal alteration characteristics, and ore mineralogy studied in the deposit. Fieldworks and several laboratory analyses were performed including petrography, ore mineralogy and X-ray diffraction (XRD). Host rock was dominated by volcanic rocks consisting of dacitic volcanic rock, diatreme breccia, and diorite intrusion. The hydrothermal alteration is characterized by argillic alteration (kaolinite-illite-smectite), propylitic (chlorite-epidote-calcite), and potassic (quartz-biotite-actinolite-magnetite), with the presence of sulfide minerals such as pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and chalcocite (Cu_2S), and the oxide minerals such as magnetite (Fe_3O_4), and hematite (Fe_2O_3). The alteration zone stage in the study area begins with forming a quartz-biotite-magnetite (potassic zone) formed at a high temperature of around 300–360 °C and at pH 7–8. This stage is followed by forming a chlorite-epidote-calcite (propylitic zone) outside the potassic zone, at a temperature range of 290–340 °C and pH of 5–6, which indicates a hydrothermal system cooling process. Then, due to the increasing influx of meteoric fluid that enters the fractures formed due to fault activity, a quartz-kaolinite-illite (argillic zone) is formed with a temperature range of 130–210 °C and pH 4–6. The presence of diatreme breccia and stockwork within the mineralization in the Brambang deposit supported the theory related to porphyry copper–gold deposits.

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1. Introduction

Volcanism and magmatism activities have become a source of mineralization in some areas south of Lombok, making it potential for copper–gold deposits [1] describes the genesis of Cu-Au porphyry associated with plate tectonic models and explains that Cu-Au deposits result from subduction activity between the oceanic plate forms an island arc. The tectonic map made by [2] depicts the distribution of Late Cretaceous to Pliocene magma arcs with mineralization controlled by this tectonic pattern. Mineralization and alteration in the form of propylitic, argillic, and silicic, which is sometimes associated with pyritization and stockwork structures, may be found throughout the southern half of Lombok, particularly in the Brambang area [3]. According to [4], the mineralization found in the southwestern section of the island of Lombok, where the Brambang potential area is located, is described as a porphyry copper–gold mineralization complex. However, research on the characteristics of porphyry copper–gold deposits in this area is still quite restricted [4] conducted a regional study on the mineralization system in South Lombok, which included the areas of Selodong, Mencagah, Brambang, and Pelalang [5] also investigated the geology and mineralization of the Pelangan area

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and its environs. Since there has been no previous research in the Brambang area on the relationship between the geology of the study area, host rock petrology, alteration zones, and ore mineralogy, this work aims to study the characteristics of newly obtained data of copper–gold deposit characteristics, specifically those in Brambang, Lombok, West Nusa Tenggara Indonesia.

Lombok Island is in the Sunda arc, an archipelago formed by volcanic mountains (Fig. 1a). Lombok Island is also part of the Nusa Tenggara archipelago [6]. The lithological phases that make up the southern part of Lombok Island include Late Oligocene-Middle Miocene andesitic volcanic rocks and intercalated volcanoclastic rocks, which are associated with low-k intermediate intrusive rocks, shallow marine sedimentary rocks, and limestone [7]. Intrusive rocks are prevalently cropped out throughout Lombok's west-east trending belt. The oldest intrusion, diorite stocks or dykes, has intruded volcanic and sedimentary strata [8]. In the peripheral of dacite porphyry, the diatreme breccia complex is mapped out. Quaternary volcanic products, preserved in the island's northern section, are the region's youngest rocks. The presence of diatreme breccia could represent a late phase of magmatic activity in the area, leading to the end of hydrothermal alteration [4]. Porphyry copper–gold is overlaid above the high-sulfidation epithermal

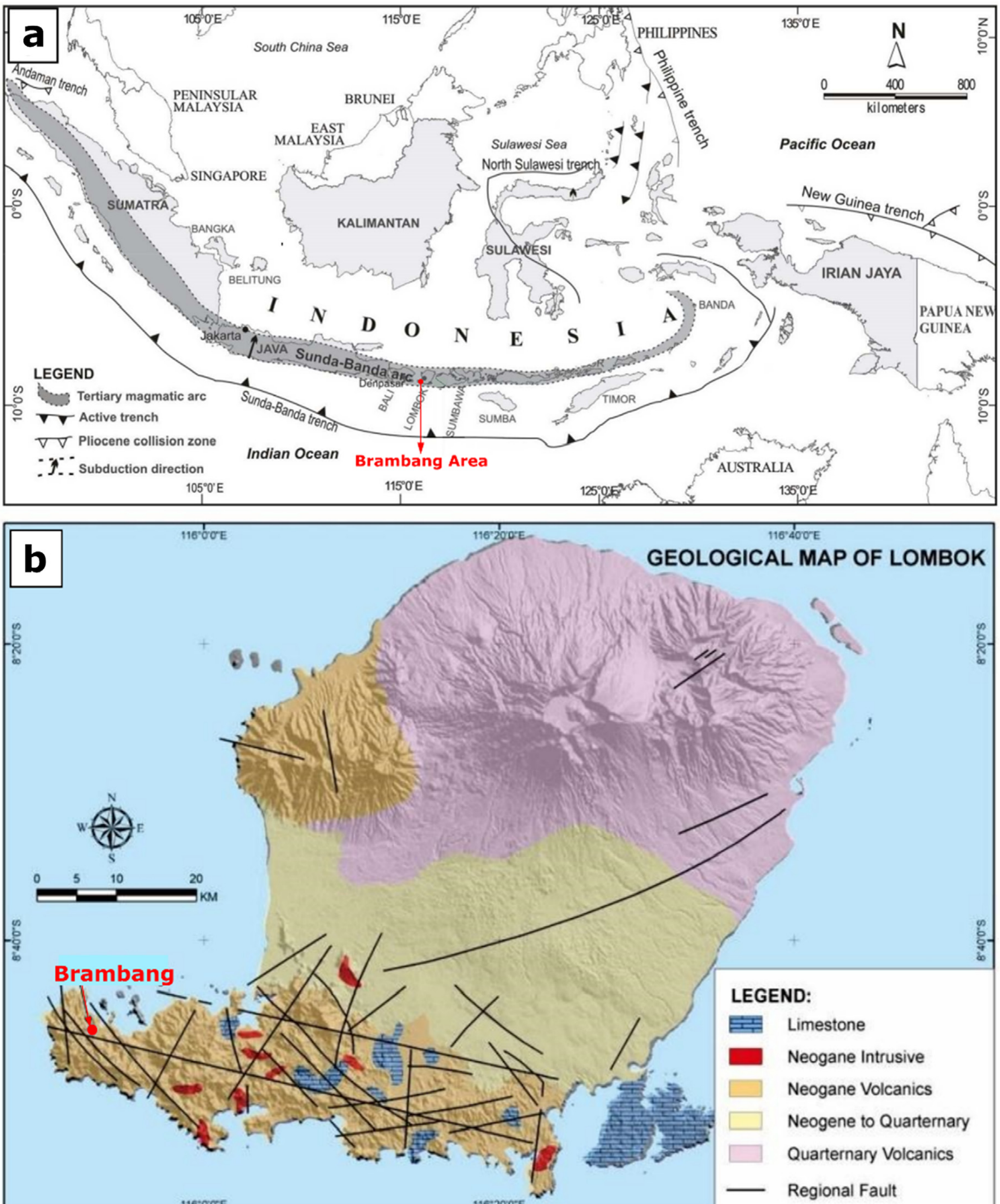

Fig. 1. (a) Regional Map of Indonesia showing the location of the Brambang deposit area (modified from [9]) (b) Geological map of Lombok Island (modified after [10]).

gold-silver in the Lombok Island mineralization system. Regional features include north–south extension, folding and thrust faults, and NNW-NNE trending strike-slip faults due to a north–south Late Miocene compressional regime (Fig. 1b).

2. Methodology

Generally, research methods are divided into fieldwork and several laboratory analyses. Geology of host rock and hydrothermal alteration observations were prioritized during fieldwork. The selected samples were analyzed in the lab for host rock petrology, ore mineralogy, and hydrothermal alteration characteristics. An integrated petrographic analysis of host rocks related to Brambang deposits has been carried out by preparing the thin sections. For the ore microscopy study, several samples were selected from mineralized veins containing abundant sulphide and oxide minerals and then prepared for polished sections. Preparation was done with reference to [11]. Hydrothermal alteration minerals were determined by X-ray diffraction (XRD). These laboratory analyses were carried out in the Geological Engineering Department Laboratories, Universitas Gadjah Mada, Indonesia.

3. Results and discussion

3.1. Host rock petrology

Almost all the host rocks in the Brambang area comprise dacitic volcanic rocks. They are characterized by rocks that have been converted into argillic alteration and propylitic alteration. The dacitic volcanic rock is grayish-white in color, strongly altered (Fig. 2a), grain size 0.1–0.5 mm, composed of quartz, opaque minerals, albite, plagioclase, olivine, and some clay minerals (Fig. 2b). The diatreme breccia occurred in several spots, petrographically is colored: grayish-white, moderately altered, has a grain size of 0.1–0.5 mm (Fig. 2c) composed of quartz, clay minerals, and opaque (Fig. 2d). In particular, diorite intrusion (Fig. 2e) is characterized by gray, medium-coarse phaneritic, holocrystalline, subhedral, and equigranular porphyritic with the chlorite, epidote, quartz, plagioclase mineral compositions (Fig. 2f).

3.2. Hydrothermal alteration

Based on petrography and XRD analysis, the hydrothermal alteration characteristics in the Brambang deposit are divided into four types of alteration: potassic, propylitic, and argillic.

Argillic alteration is widely distributed in the study area, where the appearance of the argillic altered rocks is characterized by grayish-white rocks, which indicate rich in clay minerals (Fig. 3a). Petrographic analysis on altered dacitic volcanic rocks samples (Fig. 3b) showed a microscopic appearance of the clay minerals (>40%) and quartz (>40%). Clay minerals can be identified in detail using XRD analysis of rock samples. In general, clay minerals identified include illite, kaolinite, smectite (Fig. 3c). Based on the alteration mineral assemblage, which is dominated by clay and quartz minerals, the alteration mineral assemblage is classified as argillic alteration according to the classification of [12], formed at low temperatures (200–250 °C) and generally has a low pH (4–5) [12].

Propylitic alteration is widespread in about 20% of the research area, and the altered rocks include diorite intrusion rock. Greenish-gray rocks characterize the appearance of the altered outcrop rock as an indication of chlorite mineral content (Fig. 4a). The dominant alteration mineral assemblages found include chlorite (10–17) %,

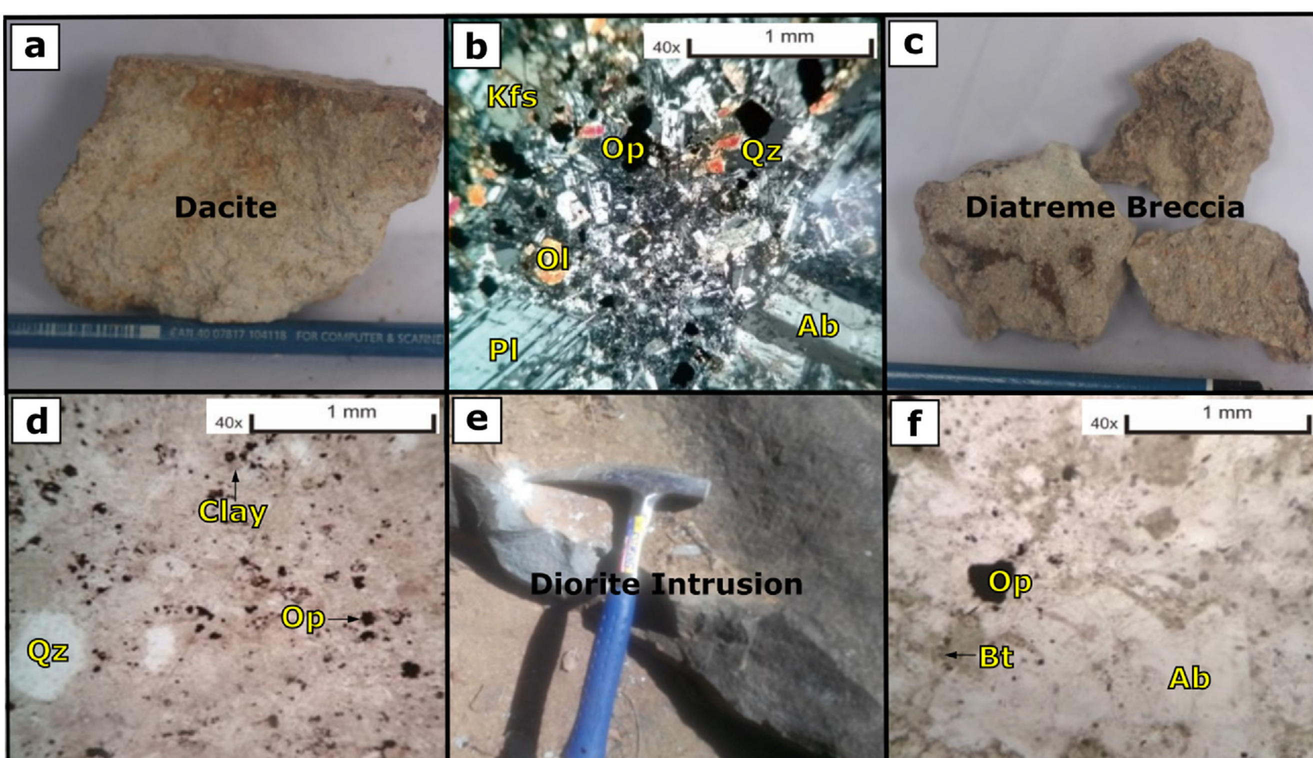

Fig. 2. (a) Hand sample of dacite volcanic rock. (b) Photomicrograph of dacite rock sample. (c) Hand sample of diatreme breccia. (d) Photomicrograph of diatreme breccia rock sample. (e) Field photo of diorite intrusion outcrop and (f) Photomicrograph of diorite rock sample. Abbreviations: Kfs-Potassium feldspar, Op-Opaque, Ol-Olivine, Ab-Albite, Pl-Plagioclase, Qz-Quartz, Bt-Biotite.

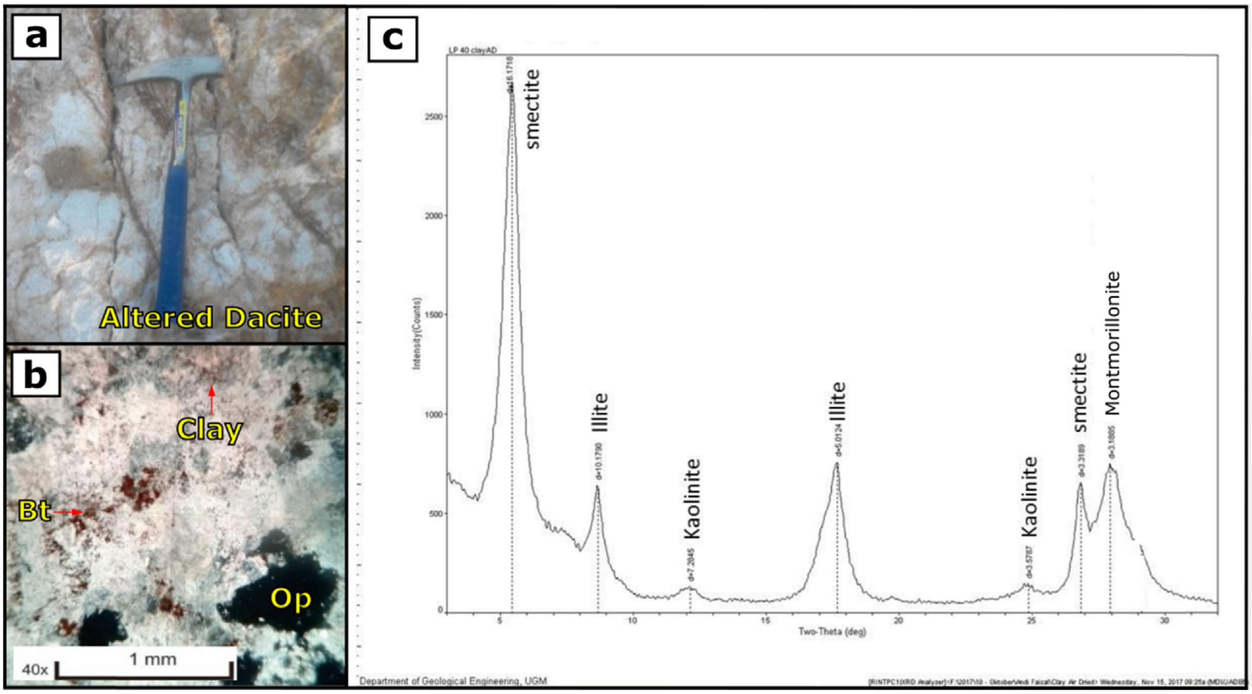

Fig. 3. Argillic alteration rock data (a) Field photo of argillic altered dacite outcrop. (b) Photomicrograph of argillic altered dacite rock sample. (c) XRD analysis results for clay minerals in argillic altered dacite rock sample. Abbreviations: Bt-Biotite, and Op-Opaque.

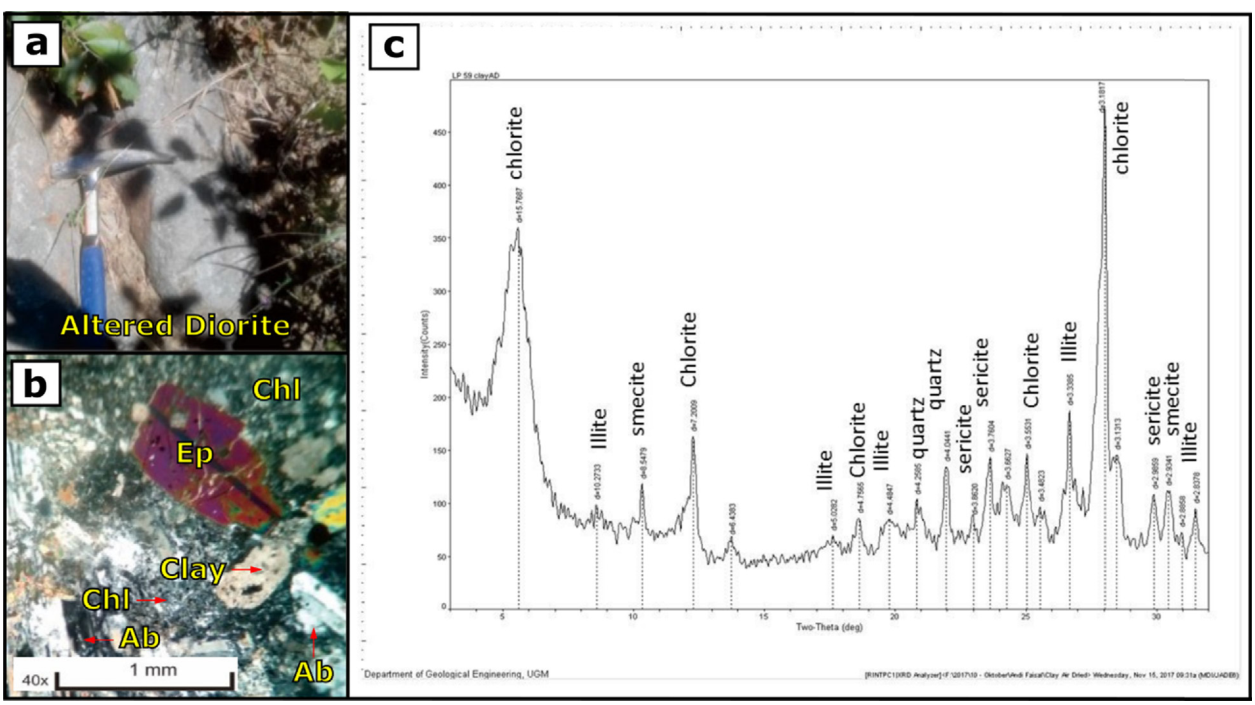

Fig. 4. Propylitic alteration rock data. (a) Field photo showing the outcrop of porphylitic altered diorite intrusion. (b) Photomicrograph of propylitic altered rock sample. (c) XRD data for prophylitic altered rock sample. Abbreviations: Chl-Chlorite, Ep-Epidote, and Ab-Albite.

quartz (25–40) %, and epidote (3–8) % (Fig. 4b). Clay minerals are changes from feldspar minerals and quartz results from cooling hydrothermal solutions when experiencing sudden changes in temperature and pressure. XRD analysis resulted in the clay minerals identified as chlorite, calcite, and epidote (Fig. 4c). Based on the alteration mineral assemblage, which is dominated by chlorite, calcite, and epidote, the alteration group is classified as propylitic alteration according to the classification of [12] they formed at moderate temperatures (<200–250 °C) and generally has a low pH of 4.

The potassic alteration was only spread over 2% of the total area of the study. The altered rock is quartz diorite with a porphyritic

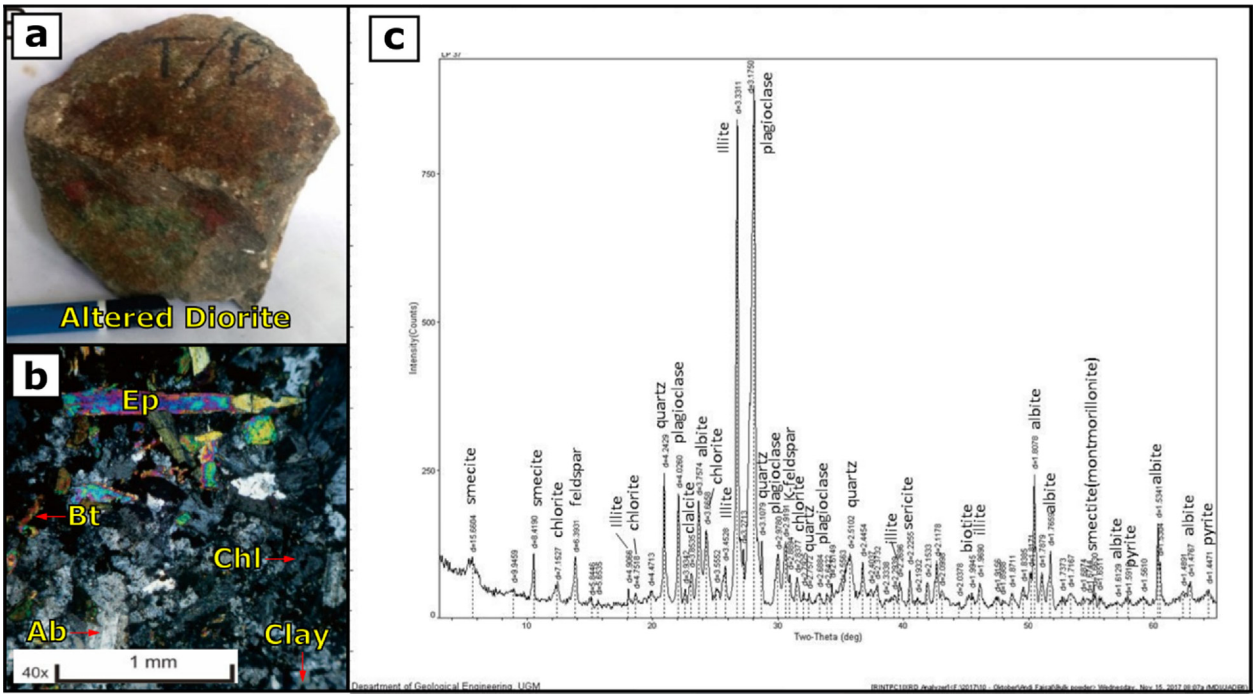

Fig. 5. Potassic alteration rock data. (a) Hand sample of potassic altered diorite rock. (b) Photomicrograh showing the potassic altered diorite rock. (c) XRD data of potassic altered diorite rock. Abbreviations: Chl-Chlorite, Ab-Albite, Bt-Biotite, and Ep-Epidote.

texture. The appearance of the rock outcrop is light gray, holocrystalline, and the presence of mineralization in the rock (Fig. 5a). Petrographically, the minerals present are plagioclase (45%), anhedral quartz (15%), pyroxene (10%) is slightly converted to actinolite. Secondary quartz minerals (10%) are present to fill rock fractures (quartz veins), secondary biotite (6%), and epidote (3%) (Fig. 5b). The bulk XRD analysis also shows that the rock is rich in potassic minerals like biotite and k-feldspar (Fig. 5c).

3.3. Ore mineralogy

Several polished section analyses of ore minerals on rock samples with high sulfide/oxide mineral contents. Ore minerals identifications follows [11]. The sulphide minerals discovered were:

- Pyrite (FeS_2), usually euhedral to subhedral, yellowish white in color, isotropic, and without pleochroism (Fig. 6a).
- Chalcopyrite ($CuFeS_2$), yellow in color, weakly anisotropic (dark brown – dark blue), and without pleochroism (Fig. 6b), and
- Chalcocite (Cu_2S), are blue grey in color, are weakly isotropic, and without pleochroism (Fig. 6c).
- Several oxide minerals found are:
- Magnetite (Fe_3O_4), gray-pink in color, isotropic and without pleochroism (Fig. 6d).
- Hematite (Fe_2O_3), gray reddish in color, with reddish-brown internal reflections, and without pleochroism (Fig. 6e).

4. Discussion

The approximate stages of the alteration zone may be seen based on the grouping of hydrothermal alteration minerals according to [12]. There are three types of alteration zones in the Brambang deposit, namely the quartz-biotite-actinolite-mag netite zone (potassic zone), the chlorite-epidote-calcite zone (propylitic zone), and the kaolinite-illite–smectite zone (argillic) indicates a change in temperature and pH of the hydrothermal solution.

The alteration zone stage in the study area begins with forming a quartz-biotite-magnetite (potassic zone) formed at a high temperature of around 300–360 °C and at pH 7–8. This stage is followed by forming a chlorite-epidote-calcite (propylitic zone) on the outside of the potassic zone, at a temperature range of 290–340 °C and at a pH of 5–6, which indicates a hydrothermal system cooling process. Then, due to the increasing influx of meteoric fluid that enters the fractures formed due to fault activity, a quartz-kaolinite-illite (argillic zone) is formed with a temperature range of 130–210 °C and pH 4–6. These alteration zones show a change in mineralogy due to changes in temperature and pH of the hydrothermal fluid.

Diatreme breccias are exposed in several places, one of which is in Brambang as a sign of the final stage of the main activity of hydrothermal alteration [4]. This diatreme breccia body is generally shaped like a pipe or irregular cylindrical mass, with a diameter of several meters to several hundred meters. Some diatreme breccias (pipe breccias) are shaped like carrots that taper down and taper off. Typically, the diatreme breccia usually has more rounded fragments when compared to fragments in hydrothermal breccias. From the outset, diatreme breccias generally have good porosity and permeability; they can serve as mineralization channels and form important ore bodies.

Stockwork (scattered) in huge rock masses associated with alteration and mineralization processes after porphyritic intrusions characterise porphyry deposits [7]. The accompany of stockwork textures in the rock and sulphide minerals in the veins is the porphyry system's main indication. In the study area, several stockwork structures were found which are closely related to intrusion and ore mineralization and are associated with overprinted potassic alteration.

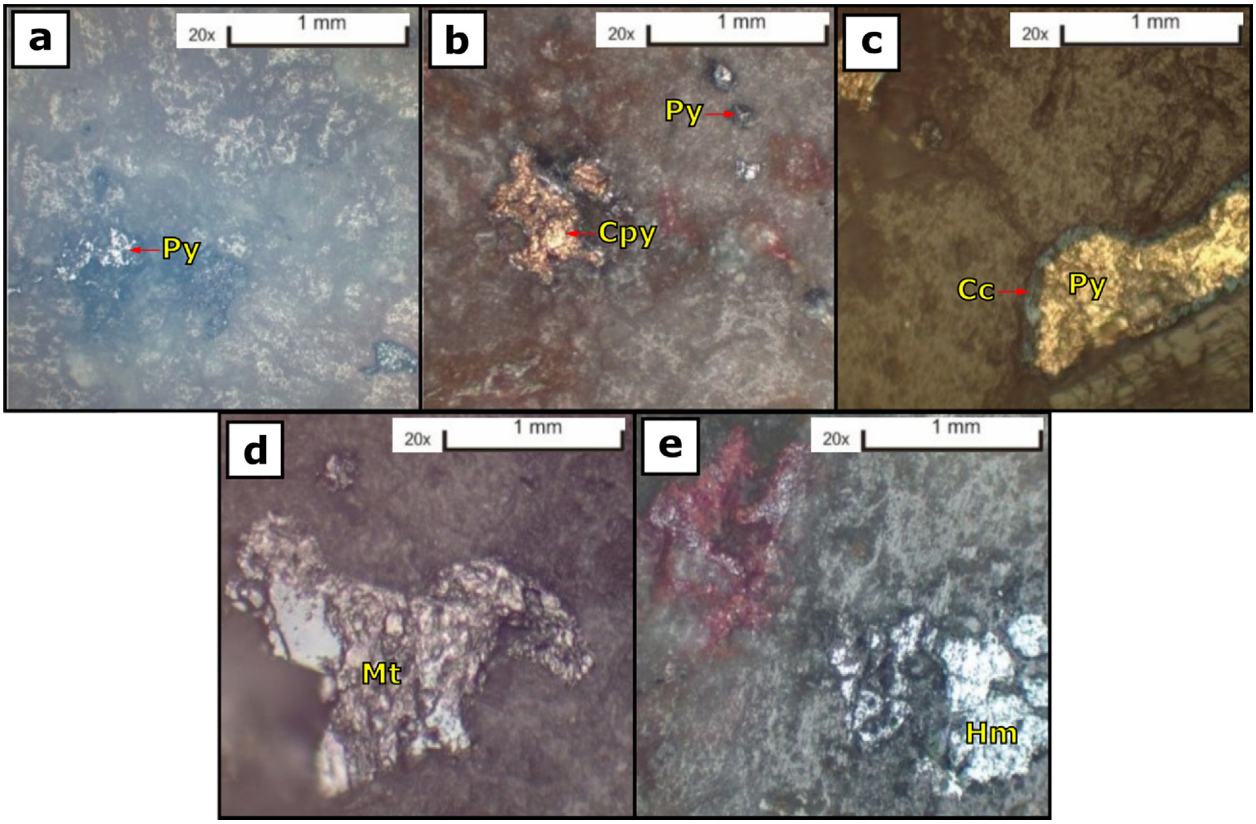

Fig. 6. Photomicrograph of ore minerals from Brambang deposit rock samples. Abbreviations: Py-Pyrite, Cpy-Chalcopyrite, Cc-Chalcocite, Mt-Magnetite and Hm-Hematite.

5. Conclusion

Dacite volcanic rocks and diatreme breccia characterize the Brambang deposit as the host rock with diorite intrusion. The hydrothermal alteration is characterized by argillic alteration (kaolinite-illite–smectite), propylitic (chlorite-epidote-calcite), and potassic (quartz-biotite-actinolite-magnetite), while mineralization is characterized by the presence of sulfide minerals; pyrite (FeS_2), chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S), and the oxide minerals magnetite (Fe_3O_4), and hematite (Fe_2O_3). The presence of diatreme breccia and stockwork together with the mineralization in the Brambang deposit, as discussed before, supported the theory related to porphyry copper–gold deposits. Regionally and preliminary studies can conclude that the Brambang deposit shares geologically similarities (in term of tectonic setting, host rock, hydrothermal alteration characteristics and ore mineralogy) with many other copper–gold deposits in the world such as Batu Hijau deposit etc. However, several inferences on classified Brambang deposit model as porphyry copper–gold deposit remains speculative in the absence importance data like rock geochemistry and ore fluid characteristics.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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