The alteration characteristic of Cu-Au skarn and porphyry-style alteration in The Deep Mlz, Ertsberg District, Papua, Indonesia

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Abstract. The Deep Mill Level Zone (DMLZ) is a mining zone within the lower part of the East Ertsberg Skarn System (EESS), a world class copper-gold skarn deposits that linked to porphyry system. Macroscopic observation along with microscopic analysis such as Petrography, SEM, and Mineragraphic analysis were made on each core samples to determine the zonation of Skarn alteration that superimposed with porphyry style alteration system within the mineralization zone. The DMLZ hosted in the Paleocene Waripi Formation that was intruded by Diorite to Quartz Monzodiorite. The Diorite characterized by its equigranular texture with the appereance of Hornblenda-Biotite phenocrysts, meanwhile later Quartz Monzodiorite shows porphyritic texture with abundant Pyroxene-Biotite phenocrysts embedded in allotriomorphic granular quartz groundmass. The DMLZ is hosted by mixed assemblages of siliciclastic and dolomitized carbonate that associate with the multiphase intrusive complex. The Skarn alteration zonation can be identified based on dominant lithology, such as: 1) Forsterite-diopside Skarn 2)Anhydrite 3)Magnetite Skarn 4)Hornfels 5)Marble and 6)Endoskarn. Meanwhile Porphyry system that identified in the diorite to quartz monzodiorite intrusion consist of: Secondary biotite-K Feldspar-actinolite±tremolite±anhydrite-magnetite; Sericite-pyrophyllite-illite±secondary quartz; Chlorite-clay minerals-calcite-epidote-secondary quartz; Calcite ± dolomite ± siderite±... Some alteration zones occur together in several depth indicating overprinting of different alteration episodes, but there is evidence that the carbonate alteration is the latest event. Cu-Au mineralization consists of bornite and chalcopyrite predominantly, both within skarn system and also porphyry copper system.

Keywords: DMLZ, Porphyry, Skarn Deposit, Ertsberg Intrusion, Alteration

1. Introduction
The Deep Mill Level Zone (DMLZ) is a world class copper-gold deposit within the lower part of the East Ertsberg Skarn System (EESS), West Papua, Indonesia. It is Intrusion and carbonate-hosted mineralization which associated with the 3.28-2.97±0.54 Ma multi-phase intrusive complex (Fig.1). The DMLZ is located in the deepest part of East Ertsberg Skarn System (EESS) that has contonuity vertically steeply dippng at about 1.5 km below the surface. The EES has discovered five mineralized zones within it, from top to bottom are: Gunung Biji Timur (GBT), Intermediate Ore Zone (IOZ), Deep Ore Zone (DOZ), Mill Level Zone (MLZ), and the deepest Deep Mill Level Zone (DMLZ) which lies at 2900-2600 m from the surface and still opens at depth.
The DMLZ as a world class copper-gold deposit has reserved of 472 million tons with 0.87% Cu, 0.71 g/ton Au, 4.36 g/ton Ag. It belongs to operational area of PT. Freeport Indonesia’s COW Block “A”, including the Super Giant Grasberg Porphyry Cu-Au deposits (Fig.2). The high grade of Cu-Au reserved is possible due to superimposed between skarn deposit and the porphyry system within host igneous rock. The main purpose of this paper is to describe the alteration mineral paragenesis within porphyry system, analize overprinting relationship between them, and seing their relation with Cu-Au mineralization.

2. Method
2.1. Regional Geology
The sedimentary stratigraphy of the Ertsberg District consist of Proterozoic through late Tertiary siliciclastic and carbonate rocks. It is consist of Mesozoic to late Tertiary siliciclastic of Kambelangan Group and New Guinea Limestone groups. The Kambelangan Group composed of largely siliciclastic rocks and is sub-divided into four formations; the Kopai, Woniwogi, Piniya, and Ekmai, from oldest to youngest. The Ekmai Formation is the youngest member of the Kambelangan and in the mining district is devided into three units known as Ekmai Sandstone (Kkes), Ekmai Limestone (Kkel) and Ekmai Shale (Kkeh) [1].

The Ekmai Sandstone is 600 meter thick and locally calcarceous, fine grained quartz arenite. The Ekmai Limestone overlies the Ekmai Sandstone and is a 90-meter thick unit composed of mixed assemblages of sandy and silty calcarenite. The Ekmai Shale is a locally defined unit consisting of four meters of black, calcareous shale that is used to define the stratigraphic boundary between the Kambelangan Group siliciclastics and the New Guinea Limestone Group carbonate [1].

The Tertiary New Guinea Limestone Group composed largely carbonate rocks and is also sub-divided into four formations; the Waripi, Faumai, Sirga, and Kais, from oldest to youngest. The Kais Formation is >1200m thick, generally clean and commonly highly fossiliferous limestone. The Kais Limestone is underline by the 30m thick. quartz carbonate sandstone of the Sirga Formation, a district stratigraphic marker. Below the Sirga Formation is the 150m thick, massive-bedded, clean limestone of the Faumai Formation. The Waripi and Faumai are the main host formations for skarn development in the Ertsberg East Skarn System, but the most susceptible is the lower part of the Waripi Formation. The Paleocene Waripi Formation is composed of mixed assemblages of dolostone, limestone, sandstone, and nodular anhydrite. Dolomite is abundant within the Waripi Formation, and quartz grains are common in varying percentages within the carbonate beds to form dolomitic sandstone and sandy dolostone. The Waripi Formation is interpreted as a shallow marine shelf and supratidal environment and characterizes the transition from siliciclastic sedimentation of the Kambelangan Group into carbonate deposition of the New Guinea Limestone Group. The depositional environment was most likely high-energy in shallow, warm-water, as evidenced by the lenses of well-sorted sandstone, packstone, and grainstone protoliths for the dolostone units [1].

Regional geology is controlled by a prominent complex system of west and northwest strike sub-parallel structures. COW “A” is situated in the center of New Guinea island, which is the boundary collision of Australia plate and Indo- Pacific plate [2] (Fig. 4). Rock deformation within Ertsberg District started about 13 Ma, jamming that was caused by rapid lifting and strong deformation in oceanic rock that formed fold and thrust mountain belt as the culmination of events. This mountain belt is known as the Central Range. This deformation form giant fold structure with km length of N110°E strike Yellow Valley Sincline and northwest-southeast fault with several km offset (Wanagon Fault and Idenberg #2 Fault). Northeast-southwest fault formed lately to cut the earlier fault.
Figure 1. Ertsberg District Geology Cross Section, Looking NW and the EESS ore bodies.

Figure 2. Geology map of COW A and location of EESS mining area (in blue circles) (PTFI geology map of COW A)
2.2. Method
To determine the alteration zones and analyze alteration mineral within each zone, Macroscopic observation along with microscopic analysis such as Petrography, SEM, and Mineragraphic analysis were made on samples from two wells that located in the middle section of DMLZ. Petrographic analysis is performed of all alteration zones either in the Porphyry system and also in the Skarn zone. While SEM analysis only conducts on sample of Pottassic zone, in order to compare geochemical composition of primary biotite and secondary biotite within Potassic zone.

3. Result
3.1. DMLZ Intrusion
The geology of DMLZ is greatly affected by volcanism and intrusion activity. Macroscopic observations along with microscopic analysis such as Petrography from core samples in the middle section of DMLZ (TE-03) have recorded two types of igneous rocks of Tertiary host mineralization, the Diorite and the Quartz Monzodiorite.

The Diorite characterized by its dark grey colour, phaneritic equigranular texture, mafic minerals contain of hornblende, pyroxene, biotite in 1-2 mm in size, and moderately altered to greenish yellowish epidote and chlorite. Petrographic analysis of Diorite shows holocrystalline texture, phaneritic, hypidiomorphic texture with felsic mineral composed of dominant plagioclase (25-30%), less K-Feldspar (8-10%) and also quartz (8-10%) (Fig.3). Plagioclase generally shows the twin albite, with labradoriteandesine composition. The mafic minerals composed of Hornblenda (15-18%), yellowish to greenish Aegirine and Augite Clinopyroxene (10-13%), and minor biotite. The mafic minerals have intensively altered to anhydrite-secondary biotite, sericite chlorite, and calcite. The diorite is spread in the shallow part of the intrusion and has generally been altered into calcite-epidote-chlorite.

The Quartz Monzodiorite shows light grey to whitish colour with blackish spots, porphyritic inequigranular, phenocryst contain of dominant pyroxene-biotite, and minor hornblende, embedded in whitish sugary quartz groundmass. The quartz monzodiorite partially cross cut by quartz±sulphide vein, and locally there are yellowish salvage sericite-clay mineral in some part of quartz monzonite intrusion. Petrographic analysis of Quartz Monzodiorite shows holocrystalline texture, porphyritic with phenocrysts composed of Clinopyroxene (10-12%), biotite (7-10%), hornblenda (5-8%) K-Feldspar (15-20%), plagioclase (25-30%), measuring 1-2.75 mm sized, embedded in allotriomorph granular quartz groundmass (18-25%). The mafic phenocryst minerals are all subhedral to anhedral shaped and have been intensively altered to secondary biotite-chlorite-pyrophyllite-sericite-calcite siderite. While the felsic phenocryst minerals appear in anhedral interlocking pattern with the quartz groundmass. The plagioclase are composed of Andesine-Labradorite, dominantly show albite twinning, whereas K-Feldspar mostly show Carlsbad twinning with perthite texture within it. The perthite texture is an intergrowth between the sodic albite plagioclase within K Feldspar as a host grain (Fig 3). It is only appears in quartz monzodiorite, which distinguishes it from the diorite. The allotriomorphic granular quartz groundmass occurs as anhedral mineral in 0.1-0.25 mm sized, the quartz also has also been altered to secondary biotite-pyrophyllite-sericite-and opaque minerals.

3.2. DMLZ Alteration
Alteration in DMLZ resulted from interaction of hydrothermal fluid with wallrocks that produced various mineral assemblage under specific geochemical conditions. The DMLZ hosts multiple skarn that link to porphyry-related system which responsible for the high content Cu-Au in the area. Through macroscopic analysis and microscopic analysis (Petrography, XRD, SEM) of each core samples in the middle section of DMLZ (TE-03), the alteration of DMLZ from hanging wall to footwall are shown below.
3.3. The Porphyry Copper Zones

3.3.1. The Secondary Biotite-K-Feldspar±anhydrite±tremolite-actinolite ±magnetite

The high temperature Sec.Biotite-K-Feldspar±anhydrite±tremolite-actinolite –magnetite zone develops in the deeper part of Quartz Monzodiorite intrusion. It occurs as irregular shape secondary biotite replaced the mafic minerals (clinopyroxene, hornblende) as well as felsic minerals. SEM analysis of sample in pottasic zone show Phlogopite biotite mineral which its composition more Anhydrite also occurs as replacement of mafic minerals, whereas the amphibol (tremolite-actinolite) locally occur as nodules/veinlets in the intrusion. There was overprint of high temperature secondary biotite being replaced by greenish sericite±phyrophyllite, and also chlorite-calcite, indicating overprinting process and changes in the composition of hydothermal fluid (Fig.4).

The Sec.Biotite-K-Feldspar±anhydrite±tremolite-actinolite –magnetite are also associated with pyrite and chalcopyrite, while bornite and covellite are less abundant. There were quartz-anhydrite-pyrite-chalcopyrite stockwork vein that cut this alteration zone. Referring to the presence of alteration minerals, this zone can be compared with pottaslic zone in the early retrograde stage (Corbett and Leach, 1997), with a temperature range of about 330-360°C.

3.3.2. Sericite-pyrophyllite-illite-secondary quartz

The sericitite-pyrophyllite-illite-secondary quartz zone develops in Quartz Monzodiorite intrusion. It characterized by the occurrence of abundant sericite-pyrophyllite and also moderately illite-secondary quartz as secondary minerals. The sericite shows two types various minerals, the green sericite and the colourless one. The greenish sericite occurs as replacement of secondary biotite and also primary felsic-mafic minerals, meanwhile the colourless composing the salvage sericitic zone (Fig.5). The yellowish salvage sericitic zone are composed of equigranular secondary quartz that replaced by dominantly illite-sercite-phyrophyllite mineral. Several quartz vein with zoning texture occur together with phyrophyllite and opaque mineral in the salvage zone.

The sericitite-pyrophyllite-illite-secondary quartz zone is characterized by the presence of quartz-anhydrite veins and yellowish salvage zone. The zone also associated with the chalcopyrite, pyrite, bornite, and covellite. Magnetite also occur as opaque minerals ini the veinlets. Referring to the presence of alteration minerals, this zone can be compared with phyllic zone (Corbett and Leach, 1997) in the late retrograde stage, with a temperature range of about 280-320°C.
Figure 3. Hand specimen igneous rock host mineralization of (A) Quartz Monzodiorite and (B) Diorite. Petrography of (C) (E) Quartz Monzodiorite, and (D) (F) Diorite. See the perthite texture as shown by abite twinning plagioclase that intergrowth within K-Feldpsar as a host grain mineral (E).

3.3.3. Chlorite-clay minerals-calcite-epidote-secondary quartz
The Chlorite-clay minerals-calcite-epidote-secondary quartz zone is develops in Diorite intrusion and the shallower depth near contact between intrusion with - chalcopyrite-carbonate-quartz vein with minor disseminated pyrite-chalcopyrite. The yellowish green epidote occur the skarn zones. The zone is characterized by the greenish colour altered rock which is cut by pyrite replaced felsic mineral (Plagioclase and K.Feldspar). Chlorite-calcite+clay minerals are also occur replaced the mafic minerals (Fig.6). The zeolites are occur locally with less percentage in some part of the intrusion. Referring to the presence of alteration minerals, this zone can be compared with prophylitic zone (Corbett and Leach, 1997), with a temperature range of about 250-300°C.
Figure 4. Petrography analysis of Sec.Biotite-K-Feldspar±anhydrite±tremolite-actinolite-magnetite zone in quartz monzodiorite intrusive rock. Note the irregular pattern/shreddy secondary biotite that appear together with subhedral primary biotite in quartz (A) (B). The (C) and (D) show actinolite-anhydrite that replaced the igneous rock.

3.3.4. Calcite ± dolomite ± siderite
The Carbonates are present in several phases of alteration. There is an earlier dolomite that has been replaced by secondary biotite, and also calcite as the latest alteration mineral that replaces secondary biotite-sericite, within deeper part of DMLZ (figure 7). SEM analysis of dolomite performed in potassic zone shows primary biotite phlogopite that replaced into a secondary biotite lacking of Fe-Mg, as well as it also been replaced into dolomite. This indicates that Mg from the phlogopite is transferred to dolomite and triggers the formation of secondary biotite that lacks of Fe Mg kations. Calcite ± siderite as the latest alteration phase, overprint high temperature alteration minerals and indicate a retrograde process that triggers mineralization.
3.4. Skarn Zones
3.4.1. Forsterite-diopside Skarn
Forsterite–Diopside skarn was develops in the upper levels of the EESS within Foumai and Waripi host stratigraphy. Forsterite and diopside are locally found together in the same rock, but generally occur as forsterite-dominant or diopside-dominant skarn assemblages. As handspecimen, forsterite-diopside skarn characterized by its light to dark greenish colour, indicating abundance of diopside and forsterite minerals. Microscopic analysis of samples from forsterite-diopside Skarn show light to pale greenish diopside, the colourless with strong relief and high birefringence. The forsterite-diopside skarn have been intensively altered to serpentine and talc, but diopside more likely associated with carbonate (ankerite-calci) than forsterite. Anhydrite and carbonate minerals overprint forsterite-diopside skarn assemblages, but tremolite is consistently associated with diopside within forsterite-diopside skarn. Diopside and forsterite are both associated with chalcopyrite and bornite veins, dissemination magnetite also common within forsterite-diopside skarn.
Figure 5. Petrography analysis of Sericite-pyrophyllite-illite-secondary quartz zone. Note the pyrophyllite-sericite-zoned sec. quartz that appear as a vein (A) (B) than sericite-illite-secondary quartz that replaced the igneous rock (C) (D).

Figure 6. Petrography analysis of Chlorite-clay minerals-calcite-epidote-secondary quartz zone. The (A) and (B) show calcite-chlorite that replaced the mafic minerals, and epidote-calcite that replaced the felsic minerals in diorite intrusive rock.
3.4.2. Anhydrite

Anhydrite occurs within all alteration types of the DMLZ skarn, forming masses and veins or vug fill within prograde skarn. Anhydrite as hand specimen characterized by it white greenish colour with blackish to blue scattered spots and it develops in dolomitized limestone Waripi Formation. Microscopic analysis of samples from anhydrite zone show the occurrence of anhydrite associated with actinolite, diopside, talc, and cut off with the secondary quartz-calcite-magnetite vein.

Figure 7. Petrography analysis of Calcite ± dolomite ± siderite in quartz monzodiorite intrusive rock. Note the rhombic dolomite that occur before secondary biotite, and the shreddy calcite as the latest alteration that replaced the secondary biotite and sericite.
3.4.3. Magnetite Skarn
Magnetite is present within each skarn alteration type and occurs in veins and disseminations of the DMLZ skarn system. Chalcopyrite and bornite occur as disseminations within massive magnetite skarn, pyrrhotite is locally abundant. Bornite is locally altered to covellite, and magnetite is altered to hematite along crystal margins. Magnetite skarn is also associated with anhydrite, forsterite, phlogopite and serpentine, some of them show the occurrence of talc, carbonates, quartz, in a minor assemblages.

3.4.4. Marble
Marble is the earliest zone that is formed due to contact metamorphism of dolomitized limestone intruded by the diorite to quartz monzodiorite intrusion. The marble in hand specimen shows its brownish white colour, holocrystalline, weakly reaction with the HCL, and sometimes show vuggy structure with fine grain pyrite veinlets. The marble characterized by its dominant carbonate minerals and brucite, associate with garnet that become more Al rich gets to the endoskarn. The high birefringence forsterite-diopside sometimes occur in marble, together with minor amount of anhydrite and chaledony.

4. Discussion
The DMLZ is Cu-Au skarn deposit that link to the porphyry system due to multi phase intrusive complex in the Ertsberg Intrusion. The Ertsberg Intrusion has been referred as a texturally homogenous igneous intrusion, with compositional variations resulting from heterogeneities in the original magma [3] [4]. Thereafter, Gibbins et al., 2003; Friehauf et al., 2005, propose four different rock types which identified within the intrusive center consisting of a series of porphyry dikes, aplite dikes, and two phaneritic phases including the Ertsberg Diorite. The Ertsberg Diorite has inequigranular to seriate phaneritic texture in the shallow portions of the intrusion; however, at depths below 3000 m elevation, the texture becomes porphyritic [5]. According to macroscopic and microscopic analysis of core samples in middle section of DMLZ, there are two types igneous rock that composed the Diorite intrusion, the equigranular diorite and porphyritic texture quartz monzodiorite. The equigranular diorite is spread out near contact with skarn system in the shallow part of the intrusion, whereas the porphyritic quartz monzodiorite occurs in the deeper part.

The Ertsberg Diorite can be distinguished based on their mafic mineral assemblage and spatial distribution. The diorite type characterized of its hornblende-pyroxene mafic minerals and less abundant of biotite. Large amount of andesine plagioclase compared with K-Feldspar is another characteristic of it. The quartz monzodiorite characterized by its large amount of mafic phenocryst (dominantly clinopyroxene and biotite) that embedded in sugary quartz groundmass. Macroscopic observation of quartz monzodiorite show the appereance of perthite texture, an intergrowth of albite plagioclase within K.Feldspar as a host grain. The diorite is typically altered into prophylitic type alteration, meanwhile quartz monzodiorite is intensively altered to pottasic alteration and also locally phyllic/sericitic zone.

The alteration zones of DMLZ are classified into two large groups, the Skarn alteration zone and the porphyry copper system. The skarn system shown by its massive coarse grained with Calc-silicate minerals (pyroxene, garnet) dominated. Meanwhile, the porphyry characterized by the occurrence of silica and sulphide veinlet that cross cut the intrusive igneous rock. The porphyry system are entirely occur in host igneous rock, whereas the skarn formed on the outside of intrusive body (endoskarn) and comes in contact with the carbonate unit (észszoskarn). From bottom to shallower diorite intrusion, the porphyry system composed of: The Sec.Biotite- K-Feldspar±anhydrite±tremolite-actinolite –magnetite (Pottasic Zone); Sericite-pyrophyllite-illite-secondary quartz (Phyllic Zone); Chlorite-clay minerals-calcite-epidote-secondary quartz (Prophyllitic Zone); and the latest Calcite-dolomite-siderite (Carbonates group) that crosscut all the porphyry alteration zones.
There were overprinting of different episodes of porphyry zones, such as secondary biotite that have been replaced by sericite-phyrophyllite (Phyllic Zone) or another secondary biotite which replaced by chlorite-calcite (Prophylitic Zone). The overprinting of the alteration minerals indicates changes in specific geochemical conditions which is triggered by reaction in hydrothermal solution. Seedorff et al., 2005 describes four types reactions that are responsible in producing hydrothermal alteration, they are: volatile exchange (e.g., propylitic alteration), hydrolysis (e.g., phyllic, argillic, and intermediate argillic alteration), alkali exchange (e.g., potassic alteration), and silica addition (e.g., silicic alteration). Secondary biotite replaced by sericite-phyrophyllite indicates the hydrolysis process in hydrothermal solution, it is evidence of water influx at a the certain depth in the alteration zone. While chlorite-calcite that replaced the secondary biotite is another different process due to volatile exchange (CO$_2$ and H$_2$O) in the hydrothermal solution.

The interesting phenomena comes from SEM-EDS analysis of sample from Pottassic zone. The alteration zone that being characterized by the presence of secondary biotite replaces mafic minerals, show that secondary biotite lacking of Fe-Mg occurs together with carbonates with high presentage of Mg (dolomite). It seems that Fe-Mg from primary biotite (Phlogopite) are transferred into dolomite and trigger the formation of secondary biotite which is lacking Fe-Mg. These type of carbonate occur in the first stage of alteration and different type from the last stage carbonate that cross cut all the alteration zones.

The DMLZ is hosted by mixed assemblages of silisiclastic and dolomitized carbonate that produce Mg-rich skarn assemblages. Some alteration zonation can be identified based on dominant lithology such as: 1) Forsterite-diopside Skarn 2)Anhydrite 3)Magnetite Skarn 4)Hornfels 5)Marble and 6)Endoskarn within the Ertsberg intrusion. There are some typical associated mineral that can be seen from microscopic observation, such as the forsterite and diopside Skarn are intensively altered to serpentine and talc, but diopside more likely associated with carbonate (ankerite-calcite) than forsterite. The marble zone characterized by its dominant carbonate minerals and brucite, associate with garnet that become more Al rich gets to the endoskarn. Cu-Au mineralization consists of bornite and chalcopyrite predominantly within magnetite skarn and anhydrite units. Magnetite skarn was introduced during the metasomatic fluid phase, and these fluids were also responsible for the emplacement of Cu and Au. Magnetite is commonly associated with forsterite-diopside mineralization and is associated with Cu-Au mineralization.

The Au-Cu mineralization in Porphyry style alteration system associated with the occurance of bornite,chalcopyrite, and magnetite. The chalcopyrite and magnetite occur in the secondary,biotite-K-Feldspar-ankerhide-magnetite (Potassic zone), meanwhile bornite-chalcopyrite occur in the sericite-phyrophyllite-secondary quartz (Phyllic zone).

5. Conclusion
The DMLZ is Cu-Au skarn deposit which is developed in an Upper Cretaceous to Lower Tertiary siliciclastic and carbonate succession, adjacent to the multi-phase Pliocene intrusive complex. There are at least two types of igneous rock that recorded in the igneous intrusive rock of DMLZ: the equigranular diorite and the porphyritic texture Quartz Monzodiorite. The Diorite characterized by its equigranular texture with the apereance of Hornblenda-Biotite phenocrysts, meanwhile later Quartz Monzodiorite shows porphyritic texture with abundant Pyroxene-Biotite phenocrysts embedded in allotriomorphic granular quartz groundmass. Locally, the porphyritic quartz monzonite show intergrowth between K-feldspar and albite plagioclase (perthite texture).

The DMLZ is hosted by mixed assemblages of silisiclastic and dolomitized carbonate that produce Mg-rich skarn assemblages. Some alteration zonation can be identified based on dominant lithology such as: 1) Forsterite-diopside Skarn 2)Anhydrite 3)Magnetite Skarn 4)Hornfels 5)Marble and 6)Endoskarn within the Ertsberg intrusion. Cu-Au mineralization consists of bornite and chalcopyrite predominantly
within magnetite skarn and anhydrite units.

Porphyry system are also present in the Ertsberg intrusion. There are five alteration zones identified in the diorite to quartz monzodiorite intrusion, those are: Secondary biotite-K-Feldspar±actinolite±tremolite ±anhydrite-magnetite; Sericite-pyrophyllite-illite-secondary quartz; Chlorite-clay minerals-calcite-epidote- secondary quartz; Calcite ± dolomite ± siderite. There are some overprinting of different alteration episodes in several zones in Porphyry system indicating changes in specific geochemical conditions in hydrothermal solution such as hydrolysis process and volatile exchange (CO2 and H2O) in the hydrothermal solution. The most interesting feature is the presence of Mg Carbonates (dolomite) that occur together with secondary biotite lacking of Fe-Mg. There also an evidence that the Fe and Ca carbonates alteration is the latest event that crosscut all the alteration episodes in Porphyry system.

The Au-Cu mineralization in Porphyry style alteration system associated with the occurrence of bornite, chalcopyrite, and magnetite. The chalcopyrite and magnetite occur in the secondary biotite-K-Feldspar±anhydrite-magnetite (Potassic zone), meanwhile bornite-chalcopyrite occur in the sericite-pyrophyllite-secondary quartz (Phyllic zone)

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