Alteration and Ore Mineralogy Of Metamorphic Rocks Hosted Hydrothermal Gold Deposit At Rumbia Mountains, Bombana Regency, Southeast Sulawesi, Indonesia

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Abstract. In Indonesia, gold is commonly mined from porphyry, epithermal and skarn type deposits that are commonly found in volcanic/magmatic belts. However, recently numerous gold prospects discovered in association with metamorphic rocks. This paper is intended to describe an alteration and ore mineralogy hosted by metamorphic rocks at Rumbia mountains, Bombana regency, Southeast Sulawesi province, Indonesia. The study area is found the placer and primary gold hosted by metamorphic rocks. The placer gold is evidently derived from gold-bearing quartz veins hosted by Pompangeo Metamorphic Complex (PMC). This study is conducted in three stages, three stages including desk study, field work and laboratory analysis. Desk study mainly covers literature reviews. Field work includes mapping of surface geology, alteration and ore mineralization as well as sampling of representative rocks types, altered rocks and gold-bearing veins. Laboratory analysis includes the petrologic observation of handspecimen samples, petrographic analysis of the thin section and ore microscopy for polished section and XRD (X-ray diffraction) analysis. From petrographic observation, the type of alteration found in the study area can be divided into six types including sericitization, argillic, inner propylitic, propylitic, carbonization and carbonatization alterations. These quartz veins are currently recognized in metamorphic rocks at Rumbia mountains. Mineralologically, gold is closely related to chalcopyrite, pyrite, hematite, cinnabar, stibnite and possibly minor goethite. Based on those characteristics, it obviously indicates that the primary gold deposit present in the study area is of orogenic gold deposits type. The orogenic gold deposit is one of the new targets for exploration in Indonesia.

1. Introduction

Gold has had an impact on the everyday economic activities of ordinary people since at least Egypt in 1400 BC, where it was used as a monetary standard. Perhaps the most famous usage of gold was as money under various gold standards. Gold is one metal of the most malleable, ductile, dense, conductive, nondestructive, brilliant, and beautiful of metals. This unique set of qualities has made it a coveted object for most of human history in almost every civilization, [1]. Based on this, many researchers and mining companies are trying to find gold reserves to explore.

Commonly, gold is mostly mined in Indonesia from hosted by volcanic rocks including porphyry, epithermal, and skarn type deposits that are commonly found in volcanic belts along island arcs or active continental margin settings. Several gold deposits were discovered are BatuHijau in Sumbawa
Island [2], [3] and Grasberg in Papua including porphyry type; Pongkor in West Java [4], Gosowong in Halmahera Island including epithermal type and Erstberg, Kucing Liar, Deep Ore Zone (DOZ) in Papua including skarn type. In Sulawesi Island, gold is also predominantly related to volcanic rocks, which are extended along western and northern Neogene magmatic arcs of the island [5] (Figure 1).

However, were recently in gold exploration activities are not only focused along volcanic-magmatic belts, but also starting to shift along metamorphic and sedimentary terrains because numerous gold prospects discovered in association with metamorphic and sedimentary rocks. Several primary gold deposits were discovered with metamorphic rocks for instance, Langkowala area and Wumbubangkamountains, Bombana in Southeast Sulawesi [6], [7], [8], Awak Mas in South Sulawesi; Poboya LS-epithermal in Central Sulawesi and GunungBotak in Buru Island, Mollucas [9]. Gold-bearing quartz veins are also recognized in Derewo metamorphic belt at northern and northwestern part of Central Range Papua. Some exploration reports categorized the Derewo metamorphic-related quartz veins into mesothermal gold deposit type [9]. The gold mineralization genetically occur in association with sedimentary rocks is Paningkaban, Banyumas Regency, Central Java[10].

Rumbia mountains area is located in the Bombana Regency of Southeast Sulawesi, Indonesia (Figure 2). This research aims to explore the alteration and ore mineralogy of metamorphic rocks hosted hydrothermal gold deposit at Rumbia Mountains by the application of petrographic, ore microscopy and XRD (X-ray diffraction) analysis.

2. Geological Setting
The stratigraphy in the southeastern arm of Sulawesi consists of three constituent rocks are Sulawesi Molasse composed of clastic sediments and carbonate, ophiolite complex are dominated by mafic and ultramafic rocks and continental terrain composed of metamorphic rocks [13]. The mountains Rumbia is a part of continental terrain is subsequently occupied by metamorphic rocks (Pompangeo Complex, Mtpm) consisting of mica schist, quartzite, glaucophane schist and chert. The continental terrain, which were firstly described by [14]. The metasediments and metamorphic rocks are of Permian-Carboniferous in age and occupy the Mendoke and Rumbia Mountains. Mica schist and metasediments particularly meta-sandstone and marble are commonly characterized by the presence of quartz veins various width up to 2 meters containing gold in some places [7].

The Langkowala Formation is unconformably underlain by Paleozoic metasediments and metamorphic rocks (Pompangeo Complex, Mtpm) and conformably overlain by the Eemoiko Formation (Tmpe), which is composed of corraline limestone, calcarenite, marl and sandstone; and Boepinang Formation (Tmpb), which is composed of sandy claystone, sandy marl and sandstone. The Eemoiko and Boepinang Formations were reported having Pliocene age [13].
Figure 1. Geological setting of Sulawesi Island and location of the study area in Rumbia mountains (squared area), Southeast Sulawesi (modified from [11]).

Figure 2. Geological map of Rumbia mountains area occupied by Paleozoic metamorphic rocks (Pompongeo Complex; Mtpm) (Modified from [12]). Squared area indicates the location area of this study.
3. Research Methods
This study is conducted in three stages, three stages including desk study, field work and laboratory analysis. Desk study mainly covers literature reviews. Field work includes mapping of surface geology, alteration and ore mineralization as well as sampling of representative rocks types, altered rocks and gold-bearing veins. Laboratory analysis includes the petrologic observation of handspecimen samples, petrographic analysis of the thin section and ore microscopy for polished section and XRD (X-ray diffraction) analysis. Mineralogical analysis was conducted at Department of Geological Engineering, GadjahMada University.

4. Result and Discussion
4.1. Hydrothermal Alteration
Six main alteration zones that are indentified, including : (i) sericitization alteration is characterized by the presence of sericite (or muscovite), chlorite and quartz, (ii) argillic alteration typified by kaolinite, chlorite and quartz, (iii) inner propylitic alteration composed of actinolite, chlorite, quartz and calcite, (iv) propylitic alteration presented by epidote and/or chlorite, quartz and opaque mineral (pyrite), (v) carbonization is probably represented by (rare) occurrence of graphite with commonly black in colour in the quartz vein and altered mica schist, (vi) carbonatization alteration typified by the presence of calcite veinlets/strings while (Figure 3). Ore mineralization is closely associated with seritisization, argillic, inner propylitic, propylitic and weak carbonatization alterations.

![Figure 3](image)

The carbonization is considered to be one of the alteration type characteristics, associated with orogenic/ metamorphic-hosted gold deposit [8]. The presence silicification alteration is represented by silicified metasediment and mica schist mostly present surrounding quartz veins or along structural zones. The presence of narrow clay-sericite alteration halo (10 cm to 1 m) around the quartz veins in the Roko-Roko hill [8]. Based on data shows that gold-bearing quartz (Qz) veins/veinlets have been discovered in association with Paleozoic metamorphic rocks. The Pompanegeo Metamorphic Complex (PMC) particularly consists of mica schist (dominant rock type), actinolite schist, phyllite and
metasediment. Mica schist is abundantly composed of muscovite, sericite, chlorite, quartz, actinolite, calcite, opaque minerals with a small amount of rutile, kyanite and hornblende minerals.

4.2. Ore Mineralogy

Mineralization in the study area is generally inform of quartz veins in metamorphic rocks (Figure 4). Based on ore microscopic analysis there some precious metal are indentified, including native gold and ore mineralization consist of chalcopyrite (CuFeS₂), pyrite (FeS₂), hematite (Fe₂O₃), cinnabar (HgS), stibnite (Sb₂S₃) and goethite (FeHO₃) (Figure 5). The presence tripodite (FeSbO₄) and rare arsenopyrite (FeAsS₂) are present in the quartz veins and silicified metamorphic wallrocks [8].

Figure 4. (a) The outcrop of quartz veins associated with mineralization. (b) mineralization with the presence pyrite mineral with associated quartz veins. The scale bar without expression in each of photomicrograph on this paper indicates 1 mm. x-nicol 40x. Ms=muskovit, Ser= sericite, Chl= chlorite, Opq = opaque, Py= pyrite, Qz= quartz.

Pyrite, hematite, cinnabar and stibnite are present abundantly in the primary mineralization gold deposits, present in the quartz veins and wallrocks; and commonly present at alteration rocks. Pyrite occurs as isolated idiomorphic crystals, angular fragments, strongly brecciated fragments, anhedral shape, medium reflectance and isotropic. Pyrite generally occurs as replacement and/or fractures or open-space filling. It replaces the mafic minerals in the alteredhost rocks and directly deposited from solution filling the fractures, forming vein and veinlets. Pyrite can be seen as anhedral to euhedral grains. Some pyrite grains are partly enclosed by hematite, chalcopyrite and possibly stibnite. Fractures and brittle cavities in pyrite are often filled by hematite and chalcopyrite.

Hematite is typically pinkish orange in color and commonly present in altered rocks, internal purple reflections, subhedral-anhedral crystals, present as sulfide mineral interactions with oxygen causing the oxidation of sulphide minerals, especially pyrite. Hematite is looked replacing pyrite.

Chalcopyrite are associated with pyrite and quartz; and subhedral-anhedral fragments. Cinnabar is typically pinkish red in color and commonly occurred in the form of mineralized layers along foliations of the metamorphic rocks. Pyrite, hematite, cinnabar and stibnite are genetically closely related to gold mineralization.

Graphite (Gr) is present as a result of carbonization and associated with stibnite minerals. Those sulfides could be pathfinder minerals for the exploration of the metamorphic-hosted gold deposit. In general, gold is very fine-grain, but occasionally native gold is visible in quartz veins.
5. **Conclusion**

The metamorphic rocks are strongly weathered, however trenching program has has opened up the soil cover and exposes the hydrothermal alteration zones. In general, the wallrocks are weakly altered. Hydrothermal alteration types include sericitization, argillic, inner propylitic, propylitic, carbonatization and carbonization. The PMC particularly consists of mica schist (dominant rock type), actinolite schist, phyllite and metasediment. Mica schist is abundantly composed of muscovite, sericite, opaque, chlorite, quartz, actinolite, with a small amount of calcite, rutile, kyanite, graphite and kaolinite minerals. Hence, the metamorphic rock is categorized into green schist facies, which is noted as an important host rock facies for orogenic gold deposit worldwide. Mineralogically, gold is genetically related to consist of pyrite (FeS$_2$), chalcopyrite (CuFeS$_2$), hematite (Fe$_2$O$_3$), cinnabar (HgS), stibnite (Sb$_2$S$_3$) and goethite (Fe$\text{O}_2\text{H}$). The presence triphylite (FeSbO$_4$) and rare arsenopyrite (FeAsS$_2$) are present in the quartz veins and silicified metamorphic wallrocks [8]. Gold is mainly identified in the form of 'free gold' among silicate minerals particularly quartz. Based on those characteristics, it obviously indicates that the primary gold deposit present in the study area is of orogenic gold deposit type (cf. [15], [16], [17]). The orogenic gold deposit is one of the new targets for exploration in Indonesia.

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References
[1] O'Connor, F.A., Lucey, B.M., Batten, J.A., and Baur, D.G. The financial economics of gold-A survey. International Review of Financial Analysis, 1-20p, 2015.
[2] Idrus, A., Kolb, J., and Meyer, F.M. Chemical composition of rock-forming minerals in copper-gold-bearing tonalite porphyry intrusions at the Batu Hijau deposit, Sumbawa Island, Indonesia: Implications for crystallisation conditions and fluorine-chlorine fugacity, Special Issue. Resource Geology, 57 (2) (2007) p.102-113.
[3] Imai, A. and Ohno, S. Primary ore mineral assemblage and fluid inclusion study of the Batu Hijau porphyry Cu-Au deposit, Sumbawa, Indonesia. Resource Geology, 55, (2005) p.239-248.
[4] Warmada, I W. Ore mineralogy and geochemistry of the Pongkor epithermal gold-silver deposit, Indonesia. Dissertation. Papierflieger, Clausthal-Zellerfeld. ISBN: 3-89720-658-7, 2003.
[5] Idrus, A. Potensi Sumberdaya Mineral Bijih pada Busur Magmatik Sulawesi bagian Barat dan Utara, Invited speaker on National Seminar “Geologi Sulawesi dan Prospeknya”, Makassar, 3 Oktober 2009, 26pp.
[6] Idrus, A. and Prihatmoko, S. The metamorphic-hosted gold mineralization at Bombana, Southeast Sulawesi. A new exploration target in Indonesia. Proceedings MGEI Conference Mineral Resources of Sulawesi, Manado, 2011.
[7] Idrus, A., Nur, I., Warmada, I W., and Fadlin. Metamorphic rock-hosted orogenic gold deposit type as a source of Langkowala placer gold, Bombana, Southeast Sulawesi. Jurnal Geologi Indonesia, (6) 1 (2011) 43-49.
[8] Idrus, A., Fadlin., Prihatmoko, S., Warmada, I.W., Nur, I., and Meyer, F.M. The metamorphic rock-hosted gold mineralization at Bombana, Southeast Sulawesi: a new exploration target in Indonesia. Jurnal Sumber Daya Geologi, (22) 1(2012) 35-48.
[9] Idrus, A., Prihatmoko, S., Hartono, GH., Idrus., Erno Idrus, A., Hakim, F., Warmada, I.W., Aziz, M., Kolb, M and Meyer, F.M. Geology and ore mineralization of Neogene sedimentary rock hosted LS epithermal gold deposit at Paningkaban, Banyumas Regency, Central Java, Indonesia. Journal of Southeast Asian Applied Geology,Volume 7(2) (2015) pp. 73-79wo, Franklin, Moetamar, Setiawan, I. Some Key Features and Possible Origin of the etamorphic Rock-Hosted Gold Mineralization in Buru Island, Indonesia. Indonesian Journal on Geoscience, 1, p. 9-19, 2014.
[10] Idrus, A., Hakim, F., Warmada, I.W., Aziz, M., Kolb, M and Meyer, F.M. Geology and ore mineralization of Neogene sedimentary rock hosted LS epithermal gold deposit at Paningkaban, Banyumas Regency, Central Java, Indonesia. Journal of Southeast Asian Applied Geology,Volume 7(2) (2015) pp. 73-79.
[11] Van Leeuwen, T.M. and Pieters, P.E. Mineral Deposits of Sulawesi, Geological Agency, Bandung, 1992.
[12] Simandjuntak, T.O., Surono, and Sukido. Peta Geologi Lembar Kolaka, Sulawesi, skala 1 : 250.000. Pusat Penelitian dan Pengembangan Geologi, Bandung,1993.
[13] Surono. Geologi Lengan Tenggara Sulawesi. Badan Geologi, Kementerian Energi dan Sumber Daya Mineral. Bandung, 169p, 2013.
[14] Surono. Stratigraphy of the Southeast Sulawesi Continental Terrane, Eastern Indonesia. Journal of Geology and mineral 31, 1994.
[15] Groves, D. I., Goldfarb, R. J., Gebre-Mariam, M., Hagemann, S. G., and Robert, F. Orogenic gold deposit: A proposed classification in the context or their crustal distribution and relationship to other gold deposit types. Ore Geology Review, 13, p.7-27. 1998.
[16] Groves, D. I., Goldfarb, R. J., and Robert, F. Gold deposit in metamorphic belts: Overview or current understanding, outstanding problems, future research, and exploration significance. Economic Geology, 98 (2003) p.1-29.

[17] Goldfarb, R.J., Baker, T., Dube, B., Groves, D.J., Hart, C.J.R., and Gosselin, P. Distribution character and genesis of gold deposits in metamorphic terrains. In: Hedenquist, J.W., Thompson, J.F.H., Goldfarb, R.J., Richards, I.P (Eds.), Economic Geology. One Hundredth Anniversary Volume, p. 407-450, 2005.