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Geochemistry and Mineralization Characteristic of Sungai Mak Deposit in Gorontalo, Northern Sulawesi, Indonesia

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ABSTRACT

This study reports geochemistry and mineralization characteristics of Sungai Mak deposit in Gorontalo, Northern Sulawesi, Indonesia. SiO_2 and K_2O+Na_2O (Total Alkali Silica or TAS diagram) show that the intrusive rock found in this deposit are granodiorite. Ore minerals consist of chalcopyrite, pyrite, bornite, digenite and covellite which were confirmed by microscopy and SEM-EDS analysis of polished section. Gold mineralization was confirmed by X-ray Fluorescence Analysis. The result of plotted gold grade and copper grade show a positive relationship showing a similarity to another porphyry copper deposit in Tombolilato Distrit located in the southern part of the studied area. By characteristic of combination of ore minerals, there is boundary of primary sulfide zone and intrusive rock in around 160 m from surface. As a result of measurement of the gas-liquid two-phase fluid inclusions that were contained in quartz stock work (width 1 - 3cm), salinity is 2.4-17.8%, homogenization temperature is 282-326ºC (mode value 320ºC). The alteration mineral of intrusive rock was identified by thin section observation and XRD was quartz, chlorite, illite and pyrophyllite. From observation of thin section, hornblende and plagioclase was confirmed as rock forming mineral and these show porphyritic structure.

Keywords: Indonesia; Tombolilato; Sungai Mak; Porphyry

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1. INTRODUCTION

Sulawesi Island can be divided into four tectonic provinces namely 1) West and North Sulawesi Volcano-Plutonic Arc, Central Sulawesi Metamorphic Belt, East Sulawesi Ophiolite Belt and Banggai-Sula and Tukang Besi is Continental Fragments [1],[2],[3],[4]. Study area is located in Gorontalo area in the Northern Province which is composed by Cenozoic volcanics and plutonic rocks [5],[6].

Sungai Mak deposit is located in Tombolilato mining area in which PT BUMI Minerals has obtained the Exploration Borrow & Use Permit in December 2010. According to the previous study [7],[8],[9], the geology of the Tombulilato district is characterized by an island arc-type volcano-sedimentary pile, >3400 m thick and of late Miocene-Pleistocene age, which is made up of submarine to subaerial basic to acid volcanic rocks interbedded with marine and continental sedimentary rocks. The sequence is intruded by high-level stocks and dikes, and cut by diatreme breccias of late Pliocene and Pleistocene age, some of which are associated intimately with porphyry Cu-Au and

epithermal Cu-Au-Ag mineralization. A main compressive deformation event took place in the Pliocene.

This research aimed to determine the characteristic and genesis of the ore intrusive rock and mineralization.

2. METODOLOGY

By outcrop observation, 1m width of quartz vein (Figure 2) and chalcocite blanket (Figure 3) was confirmed. In chalcocite blanket, average copper grade is 2.83%. Chalcocite blanket was seen in oxidation zone of the porphyry copper. Copper ore stone of the sulfide mineral dismantles, and copper was carried by rainwater, after that copper is reprecipitated.

Figure 2. Quartz vein outcrop

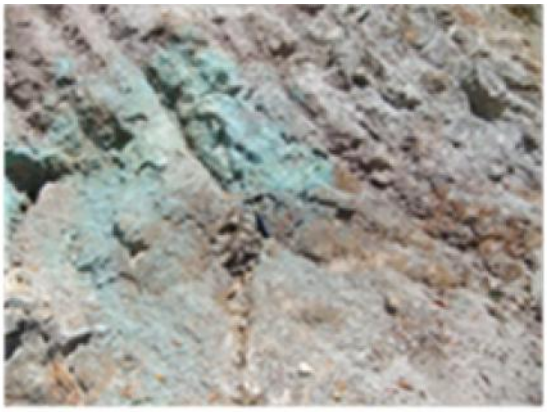

Figure 3. Chalcocite blanket

$14CuSO_4 + 5FeS_2 + 12H_2O \rightarrow$
[Reaction of secondary enrichment]

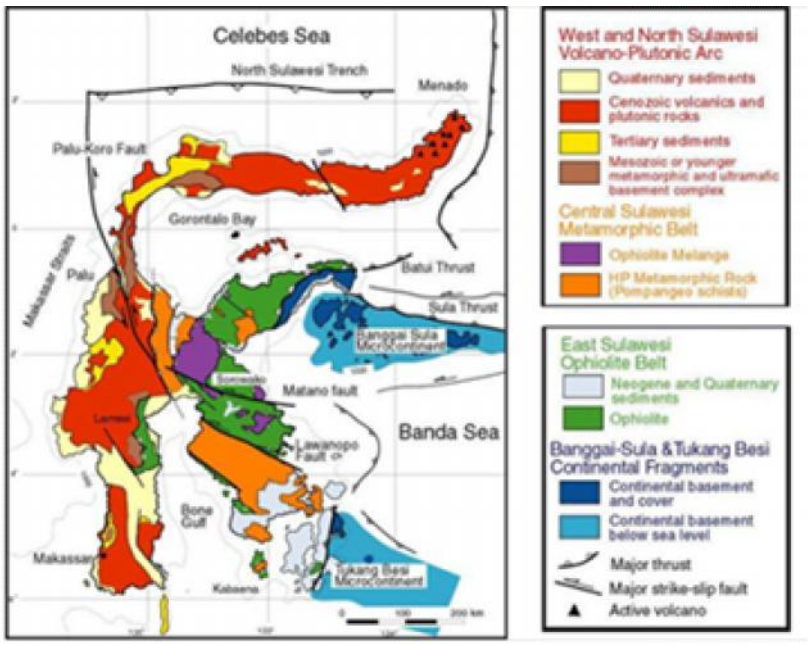

Figure 1. Geology map of Sulawesi Island [1],[2].

$7Cu_2S + 5FeSO_4 + 12H_2SO_4$
Chalcocite (reaction of pyrite with copper sulphate)

$11CuSO_4 + 5CuFeS_2 + 8H_2O \rightarrow$
Chalcocite (reaction of chalcopyrite with copper
sulphate)

$8CuS + 5FeSO_4 + 8H_2SO_4$

From these, hydrothermal activity and secondary enrichment was confirmed.

In order to clarify the subsurface condition, ore samples that collected from drill core was analyzed by XRF, XRD analysis, thin section observation, polished section observation, the fluid inclusion measurement and SEM-EDX observation. A total of 20 samples were collected from two drill cores (SMD057, SMD098).

3. RESULT AND DISCUSSION

A. Sample observation

Boring core is able to classified two types of deposits. One is altered by hydrothermal activity and contains quartz stock work (Figure 4), the other showed characteristics of porphyry (Figure 5). Boundary of these characteristics was seen between 165.20 m and 176.00m. Under the 176.00m from surface, samples are fresh.

Figure 4. Picture of alteration rock (SMD057-78.50m)

Figure 5. Picture of porphyry rock (SMD057 - 204.70 m)

B. X-ray Fluorescence analysis

The result of X-ray Fluorescence analysis of boring core samples showed the average grade of copper is 0.98%. From three samples, gold mineralization was confirmed (8 - 21ppm), and its copper grade is higher than any other samples (over 2%). Gold and copper grade showed positive correlation (Figure 6). This show similarity to other porphyry copper deposit in Tombolilato [8],[9],[10].

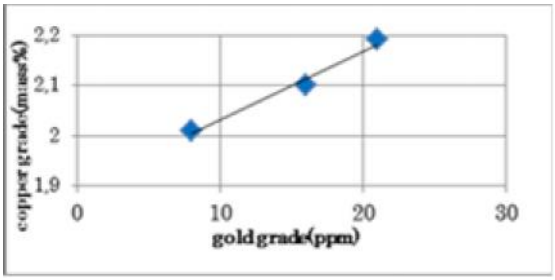

Figure 6. Positive correlative of gold and copper grade.

The samples that contain the gold can be divided to three part: hydrothermal alteration part (Figure.7), quarts stock work part (Figure 7), mineralization part (Figure 8). The result of X-ray Fluorescence analysis, gold was found only from mineralization part. Therefore, it is thought that the gold is mineralized along with high-grade copper.

Figure 7. Picture of alteration part and quartz stock work part (SMD057 78.50m).

Figure 8. Mineralization part (SMD057 78.50m).

C. X-ray Diffraction analysis

The result of X-ray Diffraction analysis, quartz, chlorite, illite and pyrophyllite were confirmed as altered mineral.

D. Thin section observation

Thin sections were made from fresh samples (under 176.00m level samples). As a rock forming mineral, hornblende and plagioclase were confirmed by thin section observation (Figure 9; Figure 10). In addition, fresh samples showed porphyry texture.

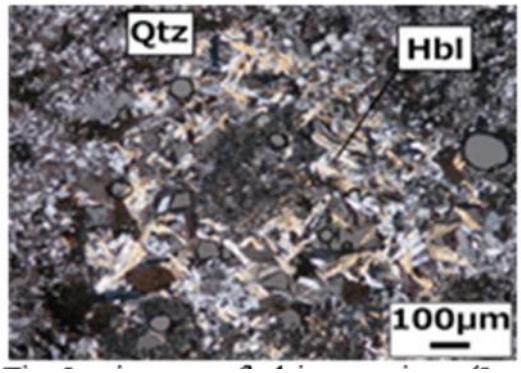

Figure 9. Picture of thin section in plane-polarized light with crossed nicols (SMD057 176.00 M); Qtz : quartz; Hbl: hornblende.

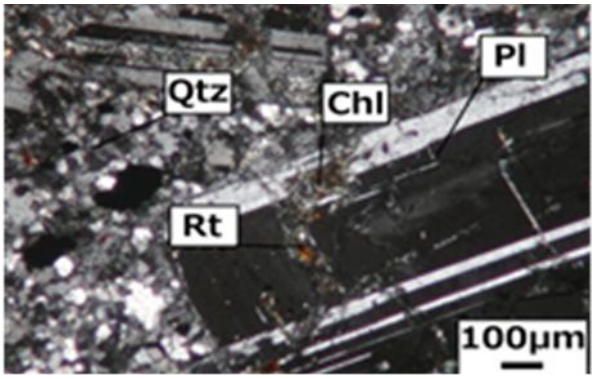

Figure 10. Picture of thin section in plane-polarized light with crossed nicols (SMD057 204.70m); Qtz:quartz, Chl: chorite, Pl:plagioclase, Rt:rutile

E. Polish section observation

Chalcopyrite, pyrite, bornite, digenite and covellite were confirmed as ore minerals (Figure 11). Table 1 indicated the occurrence of ore minerals and gangue minerals. In this Table, big difference of combination of ore minerals between 165.20m and 176.00m was confirmed. From this result and sample observation, it is estimated that there are boundary of primary sulfide zone and intrusive rock.

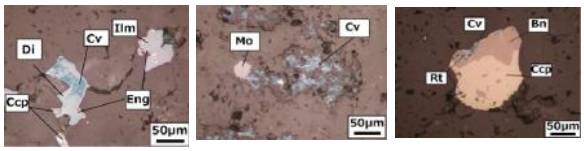

Figure 11. Picture of ore mineral. In reflected light with open nicol (Di: digenite, Cv: covellite, Ccp: chalcopyrite, Ilm: ilumenite, Eng: enargite, Mo: molybdenite, Rt: rutile, Bn: bornite.

F. Fluid inclusion analysis

Quartz was cut out from quartz stock work, and fluid inclusion was measured. All fluid inclusion size is under 3 μm (Figure 12). From homogenization temperature, the temperature of vein formation was estimated. The temperature of vein formation in Sungai Mak is 282-350ºC (Mode value: 320ºC) (Figure 13), salinity is 2.4-17.8wt%.

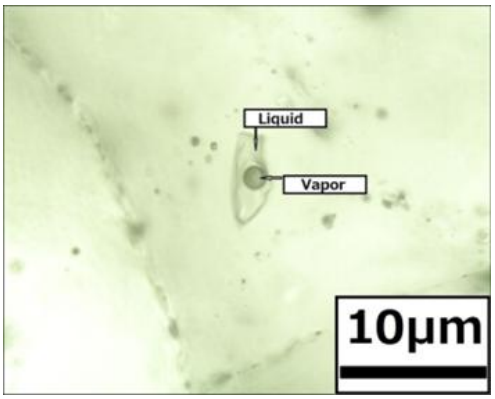

Figure 12. Picture of fluid inclusion

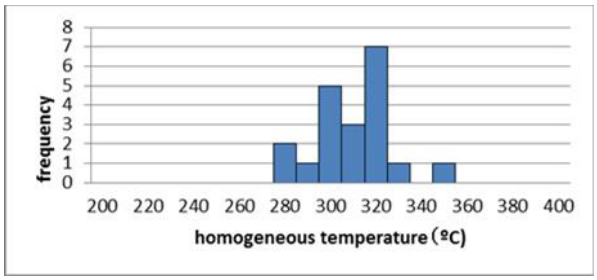

Figure 13. Mode distribution of homogeneous temperature

Table1.Ore mineral and gangue

Sample No.	Sample Name		chalcopyrite	covellite	bornite	digenite	enargite	pyrite	ilmenite	hemanite	molybdenite	rutile	titanium
YM20120909-05	SMD057	78.50M	+++	TR.	TR.	TR.		+					
YM20120909-08		102.00M	+++	TR.	TR.	TR.		+				TR.	
YM20120909-10		135.50M	+++		+				+			TR.	
YM20120909-11		150.00M	++	TR.	TR.			+++	TR.				TR.
YM20120909-12		165.20M	+++	TR.	TR.	TR.							
YM20120909-13		176.00M	+									TR.	TR.
YM20120909-14		183.00M	+++					+++		+		+	+
YM20120909-15		194.00M	++		TR.				++	+		TR.	
YM20120909-16		204.70M	+						++	++		++	+
YM20120909-19	SMD098	45.50M	++	++		+	++				TR.	TR.	
YM20120909-23		176.20M										++	

+++>++>+ quantity of existence TR.=trace

G. Classification of intrusive rock

The result of plotted of SiO_2 and (Na_2O+K_2O) in TAS diagram (Figure 14) (Cox, 1979), intrusive rock were divided into grano-diorite.

Figure 14. Nomenclature diagram for plutonic rock from the Sungai Mak (after [11]).

4. CONCLUSIONS

Based on geochemical composition and thin section observation, the intrusive rock in the studied area is classified as grano-diorite porphyry. Maximum copper grade is 2.1%, and average copper grade is 0.98%. Gold mineralization (8-21ppm) was associated with high-grade copper. The temperature of vein formation in Sungai Mak is 282-350ºC (Mode value:320ºC), salinity is 2.4-17.8wt%. Ore characteristic shows typical of porphyry copper deposit.

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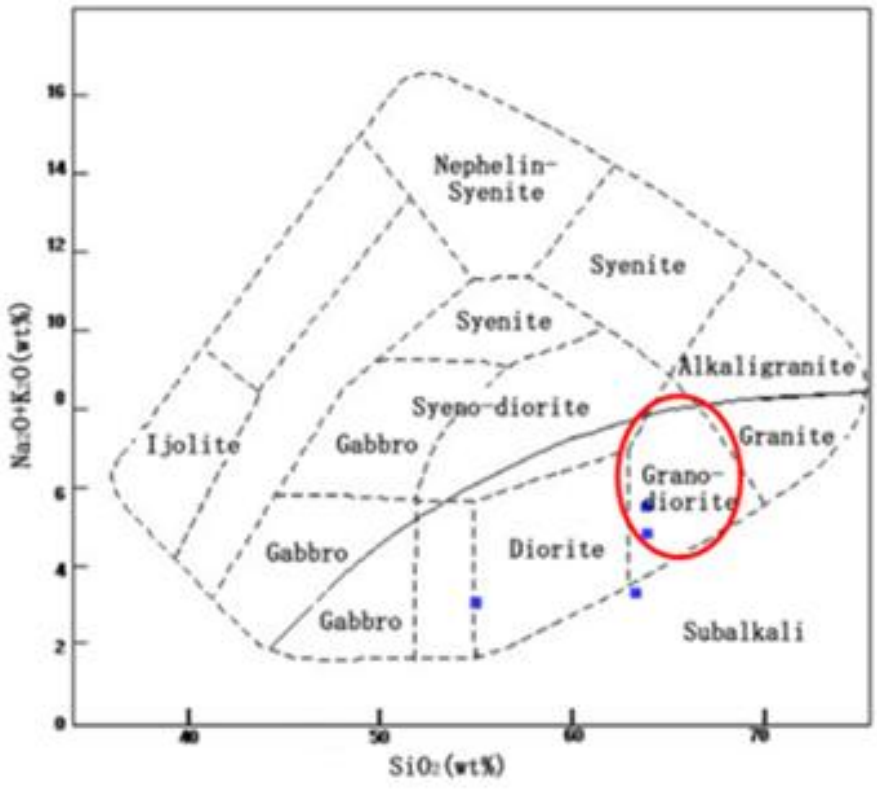

Figure 14. Nomenclature diagram for plutonic rock from the Sungai Mak (after [11]).

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