The Mineralization Characteristics of copper and gold at Sungai Mak Deposit in Gorontalo, Northern Sulawesi, Indonesia.

M. YAMAMOTO\textsuperscript{1}, A.MAULANA\textsuperscript{2}, K.YONEZU\textsuperscript{1}, K.WATANABE\textsuperscript{1} and A.SUBEHAN\textsuperscript{3}

\textsuperscript{1}Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Fukuoka 819-0395, Japan
\textsuperscript{2}Department of Geology Engineering, Faculty of Engineering, Hasanuddin University, Makassar 90245, Indonesia
E-mail:yamamoto-masanori@mine.kyushu-u.ac.jp

Abstract

Sungai Mak deposit had been considered as porphyry copper deposit. However detail research on this deposit has not been done. The object of this study is to reveal the mineralization characteristics of the Sungai Mak using core and outcrop samples. Chalcocite blanket that caused by second enrichment effect and quartz vein that caused by hydrothermal activity was confirmed. The alteration mineral of intrusive rock 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. \(\text{SiO}_2\) and \(\text{K}_2\text{O}+\text{Na}_2\text{O}\) diagram or TAS diagram shows that intrusive rock was granodiorite. Ore minerals consist of chalcopyrite, pyrite, bornite, digenite and covellite. From the three samples, gold mineralization was confirmed by X-ray Fluorescence Analysis. The result of plotted gold grade and copper grade show a positive relationship, similar to other porphyry copper deposit within Gorontalo area in Tombulilato district. By characteristic of combination of ore minerals, there are boundary of primary sulfide zone and intrusive rock in around 160 m from surface. Result of measurement of the gas-liquid two-phase fluid inclusions in quartz stock work(width1-3cm) show salinity of 2.4-17.8%, homogenization temperature 282-326\(^\circ\)C(mode value 320\(^\circ\)C). These results confirm that Sungai Mak deposit is recognized as part of porphyry copper deposit.

Keyword: Indonesia, Tombilato, Sungai Mak, porphyry

Introduction

Sungai Mak deposit is located in Tombililato mining area in which PT BUMI Minerals has obtained the Exploration Borrow & Use Permit in December 2010. According to the previous study, 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. Northern Sulawesi is located in the convergent boundary of the Eurasian plate and the Australia plate. This research aimed to determine the characteristic and genesis of the ore mineralization and confirm the type of deposit.

**Regional geology**

Sulawesi Island can be divided to four parts (Fig.1). West and North Sulawesi is Volcano-Plutonic Arc, Central Sulawesi is Metamorphic Belt, East Sulawesi is Ophiolite Belt and Banggai-Sula&TukangBesi is Continental Fragments. Gorontalo is composed Cenozoic volcanics and plutonic rocks.

![Geology map of Sulawesi Island](image)

**Figure 1.** Geology map of Sulawesi Island (Kadarusaman et al, 2002; Maulana et al, 2009)

**Field observation**

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.

[Reaction of secondary enrichment]

Chalcocite (reaction of pyrite with copper sulphate)

\[
14\text{CuSO}_4 + 5\text{FeS}_2 + 12\text{H}_2\text{O} \rightarrow 7\text{Cu}_2\text{S} + 5\text{FeSO}_4 + 12\text{H}_2\text{SO}_4
\]

Chalcocite (reaction of chalcopyrite with copper sulphate)

\[
11\text{CuSO}_4 + 5\text{CuFeS}_2 + 8\text{H}_2\text{O} \rightarrow 8\text{Cu}_2\text{S} + 5\text{FeSO}_4 + 8\text{H}_2\text{SO}_4
\]
From these, hydrothermal activity and secondary enrichment was confirmed.

**Geochemical characteristics of boring core samples**

In order to clarify the state of the subsurface, ore samples that collected from drill core, was carried out by XRF analysis, 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)

**Sample observation**

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

**Table 1. Ore mineral and gangue**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Sample Name</th>
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<tbody>
<tr>
<td>SMD057-05</td>
<td>CaSO4</td>
</tr>
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</tr>
<tr>
<td>SMD098-23</td>
<td>CaSO4</td>
</tr>
</tbody>
</table>

+++ +++ quantity of existence  TR trace

Table 1. Ore mineral and gangue

- CaSO4: Calcium Sulphate

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

Figure 5. Picture of porphyry rock (SMD057-204.70m)
X-ray Fluorescence analysis

The result of X-ray Fluorescence analysis of boring core samples show the average grade of copper is 0.98%. From three samples, gold mineralization was confirmed (8-21 ppm), and its copper grade is higher than any other samples (over 2%). The result of piloted gold and copper grade show positive correlative (Fig. 6) similar to the other porphyry copper deposit in Tomblilato, Gorontalo area.

![Figure 6. Positive correlative of gold and copper](image)

The samples that contain the gold can be divided to three part (hydrothermal alteration part (Fig. 7), quartz stock work part (Fig. 7), mineralization part (Fig. 8)). The result of X-ray Fluorescence analysis show 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).](image)  
![Figure 8. Mineralization part (SMD057 78.50m).](image)

X-ray Diffraction analysis

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

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 (Fig. 9, 10). In addition, fresh samples are porphyry because these formed a spot-formed organization.
Polish section observation

Polish section is made from all samples. The result of polish section observation show the occurrence of chalcopyrite, pyrite, bornite, digenite and covellite (Fig.11). Ore minerals and gangue minerals were indicated in Table 1. There is a significant difference of combination of ore minerals between 165.20m and 176.00m. From this result and sample observation, it is estimated that there are boundary of primary sulfide zone and intrusive rock.

Fluid inclusion analysis

Fluid inclusion was measured from quartz from quartz stock work. All fluid inclusions size is under 3 µm (Fig.11). From homogenization temperature of vein formation in Sungai Mak is 282-350°C (Mode value: 320°C) (Fig.13), salinity is 2.4-17.8wt%.

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Fig.9 picture of thin section (In plane-polarized light with crossed nicsols.) (SMD057 176.00m) (Qtz:quartz, Hbl:hornblende)

Fig.10 Picture of thin section (In plane-polarized light with crossed nicsols.) (SMD057 204.70m) (Qtz:quartz, Chl:chorite, Pl:plagioclase, Rt:rutile)

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Figure .12 picture of fluid inclusion

Figure 13. Mmode distribution of homogeneous temperature
Classification of intrusive rock

The result of plotted of SiO$_2$ and (Na$_2$O+K$_2$O) in TAS diagram (Fig.14) (Cox, 1979), intrusive rock were divided into grano-diorite.

![Diagram of Plutonic Rock Nomenclature](image)

Fig.14 Nomenclature diagram for plutonic rock from the Sungai Mak (after Cox et al., 1979, adapted by Wilson, 1989 for plutonic rocks).

Conclusion

Intrusive rock is grano-diorite porphyry. Maximum copper grade is 2.1%, and average copper grade is 0.98%. Gold mineralization (8-21ppm) was occurs within high-grade copper. The temperature of vein formation in Sungai Mak is 282-350°C (Mode value:320°C), salinity is 2.4-17.8wt%. There are ore characteristic of porphyry copper deposit. From these Sungai Mak is considered as porphyry copper deposit.

References


