Copper-Gold Mineralization Characteristics of the Sungai Mak Deposit in Gorontalo, Northern Sulawesi, Indonesia

M.Yamamoto¹, A.Maulana¹, ², K.Yonezu¹, K.Watanabe¹ and A.Subehan³
¹Department of Earth Resources Engineering, Kyushu University, Japan
²Department of Geology Engineering, Faculty of Engineering, Hasanuddin University, Makassar 90245, Indonesia
³PT Gorontalo Mineral, Indonesia
* E-mail:yamamoto-masanori@mine.kyushu-u.ac.jp

ABSTRACT

Tombulirato region in Indonesia, Sulawesi Island, Northern Gorontalo is located in the convergent boundary of the Eurasian plate and the Australia plate. The survey was started in the 1970s, as a result, hydrothermal gold-silver deposit shallow low-sulfide type porphyry copper gold deposits, and hydrothermal copper gold-silver deposit shallow high sulfide type has been confirmed. Sungai Mak deposit was estimated as porphyry copper deposit, but detail research was not yet doing. In this study, object is to reveal the Mineralization characteristics of the Sungai Mak by researching boring core and observation of outcrop.

By the observation of outcrop, malachite layer that caused by second enrichment effect, and quartz vein that caused by hydrothermal activity were confirmed. The alteration minerals of intrusive rock identified by thin section observation and X-ray diffraction analysis 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. So intrusive rock was confirmed that it is porphyry. As a result of plotted SiO2 and K2O+Na2O relationship in TAS diagram, intrusive rock was classified grano diorite. From the above intrusive rock was grano diorite porphyry. Ore minerals, chalcopyrite, pyrite, bornite, digenite and covellite were confirmed by microscopy and SEM-EDS analysis of polished section. From the three samples, gold mineralization were confirmed by X-ray Fluorescence Analysis. The result of plotted gold grade and copper grade, they have a positive relation ship. This was correspond with characteristic of another porphyry copper deposit in Tombulirato district. By characteristic of combination of ore minerals, there are 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 was contained in quartz stock work(width 1-3cm), salinity is 2.4-17.8%, homogenization temperature is 282-326°C(mode value 320°C). In general, there are many examples that the salinity of the fluid of the copper mineralization time is under 12wt.%, and homogenization temperature is under 320°C in porphyry copper deposit. This was reconciling with this study.

From these result and the fact that Sulawesi is located in the convergent boundary of the Eurasian plate and the Australia plate, Sungai Mak deposit is recognized as part of porphyry copper deposit.

KEY WORDS: porphyry copper /Sungai Mak/ Sulawesi/Indonesia

1. INTRODUCTION

Sungai Mak deposit is located in Tombulirato mining area that PT BUMI Minerals has obtained the Exploration Borrow & Use Permit in December 2010. According to the previous study, the geology of the Tombulirato 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. And Northern Sulawesi is located in the convergent boundary of the Eurasian plate and the Australia plate. This study aims to reveal the mineralization characterizing of the Sungai Mak deposit by observational analyses of rock outcrops and drill cores.

2. 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&Tukang Besi is Continental Fragments. Gorontalo is composed Cenozoic volcanics and plutonic rocks.

3. FIELD OBSERVATION

By outcrop observation, 1m width of quartz vein (Fig.2) and malachite layer (Fig.3) was confirmed. Malachite 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. From these, hydrothermal activity and secondary enrichment was confirmed.

3. X-RAY FLUORESCENCE ANALYSIS OF OUTCROP SAMPLES

The result of XRF analysis of sample that collected from quartz vein (Fig.2), there are no characteristic of mineralization. From this, it was estimated that there are no relationship between quartz vein and mineralization. The result of XRF analysis of Ore body (Fig.3), high copper grade (2.23%) was confirmed.

4. GEOCHEMICAL CHARACTERISTICS OF BORING CORE SAMPLES

In order to clarify the state of the subsurface, ore samples that collected from drill core, we conducted 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)

4.1 SAMPLE OBSERVATION

Boring core is able to classified two types. 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.

4.2 X-RAY FLUORESCENCE ANALYSIS

The result of XRF analysis of boring core samples show the 0.98% average grade of copper was confirmed. From three samples, gold mineralization was confirmed (8-21ppm), and its copper grade is higher than any other samples (over 2%). The result of piloted gold and copper grade, there are positive correlative (Fig.6). This result was also confirmed in another porphyry copper deposit in Tombulilato.

Table.1 Ore minerals identified in the drill core

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Sample Name</th>
<th>chalcopyrite</th>
<th>covellite</th>
<th>bornite</th>
<th>djurite</th>
<th>enargite</th>
<th>pyrite</th>
<th>limonite</th>
<th>molybdenite</th>
<th>rutil</th>
<th>zircon</th>
</tr>
</thead>
<tbody>
<tr>
<td>YM20120909 05</td>
<td>SMD057</td>
<td>76.50M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 08</td>
<td>SMD057</td>
<td>102.00M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 10</td>
<td>SMD057</td>
<td>135.50M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 11</td>
<td>SMD057</td>
<td>150.00M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 12</td>
<td>SMD057</td>
<td>165.20M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 13</td>
<td>SMD057</td>
<td>176.00M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 14</td>
<td>SMD057</td>
<td>183.00M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 15</td>
<td>SMD057</td>
<td>194.00M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 16</td>
<td>SMD057</td>
<td>204.70M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 19</td>
<td>SMD09B</td>
<td>45.50M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YM20120909 23</td>
<td>SMD09B</td>
<td>176.20M TR. TR. TR. +</td>
<td>TR. TR. TR. +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+++ > +++ > +++ quantity of existence TR.=trace
4.3 X-RAY DIFFRACTION ANALYSIS

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

4.4 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 (Fig. 7&8). In addition, fresh samples are porphyry because these formed a spot-formed organization.

4.5 POLISH OBSERVATION

Polish section is made from all samples. Chalcopyrite, pyrite, bornite, digenite and covellite were confirmed as ore minerals (Fig. 9). In table 1, ore minerals and gangue minerals were indicated. 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.

4.6 FLUID INCLUSION ANALYSIS

Fluid inclusions from the quartz Tombulirato taken from drillcore sample SMD057 150.00m were analyzed. The size of the inclusions are under 8 µm, with an average size of about 3 µm (Fig. 10). The temperature at the time of vein formation was estimated from the result of fluid inclusion measurement. Homogenization temperatures at Sungai Mak range from 282-350ºC (mode:320ºC) (Fig. 11), with salinities of 2.4-17.8wt.%.

5. CLASSIFICATION OF INTRUSIVE ROCK

The intrusive rocks were classified as granodiorite to diorite in TAS diagram of Cox (1979).
6. CONCLUSION

The results of this study indicate that the Sungai Mak deposit displays characteristics corresponding with porphyry copper deposits. Several of these characteristics are: a porphyritic intrusive host that includes hornblende as a phenocryst; hydrothermal alteration; and a combination of Cu-Au mineralization. The mineral assemblage observed in the Sungai Mak region include chalcopyrite, pyrite, covellite, bornite, digenite, arsenopyrite, and molybdenite, which are typical ore minerals of porphyry copper deposit. Maximum copper grade is 2.1%, and average grade is 1.2%. The estimated value of salinity and temperature at the time of vein formation by fluid inclusions is 2.4-17.8 wt.% and 282-350 ºC (mode: 320ºC).

From these results, the Sungai Mak deposit can be identified to be of porphyry copper mineralization type.

ACKNOWLEDGMENTS

I would like to express my appreciation to PT Gorontalo Mineral Mines for permitting our fieldwork and for making it very comfortable and enjoyable. I would also like to thank Mr. Zhiivko Budinov for his support during field work.

REFERENCES


Fig.12 Nomenclature diagram for plutonic rock from the Sungai Mak (after Cox et al., 1979, adapted by Wilson, 1989 for plutonic rocks).