PETROLOGY AND GEOCHEMISTRY OF INTRUSIVE ROCKS FROM SELOGIRI AREA, CENTRAL JAVA, INDONESIA

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ABSTRACT

Selogiri is one of the gold prospects in Indonesia. The deposit model is espected to be a porphyry copper-gold deposits, which overprinted by low sulfidation epithermal gold quartz deposits. Geochemically, the calc-alkaline rocks from Selogiri range from primitive to relatively fractionated compositions, as reflected by SiO_2, MgO contents and variable concentrations of the mantle-compatible elements (67–272 ppm V, 4–81 ppm Ni). These data are consistent with K_2O contents, low average K_2O/Na_2O ratios (0.4), with some anomalous K_2O/Na_2O ratios (up to 50) and Ba/Zr ratios (up to 8.5), which indicate moderate potassic alteration. The concentration of copper and gold in the bulk-rock is low, Cu < 0.1% and Au < 0.1 ppm, respectively). Most economic porphyry Cu systems are characterized by multiple intrusions and repeated episodes of mineralizing hydrothermal activity, the Selogiri deposit formed during a single or up to two times intrusion periods. Therefore, the short period of hydrothermal activities in Selogiri did not reach an economic ore deposit.

INTRODUCTION

Selogiri is one of the gold prospects in Indonesia, which has been mined since about 10 years by local people. It is located in Wonogiri Residency, southern part of Central Java, Indonesia. The gold grade is estimated around 9 g/t and estimated product is about 10 g per day in some mines. The gold has been mined by using amalgamation and a complex adit and shaft entry method (Soe, *et al.*, 2004).

Since 1998, Jogmec, a Japanese mining company had taken Selogiri as an exploration project for gold and copper mineralization by doing some investigation, stream sediment survey, some ore samples collection and laboratory analyses. Based on Jogmec results, it has a high gold potential with average of about 0.5 ppm to 21 ppm and copper potential of about 1%. The detailed geology and setting of the Selogiri was described in detail in earlier paper (Prasetyanto, *et al.*, 1997; Suprapto, 1998; Soe, *et al.*, 2004; Widagdo & Pramumijoyo, 2004). This paper deals with petrology and geochemical signature of dioritic intrusions in the area.

GEOLOGICAL SETTING

Selogiri area is belonging to western part of Southern Mountain in Central Java, which consists of a series of mixed and flysh-like deposits with a total thickness of about 4500 m (Bothe, 1929 vide Rahardjo, *et al.*, 1993). These rocks overly unconformably the Pre-Tertiary metamorphic rocks and Eocene sedimentary formation of the Jiwo Hill complex, which was covered by limestone formation (Gamping-Wungkal Formation). The series of mixed and flysh-like deposits can be devided into Oligocene-Lower Miocene of Kebo-Butak Formation, Sambipitu Formation of Early-Middle Miocene age, and Oyo Formation of Middle Miocene age. These formations are covered unconformably by Middle Miocene-

Pliocene limestone of Wonosari Formation, Late Miocene of Kepek Formation, and Quaternary alluvial deposits.

According to the geological succession of the Southern Mountain area (Surono, *et al.*, 1992), Selogiri area consisted of two Tertiery formations of rocks, i.e., sandstone as a member of Kebo-Butak Formation and igneous rocks as the members of Mandalika Formation. According to Toha, *et al.* (1994), sandstone unit is a member of Kebo-Butak Formation, whereas a breccia unit is a member of Besole Formation, which both of them were intruded by Oligocene igneous rocks. Magmatisms are started at Late Oligocene by the formation of microdiorite intrusion (about 21.7 Ma (Jogmec)) and at Late Miocene-Pliocene by diorite intrusion, which is closed to the K-Ar date of hornblene-rich tuff of about 12.5 ± 0.9 Ma to 11.9 ± 0.7 Ma (Akmaluddin, *et al.*, 2005). The earlier intrusion was cut by the NW-SE dextral-slip fault (Suprapto, 1998) and N-S and NE-SW sinistral-slip fault (Widagdo & Pramumijoyo, 2004). These intrusions probably become a mineralizing agent of the gold-copper mineralization in the district.

There are four main type of rocks present in the Selogiri area (Fig. 1): volcanic (andesitic) breccia, tuffaceous sandstone, microdiorite, and diorite, which is covered by alluvial deposits.

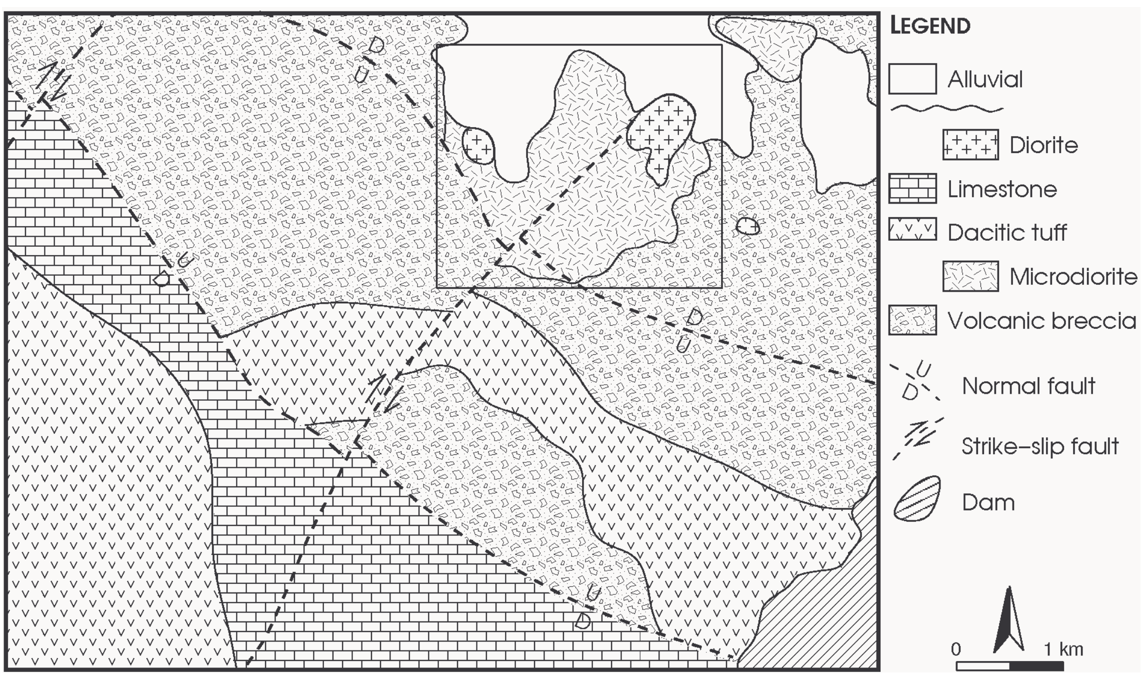

FIGURE 1: Geological map of Selogiri area and its vicinity showing mapped major faults (after Prasetyanto, 1997). Box: location of the samples collection.

PETROLOGY OF INTRUSIVE ROCKS

The intrusive rocks from Selogiri area consist of three main type of rocks, i.e., hornblende andesite, microdiorite, and basaltic andesite.

Microdiorite is holocrystalline with porphyritic texture and with strongly altered plagioclase and hornblende as the main phaenocryst phases. It occurs as a 2.5×1.5 km-wide intrusion. The mafic phenocrysts are pseudomorphically altered to chlorite (propylitic alteration). The groundmass consists of fine crystalline feldspar. This intrusion host a porphyry copper-gold mineralization, which characterized by the present of quartz storkwork and disseminated pyrite.

Diorite is massive, subophitic texture, less altered. It intrude hornblende andesite unit, and exposed in G. Jangleng and Tenongan area and andesitic xenoliths are common found in this rock. Most of this rock are subjected to phyllic and argillic alteration and also shows a speroidal weathering.

Basaltic andesite is found in Ngembang, Sukamerta and in the eastern foot hills of Sourthern Mountain Ranges (Guli and Kalipuru). A dark grey color of basaltic andesite consists of hornblende, and some mafic minerals. The columnar joint is very common in this rock and found in Sukamerta.

GEOCHEMISTRY

Whole-rock major and trace elements analyses of 35 samples from Selogiri area were performed at Kyushu University and Activation Laboratories, Canada. On the basis of the Le Bas, *et al.* (1986) classification, the rocks have a broad range definition (from basalt to dacite), which is probably due to the increase of SiO_2 and K_2O content during propylitic/potassic alteration, with SiO_2 range 42.25–66.06 wt.% and K_2O range 0.13–4.03 wt.%, respectively. The overall MgO content ranges from 0.48 to 9.94 wt.%.

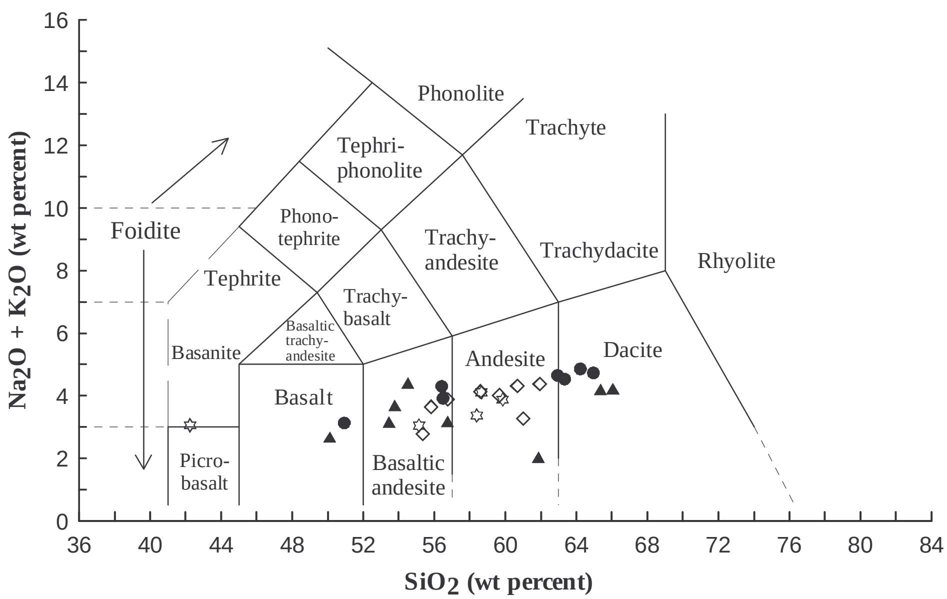

FIGURE 2: TAS diagram of the bulk rock samples (after Le Bas, *et al.*, 1986)

Geochemically, the intrusive rocks from Selogiri range from primitive to relatively fractionated compositions, as reflected by SiO_2, MgO contents and variable concentrations of the mantle-compatible elements (67–272 ppm V, 4–81 ppm Ni). These data are consistent with K_2O contents, low average K_2O/Na_2O ratios (0.4), with some anomalous K_2O/Na_2O ratios (up to 50) and Ba/Zr ratios (up to 8.5), which indicate moderate potassic alteration (Müller, et al, 2001). The oceanic (island) arc setting is confirmed by plotting the data on the Zr vs. Y biaxial plot (Fig. 4).

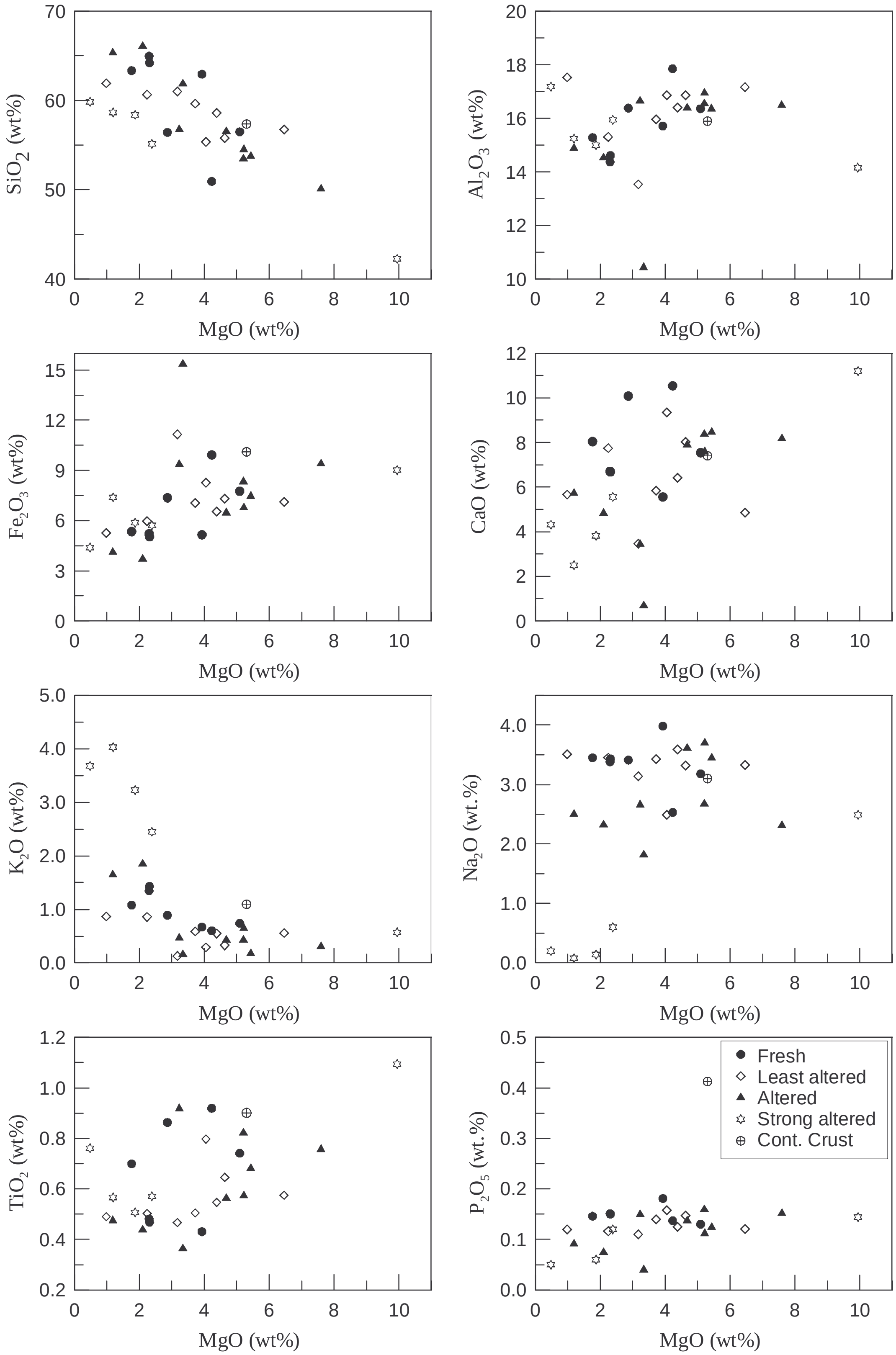

Figure 3: MgO variation diagram for the major elements of bulk rock samples. The composition of continental crust is taken from Rudnick, 1995).

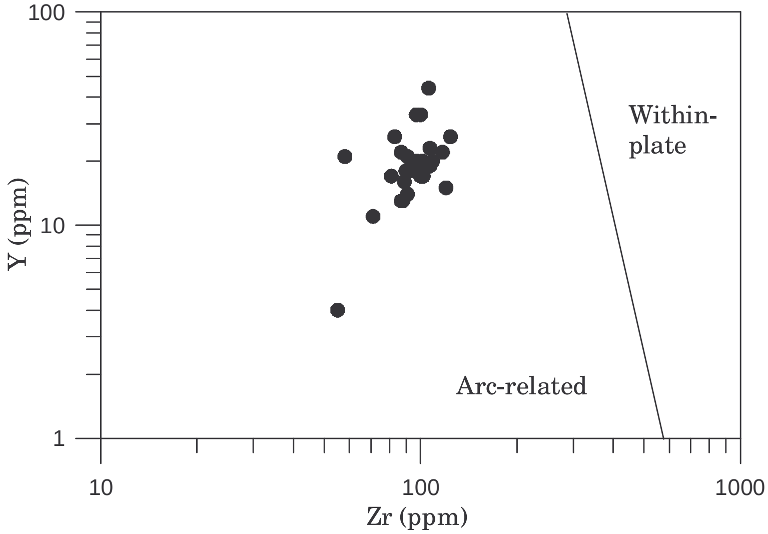

FIGURE 4: Zr vs. Y biaxial geochemical discrimination diagram indicating the subduction-arc feactures of the rocks from Selogiri area (Müller, et al, 2001).

Like most island-arc volcanic rocks in the Sunda-Banda arc, Indonesia (Wheller, *et al.*, 1987; Whitford, *et al.*, 1979), those from the Selogiri district are characterized generally by wide variation of SiO_2 contents, high amounts of Al_2O_3 (mostly 14-18 wt.%), low TiO_2 contents (<1 wt.%), and low Na_2O and MgO content compared with most basalts from mid-oceanic ridge and ocean island settings. TiO_2 and Fe_2O_3 define slightly positive correlation trends with MgO, whereas SiO_2 is inversely correlated with MgO. The scatter distribution of K_2O and Na_2O is probably due to hydrothermal alteration (Fig. 3). The MgO diagrams also display a significant trends of the major element composition of the intrusive rocks with those of continental crust, suggesting that the continental crust involve in the formation of the intrusive rocks. Some of the scatter in the MgO diagrams can be attributed to analytical problems, alteration, and subsolidus oxidation. Acid-soluble sulfide present in some samples result in high measured Fe_2O_3.

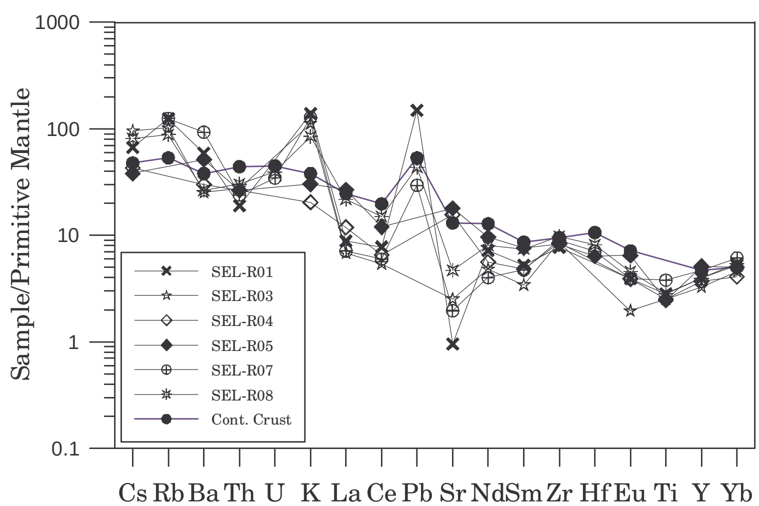

FIGURE 5: Mantle-normalized multi-element diagram of the bulk rock samples from the Selogiri area. The samples range from basalt to dacite and plot close to bulk continental crust.

Trace element data are summarized in a mantle-normalized multi-element plot (Fig. 5), which is generated by using the primitive mantle values of McDonough and Sun (1995). The rocks show typical calc-alkaline island arc basalt trace element patterns, with enriched large-ion lithophile elements (LILE: Rb, Sr, Ba, and K) and light rare earth element (LREE: La, Ce, and Nd) contents relative fo heavy rare earth elements (HREE: Y and Yb) and high field strength elements (HFSE: Ti and Th, except Zr and Hf) contents, and slightly flat REE patterns. The rocks have a negative Nb and Ti anomalies but are enriched in Rb relative to Th. The positive K and Pb anomalies are due to hydrothermal alteration. The high LILE (Rb, Sr, Ba up to 75, 525, 748 ppm, respectively), low HREE (La <17.3 ppm, Ce <25 ppm), and very low HFSE concentrations (Zr <102 ppm) of the samples are also typical for potassic igneous rocks from oceanic arc setting (Müller, et al, 2001). The low average Ba/La and U/Th ratios (26.9 and 0.35, respectively) of the rocks suggest only a minor sediment input to their mantle source during subduction.

Chondrite-normalized REE patterns of the intrusive rocks on Fig. 6 show generally an increase in LREE contents relative to HREE, which are relatively similar to those of calc-alkaline rocks. None of the intrusive rocks shows negative Ce anomalies, which are interpreted as indicating the involvement in magmagenesis of Ce-depleted oceanic sediments or altered basaltic crust, or by the production of Ce^{4+} during slab dehydration (Wheller, et al., 1987). All samples have negative Eu anomaly. The negative Eu anomaly could indicate that plagioclase was an important fractionating phase in the andesitic-basaltic rocks (Wheller, et al., 1987). Negative Eu anomalies can also derive from the breakdown of plagioclase during hydrothermal alteration, which Eu is more mobile than the other REEs.

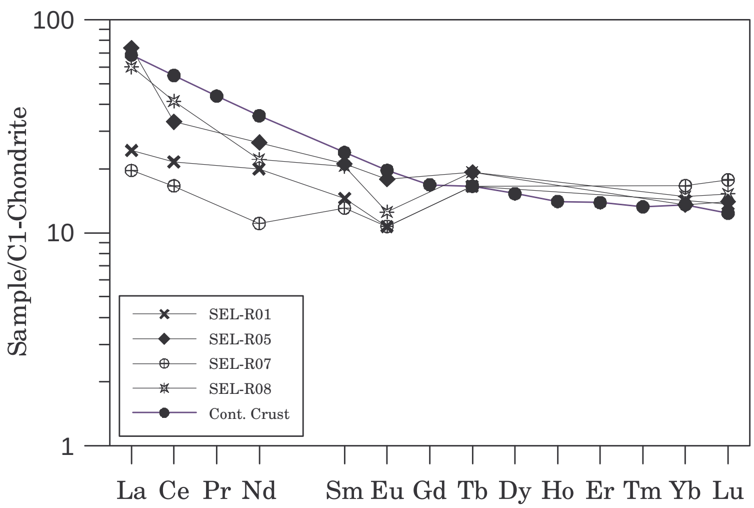

Figure 6: Chondrite-normalized REE pattern of bulk rock samples.

DISCUSSION AND CONCLUSION

Selogiri area consists of three type of intrusions, i.e., microdiorite, diorite, and basaltic andesite. On the basis TAS diagram of the Le Bas, *et al.* (1986), the rocks have a broad range definition (from basalt to dacite). Geochemically, the rocks from Selogiri range from primitive to relatively fractionated compositions, as reflected by SiO_2, MgO contents and variable concentrations of the mantle-compatible elements. High La/Yb and Zr/Y ratios (1.7–7.68 and 3.95–13.75, respectively) are characteristic of calc-alkaline rocks (Lentz, 1996). These are confirmed by mantle-normalized trace element patterns, which show typical calc-alkaline island arc basalt trace element patterns.

Based on the characteristics of mineralization style, the Selogiri gold-copper deposits is more likely closed to porphyry copper-gold system. It is characterized by the host of mineralization is a porphyritic microdiorite, which rich in hydrous phase of minerals, such as hornblende (Tosdal & Richards, 2001). However, the concentration of copper and gold in the bulk-rock is generally low, Cu < 0.1% and Au < 0.1 ppm, respectively). This is probably due to hydrothermal activities in this area are short. By assuming a single small-sized pluton (10^3 km^3) has 2×10^{14} kJ/a, it has an advective life of about 25,000 a (Cathles, 1997 vide Barnes, 2000). If Selogiri has two continuous period of small-sized intrusions, it could have a hydrothermal activities for 50,000 a. An economic ore deposits can be reach if the series of intrusions continue at least 10^6 a (Barnes, 2000). Most economic porphyry Cu systems are characterized by multiple intrusions and repeated episodes of mineralizing hydrothermal activity (Stefanini & Williams-Jones, 1996), the Selogiri deposit formed during a single or up to two times periods. Therefore, the short period of hydrothermal activities in Selogiri did not reach an economic ore deposit.

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