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Fluid Inclusion Studies of the Cijulang High-sulfidation Epithermal Prospect, West Java, Indonesia

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Abstract. Cijulang prospect is located in Talegong Sub-District of Garut Regency, West Java, Indonesia. The prospect is characterized by enargite-gold mineralization and associated acid sulfate alteration. Mineralization is hosted by Tertiary calc-alkaline volcanic and volcaniclastics rocks. Fluid inclusions were studied in order to constrain the temperature, pressure and evolution of fluids responsible for high-sulfidation mineralization. Microthermometric measurements on fluid inclusions were made by freezing/heating experiment. Temperatures of homogenization (*Th*) and final ice-melting (*Tm*) were measured for primary two-phase inclusions in quartz from vuggy silica zone. *Th* values range from 200 ℃ to 310 ℃. Salinities range from 0.71 to 4.03 wt. % NaCl eqv. Microthermometric data indicates that boiling, mixing and cooling occurred during the evolution of hydrothermal system. Paleodepth of formation is estimated at 400m, at a pressure of 39bar. Characteristic low salinities and moderate temperatures of the inclusions are similar to other fluids inclusions from various world-known epithermal high-sulfidation deposits.

Keywords: High-sulfidation, epithermal mineralization, fluid inclusion microthermometry.

1. Introduction

Cijulang is one of the high-sulfidation epithermal prospects from Papandayan Mineral District of West Java and administratively belongs to the Talegong Sub-District, Garut Regency of West Java, Indonesia (Figure 1). The prospect was discovered by the Indonesia state-own mining company PT Aneka Tambang (Persero) Tbk in 1994 during the extensive exploration in the search for gold in West Java area. The prospect is now in an advanced exploration stage and favourable target diamond drillings, in order to define the mineral potential and extend the coverage of mineralization, are conducting based on the detailed geological mapping, geophysical surveying and samplings. This paper presents the characteristics of the hydrothermal fluids responsible for the high-sulfidation epithermal alteration and associated mineralization by documenting temperature, pressure and the evolution of fluids.

2. Geologic background and setting

Cijulang prospect is located in the Southern Mountains of West Java, a present-day fore-arc region between the Quaternary volcanic chain and the Java trench. Southern Mountains [1] is one of the mineralized regions in West Java and mainly composed of Tertiary calc-alkaline volcanics and volcaniclastic rocks and

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Eocene-Miocene sediments. Tectonically, West Java formed as a part of Sunda-Benda magmatic arc system which has resulted from the subduction of Indo-Australian plate beneath the SE-Asian (Eurasian) plate during Cenozoic time [2]. Two main magmatic episodes occurred within the magmatic arc [2]. The early magmatism (late Eocene to Early Miocene) yielded tholeiitic rocks of "Old Andesites" occupying the southern coast of Java Island (Southern Mountains) and the later Neogene (Late Miocene to Pliocene) activity forming a magmatic arc, produced medium- to high-K calc-alkaline volcanic products; basaltic to dacitic rocks, and their intrusive equivalents. Clastics and non-clastics were deposited and intercalated with magmatic rocks along the arc. Basaltic to dacitic rocks (with local rhyolitic rocks) resulted from Quatenary active volcanisms cover the older volcanics throughout the magmatic arc [2]-[4].

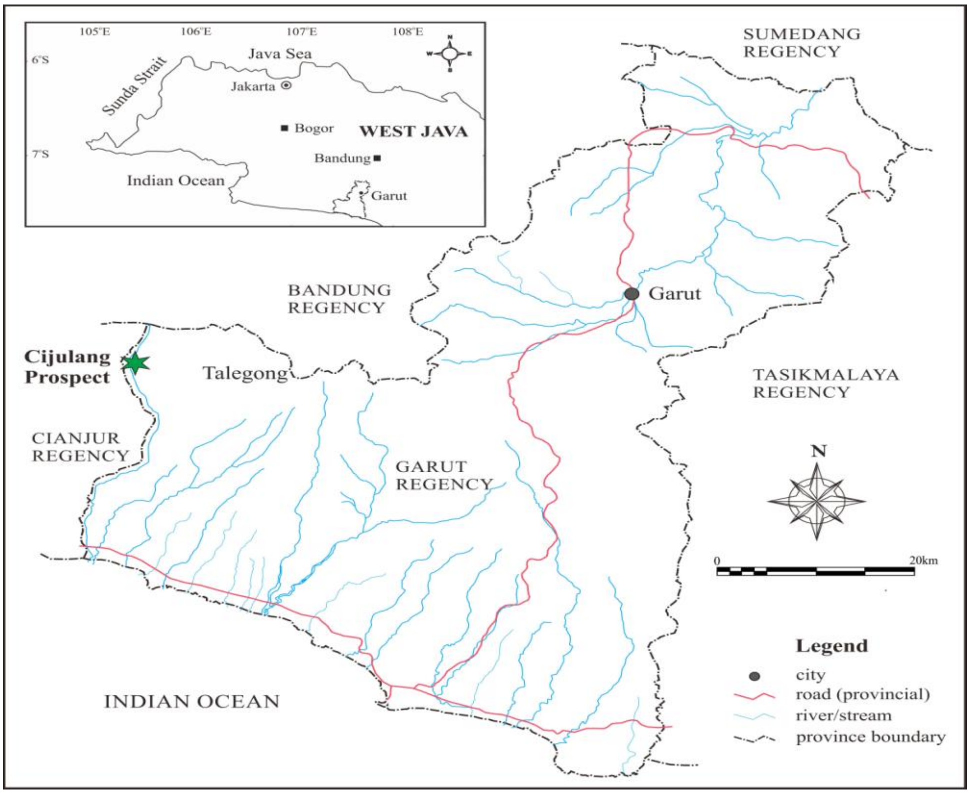

Fig. 1: Location map of the Cijulang Prospect, Garut Regency, West Java, Indonesia.

Epithermal mineralization in the Cijulang prospect area is characterized by enargite-pyrite-gold mineralization and accompanying acid sulfate alteration [5]. Mineralization and alteration are hosted by Tertiary volcanic and volcaniclastic rocks. Host rocks belong to lava andesite, tuff and breccia. Typical ore minerals include pyrite, enargite, luzonite, tennantite, chalcopyrite, covellite, galena, emplectite, and tellurides. Principal hypogene hydrothermal alteration types are silicic (vuggy/massive), advanced argillic, argillic and propylitic.

3. Sample preparation and analytical methods

Petrographic and micro-thermometric analyses were conducted on the fluid inclusions which were entrapped in the quartz from the silica zone (vuggy quartz) of hydrothermal alteration. Samples were collected from the surface of 715m elevation. In the samples, fluid inclusions were generally contained in the vug-filling coarse crystalline hydrothermal quartz and primary igneous quart phenocryst. Doubly polished thin-sections of variable thickness (100-200μm) were prepared from quartz for preliminary petrographic study. Fluid inclusion shapes, sizes, spatial relationships, and phases within inclusions were observed. The petrographic determination of inclusions followed the standard criteria of Roedder [6] and Bodnar [7]. Then, five sample plates containing representative population of inclusions were selected for detailed microthermometric measurements.

Fluid inclusion studies were carried out from by means of heating and freezing experiments. Microthermometric measurements were done using a Linkam TH600 heating/freezing stage at Economic

Geology Laboratory, Department of Earth Resource Engineering, Kyushu University, Fukuoka, Japan. Heating and freezing were performed by a minimum cooling/heating rate of 1 degree per minute and a maximum of 20 degree per minute. The temperatures of homogenization (*Th*) and final ice-melting (*Tm*) were measured. Microthermometric data were collected mainly for inclusions within growth zones of hydrothermal quartz and isolated planes of igneous quartz, which exhibited consistent volumetric liquid-vapor ratios. Temperatures of homogenization were obtained from 32 fluid inclusions and final ice-melting temperatures were collected from 27 fluid inclusions. *Th* and *Tm* measurements were made on the same fluids inclusions. In general, the scarcity of the primary inclusions and their relative small size limited the number of microthermometric measurements.

4. Results and Discussion

Primary igneous and secondary hydrothermal quartz from the Cijulan prospect contains mainly two-phase (liquid + vapor) inclusions (Figure 2a). Most of the fluid inclusions have negative crystal shape (Figure 2a) and some inclusions exhibit irregular shape. Fluid inclusions were identified as either primary or secondary in origin based on the criteria of Roedder [6] and Bodnar [7]. Liquid-dominated inclusions were the most common and identified as primary origin as they occurred along the growth zones of quartz. Liquid-dominated fluid inclusions generally have 10 to 30% vapour phase by volume (visual estimation). The size of observed fluid inclusions ranged from 5 µm to a maximum 10 µm and most inclusions were 10 µm across. They always tend to homogenize into a liquid upon heating. Liquid- and vapor-rich inclusions were observed together within the primary quartz phenocrysts (Figure 2b). Vapor-rich inclusions were less common and comprised only about 5 to 10 percent of total observed fluid inclusion population. These fluid inclusions generally have >80 percent vapour phase by volume (visual estimation). Secondary inclusions also occurred in the samples together with primary inclusions. But, they are also less common and their sizes are generally less than 5 µm.

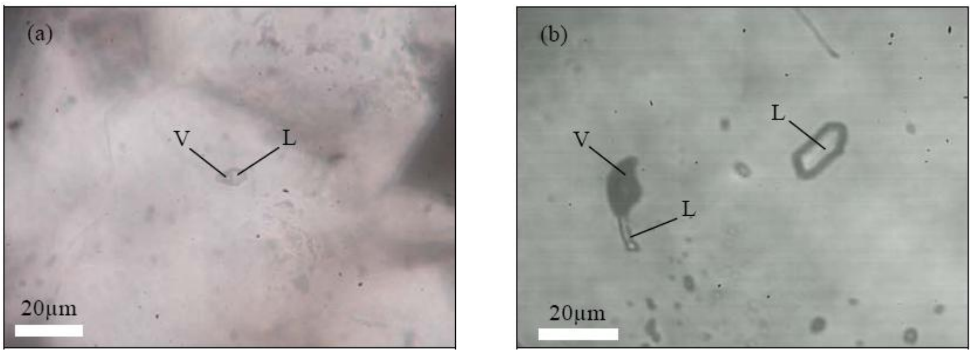

Fig. 2: Photomicrographs of (a) a bi-phase liquid-dominated primary fluid inclusion entrapped in the secondary hydrothermal quartz (b) liquid- and vapor-rich inclusions from the primary igneous quartz phenocryst of the vuggy silica alteration zone from Cijulang prospect. L: liquid and V: vapor.

The measurements of homogenization temperature of fluid inclusions range from 200 ℃ to 310 ℃ with the primary mode range from 270 ° to 280 ℃. Frequency distribution of homogenization temperatures of fluid inclusions are shown in Figure 3a. The final ice-melting temperatures of inclusions generally have a range between -0.4 and -2.4 ℃ with an average of -0.98 ℃. The salinities of the fluid inclusions were calculated from final ice-melting temperature by using the equation of Bodnar [8]. Salinities of the fluid inclusions range from 0.72 to 4.53 wt percent NaCl equivalent with an average of 1.81 wt percent NaCl equiv. A diagram of salinity versus homogenization temperature is also shown in Figure 3b. From the diagram, despite the small data set, it can be seen that the majorities of the fluid inclusion salinities show variation within a wide range of homogenization temperature.

The relationship between *Th* and the salinities of fluid inclusions probably reflects a complex sequence of fluid event, such as cooling, mixing, and boiling. The trend of increasing salinities with decreasing temperatures, as observed in Figure 3b, may be related to boiling because during the process, vapor loss led to an increase in the salinity in the cooling residual liquid [9]. Consequent cooling, as indicated by secondary inclusions, might have been caused by mixing with meteoric fluid, or by falling water table due to uplift and erosion. The coexistence of vapor- and liquid-rich fluid inclusions strongly support that they were resulted from a boiling solution [6], [7]. Low *Th* fluid inclusions from quartz contain the fluids that presented during the deposition of pyrite and/or enargite coeval with euhedral hydrothermal quartz crystals lining the vuggy silica. These pyrite and enargite were deposited during the ore stage and hence these inclusions probably represent some of fluids directly related to ore deposition.

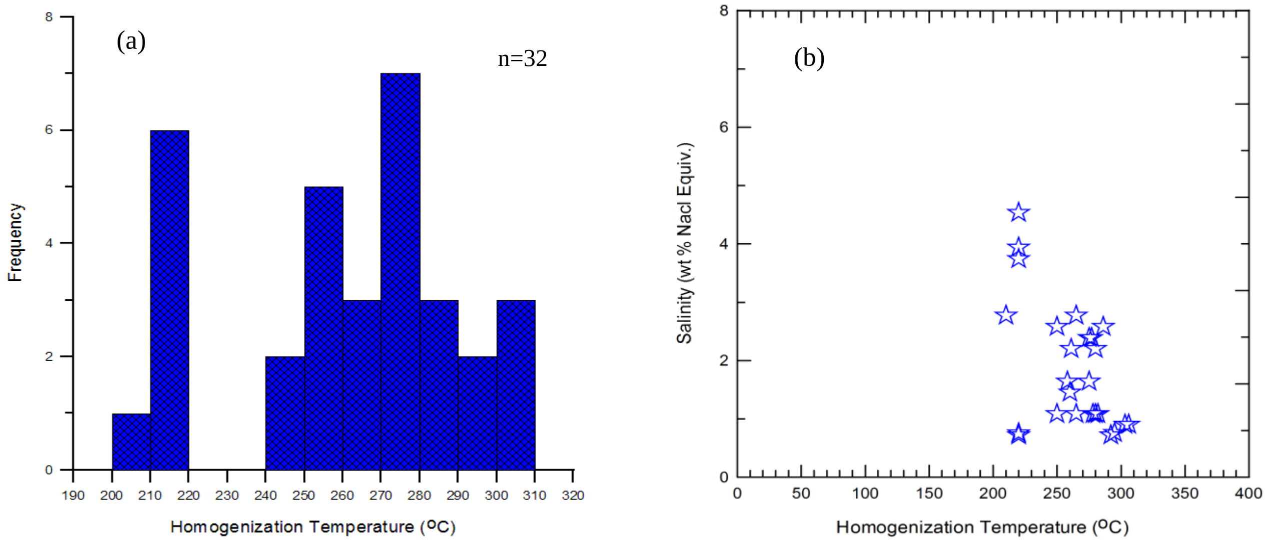

Fig. 3: Microthermometric data for primary fluid inclusions in quartz from the Cijulang prospect, West Java: (a) frequency distribution of homogenization temperatures of fluid inclusions and (b) salinity (wt.% NaCl eq.) versus average homogenization temperatures (*Th*) for fluid inclusions.

Temperature and pressure conditions can provide an estimate for paleodepth of boiling fluids below the water table in the hydrothermal system. The salinity of the fluids adjusts the boiling curve to determine the actual temperature of entrapment and reconstruct the paleodepth [10]. A salinity of 2wt% NaCl equiv. with assumed minimum temperature of boiling at 250 ℃ is fitted with the paleodepth of 400m (Figure 4), which is equivalent to the hydrostatic pressure of about 39 bars with fluid density of 0.8 g/cm^3 [10]. No pressure correction on *Th* was made as little or no correction is needed in the epithermal type deposits [7].

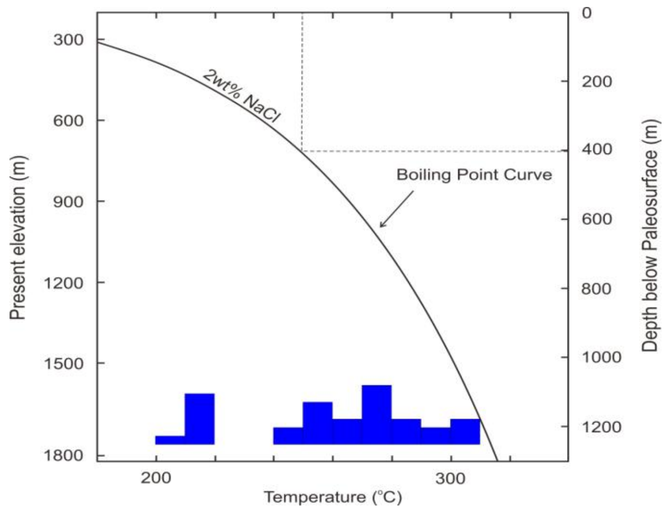

Fig. 4: Elevation Vs temperature diagram showing the plot of homogenization temperature measured in quartz from Cijulang High-sulfidation epithermal prospect. Reference boiling point curve of Haas [10] with 2%wt NaCl is shown.

5. Conclusion

The epithermal gold mineralization in Cijulang prospect area shares the common characteristics of typical high-sulfidation systems; the tectonic setting, associated calc-alkaline volcanic rocks, acid sulfate alteration, ore mineral assemblages and possible link with a porphyry-style mineralization at depth [11]. The evolution of the hydrothermal system is characterized by an early stage acidic wall-rock alteration which is followed by a later stage of ore deposition. In an early stage, hot acidic hypogene magmatic fluids were responsible for the extreme leaching of host rocks, resulted in the vuggy silica bodies and advanced argillic alteration. Following acidic alteration, ore deposition occurred in the central part of the system, in association with hydrothermal brecciation, deposition of amorphous silica and sulfides mineralization along open fractures or in open spaces.

Fluid inclusion data provide information on the hydrothermal fluids circulating at the mineralized hydrothermal system of the Cijulang prospect. Fluid inclusion types and microthermometric data of inclusions are similar to the fluid inclusions of documented high-sulfidation deposits around the world. For example, moderate- to low-salinity fluid inclusions with homogenization temperature mostly ~300 ℃ were recorded in many high-sulfidation systems [11], [12]. These fluid inclusions include the main stage fluids of high-sulfidation epithermal mineralization. The homogenization temperature, the boiling temperature and depth of formation are consistent with those of magmatic hydrothermal system setting [13]. Boiling in the system at a level of 400m is a suitable environment for epithermal ore deposition.

6. Acknowledgement

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