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RESEARCH ARTICLE

Ore Forming Fluid of Epithermal Quartz Veins at Cisuru Prospect, Papandayan District, West Java, Indonesia

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Abstract

The Cisuru area is located in Talegong Sub-district, Garut Regency, West Java, Indonesia which is belongs to the central part of Southern Mountain Slope. The aim of this research is to understand the nature and characteristic of fluid inclusion from quartz veins (especially drill core samples) in the study area. Rock units in the area are characterized by Tertiary volcanic rocks and volcaniclastic sequence which is mainly composed of andesite, andesitic breccia, volcanic breccia, lapilli tuff, dacite and related to the intrusion of diorite. The Cisuru epithermal mineralization is dominantly hosted by andesite, dacite, breccia and lapilli tuff, and would probably be controlled by both permeable rocks and NS and NE-SW trending strike-slip faults. The mineralization is shown as void filling and replacement within the silica zone, veinlets along with the open space/fractures and dissemination. Fluid inclusion from quartz veins was studied to know nature, characteristics and origin of hydrothermal fluids. Microthermometric measurements of fluid inclusions were realized by using a Linkam THMSG 600 combined freezing and heating stages. Homogenization temperature and final ice melting temperature were measured for primary two-phase inclusion from quartz veins. Base on the study of the fluid inclusion, the value of homogenization temperature (Th) range from 200 ºC to 395 °C and ice melting temperature range from -0.1 to - 4.5 where salinity range from 0.2 to 7.2 wt. % NaCl equivalent. Fluid inclusion petrography and microthermometric measurement data exhibit that fluid mixing, dilution and boiling were main processes during the hydrothermal evolution. The formation temperature of each quartz vein is 260 ºC to 290 ºC and also their formation depth is estimated between 560m to 925m respectively. Combination of fluid inclusions petrography, microthermometric measurement, and estimate paleo depth from Cisuru area were suggested under the epithermal environment.

Keywords: Quartz Veins, homogenization temperature, salinity, Paleo-depth, Epithermal High Sulfidation, Cisuru Prospect

1. Introduction

The Cisuru area is one of the prospect of Cjilulang gold project, Parpandayan District, Garut Regency, West Java, Indonesia which belongs to central part of Southern Mountain Slope (Fig. 1). The Cisuru prospect lies in the central part of so called "Southern Slope Regional Uplift" of West Java area. Southern Mountains [8], is one of the mineralized regions in West Java. The research area is categorized as the high sulfidation epithermal prospect in the Parpandayan District. This prospect was discovered by the P.T Aneka Tambang (ANTAM) mining company. The research is mainly composed of volcanic and volcaniclastic rocks in Tertiary age such as andesite, lapilli tuff, dacite, breccia, andesitic breccia and diorite. The presence of high sulfidation epithermal deposit at Cisuru is hosted in lapilli tuff, andesite lava and breccia. It is characterized by extensive alteration of silicification (vuggy/massive silica) with advanced argillic, argillic and prophylitic alteration. Generally, hydrothermal alteration in study area were suffered silicic alteration (vuggy / massive silica), advanced argillic alteration (quartz-kaolinite-dickite pyrophyllite-pyrite), argillic alteration (quartz-kaolinite-illite-smectite) and prophylitic alteration (quartz-chlorite-illite-smectite).

Moreover, mineralized vein are observed in silicic alteration and advanced argillic alteration which occurs as vugs filling, massive vein, veinlet, replacement, dissemination and matrix in the hydrothermal breccia. The recent study focuses on nature and characteristic of fluid inclusion from quartz veins in Cisuru area. Based on the fluid inclusion studies, two types of fluid inclusions were distinguished in quartz veins. They are two-phase liquid-rich inclusion with vapour rich inclusions and single-phase vapour rich inclusions. The two-phase of inclusion are predominant in sample and thus used for observational homogenization temperature (Th) and salinity (NaCl wt. % equivalent) analyses. Quartz has low salinity (0.2 to 7.2 NaCl wt. % equiv) with Th ranging from 210º to 385ºC.

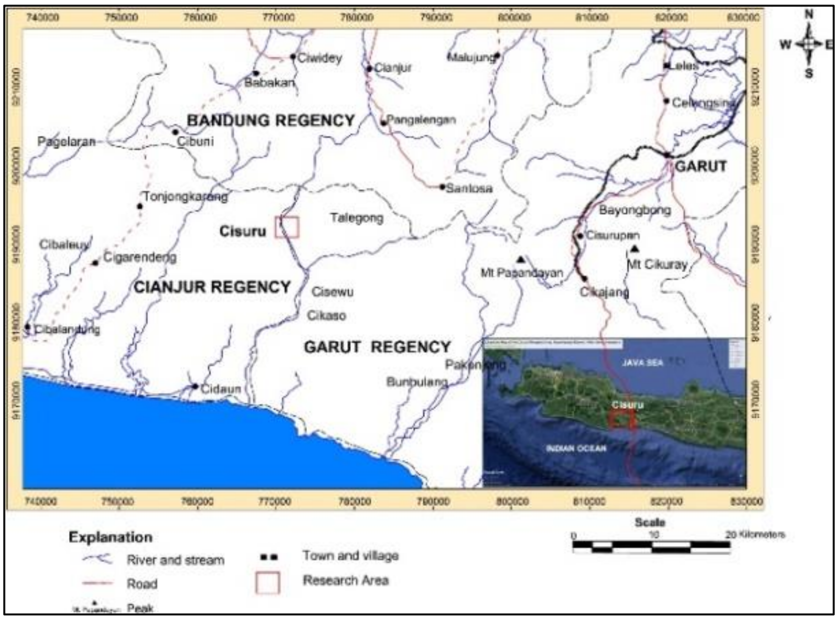

Fig. 1. Location map of Cisuru area, Parpandayan District, Garut Regency, West Java, Indonesia.

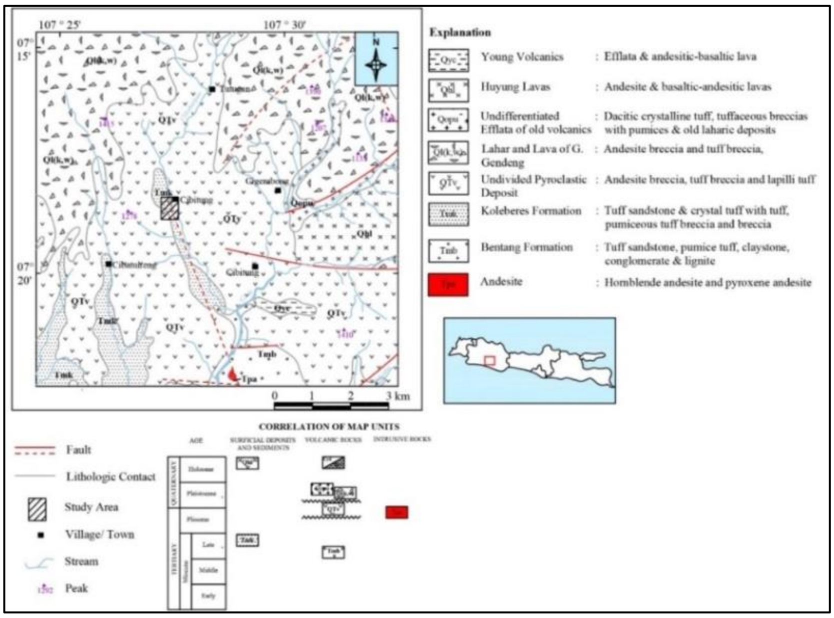

Fig. 2. Regional Geological Map from Sindangbarang and Bandarwara sheet and rectangle showing the research area (Alzwar et al., 1992).

2. Geology Background

Indonesia is situated between the Eurasian Plate and Indo-Australian and Pacific Plates (Hall, 2009). Java Island is part of the Sunda Banda Magmatic Arc, which is the longest magmatic arc in Indonesia. West Java formed as a part of Sunda Banda Magmatic Arc system which has resulted from the subduction of Indo-Australian plate beneath the Eurasia plate during the Cenozoic time. Most deposits and major prospects are associated with Miocene to Pliocene magmatic arcs. According to Soeria-Atmadjia et al., 1998, two distinct magmatic events observed within the magmatic arc. The early magmatism gas provided tholeiitic rocks of "Old Andesites" belong to southern coast of Java Island (Southern Mountains) in Late Eocene to Early Miocene age.

The Late Neogene activities have produced medium to high-K calc-alkaline volcanic products such as basaltic to dacitic rocks, and their intrusive equivalents in Late Miocene to Pliocene. The Cisuru prospect is lie in the Southern Mountains of West Java. The research area is mainly composed of Tertiary calc-alkaline volcanic and volcaniclastic rocks. Koleberes Formation and Undifferentiated Old Volcanics including tuff, breccia and lava of the Tertiary and Quaternary age, are widely distributed in study area. Regional geology and rock sequence of the research area and surrounding area are shown in Fig 2.

The prospect was explored by Indonesia's state-own mining company, PT. Antam, Tbk and Straits Resources Limited (SRL) since (1966), PT Antam Tbk in (2011) such stream sediment survey, geological mapping, geophysical survey, trenching and drilling.

Verdiansyah et al . 2012, described on the high-sulfidation epithermal gold occurrences in the Cijulang area. They were studying the type of alteration and mineralization found in volcanic rocks. Alteration type occurs as advanced argillic (kaolinite, dickite, pyrophyllite, alunite, sericite – pyrite), Massive silica -vuggy quartz, and prophylitic (chlorite, smectite, pyrite) with crystalline tuff, phreatomagmatic breccia and dacite host rock.

Mineralization occurs as dissemination and fracture filling by pyrite, enargite, tennantite, sphalerite, galena, chalcopyrite in advanced argillic and massive silica. High sulfidation epithermal mineralization with gold grade> 0.4 g/t from advanced argillic. Hatmanda (2013) carried out the investigation on geology and characteristics of high-sulfidation epithermal gold deposits in Cijulang Prospect. Tun (2015) described the surface geology, mineralogy, geochemistry and origin of Cijulang prospect in West Java, Indonesia. He was studying the surface geology and some drill core of the Cjiulang area.

3. Geology of the Study Area

Cisuru area is mainly composed of Eocene-Miocene sediments such as andesite, lapilli tuff, dacite, breccia, andesitic breccia and diorite. The main structure in the study area could be recognized by NE-SW trending strike-slip fault system that lies along the Chikahuripan River at the central part of the area (Fig. 3).

Mineralization is mainly hosted by tuff, andesite, and dacite which are associated with silicic and advanced argillic alterations. Mineralization occurs as vugs filling, massive vein, veinlet, replacement, dissemination and matrix in the hydrothermal breccia. Mineralization probably to be controlled by both permeable rocks and NE-SW trending strike-slip faults.

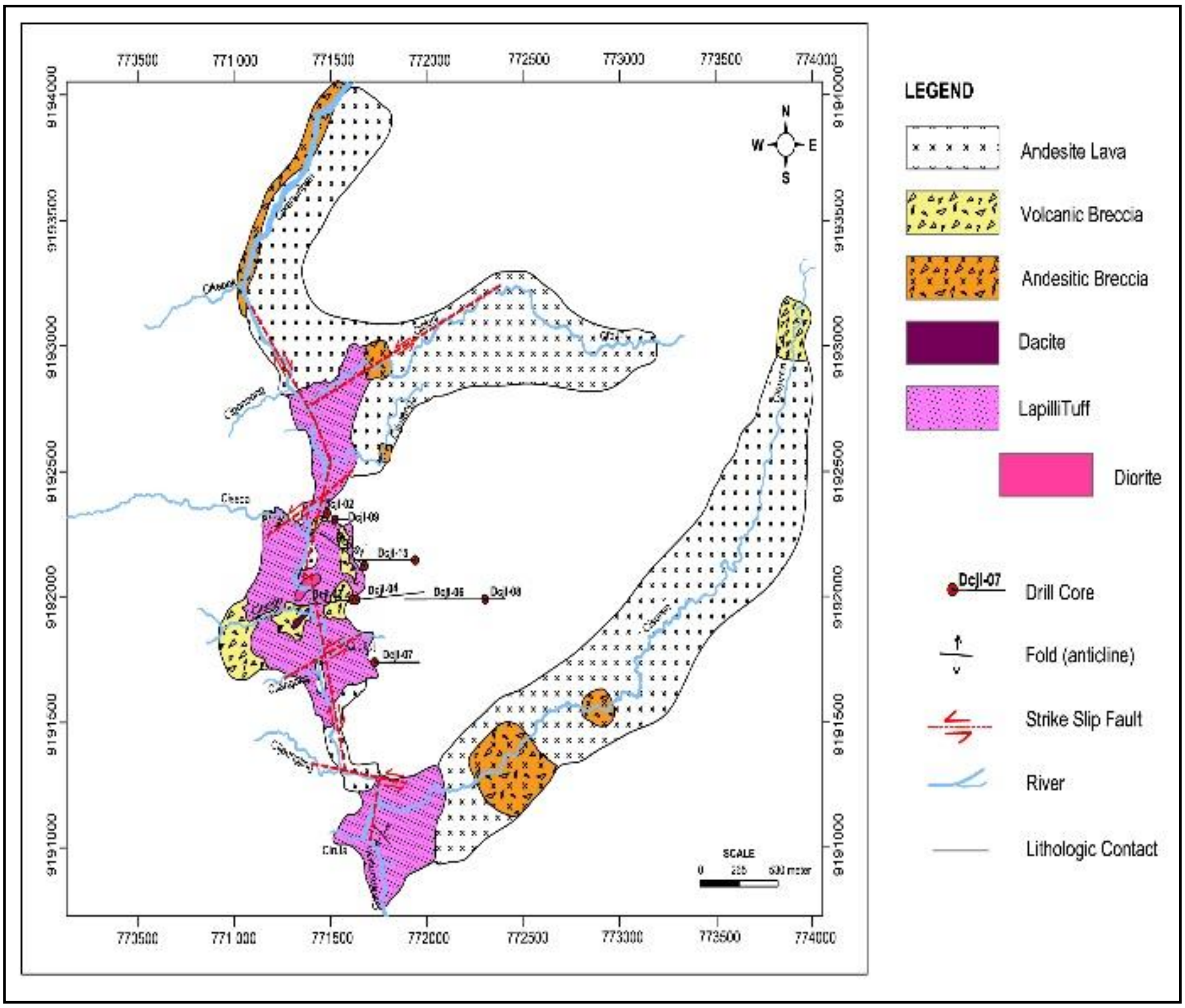

Fig. 3. Geological map of research area.

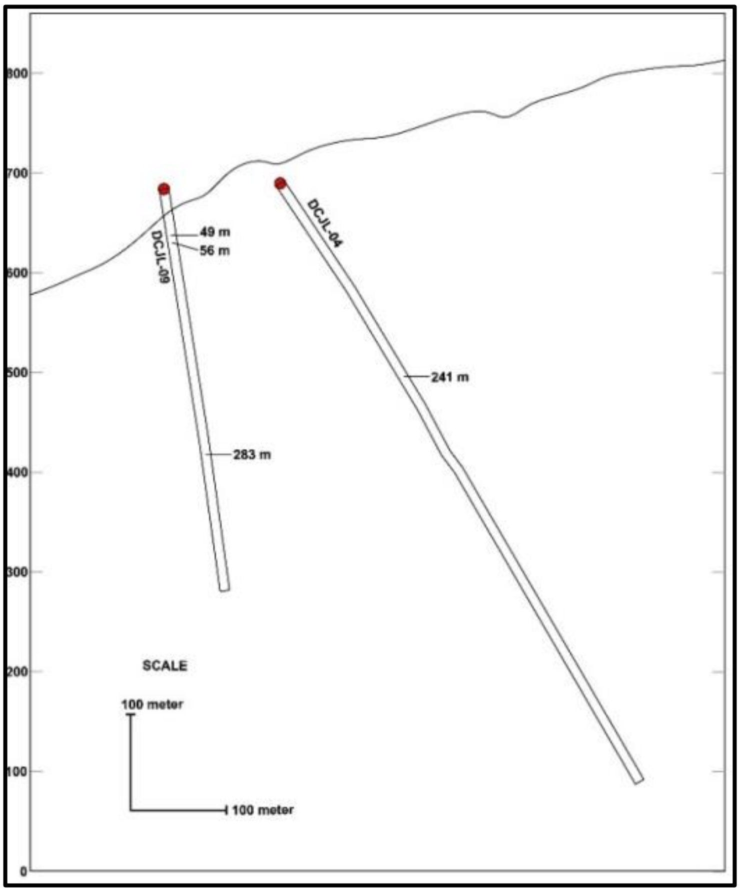

Fig 4. Cross-section of Drill Cores Dcjl – 04 and Dcjl – 09.

4. Research Methods

The samples were collected from drill cores which are Dcjl-09 - 49, 56 and 293m and Dcjl-04 -241m (Fig. 4). Quartz vein samples were prepared double-polished section where the thickness of slice was approximately between 150 -300 µm. And then, these wafers were analyzed by microscopic study to know sizes, shapes, phases and nature of occurrences within fluid inclusions.

Moreover, fluid inclusion microthermometry was conducted to obtain homogenization temperature and final ice melting point of fluid inclusions using Linkam THMS600 heating / cooling stage. The salinity of fluid inclusions was calculated as wt. % NaCl equivalent using an equation given by Bondar et al.,1983. This analysis was done at the Department of Earth Resources Engineering, Kyushu University, Japan.

5. Results

5.1. Fluid Inclusions Petrography

Fluid inclusion was conducted from mineralized quartz veins in research area (Fig .5). The shape of fluid inclusions shows circular, rounded, elongated, prismatic, negative crystal faceted. The size of fluid inclusion in this research ranges from 2-25 µm. The common size of fluid inclusions are 10-20 µm. These fluid inclusion have occurred along the growth zones. It was classified primary fluid inclusions as well as secondary fluid inclusions.

The primary fluid inclusion were occurred within mega-quartz cement characterized by their alignment along concentric growth zones. And then, secondary fluid inclusions were observed trapped along the fracture. In addition, secondary necking inclusions are found in this sample which is a typical dissolution precipitation process that are led to negative crystal faceted. All measured fluid inclusions are vapour + liquid phase (Fig. 6). The vapour bubbles were occupied 10-80 vol. % of the inclusions.

There are three types of fluid inclusions are identified based on their phase relation (a) Two-phase (L+V) liquid-rich inclusions (Fig 6-c, f, and d), (2) Two-phase (L+V) vapor-rich inclusion (figure 7-e) and (3) Two-phase (L+V) vapor and liquid-rich inclusions (Fig. 6). Liquid and vapour characteristic of fluid inclusions are commonly utilized to determine where or not boiling has observed within the hydrothermal system. Two-phase fluid inclusions with constant ration of liquid and vapour are exhibited that consistent condition of temperature and pressure (non-boiling condition) in hydrothermal system. On the other hand, two-phase fluid inclusions are coexisting liquid-rich and vapour rich in the same place which is indicating the boiling or effervescence fluid system (Fig. 6, a).

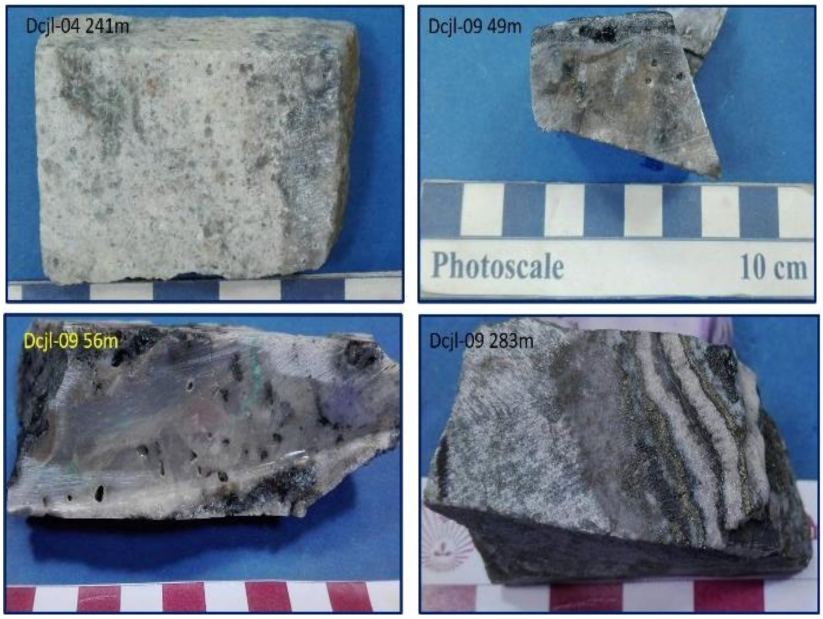

Fig 5. Photograph of mineralized quartz veins showing the a) quartz vein found in lapilli tuff Dcjl-04 241m, b) quartz sulfide veinlet observe in lapilli tuff Dcjl-09 49m, c) vuggy quartz occur as vein Dcjl-09 56m, d) quartz sulfide veins occur in andesite Dcjl-09 283m.

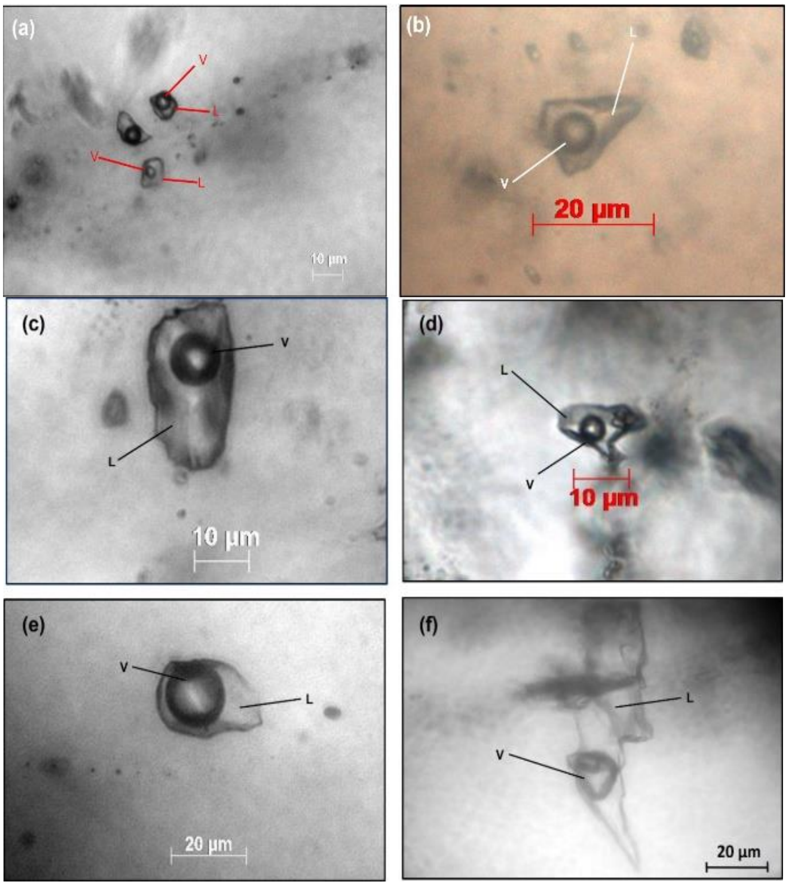

Fig 6. (a) Photomicrograph of fluid inclusions in quartz (a, b) two phase fluid inclusion from Dcjl -09 283m, (c, d) liquid rich fluid inclusion from Dcjl-09 49m, 56m, (e) vapor rich fluid inclusion from Dcjl-04 241m, (f) necking down fluid inclusion from Dcjl-09 49m. (L = Liquid, V = Vapor).

5.2 Fluid Inclusion Microthermometry

In this research, fluid inclusion microthermometry can be measured to estimate formation temperature, salinity and paleo depth of hydrothermal fluid.

The homogenization temperature (Th) were measured range from 200 to 334 °C with ice melting temperature range from -01 to -3.1°C at Dcjl -09 49m, 250 to 308 °C with ice melting temperature range from -0.2 to -3 °C at Dcjl -09 56m, 210 to 385 ºC with ice melting temperature range from -0.2 to -4.5 °C at Dcjl -09 283m respectively (Fig. 7).

Additionally, homogenization temperature (Th) of Dcjl - 04 241m range of 230 to 395 ºC (Fig. 7-d) with ice melting temperature range from -0.2 to -2.7 °C.

The formation of ice melting temperature were shown -0.8 and -1 °C for Dcjl-09 49m, -0.5 °C for Dcjl-09 56m, -2.2 and -2.7 °C for Dcjl-09 283m and -1 and -1.2 for Dcjl-04 241m (Fig. 7-a,b,c, d).

As a result, the homogenization temperature of fluid inclusions for Cisuru area ranging from 200 to 395 ºC that suggested by high sulfidation epithermal deposit.

The salinity of fluid inclusions from Homogenization temperature (Tm) of each sample were calculated, ranging from 0.2 to 5.1 wt. % NaCl equivalent for Dcjl-09 49m, 0.4 to 5.0 wt. % NaCl equivalent for Dcjl-09 56m, 0.4 to 7.2 wt. % NaCl equivalent for Dcjl-09 283m, 0.4 to 4.5 wt. % NaCl equivalent for Dcjl-04 241m. A plot salinity versus homogenization temperature and salinity are used in order to recognize the mineral deposits (Wilkinson, 2010). Especially, salinity and homogenization temperature of fluid inclusions were very important for estimating the formation temperature, trapping pressure, paleo-depth, fluid evolution process and deposit type.

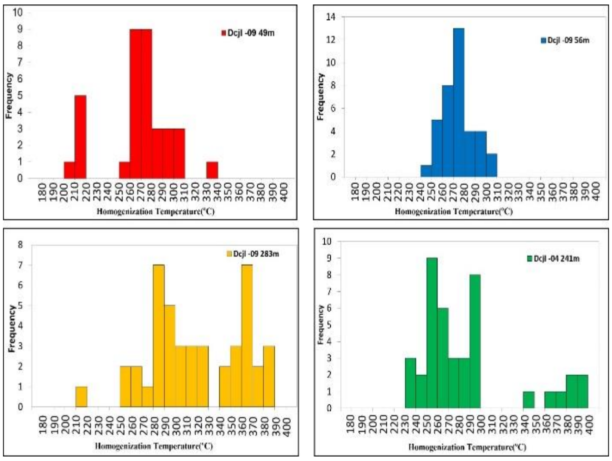

Fig 7. Histogram showing the homogenization temperature of fluid inclusion in quartz veins (a) Dcjl-09 49m, (b) Dcjl-09 56m, (c) Dcjl-09 283m and (d) Dcjl-04 241m.

Based on salinity and homogenization temperature (Th) diagram, the trend of increasing temperature and salinity (positive directions) estimates fluid dilution process for Dcjl-09 49m and for Dcjl-04 241m (Fig.8-a,d). Moreover, the trend of decreasing temperature with increasing salinity (negative directions) indicates boiling process for Dcjl-09 56m (Fig .8-b). Otherwise, fluid mixing also could be happening by adding and mixing with more or less saline solutions some fluid in specific mixing trend in Fig.10-c.

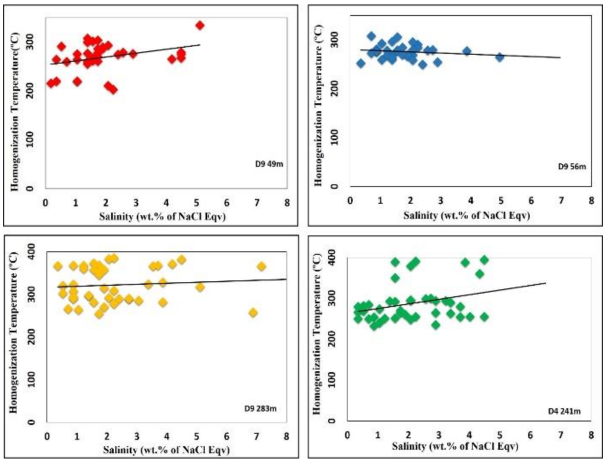

Fig 8. The salinity and Th of fluid inclusions in quartz veins (a) Dcjl-09 49m, (b) Dcjl-09 56m, (c) Dcjl-09 283m and (d) Dcjl-04 241m.

5.3 Discussions

Based on the fluid inclusion petrography and microthermometric measurement results, which is estimated the cooling, mixing and boiling of fluid inclusions, formation depth, pressure, temperature and type of deposit. According to the fluid inclusion petrography, characteristics of two phase (L+V) fluid inclusions were dominantly classified to determine whether or not boiling has observed within the hydrothermal system. Fluid inclusions are trapped in immiscible or boiling fluid system, some of the fluid inclusion will trap in the liquid phase, some will trap in the vapor phase, and some will trap in the mixture of the two phases (Bodnar et al. 1985). In the research area, intergrowth of liquid rich and vapor rich fluid inclusions were indicated boiling condition.

Moreover, vapor rich fluid inclusion were indicating the intense boiling condition (Moncada and Bondar, 2012). In addition, dominant two phase fluid inclusions, moderate Th (200-395 ºC) and low salinity (>7.5 wt. % NaCl equ.) are closely similar to high sufidation epithermal system (Arribas et al., 1995).

Depend on the fluid inclusion microthermometry, homogenization temperature and salinity were determined to show fluid characteristics. Salinity and homogenization temperature (Th) diagram assumed that positive direction estimates fluid dilution process (Fig 8-a, d) and negative trend indicates boiling process (Fig 8-d). And then, coexistent of two phase liquid rich and vapor rich fluid inclusions are observed in same place (Fig. 6-a) were indicating the boiling or effervescence fluid system.

Moreover, fluid mixing also could be happen by adding and mixing with a more or less saline solutions some fluid in specific mixing trend in Fig-c. In place, the mixing process can be caused by meteoric fluid, or falling water table due to uplift and erosion Roedder, 1984 and Bondar et al., 1985. The homogenization temperature and salinity fluid inclusion data from the study area belongs the epithermal environment where mixing, boiling and dilution have been taken place in fluid system (Fig. 9).

Otherwise, dominant two phase fluid inclusions, moderate Th (200-395 ºC) and low salinity (>7.5 wt. % NaCl equ.) are classified as high sufidation epithermal system . Salinity and homogenization temperature (Th) result from research area can be suggested that it occupied within the epithermal deposit (Fig. 10). The fluid densities are important with respect to the mechanism of fluid flow and evaluation of spatial variations in fluid that constrain on the flow process (Wilkinson, 2001). Density of fluid inclusion in the study area shows range from 0.6 to 0.9 g/cm3 (Fig. 10).

The formation temperature of fluid inclusion from quartz veins can be used to know formation temperature and their salinity content in fluid. The effect of salinity on the temperature-depth relation of brain adjuata the boiling curve to determine the paleodepth where including fluid inclusions which indicate boiling of the brain (Hass, 1971). The formation depth of fluid inclusion can assumed that 270°C for Dcjl-09 49m, 280 °C for Dcjl-09 56m, 290 °C for Dcjl -09 283m and 260 °C for Dcjl-04 241m respectively. The estimated formation depth are 560m for Dcjl-04 241m, 660m for Dcjl-09 49m, 790m for cjl-09 56m and 930m for Dcjl-09 283m below the paleo water table (Fig. 11).

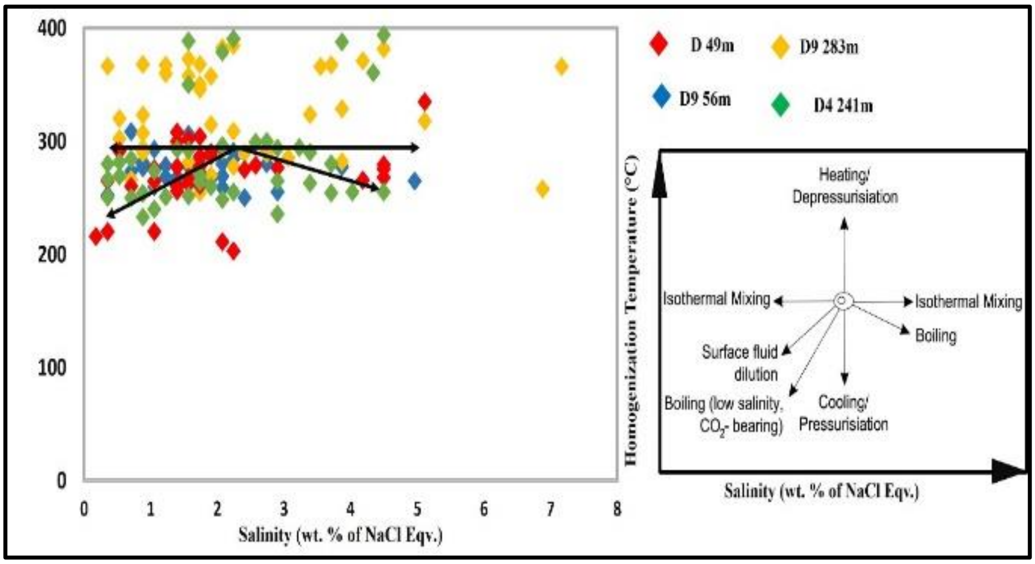

Fig. 9. Salinity versus homogenization temperature Th (◦C) for fluid inclusion in four quartz veins from Cisuru deposit. (Wilkinson, 2001).

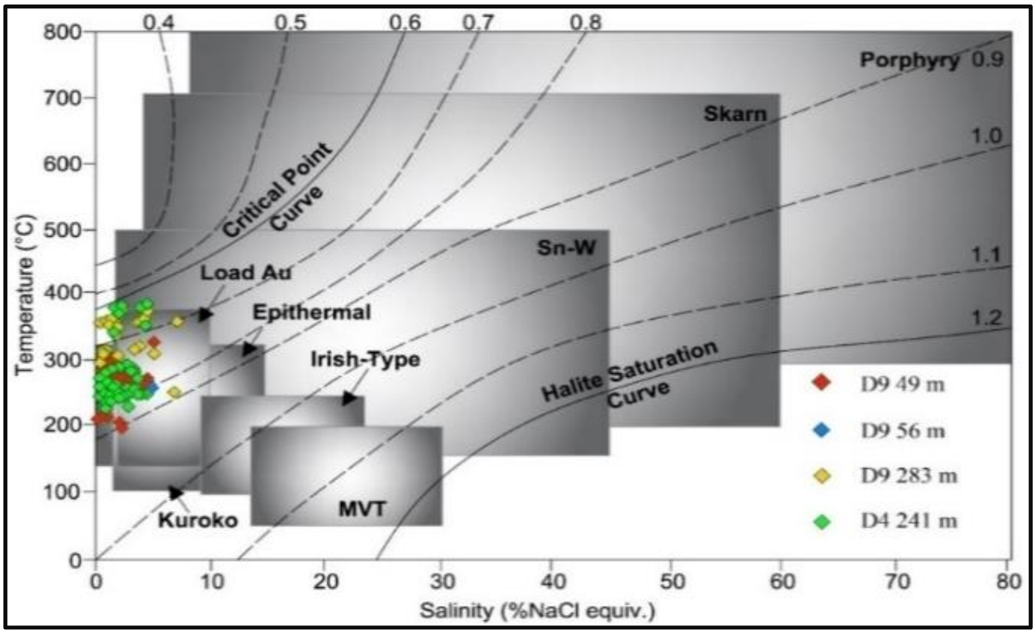

Fig 10. Salinity vs homogenization temperatures Th (ºC) diagram illustrating typical range for fluid inclusion from different type of deposits and their density range. Note that files should not be considered and compositions exist outside the ranges (Wilkinson, 2001).

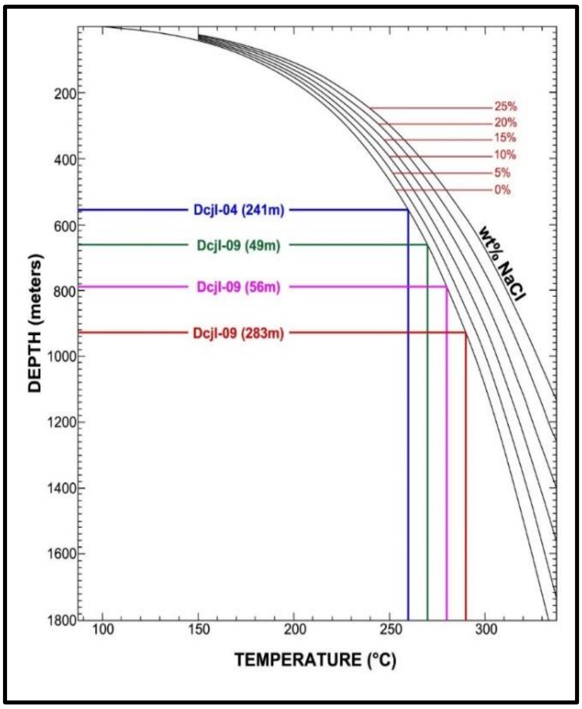

Fig 11. Diagram of temperature and paleo depth with boiling-point curves for brines of constant composition given in wt. % NaCl equv. [12], showing an estimation of average minimum formation depth of quartz veins from Cisuru deposits.

6. Conclusions

Fluid inclusion study is very important to know the condition of hydrothermal fluids and their origin. According to fluid inclusion petrography and microthermometric results, quartz veins of research area are suggested by moderate homogenization temperature (Th) and low salinity. Most of the fluid inclusion trapped in growth zone of quartz veins which shows mega-quartz crystal where two-phase fluid inclusions (L+V). These inclusions are liquid-rich, whereas coexisting of vapor rich inclusions are occurred in the sample indicating that boiling observed in the hydrothermal system of research area.

The homogenization temperature and ice melting were measured two-phase of primary fluid inclusion. The homogenization temperature are ranging from 200 to 395 ºC for four quartz veins. The salinity of fluid inclusion range from 0.2 to 7.2 wt. % NaCl for all quartz veins. Moreover, formation temperature of all quartz veins are 260 to 290 ºC and also their formation depth are estimated between 580 m to 925 m. According to fluid inclusions petrography and microthermometric measurement, it can be suggested that the mineralization the research area is classified into the high sulfidation epithermal deposit.

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