Possible generation and existence of quartz veins at Cisolok Geothermal Area

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Abstract. Cisolok area located at Southern West Java shows various geothermal manifestations. The igneous and volcanic rocks forming the main component of lithology in the area contains quartz veins. This indicates the rocks units in the area may have a close relation to the widely known Cikotok Formation containing valuable minerals. Macroscopic description of Cisolok quartz vein samples show pyrite and possibly other heavy metal minerals in the veins. Geological condition shown close relation of Cikotok Formation having older geological age to dacitic volcanic rocks extrusted in Cisolok geothermal area. Further and detail research of quartz veins in Cisolok geothermal area will provide relationship to the Cikotok Formation, possible generation and component of valuable heavy minerals. This paper discusses the case condition under lithological and stratigraphic analysis of the volcanic and igneous rocks having quartz veins at Cisolok geothermal area.

Keywords: quartz vein, Cisolok geothermal, volcanic rocks

1. Introduction
Indonesia is a country having significant potential of geothermal resources. This paper explores the geological potential of Cisolok geothermal area, located at south western area of West Java. Cisolok is one of Indonesian geothermal area that has long been studied, evaluated and even explored by drilling geothermal exploration wells. Pertamina Geothermal Energy has at least drilled one exploration well. Studies performed by various institution provides geology, geochemistry, as well as geophysics data. The utilization of the potential reserve is being developed. It is interesting to assess the various aspects. Not only heat and geothermal reserve, but there may be other geological potential available in many Indonesia geothermal fields.

In addition to geothermal reserves, Cisolok area has volcanic rocks interesting to assess, those are quartz veins discovered in some locations and outcrops. Geologically at Cisolok geothermal area are found quartz veins especially in northern part of the area. The formation of dacitic rock unit may have correlation to the formation of the quartz veins. This paper discusses the existence and genesis of the quartz veins in the area. Laboratory analysis conducted to quartz veins samples show possible valuable mineral contents that might be potential for mining purposes. This paper discuss preliminary assessment of the quartz veins found in the area. Further assessment may be conducted to ensure potential content of valuable minerals.

2. Methodology
Regionally the southern area of West Java particularly in the area between Pelabuhan Ratu to Malingping, various Tertiary sedimentary rocks has been formed which have been covered and intrusized by Quartenary volcanic rocks. In Cikotok and surrounding area there have been discovered
valuable metals such as gold and silver. Mining of such metals has long been operated particularly by extracting quartz veins, specific volcanic activity products found in Cikotok Formation generated in the area.

Meanwhile, geothermal exploration has long been initiated at Cisolok area in the eastern part of Malingping-Pelabuhan Ratu area. Not only heat and geothermal potential being explored in the area, however, there are quartz veins outcrops in the area that may have a relation to the one found at Cikotok Formation. Quartz veins rock samples have been analysed to explore possible content as well as geological preview of the generation.

2.1. Regional Geology

Geomorphologically, Cisolok is a hilly area produced by a volcanic activity with a height of 150 – 900 masl, having a rather steep until steep slope class [1]. Geologically, Cisolok area is a part of the Bayah Dome (Bemmelen, 1949) [2]. Figure 1 shows geology map of Cisolok area. The Bayah Dome is constructed by Cikotok Formation as an oldest formation having Oligocene age with rock units comprised of volcanic breccias, tuff and lava deposits. These units are exposed in west of Cisolok (Sujatmiko and Santosa, 1992). By Early Miocene, rock units consist of Citarete and Cimapag Formation. The Andesite and Dacite intrusion of Late Miocene was exposed at south of this area (Sujatmiko and Santosa, 1992). Finally, the area is covered by Citorek Tuff, breccias of Tapos Formation and basalitic lava of Quaternary age (Figure 1).

![Geological Map of Cisolok Area](image)

**Figure 1.** Geology Map of Cisolok area (modified from Sujatmiko and Santosa, 1992) [3].

2.2. Cisolok Geothermal Area

A geological survey team has conducted study and research of Cisolok geothermal area. Many rocks and hot spring fluids from the area has been sampled. Figure 2 shows geological map of Cisolok geological map.
Figure 2. Geological map of Cisolok geothermal area.

Stratigraphic study and analysis has also been performed in the survey. Four different rock units are recognized in the area. Figure 3 shows Legend that provides stratigraphic sequence of the area. Geological history of the area is based on limestone sedimentary rock of Citarate Formation. Unconformably above this basement, a lava flow forming Dacitic volcanic rock was formed followed by andesitic lava flow. The youngest rock unit is a volcanic tuff belonged to Citorek Formation.
Figure 3. Lithostratigraphy of rock units at Cisolok geothermal area.

Rock fragments were sampled from the area. Among the existing rock units as described above there are found outcrops of quartz veins in some locations. Figure 4 shows location map of quartz veins samples in the northern part of Cisolok geothermal area. Figure 5 shows an example of quartz veins outcrop at CSL-5 location.

Several outcrops were sampled to be analyzed petrographically as well as using AAS (Atomic Absorption Spectrometry) analysis. Table 1 provides the output of the AAS analysis. Figure 5 shows one of the quartz veins outcrops in the northern area of Cisolok geothermal field.
Table 1. Atomic Absorption Spectrometry (AAS) Analysis result of quartz veins samples of northern Cisolok geothermal area.

| IDENT | Au | Ag | Cu | Pb | Zn |
|-------|----|----|----|----|----|
| UNITS | ppm| ppm| ppm| ppm| ppm|
| DETLIM | 0.01 | 1 | 2 | 4 | 2 |
| SCHEME | FA30/AA | 2AA201 | 2AA201 | 2AA201 | 2AA201 |
| CSL-1 | 0.02 | <1 | 6 | 8 | 35 |
| CSL-2 | <0.01 | <1 | 5 | 25 | 119 |
| CSL-3 | <0.01 | <1 | 6 | <4 | 4 |
| CSL-4 | 0.01 | <1 | 6 | 10 | 45 |
| CSL-5 | 0.02 | 2 | 5 | 10 | 32 |
| CSL-6 | 0.01 | <1 | <2 | <4 | 3 |
| CSL-7 | <0.01 | <1 | 31 | 114 | 108 |
| CSL-8 | <0.01 | <1 | 51 | 15 | 5 |
| CSL-9 | <0.01 | <1 | 7 | 6 | 24 |

Figure 5. Quartz vein outcrop in the northern part of Cisolok geothermal area.

2.3. Quartz Veins and Hydrothermal System

In geology, a vein is a distinct sheetlike body of crystallized minerals within a rock. Veins form when mineral constituents carried by an aqueous solution within the rock mass are deposited through precipitation. The hydraulic flow involved is usually due to hydrothermal circulation [4]. The hydrothermal system can be defined as hot fluid circulation (50 to > 500 °C), laterally and vertically at temperature and pressure that varies, below the surface of the earth (Pirajno, 1992) [5]. This system contains two main components, namely heat source and fluid source. Quartz veins generation as a product of hydrothermal system could be interpreted based on experts' analysis of developing hydrothermal system.

In addition to alterations formed or change of form in a hydrothermal system, Lindgreen (1933, in Bateman and Jensen, 1991 [6]) divides hydrothermal deposits into 3 different types of deposits based on the relation of temperature, pressure, and geological conditions reflected in the minerals formed. The deposit types are:
1. Hydrothermal deposits, formed in areas close to magmatic intrusions at temperatures ranging from 500-600 °C and very high pressure
2. Mesothermal deposits, formed at a certain distance from intrusion at temperatures ranging from 200-500 °C and high pressure
3. Epithermal deposits, formed far away from intrusions at temperatures ranging from 50-200 °C and medium pressure.

Other experts have explained the genesis of hydrothermal and geothermal systems in an area. There are two types of hydrothermal systems in the epithermal environment, namely the geothermal system and the hydrothermal-volcanic system. Two contrasting epithermal deposits in terms of alteration and ore minerals (high sulphidation and low sulphidation) are formed on these two different systems, which are somewhat contrasting in terms of their volcanic order (Sillitoe and Hedenquist, 2003 [7]; Hedenquist et al. 1996, 2000 [8]). Figure 6 shows a co-generation and development of geothermal and hydrothermal systems producing valuable element (Au, Ag, and others).

![Figure 6. Schematic cross-section of shallow sub-volcanic intrusion and stratovolcano association, as well as porphyry precipitating environment, and high epidermal sulfidation or low sulfidation ore deposits (Hedenquist et al., 1996; 2000) [8].](image)

Meanwhile according to Sillitoe and Hedenquist (2003) [6], High Sulfidation that could form valuable elements (Au, Ag, Cu, etc) of hydrothermal system may be generated in a volcanic activity that produced andesite and dacite volcanic igneous rocks. Figure 7 shows this phenomenon.
2.4. General Analysis of Cisolok Quartz Veins

The quartz veins found in Cisolok are directly exist in geothermal area, thus highly possible correlated to geothermal system developed at Cisolok area. Based on result of available and analysed data, the generation of quartz veins and geothermal resource is formed by the following process’s stages:

A. Preliminary activity started by sedimentary deposition during Tertiary age, followed by uplifting due to tectonic activity. The basement may be of limestone, sandstone, breccia, and other sedimentary rocks deposited during the Tertiary age. The geological process continued by volcanic activity of magmatic outflow producing dacite, andesite, tuff, breccia and other volcanic rocks.

B. During the history until recent time, in the Java island and especially Cisolok area, volcanic and tectonic activities continue to form geothermal activity where hydrothermal activity happened under subsurface of Cisolok and many other areas. The hydrothermal activity formed quartz veins as geothermal activity produces heat and fluid flows causing rock alteration as well as new deposition.

C. Entering Quartenary period, causing surface erosion and deposition of alluvial deposits above the area due to rain falls and sun drying process as an effect of tropical climate. Geothermal activity produces surface manifestation such as hot springs and geysers in Cisolok area especially along Cipanas river, where faults and fractures play a role as porous and permeable flowline zone of geothermal fluids to the earth surface. The erosion process of the river and valley causing outcrops of quartz veins that have been formed early in the geological history.

Based on the above hydrothermal and geothermal systems generation described by experts, with the Cisolok geothermal system having quartz veins, it can interpreted that the quartz veins are products of hydrothermal system activity during the past geological age containing quite valuable elements. Figure 8 shows the possible existence and genesis of quartz veins from hydrothermal system within Cisolok geothermal system.
Figure 8. Tectonic and volcanic activities that formed the existence and genesis of quartz veins from hydrothermal system within Cisolok geothermal system.
3. Conclusions

With the survey, analysis, study and modeling of the quartz veins in Cisolok geothermal area, it can be concluded as follows:

1. Tectonic and volcanic activities in sedimentary basin of south-east Asia formed Indonesian islands having volcanic to generate potential geothermal fields. Detail survey and study found quartz veins at Cisolok geothermal area, south of West Java island.

2. According to science, knowledge, technology and experience in many geothermal fields, quartz veins may be formed in the geothermal areas. Experts realized that hydrothermal system may be developed in the existence of geothermal system in many part of the world.

3. Quartz vein outcrops in Cisolok geothermal area have been sampled to analyze the components in the samples. AAS analysis found valuable elements (Au, Ag, etc) in the samples taken from the outcrops.

4. Study and analysis found that the existence and generation of the quartz vein was a product of hydrothermal system existed with geothermal system in Cisolok geothermal area.

Further study, survey and analysis may be performed to evaluate potential content of valuable mineral and elements (Au, Ag, etc). It is quite possible due to the close distance and geologic conditions with Cikotok area where gold and silver have long been mined until presently.

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