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Geology and Surface Hydrothermal Alteration of Malabar Area, Northern Part of the Wayang Windu Geothermal Field, Indonesia

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Keywords

Wayang Windu, Malabar, geothermal, geology, hydrothermal alteration, xrd, petrography

ABSTRACT

The Wayang Windu Geothermal Field is situated in the West Java province of Indonesia. Geological field surveys were conducted in the Malabar area of the field to characterize distribution of rock units, geological structures, hydrothermal alteration and geothermal manifestations. Geological features and surface hydrothermal manifestations could indicate an extension of geothermal potential in northward from the developed area. Rock samples were collected from surface and subjected to petrographic observations and X-ray diffraction analyses.

The volcanic stratigraphy consists of four units, from oldest to youngest. There are: Pangalengan Volcanogenic Deposits Unit, Old Malabar Volcanic Unit, Young Malabar Volcanic Unit, and Andesite Intrusion Unit. Geologic structures developed in the Malabar area include brecciation, fractured zone, normal fault and dextral strike-slip faults trending NE and NW.

Geothermal manifestations include fumaroles at Kawah Burung-1 and Kawah Burung-2, hotsprings at Kawah Burung-3, H_2S gas emissions and altered ground. The hydrothermal alteration is spatially associated with faults and fractures. The alteration is characterized by the occurrence of secondary cristobalite, tridymite, quartz, alunite, natroalunite, montmorilonite, halloysite, kaolinite, pyrophyllite, muscovite, calcite, chlorite, epidote, zeolite, pyrite, and iron oxide.

1. Introduction

The Wayang Windu Geothermal Field is situated in West Java province of Indonesia (Figure 1). The Wayang Windu geothermal field is displays features transitional between vapour-dominated and liquid-dominated conditions. It consists of four coalesced fluid upwelling centres that generally become younger and more liquid-dominated towards the south. Geothermal manifestations in this field include fumaroles, steaming and altered ground, and acid–sulfate springs. Geological structure develop in this area are fractures and faults trending 30°-40° and 330°-340°. The wells have highly localized structural permeability, with the most permeable geologic structures following the regional trend of 40°. As these structures have trends similar to regional faults, it is likely they are strike-slip faults (Bogie, et. al., 2008).

The Wayang Windu geothermal field is operated by Star Energy Geothermal (Wayang Windu) Ltd. Wayang Windu Unit 1 and 2 have a total capacity of 227 MW. Star Energy is exploring the northern extension of the field with the ultimate goal of obtaining steam to generate 440 MW for Units 3 and 4. We carried out geological surveys in the Malabar area in 2010. Here,

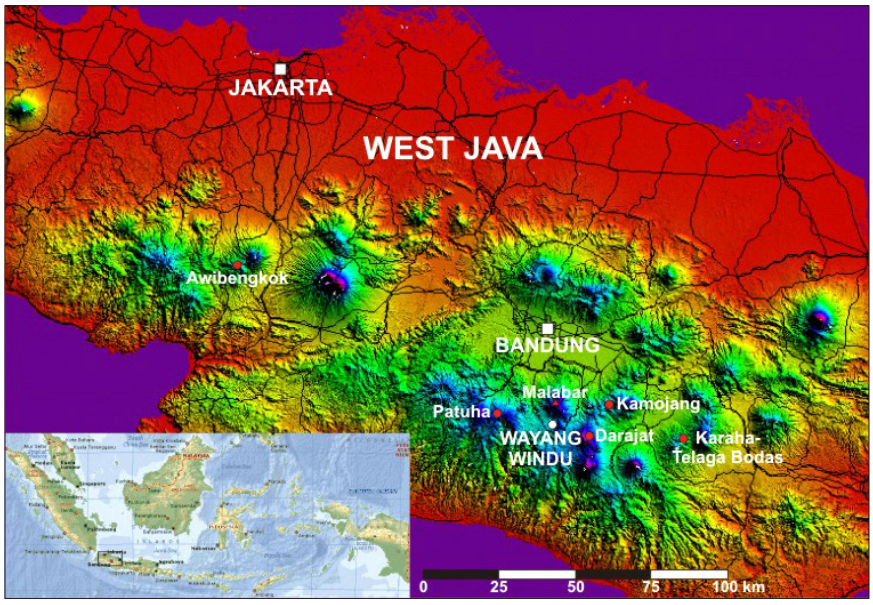

Figure 1. Wayang Windu Geothermal Field.

we describe briefly the characteristics of the Malabar area based on the field survey.

2. Methodology

The study was divided into three stages: surface geological mapping (systematic traverse mapping) including observations on the lithologies, geologic structures, alteration; laboratory study including petrographic and X-Ray Diffraction analyses; and synthesis of the result with the existing data.

3. Geology of Malabar

3.1 Volcanic Stratigraphy

Based on the eruption sources, volcanic rocks in Malabar area are grouped into four units from oldest to youngest. There are:

a) Pangalengan Volcanogenic Deposits Unit, a brown-grey coloured tuff, that is well sorted, and contain granules-boulder size of andesite, basalt and pyroclastic. This unit is compacted, mostly weathered, and partly altered especially near Kawah Burung area.

b) Old Malabar Volcanic Unit, consist of andesite, basalt, basaltic andesite and andesitic volcanic breccia. The andesites are grey-dark grey in colour, aphanitic, crystalline, and porhyritic with phenocrysts of plagioclase and hornblende in a groundmass, displaying trachytic textures. The basalt is dark grey in colour, aphanitic and crystalline. The basaltic andesite is grey in colour, aphanitic, crystalline, and porhyritic with phenocrysts of plagioclase and hornblende in a groundmass. The volcanic breccia is cream to brown in colour, poorly sorted with angular-subangular fragmnet, in a tuffaceous matrix. The andesitic volcanic breccia is brown to grey in colour, poorly sorted with angular-subangular andesite fragment, in coarse tuffaceous matrix. The Old Malabar Volcanic Unit is partly altered, secondary minerals include clay minerals, quartz, chlorite and pyrite.

c) Young Malabar Volcanic Unit. The unit consists of pyroclastic breccia, andesite and volcanic breccias. The pyroclastic breccia is cream to brown in colour, and poorly sorted with angular-subangular of pyroclastic fragments, in a tuffaceous matrix. The andesite is dark grey in colour, aphanitic, crystalline and porhyritic with phenocrysts of plagioclase and hornblende. The volcanic breccia is brown, grey, reddish, greenish in colour, and poorly sorted, with andesite and basalt fragments, in a coarse tuffaceous matrix. The Young Malabar Volcanic Unit is partly altered to secondary minerals include clay minerals, quartz, chlorite and pyrite.

d) Andesite Intrusion Unit. The unit include intrusive rocks at Puncak Besar, Curug Panganten, Tikukur, Haruman, Cigentong, Curug siliwangi and Malabar Intrusions. The intrusions are dark grey in colour, aphanitic, crystalline, and porhyritic with phenocrysts of plagioclase and hornblende, embedded in groundmass. This unit is relatively fresh and weakly altered to chlorite and pyrite.

3.2 Geological Structure

The geological structure in study area is based on interpretation of satellite images, topographic maps and field observations. Geological structure include brecciation, fractured zone, normal fault and strike-slip fault trending NW and NE. Normal faults found along the Curug Panganten river, along river east of MBB and MBD well, and in the waterfall of Curug Siliwangi. Dextral strike-slip fault occur along Cigentong river. This strike-slip fault cross cuts the normal fault. Normal and strike-slip faults cut the Pangalengan Volcanogenic Deposits Unit, Old Malabar Volcanic Unit, and Young Malabar Volcanic Unit. A geological map of Malabar area is shown in Figure 2.

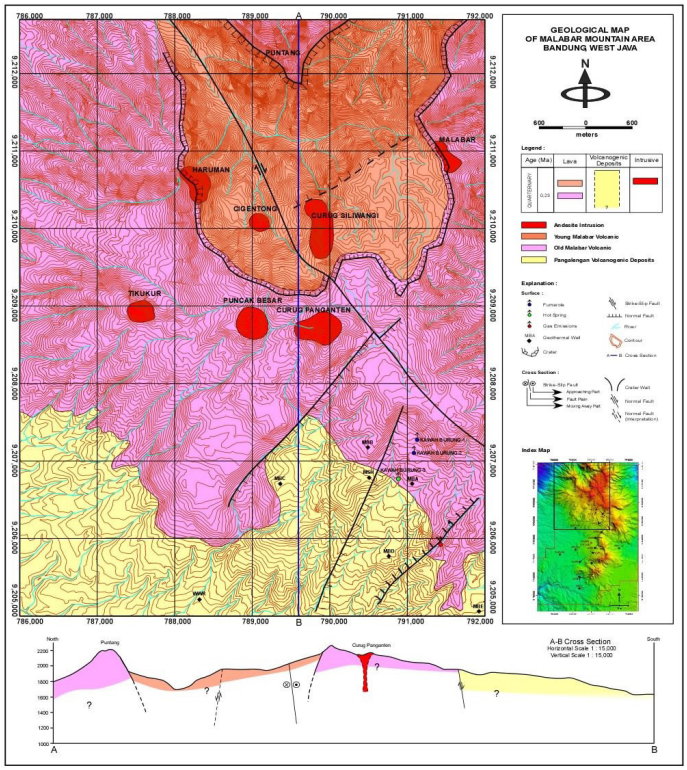

Figure 2. A Geological Map of Malabar Area.

4. Geothermal Manifestations

Geothermal manifestations are found on the southern slope of Malabar complex include fumaroles at Kawah Burung-1 and Kawah Burung-2, hotsprings at Kawah Burung-3, and H_2S gas emissions. Fumaroles at Kawah Burung-1 and Kawah Burung-2 have temperatures of 93.8ºC and 93.6ºC. The hotsprings at Kawah Burung-3 are acid-sulfate spring, these fluids are relatively high in SO_4, low in Na, K, Ca, Mg and HCO_3, low in pH, temperature of 66ºC and develop near the fumarole areas of Kawah Burung-1 and Kawah Burung-2. These fluids are strongly influenced by gas components from the reservoir that are released to the surface through the permeable zone (MNL, 2003).

5. Hydrothermal Alteration

Alteration assemblages in the Malabar area have been investigated by geological mapping, and detailed of petrographic and

XRD analyses. The hydrothermal alteration is spatially associated with faults and fractures. Alteration intensity was based on the abundance of alteration minerals : weak (<25%), moderate (25-75%), and strong (>75%). The temperature range of alteration zone based on temperature range composed by Kingston Morrison Ltd (1997). Alteration zone characteristized by mineral assemblages and association, that stable on same condition. The hydrothermal alteration in the research area can be grouped into two types : Epidote-Chlorite and Alunite-Cristobalite-Halloysite. A map of the hydrothermal alteration is shown in Figure 3.

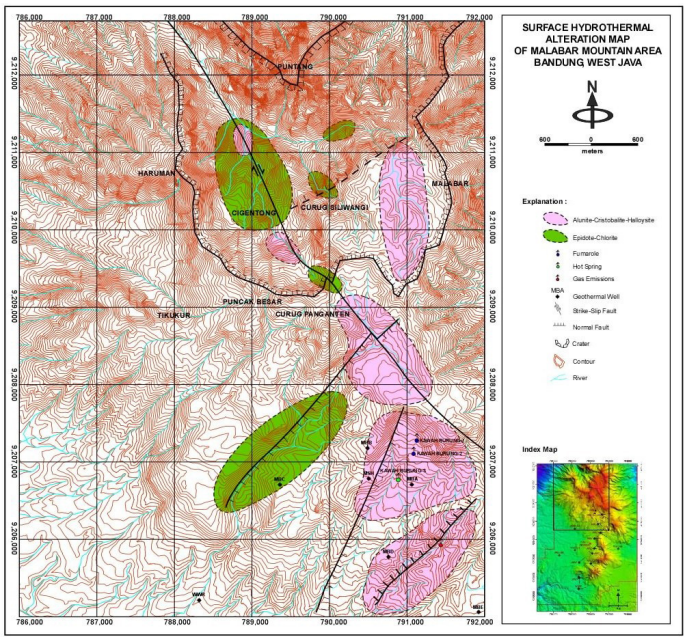

Figure 3. A Surface Hydrothermal Alteration Map of Malabar Area.

Epidote-Chlorite Assemblage

The alteration is represented by epidote and chlorite. Quartz, calcite, chalcedony, stilpnomelane, zeolites, opaque minerals and iron oxides maybe present. This assemblage is generally present in andesite, basalt and volcanic breccia. Alteration intensity varies from weak to moderate (4%-64%). The temperature of hydrothermal alteration is estimated to be 240 – 320 ^{o}C. Epidote-chlorite alteration is comparable to propylitic alteration described by Corbett and Leach (1997).

Alunite-Cristobalite-Halloysite Assemblage

The alteration is represented by assemblage contains alunite, cristobalite, halloysite. Quartz, tridymite, kaolinite, montmorilonite, calcite, chalcedony, zeolites, natroalunite, pyrite and iron oxides maybe present. This assemblage is generally present in tuffs, pyroclastic breccias and andesite. This assemblage overprints the epidote-chlorite assemblage in the lower Cigentong river. This assemblage also overprints pyrophylite and muscovite assemblage around the Kawah Burung fumarols and the upper Cigentong river. Alteration intensity varies from weak to strong (17%-100%). The temperature of hydrothermal alteration is estimated to be 20^{o} – 80 ^{o}C. Alunite-cristobalite-halloysite alteration is comparable to advanced argillic alteration described by Corbett and Leach (1997).

6. Conclusion

- Volcanic stratigraphy in the Malabar area is grouped into four units from oldest to youngest. There are: Pangalengan Volcanogenic Deposits Unit, Old Malabar Volcanic Unit, Young Malabar Volcanic Unit, and Andesite Intrusion Unit.
- The geological structure in study area include brecciation, fractured zone, normal and strike-slip faults.
- Geothermal manifestations include fumaroles at Kawah Burung-1 and Kawah Burung-2, hotsprings at Kawah Burung-3, H_2S gas emissions and altered ground.
- The hydrothermal alteration is spatially associated with faults and fractures. The hydrothermal alteration can be grouped into two types : Epidote-Chlorite and Alunite-Cristobalite-Halloysite. Epidote - Chlorite Zone and Alunite - Cristobalite - Halloysite Zone. The temperature of hydrothermal alteration are 240 – 320 ^{o}C and 20^{o} – 80 ^{o}C.

Acknowledgements

The first author are very thankful to the management of Star Energy Geothermal (Wayang Windu) Ltd., which has given permission and supporting to conduct my research in Malabar Area, and JAPEX for scholarship to study in Tohoku University.

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