HYDROTHERMAL ALTERATION STUDY IN MALABAR AREA, NORTHERN PART OF THE WAYANG WINDU GEOTHERMAL FIELD, INDONESIA

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ABSTRACT

The Malabar area, northern part of the Wayang Windu geothermal field is situated in the West Java province of Indonesia. Hydrothermal alteration study were conducted in the Malabar area to characterize surface and subsurface hydrothermal alteration. Rock samples were collected from surface and subsurface, subjected to petrographic observations, X-ray diffraction and fluid inclusion analyses.

New data of surface hydrothermal alteration was identified in the Malabar area. These manifestations could indicate an extension of geothermal potential in northward from the developed area. The hydrothermal alteration is spatially associated with faults and fractures. The surface hydrothermal alteration can be grouped into two types: propylitic and advanced argillic alteration. While three types of hydrothermal alteration including advanced argillic, subpropylitic and propylitic alteration was observed in the subsurface of MBA-2 and MBB-1 wells.

Keywords: Wayang Windu, Malabar, geothermal, hydrothermal alteration, xrd, petrography, fluid inclusion

1. INTRODUCTION

The Wayang Windu geothermal field is situated in the West Java province of Indonesia, about 35 km south of Bandung (capital city of West Java) (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 (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 planning to development two unit power generation with capacity 2 x 120 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. To improve the chances of success of these drilling programs, especially in the step-out area to the north, additional work on the studies of resources based on investigation of geological setting of the resource is being proposed. We carried out geological surveys in the Malabar area in 2010. The study will focus on hydrothermal alteration mapping in Malabar Area. The results are of this study expected to be able to help define the potential extension of the reservoir further north.

2. GEOLOGIC SETTING

The Wayang Windu geothermal field are associated with andesitic stratovolcano of the Sunda Volcanic Arc. The Sunda arc from northwestern Sumatra to Flores, represents the subduction of the India-Australia plate beneath the Eurasian plate. This northward subduction nearly perpendicular to the arc front in Java and increasingly oblique towards Sumatra (Hall, 2008).

The field is located in a mountainous area ranging from about 1280 to 2341 m asl (above sea level) elevation, and associated with Malabar volcanic, a large and extinct andesitic stratovolcano. Based on field survey, and supported by remote image interpretation, volcanic rock in Malabar area are grouped into five units from oldest to youngest, which are : Pangalengan Volcanogenic Deposits, Old Malabar Volcanic, Young Malabar Volcanic, and two intrusion units (Old Intrusion and Young Intrusion). Pangalengan Volcanogenic Deposits Unit occurs along the south flank of Malabar caldera until Pangalengan basin, consist of well sorted tuff, contain granules-boulder size of andesite, basalt and pyroclastic. The upper part consist of pyroclastic rock and laharic breccias, so-called mass-waste deposits. Old Malabar Volcanic Unit covers nearly all of the surrounded Malabar Caldera flanks, consisting of various kinds of andesitic to basaltic lavas, intercalated with volcanic

breccias. The Young Malabar Volcanic Unit is only distributed within the Malabar Caldera, consists of pyroclastic breccia, andesite and volcanic breccias. The Old and Young Andesite Intrusion Units are intrusion bodies that characterized by dome features, some showing isolated peak suggesting the presence of parasitic cone. Most of these intrusions are of andesitic composition. The Old Andesite Intrusion is marked by its porhyritic texture composed of plagioclase, pyroxene and minor pseudomorphic mafic minerals as phenocrysts which are embedded in a micro- to crypto- crystalline matrix. The Young Andesite Intrusion is marked by hyalophyllitic texture groundmass and the presence of amygdaloidal texture. The phenocrysts are composed of plagioclase and pyroxene.

Geological structure in this area include brecciation, fractured zone, normal fault and strike-slip fault. Four structural pattern have been mapped, there are NE, NNE, NW and NNW, which important structural orientation for reservoir permeability in Wayang Windu geothermal field. The surface thermal manifestation found in the study area include fumaroles at Kawah Burung-1 and Kawah Burung-2, hotsprings at Kawah Burung-3, and H_2S gas emissions. Most of these thermal manifestations are situated in the south flank of Malabar caldera. A geological map of Malabar area is shown in Figure 2.

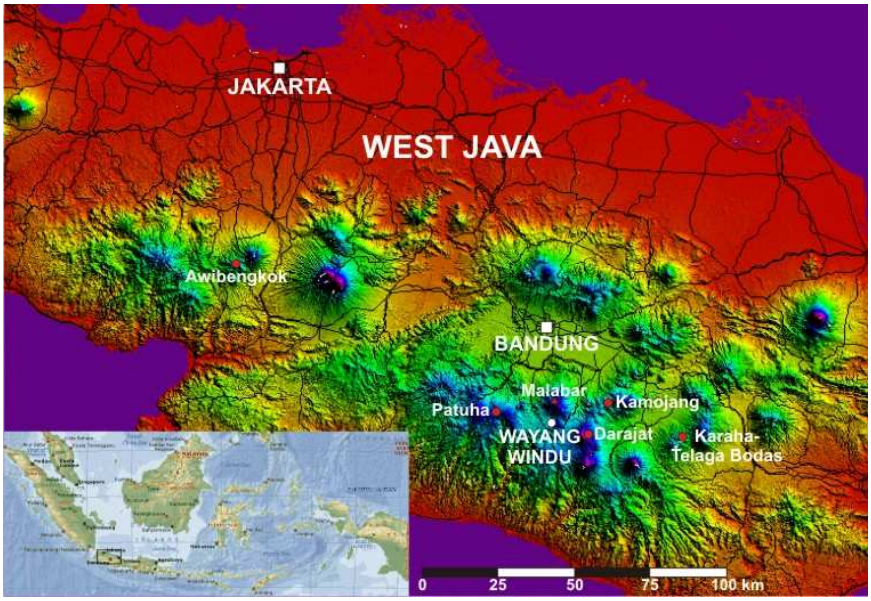

Figure 1. Wayang Windu Geothermal Field

3. METHODS

The study was divided into three stages: surface geological mapping, mainly focus in hydrothermal alteration survey; rocks samples collecting from surface (outcrop) and subsurface (cutting and core from MBA-2 and MBB-1 wells); laboratory study including petrographic, X-Ray Diffraction and fluid inclusion analyses; and synthesis of the result with the existing data.

4. RESULTS

4.1 Surface hydrothermal alteration

A large number rock samples are taken from the surface during the fieldwork, all of them are petrographically analyzed for determining its texture & mineralogy (primary & secondary minerals) as well. Some of the altered rocks are XRD's analyzed to identify clay mineralogy and other finer grained minerals.

Intensity of alteration is classified using quantitative method (ratio between secondary minerals versus total rock volume in %) as such follow: weak (<25%), moderate (25-75%) and strong intensity (>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 study area can be grouped into two types : propylitic and advanced argillic alteration. This alteration is spatially associated with faults and fractures. Most of them seem to be closely related with NE-SW and NW-SE trends of fault systems, with an exception for smaller areas of propylitic alteration which is situated north of Curug Siliwangi, within the Malabar Caldera and the N-S trend of advanced argillic alteration zone that might be related with fractures. A map of the hydrothermal alteration is shown in Figure 3.

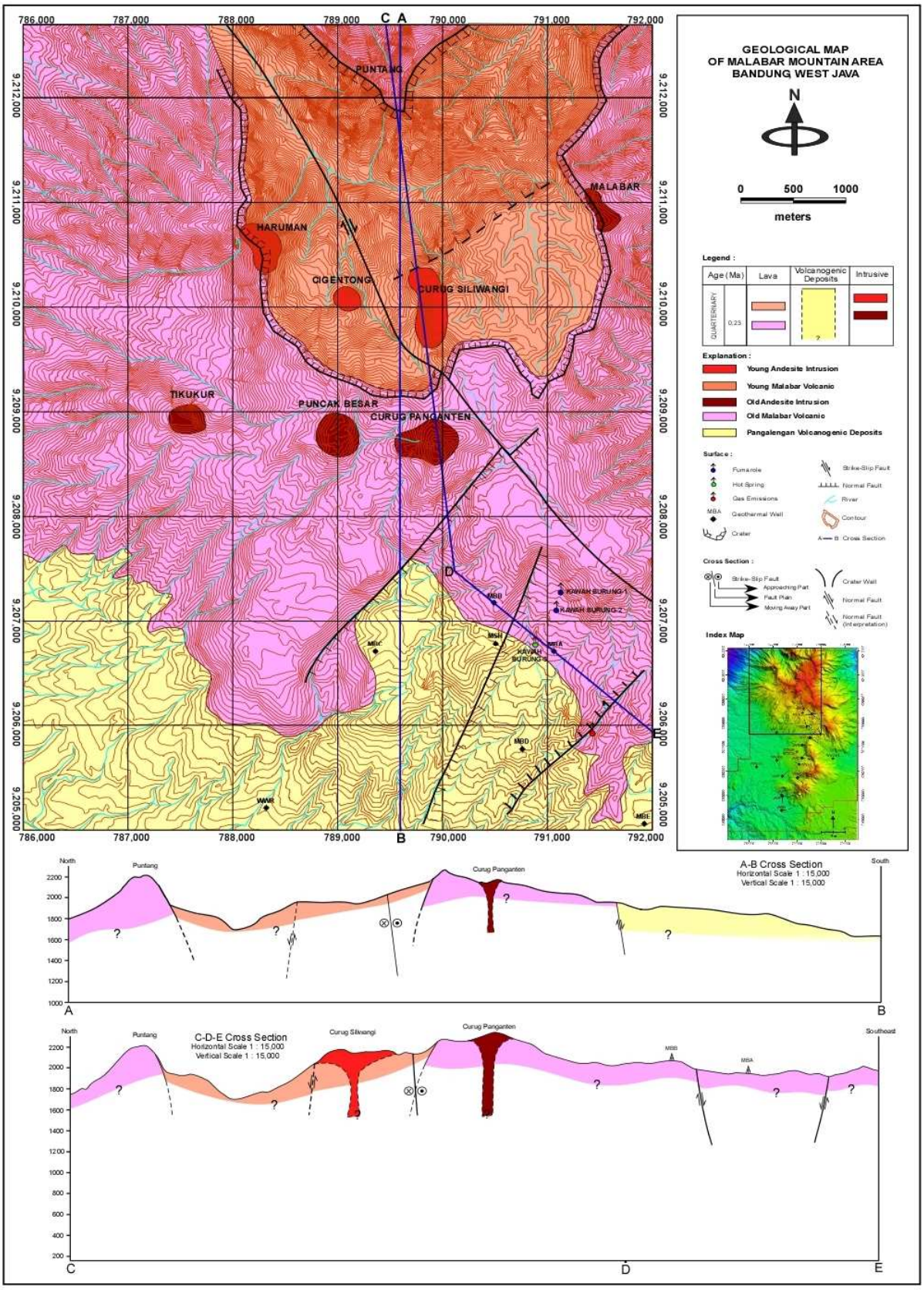

Figure 2. A Geological Map of Malabar Area.

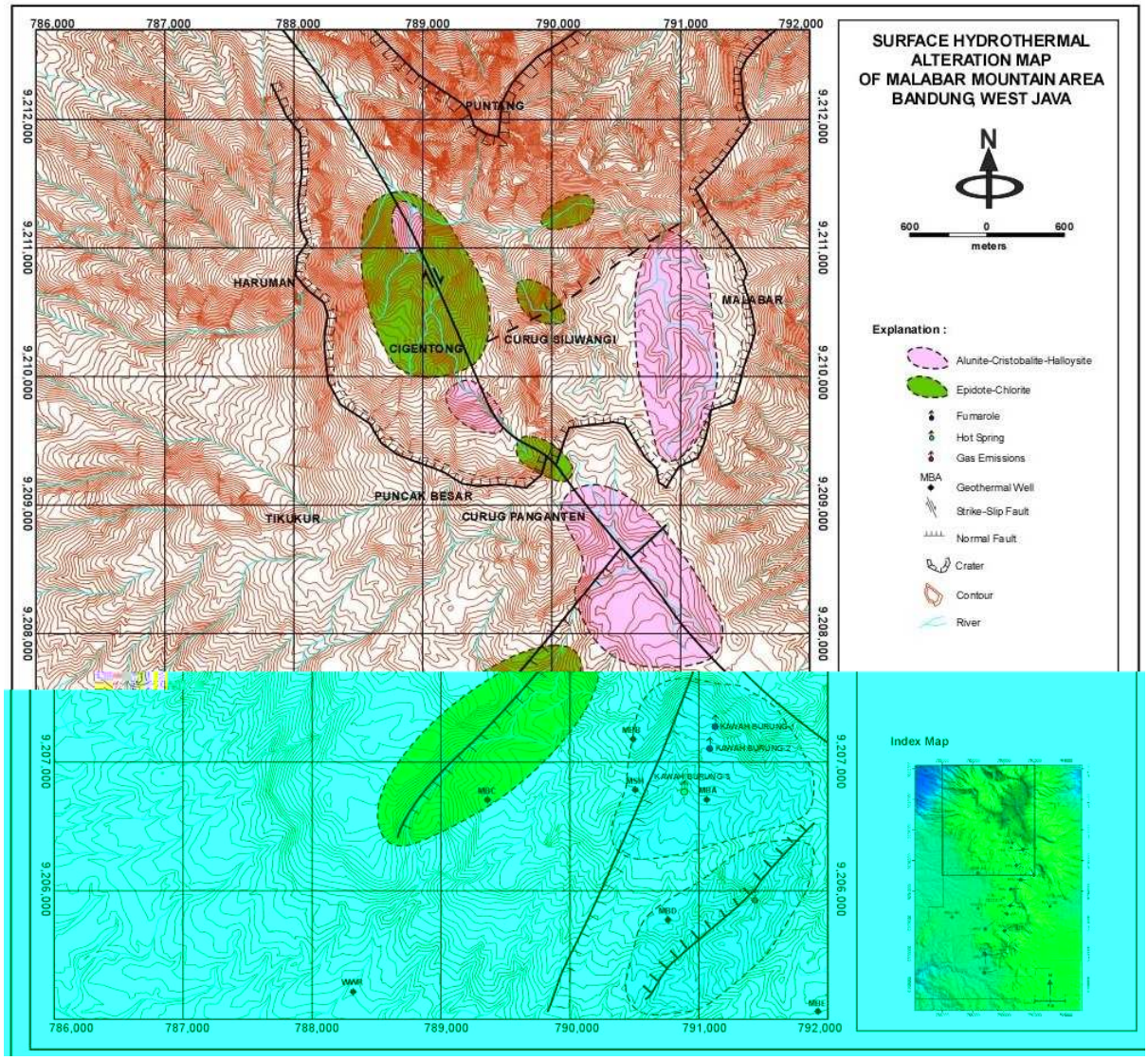

Figure 3. A Surface Hydrothermal Alteration Map of Malabar Area.

Propylitic Alteration

This alteration is characterized by the presence of epidote and chlorite as secondary minerals, besides secondary quartz, calcite, chalcedony, stilpnomelane, zeolite, opaque mineral and iron oxides are oftenly present. This assemblage is generally present in andesite, basalt and volcanic breccia. Alteration intensity is varies from weak to moderate (4%-64%). The presence of epidote-chlorite assemblage indicating the neutral-pH fluid alteration with the temperatures ranging between 240 – 320 ^{o}C.

Advanced Argillic Alteration

Mineral assemblage contains alunite, cristobalite, halloysite is characterizing this alteration type. The other secondary minerals are secondary quartz, tridymite, kaolinite, montmorilonite, calcite, chalcedony, zeolites, natroalunite, pyrite and iron oxides. This assemblage is generally present in tuff, pyroclastic breccia and andesite. Alteration intensity is varies from weak to strong (17%-100%). Based on the presence of alunite associated with cristobalite the fluid pH should be more acid with a very low temperature, is estimated to be 20^{o} – 80 ^{o}C. This assemblage overprints the epidote-chlorite assemblage in the lower Cigentong river. XRD analysis result from two samples (RO A1-2, east of MBA drill pad and RO A5-8, nearby Kawah Burung-2 fumarole) showing the presence of high temperature pyrophyllite.

4.2 Subsurface hydrothermal alteration

Two wells of MBA-2 and MBB-1 are served to be used for this subsurface alteration study. A number of 51 samples from MBA-2 (samples from 52 to 1495 m depths) and 32 samples from MBB-1 wells (samples from 50 to 1070 m depths). Most of the samples are cutting samples and some are core samples. All of them are petrographically analyzed and a few of them are analyzed using XRD's method. Based on these laboratory analyzed, subsurface alteration can be devided into 3 (three) types: advanced argillic, subpropylitic, and propylitic alteration types. A subsurface distribution of hydrothermal alteration on Malabar area is shown in Figure 4.

Advanced Argillic Alteration

This alteration is only found in shallow level of this well (52-55 m, 82-85 m and 172-175 m depths in MBA-2 well; and 50-53 m depths in MBB-1 well). It is dominated by clay minerals with minor amounts of quartz, tridymite, cristobalite, stilpnomelane, zeolite, and opaque minerals. The occurrence of illite together with stilpnomelane in MBA-2 well indicate high temperature (>260◦C), neutral-pH fluid derived. While in MBB-1 well, the occurrence of smectite-cristobalite, suggests acid-pH alteration fluid with temperatures ranging from 120°C-160°C.

Subpropylitic Alteration

This subpropylitic alteration occurs in subsurface level (started from 112-115 m to 802-805 m level in MBA-2 well and from 80-83 m to 830-833 m level in MBB-1 well). Smectite-carbonate/calcite-chlorite-quartz-opaque mineral association is characterizing this alteration type. Anhydrite and stilpnomelane are present in some samples. The intensity of alteration is classified as moderate to strong (up to 75% in total); veinlets of quartz ± chlorite ± carbonate ± opaque minerals are noted. The presence of stilpnomelane are observed in shallower levels suggest that stilpnomelane represents the former secondary minerals and then is overprinted by the lower temperature minerals. The association of smectite-chlorite-anhydrite indicate the temperature limits for this alteration fluid is between 190°C-260°C, in neutral-pH condition.

Propylitic Alteration

The presence of epidote-chlorite in 860-863 m to 1070-1073 m depth of MBB-1 well and 832-835 m to 1492-1495 m depth of MBB-1 well indicates the beginning of propylitic alteration zone. The other minerals such as quartz, anhydrite, stilpnomelane, wairakite and iron-oxides are present in some levels. Veinlets of quartz ± carbonate ± epidote ± anhydrite ± chlorite ± wairakite ± opaque minerals are common. Based on epidote-chlorite assemblages the temperature ranges of the alteration fluid between 240°C-340°C with neutral-pH alteration fluid. The presence of stilpnomelane can also be considered as this mineral belongs to high temperature minerals the same as the other minerals such as epidote, chlorite, wairakite. By put stilpnomelane mineral in addition, the temperature fluid will be corrected; giving the temperature ranges from 270°C - 340°C.

5. SUMMARY

- The hydrothermal alteration is spatially associated with faults and fractures. The surface hydrothermal alteration can be grouped into two types : propylitic and advanced argillic alteration. The temperature of hydrothermal alteration ranging between 240 – 320 ^{o}C and between 20 – 80 °C.
- The subsurface hydrothermal alteration study in MBA-2 and MBB-1 wells reveals three types of alteration including advanced argillic alteration, subpropylitic and propylitic alteration.
- The occurrence of illite together with stilpnomelane in advanced argillic alteration of MBA-2 well indicate high temperature (>260◦C), while in MBB-1 well, the presence of smectite-cristobalite, suggests temperatures ranging from 120°C to 160°C with acid-pH alteration fluid.
- The association of smectite-chlorite-anhydrite in subpropylitic alteration indicate the temperature between 190°C-260°C, in neutral-pH condition.
- Propylitic alteration is characterized by the presence of epidote-chlorite assemblages, indicate the temperature ranges of 240°C-340°C with neutral-pH alteration fluid. The presence of stilpnomelane suggests the temperature ranges from 270°C - 340°C.

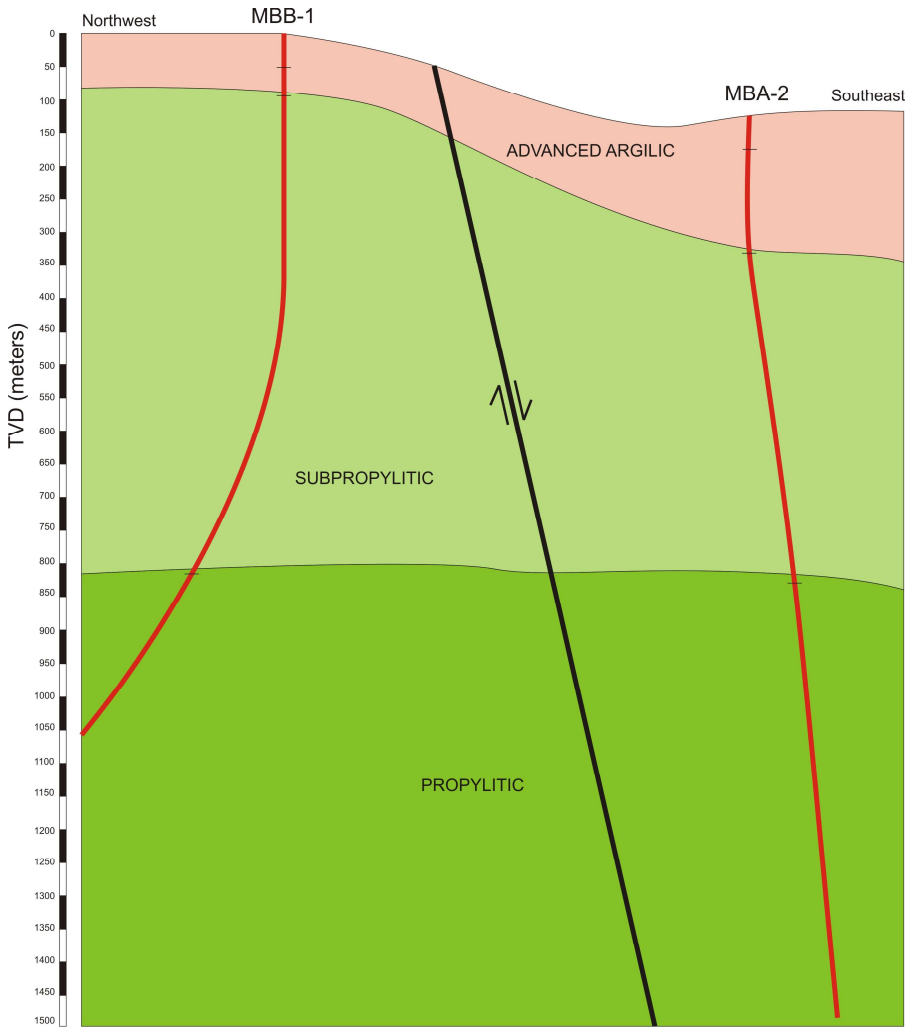

Figure 4. A Subsurface Distribution of Hydrothermal Alteration Zone on Malabar area.

6. ACKNOWLEDGEMENTS

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