Determining the hydrothermal flow media using seismicity properties in Kaliulo geothermal field, Semarang, Central Java, Indonesia

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Abstract. Geothermal system requires specific geological condition that allow deep circulation of ground water to extract heat from the heat source. Faults and fractures play a major role in the localization and evolution of hydrothermal flow on several scales. The research aim was to obtain the permeability pattern of hydrothermal fluid base on response of micro seismic waves to subsurface structures. In one dimensional structure, average Horizontal to Vertical (H/V) spectral ratios can be assumed to measure the ellipticity of fundamental mode Rayleigh wave. Hence the shape of H/V ratios can be used to estimate the shear-wave velocity profile. The poisson’s ratio value of the hot spring corresponds to the physical properties of rock containing fluids. The thickness of the sand deposit and the soft layer indicated in the hot spring zone. We interpreted that we have warm springs in the research area comes up by the fracture or fault zone and permeable zone of sand soil. The mixing waters flow to the earth’s surface through the structure.

1. Introduction
The utilization of geothermal sources is one of the human efforts to fulfil one of their necessities of life. Geothermal sources that are found in the natural world around us are easily manifested. Java Island has the potential for large geothermal reserves. Most of the geothermal potential fields are characterized by the discovery of manifestations such as hot springs, fumaroles, warm ground, sulfatars, etc. The existence of this manifestation is an early indicator of a geothermal system. To explore further, it can be done in the area around the manifestation. At least 62 geothermal fields are located on the island of Java [1]. The entire Indonesian geothermal system related to surface manifestations found in the manifestation of high temperature hot springs (boiling temperature) is only found in quaternary volcanic mountains and active volcanoes along volcanic arcs [2].

Kaliulo hot springs are located in Semarang district, which is about 10 kilometres from the central city of Semarang (figure 1). This manifestation is more widely known by the local community as Pablengan (Javanese language) which means salty water production. Bleng water is water that tastes salty, one of the ingredients for producing snacks. The Kaliulo hot springs are believed to be part of the outflow zone of the Gedongsongo geothermal system [3]. The temperature of hot springs commonly found in geothermal systems ranges from 35°C to 81°C and is usually fluid dominated by HCO$_3$-Na.Ca [4]. The Kaliulo hot springs, the fluid temperature ranges from 33°C - 38°C. Some of the important factors for estimating the potential of geothermal resources and systems are temperature, fluid to vapor ratio, chemical evolution and the geothermal fluid flow system [5].
The fault and fracture patterns in the geothermal system are the main indicators for detecting hot water flow patterns. The existence of the fault controls the hot water circulation system that circulates in the subsurface structure [6]. The hot water circulation pattern also follows the interaction between heat sources, fluid circulation and permeable path patterns [7]. The HVSR method has been widely used for exploration of rock and geothermal structures. Velocity modeling is used to determine the subsurface structure in Ijen Crater, which is done by inverting the dispersion curve from the cross-correlation result of the ambient recording signal[8]. Other results applied to the volcanic system were lower than the results of laboratory analysis of rocks in 5 volcanoes. The difference in results between velocity modelling and rock analysis was due to differences in rock scale and depth of measurement targets [9]. Based on research that has been applied in several fields, encourages the author to apply it to the Kaliulo geothermal area. This research is important to do because the Kaliulo geothermal system is a manifestation in the middle of a settlement, so it is necessary to know the mechanism of its occurrence, henceforth it can be designed to develop its utilization. The purpose of this study is to obtain permeability pattern of hydrothermal fluid base on response of micro seismic waves.

Figure 1. Study area of Kaliulo geothermal hot spring

2. Geological setting
The tectonic setting of the Java island is dominated by four main faults, namely the Kendeng Fault which runs west-east direction, the Cimandiri Fault which traverses NE-SW, the Citandui Fault and the Central Java fault. These faults are caused by the presence of compressional forces [1]. Volcanic growth along the transverse fault from north to south. Old Ungaran deposits are caused by a submerged deposition process [3].

The rock stratigraphy in the study area (as shown on figure 2) consists of Augit basalt (Tmb), is found at G.Klesem as dyke. This rock is Middle Miocene age. The next formation is Kerek Formation (Tmk), which consist of alteration of claystone, marl, tuffaceous, sandstone, conglomerat, volcanic breccia and limestone. Claystone, light grey-dark grey, calcareous; partly interlayered with siltstone or sandstone; locally contains forams, molluscs and coral colonies. Limestone is commonly bedded, cristalline and sandy with total thickness of greater than 400m. The unite is of Middle Miocene age. While volcanic product is Gajahmungkur Volcanics (Qhg) consisting of hornblende-augite andesite commonly occurred as lava flows. The next formation is Kaligetas Formation (QPKG), there are volcanic breccia, lava flows, tuff, tuffaceous sandstone and claystone. Flow breccia and lahar with
intercalation fine-grained to coarse tuff. Locally mollusc-bearing claystone and sandstone are found at the lower part. Weathered volcanic rock is reddish brown and often form the big blocks. Thickness ranges from 50 m to 200 m.

3. Methods
Geothermal fluid flows towards the surface through a permeable medium. One type of permeable media is media that has a structure such as fractures. Usually the fluid flows through the medium. Measurement records of microtremor waves is then analysed to obtain physical rock parameters, such as peak frequency distribution to determine the thickness of the bedrock layer. The $V_{S30}$ distribution and poisson ratio’s map was used to determine the physical properties or as an indicator of rock nature as a hydraulic fracture property.

Microtremor data were recorded in the area around the hot water manifestation. The measurement design is deliberately carried out in such a way as to form 2 intersecting paths. The intersection between the two paths is chosen at the location where the manifestation occurs. The equipment used is in the form of 2 sets of recording devices, each of which consists of a 3-component seismometer sensor, a data logger, and a battery power supply (figure 3).
In this microtremor measurement, a time series seismometer is used for small amplitude changes. Sample data measured in three oscillation directions, namely vertical (V), North-South component (N-S) and East-West component (E-W). The duration of measurement at each point is between 15 - 20 minutes [10]. This data recording is used with sampling intervals adjusted to the amplitude of the quasi stationary signal. Furthermore, data processing and analysis were carried out using Geopsy free software. This software was introduced in 2005, as a widely used data processing package for analysing ambient vibration data and has been released under the GNU version 3 license [11]. Initial data processing is applied Fast Fourier Transform to obtain the sample frequency-amplitude spectrum, which is smoothed using the Konno-Ohmachi function at a bandwidth of 40.

4. Results and discussion

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4.1. HVSR peak frequency distribution

HVSR measurements at the research location were carried out with a cross-shaped pattern forming lines in the north south and east west directions. This horizontal section shows the distribution of measurement points in the Kaliulo manifestation area. Scientifically the peak of the HVSR frequency in a region can describe the variation in the depth of the basement layer at several points, the thickness determination of the basement layer is inversely proportional to the peak frequency [12]. HVSR peak frequency contour (figure 4) indicates the thickness of the basement layer at the manifestation site is thicker than the surrounding location.

4.2. The $V_{s30}$ mapping

Seismic recording is carried out at the cross lines passing the hot water manifestation, after inversion processing the Vs and Vp curves are obtained. This inversion processing aims to obtain a subsurface profile to interpret the rock properties. Based on the $V_{s30}$ map (figure 5) can be determined the thickness of the sand deposit $V_{s30}$ 180-360 m/s and the loose and soft layer indicated by the value of $V_{s30}$ 600-1500 m/s in the hot spring zone [13].
4.3. Poisson’s ratio mapping

Poisson’s ratio is a tool to measure the nature of how deformed a material is in the direction perpendicular to the applied force. The application of this method is to determine how strong a rock is exerted a force on it, whether the rock will be damaged in the form of fragments, or cracks. The poison’s ratio of a formation will change layer to layer. The criterion of a rock for the hydraulic properties of the fracture is the smallest Poisson ratio. For example, a small Poisson ratio value of 0.1 - 0.25 means that the rock is easy to be fracture [14].

Figure 5. The Vs,30 Microzonation Mapping (a) Horizontal layer and (b) slice layer of E-W direction.

Figure 6 (a) Horisontal poisson ratio’s map, the E-W profile (b) and N-S profile (c) of poisson ratio
The Poisson's ratio distribution map values in the study area (figure 6) shows a low value of poisson's ratio which coincides with the area zone of hot water manifestations. The poisson’s ratio value of the hot spring corresponds to the physical properties of rock containing fluids in the andesite and basalt at the pressure and temperature conditions in the range 0.1 to 0.35 [9].

5. Conclusion
The results of the HVSR peak frequency analysis showed the thickness of the basement layer at the manifestation site is thicker than the surrounding location. The thickness of the sand deposit and the soft layer indicated in the hot spring zone. The average poisson's ratio in Kaliulo is estimated to be 0.29 at a depth of 200 - 250 m. We interpreted probably the sand layers representing as the meeting place of hot fluids from the sideways products of geothermal and meteoric fluids.

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