Study of the Wadas Malang Hot Spring as Non-Volcanic Geothermal Potential, Kebumen Central Java

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Abstract: In general, the research area has complex geological characteristics. Wadas Malang is non-volcanic area, dominated by sedimentary rocks, transition between Waturanda and Penosogan Formation. Wadas Malang area has a hot spring manifestation which may indicate geothermal potential. Unfortunately, this geothermal manifestation has not yet been seriously developed. Absolutely, this potential could be integrated with Sindaro waterfall as one of geotourism destination at the Karangsambung-Karangbolong National Geopark. Wadas Malang hot spring interpreted as non-volcanic geothermal system. The main aim of this research is to determine the correlation of Fault and Fracture Density (FFD) with hot spring manifestation in the study area. This research using FFD method and lyneaments analysis from SRTM and digital topography data. Lineaments analysis was processed from a raster image of ASTERGDEM 10 M by using GIS software (ArcGIS) to generate a lineament map. Regional geology and geochemistry data of the hot spring manifestation from the literature have been used as reference in this study. This study indicated that the occurance of the Wadas Malang hot spring is related with outflow system which are controlled by Kedungkramat sinistral fault as a result of tectonic deformation. The occurrence of this manifestation is not only controlled by fractures, but also by regional hydrology, contact and formation dips. FFD maps could be used as an alternative to identify segmentations lineament trends which is used in field surveys. This morphology strongly affects the results of FFD analysis which is correlated with surface manifestation in the study area.

Keywords: fault; FFD; fracture; geothermal; hot spring

1 Introduction

The Wadas Malang hot spring, Kebumen Regency is one of the surface geothermals in the southern part of Central Java (Permana & Mulyadi, 2015). The existence of the Wadas Malang hot spring in the study area is close to the Sindaro waterfall and Banda Hill which is well known as one of the geosite Karangsambung-Karangbolong National Geopark (Figure 1). Unfortunately, this geothermal manifestation has not yet been seriously developed. Wadas Malang area is non-volcanic active, consist of Early Miocene volcanic rocks a part of Waturanda Formation (Asikin, S., Handoyo, A., Busono, H., dan Gafoer, 1992). Geothermal manifestations in the study area related to a non-volcanic geothermal system, especially sedimentary basin (Permana & Mulyadi, 2015).

Thermal water from the lower aquifer to flow into the upper related with the circulation of meteoric water at along fault/fracture zone (Anderson & Lund, 1979). The existence of the faults, fractures, or contacts between intrusive and surrounding rocks may become conduits for thermal water (Wibowo, 2010). The ability of fluid through faults and fractures are representing the existence of a secondary permeability. High frequency of fault and related fracture zones play an important role in fluid migration which is related to hydroulic properties and the hydrogeologic setting during fault slip and fluid flow (Hammond & Evans, 2003).

The purpose of this research is to determine the correlation of Fault and Fracture Density (FFD) with hot spring manifestation in the study area. One of a method that could describe faults and fractures existence was called a Fault and Fracture Density (FFD) which is developed by Soengkono (S Soengkono, 1999; Supri Soengkono, 1999). Delineation and detection of the geothermal exploration and exploitation areas with high frequency / densities of faults and fractures are very important (Wibowo, 2010). FFD method have proven for delineating geothermal system in Te Kopia (S Soengkono, 1999; Supri Soengkono, 1999) and Mokai (Supri Soengkono, 2000) geothermal fields in the Taupo volcanic zone. In contrary, high value of FFD which depict the high permeability zone show have no correlation with the occurrence of surface manifestation for geothermal non-volcanic systems in Marawa, Suwawa, Palu (Wibowo, 2010) and Amohola (Nahli et al., 2016). FFD method have been used to detect lineaments automatically using different spatial resolution images. Unfortunately, the FFD

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method is not success to discover the existence of surface manifestation and also relationships between lineaments and prospect zones using spatial resolution SRTM 90-M, SRTM 30-M, and Aster GDEM 30-M (Van Bemmelen, 1949). This research tries to utilize digital topography data with spatial resolution (DEM 10 M). This digital topography data is used to generate lineament maps. FFD maps could be used as an alternative to identify segmentations lineament trends which is used in field surveys.

Figure 1. Wadas Malang hot spring in the study area (a and b). This manifestation is close to the Sindaro waterfall (c,) and Banda Hill (d) which is well known as one of the geosite Karangsambung-Karangbolong National Geopark.

2 Geological Setting

The physiographic of study area is a part of the South Serayu Mountain (Van Bemmelen, 1949), which is well known as Early Miocene volcanic rocks of Waturanda Formation (Asikin, S., Handoyo, A., Busono, H., dan Gafoer, 1992) (Figure 2). This formation consists of lower breccia and upper gradually change into massif sandstone. The breccia unit consisting of angular varied fragments, such as andesite basaltic igneous rock, pelagic sedimentary rock, and metamorphic rocks (Krisnabudhi, A., Rahmanto, B., Hapsoro, S. E., Sulaeman, H. I., Rachman, M. G., Pratama, 2015).

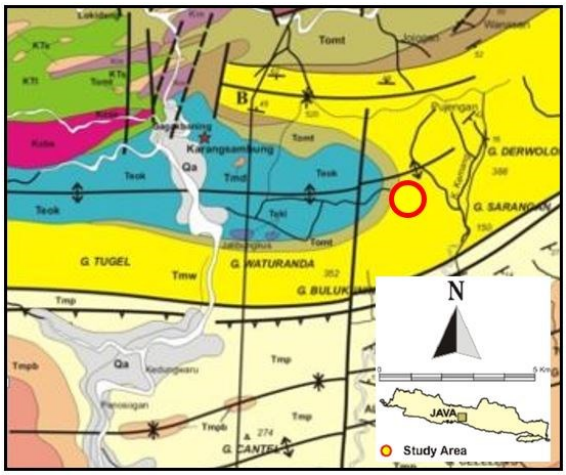

Figure 2. Geological Map of the study area. Waturanda Formation (yellow colour).

The provenance of Waturanda Formation originated from recycled orogeny and magmatic arc tectonic environment. The provenance of tectonic environment recycled orogeny originated from Luk Ulo Melange Complex, whereas the provenance of magmatic arc originated from volcanism which is deposited at the same time in fluvial marine environment by turbidity current (Krisnabudhi, A., Rahmanto, B., Hapsoro, S. E., Sulaeman, H. I., Rachman, M. G., Pratama, 2015). The deposition of Waturanda occurred when the Luk Ulo Melange Complex was maximum uplifted in tertiary orogenesis. This tectonic events formed oblique normal and normal faults as the result of extensional force. In the north and south of Southern Serayu depression zone is affected by imbrication structure formed maximum uplift from isostatic effect in Miocene – Pliocene (Satyana & Purwaningsih, 2002). This events occurred at the same time with Neogene compressional wrenching tectonic phase which caused volcanic belt in southern Java Island.

3 Methods

FFD method is used to distinguish of intense faulting and fracturing area by measure a total length of lineaments per unit area (S Soengkono, 1999; Supri Soengkono, 1999). Highly fractured areas usually correlate well to potentially permeable zones that can act as paths for thermal fluid to flow from the reservoir at depth to the shallower level. These fractures could be developed due to rock deformation, such as faulting and folding which is controlled by tectonic activity. Therefore, FFD method is very important to apply in geothermal exploration for delineation of high density of faults and fractures areas.

The study area is divided into a grid for obtain density contour map. The density value in each grid is reflect fractures density. High permeability could be interpreted from high intensity of fractures density which is indicate from high density contour. Lineaments analysis was processed from a raster image of ASTERGDEM 10 M (Advanced Spaceborne Thermal Emission and Reflection Global Digital Elevation Map) by using GIS software (ArcGIS). The shaded relief features from ASTERGDEM image are used to delineate the lineaments (Figure 3). Regional geology and geochemistry data of the hot spring manifestation from the literature study was conducted to identify the type of thermal water in the research area.

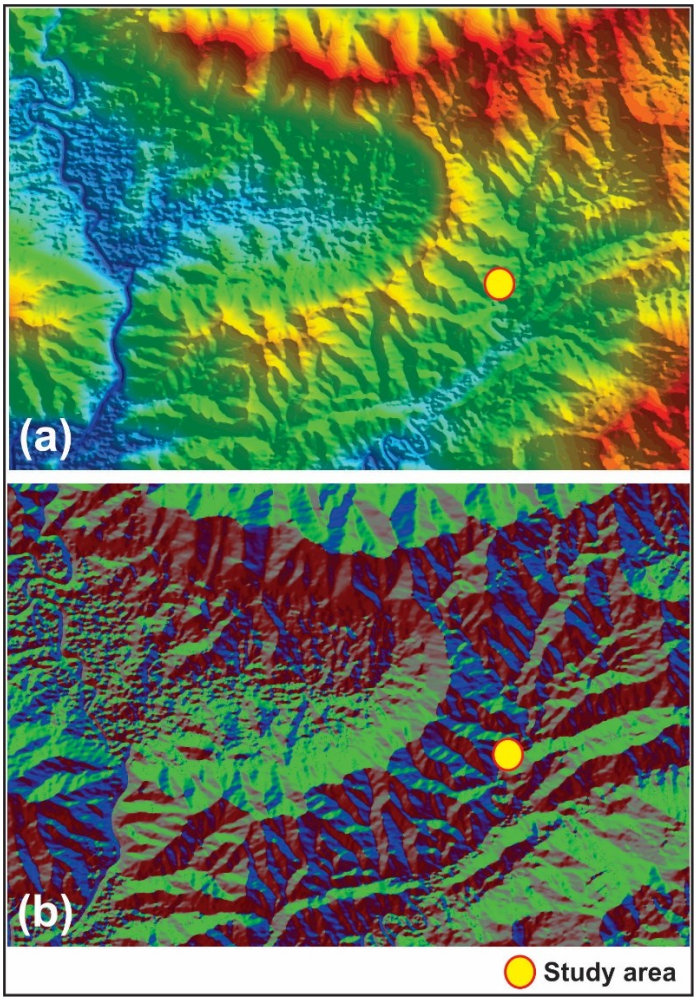

Figure 3. ASTERGDEM 10 M image are used to delineate the lineaments, (a) DEM colour, and (b) The shaded relief features

4 Discussion

4.1 Geothermal system of the study area

Kebumen regency has two locations that indicate the occurrence of the geothermal manifestation, there are Krakal and Wadas Malang hot spring. Wadas Malang hot spring was the focuses of this study absolutely could be integrated with Sindaro waterfall and Banda Hill as one of geotourism destination at the northern part of Karangsambung-Karangbolong National Geopark. Wadas Malang hot spring is dominated HCO3 ion, approximately 93,50 - 111,07 mg/l, is categorized as bicarbonate water. The hot spring has pH 7.19 and at 38.2°C manifestation temperature and 27.8°C air temperature (Permana & Mulyadi, 2015). It is estimated that these waters are associated with the thermal water than contain gas which condenses at the upper of aquifer. Based on the the NaK-Mg geothermometers from Wadas Malang hot spring is interpreted as immature water zone that

suggested the reservoir temperature is less than 160°C. Wadas Malang hot spring could be estimated as the outflow area of geothermal system (Permana & Mulyadi, 2015).

3.2 Fault and Fracture Density and The Geothermal Possibility Area

The FFD maps of the Wadas Malang hot spring was constructed from the shaded relief features from ASTERGDEM image. In this study, 1 km/km2 FFD contour was attempted to define an anomalous area as a cut off. The high FFD anomaly value of the Wadas Malang hot spring is located in the east – southeast of the expected area (Figure 4). These areas are associated with the sandstone and breccia of the Waturanda Formation in the geology map, respectively.

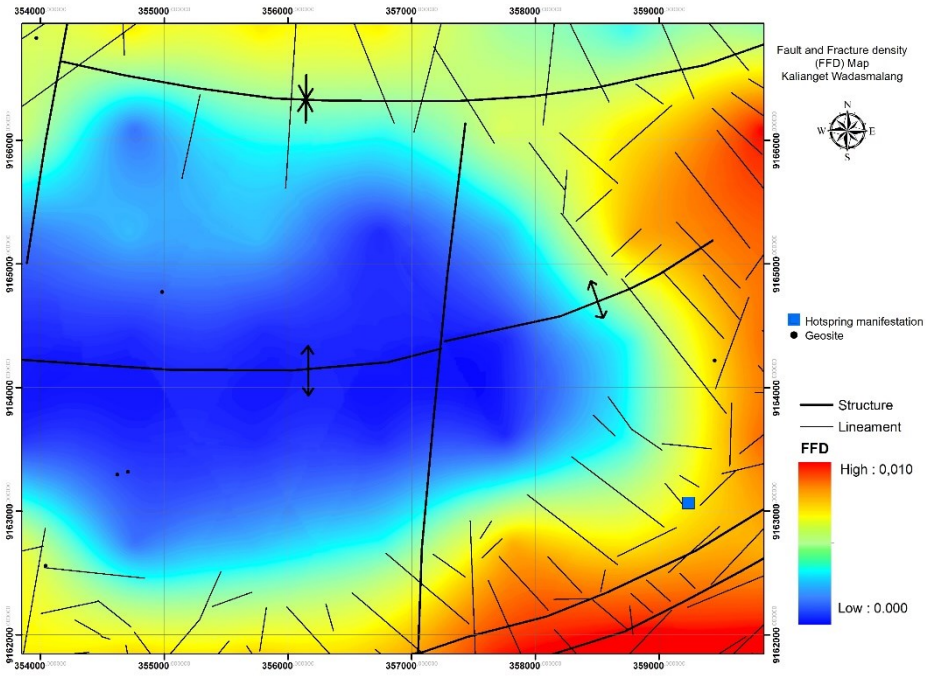

Figure 4. FFD anomaly value of the Wadas Malang hot spring

Wadas Malang hot spring is located at the transition of the medium to high FFD contour, which is reflected high permeability zones. Surface manifestations often occur at transition between high and low FFD contours that reflect the slope of the the terrain (Wibowo, 2010). Wadas Malang hot spring is bordered by high topography on the west and the north. This morphology strongly affects the results of FFD analysis. The high intensity of fractures in the study area is developed in the flank of high topography. Wadas Malang hot spring is associated with KedungKramat strike slip fault and folding which controlled by tectonic activity. These deformation processes are representing the existence of a secondary permeability may become conduit for thermal manifestation could appear on the surface. Fracture zone around Wadas malang hot spring play an important role in fluid migration. It is estimated that thermal water that contain gas, in particular CO2 are associated with meteoric water at the upper of aquifer, then the manifestation temperature less than 50oC and dominated by bicarbonate water.

Based on the discussion above, it could be concluded that the occurrence of the geothermal manifestation at the Wadas Malang hot spring is caused by high intensity of fractures and situated exactly on the fault zone.

5 Conclusion

Wadas Malang hot spring could be estimated as recharge area. Wadas Malang hot spring is located at the transition of the medium to high FFD contour. This morphology strongly affects the results of FFD analysis which is correlated with surface manifestation in the study area. High topography on the west and the north has high intensity of fracture which are controlled by Kedungkramat sinistral fault as a result of tectonic deformation. This area was estimated as limit of high permeability zones which have play an important role for fluid migration.

Further study, especially related subsurface data may be could be a good indicator to obtain more convincing interpretation the occurrence of thermal springs. Detailed field study related contact and formation dips, regional hydrologic conditions and associated faults are mapped especially around surface manifestations.

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