Identification of Geothermal Prospect Zone in Mount Lawu using Geospatial and Geological Analysis

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Key words: Mount Lawu, Fault Fracture Density (FFD), Geothermal Manifestations

SUMMARY

Indonesia's prospect of geothermal potential energy is Mount Lawu area as indicated by surface manifestation such as hot springs. Mount Lawu, located in Karanganyar District, Central Java, and Magetan District, East Java. Mount Lawu has a manifestation of volcanic activity in the form of craters that are still fumaroles, hot springs, alteration rocks, and lava domes, Selayur. The manifestation-oriented North-South follows trending fault Sidoramping together and passing through a mountain peak Lawu. It can be analyzed using geospatial and geological data validation.

Data are obtained from a topographic map, Digital Elevation Model (DEM), geological map, and field observation. The purpose of this research is to conduct a preliminary survey in identifying potential geothermal areas in Mount Lawu, using geospatial and geological data. To identify the prospect zone of Mount Lawu geothermal area, a Digital Elevation Model (DEM) analysis and geological mapping were conducted. From the DEM analysis, lineaments were delineated to produce the Fault Fracture Density (FFD). These faults and fractures are assumed as weak planes that act as a fluid thermal movement. Field observations have been made to locate major structures, lithology distribution, and collect springs data.

The analysis showed that pattern structure straightness of alignment in the area of Mount Lawu has a straightness of West-East direction and Southeast - Northwest and based on known geological mapping that area composed lithology by mudstone units and sandstone units. The result of this shows that the area geothermal prospects slopes of Mount Lawu are at the southwest of the summit of Mount Lawu and the area of Mount Jobolarangan. This is supported by the emergence of geothermal manifestations such as hot springs at high FFD and the contact area between lava layers (impermeable), the top covered with volcanic breccia (permeable).

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1. INTRODUCTION

Geothermal energy as a renewable energy and environmentally friendly. Geothermal energy is naturally occurring energy that have been heated from the aquifers in reservoir rocks by magma (Shigeno, 1993). Indonesia is located at the intersection of the ring of fire volcanic belt, as a result Indonesia has great potential in the field of environment friendly energy such as geothermal. Indonesia has the potential for geothermal energy reaching 28,910 GW,drawn from 312 fields located across several islands, but the total installed capacity estimated at 1533.5 MW and thisshows a low utilization ratio (Pambudi A.N., 2017). Geological conditions, especially those related to geological structures, are important because geological structures influence the stability or properties of the rocks. The geological structure plays an important in the formation of fractures that forms a weakness zone produce permeability turn to permeable rocks. One of the controllers for the emergence of these manifestations is the presence of a medium for emission of manifestations or permeable zones (Hochstein & Browne, 2000). Geothermal manifestation that appear on the surface such as steam and hot spring are traversed by fault or fractures.

Geothermal manifestations on the surface occur due to heat propagation from below the surface or due to fractures that allow geothermal fuels (steam and hot springs) to flow to the surface (Saptadji, 2003; Santoso, 2007). The geological structure that has developed in the research area is west-east and northwest-southeast and a small part has a southwest-northeast and north-south direction. Identify the existence of faults through high-resolution image analysis in the form of geological lineages in the same direction as the fault planes. The geological structure that develops in the Mount Lawu area is inseparable from the influence of the development of the regional tectonic style of the island of Java. This fault is thought to control the emergence of some geothermal manifestations along the upflow and outflow zones of Mount Lawu (Kurniawan, 2020).

The geomorphological approach by performing remote sensing analysis on the calculated image of the straightness density, calculated from the lineage density pattern on the satellite image, so that we can identify the weak zones (Thannoun; 2003). All analysis of straightness patterns can show that the study area has faults and fractures as a geothermal permeable zone. Classification based on the area is calculated as the number and length of each line that is overlaid on a 1x1 km grid. This analysis is known as Fault Fracture Density (FFD) Analysis (Soengkono S., 1999; Asokawati, 2020).

Mount Lawu is a volcanic cone located on the border of Central Java and East Java Provinces. The Mount Lawu area has the appearance of geothermal manifestations such as fumaroles, hot springs, and altered rocks indicates geothermal system (Figure 1).

Figure 1. Research Locations of Mount Lawu Area (Source: Google Earth)

2. METHOD

The methodologies of this research are desk study, fieldwork, and laboratory work. Desk study consists of literature review, topographic analysis, and Digital Elevation Model (DEM) analysis. DEMs from satellite images are made by DEM Nasional (DEMNAS) produced by the Indonesian Geospatial Information Agency where constructed from Interferometric Synthetic Aperture Radar images (IFSAR), TerraSAR-X images and ALOS PALSAR images by adding mass-point data from stereo plotting (Geospatial Information Agency DEMNAS Info).
In order to identify the structural lineaments features from the DEM, eight shaded relief images with different sun azimuth values including 0°, 45°, 90°,135°, 180°, 225°, 270°, and 315° were generated. Shaded relief images were devided into 2 combinations, includes: the first four shaded relief images (0˚, 45˚, 90˚, dan 135˚) are overlaid to produce one image with altitude 45˚(Figure 2.a) and the second four shaded relief images (180˚, 225˚, 270˚, dan 315˚) are overlaid to produce one image with altitude 45˚ (Figure 2.b).

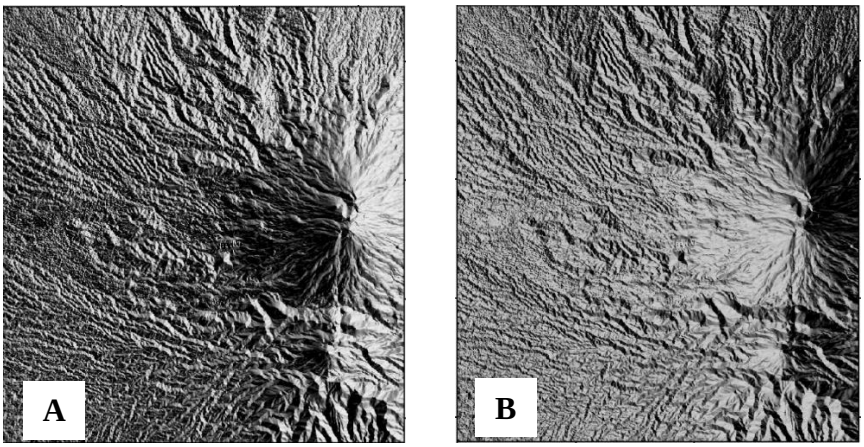

Figure 2. Combining shaded relief images a) with sun azimuth values (0˚, 45˚, 90˚, dan 135˚) and (b) with sun azimuth values (180˚, 225˚, 270˚, dan 315˚)

3. RESULT AND DISCUSSION

Morphographic, morphometric and morphogenetic classification, in general, the geomorphology of the investigation area can be grouped into four units (Figure 3) including:
Intrusion dome unit, this geomorphological unit occupies the eastern part of the investigation area which covers about 0.5% of the area of the investigation area, the slope of the slope is between 45 ° - 80 °. The river pattern is radial in shape with a narrow river valley and is in the shape of a "V". This indicates a dominant vertical erosion. This unit is in the form of a dome composed of intrusive rocks with andesitic composition. The elevation of this morphological unit ranges from 575 - 775 m above sea level (masl).
Jobolarangan Mountain volcanic unit, this geomorphological unit occupies the western, northwest, and southern part of the investigation area which covers about 43% of the investigation area. This geomorphological unit is separated into three geomorphological sub-units, the peak, body, and foot geomorphological units of Mount Jobolarangan.
Mount Lawu volcanic unit, this geomorphological unit occupies the northern, central, eastern and extends along with the Tawangmangu depression which covers about 51% of the area under investigation. This geomorphological unit is separated into three geomorphological sub-units, the peak, body, and foot geomorphological unit (Figure 3).
P lain geomorphological unit, this geomorphological unit occupies the western and northwestern parts of the study area which covers about 5.5% of the study area with a slope between 0 - 10. The river basin is wide and has a "U" shape, the slopes of the river are flat to gentle. The river is meandering, it shows the stage of erosion at an advanced stage and in some places there are sandbanks. This unit is composed of surface sedimentary rock units consisting of lava and river sediment (alluvium) which consists of loose material originating from rock fragments in the upper reaches of the river in the form of rounded, round fragments. The height of this unit ranges from 225 - 600 masl.

Figure 3. Geomorphological Photo of Mount Lawu (a) intrusion dome unit (b) Mount Jobolarangan volcanic unit (c) Mount Lawu volcanic unit (d) plain geomorphological unit (photo by; ESDM, 2009)

The results of the analysis on the DEM (digital elevation model) map show that the geological structure in the study area is dominated by normal fault structures. Faults in the study area are west-east and north-south. The faults are thought to ease the discharge of many hot springs at the study area. From the straightness of the valley and ridge and the calculation results of the Fault Fracture Density (FFD), it shows that the permeable zone in the study area has a low to high linemanet density value areas with low linemanet density values in the eastern and central parts of the region with a value of 8,96 to 561,38 km/km2 are currently occupying the South, Central, Northeastern, and areas with medium linemanet density, with values of 561,30-916,09 km/km2 density, while high lineament density occupies the North, Northwest, West, and East-West of the study area with a value of 916,10-1.4191,47 km/km2. The lineament trend tends to be the NW-SE direction (Figure 4)

The data structure that has developed includes; fractures, fault planes, and rock crushed zones, several fault structures were observed in the investigation area: (1) The rim of the crater at the summit of Mount Jobolarangan, which is a collapsed or collapsed area caused by a vacuum in the bowels of the earth the eruption of Mount Jobolarangan. (2) Normal faults are west-east trending and north-south trending which control the emergence of geothermal manifestations in the Mount Lawu area. In several places, these normal faults form a depression zone, the Tawangmangu depression, and the Karangpandan depression. (3) strike-slip trending southwest-northeast which intersects and cause shifts in before formed rocks and structures.

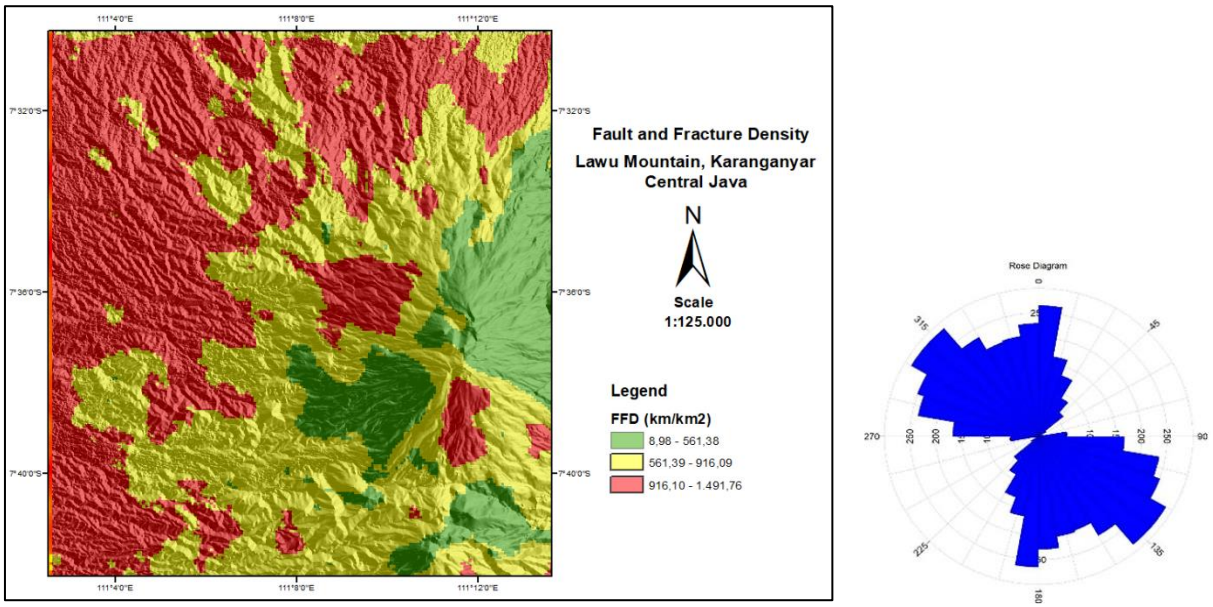

Figure 4. Fault Fracture Density (FFD) alignment map of Mount Lawu area and Roset Diagram

The spread of geothermal manifestation in the study area is in the southern part of Mount Lawu, there are manifestations such as; fumarole, hot springs, and alteration rock. Meanwhile, in the western part of Mount Lawu, there are hot springs with low temperatures. The appearance of manifestation in this area is controlled by normal faults that are west-east and north-south trending. From a geological analysis, the Mount Lawu area is very enticing because it is

associated with a volcanic activity that is 0.2 ± 0.1 million years old or during the Pleistocene Period (ESDM, 2000).

The geothermal manifestations in the Mount Lawu area consist of fumaroles, hot springs, and alteration rocks. The location of the manifestation is; Fumarol Candradimuka, which is located on the southern slope of Mount Lawu at coordinates UTM X = 520889 mT and Y = 9155657 mU, elevation 2540 masl. The fumaroles have a temperature of 93.1°C, air temperature 16.8-46°C, sulfur sublimation, alteration and hot water temperature of 94°C, air temperature 16.5°C, pH 1.35 with the discharge of 10 l/s. The hot water is murky, sour, the smell of H2S is strong, makes a strong sizzling sound, and has a 6300 µS/cm electric discharge. (ESDM, 2009).

In Tasin, there is a hot spring located in the southwest of Mount Lawu at the coordinates of UTM X = 514860 mT and Y = 9149512 mU, at an elevation of 1029 masl. Hot springs appear in lava rock fractures, with hot water temperatures of 40°C, at air temperatures of 20.1°C, pH of 6.35 with a discharge of 1 l / second (Figure 5).

Figure 5. Location of Geothermal Manifestation 1, location in the southwestern part of the Mount Lawu area (ESDM, 2009)

Cumpleng hot spring resides in the west of the Mount Lawu hillside at coordinates UTM X = 510255 mT and Y = 9154038 mU, elevation 697 meters above sea level. The hot spring has a temperature of 37.4 °C at an air temperature of 26.6 °C, a pH of 6.32 with a discharge of 4 l/s. Bayanan hot spring resides in the northwest foothills of Mount Lawu, at coordinates UTM X = 513553 mT and Y = 9169819 mU, at an elevation of 297 meters above sea level, a hot spring with a temperature of 39.8 °C, at an air temperature of 31.5°C, pH 6.57 with a discharge of 2 seconds.

The formation of Mount Lawu geothermal system is estimated to be related to the volcanic activity of the youngest Mount Lawu which still has residual heat from the magma chamber. The residual heat acts as a heat source that heats the subsurface water which then rises through the fracture and is trapped in the geothermal reservoir. Mount Lawu, which is located in a volcanic rock environment is controlled by geological structures (joints and faults). Interpretation of the correlation results of zones that have a geothermal system is subject to geological structures that cause the deformation of geothermal reservoir rocks. This is indicated by the formation of a morphographic line in the research area. The deformed rock is traversed by geothermal fluids that cause it to transform (altered) due to a high temperature (Figure 6).

Rocks that undergo the alteration process lose their magnetic properties due to the high temperature received. Thus, it develops and makes.

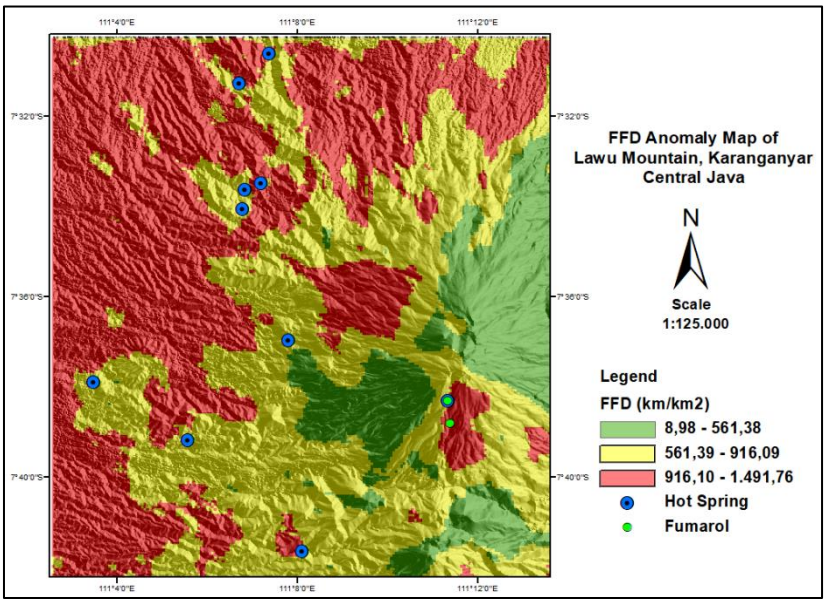

Figure 6. Map of Fault Fracture Density (FFD) Anomaly as well as the distribution of surface geothermal manifestations in the area of Mount Lawu and its surroundings.

Some meteoric water interacts with magmatic fluid and volcanic gases from the magma body and occurs a heat rush that produces hot fluid. The hot fluid formed is then accumulated into a stratum of a reservoir that is permeable. The reservoir stratum is located on the volcanic rocks of Mount Jobolarangan and Mount Lawu on claystone units that are rich in fractures. The interaction between the hot fluid stored in the reservoir and the rocks above it (surrounding) produces impermeable rocks (cap rock). This rock is the cause of the movement of hot fluids found in the reservoir stratum is prevented to the surface. This cap rock is thought to be located on the volcanic rocks of Mount Lawu that have been altered.

4. CONCLUSION

The calculation result of Fault Fracture Density (FFD), shows the area of permeable zone in the research area has a low to high density value. The emergence of manifestations of hot springs and fumaroles in the mount Lawu coincides with fair to high lineament density ranges from 916,10 to 1.4191,47 km/km^2. The other hot springs which have lineament density ranging from 561,30-916,09 km/km^2. It is thought that the area most influenced by geological structures is the emergence of the development of geothermal surfaces; this is supported by the development of morphology complex in the area of Mount Lawu.

The geothermal system in Mount Lawu is formed by the heat from the residual heat (magma chamber) that arises from the last volcanic activity of Mount Lawu that forms the lava body of Mount Lawu, that appears on the top of Mount Lawu. The residual heat from the volcanic body

of Mount Lawu supports the activity of geothermal systems that form the reservoirs in the geothermal area of Mount Lawu. The geothermal system of the Mount Lawu area is a type of volcanic system volcano complex. The temperature is estimated to be around 250°C which is related to the geothermal reservoir in the Mount Lawu area that includes high temperature. Upflow zone of Mount Lawu is around the manifestation of fumaroles and hot water crater Candradika. The Intensity of geothermal energy in the Mount Lawu area amounted to approximately 325 MWe, allowing it to be used as a power plant and direct use, with consideration of the opportunities and obstacles of development in the area.

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Denny Lumban Raja received his Doctoral degree from Postgraduate program of Geological Engineering at Padjadjaran University. He is a lecturer and Head of Metallurgical Technology at the Bandung Polytechnic of Energy and Mining and his research focuses on Geographic Information System (GIS), Remote Sensing, UAV for aaplied geomorphology and erosion.

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