IDENTIFICATION OF KAWI-SONGGORITI GEOTHERMAL PROSPECTS BASED ON FAULT AND FRACTURE DENSITY (FFD)

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ABSTRACT

This research aimed to identify the surface structures of geothermal area in Kawi-Songgoriti based on lineament density and surface manifestation. The lineaments can be extracted from digital elevation model (DEM) via PCI Geomatica and Arcgis. The surface structures were analyzed through the density of lineaments on the surface using FFD method. It is assumed that the lineaments are associated with fractures or faults found in geothermal areas. Those fractures are generally covered by surface manifestations which are hard to identify. These faults and fractures are assumed to be weak lines that act as fluid thermal movement, thereby they can indicate the location of permeable area or a reservoir. As a result, the high lineament density in Kawi assumed to be the control of Songgoriti manifestation.

Keywords: *FFD, geothermal, lineament, DEM, Kawi, Songgoriti*

1. INTRODUCTION

The research area is situated in Kawi-Songgoriti geothermal prospect area. Morphologically, the research site is located in mountainous area in the form of steep slopes, wide to narrow and deep valleys. The steep morphology resulted in limited field data acquisition so that satellite imagery analyses would prove to be more effective for preliminary study prior to field data collection. Remote sensing through satellite images has been widely used in geothermal exploration, especially in preliminary studies to determine lineament patterns and studies of volcanic bodies using DEM (digital elevation map) images. ((Iqbal and Juliarka, 2019).

Lineaments are one of the most important properties indicating subsurface elements or structural weakness, such as faults, and are usually extracted by visual analysis of enhanced image data (Abdullah, 2012). The DEM data are the processed through relief shading that aims to improve the image data by providing a 3-dimensional effect. This method provides topographic map in natural and aesthetical manner (Alhirmizy, 2013) . The Fault and Fracture Density (FFD) method is a development of geospatial analysis that can be used to determine the condition of the macro structure (Yanis *et al.*, 2019). FFD method is based on the calculation of the lineation of density pattern in the satellite image which is assumed to be a weak zone. The weak zone may be a topographic expression of faults, joints or other line weakness. Moreover, the lineaments may have a geomorphological expressions, i.e terraces, cliffs, ridges (Thannoun, 2013).

Additionally, the weak zone can indicate a thermal fluid flow path that leads one to speculate that it is the location of a steam reservoir or reservoir zone (Bujung *et al.*, 2011). Thermal fluids can flow mainly through fractures and fault zones that interact with the surrounding rock and exhibit lineament patterns. Fractures and faults that develop around intrusion bodies are potentially permeable zones that can act as pathways for thermal fluids to flow from reservoirs at depth to shallower levels (Suryantini and Wibowo, 2010). Studying fault patterns and fracture zones, can guide on to indications of productive areas in a geothermal reservoir.

Songgoriti geothermal system is formed by the Kawi-Butak Volcano Complex (Figure 1). Physiographycally, the research area is situated in the Solo-Volcano Quaternary East Java Lane which is flanked by the Kendeng

Lane in the north and the Southern Mountains Lane in the south. The southern mountain range includes a series of mountains, hills, and plains that stretch from west to east and are occupied mostly by sedimentary, carbonate, pyroclastic, and igneous rocks (Santosa and Atmawinata, 1992). The Songgoriti - Kawi geothermal system is recognized by the presence of hot springs in the Songgoriti Pesanggrahan area which is a reflection of dilute chlorite water (Bumi and EBTKE, 2017).

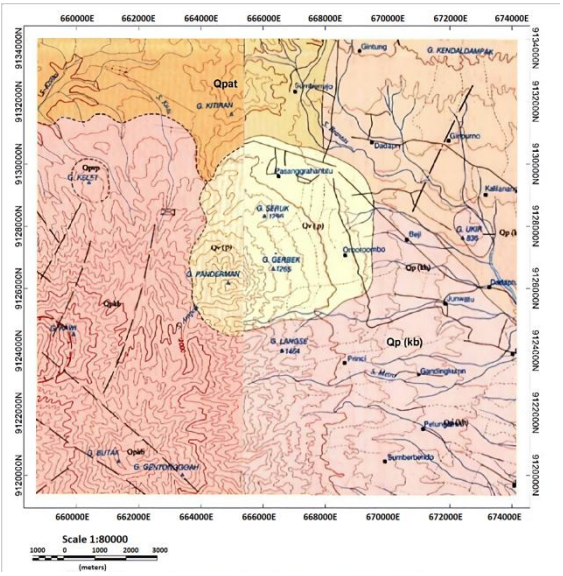

Figure 1. Geological map of the research area (Triharto, 2018)

2. METHODS

The data utilized in this research are taken from National elevation map (DEMNAS) downloadable at http://tides.big.go.id/DEMNAS/. DEMNAS can provide a detailed morphological picture of lineaments in the study area. DEMNAS spatial resolution is 0.27-arcsecond, including IFSAR data (5m resolution), TERRASAR-X (5m resolution) and ALOS PALSAR (11.25m resolution), stereo-plotting masspoint data and vertical datum using EGM2008 (Iqbal and Juliarka, 2019). Next, the shaded relief was made and the lineament was extracted to obtain the FFD map using PCI Geomatica and Arcgis software and the dominant direction was determined based on the rose diagram using Rockworks software.

2.1. SHADED RELIEF MAKING

Eight shaded relief images were generated with the solar elevation of 30^0. The four shaded relief images were created with four contrasting illumination directions 0°,45°,90°, 135°,180°,225°,270°, 315° (Figure 2). Figure 3 is an overlay performed on the shaded relief at angles of 0°,45°, 90° and 135° to combine various lighting angles to find one multi-exposure. Likewise, shaded reliefs at angles of 180°, 225°, 270°, and 315° are combined into one shaded relief (Muhammad and Awdal, 2012).

2.2. LINEAMENT EXTRECTION

The extraction was done semi-automatically on multi-light shaded relief using PCI Geomatica 2016 software LINE algorithm. The extraction parameters have been briefly described by Thannoun (2013)

a. RADI (*Filter radius*) : This parameter defines the edge of the filter radius (in pixels) which determines the level of image detail to be detected.

b. GTHR (*Gradient threshold*) : The minimum gradient level threshold of a pixel edge to obtain a binary image.

c. LTHR (*Length threshold*) : The minimum length of a curve (in pixels) that is considered an advanced straightness (for example, as a straight line connected to another curve).

d. FTHR (*Line fitting error threshold*) : The maximum error (in pixels) allowed in a polyline. Lower FTHR values give better segments,and shorter polylines.

e. ATHR (*Angular difference threshold*) : The maximum angle (in degrees) between polyline segments that is allowed or also the maximum angle limit between two vectors to be connected.

f. DTHR (*Linking distance threshold*) : The minimum distance (in pixels) between the endpoints of two vectors to connect.

The parameters used are modifications of the PCI Geomatica standard parameters by adjusting the geological conditions of the research area. The parameters used are shown in table 1

Table 1. Lineament parameter input values in PCI Geomatica 2016 software

Parameters	Value
RADI	15
GTHR	60
LTHR	15
FTHR	3
ATHR	30
DTHR	10

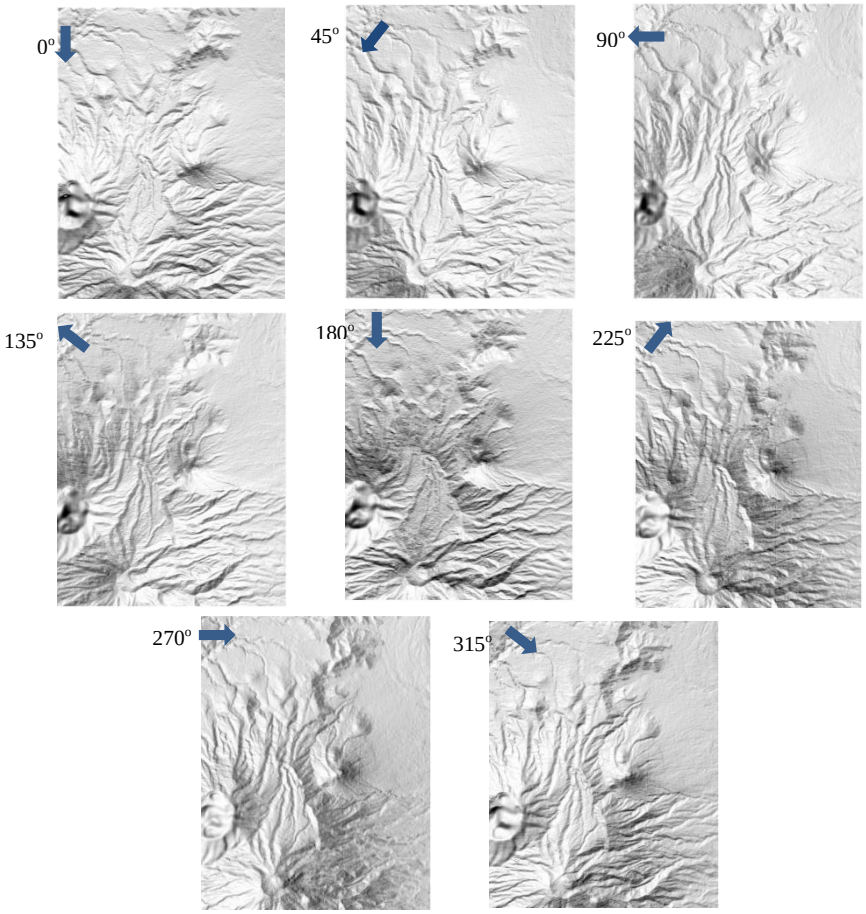

Figure 2. Shaded relief image generated from DEM with azimuth of 0°,45°,90°, 135°,180°,225°,270°, 315° and altitude of 30^0.

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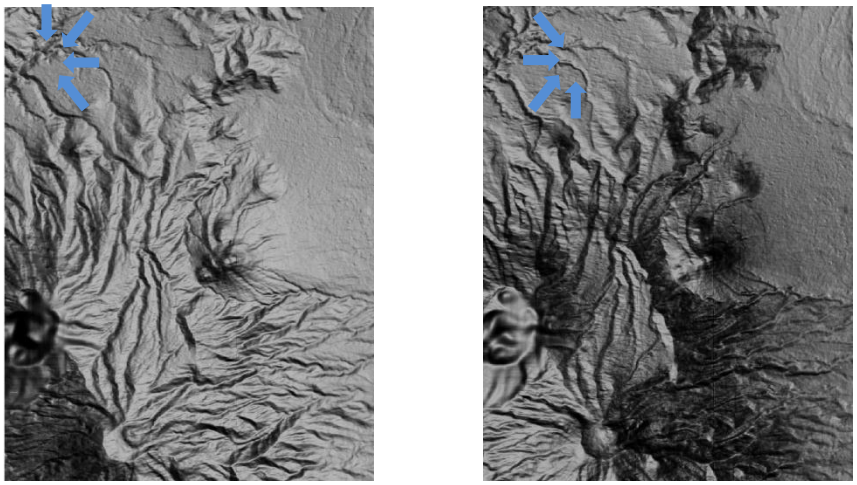

A B

Figure 3. Shaded relief image created by combining various images

A : Combination of shaded relief images with sun angles of 0°,45°,90°, 135°.

B : Combination of shaded relief images with sun angles of 180°,225°,270°, 315°.

3. RESULTS AND DISCUSSION

The results of the lineament extraction (Figure 4a & Figure 4b) obtained lineaments associated with the structures found in the study area which are a reflection of the topography in the form of streamlines, valleys, fault and fracture structures, rock contacts and the appearance of geothermal manifestations. There are 4 straight trends with different dominant directions. The results of the lineament trend in the western area of the research direction are in accordance with the presence of the main structure that is the graben zone formed at the intersection of the Srandil Nomal Fault - Pitrang Normal Fault - Normal Fault. While the results of the lineaments trend in the eastern area of Mount Buthak are suspected to be faults that are developing in the study area. There is also a difference between the lineaments trend in area C for eastern (0^0-135^0) and western (180^0-315^0) sun azimuth (Figure 4b) depicts the rose diagram for area C which has a dominant direction that is the opposite of the main structure, it is suspected to be a joint or minor structure. Analysis shows that the main structure in the study area is seen in the direction of the west sun azimuth so that it controls the direction of the lineament trend.

Based on the results of the linear density calculation using the FFD method, the density value of Kawi-Songgoriti Geothermal area can generally be grouped into 3 classes of density : high density (5.0-8.6 m.unit/km^2) which is indicated by the red color, medium density (2.5-5.0 m.unit/km^2) which is indicated by the yellow color and low density (< 2.5 m.unit/km^2) which is indicated by the green color (Figure 5a and Figure 5b). The dominant low density is in Junrejo, Oro-oro ombo, and Sisi areas, the medium density is scattered in various locations, while the high density is dominant in the area of the Kawi-butak mountain complex. Based on these topographical conditions, the intersection of the Coban Menteng Normal Fault and the Srandil Normal Fault forms a triangular graben zone located to the north of the peak of Mount Butak (Bumi and EBTKE, 2017).

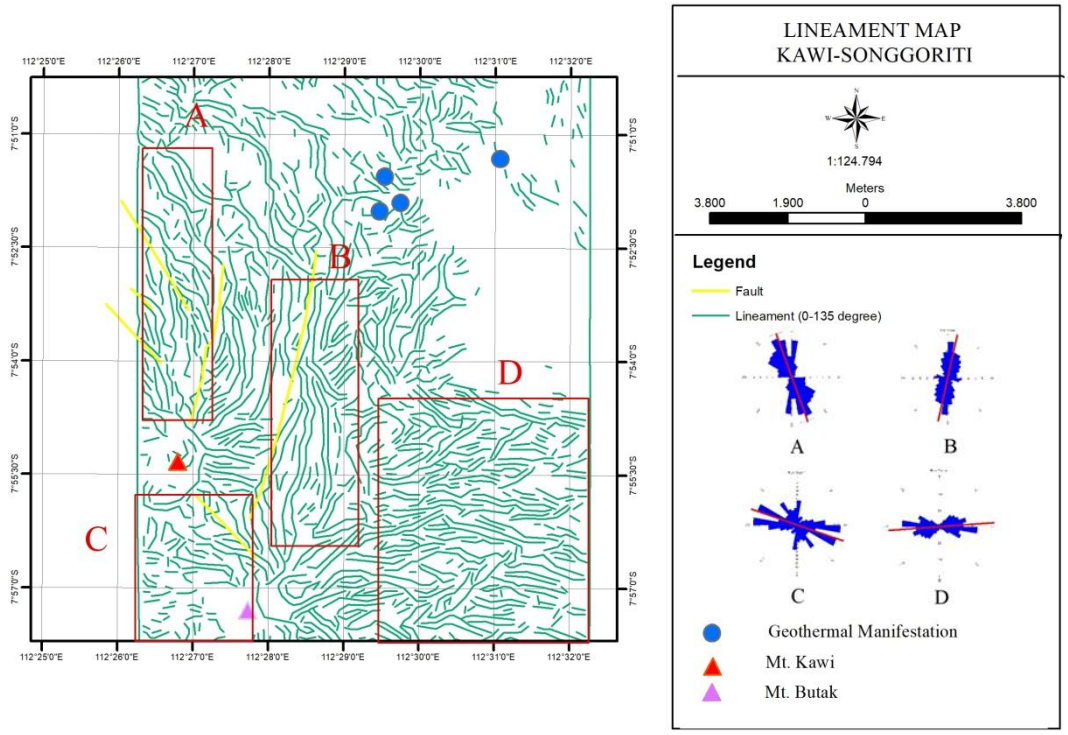

Figure 4a. The results of the extraction of lineament shaded relief with sun angles of 0°,45°,90°, 135°

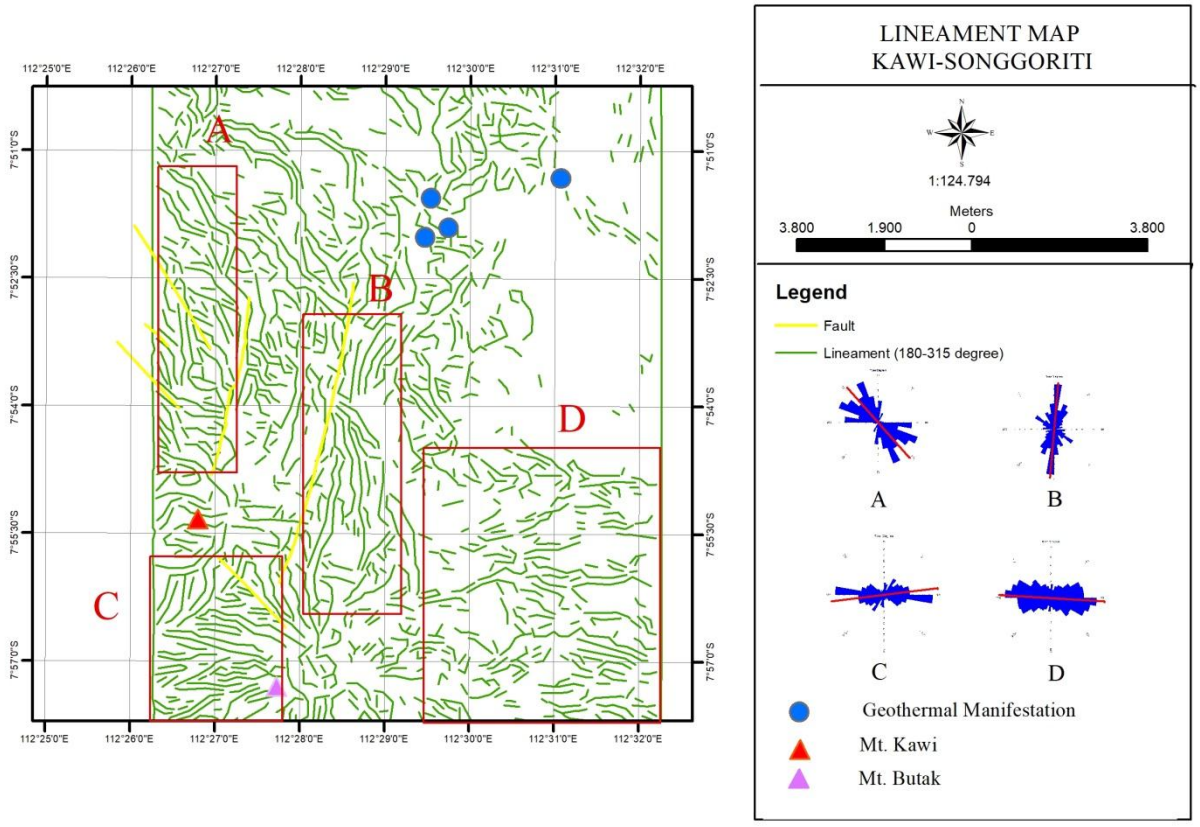

Figure 4b. The results of the extraction of lineament shaded relief with sun angles 180°, 225°, 270°, 315°

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Based on rose diagrams, the results of the straightness trend in the east and west lineament map areas generally correspond to the presence of the main structure, the Srandil Nomal Fault and Pitrang Normal Fault. However, the results of the straightness trend in area C for western irradiation have a dominant direction that is opposite the main structure, it is suspected to be the minor structure of the main structure in the study area appearing in the direction of western irradiation so that it controls the direction of the lineament trend.

FFD can also provide information on density anomalies of faults and faults to predict recharge and discharge areas (Yanis *et al.*, 2019). The graben zone in the northeast of the Kawi-Butak Volcano complex is thought to be the main area that maintains the continuity of the meteoric water supply into the geothermal system to support the Songgoriti geothermal energy conservation system (Bumi and EBTKE, 2017). The area is thought to be a recharge area from the emergence of the Songgoriti manifestation.

Based on the FFD map, it is estimated that the high lineament density in mount Kawi is the controller of the manifestations found in Songgoriti. Other locations that have high lineament densities are around the slopes of Mount Buthak. While no geothermal manifestations are found, it is estimated that the faults and fractures in this area are hydrological paths from lava flows and lahars.

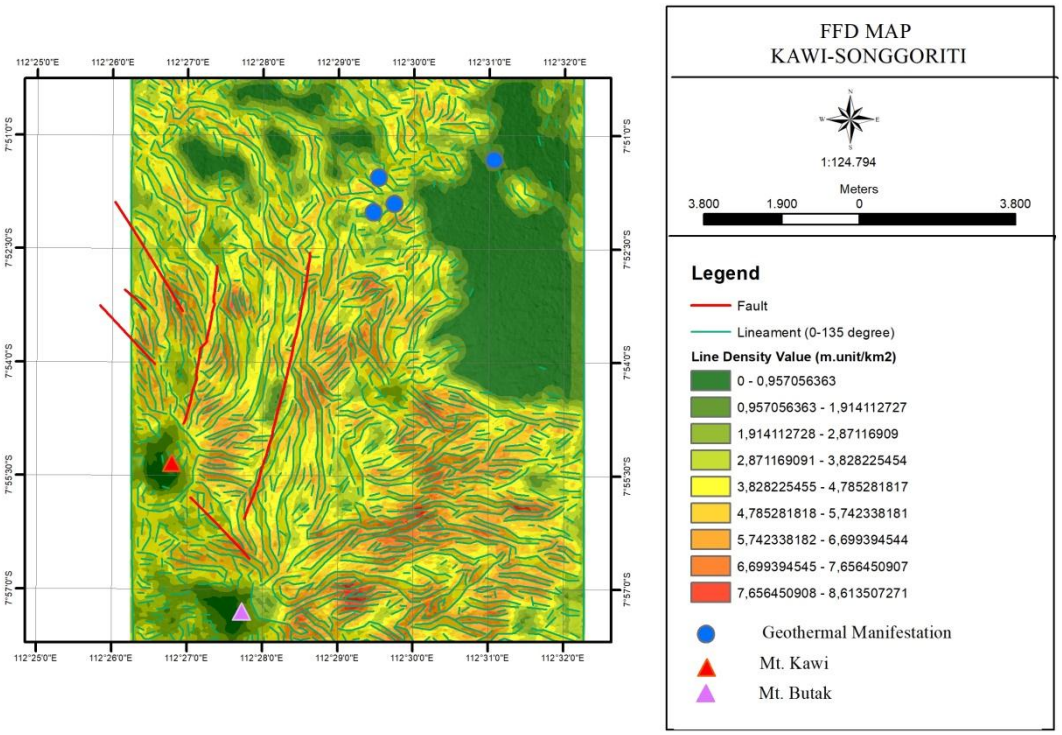

Figure 5a. FFD map sun angle 0°, 45°, 90°, 135°

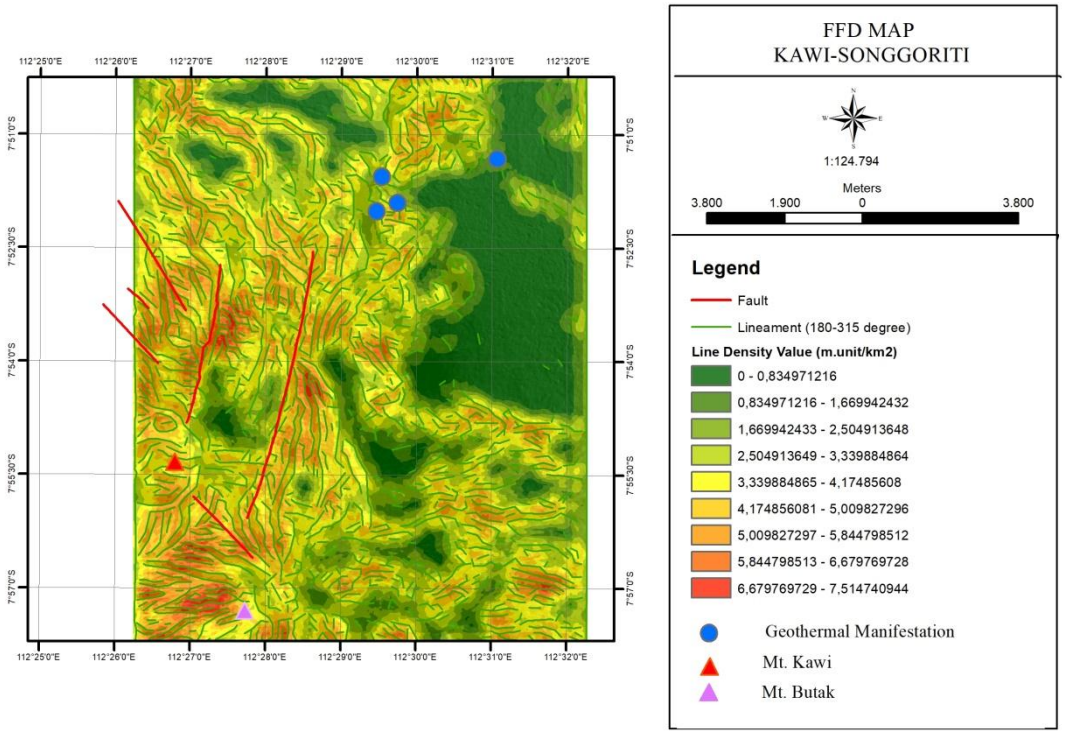

Figure 5b. FFD map sun angle 180°, 225°,270°, 315°

5. CONCLUSION

Based on rose diagrams, the results of the straightness trend in the east and west lineament map areas generally correspond to the presence of the main structure . There are areas of low density value (< 2.5 m.unit/km^2) dominantly located in Junrejo, Oro-oro ombo, and Sisi areas, medium density (2.5-5.0 m.unit/km^2) scattered in various locations, while the dominant high density (5.0-8.6 m.unit/km^2) is in the area of the Kawi-butak mountain complex. It is estimated that mount Kawi is the controller of the manifestations found in Songgoriti.

Suggestion :

It is necessary to prove that areas with high density value in mount Butak are associated with high geological structures in the field.

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