IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 7, Issue 5 Ser. II (Sep. – Oct. 2019), PP 01-08
www.iosrjournals.org

Preliminary Study of SRTM Dem Data in Kelud, Kasinan-Songgoriti, and Arjuno-Welirang, East Java, Indonesia

Novita Wahyuningsih [1], Sukir Maryanto [2*], Wiyono [3]
[1]*Master Student of Physics, Faculty of Mathematics and Sciences, Universitas Brawijaya, Malang 65145, East Java Province, Indonesia*
[2]*Brawijaya Volcano and Geothermal Research Center, Universitas Brawijaya, Malang 65145, East Java Province, Indonesia*
[3]*Department of Physics, Faculty of Mathematics and Sciences, Universitas Brawijaya, Malang 65145, East Java Province, Indonesia*

Abstract: *The present research aims to identify the geological structure of Kelud, Kasinan-Songgoriti, and Arjuno-Welirang, East Java Province based on remote sensing data, i.e. SRTM DEM (Shuttle Radar Topography Mission and Digital Elevation Model) data. The results of the SRTM DEM analysis revealed the pattern of lineament related to faults and fractures as a path of thermal fluid displacement. Lineament interpretation from SRTM DEM data was based on FFD (Fault and Fracture Density) map. The regions included in the classification of the most dominant line structures were Kelud volcano in Kediri Regency, Kawi-Butak to Jombok-Pujon in Malang Regency, Gondang-Pacet in Mojokerto Regency, and Arjuno-Welirang volcanoes, East Java Province, Indonesia. The most dominant direction of the line structure was towards the Northwest-Southeast. The manifestation of hot springs passed by the lineament structure was in the manifestations of Cangar and Kasinan-Songgoriti geothermal manifestations in Batu City, as well as the manifestation of Padusan geothermal manifestation in Pacet District, Mojokerto Regency, East Java Province, Indonesia.*

Keywords: *Geological structure, lineament, SRTM DEM, Fault and Fracture Density, manifestations*

Date of Submission: 07-10-2019 Date of acceptance: 23-10-2019

I. Introduction

An analysis of the geological structure of a volcano is an important parameter to know before carrying out the natural resource utilization in research area [1]. Geological structures such as fractures and fractures are important factors in the emergence of a geothermal manifestation since the faults and fractures or other discontinuity structures become weak zones as a path of thermal fluid displacement [2]. Initial analysis of the geological structure of a volcano can be conducted using remote sensing data, i.e. SRTM DEM data. Interpretation of SRTM DEM data is performed to obtain lineament density or FFD maps. Interpretation of lineament structure is analogous to the faults and fractures which becomes one of the factors in geothermal manifestations. The research area includes geothermal manifestation in the Kelud, Kasinan-Songgoriti, and Arjuno-Welirang of East Java Province, Indonesia (Fig. 1).

Most of the manifestations of geothermal energy is associated with volcanic lines [3]. Volcano hosted geothermal or volcanic geothermal system is dominating the geothermal system in Indonesia [4]. Kelud, Kasinan-Songgoriti, and Arjuno-Welirang geothermal systems were known based on the presence of manifestations in this areas.It was found the fumaroles in Kelud volcano. It was also found the manifestations of hot springs in Kasinan-Songgoriti geothermal manifestations. The Arjuno-Welirang volcanoes is one of the areas that has a potential energy of geothermal in East Java [5]. Arjuno-Welirang is an active volcano, located in Batu City, Malang Regency, Mojokerto Regency, and Pasuruan Regency, East Java Province [6]. In the Arjuno-Welirang volcanoes, the manifestations of hot springs, fumaroles and solfatara were found. The source of hot springs in Arjuno-Welirang volcanoes was thought to originate from under the cone of Mount Arjuno-Welirang. The manifestations of fumaroles and solfatara appear around the peak of Mount Welirang [7]. The source of hot springs in Arjuno-Welirang volcanoes include Cangar hot springs, Kasinan hot springs, Songgoriti hot springs in Batu City, and Padusan in Mojokerto Regency [8]. Kasinan-Songgoriti-Cangar geothermal potential areas are associated with Arjuno-Welirang complex, Kelud volcano, and Mount Kawi complex [9].

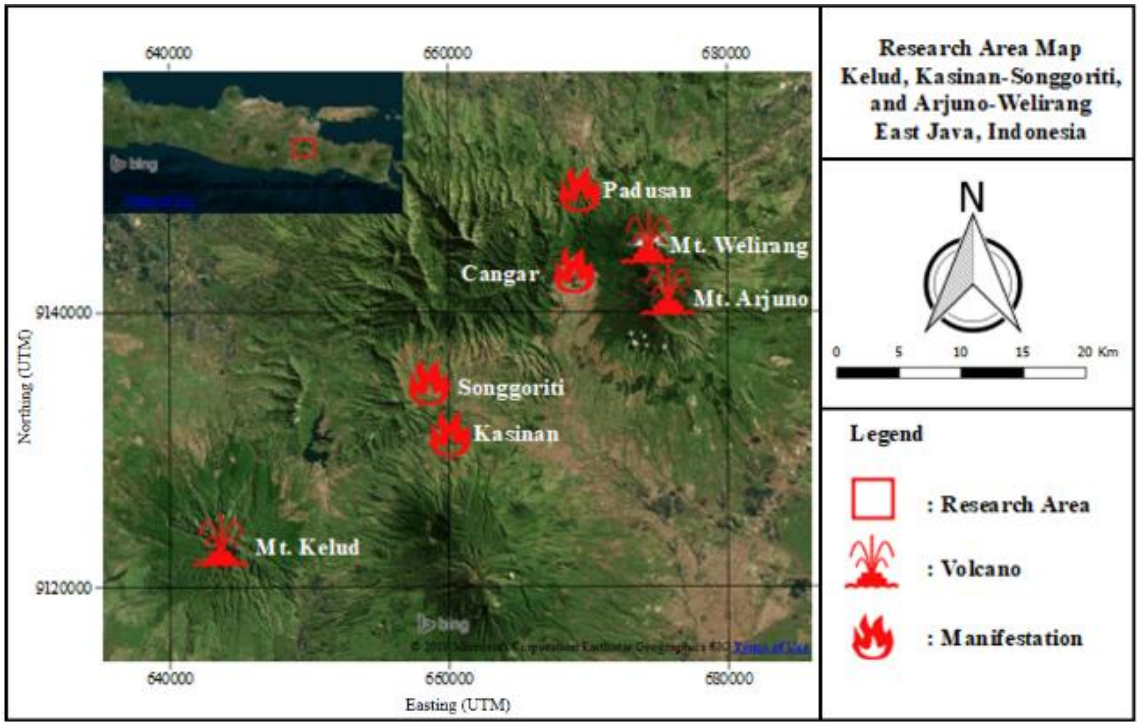

Figure 1: Research area map

The nature of Kelud's morphology is irregular due to explosive eruptions and followed by the formation of lava domes [10]. The peaks morphology of Kelud volcano was steep, irregular sharp, and there was a lake crater. Type of Kelud volcano is stratovolcano that has hot eruption cloud deposits, and consists of pyroclastic rocks and andesitic lava [11]. Kelud rock formations in the west volcano are young volcanic rocks and old volcanic rocks in the east volcano [12]. Kasinan-Songgoriti geothermal manifestations has upper quaternary of volcanic rock formations and is located under the foot of Mount Anjasmara Tua, Mount Panderman-Kawi-Butak, and Mount Arjuno-Welirang, which are administratively located in Batu City [13]. Arjuno-Welirang complex is categorized as the quaternary volcano, a source of heat originating from a source of magma and coming out in igneous rock formations [14].

Kelud is an active volcano located in Kediri Regency. The manifestation found in Kelud is a fumarole that appears in Kelud crater. Kelud constituent rocks are dominated by andesite, basalt, volcanic sand and lava [12]. Arjuno-Welirang is a quaternary active volcano which belongs to Arjuno-Welirang volcano complex located in East Java. Arjuno-Welirang volcano complex is a geothermal system associated with volcanic system and has steep terrain [15].

Geothermal manifestations in the form of Kasinan and Songgoriti hot springs are surrounded by Mount Arjuno-Welirang, Mount Kawi-Butak, and Mount Anjasmara Tua which control Kasinan-Songgoriti's source of geothermal [13]. The manifestation of Cangar hot springs is under the foot of an active volcano, i.e. Mount Arjuno-Welirang. Its activity produces some products that can be distinguished in units, such as lava eruption unit of Welirang 1, sampling eruption, pyroclastic flow of Kembar 1, and Anjasmara products [16]. The manifestations of Cangar and Padusan hot springs are at the foot of Mount Arjuno-Welirang, where the Cangar fault is the main controlling factor of Cangar hot springs, and the Padusan faults become the main controller of the Padusan hot springs in Mojokerto [8].

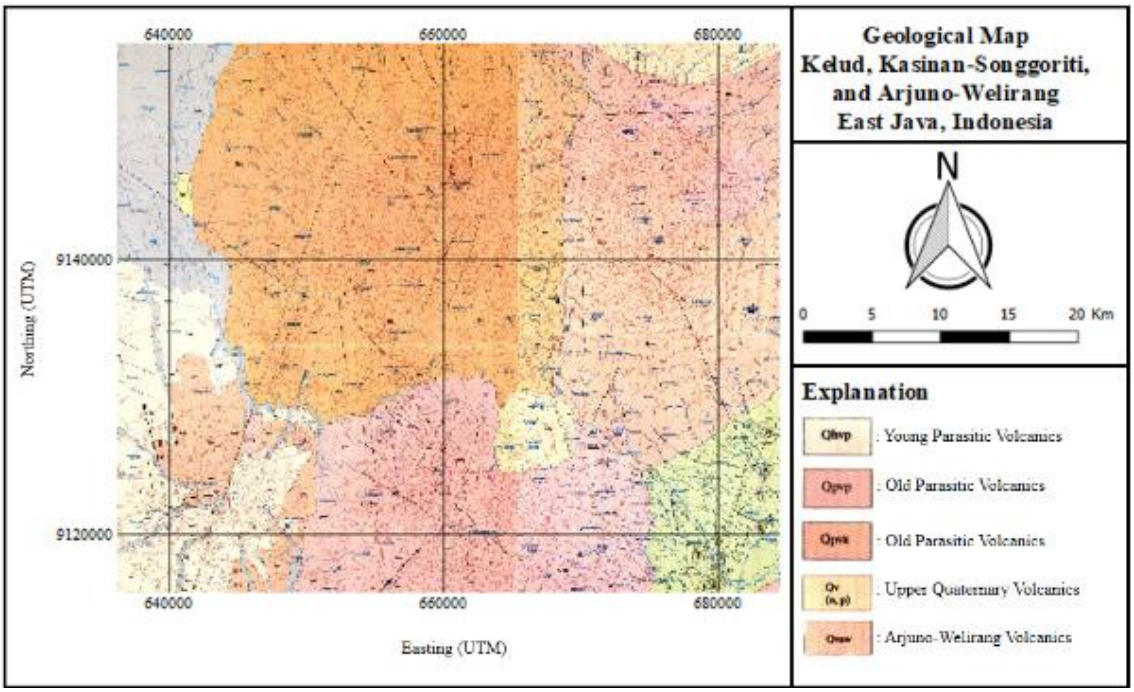

Figure 2: Geological map of research area

The initial stage in the development of natural resources such as geothermal potential was a preliminary survey. One of the preliminary surveys was carried out by identifying the lineament structure of geothermal volcano using both DEM and SRTM data. The identification of lineament structure was carried out by making lineament density map using FFD method. The lineament structure represents the fault which is a weak zone as a path of thermal fluid displacement [2].

II. Methods

The present research was conducted in geothermal volcano of Kelud, Kasinan-Songgoriti, and Arjuno-Welirang, East Java Province, Indonesia. In analyzing the structure of straightness, the SRTM DEM data were obtained from USGS (United States Geological Survey) page. Interpretation of the SRTM DEM was associated with faults in the research area that became a weak zone of thermal fluid displacement resulting in geothermal manifestations on the surface. The interpretation was based on the lineament density or FFD maps.

The stage of SRTM DEM data processing was begun by downloading data on the USGS website. Then cropping was done in the research area. Based on the results of the cropping, conversion was then made to the shape of shading irradiation (hillshade). The process of pulling out the lineament was compared to the geological the research area map to distinguish the interpreted structure. The final result was lineament density or FFD maps. The results of lineament interpretation from the SRTM DEM data are analogous to faults and fractures [17].

The results of cropping the research area on DEM map was then converted to hillshade with different horizontal azimuth angles. The azimuth horizontal angles used in the present research were 0°(Fig. 3), 90°(Fig. 4), 180°(Fig. 5), and 270° (Fig. 6). The lineament of the results of DEM interpretation was then gridding with a size of 4 km ×4 km and it obtained the lineament density. Based on the total lineament of each grid, its density will finally be obtained.

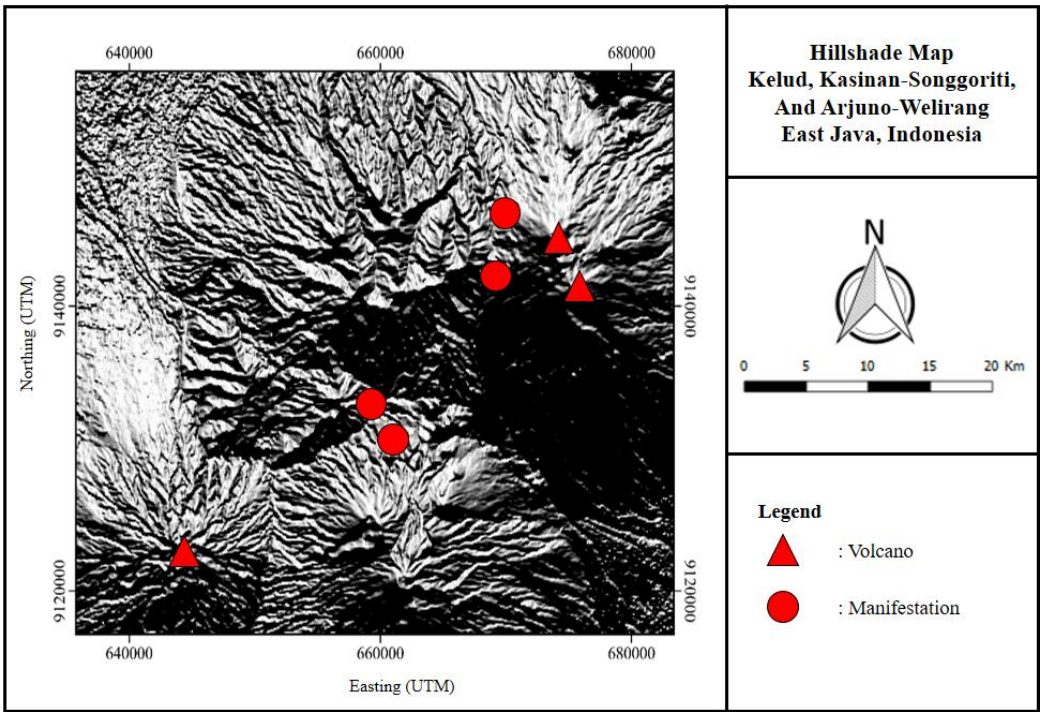

Figure 3: Hillshademap of the research areawith horizontal azimuth angles0°

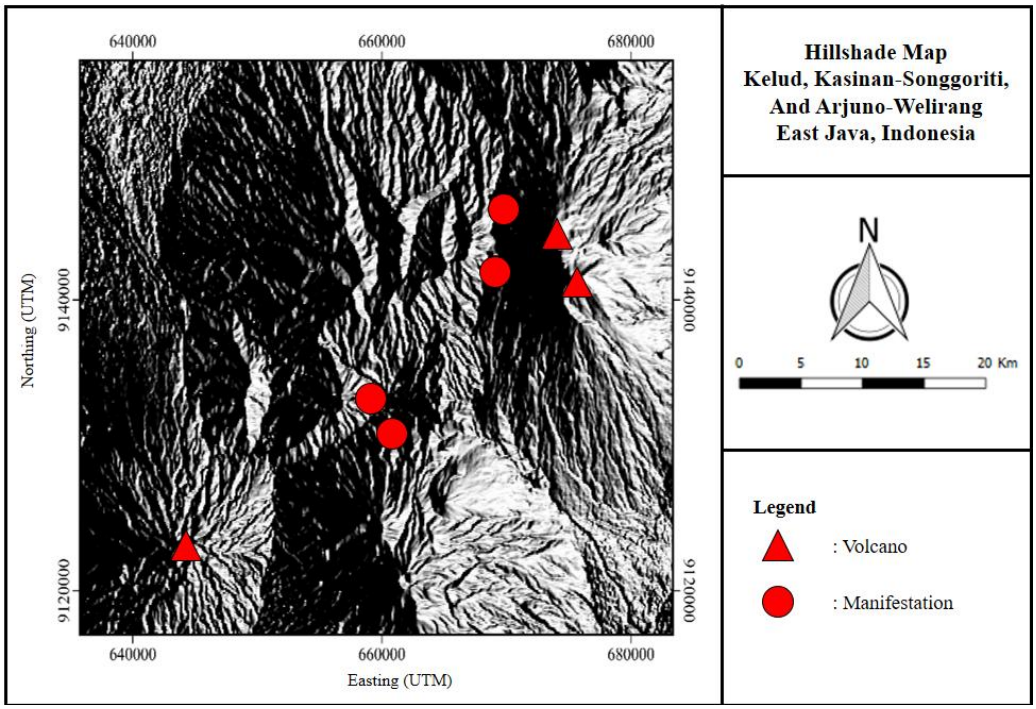

Figure 4: Hillshade map of the research areawith horizontal azimuth angles90°

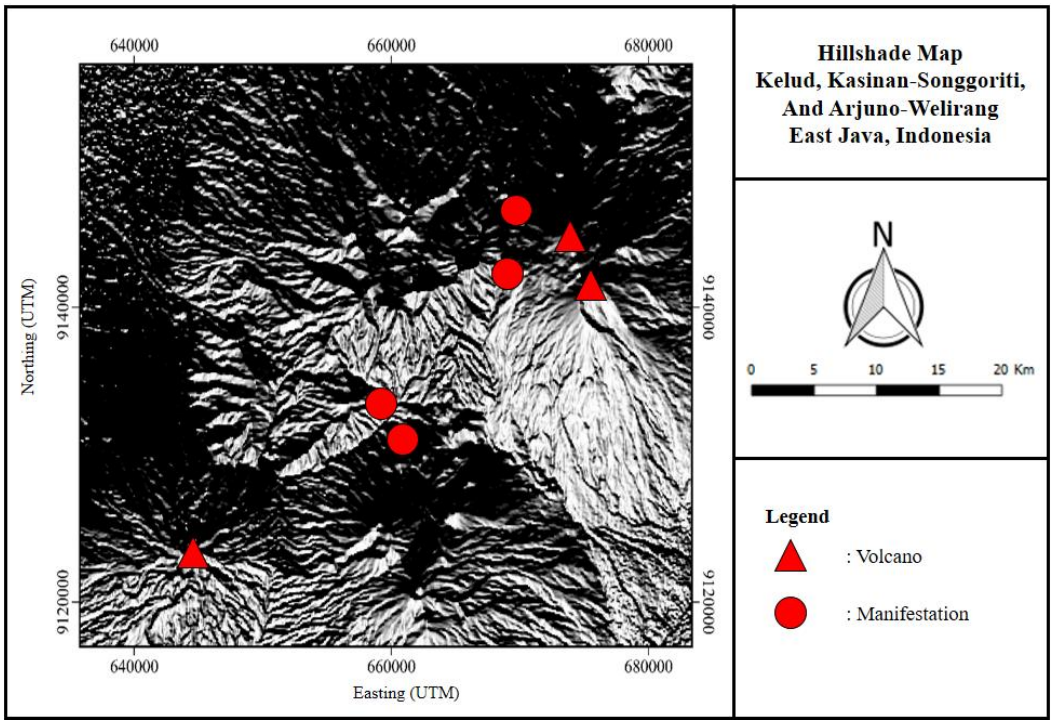

Figure 5: Hillshade map of the research areawith horizontal azimuth angles180°

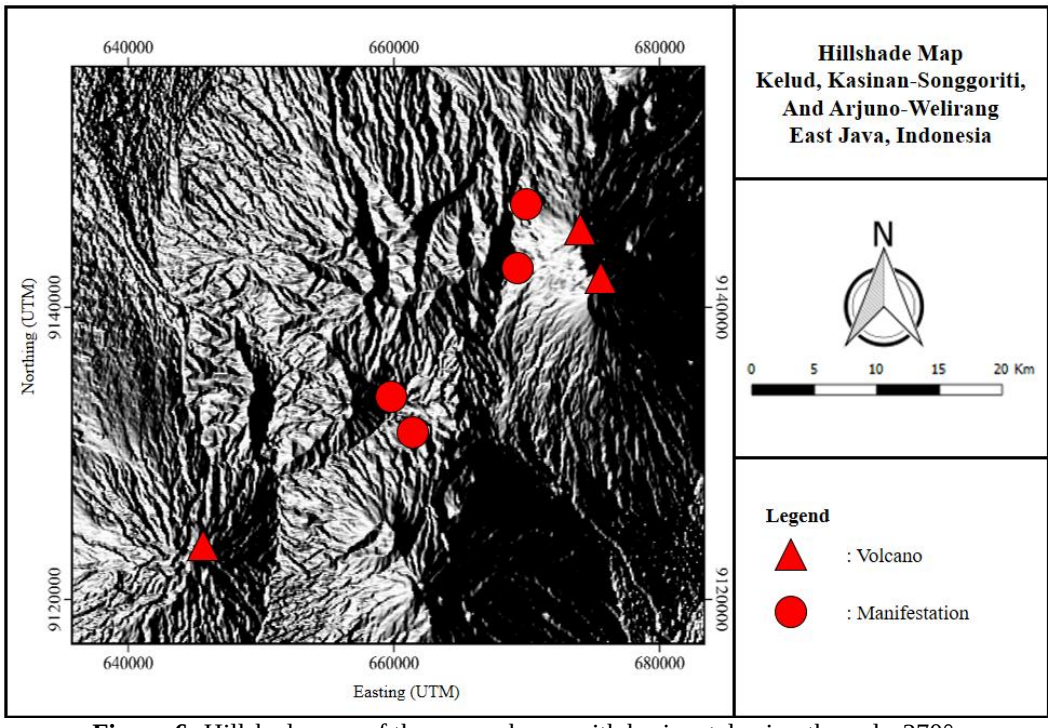

Figure 6: Hillshade map of the research areawith horizontal azimuth angles270°

III. Results and Discussion

Preliminary study of geological structures is important to do before exploring the natural resources in the research area. Geological structure analysis was carried out since the geological structures such as faults and fractures are related to the emergence of geothermal manifestations. Broken structures and fractures were weak zones of thermal fluid displacement in volcanoes where geothermal manifestations were possible. Fracture structure analysis was conducted to determine the most dominant morphological structure in the research area based on lineament density map which became the result of interpretation of SRTM DEM data.

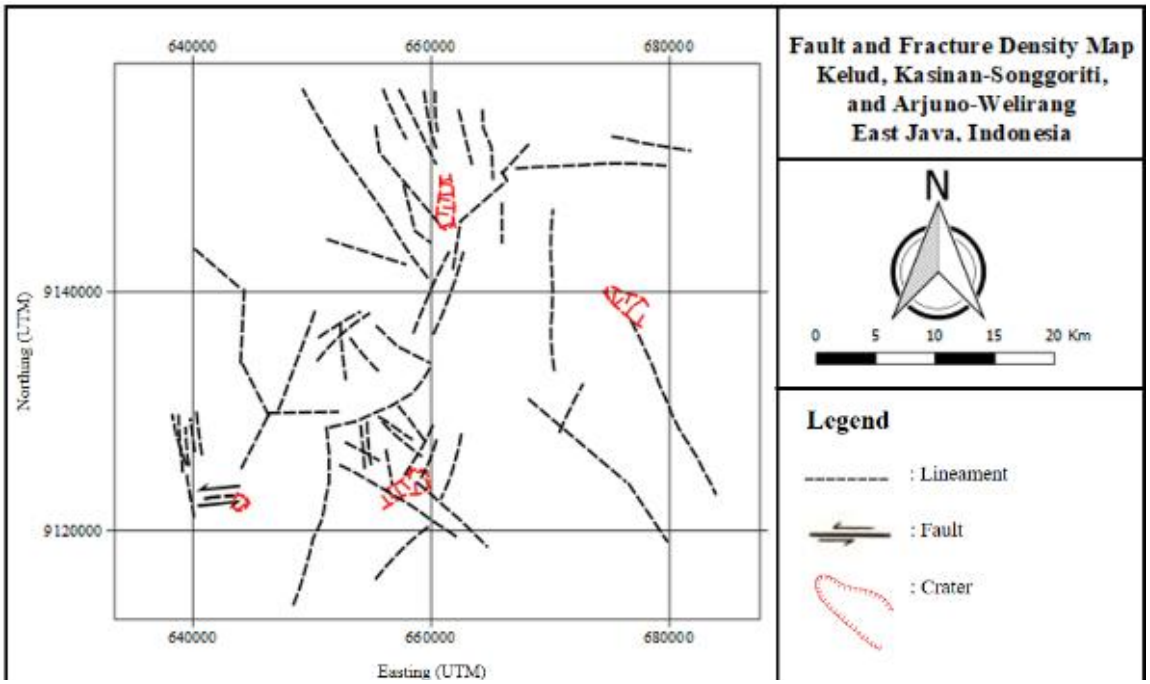

Figure7: Interpretation of lineament density map of the research area

Based on the results of geological structure mapping of Kelud, Kasinan-Songgoriti, and Arjuno-Welirang, East Java from the FFD map (Fig. 4), the lineament density values can be categorized into three classifications, i.e. low (0-6 km/16 km^2), moderate (6-10 km/16 km^2), and high (10-18 km/16 km^2). The category of lineament structure with high classification is possible because of the fracture structure which creates fractures along the fault lines. The most dominant direction of lineament is directed towards the Northwest-Southeast of the study area. The geological structure of the present research is influenced by volcanic activities from volcanoes that surround the research area.

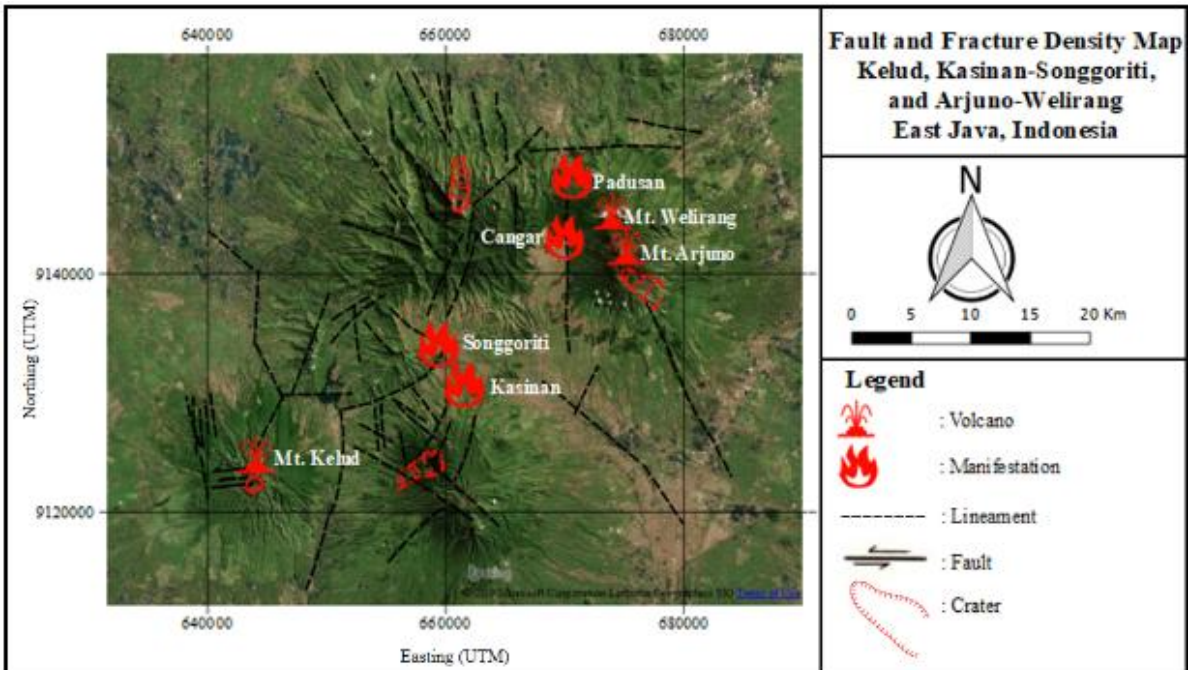

Figure 8: Lineament structure map of the research area

The results of the FFD map show the area with the most dominant lineament density values. The lineament is possible as faults or fractures which become a weak zone as the path of thermal fluid displacement. It can be said that there are several manifestations of hot springs that are indeed traversed by lineament

structure. The most dominant lineament structure is located in Kelud volcano of Kediri Regency, Kawi-Butak area to Jombok-Pujon region in Malang Regency, Gondang-Pacet in Mojokerto Regency, and Arjuno-Welirang volcanoes, East Java. There are manifestations that the lineament goes through, i.e. the manifestation of Cangar hot springs in Batu City, the manifestation of Kasinan-Songgoriti in Batu City, and the manifestation of Padusan in Mojokerto Regency.

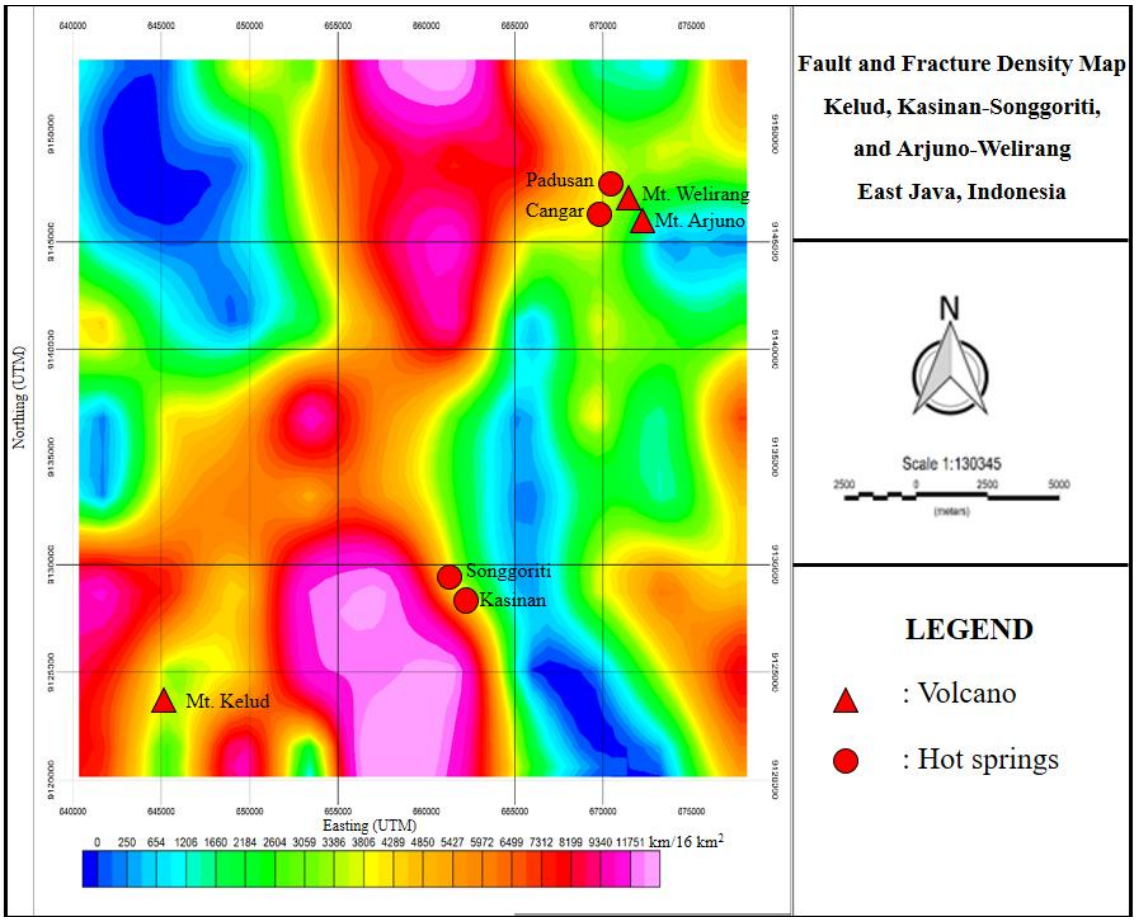

Figure9: Fault and fracture density map of the research area

FFD map can be correlated with the permeability (Fig. 9), it can be seen about zones that have high permeability. Permeability is one of the characteristics of geothermal reservoir rocks that used as parameters in geothermal exploration activities. FFD map illustrates the distribution of permeability on the surface with total length of alignment of 0-11751 km/16 km^2. Based on FFD map it can be seen zones with low permeability, moderate permeability, and high permeability. Low permeability is indicated by total length of lineament 0-2604 km/16 km^2. Moderate permeability zone is indicated by by total length of lineament 3059-5972 km/16 km^2. High permeability zone is indicated by by total length of lineament 6499-11751 km/16 km^2. Theoretically, the zone that have high permeability indicate a geothermal reservoir zone. High permeability means that the rocks have a high ability to pass heat from inside of the earth to the surface.

IV. Conclusion

The morphological structure of Kelud, Kasinan-Songgoriti, and Arjuno-Welirang can be revealed according to the results of the interpretation of SRTM DEM data which has the dominant direction in the North-West. The area with the most dominant structure are Kelud in Kediri Regency, Kawi-Butak to Jombok-Pujon in Malang Regency, Gondang-Pacet in Mojokerto Regency, and Arjuno-Welirang, East Java Province. The manifestation of hot springs that the lineament goes through is in the geothermal manifestations of Cangar, Kasinan-Songgoriti in Batu City and Padusan in Pacet District, Mojokerto Regency, East Java Province, Indonesia.

Acknowledgements

The authors deliver their gratitude to Brawijaya Volcano and Geothermal Research Center (BRAVO GRC) of Universitas Brawijaya Malang and Hibah Penelitian Unggulan Tahun Anggaran 2019, Nomor: 697.20/UN 10.C10/PN/2019 for the fund, support, and valuable thoughts as well as the USGS that has provided the SRTM DEM data for the present research.

References

[1]. M.A. Massinai, Rusman S., Syamsuddin, *Struktur Geologi Sulawesi Barat Ditinjau dari Lineament Geomorfologi Regional*, Seminar Nasional Geofisika 2014, Makassar, September 13, 2014.

[2]. Lukmanul Hakim, Nazli Ismail, and Faisal, *Kajian Awal Penentuan Daerah Prospek Panas Bumi di Gunung Bur Ni Telong Berdasarkan Analisis Data DEM SRTM dan Citra Landsat 8*, *Journal of Rekayasa Elektrika Vol. 13, No. 3, December 2017, pp. 125-132*, DOI: 10.17529/jre.v13i3.8332, 2017.

[3]. S. Maryanto, C.N. Dewi, Vanisa Syahra, A. Rachmansyah, James H. Foster, A. Nadhir, Didik R. Santoso, *Magnetotelluric-Geochemistry Investigations of Blawan Geothermal Field, East Java, Indonesia*, *Geosciences 2017, 7, 41*. www.mdpi.com/journal/geosciences, DOI: 10.3390/geosciences7020041, 2017.

[4]. S. Maryanto, *Microseismicity of Blawan Hydrothermal Complex, Bondowoso, East Java, Indonesia*, *IOP Conference. Series: Journal of Physics: Conf. Series 997 (2018) 012019*, DOI: 10.1088/1742-6596/997/1/012019, 2018.

[5]. Rahmawati, S. Maryanto, A. Susilo, *Identifikasi Sistem Panas Bumi Daerah Cangar, Jawa Timur menggunakan Metode Magnetotellurik, Journal of Physics Sciences and Engineering. JPSE, Vol. 2, No. 2, 2017, Page 72-82, 2017*.

[6]. S. Maryanto, *Microseismicity Recorded at Cangar, Arjuno-Welirang Volcano-Hosted Geothermal Complex, Batu City, East Java, Indonesia, The 9th International Conference on Global Resource Conservation (ICGRC) and AJI from Ritsumeikan University, AIP Conference Proceedings 2019, 030017 (2018)*, DOI: https://doi.org/10.1063/1.5061870, 2018.

[7]. Ministry of Energy and Mineral Resources, Directorate of Geothermal, *Potensi Panas Bumi Indonesia Jilid 1*, Jakarta: Directorate of Geothermal, General Dorectorate of New Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources, 2017.

[8]. S. Maryanto, *Geo Techno Park Potential at Arjuno-Welirang Volcano Hosted Geothermal Volcano, Batu, East Java, Indonesia (Multi Geophysical Approach), Conference Paper in AIP Conference Proceedings November 2017, The 8th International Conference on Global Resource Conservation (ICGRC 2017) AIP Conf. Proc. 1908, 030012-1–030012-12*, DOI: https://doi.org/10.1063/1.5012712, 2017.

[9]. S. Maryanto, *Preliminary Investigation of Volcano Hosted Geothermal Area at Kasinan-Songgoriti-Cangar, Batu City, Based on Gravity-Seismic Methods, The 8th Annual Basic Science International Conference. AIP Conference Proceedings 2021, 050010 (2018)*, DOI: https://doi.org/10.1063/1.5062760, 2018.

[10]. Bagus J. Santosa, Mashuri, Wahyu T.S, A. Wafi, R. Salim, R. Armi, *Interpretasi Metode Magnetik Untuk Penentuan Struktur Bawah Permukaan di Sekitar Gunung Kelud Kabupaten Kediri*, *Jurnal Penelitian Fisika dan Aplikasinya (JPFA) Vol. 2 No. 1, June 2012. ISSN: 2087-9946, 2012*.

[11]. S. Maryanto, A. Nadhir, Didik R. Santoso, *Implementation of Town Watching and Development of Observatory for Community Education in Volcano Hazard Mitigation (Study Case at Kelud and Arjuno-Welirang Volcanoes, East Java, Indonesia), Conference Paper, June 2018*, DOI: https://doi.org/10.1145/3233347.3233349, 2018.

[12]. R. Rifaldi, Anggi Kristanto, Novita A. Ristanti, Indri Dwi Y., Ira R. Koswara, Cholisina A. Perwita, *Pendugaan Arah Aliran Hidrotermal dengan Metode Gravitasi Menggunakan Data Citra Satelit di Kawasan Gunung Kelud Kabupaten Kediri*, Proceeding Seminar Nasional Kebumian ke-10. Peran Penelitian Ilmu Kebumian dalam Pembangunan Infrastruktur di Indonesia. September 13 – 14, 2017, Grha Sabha Pramana, 2017.

[13]. Laily W. Mawarni, S. Maryanto, A. Nadhir, *Magnetic Method Used in Geothermal Reservoirs Identification in Kasinan-Songgoriti, East Java, Indonesia*, *Environmental and Earth Sciences Research Journal Vol. 5, No. 4, December, 2018, pp. 87-93*, DOI: https://doi.org/10.18280/eesrj.050402, 2018.

[14]. Untung Sumotarto, *Geothermal Energy Potential of Arjuno and Welirang Volcanoes Volcano, East Java, Indonesia*, *International Journal of Renewable Energy Research. Vol. 8, No. 1, March, 2018*.

[15]. Hari W. Utama, Agung Harijoko, and S. Husein, *Studi Vulkanisme dan Struktur Geologi untuk Eksplorasi Awal Panas Bumi di Kompleks Gunung Api Arjuno Welirang*, Proceeding, Seminar Nasional Kebumian ke-9, October 6 - 7, 2016: Grha Sabha Pramana, 2016.

[16]. S.A. Rohmah, S. Maryanto, A. Susilo, *Identifikasi Air Tanah Daerah Agrotechno Park Cangar Batu Jawa Timur Berdasarkan Metode Geolistrik Resistivitas*, *Jurnal Fisika dan Implementasinya. Volume 14, Number 1, January 2018*, DOI: http://dx.doi.org/10.12962/j24604682.v14i1.3106, 2018.

[17]. Anjar P. Azhari, S. Maryanto, A. Rachmansyah, *Identification of Geological Structure and Its Impact to Land Surface Temperature Based on Landsat 8 Data on Blawan Geothermal Field*, *Jurnal Penginderaan Jauh. Vol. 13 No. 1 June 2016 : 1-12, 2016*.

Novita Wahyuningsih. " Preliminary Study of SRTM Dem Data in Kelud, Kasinan-Songgoriti, and Arjuno-Welirang, East Java, Indonesia. "IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 7.5 (2019): 01-08.