High Permeability Zone on Geothermal Manifestations Using Fault Fracture Density in Sembalun Area, Lombok

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ABSTRACT

Geothermal manifestations can occur in zones of high permeability. Permeability zones can be analyzed through lineament density, assumed to be associated with faults and fractures which are considered as weak areas that can allow geothermal fluid to pass from reservoir to the surface. Indonesia has a geothermal potential of 23.9 GW. However, this potential has only been utilized by 8.9% or 2,139.6 MW. This study intends to determine the zone with high permeability in geothermal manifestations using Fault Fracture Density (FFD) method by modeling of surface data in the form of lineament pattern. The lineament pattern is obtained based on the appearance through DEMNAS imagery which formed by satellites imagery, including IFSAR, TERRASAR-X, and ALOS PALSAR. The lineaments pattern delineated by providing lighting from several angles, from lighting azimuths of 0°, 60°, 120°, 180°, 240° and 300° at a constant altitude of 45°. Lineament density is calculated based on the area (grid) which is divided into 1 km x 1 km in size with an area of 1 km^2 each. Total length of the lineament density on each grid is then made into a density contour which is colored from the lineament which shows the level of the permeability zone. The value of the lineament length range in the study area ranges from 1424 m - 9088 m/km^2. General direction of lineament pattern shows northeast – southwest. FFD analysis shows geothermal manifestations appear in the high permeability zone with a density value between 6001 – 9088 m/km^2 in the Sembalun area, Lombok.

Keyword: fault fracture density, permeability zone, lineament, geothermal.

INTRODUCTION

Geothermal energy is one of the renewable energy sources, which is produced and stored in the earth's core. Indonesia has a geothermal potential of 23.9 GW. However, this potential has only been utilized by 8.9% or 2,139.6 MW (Energi Baru Terbarukan dan Konservasi Energi, 2020). Geothermal energy can be a substitute for fossil energy where its use can damage the environment and its availability will continue to deplete over time. The appearance of manifestations of hot springs on the earth's surface in the form of an indication of geothermal potential in an area (Danakusumah and Suryantini, 2020). The West Nusa Tenggara area has the potential for geothermal resources. This can be proven by the presence of hot springs manifestation, precisely in Sembalun, Lombok, West Nusa Tenggara.

Geothermal manifestations can occur in high permeability zone. Permeability zone can be analyzed through lineament density, identified from the number of lineament pattern in an area. The presence of lineament is assumed to be associated with faults and fractures which are considered as weak areas that can allow fluid to pass from below to the surface (Bujung et al., 2011; Thannoun, 2013; Mardiati et al., 2020). With the presence of a high density of lineament pattern, it can be seen that there is a possible center of movement of fluid activity (Agista et al., 2014). So from this analysis, it produces a structure density zone map that becomes a reference for the location of fluid flow in the fracture.

The location of the geothermal research is in the Sembalun Geothermal Working Area (WKP Sembalun). Geographically, research area located at the coordinates between 116°28'56.651" E - 116°35'28.407" E and 8°22'4.012" S - 8°27'27.122" S with an area of 10 x 12 km^2.

Figure 1. Research Area

This study intends to determine the zone with high permeability in geothermal manifestations. To extract economical fluids, geothermal fluids requires wells in areas of high permeability to enter rocks with high porosity (Soengkono, 1999a). Zone of high permeability are often associated with rock fractures caused by geological structures. It is possible to tracing fault and fracture from

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topographic model surface data by analysis the lineament using Fault Fracture Density.

RESEARCH METHOD

Fault Fracture Density is one of the remote sensing methods to be able to determine the high permeability zone based on the level of lineament density. Factors that can form a lineament pattern are caused by geological structure, which it can be illustrate by the topography such fractures, joints, lithology contact, appearance of geothermal surface manifestation, river, ridge and valley lineament (Oktoberiman et al., 2015). The existence of this structure is an important element in geothermal exploration, because it can open a path for geothermal fluid to flow to the surface (Soengkono, 1999b). The lineament pattern is obtained based on the appearance through Digital Elevation Model National (DEMNAS) imagery. DEMNAS data was formed by IFSAR, TERRASAR-X, and ALOS PALSAR. (Badan Informasi Geospasial, 2018), it is provides a detailed morphological representation so that the delineation of the lineament can be more detail (Iqbal and Juliarka, 2019). The delineation of the lineament pattern made is obtained by providing lighting from several angles, from lighting azimuths of 0°, 60°, 120°, 180°, 240° and 300° at a constant altitude of 45°. The result of delineation the lineament pattern is known to have a general direction of northeast-southwest

In the study area, lineament density is calculated based on the area (grid). The area of each grid is divided into 1 km x 1 km with an area of 1 km^2, and also some areas may not be considered (Casas et al., 2000). The process of doing the grid division aims to find out in more detail and evenly the value of lineament density in the research area.

Each grid will be calculated from the total line length. The total length of the lineament density on each grid is then made into a density contour which is colored from the lineament which shows the level of the permeability zone.

RESULT AND DISCUSSION

1. Lineament Patten Analysis

To be able to delineation the lineament, DEMNAS imagery is processed into 3 dimensions. The processing uses ArcGIS software. The delineation of the lineament pattern is obtained by providing lighting from several angles, from lighting azimuths of 0°, 60°, 120°, 180°, 240° and 300° at a constant altitude of 45°. as shown in Figure 2.

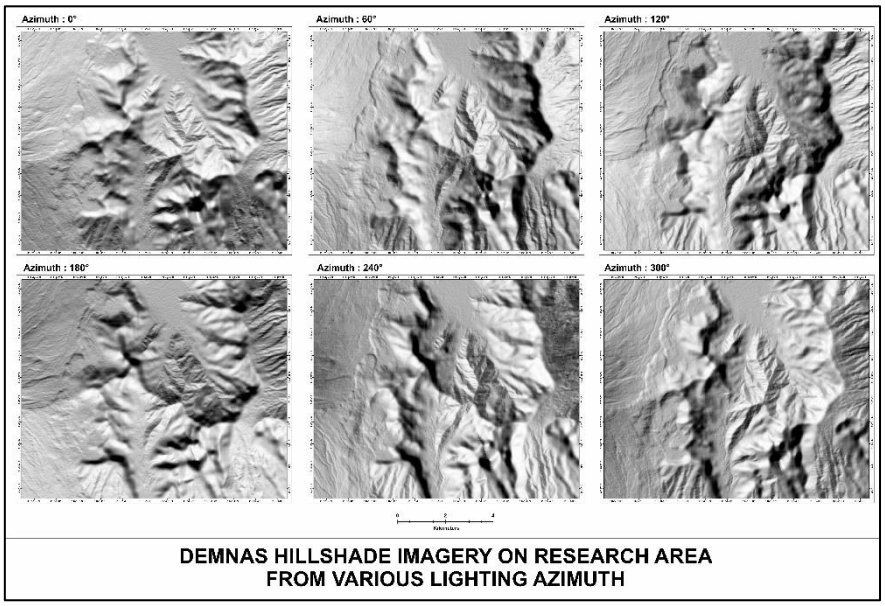

Figure 2. DEMNAS Imagery from Lighting Azimuths Of 0°, 60°, 120°, 180°, 240° and 300° At A Constant Altitude Of 45°

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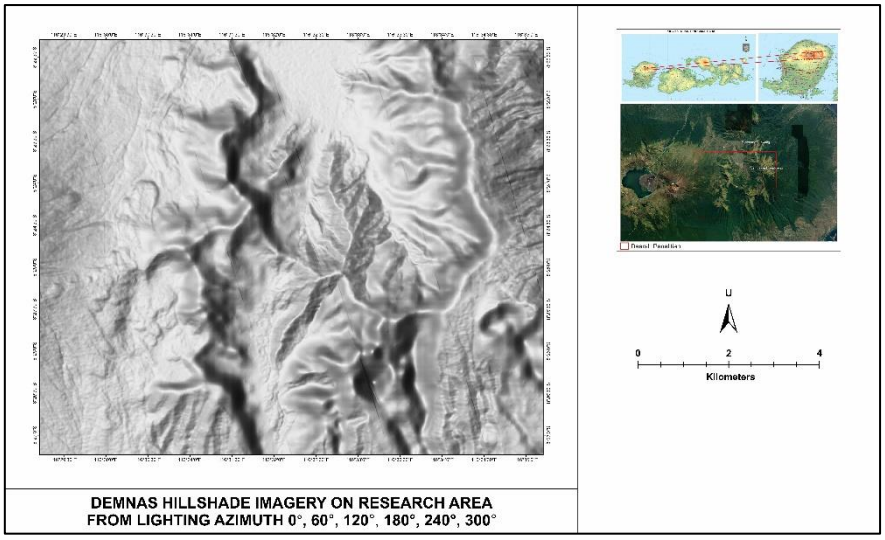

Figure 3. DEMNAS Imagery with Combination of Various Azimuth of Lighting Angles

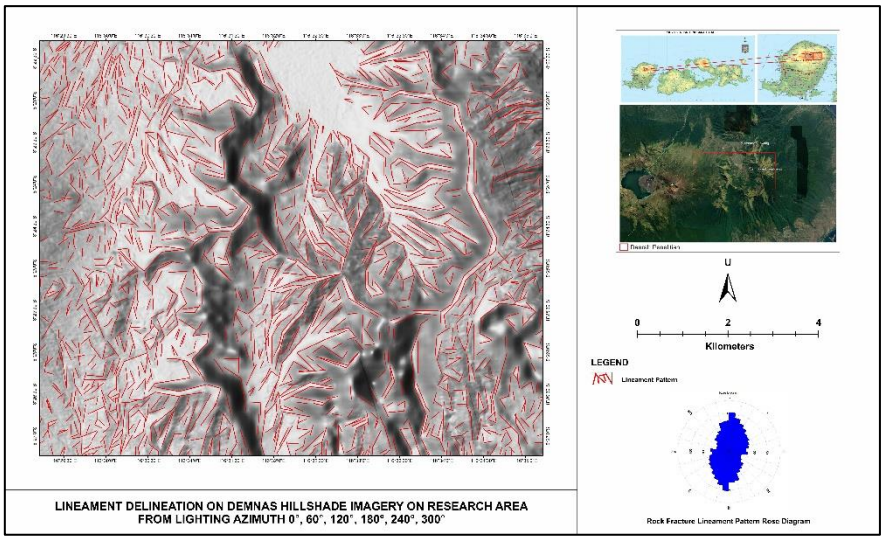

Figure 4. Lineament Pattern from DEMNAS Imagery

From the DEMNAS imagery that has been lit from 0°, 60°, 120°, 180°, 240° and 300° azimuths, they are combined into one (Figure 3). Which aims to show the appearance of lineament evenly, not only from one lighting angle. With the multidirectional hillshade function in ArcGIS software, a lineament pattern is delineated from the merger (Figure 4).

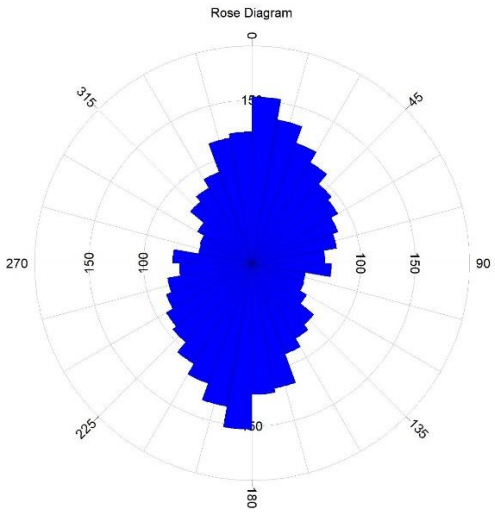

Figure 5. Rose Diagram of Lineament Pattern

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From the results of the delineation lineament pattern, the general direction of the lineaments that have been made in the form of a rosette diagram is obtained (Figure 5). It is known that the resulting general direction is northeast – southwest.

2. Fault Fracture Density

Fault Fracture Density is one of the remote sensing methods to be able to determine the high permeability zone based on the level of lineament density (Danakusumah and Suryantini, 2020). In this research, lineament density is calculated based on the area (grid) which is divided into 1 km x 1 km in size with an area of 1 km^2 each (Figure 5).

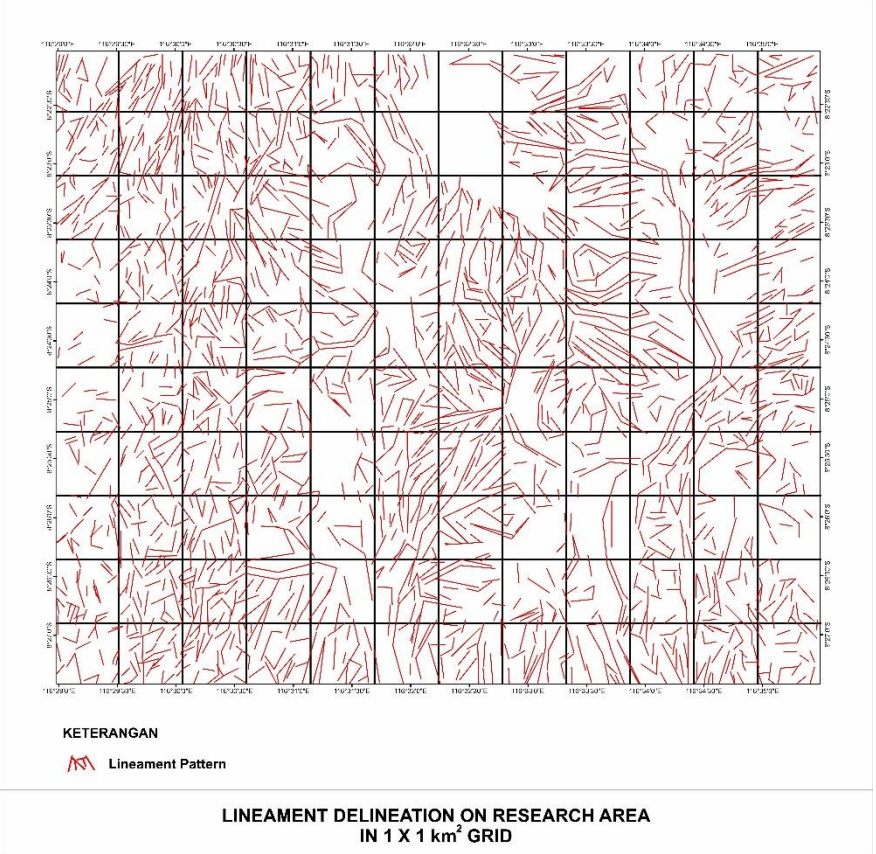

Figure 6. Lineament Patterns in an Area of 1 x 1 km^2

The process of doing the grid division in the research area aims to find out in more detail and evenly the value from the delineation of lineament. Each grid will calculate the total length of the lineament of each grid 1 km x 1 km (Suryantini and Wibowo, 2010) as shown in the Figure 6. The value of the lineament length range in the study area ranges from 1424.3 m - 9088.4 m/km^2. The results of these calculations show, the length value of the lineament density is then made into the density contour which is colored from the lineament which shows the level of the permeability zone (Figure 7). The density values are divided into 3 classes:

i. Low density zone; showed by dark blue to yellowish blue with a density value between 0 – 3000 m/km^2.
ii. Medium density zone; showed by a light yellow to reddish yellow color with a density value between 3001 – 6000 m/km^2.
iii. High density zone; showed by a yellowish red to dark red color with a density value between 6001 – 10000 m/km^2.

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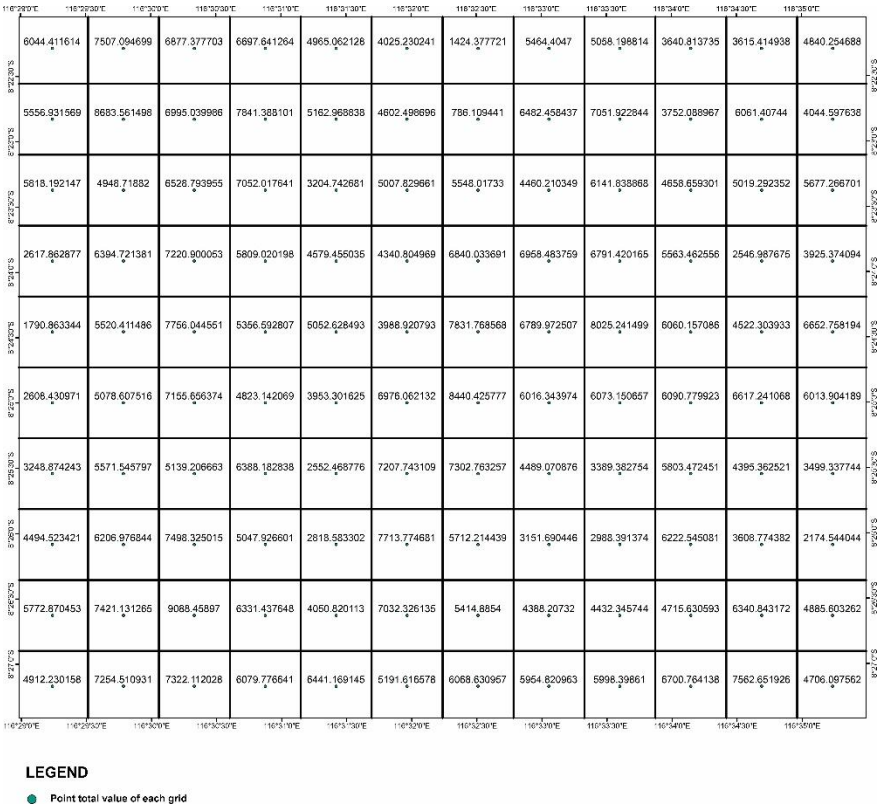

Figure 7. Calculation of Lineament Density Value in Units (m/km^2)

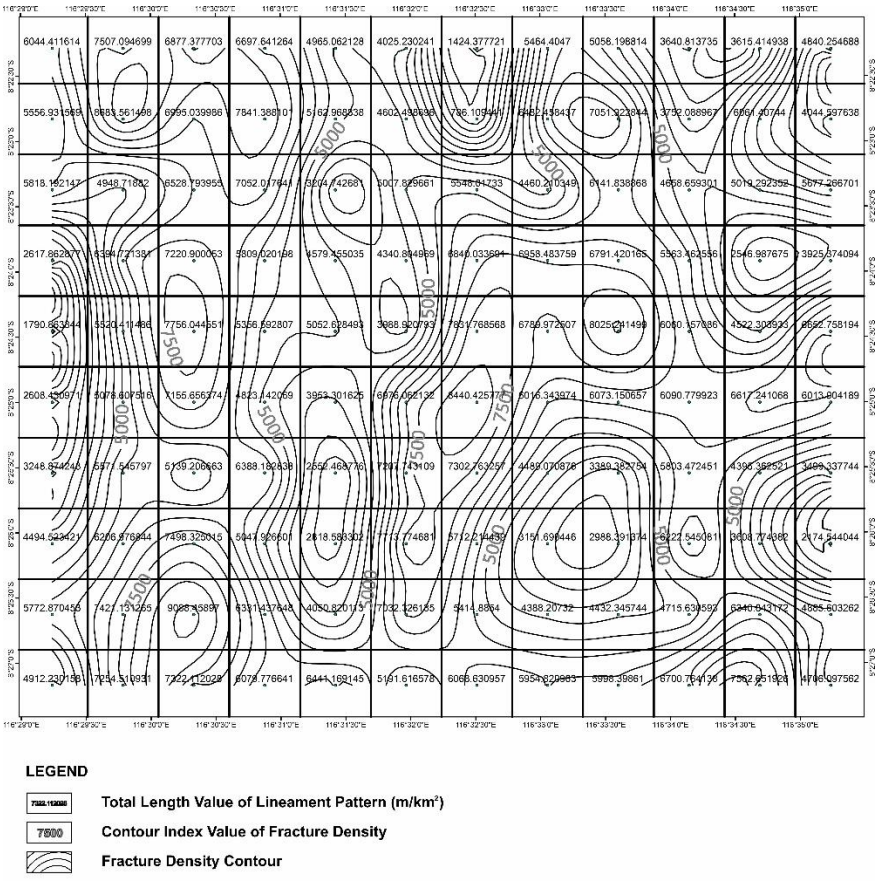

Figure 8. Calculation of Lineament and Contour Density Based on Lineament Density Value

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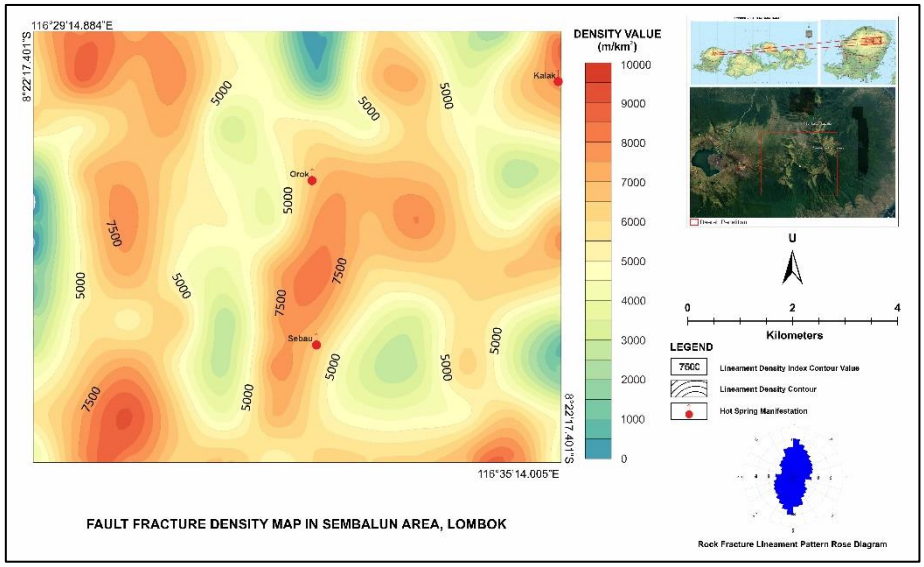

Figure 9. Lineament Density Map Of Fault Fracture Density In Sembalun, Lombok

3. Geothermal Manifestation

Geothermal manifestations in the study area are found in three areas. Namely the manifestation of Kalak, Sebau, and Orok. The Kalak manifestation is located at coordinates 116° 35' 16,788" E and 8° 22' 40,817" S with an altitude of 1080 (MASL), the Sebau manifestation is at coordinates 116° 32' 27,257" E and 8° 25' 48.352" S with an altitude of 1350 (MASL), Orok manifestation is at coordinates 116° 32' 24,411" E and 8° 23' 58,483" S with an altitude of 1313 (MASL).

CONCLUSION

From the results of the of the lineament pattern, it is known that the general direction is northeast-southwest, it can be assumed that the general orientation of the geological structure that developed has the same orientation with the lineament pattern in the study area. Fault Fracture Density analysis shows that in the study area, geothermal surface manifestations appear in high density zone. Zones with high density indicate that the zone has a high level of permeability. It can control the fluid flow in the permeable area.

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REFERENCES

Agista, Z., Rachwibowo, P., Aribowo, Y., 2014. Analisis Litologi dan Struktur Geologi Berdasarkan Citra Landsat pada Area Prospek Panasbumi Gunung Telomoyo dan Sekitarnya, Kabupaten Magelang, Provinsi Jawa Tengah. Geol. Eng. E-Journal 6, 278–293.

Badan Informasi Geospasial, 2018. DEMNAS: Seamless Digital Elevation Model (DEM) dan Batimetri Nasional [WWW Document]. URL https://tanahair.indonesia.go.id/demnas/#/ (accessed 7.30.21).

Casas, A.M., Cortés, A.L., Maestro, A., Soriano, M.A., Riaguas, A., Bernal, J., 2000. LINDENS: A program for lineament length and density analysis. Comput. Geosci. 26, 1011–1022.

Danakusumah, G., Suryantini, 2020. Integration of the Lineament Study in the Karaha-Bodas Geothermal Field, West Java. IOP Conf. Ser. Earth Environ. Sci. 417.

Energi Baru Terbarukan dan Konservasi Energi, 2020. Potensi Besar Belum Termanfaatkan, 46 Proyek Panas Bumi Siap Dijalankan [WWW Document]. URL https://ebtke.esdm.go.id/post/2020/03/27/2518/potensi.besar.belum.termanfaatkan.46.proyek.panas.bumi.siap.dijalankan (accessed 7.29.21).

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Iqbal, M., Juliarka, B.R., 2019. Analisis Kerapatan Kelurusan (Lineament Density) di Lapangan Panasbumi Suoh-Sekincau, Lampung. J. Sci. Appl. Technol. 3, 61–67.

Mardiati, D., Setianto, A., Harijoko, A., 2020. Revealing Geothermal Potential Areas with Remote Sensing Analysis for Surface Temperature and Lineament Density: Case Study in South Bajawa, NTT, Indonesia. IOP Conf. Ser. Earth Environ. Sci. 417.

Oktoberiman, Ramadhan P, D.A., W, F.R., A, R.T., 2015. Identification of Geothermal Potential Based on Fault Fracture Density (FFD), Geological Mapping and Geochemical Analysis, Case Study : Bantarkawung, Brebes, Central Java. KnE Energy 2, 141–151.

Soengkono, S., 1999a. Analysis of digital topographic data. 21st New Zeal. Geotherm. Work. 163–167.

Soengkono, S., 1999b. Te Kopia geothermal system (New Zealand) - the relationship between its structure and extent. Geothermics 28, 767–784.

Suryantini, Wibowo, H., 2010. Application of Fault and Fracture Density (FFD) Method for Geothermal Exploration in Non-Volcanic Geothermal System; a Case Study in Sulawesi-Indonesia. Proc. World Geotherm. Congr. 25–29.

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