Application of Fault Fracture Density in Determination of Zones with High Permeability Levels on Geothermal Surface Manifestations in the Sukarame Region, Sukabumi Regency, West Java Province

Galih Hadisurya Ramadhan[1], Agus Didit Haryanto[1], Iyan Haryanto[1], Mochamad Nur Hadi[2], Santia Ardi Mustofa[2]
[1]Faculty of Geological Engineering, Padjadjaran University
[2]Center for Mineral, Coal and Geothermal Resources

Corresponding author: galih17001@mail.unpad.ac.id

ABSTRACT

Indonesia is a country with quite large geothermal potential with a volcanic distribution that extends from Sabang to Merauke. The total potential for developing geothermal energy in Indonesia can reach 28,579 MWE if it is developed properly. This study was conducted for determining a permeable zone at the research location which is in Sukarame Village that can be related to the emergence of hot springs as a geothermal surface manifestations, besides that this research can also provide an overview of the general direction of geological structures that may develop in the research area. The method used in this study is Fault fracture density analysis which can determine the zone with a high level of permeability based on the lineament pattern drawn from remote sensing interpretation. The main data source for interpreting lineament pattern analysis is DEMNAS imagery which built from 3 satellites imagery including IFSAR, TERRASAR-X and ALOS PALSAR. The lineament pattern that have been analyzed then processed computationally into rose a diagram to get the general direction of structural geology which may develop. The total length of the lineament pattern is also calculated to obtain the lineament density value that leads to the determination of the permeable zone. The lineament pattern in the research area has a general direction of northeast-southwest, while the lineament density value in the study area has a value range of 4534.714078 – 9084.119758 m/km2. Areas with a high level of permeability coincide with the point of hot springs as a manifestation of the geothermal surface.

Keyword: Geothermal, Permeable Zone, Hot Spring, Geological Structures, Fault Fracture Density, Lineament

INTRODUCTION

Ring of fire is a location that has complicated geological aspects with the presence of volcanic clusters as a reflection of the ongoing tectonic processes. one of the areas traversed by the volcanic cluster is Indonesia with around 200 series of volcanoes spread from Sabang to Merauke, causing volcanism activity to occur quite often. The presence of volcanoes will support the creation of potential utilization of geothermal energy in Indonesia. It is known that the total potential of geothermal energy that can be developed in Indonesia reaches 28,579 MWe, with details in the form of energy reserves of 17,606 MWe and geothermal resources capacity of 11,073 Mwe (Anon., 2018). To date, there are a total of 64 geothermal working areas that have been developed in Indonesia with an electricity production of 9,078 Gwh (Anon., 2020). Thus, it can be seen that the potential for developing geothermal energy in Indonesia is very large if it is utilized and managed properly.

One of the areas in Indonesia that has the potential for developing geothermal energy is the Sukarame area which is administratively included in Sukabumi Regency, West Java Province.

Figure 1. The research location that located in the Cisolok-Sukarame area, Sukabumi Regency, West Java Province.

The existence of potential development of geothermal energy in the region can be seen from the presence of hot springs as a geothermal surface manifestations by a ranging of temperatures from 93-98°C with a pH value of around 8 (Abdillah, et al., 2017). In addition can also be found several other manifestations such as hot mud pool, hot pool, and travertine fossils.

E-ISSN : 2579 – 3136

Fault Fracture Density is a method that can be used to show areas based on their respective permeability levels. In principle, the determination of the level of permeability of an area is based on the interpretation of the drawing of lineament patterns on satellite images which can be assumed as a description of the geological structure that develops in an area in the form of faults or fractures (Soengkono, 1999). In a narrow sense, permeability can be said as the ability of a rock to be able to flow fluids, in this case the permeability in question is secondary permeability caused by the geological structure. In geothermal systems, geological structures can be a pathway for geothermal fluids to migrate to the surface (Suryantini & Wibowo, 2010). Geothermal fluid that successfully migrates to the surface will come out as a manifestation in several types, Some of the possible types of these manifestations can be a mud pool, hot springs geysers, travertine, solfatara and several other types

The application of Fault Fracture Density is usually used in the early stages of geothermal exploration to be able to show areas with a high level of permeability so that they can be analyzed further to determine geothermal prospect areas. Geothermal manifestations that appear in areas with high lineament density prove that these manifestations arise through existing fractures (Sasilani, et al., 2019). The presence of geological structures is an important element in the creation of a geothermal system in an area.

This study was conducted to determine the zone with a high level of permeability based on the Fault Fracture Density analysis from the interpretation of the draw from lineament pattern in the Sukarame area and to relate it to the appearance of surface manifestations in the field to determine the relationship between the appearance of these manifestations and the results of this remote sensing analysis. If the surface manifestation appears in a zone with a high lineament pattern density value, it can be assumed that the manifestation appears due to the influence of the geological structure that develops at that location.

RESEARCH METHOD

The method used in this study is a fault fracture density method with the main data source in the form of DEMNAS imagery of the research location with a resolution of 0.27-arcsecond (7.5m). DEMNAS or "DEM Nasional" is 2 dimensions elevation data which built from 3 satellites imagery including IFSAR, TERRASAR-X and ALOS PALSAR. Other supporting data are the location coordinates for the emergence of hot springs as a geothermal surface manifestation which were acquired directly from the field.

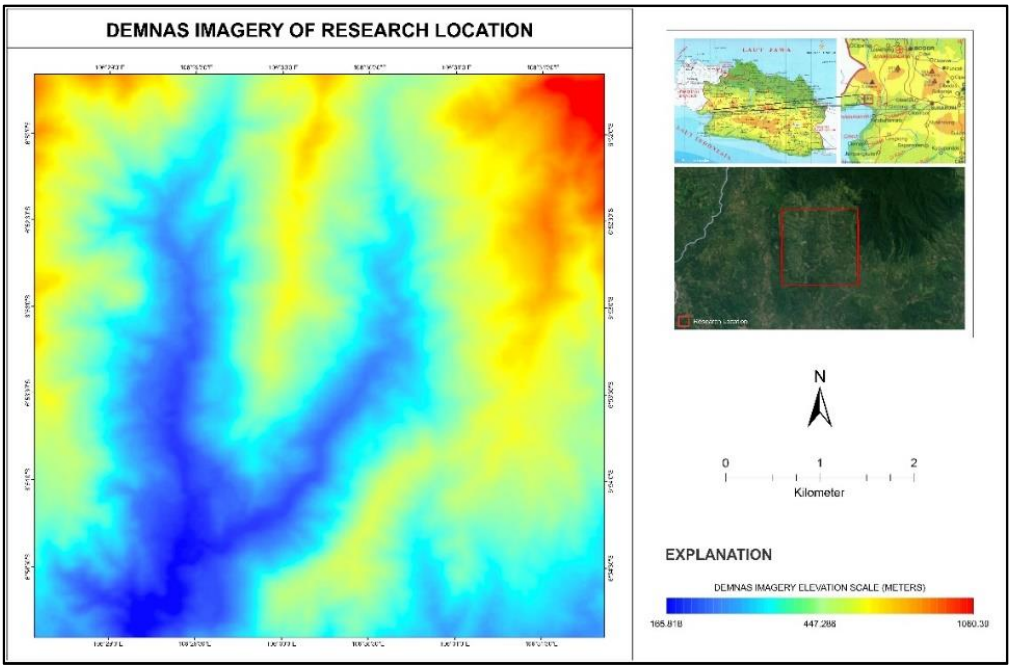

Figure 2. DEMNAS imagery of research location

DEMNAS imagery data is basically 2-dimensional data that shows the elevation of an area. The elevation data in the form of 2 dimensions is then processed computationally to show a 3-dimensional picture of the research area. The results of image processing

E-ISSN : 2579 – 3136

into 3-dimensional form can show the lineament features that appear from the morphology of the research area. To detail the morphological picture that can show the lineament features, the lighting angle is also adjusted with azimuths of 0°, 60°, 120°, 180°, 240°, and 300° with irradiation slope height of 45°. Then the results of setting all lighting directions on the DEMNAS imagery in 3 dimensions are combined computationally to get a better morphological picture so that the lineament features in the research area will be more visible. The result of the merger is called a multidirectional hillshade.

The lineament pattern is drawn and interpreted from the lineament features that appear on the DEMNAS imagery in the form of a multidirectional hillshade, the lineament are then grouped into a grid with a size of 1x1 km^2, then the total length of the lineament in one grid is calculated and then processed into the form lineament density contour that can show areas with the same lineament density value. The lineament patterns that have been drawn are then analyzed into a rosette diagram to know the general lineament's direction which can be assumed to be a fracture from the geological structure that developed in the survey location. Furthermore, the coordinates of the hot springs as a geothermal surface manifestation are plotted on the lineament density contour map to determine the relationship between high lineament density values and the appearance of hot springs.

RESULT AND DISCUSSION

Surface Manifestations of Hot Springs

Based on the results of mapping in the field, the presence of surface manifestations of hot springs is known to be at coordinates 106°29'21,485"E and 6°53'37.763"S and 106°29'25,469"E and 6°53'29,011"S. The location is in the southwest part of the research area.

Lineament Analysis and Fault Fracture Density

The DEMNAS imagery of the research location (Figure 2) shows the elevation range of the research area ranging from 165,818 – 1060.39 (MASL). The satellite image data is then processed computationally into a 3-dimensional form using lighting azimuths of 0°, 60°, 120°, 180°, 240°, and 300° with irradiation slope height of 45° to provide a morphological picture that can show the features of lineament pattern well.

The purpose of processing DEMNAS imagery into 3-dimensional form with various directions (azimuths) is to get a complete picture of the morphology in the research area, because if only use 1 lighting direction, there will be some areas whose morphological appearance cannot be displayed properly. Meanwhile, the height of the consistent irradiation direction of 45° was chosen with the aim of getting the same amount of shadow for each illuminated morphological object. The results of processing the DEMNAS imagery into a 3-dimensional form (Figure 3) are then combined into 1 for further drawing the lineament pattern.

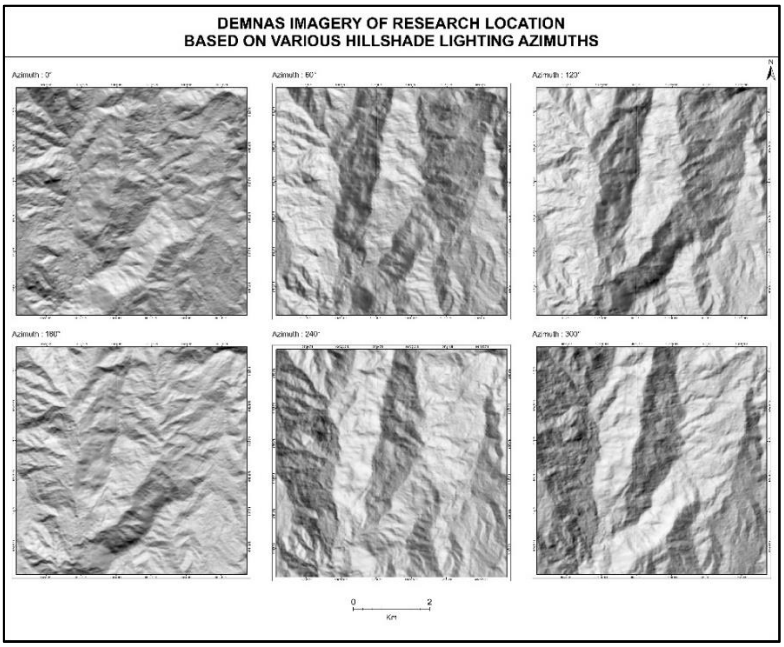

Figure 3. Results of processing DEMNAS imagery into 3-dimensional form

E-ISSN : 2579 – 3136

The results of the lineament pattern drawing show that the lineaments in the study area have a general direction (orientation) northeast – southwest (Figure 5). The lineaments that have been drawn are assumed to be associated with the geological structure that developed in the study area. So, it can be said that the geological structure .

That developed in the study area has the same orientation as the orientation of the lineament pattern. Geological structures in the form of faults and fracture are important elements in the geothermal exploration stage because they can open a permeable path for geothermal fluids to rise to the surface (Soengkono, 2000). Generally, the secondary permeability (of all types of rock) are strongly influenced by Faults structure and fractures. Areas with a high level of permeability will be associated with prospective areas for the development of early stages of geothermal exploration.

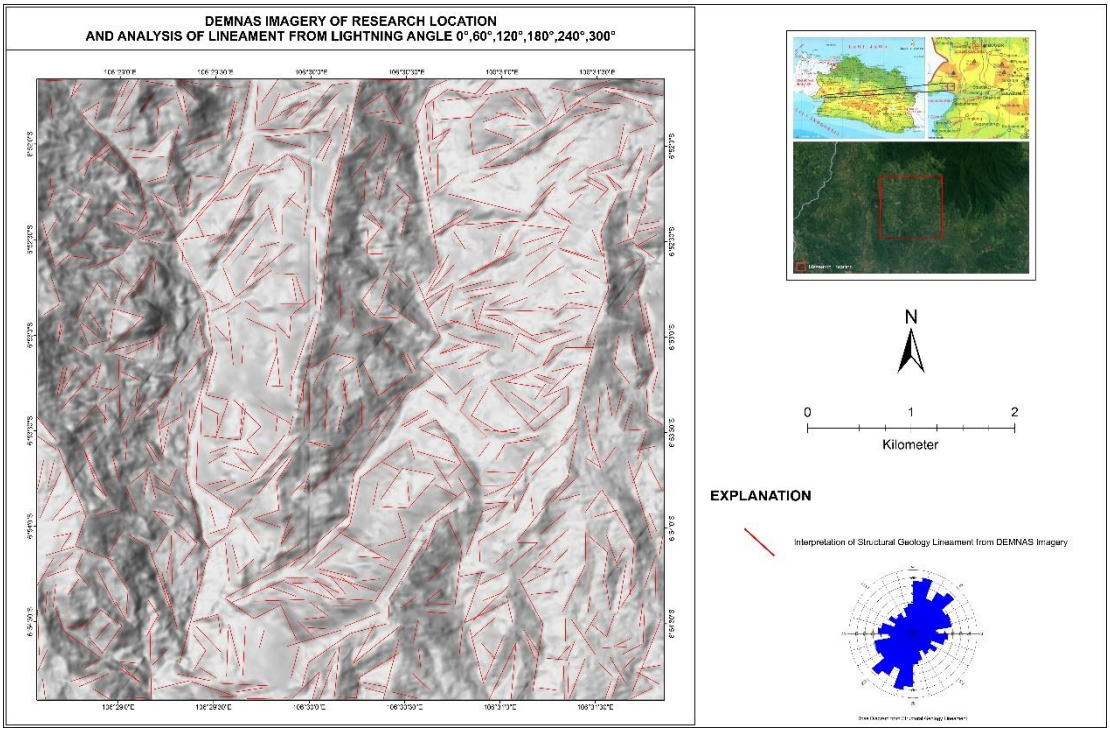

Figure 4. Lineament Pattern of The Research area by Multidirectional Hillshade

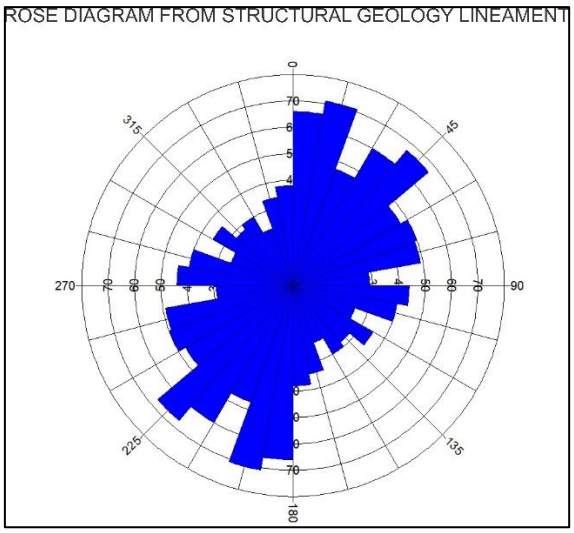

Figure 5. Rose Diagram of The Lineament Analysis

E-ISSN : 2579 – 3136

After the lineament pattern has been successfully interpreted, then the lineament patterns are grouped into a grid with an area of 1x1 km^2, then the total length of the lineament pattern is calculated (Figure 6) to get the lineament density value in meters/km^2 which can describe rock cracks at the location. The density values that have been calculated will then be made into the form of lineament density contours that represent zones with each level of permeability. The density values in the study area ranged from 4534.714078 – 9084.119758 m/km^2. The contour that has been made based on the density value of the lineament is then colored so that it can be easily read and analyzed further. The lineament density map that has been colored is called a fault fracture density map (Figure 7). On the map it can be seen that the research area is divided into 3 density classes, these classes include:

1. Low density
   Shown in dark blue – light blue color. This area most dominant presence in the northwest part of the study area.
2. Medium density
   Shown in light brown color. This area most dominant presence in the central to northeast on the lineament density map.
3. High density
   Shown in dark brown – red color. This area most dominant presence on the center and north of the location.

Areas with high density values correlate with the presence of hot springs as a geothermal manifestation on the southwest part in the research location. This indicates that the zone which shows high density value is a high permeability zone that closely related to the fracture structure that causes geothermal fluid migrate to the surface. Without fracture it will be difficult for geothermal fluids to come to the surface. The most permeable zone is the zone with the highest fracture density.

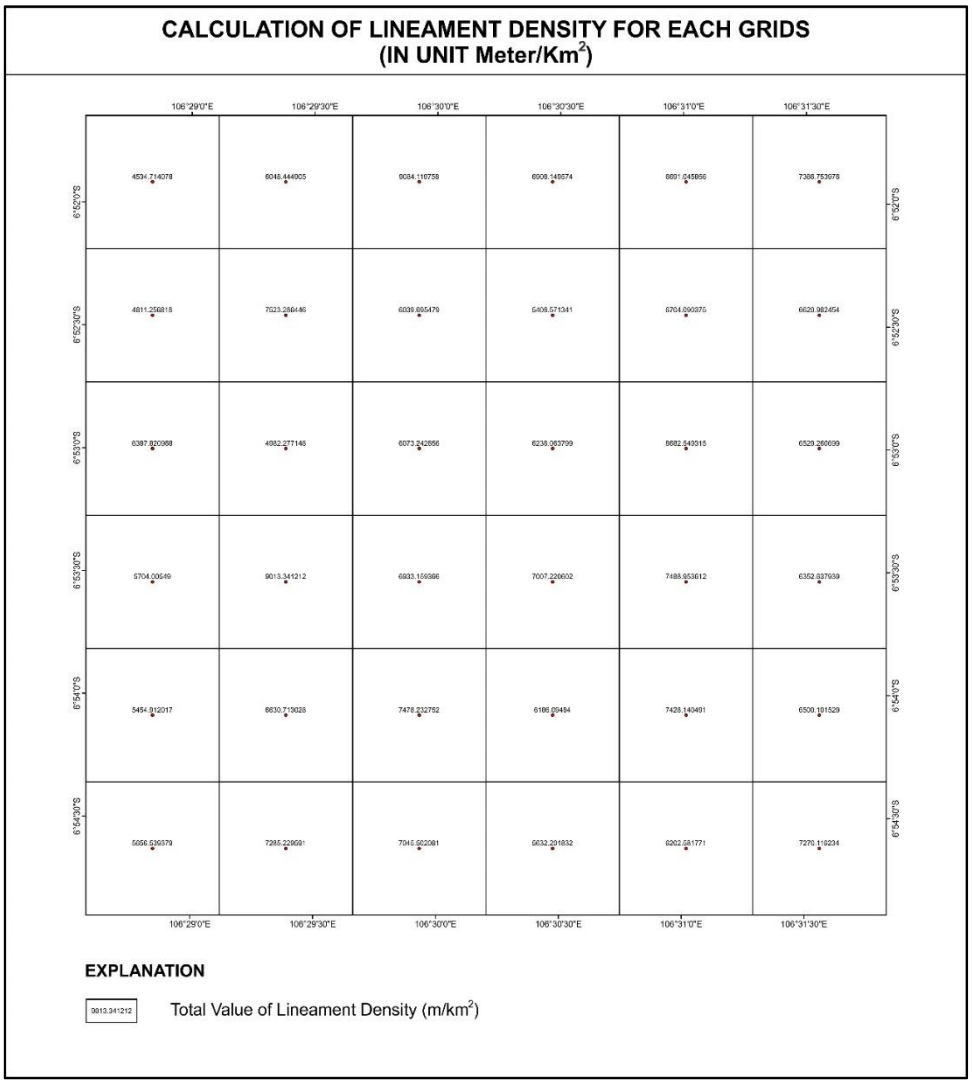

Figure 6. Calculations of Lineament Density for Each Grids (m/km^2)

E-ISSN : 2579 – 3136

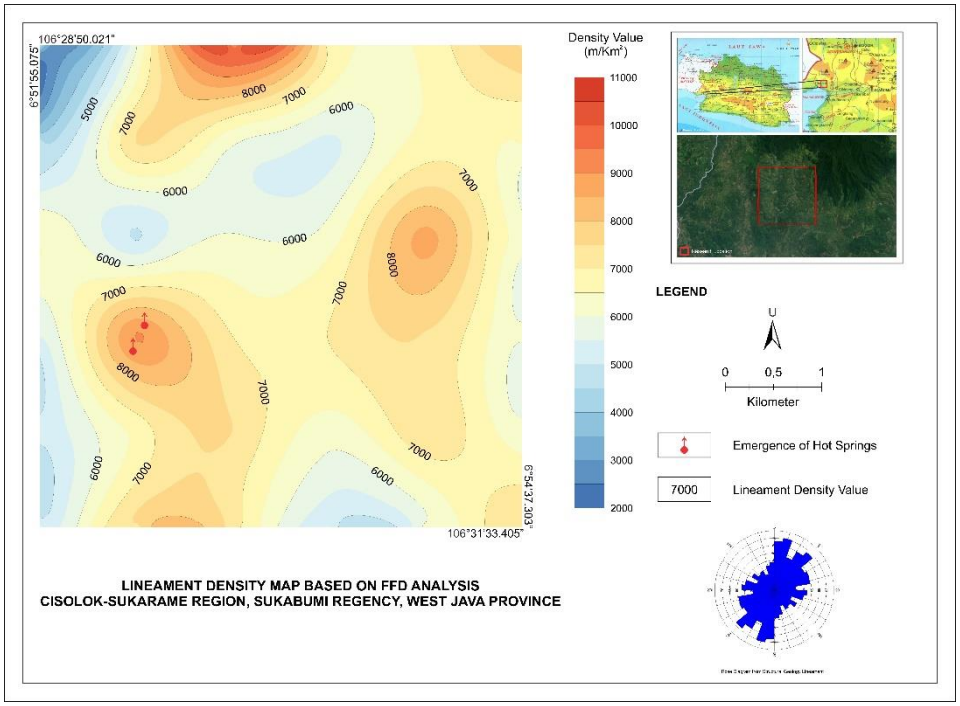

Figure 7. Fault Fracture Density Map of The Research Location

CONCLUSION

Based on the Lineament Pattern analysis, it can be seen that the general direction of the lineament pattern is northeast-southwest so that it can be assumed that the general direction of the geological structures that may develop at the study site has the same orientation as the general direction of the lineament pattern.

Based on the FFD analysis, it can be seen that the zones with a high level of permeability are in the east, southwest, and north of the research location. The appearance of hot springs is in a zone with a high level of permeability, so it shows that FFD analysis is correlated with the appearance of geothermal surface manifestations.

ACKNOWLEDGEMENT

The biggest respect and gratitude are author delivered to Dr. Eng. Ir. Agus Didit Haryanto, MT. and Dr. Ir. Iyan Haryanto MT. for supporting and giving so much wise to the author in completing this scientific work, also to Center for Mineral, Coal and Geothermal Resources for allowing author to join the geothermal survey at Cisolok-Sukarame Region.

REFERENCES

Abdillah, M. R., 2017. *Geologi dan Manifestasi Panas Bumi Daerah Cisolok Cisukarame Kecamatan Cisolok Kab Sukabumi, Jawa Barat,* Jatinangor: Unpublish.

Abdillah, M. R. et al., 2017. HIDROGEOKIMIA AIR MANIFESTASI PANAS BUMI DI DAERAH CISOLOK - CISUKARAME, KABUPATEN SUKABUMI, PROVINSI JAWA BARAT. *Padjadjaran Geoscience Journal,* 1(3).

Anon., 2018. *Kementerian Energi Dan Sumber Daya Mineral.* [Online] Available at: https://www.esdm.go.id/id/media-center/arsip-berita/kini-indonesia-menjadi-produsen-listrik-panas-bumi-terbesar-kedua-dunia [Accessed 10 Maret 2021].

Anon., 2020. *Current Geothermal Landscape and Government Objective for Future Development,* Bandung: s.n.

Sasilani, R., 2017. *Zona Prospek Panas Bumi Berdasarkan Pendekatan Fault Fracture Density (FFD) Di Daerah Sumani, Sumatera Barat,* Sumedang: Unpublish.

Sasilani, R. et al., 2019. ZONE OF GEOTHERMAL PROSPECTS BASED ON FAULT FRACTURE DENSITY (FFD) METHOD IN

E-ISSN : 2579 – 3136

SUMANI REGION, WEST SUMATERA. *JOURNAL OF GEOLOGICAL SCIENCES AND APPLIED GEOLOGY,* 3(2).

Soengkono, S., 1999. Te Kopia Geothermal System (New Zealand) - The Relationship Between Its Structure and Extent. *Geothermic,* pp. 767-784.

Soengkono, S., 2000. *ASSESSMENT OF FAULTS AND FRACTURES AT THE MOKAI GEOTHERMAL FIELD, TAUPO VOLCANIC ZONE.* Kyushu - Tohoku, Proceedings World Geothermal Congress 2000.

Suryantini & Wibowo, H. H., 2010. Application of Fault and Fracture Density (FFD) Method for Geothermal Exploration in Non-Volcanic Geothermal System; a Case Study in Sulawesi-Indonesia. *Proceedings World Geothermal Congress 2010,* pp. 25-29.

E-ISSN : 2579 – 3136