STRUCTURAL GEOLOGY ANALYSIS USING REMOTE SENSING METHOD AND ITS CORRELATION TO GEOTHERMAL OCCURENCE AT LEBAK REGENCY, BANTEN

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ABSTRACT

Research area is located in Cibeber and Malingping District of Lebak Regency, Banten Province. The research location is located approximately 80 kilometers southwest of Jakarta. This area has a complex geological structure, as well as found many intrusive and metamorphic rocks. In this research area, geothermal manifestations were found in the form of four hot springs i.e. three Pamancalan hotsprings in Cibeber District, and Citando hotspring in Malingping District.

The method used is geological structure analysis of research area using remote sensing on ASTER-GDEM satellite imagery. Structural analysis methods performed in the form of lineament delineation, determination of lineament density and major trends, and application of wrench system model. The results of structural analysis will be correlated with the existense of geothermal manifestations with the aim of identifying the most influential structural patterns as the pathway for geothermal fluid to reach surface in the study area.

Structural analysis of study area shows major trends developed in study area are NS and EW trends. The result of delineation of lineaments is in the form of lineament density map which shows the distribution of high value density that is almost evenly distributed in all area of research. The study area also indicates compatibility with the concept of wrench fault and its structure model.

Pamancalan hot springs are associated with high value of lineaments density, which are 3600-4400 m/km2, associated with an NS oriented lineament and also associated with primary right lateral wrench in the model of the Wrench Fault model. Citando hot springs are associated with a very high density area of lineament density value, which is over 4800 m/km2. These springs are also associated with directional tendencies of NS and structures of the secondary left lateral wrench.

Keywords: Geothermal, Structural Geology Analysis, Surface Manifestation, Lineament Density, Bayah

INTRODUCTION

Lebak is a administrative area in the southern of Banten Province, adjacent to West Java Province at the east. This regency is located approximately 40 kilometers at the southwest of Jakarta. Geographically, Lebak Regency is located at coordinates 105 25 '- 106 30' BT and 6 18' - 7 00' LS. The northern part of this regency is lowlands, while in the southern part it is mountains with Mount Halimun at the southeast end. Ciujung River flows to the north, and is the longest river in Banten.

In the southern area of Lebak Regency, two districts is known to have geothermal manifestations, which are hot springs located in Cibeber and Malingping districts in the southeast and southwest of the regency respectively. Geothermal manifestation is an indicator of the underlying geothermal potential that formed when geothermal fluids find a path to reach the surface. Hot water in Cibeber district is found on the banks of river, flowing from rock slits. While hot water in Malingping district has been utilized by citizens to be used for bathing.

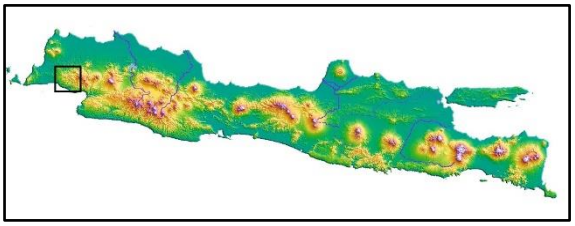

Figure 1. Lebak Regency as the study area

This study aims to determine the relationship between the structural geology that developed in Lebak Regency with its geothermal potential characterized by the existences of manifestations in the form of hot springs in Cibeber and Malingping districts. This research is expected to provide some of the preliminary data and descriptions for advanced geothermal research in the area, particularly regarding the understanding of the geological relationships of structures and geothermal manifestations.

GEOLOGICAL SETTING

Tectonic and Geological Structures

The geological structures in the western part of Java show different structural features in each region. This may occur due to different geological backgrounds in each region, such as the difference of inclination of Benioff Zones in each segment, to the reactivation of old fault by younger tectonics (Haryanto, 2013).

According to Haryanto (2013) Bayah area at the southern part of Lebak Regency is a series of sedimentary hills that have EW orientation extends to Walat in Sukabumi, West Java. This structure pattern is classified as the structure of Java Trends (Martodjojo, 1984 as cited in Haryanto, 2013).

This Bayah area is cut by two fault systems. The first system is a NNE-SSW oriented fault with almost vertical traverse direction. This first system is interrupted by the second system that trails EW. Along with this second system, the block from Bayah Complex has subsidenced in the south (Bemmelen, 1949).

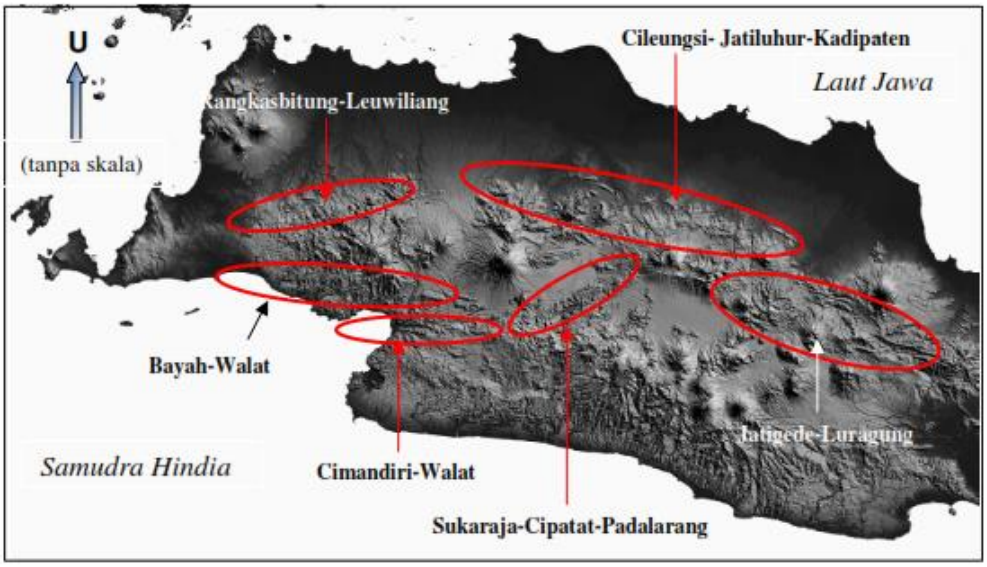

Figure 2. Bayah-Walat at the western side of Java Island has sediment hills with EW orientation (Figure after Haryanto, 2013)

Stratigraphy

The stratigraphy of study area according to Sujatmiko and Santosa (1992) in Geological Map of Leuwidamar Quadrangle, Jawa (1109-3) are composed from the youngest to oldest formations as follows:

- Alluvium (Qa): Pebble to mud
- Coastal deposits (Qc): Gravel to clay, detritus of corraline limestone and mollusk, reef limestone
- Quaternary volcanics (Qv), Basalt (Qb), Tapos breccia (Qvb), Halimun lavas (Qvl), Endut volcanics (Qpv)
- Bojong Formation (Qpb): Tuffaceouss sandstones, marl
- Cipacar Formation (Tpc): Tuffaceous sandtsones, breccia tuff, conglomerate, marl
- Citorek Tuff (Tpv), Malingping Tuff (Tpmt)
- Genteng Formation (Tpg): Pumice tuff, tuffaceous sandstones, breccia, conglomerate, marl
- Cimanceuri Formation (Tpm): Conglomerate, calcareous sandstones, dacitic tuff, breccia, limestone
- Cikasungka tuff (Tmkt): Tuff, silicified wood, tuffaceous breccia
- Andesite (Tma): basalt, diabase, hornblende andesite
- Bojongmanik Formation (Tmb): mudstone, limestone, sandstone
- Quartz diorite (Tmqd), Dacite (Tmda)
- Badui Formation (Tmd): Limestone, tuff
- Saraweh Formation (Tms): Limestone, claystone
- Cimapag Cimapag (Tmc): Limestone, tuff, claystone.
- Citarete Formation (Tmt): Limestone, tuff
- Cihara granodiorite (Tomg), Metamorphic rocks (Tomm)
- Cikotok Formation (Temv): Volcanic breccia, tuff, lava
- Cijengkol Formation (Toj): sandstone, conglomerate, breccia, tuff, and coal seams
- Ciracurup Formation (Tet): sandstone
- Bayah Formation (Teb): Sandstones, limestone, claystone, dan conglomerate

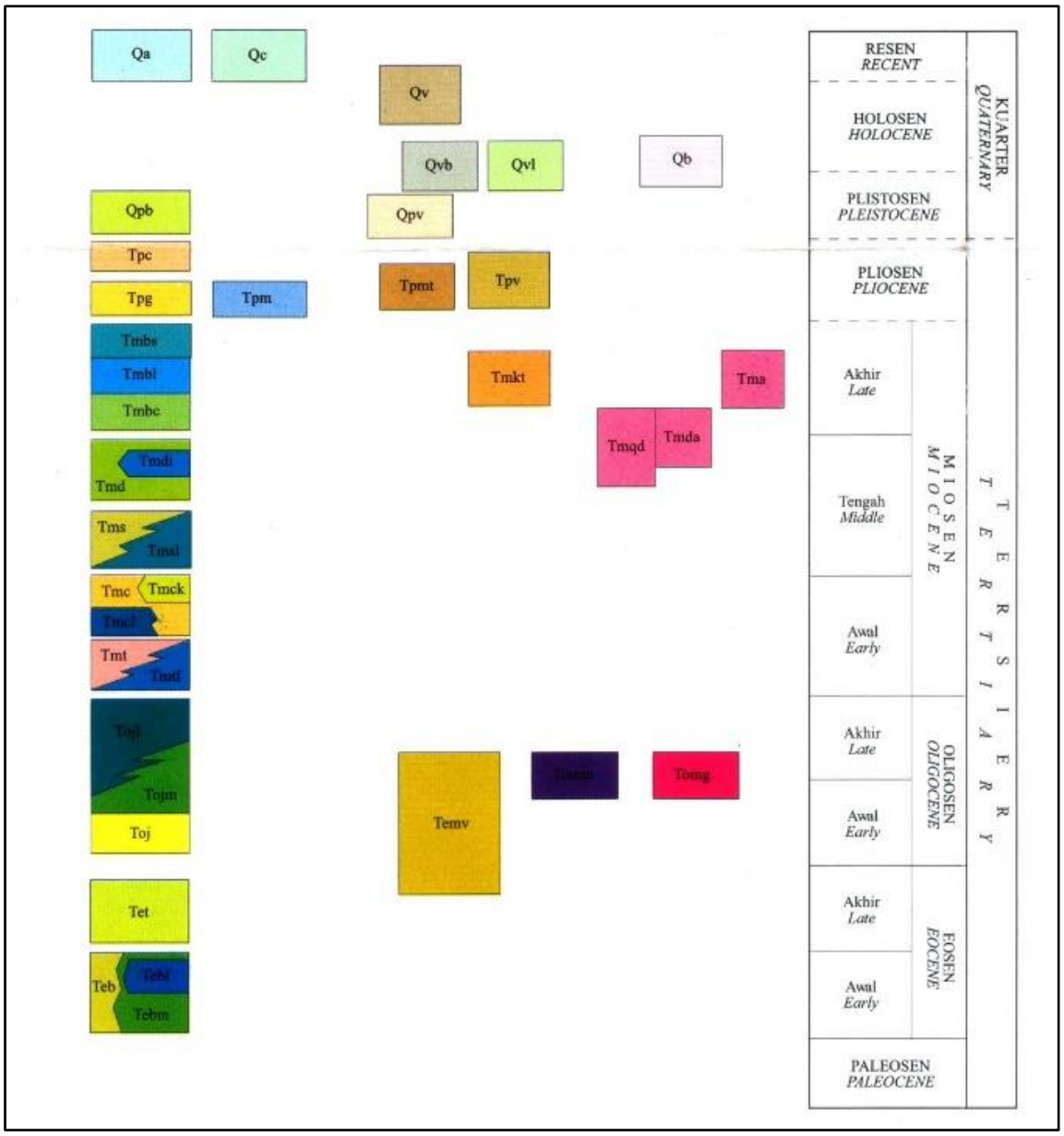

Figure 3. Stratigraphy of formations in study area (after Sujatmiko & Santosa, 1992)

METHODOLOGY

The structural analysis methods used in this research use remote sensing method on ASTER-GDEM satellite imagery. Stages in structural analysis are done in the form of lineaments delineation, determination of lineament density, determination of main trend and application of Wrench Fault Concept by Moody and Hill (1956) to regional area of research. The results of this analysis will be attributed to the presence of geothermal manifestations in the research area. The result will be a conclusion about the structure associated with the manifestation.

Lineaments Delineation

Lineaments delineation performed on satellite imagery is done using hillshading technique. Hillshading is a technique used to recognize lineament with visualize terrain as shaded relief. Digital elevation model represented from four illumination directions to optimize the delineation step. The four angles of illumination that is 0º, 45º, 90º, and 315º will support each other in showing the delineations in the image. Methods with this technique can be accessed on GIS software such as MapInfo and ArcGIS.

Lineament Density

This analysis show the concentration of the lineaments that has been delineated from the previous stage. This method calculates the frequency of the lineaments per unit area (length/km^2) that will produce an lineament density map. The grid sections will be counted in length in each grid box of 2 km x 2 km and then the result of the calculation is represented by a middle point at the center of each grid. The results of the representation will be made contours that show the large concentration of contour obtained.

Major Trend Determination and Wrench Fault Concept Application

The concept of Wrench Fault is a concept devised by Moody and Hill (1956) about the primary compression stress and its relationship to the structural elements formed in an area. This concept states that if a homogeneous isotropic material is subjected to a compression force, the material will experience wrench at an angle of 30º to the direction of the maximum principal compressive stress to which it is involved.

This assumption considers several things, such as lineament orientation, slip direction of the lineament, and literature study from regional geological map of research area by Sujatmiko and Santosa (1992). The purpose of this analysis is to know the direction of the main stress that causes the development of structural pattern, the properties of the geological structure associated with the geothermal manifestation in the research area, as well as to know to know the dominant orientation of the lineament with the help from data analysis from previous steps

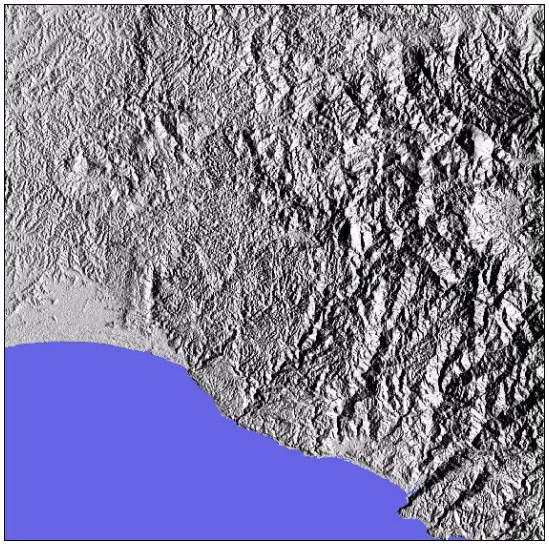

Figure 4. ASTER-GDEM satellite image from research area with a width of 50 km x 50 km. Approximately 30% of the research area is the Indian Ocean (blue color) that goes into the study area, but will not be the target of the structural analysis

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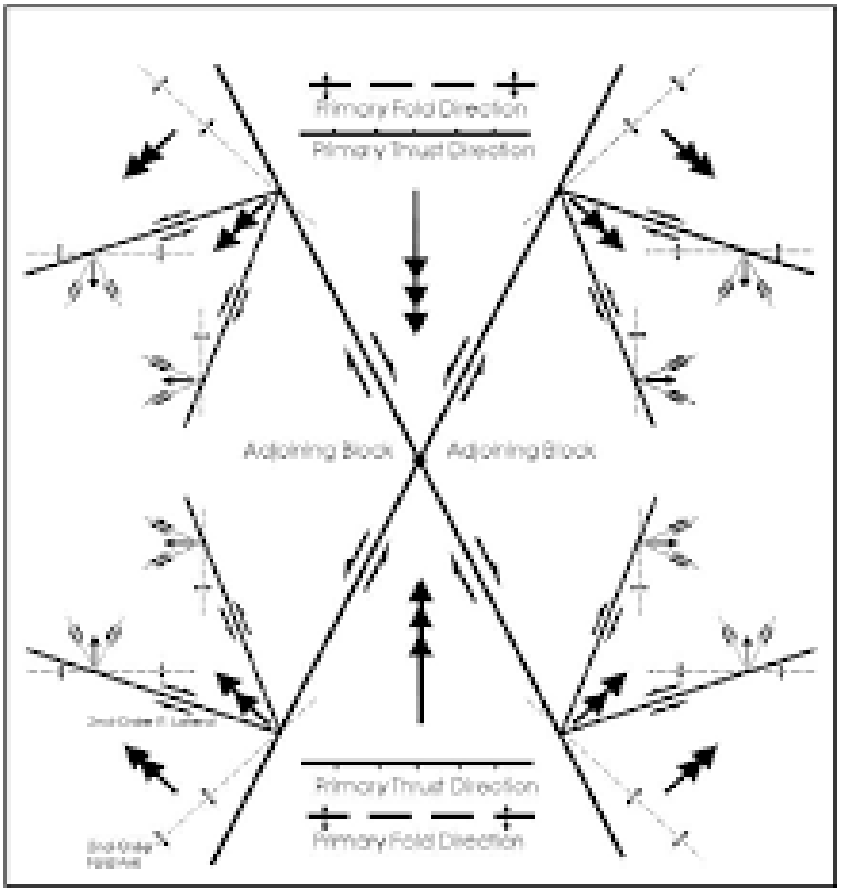

Figure 5. Model of Wrench Fault Concept (Moody & Hill, 1956)

RESULT AND DISCUSSION

Lineament Delineation

Lineaments delineation is done on all the possible lineaments that can be recognized on satellite imagery in a designated study area, utilizing four angles of illumination that cause all lineaments to be visible. The results of this method can be seen in Figure 6.

A total of 1398 lineaments were drawn at this stage and assumed to represent all areas of the study area. Delineation with a light angle of 0º has more lineaments delineated than the other three illumination angles, with 606 lineaments. Delineation with 45º illumination angle resulted in 221 lineaments, 90º angle resulted in 329 lineaments, and 315º angles resulted in 243 lineaments.

The results of all lineaments delineation are compiled into one for use in the analysis and construction of lineament density maps.

Lineament Density

The result of a lineaments compilation that has been drawn in the previous stage is a map showing the lineaments length per unit area (length / km2) using a 2x2 kilometer grid in each of each box. The map can be seen in figure 7.

The lineament density map shows a nearly equal distribution of lineaments across the study area. Areas with high densities are shown as orange to red zones on the map, which is more than 3600 m / km2.

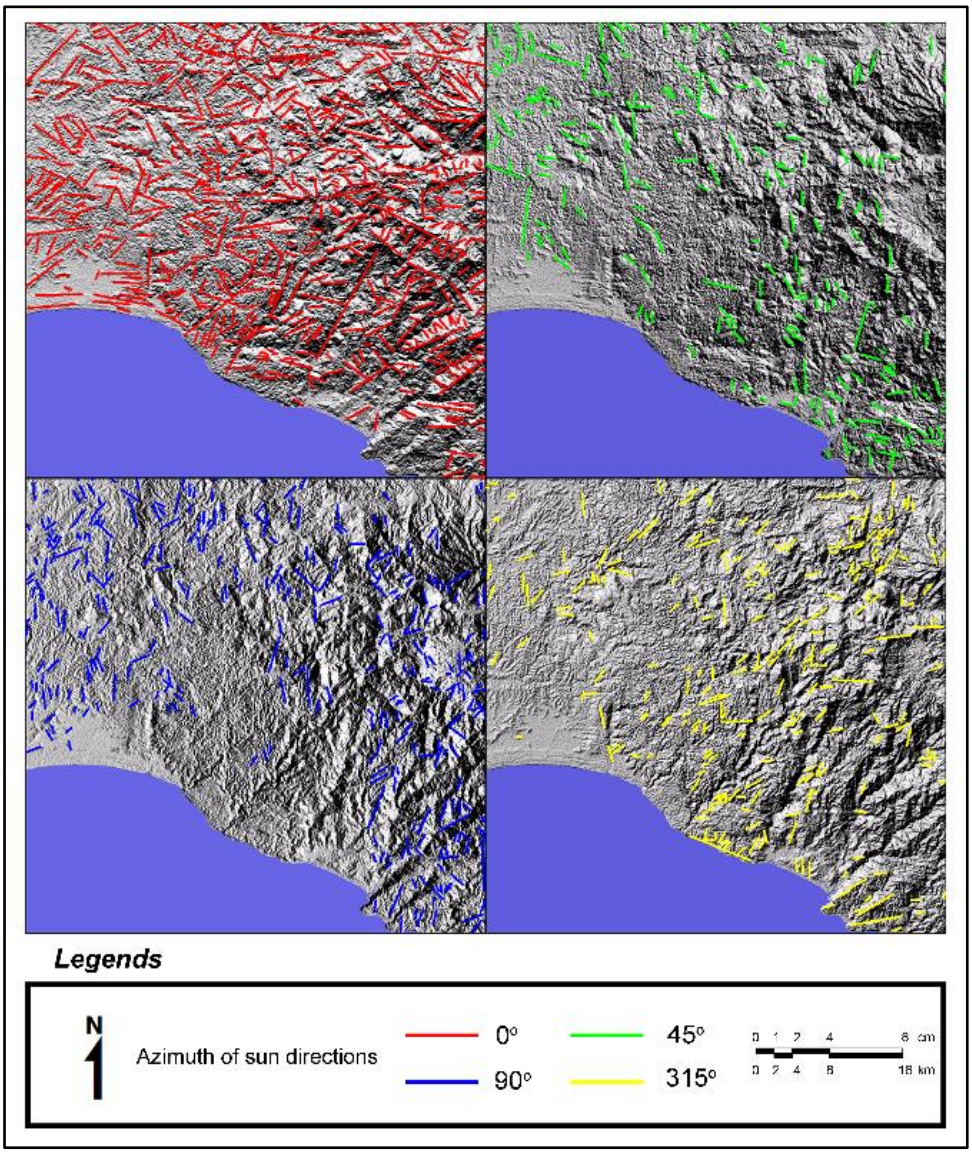

Figure 6. Results of lineaments delineation method from four different illumination directions, i.e. 0º, 45º, 90º, 315º.

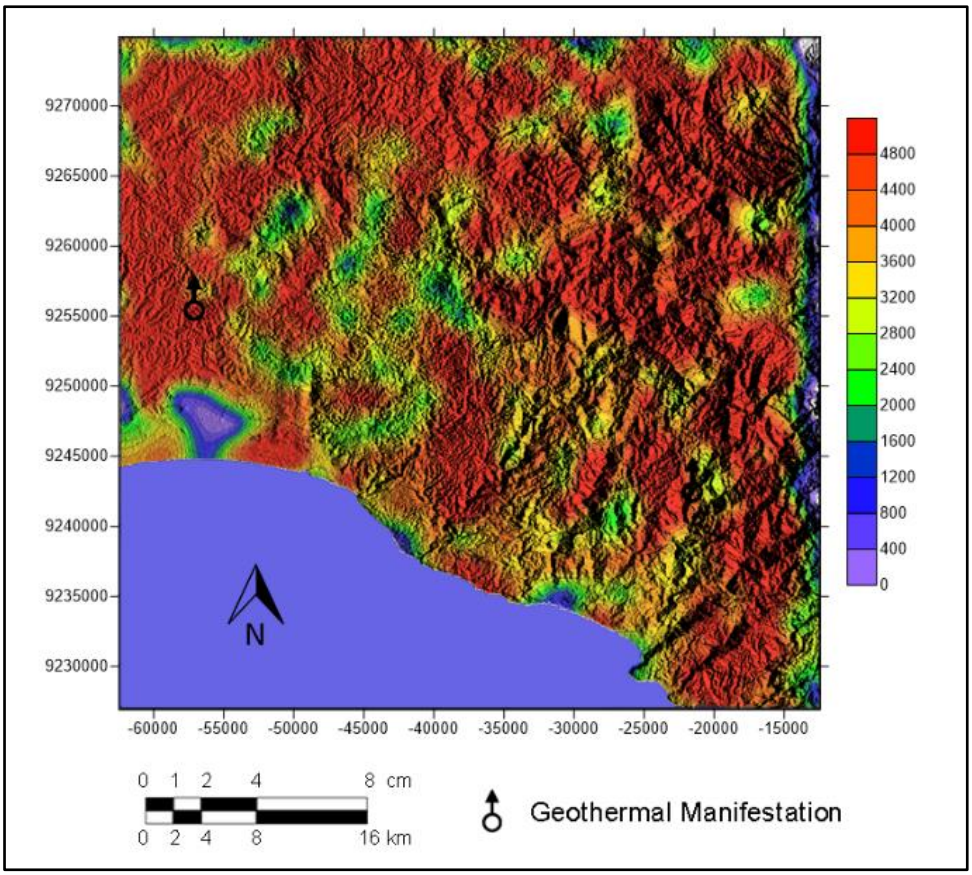

Figure 7. Lineament density map

Major Trend Determination

Results from the analysis of the two previous stages were used in determining major trends in the study area. All of delineation step results are compiled and Rose diagrams are made to find out the dominant orientation of the lineament drawn.

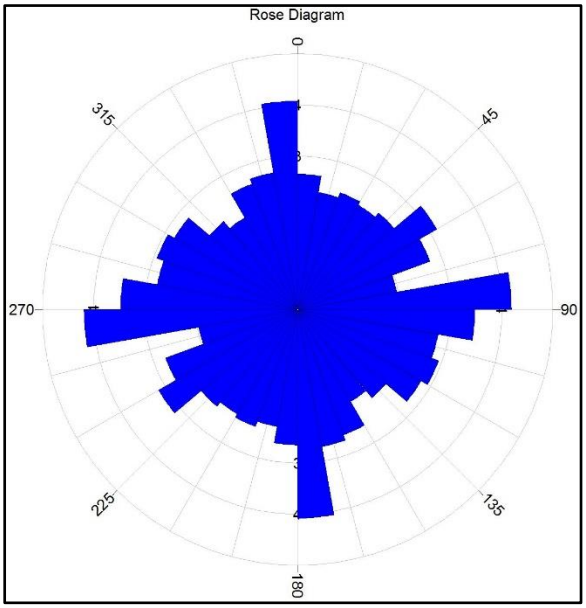

Figure 8. Rose Diagram of study area

Rose diagram above shows two trends of lineament that dominate the abundance in the research area are the NS and EW directions. These two main trends shown in the diagram to have the same dominance.

The EW trends are assumed to be associated with the Java Trends with the same orientation. According to Haryanto (2014) the pattern of EW structures began to form at Early Tertiary due to a new fault that is formed, not from the reactivation of old faults. This pattern controls highs and low lands in Java, including foreland basin, accretional prism, volcanic arc, and back arc (Haryanto, 2014).

The NS trends are assumed to be associated with the Sunda Pattern. This pattern is dominant in the western part of Java Island, while in the east it is hardly visible. According to Haryanto (2014) this structure pattern began to form at the beginning of Paleogen and control the distribution of Eocene sediments and early Miocene in Java.

Wrench Fault Concept Application

In the model of the Wrench Fault concept of Moody & Hill (1956) the three-way stresses effect of compression will produce wrench of varying scales. Order 1 represents the primary wrench that has an angle of approximately 30 º to the direction of the main firm. Order 2 represents secondary wrench. Order 3 is a continuation of Order 2 but not applied in the current study because it is difficult to distinguish the difference from order 1 in the study area. In addition, primary thrust and primary fold was applied in this study. The position of every said elements can be seen at Figure 9.

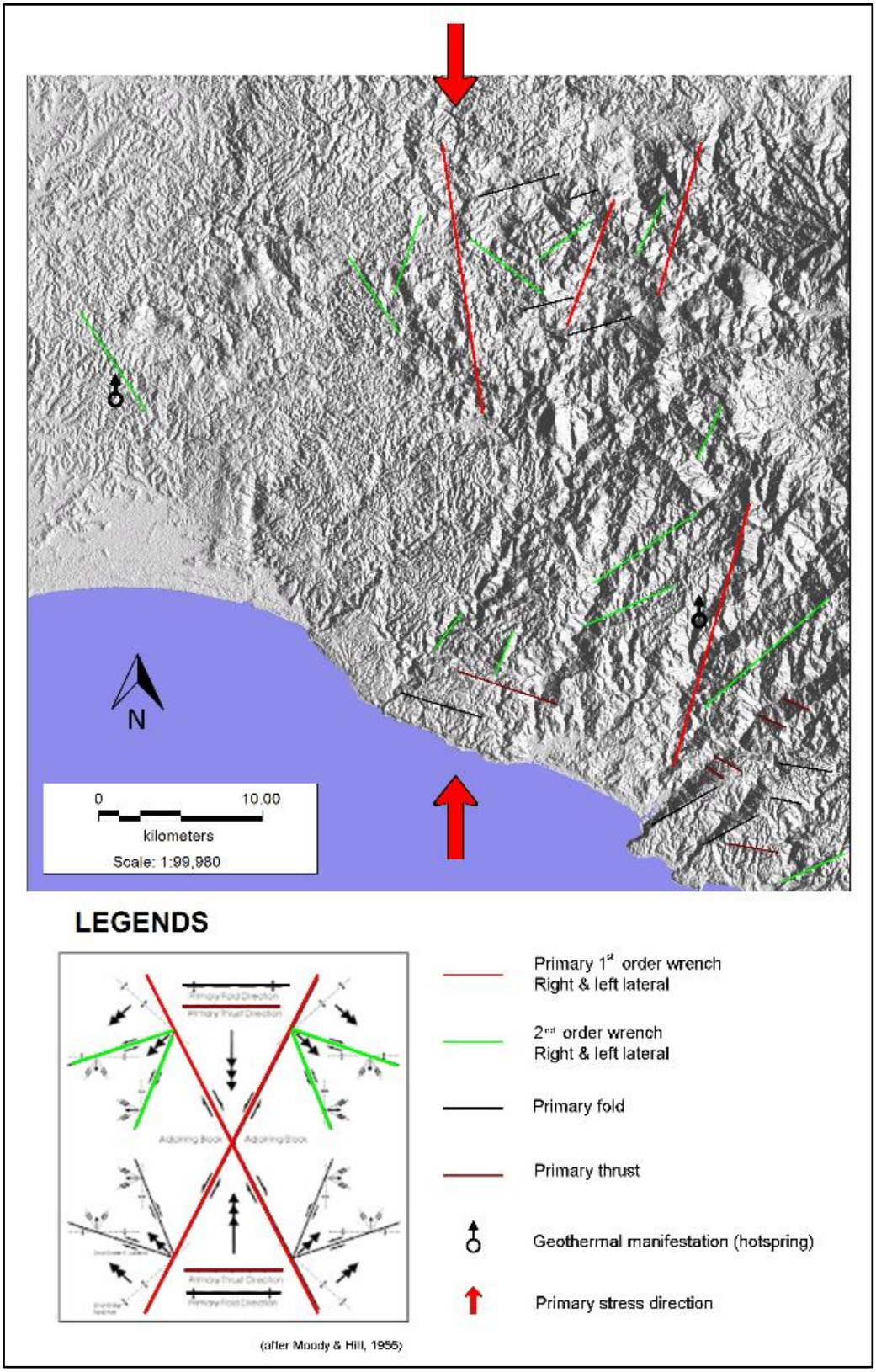

Figure 9. Application of Wrench Fault Concept (Moody and Hill, 1956) in study area

The figure contains the application result of Wrench Fault concept in study area. Four large red lineaments i.e. three NE-SW directional majors are assumed to be primary right lateral wrench and one direction of NW-SE is assumed to be primary left lateral wrench. These four lineaments form an angle of approximately 10º - 30º with NS direction.

The green lines on the map represent the secondary wrench. NNE-SSW and WNW-ESE directional alignment is assumed to be a secondary right lateral wrench. While the orientation of the oriented ENE-WSW and NNW-SSE is assumed to be a secondary left lateral wrench.

The black line is assumed to be the primary fold due to the main stress. While the brown line is assumed to be the primary thrust. In the study area, primary fold and primary thrust are tend perpendicular to the NS direction.

Looking at the results of the concept application, it can be deduced that the main direction of compression stress of the research area is from NS direction, according to the fault and fold in the model orientation. The red line that is assumed to be the primary fault forms an angle of ± 30 º with NS direction. The green colored lines that are assumed to be secondary fault have an orientation that corresponds to the Wrench Fault concept model. Similarly, the primary fault and primary fold that are perpendicular to the direction of main stress direction make the interpretation more convincing.

Geothermal Manifestation

Manifestations in the research area are located in two districts, namely Cibeber District in the southeast and Malingping District in southwest of Lebak Regency. Through the structural analysis that has been done, these two manifestations show a relationship with the existing majors.

Pamancalan hot springs are located in Sukamulya, Cibeber District, located in the southwest region of Lebak Regency. Pamancalan hot springs are divided into three springs. The first hot spring come out of the rock gap and spread over 20 meters. The second hot spring located across the location of the first hot spring. While the third hot spring is on the river bank.

Citando hot spring is located in the village of Senang Hati, Malingping District, located in the southeastern region of Lebak Regency. At this spring there is precipitated iron oxide and sinter carbonate. These hot springs have been utilized for baths.

On the lineament density map, the Pamancalan hot springs are in the orange contour area, indicating areas of high density value of lineament, ranged about 3600-4400 m/km^2. While Citando hot springs appear on red contours that indicate the highest value of lineament density, which value is over 4800 m/km^2.

Based on the determination of the major trends, hot springs Pamancalan and Citando seems to associated with lineaments that tends to orient toward the NS. This trend is one of the main trends that the development is dominant in the research area.

Based on the results of the Wrench Fault model application, the Pamancalan hot springs have an association with the lineament that is assumed to be the primary right lateral wrench. While the Citando hot spring has an association with the lineament that is assumed to be secondary left lateral wrench.

CONCLUSION

Distribution of lineaments and structural patterns are important parameters for permeable zones indicated by geothermal manifestasion occurrence. The research area shows a good distribution of lineaments with almost all of research areas fall into the category of high lineaments density of above 2000 m / km^2. The study area shows the main trends of directional directional NS and EW, which are assumed to be associated with Sunda Trends and Java Trends, respectively. The study area also showed compatibility with the Wrench Fault system model from Moody and Hill (1956) with the main stress of NS direction.

Pamancalan hot springs are associated with high value of lineaments density, which are 3600-4400 m/km^2, associated with an NS oriented lineament and also associated with primary right lateral wrench in the model of Wrench Fault model.

Citando hot spring is associated with a very high density area of lineament density value, which is over 4800 m/km^2. This spring is associated with a lineament with NNW-SSE directional tendencies and also with secondary left lateral wrench.

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