

Interpretation of Lineament and Shallow Structure in Gunung Batu - Lembang Area Based on 2D Resistivity Method

Penafsiran Kelurusan dan Struktur Dangkal di Daerah Gunung Batu - Lembang Berdasarkan Metode Tahanan Jenis 2D

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ABSTRACT

Lembang fault is still considered to be active today. The fault provides a distinctive and attractive geomorphology and is significantly explored and developed as a natural tourism destination, one of the areas is located in Gunung Batu. The research location is in the western area of Gunung Batu as a part of the Lembang fault segment. To understand the underlying geological indication that is related to the potential for resource and disaster, a geophysics study using the 2D resistivity approach is necessary. This resistivity method utilizes the electrical properties of rocks and soil which are described by the distribution of resistivity contrast value. The result of the interpretation 71 meters depth shows five layers of rock with andesite intrusion rocks as a basement. The fault is dominated by normal faults with a relatively West-East direction that cause thickening of >2 layers. These faults are related to the formation of the Lembang fault caused by extensional forces.

Kata kunci: 2D Resistivity, Lineament, Shallow Structure

ABSTRAK

Pergerakan sesar Lembang ditafsirkan masih aktif hingga saat ini, menghasilkan bentang alam yang unik dan indah, sehingga banyak dimanfaatkan dan dikembangkan menjadi objek wisata alam, salah satunya terletak di Gunung Batu. Daerah penelitian terletak di bagian barat Gunung Batu yang merupakan bagian dari segmen sesar Lembang, oleh sebab itu diperlukan penelitian geofisika untuk dapat menafsirkan gejala geologi bawah permukaan yang berhubungan dengan potensi sumberdaya dan bencana, yaitu dengan menggunakan metode tahanan jenis 2D. Metode ini memanfaatkan sifat kelistrikan batuan dan tanah yang digambarkan dengan distribusi perbedaan nilai tahanan jenis. Hasil penafsiran metode tersebut hingga kedalaman 71 meter memperlihatkan lima perlapisan batuan yang dialasi oleh batuan intrusi andesit. Pada daerah ini didominasi patahan normal dengan arah relative Barat-Timur yang mengakibatkan penebalan >2 lapisan. Patahan ini erat hubungannya dengan pembentukan sesar Lembang akibat gaya ekstensional.

Keywords: Gunung Batu, Tahanan Jenis 2D, Kelurusan, Struktur Dangkal

PENDAHULUAN

The development of natural tourism around the Bandung basin, West Java Province-Indonesia is closely related to the previous geological activity to nowadays. One of these is the Lembang fault, which extends for 22 km from Padalarang to Palasari Mountain in a relative west-east

orientation (Brahmantyo and Bachtiar, 2009). It is believed that this fault is still active today, shown by the presence of unique geomorphology and the meandering rivers' drainage pattern (Raharjo, *et al.*, 2015), a crush zone formation in the bedrock (Hartadi, *et al.*, 2015), The presence of morphotectonic activity (Hidayat, 2010), and

the M 2.8 to M 3.3 earthquake activity between 1999 and 2017 (Marjiyono, *et al.*, 2008; Meilano, *et al.*, 2012; Nugraha, *et al.*, 2019; Rasmid, 2014). In addition, the fault produces a unique and attractive geomorphology that benefits a place for tourism. Some of the destinations are Gunung Batu, Tebing Keraton, Floating Market, The Lodge Maribaya, and Curug Omas.

Geophysical survey with shallow penetration is required for the development of this natural tourism destination such as Gunung Batu. The purpose of this study is to interpret lineament and shallow structure. This research performs Two-Dimensional (2D) resistivity methods. Based on the resistivity contrast, this technique may understand the geological indication of shallow sub-surface, including the difference of rock layers, and geological structure, confirmed with surface observation, shallow drilling, and geomagnetic data correlation. The benefit of interpretation results would become a recommendation for natural tourism destination development and a referential data for further research.

The research area is in Langensari - Pagerwangi Rural Village, Lembang Sub-District, West Java Province, Indonesia. The location is in the western part of Gunung Batu, an andesite intrusion that formed 510,000 years before the Lembang Fault (Brahmantyo and Bachtiar, 2009 after Junursyah and Agustya, 2017). The location is in the middle of the intersection of the west and east parts of the Lembang fault segment creating an offset to 300 m (Rasmid, 2014). The research region and the surrounding areas are covered in volcanic rock of Quaternary age (Silitonga, 1973), ranging in age from old to young, which is as follows (Figure 1a): The undifferentiated old volcanic products (Qvu) consist of volcanic breccia, lahar, and lava repeatedly interlayered; Pumice Tuff (Qyt) consists of tuffaceous sand, lapilli, bombs, scoriaceous lava, angular fragments of dense andesite-basalt and pumice fragments; Lava Flows (Qyl); Sandy Tuff (Qyd); and Alluvium (Qa) consist of clay, silt, sand, and gravel.

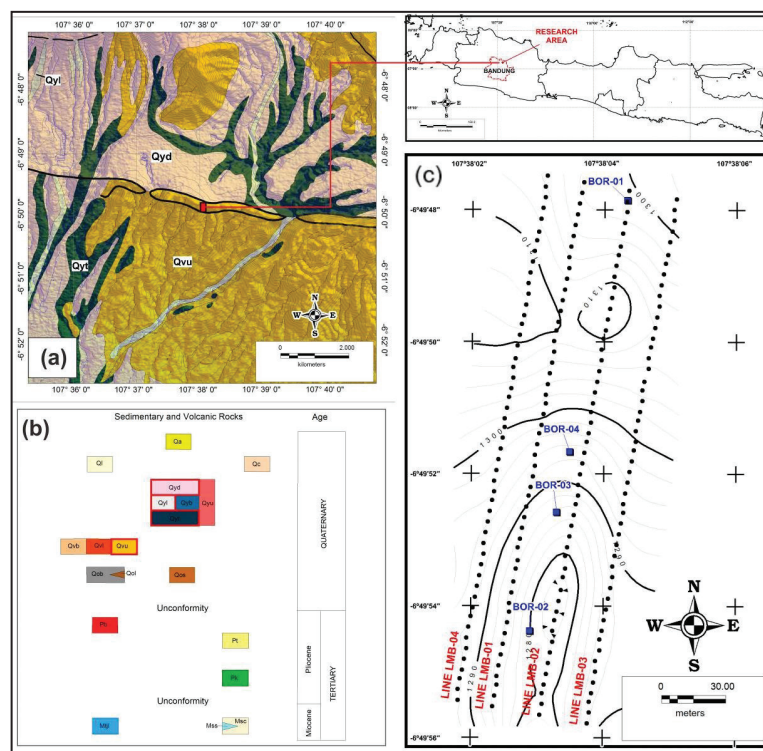


Figure 1. The research area (red square) is correlated with a (a) geological map and (b) regional stratigraphy (modified from Silitonga, 1973); (c) location of 2D - 4D resistivity measurements and shallow boreholes in the research area.

RESEARCH METHOD

The measurement of 2D resistivity method uses Supersting R8/IP instrument and applied four parallel lines with 250 m length and inter-electrode spacing is 5 m. The measurement performed by Center for Geological Survey (Figure 1c) and supported by elevation differential measurement using a Theodolite T-o WILD instrument and four shallow drilling around the Line LMB02 (Praromadani, 2015; Junursyah, 2015; Sugiarto, 2016). In order to be more sensitive to the change in resistivity vertically toward the subsurface, the configuration on 2D resistivity measurement is Wenner (Loke, 2000). Following are some steps in the data processing and interpretation process (Figure 2)

Data Processing: Surface elevation of 2D resistivity measurement data (*.stg format) corrected by elevation difference measurement data (*.trn format) before 2D inversion modeling by Smooth Model Inversion, Damped Least Square, and Robust Inversion (Grandis, 2009). Smooth Model Inversion modeling is minimizing the difference between field data and predicted

model data (Akmam and Sudiar, 2013), the 2D optimum inversion model was chosen based on noise reduction rate and the lowest percentage value of misfit data ($<20\%$), RMS error ($<3\%$), L2 Norm, and Iteration, and also applied in time lapse modeling (4D).

Analysis for Lineament Based on Demnas Image Map: Lineament drawing carried out based on National Digital Elevation Model or Demnas image map (Geospatial Information Agency, 2018) around the research area. This process observes the formation of linear ridge and valley which is related to the lithology changes, vegetation types, and geomorphic relief contrast (Herlambang and Novranza, 2016), as well as the subsurface elements such as fault, joint, fold, and fracture (Firdaus and Setiano, 2018). The observation result is analyzed using a rose diagram based on the domination of frequency and length of azimuth to acquire its relation to the regional structure

Analysis for 2D Resistivity Contrast Value and Magnetic Anomaly: The separation of subsurface layer analysis is based on the

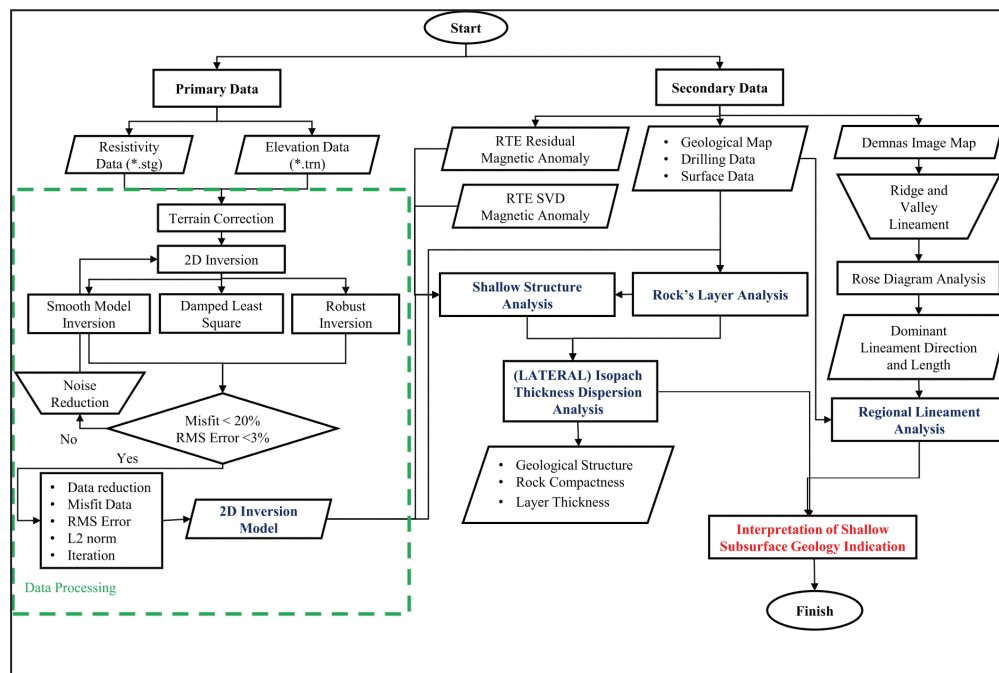


Figure 2. The flowchart of the study included steps of data processing, data analysis, and interpretation for shallow subsurface geology indication.

existence of resistivity contrast value on the 2D inversion modeling which correlated with the shallow drilling data and the surface observation (Junursyah, 2015), and geological map (Silitonga, 1973). Then, the result correlated with SVD and RTE Residual Magnetic data (Junursyah, 2016; Junursyah; 2018) to analyze shallow structures.

Analysis for Isopach Thickness Dispersion: This analysis is performed to determine each layer's thickness dispersion and how it relates to weak zone events and shallow structure dispersion.

Interpretation For Shallow Subsurface Geology Indication: This step is interpreting the formation and distribution of shallow structures in the research area related to rock layers, weak zone, and regional geological structure based on the regional lineament analysis, 2D resistivity contrast value, and isopach thickness dispersion.

RESULT AND ANALYSIS

The analysis results for ridge lineament (Figure 3a) in the rose diagram is interpreted as a result of dominant compressional force (Junursyah and Agustya, 2017). The result shows a dominant

lineament direction based on azimuth length that plotted in azimuth frequency (Figure 4a) from old to young (green-yellow-red color) as follows: 320°-350° direction (relative to Northwest-Southeast) with an increment of frequency to 320°; 270°-300° direction (relative to West-East) with the highest frequency; and 350°-20° direction (relative to North-South) with the lowest frequency. This result shows a lineament formation as a result of two times compressional force, starting from a relative direction of Northwest-Southeast which increases to a West-East direction and continued in a North-South direction.

According to the valley lineament (Figure 3b) analysis results in a rose diagram interpreted as a result of dominant extensional force (Junursyah and Agustya, 2017). The result shows a dominant lineament direction established from old to young, which is 280°-290° direction (relative to West-East direction) with a highest frequency decrease gradually to 330°-350° direction (relative to Northwest-Southeast), then, continued to 350°-30° (relative to North-South). Thus, the gradual decrease in extensional force from a West-East relative direction to a North-South relative direction is seen as the cause of linea-

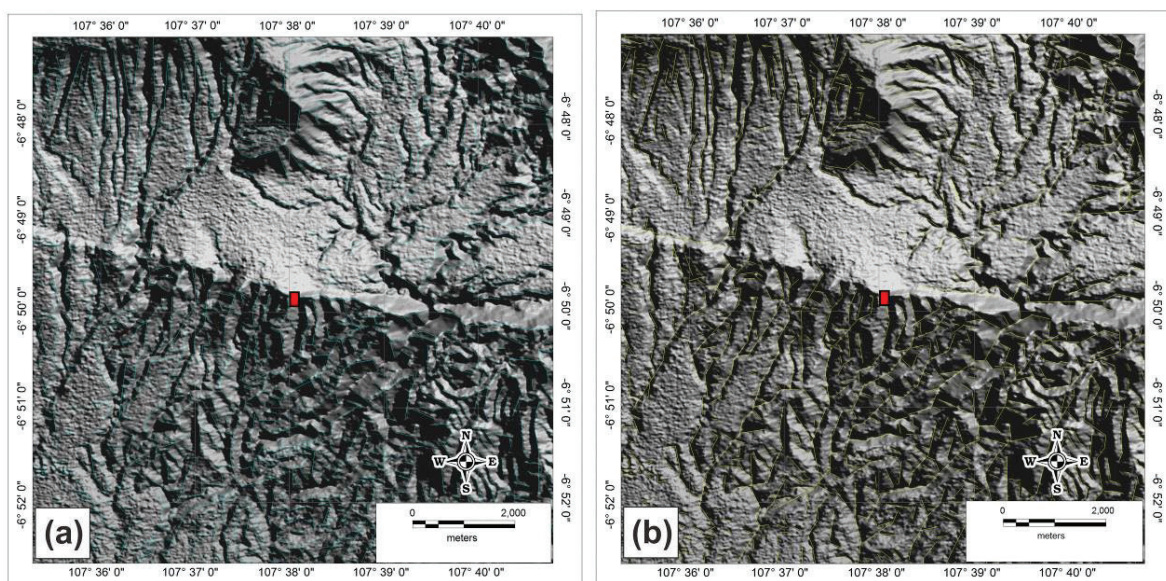


Figure 3. Lineament drawing on Demnas Images Map around the research area (red square) based on (a) ridge (blue line) and (b) valley (yellow line).

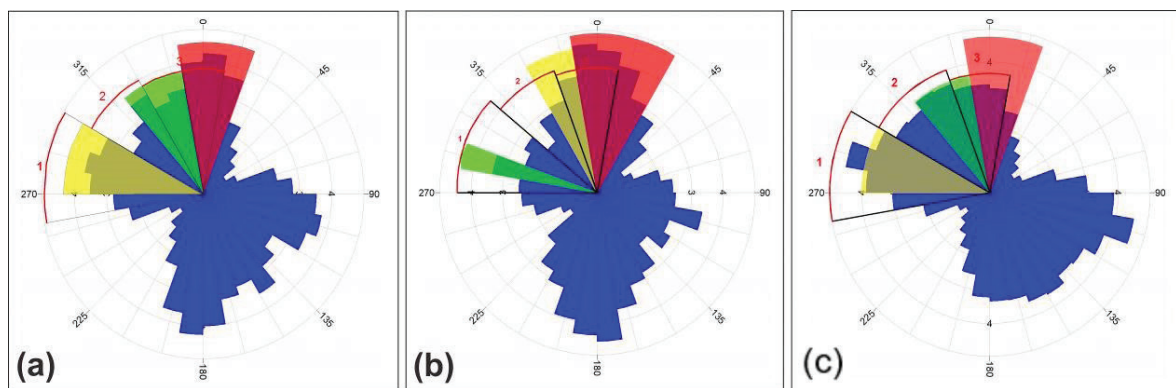


Figure 4. Rose diagram analysis based on azimuth magnitude that plotted in azimuth frequency (a) ridge lineament; (b) valley lineament; (c) composite lineament of ridge and valley.

ment creation (Figure 4b). Composite lineament analysis of ridge and valley in the rose diagram is performed to determine the dominant force in the research area in a series, from old to young (Figure 4c).

Lineament directed to 320°-350° (relative to Northwest-Southeast) with increment to West-East direction dependent on its frequency. A formation of lineament as compressional force results interpreted as a preliminary event and is closely related to the Lembang fault system in the form of a horizontal reverse fault (Rasmi, 2014), then continued by extensional force which is related to extensional joint formation around Gunung Batu, causes a dextral-normal oblique fault (Junursyah and Agustya, 2017).

A dominant lineament with 270°-300° direction (relative to West-East) exists in the research area according to frequency and tends to decrease relatively to North-South direction. The lineament formation is initiated by the effect of extensional force which is closely related to the formation of the Lembang fault formation in the form of a horizontal sinistral fault (Junursyah and Agustya, 2017). The western area is more active than the east area (Hidayat, 2010) and continued by compressional force that is related to fault reactivation which forms previously (Rasmi, 2014).

Lineament to 350°-20° direction (relative to North-South) is dominated by the formation of compressional and extensional force combined

with the lowest frequency. This is closely related to the formation of the normal dextral oblique fault and sinistral oblique normal fault (Junursyah and Agustya, 2017).

Resistivity contrast value analyses in four models of 2D resistivity section have a variance of 16.5 - 184 Ωm and in between 62 m to 71 m of depth. The result of correlation with shallow drilling data, surface observation, and regional geological map, and then the interpretation explains some rock's layers from old to young, which are (Figure 5 - Figure 8).

Layer-1 (L-1): the variance of resistivity value is 78.1 - 184 Ωm which increases to the center of the layer and forms a closure. The bottom part border is not defined clearly and the upper part shows an elevation that progressively becomes shallower toward Line LMB-04 and the north direction of a line. Its believed the layer is a part of andesite intrusion rock which appears and forms a Gunung Batu (Junursyah and Agustya, 2017).

Layer-2 (L-2): the variance of resistivity value is 48.9 - 78.1 Ωm tends to gradually decrease to the top of the layers and the dispersion closes the Layer-1. According to the surface observation around the Line LMB-04, this layer consists of fragment disjoint of igneous rock boulders with insitu weathering (Junursyah, 2015). The bed-rock has been weathered characterized by a high range of resistivity values (Asry, *et al*, 2012).

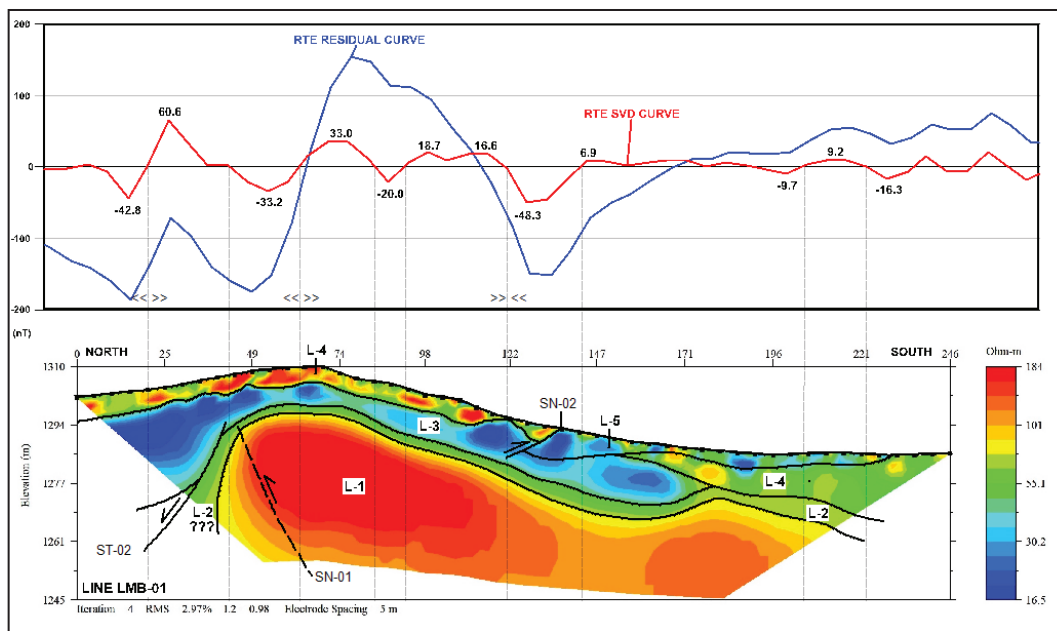


Figure 5. The result of shallow structural and rock layers analysis in Line LMB-01 shows the existence of reverse and normal faults.

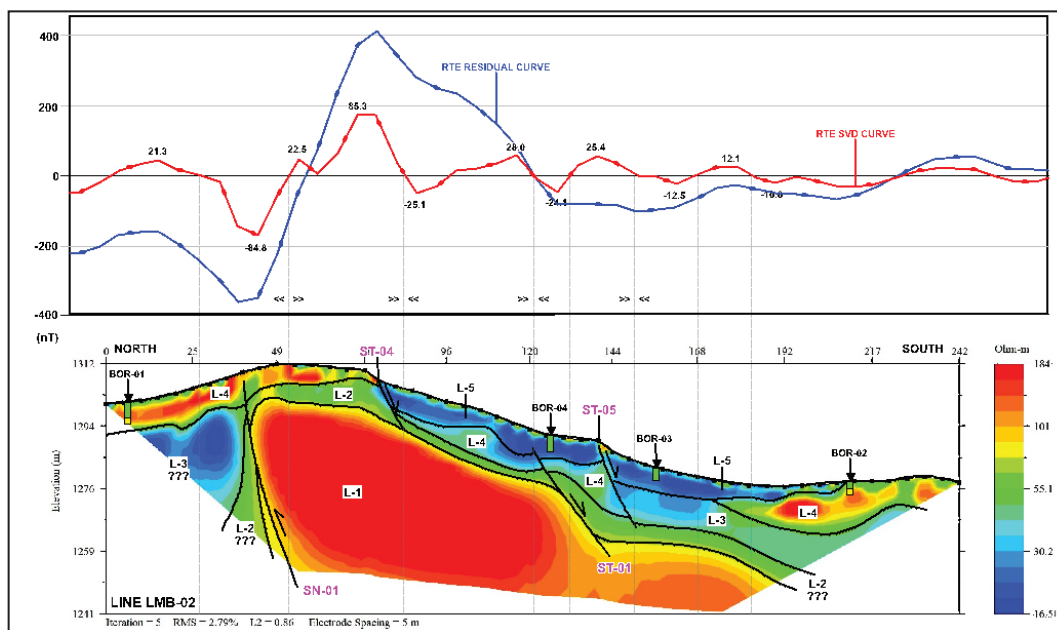


Figure 6. The result of shallow structural and rock layers analysis in Line LMB-02 shows a dominant formation of normal fault.

Layer-3 (L-3): the variance of resistivity value is in the range of 16.5 - 48.9 Ωm which decrease gradually to the center of the layer, the dispersion almost covers all the layer of Layer-2 and is lensed in some locations. According to a relatively low resistivity value, Layer 3 is believed to be composed of fine-grained rock

with a permeable property or to contain water (Junursyah and Agustya, 2017).

Layer-4 (L-4): surface layer with resistivity values variance of 48.9 - 184 Ωm which increase to the center of the layer, the dispersion covers its bottom layers inharmoniously and shows loading structure, and some areas are eroded by Layer-5.

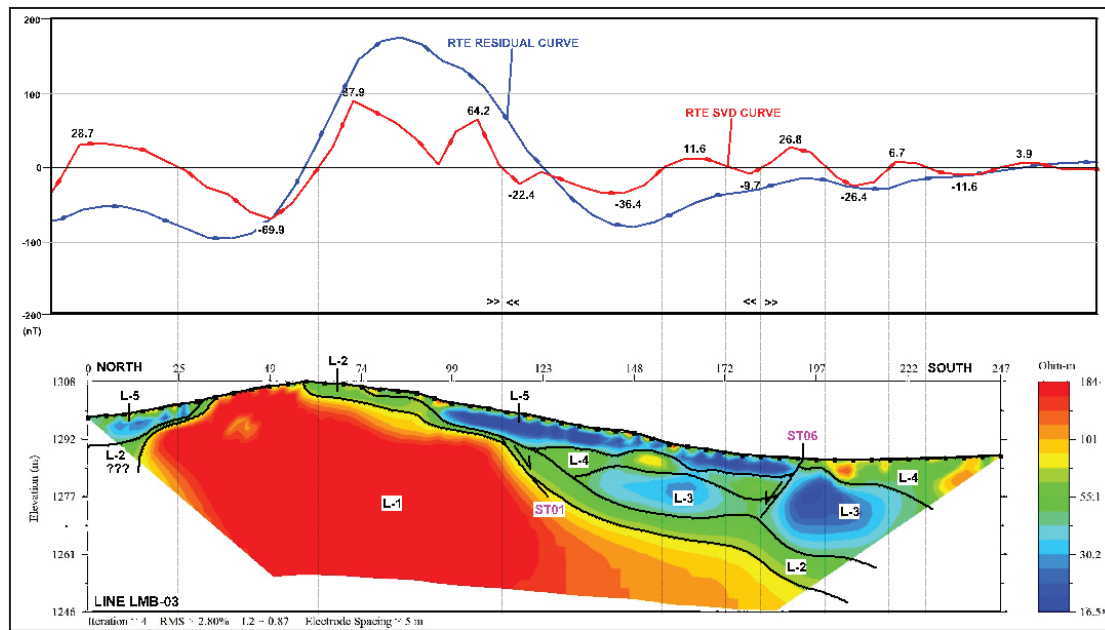


Figure 7. The result of shallow structural and rock layers analysis in Line LMB-03 based on the 2D inversion model which correlated and validated with the contrast of SVD value and residual of magnetic RTE.

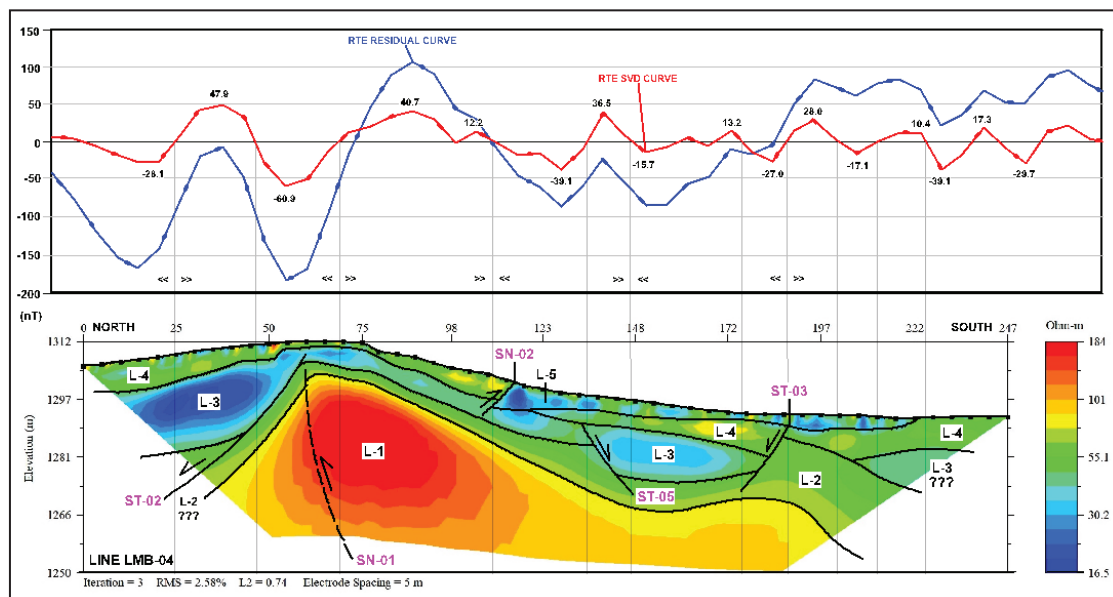


Figure 8. The result of shallow structural and rock layers analysis in Line LMB-04 shows the existence of reverse and normal faults.

According to field observation and shallow drilling data (Junursyah, 2015), this layer consists of igneous rocks fragment component that have weathered into the soil, solid and plastic characteristic with grain rough downward.

Layer-5 (L-5): surface layer with resistivity variance is dominant in the bottom part and the range

is 16.5 - 48.9 Ωm and covered by a thin layer on the upper area with a resistivity value variance is 48.9 – 184 Ωm . The dispersion is crosses and erosions the bottom layer inharmoniously. According to field observation and shallow drilling data, this layer is a soil from weathering with solid and plastic characteristics and permeable.

Shallow structural analysis was performed in four models of 2D resistivity section based on the observation of the change in resistivity contrast value as a response to various sources of the subsurface. The subsurface is influenced by mineral content, porosity, and rock saturation (Dzakiya, *et al.*, 2017). Additionally, there is a discontinuity and a change of contour pattern significantly and interpreted as the formation indicator of structure (Lutfinur, *et al.*, 2015). The analysis result continued by correlation and validation process with a section of SVD and RTE Residual Magnetic, shows an oscillation response between an extreme magnetic value of minimum and maximum in every contrast transition (Sumintadireja, *et al.*, 2018) as an indicator of structure and intrusion formation (Setiadi and Pratama, 2018; Sari, *et al.*, 2018).

The shallow structural analysis result of Line LMB-01 based on resistivity contrast value shows an increment of variation and thickness southward and northward of the line, limited and controlled by elevation (up to 1310.2 m) as the result of the formation of Layer-1. The result also explains three primary structures which form from young to old (Figure 5).

Reverse/Horizontal Fault (SN-01): The fault crosses the L-1 and L-2 layer with vertical contrast characteristic of resistivity value on hangingwall is higher than footwall (78.1 - 184 Ω m) which separates the thickness and layer elevation L-1 to the north area. The value of maximum absolute magnetic SVD is (33.0 nT) $\leq$ minimum (-33.2 nT) and magnetic RTE residual value (-174.7 to 154.3 nT) increases southward as the characteristic of reverse fault/horizontal formation on the rocks with significant composition differences.

Normal Fault (ST-02): This fault crosses the L-2 and L-1 layer, which footwall has a greater number of vertical contrast characteristics than the hangingwall (16.5 - 78.1 Ω m) which is thicker to the north; absolute magnetic SVD value [60.6 nT] $>$ [-42.8 nT]; and magnetic RTE residual value (-69.9 to -185.3 nT) decrease to

the north as the feature of normal fault formation in sedimentary rocks which experience a thickness to the north of section.

Reverse Fault (SN-02): This fault crosses the L-3 to L-5 layer, indicated by existences of resistivity value of contrast vertical on hangingwall is higher than footwall (16.5 - 184 Ω m) which limit the dispersion of L-4 and L-5 layer; absolute magnetic SVD value [16.6 nT] $<$ [-48.3 nT]; and magnetic RTE residual value (154.3 to -151.3 nT) is decreased to the south area, as a feature of reverse fault formation in the rock with a significant difference.

The subsurface structural analysis result of Line LMB-02 with variation and thickness direction of rock's layer is much more contrast than Line LMB-01 with an elevation up to 1311.7 m. The result shows four primary structures forms from young to old (Figure 6).

Reverse Fault (SN-01): The reverse fault is probably the continuity of Line LMB-01 and the fault crosses the L-1 to L-4 layer, indicated by the vertical of resistivity contrast value on the hangingwall is higher than the footwall (55.1 - 184 Ω m); absolute magnetic SVD value [22.5 nT] $<$ [-84.8 nT]; and magnetic RTE residual value (-362.7 to 410.8 nT) is increase to the south area.

Normal/Horizontal Fault (ST-01): This fault crosses the L-1 to L-5 layer, hangingwall has a fewer number of vertical contrast of resistivity value than the footwall (55.1 - 184 Ω m), the bottom part feature is a thickness of L-2 Layer to the south; absolute magnetic SVD value [28.0 nT] $>$ [-24.1 nT]; and magnetic RTE residual value (410.8 to -80.1 nT) is decrease to the south which the characteristic of normal/horizontal fault formation with sediment thickness southward.

Normal Fault (ST-04): This fault crosses the L-2 to L-5 layer. The features are vertical contrast of resistivity value on hangingwall is lower than footwall (16.5 - 184 Ω m) which limits the dispersion of L-5 layer; absolute magnetic SVD value [85.3 nT] $>$ [-25.1 nT]; and high

magnetic RTE residual values decrease southward, becomes the characteristic of normal fault formation with sediment thickness to the south area of the section.

Normal Fault (ST-05): This fault crosses the L-3 to L-5 layer and the hangingwall has a fewer number of vertical contrast of resistivity value than the footwall (16.5 - 55.1 Ωm) which limits the dispersion of L-3 and L-4 layer; absolute Magnetic SVD value [25.4 nT] > [-12.5 nT]; and low value of magnetic RTE residual is not significantly changed and decrease southward, becomes the characteristic of normal fault in thick sediment.

Rock's layer on Line LMB-03 has more thickness variation to the south of the section based on resistivity contrast value, limited by Layer-1 elevation which appears to the surface to 1308 m height. Based on the contrast analysis of resistivity value, correlated with the contrast of SVD value and residual of magnetic RTE, there are two formations of primary structure from old to young, which are (Figure 7).

Normal Fault (ST-01): This fault is possibly the continuity of others similar fault characteristics in Line LMB-02 that shows a dominant formation of normal fault (absolute magnetic SVD value [64.2 nT] > [-22.4 nT] decrease southward) and crosses the L-1 and L-2 layer, indicates by vertical contrast of resistivity value on hangingwall is lower than footwall (48.9 - 184 Ωm) and high magnetic RTE residual value decrease southward (701.5 to -317.9 nT).

Normal Fault (ST-06): This fault crosses the L-3 to L-5 layer. The characteristics of this fault are vertical contrast of resistivity value on the hangingwall is lower than footwall (16.5 - 121.8 Ωm) based on the feature of L-4 layer thickness to the north and eroded the L-3 layer, absolute magnetic SVD value [26.8 nT] > [-9.7 nT] decrease northward and becomes the normal fault formation feature, and magnetic RTE residual value change is not significant as the feature of the formation of young structure in a thick sediment.

Line LMB-04 consists of five rock layers. The subsurface structural analysis result explains the rock's layer is much more contrast in dispersion variation then Line LMB-01 and controlled by elevation to 1312.1 m, and shows five primary structures formed from old to young. The analysis results are (Figure 8).

Reverse Fault (SN-01): This fault is possibly the continuity of others similar fault with Line LMB-01 and LMB-02 characteristic which crosses the L-1 and L-1 Layer. This fault has vertical contrast of resistivity value on hangingwall is higher than footwall (78.1 - 184 Ωm), separates the dispersion and height of L-1 layer to the north; absolute magnetic SVD value [40.7 nT] < [-60.9 nT]; and magnetic RTE residual value (-187.6 to 106.3 nT) increases southward.

Normal Fault (ST-02): This fault may be a continuation of other faults with characteristics similar to Line LMB-01 that traverse the L-2 and L-3 Layers. This fault has vertical contrast of resistivity value on hangingwall is lower than footwall (16.5 - 78.1 Ωm) with thickness L-3 layer to the north area; absolute magnetic SVD value [47.9 nT] > [-28.1 nT]; and magnetic RTE residual value (-8.5 to -170.8 nT) is increase to the north area.

Normal/Horizontal Fault (ST-03): This fault crosses the L-2 to L-4 layer which hangingwall has a fewer number of vertical contrast resistivity values than the footwall (30.2 - 55.1 Ωm) with layer thickness of L-4 northward; absolute magnetic SVD value [28 nT] > [-27 nT]; and magnetic RTE residual value (80.9 to -86.4 nT) is decrease to the north which the characteristic of normal/horizontal fault.

Normal Fault (ST-05): A continuity of the fault on line LMB-02 is found in this line which crosses the L-2 and L-3 layers. There is a thickening of the L-3 layer to the south area, and has vertical contrast of resistivity value on the footwall is higher than the hangingwall (30.2 - 78.1 Ωm); absolute magnetic SVD value [36.5 nT] > [-15.7 nT]; and magnetic RTE residual value (-25.5 to -86.4 nT) is decreased to the south area.

Reverse Fault (SN-02): This fault was found with the same characteristics as on the line LMB-01 which crosses the L-3 to L-5 layer, limits the dispersion of L-4 and L-5 layer, and has a contrast resistivity value of hangingwall is higher than footwall (16.5 - 78.1 Ω m); absolute magnetic SVD value $[12.2 \text{ nT}] < [-39.1 \text{ nT}]$; and magnetic RTE residual value (106.3 to - 88.7 nT) is decrease to the south area, as a feature of reverse fault formation in the rock with a significant difference.

Dispersion analysis of isopach thickness is based on the interpretation of 2D resistivity contrast value on definite borders layer (L-2 Layer to L-5 Layer). In addition, L-1 Layer considered as a base rock with a bottom part border cannot identify clearly. This analysis was conducted to determine the dispersion of thickness of each layer and its correlation to the shallow structure formation and weak zone.

Isopach dispersion analysis of L-2 layer explains a thickness from 1.9 m to 12.9 m and the average is 5.2 m (Figure 9a). There are thickening layers in some areas. The dispersion that is controlled by the reverse fault SN-01 on the footwall portion and thicker on the hangingwall of ST-02 normal fault is in the north area ($>5.2 \text{ m}$) toward the northwest. The footwall portion of the ST-04 normal fault exhibits the highest elevation (1310 m) of the closure contour in the south. The hangingwall of normal fault ST-01 and ST-05 in the center areas to the south-southeast direction is thinning locally. The center area to the south-northwest direction eroded on the hangingwall as the result of normal fault control of ST-03 and ST-05.

Isopach dispersion analysis of L-3 layer explains a thickness from 0.9 m to 22.5 m and the average is 7.6 m (Figure 9b). There are layer thickening in some research locations. Due to the control

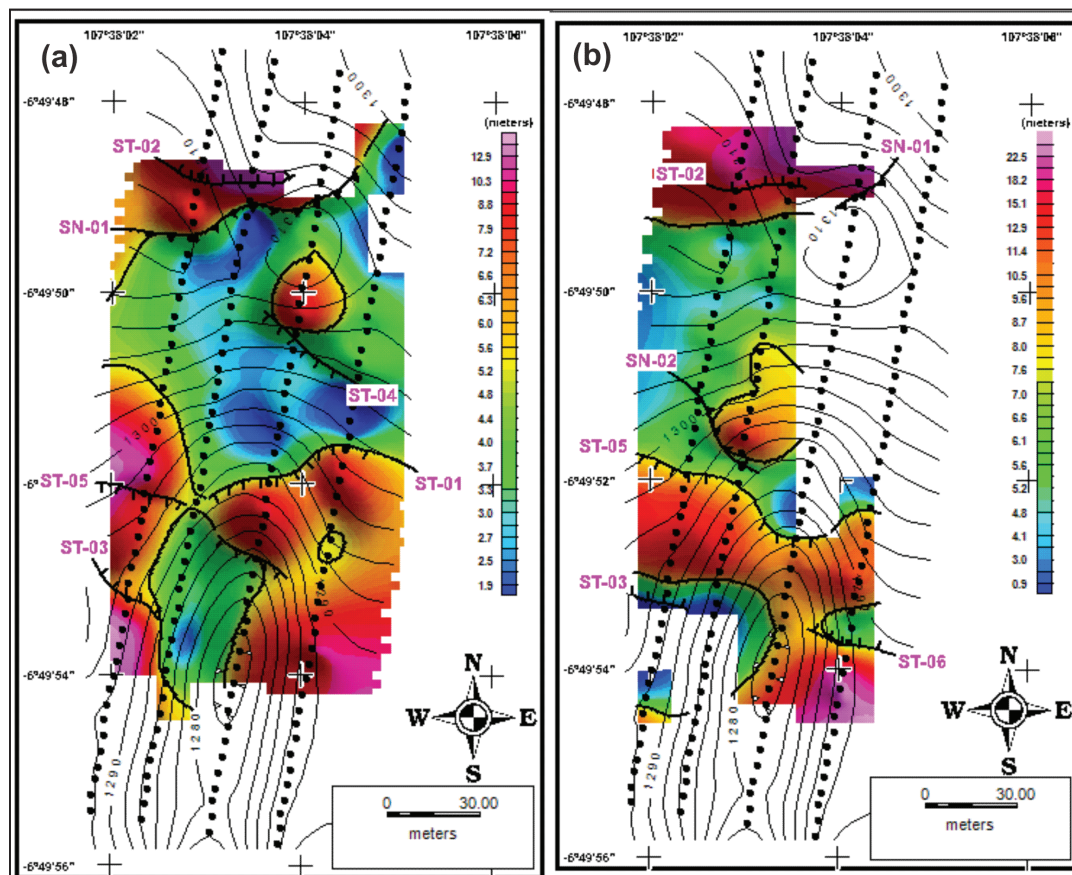


Figure 9. Analysis of layer thickness, shallow structures, and isopach dispersion on lateral distribution at (a) L-2 layer; and (b) L-3 layer.

of SN-02's reverse fault activity on the footwall region and the thicker ST-02's normal fault on the footwall, the north area (>7.6 m) seems to face north with relative dispersion to the west and east. The center area appears locally on the hangingwall from the reverse fault of SN-02. The center area towards to south-southeast is on the hanging wall of normal fault ST-05 and normal fault of ST-03 and ST-06 locally thinning. Based on the isopach distribution of L-3 layer, ST-05 and ST-06 cause a thickening area around the fault zone.

Analysis for isopach dispersion of L-4 shows layer thickness from 1.5 m to 10.4 m (Figure 10a). The thickness can be found in some places. The north section (>5.0 m) is located substantially to the northeast and some of its thickness is governed by the SN-01 reverse fault. The center area thickness is controlled by ST-01 and ST-05 fault activity on the footwall

part. Some parts of the south area are controlled by normal faults of ST-03 and ST-06 and are dominated by topography contour slopes that gradually decrease significantly to the south direction. Isopach dispersion analysis result of L-5 layer explains a thickness reaches 7.5 m and the average is 4.4 m (Figure 10b). A layer thickness exists in the center of the research area with dispersion direction relative to Northwest-Southeast (>4.4 m). The thickening of this layer is not affected by the fault. It is because the material of the layers closes to the surface change frequently.

DISCUSSION

The findings and analysis above explained the shallow subsurface geological indication on Gunung Batu's western flank, layer analysis and shallow structure from 2D resistivity contrast

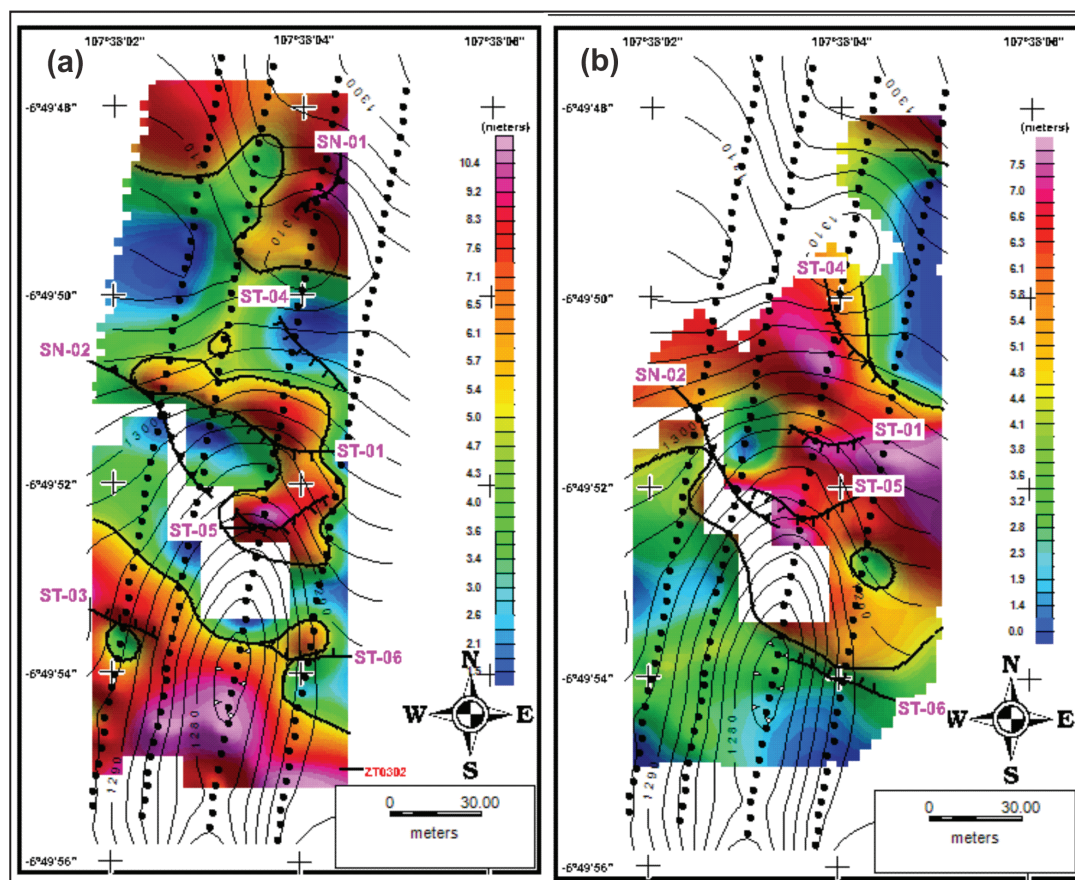


Figure 10. Analysis of layer thickness, shallow structures, and isopach dispersion on lateral distribution at (a) L-4 layer; (b) L-5 layer.

value section which correlated with magnetic anomaly value graphic (SVD and RTE), analysis of shallow structure formation which related to a thickness of the layer in the research area that reaches 71 m from old to young, and analysis for isopach dispersion. The interpretations are shown in Table 1 and Figure 11.

Reverse Fault SN-01: This fault relatively to northwest-northeast crosses the L-1 to L-3 layers, including the L-4 layer in the northeast area as a result of its activity development. According to regional lineament, most of the formation process of this fault is not at the surface. The fault zone is insignificant and did not cause layer

Table 1. The shallow structures analysis related to the layer in the western part of Gunung Batu.

Shallow Structure	Type of Fault	Crosses Layer	Thickness area>2 Layers
SN-01	Reverse Fault (250°-260°); south area is relatively up.	L-1; L-2; L-3; L-4;	-
ST-01	Normal Fault (280°-290°); south area is relatively down.	L-1; L-2; L-4; L-5;	Yes
ST-02	Normal Fault (270°-280°); north area is relatively down.	L-2; L-3;	Yes
ST-03	Normal Fault (290°-300°); north area is relatively down.	L-2; L-3; L-4;	-
ST-04	Normal Fault (320°-330°); south area is relatively down.	L-2; L-4; L-5;	-
ST-05	Normal Fault (280°-290°); south area is relatively down.	L-2; L-3; L-4; L-5;	Yes
ST-06	Normal Fault (290°-300°); north area is relatively down.	L-3; L-4; L-5;	Yes
SN-02	Reverse Fault (310°-320°); north area is relatively up.	L-3; L-4; L-5;	Yes

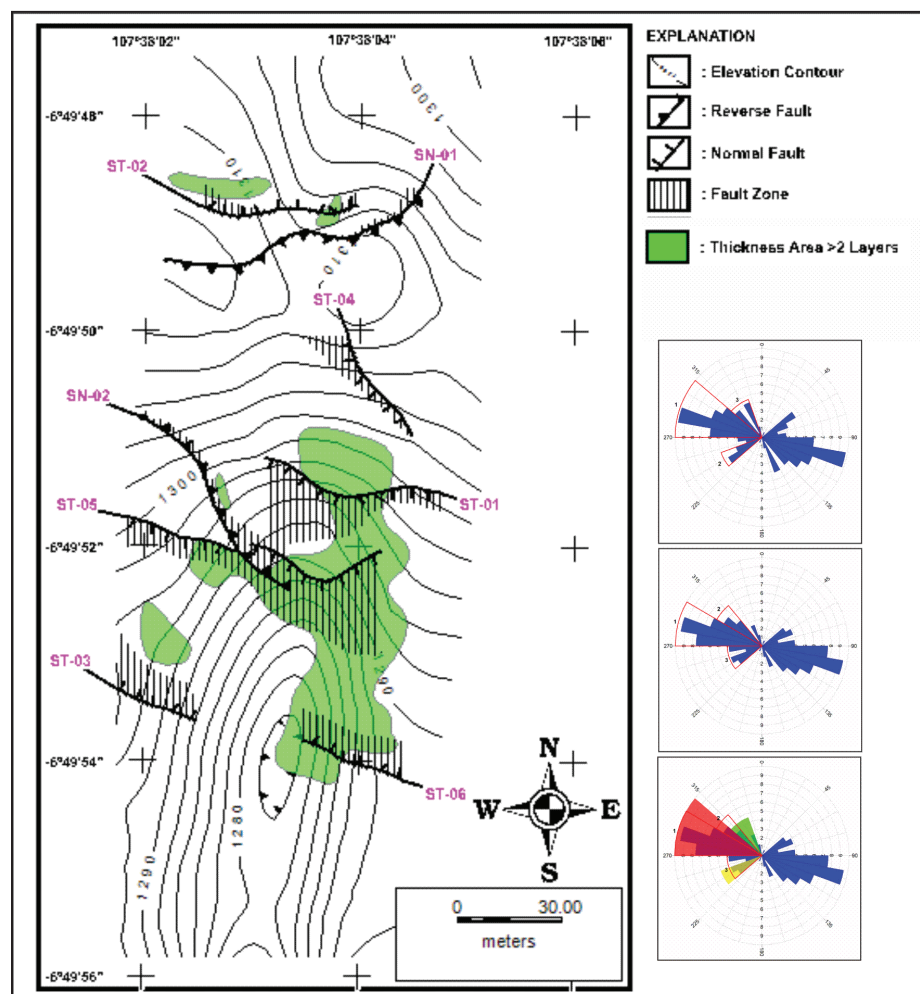


Figure 11. The shallow structure distribution in the research area. Rose diagram analysis of shallow structures lineament based on (a) azimuth magnitude; (b) azimuth frequency; and (c) composite of azimuth magnitude and frequency.

thickening. As a result, the interpretation should be closely related to the early of Lembang fault system formation in the north area (Rasmid, 2014; Junursyah and Agustya, 2017) that forms a ridge with elevation reaching 1312.1 m in the west area of the research location.

Normal Fault ST-01: This fault is relatively in the West-East direction and crosses the L-1 to L-2 Layer and continued to L-4 and L-5 layers in the west area as a result of its activity development. Nearly all layers in that area (>2 layers) encounter thicknesses ranging from 5.2 m to 7.6 m due to slope, and the direction of dispersion is to the south. According to regional lineament, this fault is closely related to the Lembang fault formation in the south area (Junursyah and Agustya, 2017), followed by the activity of normal fault formation of ST-02, ST-03, ST-05, and ST-06 with similar relative directions.

Normal Fault ST-02: This fault crosses the L-2 Layer and is a result of insitu weathering from andesite intrusive rock and L-3 Layer in the north area. A thickness layer locally in the west and east area as a result of fault activity. According to regional lineament, a chance for the formation of this fault is closely related to the Lembang fault formation in the north area (Junursyah and Agustya, 2017).

Normal Fault ST-03: This fault crosses the L-2 and L-4 Layer interpreted as no significant activity event. This fault has a wide fault zone, but is not related to layer thickening to the north. Based on lineament and similar direction with the normal fault of ST-06, the interpretation of these two faults has an interrelated connection and is separated by stratigraphy contact and erosional plane.

Normal Fault ST-04: This fault does not result in layer thickening because it crosses the L-2 to L-5 Layer in the form of weathering soil with permeability characteristics. The interpretation, this fault has no significant activity, interpreted as equal to the Lembang fault activity of orde-2 in the form of a dextral-normal oblique fault that forms a negative flower structure in the body

of surface intrusion (Junursyah and Agustya, 2017).

Normal Fault ST-05: This fault crosses the L-2 to L-5 Layer and cut by reverse fault SN-02, along with the fault activity that is dominantly to the east direction. This fault has a wide fault zone in the east and causes the thickening of >2 layers in the south.

Normal Fault ST-06: This fault crosses the L-3 to L-5 Layer. This fault is relative to the West-East direction closely related to the Lembang fault direction. This fault has a fault zone in the north and restricts the layer thickening in the south.

Reverse Fault SN-02: The development of this fault crosses the normal fault of ST-05 and L-3 to L-5 layers. There is a thickening of >2 layers at the southeast of this fault. According to the regional lineament, a chance for the formation of this fault is closely related to the final phase of Lembang fault formation (Junursyah and Agustya, 2017) and correlates with the faults re-activity that creates previously (Rasmid, 2014).

CONCLUSION

The western area of Gunung Batu had a strong correlation with Lembang fault activity, which is still believed to be active today. According to the 2D resistivity section, we can interpret the subsurface geology indication to a depth of 71 m. The five distinct rock layers range in age from old to young, which are Andesite intrusion, an insitu weathering rock of Andesite intrusion, fine-grained permeable layer, weathering soil from igneous rocks, and permeable soil. There is a dominant active fault indication that forms simultaneously with the development of the Lembang fault system. According to the lineaments in the research area, the fault is dominated by normal faults with a relatively West-East direction. According to lateral isopach distribution, there is a layer thickness of 5.2 – 22.5 m controlled by the structure. Structures that cause thickening of >2 layers include ST-01, ST-02, ST-05, ST-06, and SN-02. These faults are

closely related to the formation of the Lembang fault caused by extensional forces.

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REFERENCES

- Akmam and Sudiar, N.Y., 2013. Analisis Struktur Batuan dengan Metoda Inversi Smoothness-Constrained Least-Squares Data Geolistrik Konfigurasi Schlumberger di Universitas Negeri Padang Kampus Air Tawar. *Prosiding Semirata FMIPA Universitas Lampung*, Lampung: 215-220.
- Asry, Z., Samsudin, A.R., Yaacob, W.Z., Yaakub, J., 2012. Groundwater Investigation Using Electrical Resistivity Imaging Technique at Sg. Udang, Melaka, Malaysia. *Bulletin of the Geological Society of Malaysia*. Vol. 58: 55-58. DOI: 10.7186/bgsm58201209.
- Brahmantyo, B., and Bachtar, T., 2009, *Wisata Bumi Cekungan Bandung*, Truedee Pustaka Sejati, Bandung: 264p.
- Dzakiya, N., Nugraha, M.G.S.D., Sidik, N.L., and Galena, T., 2017. Survei Potensi Sumber Daya Geologi yang Didukung Data Resistivitas di Gunung Wungkal Yogyakarta. *POSITRON*, Vol.VII, No.1: 17-24. <http://dx.doi.org/10.26418/positron.v7i1.19205>.
- Firdaus, S., and Setiano, A., 2018. Interpretasi Struktur Geologi Berdasarkan Citra Landsat 8, SRTM dan Anomali Medan Gravitasi Satelit di Cekungan Jawa Timur Utara. *Prosiding Seminar Nasional GEOTIK*, Surakarta: 193-204.
- Grandis, H., 2009. *Pengantar Pemodelan Inversi Geofisika*. Jakarta: Himpunan Ahli Geofisika Indonesia, Jakarta: 186p.
- Geospatial Information Agency, 2018. Peta Citra Demnas 1209-31 v1.0, 42.4 MB; <http://tides.big.go.id/DEMNAS/DEMNAS.php>.
- Hidayat, E., 2010. Analisis Morfotektonik Sesar Lembang, Jawa Barat. *Majalah Ilmiah Widyariset*, Vol.3, No.2: 83-92.
- Hartadi, J., Raharjo, S., and Alfiani, O.D., 2015. Pemodelan Tingkat Aktivitas Sesar Berdasarkan Analisis Deformasi Menggunakan Pengamatan GPS. *Prosiding Seminar Nasional Kebumihan X-FTM-UPN Veteran*, Yogyakarta: 158-164.
- Herlambang, R.F., and Novranza, K., 2016. Pemetaan Kelurusan Menggunakan *Remote Sensing* dan Korelasinya Terhadap Distribusi Manifestasi Permukaan di Daerah Potensi Geothermal Kepahiang, Bengkulu. *Prosiding Seminar Nasional Fisika (E-Journal)*, Jakarta: 57-64. DOI: doi.org/10.21009/0305020412.
- Junursyah, G.M.L., 2015. Laporan Kegiatan Uji Cek Kalibrasi dan Penyusunan Standar Prosedur Peralatan Resistivity dan Bor di Daerah Lembang dan Sekitarnya Provinsi Jawa Barat. Internal Report Bidang Sarana Teknik, Center for Geological Survey, Bandung (unpublished report).
- Junursyah, G.M.L., 2016. Laporan Kegiatan Uji Coba Peralatan GEM GSM 19T dan Cesium Geometrics G-858 di Daerah Lembang dan Sekitarnya, Provinsi Jawa Barat. Internal Report Bidang Sarana Teknik, Center for Geological Survey, Bandung (unpublished report).
- Junursyah, G.M.L., and Agustya, G., 2017. Penafsiran Struktur Geologi di Daerah Gunung Batu Lembang Berdasarkan Korelasi Data Permukaan, Tahanan Jenis, dan Geomagnetik. *Jurnal Geologi dan Sumberdaya Mineral*, Vol.18, No.3: 171-182.
- Junursyah, G.M.L., 2018. Laporan Kegiatan Uji Coba Peralatan Geomagnet di Daerah Lembang dan Sekitarnya, Provinsi Jawa Barat. Internal Report Bidang Sumber Daya Minyak dan Gas Bumi, Center for Geologi-

- cal Survey, Bandung (unpublished report).
- Lutfinur, I., Khumaedi, and Susanto, H., 2015. Identifikasi Sesar Bawah Permukaan Menggunakan Metode Geolistrik Konfigurasi Schlumberger (Studi Kasus Sungai Opak Yogyakarta). *Unnes Physics Journal*, Vol.4, No.1: 63-74.
- Loke, M., 2000. *Electrical Imaging Survey for Environmental and Engineering Studies*. Edgbaston: The University of Birmingham
- Marjiyono., Soehaimi, and A., Kamawan., 2008. Identifikasi Sesar Aktif Daerah Cekungan Bandung dengan Data Citra Landsat dan Kegempaan. *Jurnal Geologi dan Sumberdaya Mineral*, Vol.17, No.2: 81-88.
- Nugraha, A.D., Supendi, P., Prabowo, B.S., Rosalia, S., Erlangga., Husni, Y.M., Widiyanto, S., Puspito, N.T., Priyono, A., 2019. The Recent Small Earthquakes around Lembang Fault, West Java, Bandung, Indonesia. *Journal of Physics: Conference Series* 1204 012083. DOI: 10.1088/1742-6596/1204/1/012083.
- Praromadani, Z.S., 2015. Laporan Uji Coba Peralatan Geolistrik SuperSting R8/IP. Internal Report Bidang Sarana Teknik, Center for Geological Survey, Bandung (unpublished report).
- Rasmid., 2014. Aktivitas Sesar Lembang di Utara Cekungan Bandung. *Jurnal Meteorologi dan Geofisika*, Vol.15, No.2: 129-136.
- Raharjo, S., Hartadi, J., and Alfiani, D., 2015. Penentuan Sesar Aktif Berdasarkan Data Geodetik dan Interpretasi Geologi sekitar Sungai Cimandiri Jawa Barat. *Prosiding Seminar Nasional Kebumihan X – FTM – UPN Veteran*, Yogyakarta: 165-171.
- Silitonga, P.H., 1973. *Geologic Map of The Bandung Quadrangle, Jawa, scale 1:100.000*. Geological Research and Development Centre, Bandung.
- Sugiarto, B., 2016, Laporan Kegiatan Pengembangan Metode Uji Peralatan Geolistrik Multichannel SuperSting R8/IP di Daerah Lembang dan Sekitarnya Provinsi Jawa Barat. Internal Report Bidang Sarana Teknik, Center for Geological Survey, Bandung (unpublished report).
- Sari, L., Seha., and Hartono., 2018. Penerapan *Second Vertical Derivative* (SVD) pada Data Gravitasi untuk Mengidentifikasi Keberadaan Patahan di Sepanjang Pegunungan Serayu Selatan Kabupaten Banyumas. *Jurnal Teras Fisika*, Vol. 1 No.2: 1-7. DOI: <https://doi.org/10.20884/1.jtf.2018.1.2.11.27>.
- Setiadi, I., and Pratama, A.W., 2018. Pola Struktur dan Konfigurasi Geologi Bawah Permukaan Cekungan Jawa Barat Utara Berdasarkan Analisis Gaya Berat. *Jurnal Geologi dan Sumberdaya Mineral*. Vol 19 No.2: 59-72. DOI: <http://dx.doi.org/10.33332/jgsm.geologi.19.2.59-72>.
- Sumintadireja, P., Dahrin, D., and Grandis, H., 2018. A Note on the Use of the Second Vertical Derivative (SVD) of Gravity Data with Reference to Indonesian Cases. *Journal of Engineering and Technological Sciences*. Vol.50 No.1: 127-139. DOI: 10.5614/j.eng.technol.scl.2018.50.1.9.