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Application of The Geoelectric Method to Identify Subscription Fault in Sambelia District due to The 2018 Earthquake

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Abstract

Earthquake activity triggers fault activity such as what happened on Lombok Island. Therefore, it is necessary to carry out research related to the existence of faults by identifying the type of fault, so that the risk of danger can be overcome before an earthquake occurs, especially in Sambelia District, East Lombok Regency. The purpose of this research is to find out whether there is a fault in the research area caused by the 2018 earthquake and to analyze its geometry in Sambelia District, East Lombok Regency. Data acquisition using the Geoelectric resistivity Wenner configuration method . The results of the research on 12 tracks with a length of 230 meters each track, on each track there are 3 rock layers in 2D cross section. Based on the inversion results, of the twelve main rock types that dominate include clay, sandstone, and breccia with a depth of up to 40 meters, with the highest elevation of 168 meters above ground level. The existence of faults on all tracks has a depth ranging from 16.75 meters. In the research area, many fractures were found which were possibly caused by the 2018 earthquake activity which led to the finding of faults on each trajectory. The type of rock that indicates the presence of a fault is breccia rock that experiences discontinuity with a resistivity value of (7.33 – 82.1) ohm-m and is filled or covered by sedimentary deposit rocks, namely clay and sandy loam with a resistivity value of (0.483 – 3.62) ohm-m. The faults in Sambelia District are micro-faults forming a line through exposed fractures extending to the northeast. The average geometry of the fault is: 15 meters wide, 77° average slope and 37° northeast strake .

Introduction

Lombok Island is an island with earthquake activity. This is because the island of Lombok is at the confluence of the Eurasian plate and the Indo- Australian plate [1] . The meeting of these plates causes activity in the earth's layers to become active. Earthquakes that occur due to activation of faults can cause the soil/rock body and the ground surface to crack and move along the fault line. This has the potential to cause damage to buildings and all types of infrastructure located on the ground surface. An example of an active fault is that the fault divides the building infrastructure in Renokenongo Village [2] and the rice field area in the

Jane'berang watershed, South Sulawesi [3]. In general, its existence can be detected well based on gravity anomaly. Our research results prove the existence of several new structures that were not found in previous geological maps, including: i) the outcrop of the Solo zone to the west of Lombok, the thick magmatic crust that forms the boundary between Lombok Island and Sumbawa Island and the uplifted area in South Lombok (SU), everything is well detected and in accordance with the statement of the researcher [10]. ii) Allegedly a new structure was detected with an indication of a low circular anomaly in the Mount Rinjani Complex area and the Jerowaru area in the southeast of Lombok [11]. Figure 1 shows an indication of a fault trending northeast-Southwest right in the study area which is used as a reference in the research process. According to information obtained from BMKG and USGS data, the epicenter of the earthquake is estimated to be in Sambelia District.

In Figure 1 there is a dotted black line which is an indication of a fault trending northeast-southwest [15]. The Sambelia area is included in two rock formations namely the Alluvium formation (*Qa*) and the inseparable volcano (*Qhv(p,n , r*)). The Qa Formation consists of gravel, gravel, sand, clay, peat and coral rubble. Volcanic rock formations consist of: lava, breccia and tuff, which are the result of the inseparable activities of the Pusuk-Nangi (*Qhvpn*) and Rinjani (*Qhvr) volcanoes.* Research conducted by [16, 20] shows that there is a fault due to the 2018 earthquake centered in Selengan Village, North Lombok which is one of the references in research. Fault geometry includes fault alignment (*strike*), fault slope (*Dip*), *slip strike* and *rake* . Several geophysical methods can be used in determining the existence and analysis of fault geometry. Among other things, the geoelectric method, the geomagnetic method, and the seismic method. [4].

One of the simplest methods for detecting shallow faults and analyzing their geometry is the electroelectric method, because it is very accurate based on variations in the resistivity values of rock types. The presence of disturbances can be identified based on the discontinuity of the resistivity values in the inversion section [4, 5, 6]. Rock discontinuity is indicated by rocks with different resistivity values that can be observed on the inverted geoelectric cross section [2].

The geoelectric method is a method used to study subsurface conditions by studying the nature of electric currents in rocks beneath the earth's surface. The principle of the resistivity method is to flow an electric current into the earth through the contact of two current electrodes, then measure the resulting potential distribution [18].

Based on research conducted by [2, 7, 8], states that the resistivity geoelectric method can be used to interpret subsurface structures accurately and can describe the presence of faults from the resistivity cross-section. The geoelectrical method consists of several configurations, namely Schlumberger, Pole-pole, Dipole-Dipole, Pole-dipole, Wenner, and Wenner-Schlumberger. According to [9, 10], the use of the Wenner configuration accurately indicates the presence of subsurface faults.

Geomorphologically, the study area is dominated by steep hills, a headwaters that extends from west to northeast and villages where most of the population works as farmers. In addition, the area is also dominated by rock types of clay, sandy loam and breccias as well as a little lava and tuff. This is the basis for data collection in the area. Data collection was carried out in four villages including Belanting Village, Dara Kunci Village, Sugian Village, and Obel-obel Village. The data collection method uses the *Wenner* 2D Geoelectrical configuration method. The data obtained from the research results are in the form of electric current strength, potential difference and electrode position, then the apparent resistivity value and geometry factor are calculated using equations 4 and 5 using *Microsoft Exel Software.* The data is then processed using *Res2dinv Software* to obtain 2D cross-section results. After the data modeling is complete, interpretation and analysis is carried out based on the actual resistivity value.

Based on the problems found, it is very important to conduct research to determine the presence of faults and analyze the fault geometry in Sambelia District, Lombok Regency using the resistivity geoelectric method .

Geological Conditions of the Study Area

Faults and folds can be found almost on the island of Lombok, including East Lombok [11]. Faults and folds can cause deformation. According to [11] Faults are found in Pemenang to the west of Mount Rinjani, in Sambelia and Pringgabaya Northeast of Mount Rinjani, the fault extends from east to west of the island of Lombok as shown in Figure 1.

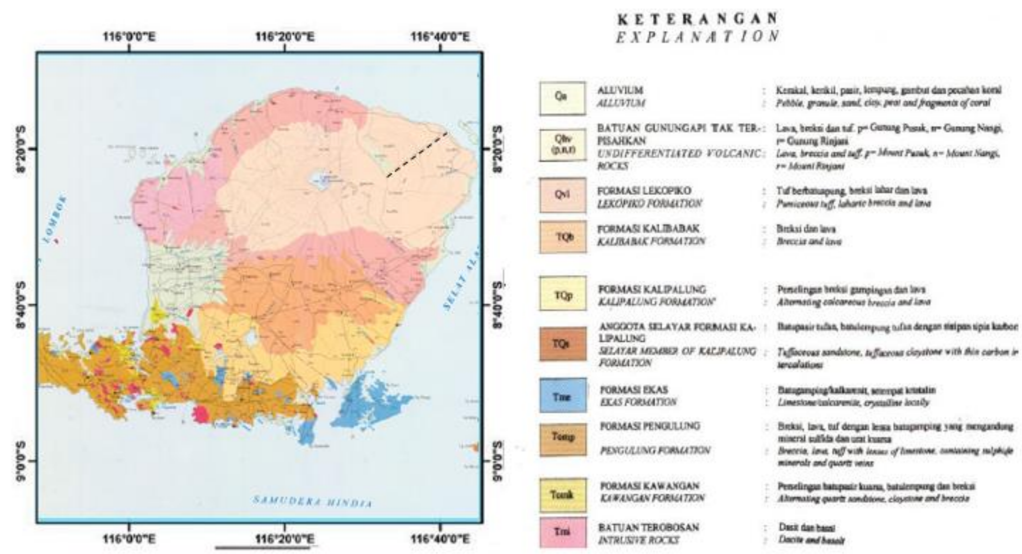

Figure 1. Geological Map of Lombok [12]

Faults are fractures in rock that have shifted through fracture planes. Some of the features that can be used as fault marks include: there is a structure that is not continuous (layers cut off by other rocks), there is repetition of layers or loss of rock layers, a distinctive appearance on the fault plane such as a fault mirror, etching lines. Typical appearances in fault zones such as *drag, fult breccias, horse* or *lice, mylonite, silicification* and mineralization along the fault zone, as well as differences in sediment facies. Physiographic intrusions, such as *scarps, scarlets (piedmont scarp),* triangular, river deflections and structural mountain range forecuts.

Regarding the features of the fault above, in studying the dynamics that have occurred, several terms are used [13] as shown in Figure 2, including; Fault *strike* , namely the direction of the fault plane is cut off by the horizontal plane and is usually measured from the north. Fault dip is the angle formed between the fault plane and the horizontal plane which is measured perpendicular to the strike. *Net Slip* is the relative displacement of a point due to a fault that initially coincides with the fault plane. Lastly *Rake* is the angle formed by the strike-slip (horizontal shift in the direction of motion) on the fault plane.

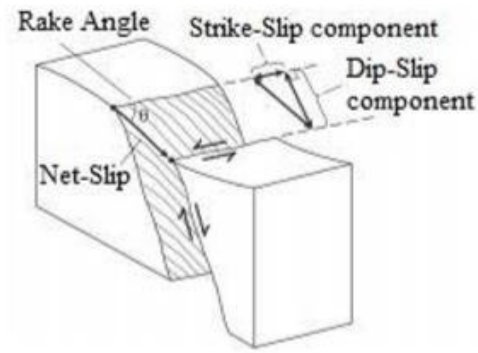

Figure 2. Geometry Components in the Fault Plane [13]

In connection with the analysis of the presence of faults in the study area based on the distribution of rock resistivity values in 2D sections, it can be seen if there are low resistivity values intersecting high resistivity values or vice versa. Grouping high resistivity values cuts low resistivity values, if air is found which is an insulator or has high resistivity entering into the surrounding rock cavities. The following are the resistivity values of the rocks found in the study area:

Table 1. Rock resistivity values

Rock Name	Rock(Ωm)
Breccia	$75 - 200$
lava	$10^2 - 5 \times 10^4$
tufa	$2 \times 10^3 - 1 \times 10^5$
Limestone	$350 - 6 \times 10^3$
Clay	$1 - 100$
Sandstone	$1 \times 10^3 - 4 \times 10^3$
Gravel	$100 - 500$

Measurement technique

The geophysical method that studies the nature of the flow of electric current in the earth by passing an electric current into the ground, then measuring the potential difference that occurs on the ground surface is geoelectric. Geoelectrical investigations are carried out based on the physical properties of the rocks against the flow of electric current, each different rock type will have a different resistivity value. So the current flow rate is also different. Thus, the geoelectric method can be used to detect rock layers in an area based on the electrical properties of the constituent rocks.

By assuming that the earth is homogeneous and isotropic. If an electric current is injected (on the surface) into an isotropic homogeneous earth through a current electrode, the electric current spreads radially into the soil. This current spreading produces a potential around the current electrode and the potential electrode. The potential lines that are formed resemble half a ball that sweeps the area $2\pi r^2$[14]. The potential difference that occurs between potential electrodes (Figure 3a) can be measured and according to equation (1):

$$\Delta V = \frac{I\rho}{2\pi}\left\{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)\right\} \quad (1)$$

where $\Delta V$is the potential difference (Volts), I is the current (A), $\rho$is the resistivity (ohm-m) [4], r is the distance between the electrodes (m).

The resistivity geoelectric method is based on the assumption that the earth is isotropically homogeneous. With this assumption, the measured resistivity value is the actual value and does not depend on the electrode spacing. However, in reality the earth is composed of layers with different resistivities, so that the measured potential is the effect of these layers. Therefore, the measured resistivity value appears to be the resistivity value for only one layer. The measured resistivity is actually the apparent resistivity (ρ_a)[17].

$$\rho_a = K\frac{\Delta V}{I} \quad (2)$$

with

$$K = 2\pi\left[\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)\right]^{-1} \quad (3)$$

Where ρ_aD is the apparent resistivity and K is the geometric factor whose magnitude depends on the electrode configuration used, ΔV is the potential difference, and I is the electric current [19].

The geoelectrical method has several configurations, one of which is the Wenner configuration. The Wenner configuration (Figure 3b) is a configuration often used in geophysical exploration, where the electrodes are in a symmetrical line with the center point and the same distance between the electrodes, for example a. the Wenner configuration has good vertical resolution, high sensitivity to lateral changes, but weak current penetration with respect to depth. The arrangement of the Wenner electrode configuration [14] can be seen in Figure 3b.

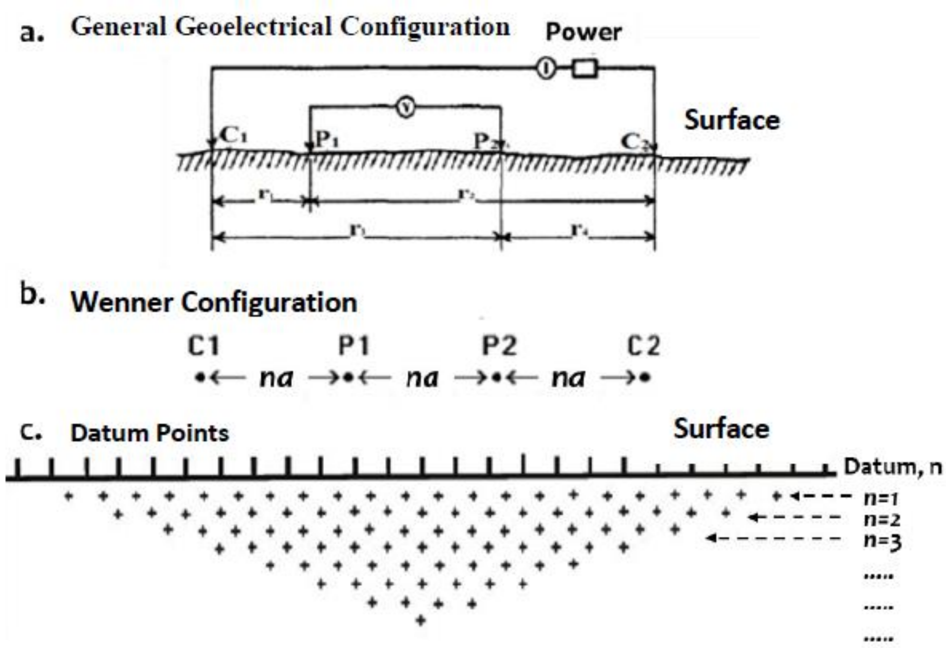

Figure 3. The arrangement of four electrodes on the ground surface using the geoelectric method [modification of [2, 9]. (a) general geoelectric configuration, (b) Wenner configuration, (c) Wenner 2D configuration datum points.

Information :

C_1, C_2 = Current Electrode

P_1, P_2 = Electrode Potential

dipole-dipole configuration equations by entering:

$$K = 2\pi\left[\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{r_3}-\frac{1}{r_4}\right)\right]^{-1}$$

$$K = \frac{2\pi}{\left(\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{r_3}-\frac{1}{r_4}\right)\right)}$$

$$K = \frac{2\pi}{\left(\frac{1}{a}-\frac{1}{2a}-\frac{1}{2a}+\frac{1}{a}\right)}$$

$$K = \frac{2\pi}{\left(\frac{1}{a}+\frac{1}{a}-\frac{1}{2a}-\frac{1}{2a}\right)}$$

$$K = \frac{2\pi}{\left(\frac{2}{a}-\frac{1}{a}\right)}$$

$$K = \frac{2\pi}{\left(\frac{1}{a}\right)}$$

$$K = 2\pi a \tag{4}$$

Apparent resistivity (ρ_a) for a number of datum points (n) in the 2D Wenner configuration according to equation (1) is expressed in equation (4);

$$\rho_a = 2\pi na\frac{\Delta V}{I} \qquad (5)$$

with a: spacing between electrodes, n: datum point. The measurement technique in this study is a two-dimensional (2D) Wenner configuration measurement performed on 12 lines at different locations. The length of each path is 230 meters with electrode spacing (a) 10 meters and datum points (n) (Figure 3c) ranging from n = 1 to n = 8.

After obtaining the measurement data, it is processed using *Microsoft Exel* to obtain the geometry factor (K) and apparent resistivity ( ) ρ). Then modeling is carried out in *Res2dinv Software* to obtain subsurface cross-sectional results in the study area. If the editing process is complete, *the display section will appear.* consists of 3 parts, namely: The first section shows the measured apparent resistivity , namely the apparent resistivity data obtained from measurements, the second section shows the calculated apparent resistivity , and the third section is the actual resistivity section. *true resistivity*) obtained after going through the inversion process (*image model resistivity section*) (Figure 4).

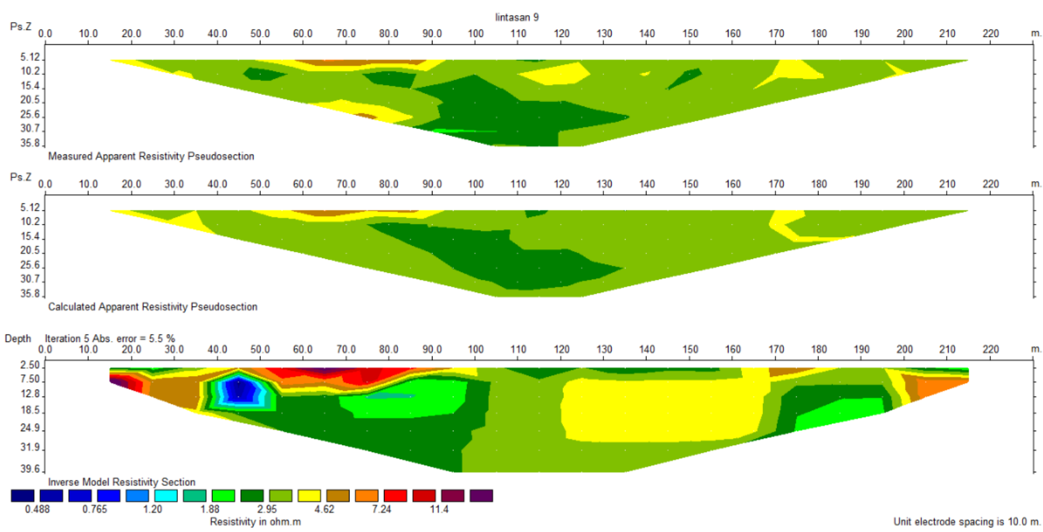

Figure 4 Display of inversion results by *Res2dinv Software*

In this research several stages were carried out which in general started from literature study, data collection, determination of research variables, data processing, analysis and interpretation of data, discussion and drawing conclusions. The flow of the stages passed in this study can be seen in Figure 5 with an explanation of each stage as follows :

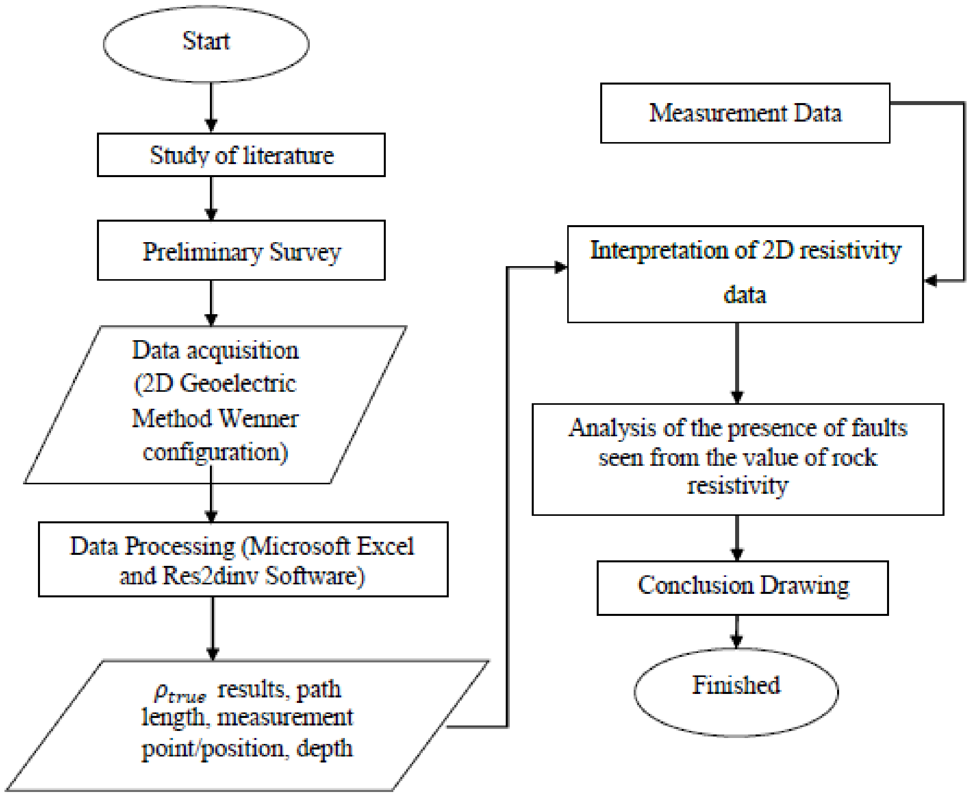

Figure 5 Research Flowchart

Results and Discussion

Based on the geological map of Lombok, the rock formations that make up the stratigraphy of the research location are the alluvium formation (*Qa*) and inseparable volcanoes (*Qhv(p,n ,r*)). The Qa Formation consists of gravel, gravel, sand, clay, peat and coral rubble. Volcanic rock formations consist of: lava, breccia and tuff, which are the result of the inseparable activities of the Pusuk-Nangi (*Qhvpn*) and Rinjani (*Qhvr) volcanoes.*

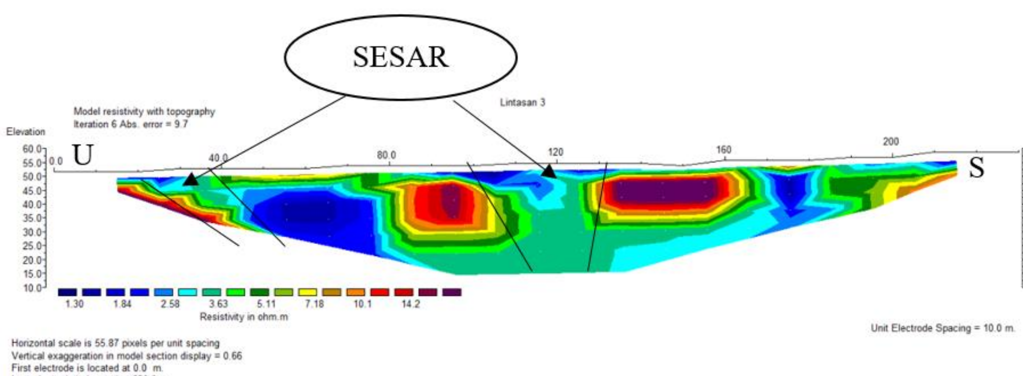

Figure 6 . Actual resistivity section from 2-D inversion modeling, on track 3. The black vertical black line is an indication of the fault boundary.

The results of 2D geoelectrical resistivity cross-sectional analysis, geological maps and field observations in the study area concluded that there were faults marked with black vertical black lines (Figure 6). The fault is visible at ground level and is thought to have been caused by an earthquake (M=6.9) in August 2018, which is located close to the research location. In addition, several other fractures were found near the study site which had the same fracture direction (Figure 7) as the fault indications found on the geological map of N.Suratno .

Based on Figure 6, the resistivity section resulting from the inversion and the geological conditions of the area on the third track, we interpret three types of rock layers. The three layers include; The clay, sandstone and breccias of the alluvial and volcanic formations are inseparable. The clay layer on the soil surface with a resistivity value of (0.1 – 0.5) ohm-m occupies a depth of up to 24 meters. The second layer with a resistivity value of (0.6 – 1) ohm-m is interpreted as sandstone reaching a depth of (25 – 39) meters. The third layer with a resistivity value of (1 – 1.4) ohm-m, is interpreted as breccia rock at a depth of (10 – 39) meters.

Furthermore, on the twelve trajectories, an analysis of indications of the presence of faults was carried out based on the discontinuity of the resistivity value, especially in the horizontal direction (width) and slope, the results can be seen in Table 2.

Figure 7 shows the discontinuity of low resistivity values (0.483 – 3.62) ohm-m in the horizontal direction at different positions from the surface to a depth of 39.6 meters. In Figure 7 you can see the structure of the breccia rock layers with high resistivity values, namely ($7.33 - 82.1)\ ohm.m$having experienced layer dislocation. Based on the geological map of the Lombok sheet there are indications of visible faults where there are visible cracks in the road extending in the direction of the Gili Sulat with a length of 16.5 meters, a width of 30 centimeters, with a slope 15 centimeters is at the point of measurement (120 – 130) meters.

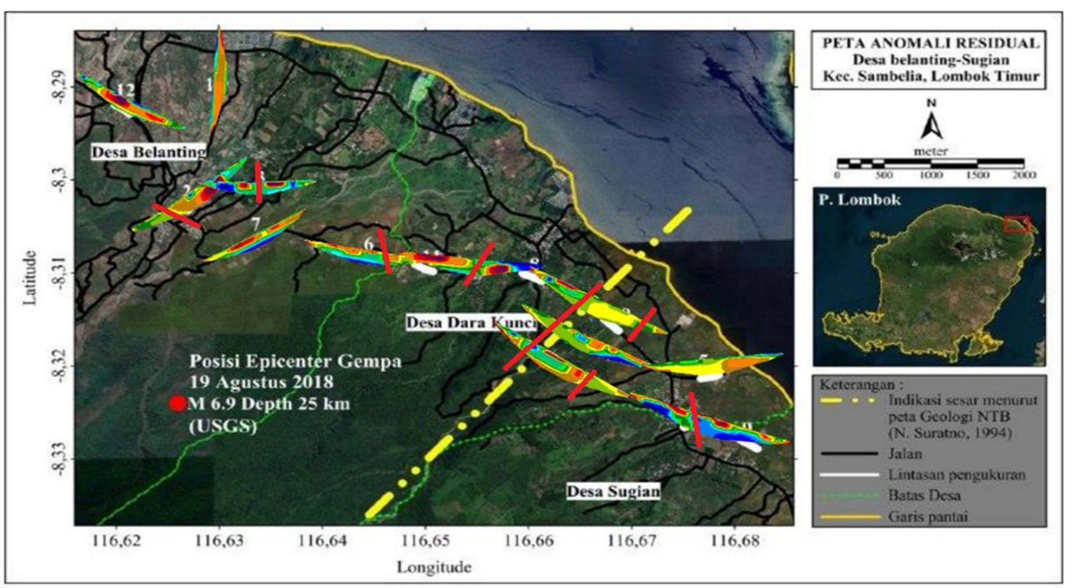

Figure 7. Map of estimated presence and direction of faults in Sambelia

Fault Geometry on track 3 (figure 6) which is located (60 – 80) meters from the starting point of measurement. The fracture direction we observed during the field survey was northeast. The depth of the fault is more than 20 meters with a width of 10 m and a fault slope of 70 ° . Likewise for the other eleven tracks, generally consisting of three layers with the same rock type as on track one above. Fault geometry in the form of depth (detected), width and slope (*Dip*) on the twelve tracks is presented in table 2. The fault alignment (*strike*) is generally 37 ° northeast, the width varies from 10 m to 30 m with a slope (*dip*) between 30 ° to 80 ° (Table 2).

Table 2. Fault Geometry Analysis

Tracks	Position (m)	Depth(m)	Tilt	Width(m)
2	60 – 80	22.4	45°	20
3	30 – 40	21.5	65°	10
	110–130	20	70°	20
5	110–140	9.5	80°	30
6	150–170	23.5	60°	20
7	30 – 40	18.5	50°	10
8	70 – 90	16	60°	20
9	110 – 130	14.5	70°	20
10	120 – 140	8	30°	20
11	120 - 150	25.5	45°	30

Overall, when viewed from the inversion resistivity model, the rock types are the same, namely alluvial deposits and inseparable breccias. The identified fault tends to point to the northeast, this is in accordance with research conducted by [13] who used the gravity method. We also found faults at a distance of approximately 0.30 km and 1 km from the study site trending 45° and 40 ° (Figure 7). This confirms the estimated 40° northeast direction of the fault. These faults are not yet available on the geological map made by Mangga 1994 and N. Suratno 1994. These faults are thought to have occurred as a result of several major earthquakes that occurred in succession in Lombok, in particular the earthquake on August 28 2018 with a magnitude of 7.0 with epicenter distance of ± 80 km to the research location. Another earthquake that occurred closer to the research location was ± 4 km with a magnitude of 6.4 on the Richter scale which was estimated to be centered in Sambelia District.

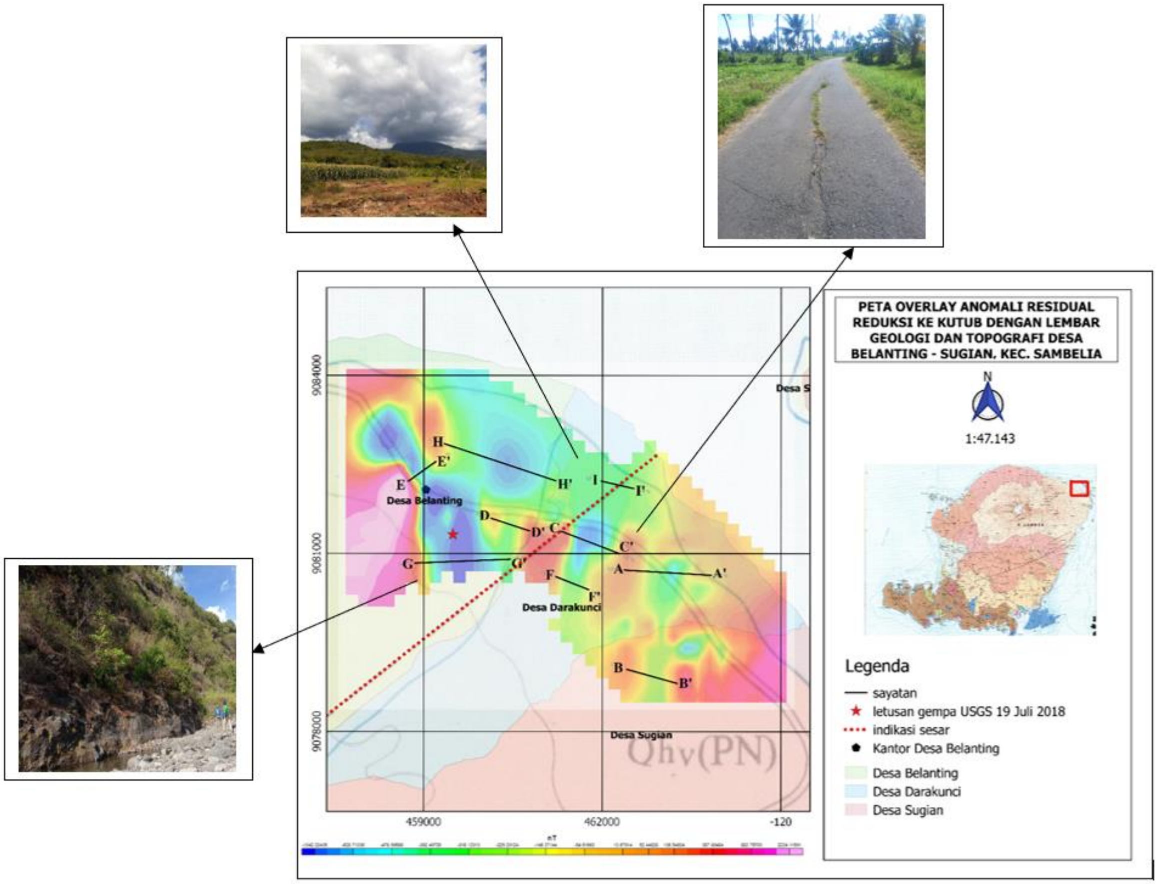

Figure 8. Outcrops and cracked roads in the study area after the 2018 earthquake in Sambelia District

Estimates of the existence of faults in the study area were also found in the results of 2D modeling using the Geomagnet method [21] which showed the presence of three layers of rock, namely the first layer has a susceptibility value as large as 0,025in SI which is a layer of sandy clay. These rocks are at a depth of 0 m to 179,29m. The second layer has a susceptibility value 0,079in SI which is a layer of breccia rock. These rocks are at a depth of 0 m to 231 m. The third layer has a susceptibility value 0,101in SI which is a layer of lava rock. These rocks are at a depth of 105,60m to 450 m. Based on theory from (Masinai, 2013), in the second layer there is a down fault or *normal fault,* where this fault is characterized by a relatively downward movement of the breccia rock block in 2D modeling of the CC' incision at a depth of 125,57m to 374 m. This is also reinforced by the indication of a cesarean crossing the incision (Figure 8).

Conclusion

Research that has been carried out by applying the geoelectrical method to identify presumed faults in Sambelia District, East Lombok Regency due to the 2018 earthquake, it can be concluded that, In Sambelia District there are indications of faults trending northeast-southwest, from the inversion results show that there are many estimated fault findings as a result of the 2018 earthquake which was marked by the occurrence of rock dislocations in each research trajectory. The rock structure indicating the presence of a fault can be seen from the type of dislocated breccia rock that has a resistivity value of (7.33 – 82.1) ohm-m and is filled or covered by sedimentary deposit rocks, namely clay and sandy loam with a resistivity value of (0.483 – 3.62) ohm -m. The position of the presence of faults on each track varies from the starting point of measurement, of the twelve tracks there are three tracks that do not indicate a fault, namely track 1, track 4, and track 12. Based on the results of the inversion that has been carried out the average fault location is located at point (110 – 150) meters. The depth of the points where the fault is on average reaches 16.7 meters. The results of the analysis of the resistivity value discontinuity in the study area show that these faults are micro-faults characterized by their small geometry, namely their width: 10 to 30 meters. mean slope of 77° and *strake of* 37° northeast.

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