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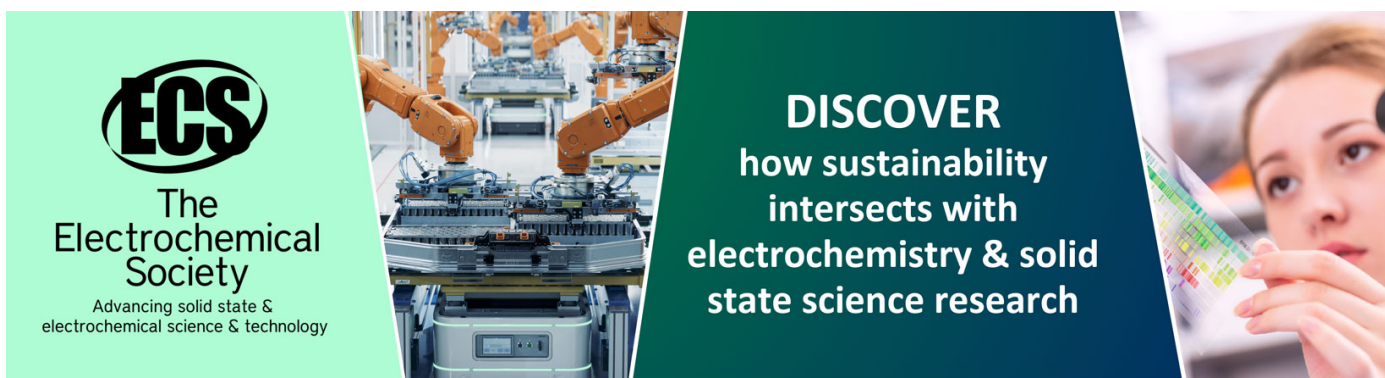
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Implementation of robust constraint inversion method on resistivity geoelectric data to study landslide precursors (case study : Sungai Lasi District and Gunung Talang Solok District, West Sumatra).

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Abstract. Landslides are natural disasters that have a major impact on the environment and surrounding communities every year. Even so, the impact of landslides can be reduced if the precursors of landslides are known through research. However, There are not much research has addressed to study this issue thoroughly. Indeed, many methods are used to study landslide precursors, one of which is to study landslide precursors based on resistivity data of rocks that form slopes or hills where landslides tend to occur. The rock resistivity data can be obtained by the Geoelectric Resistivity method, but the resistivity data that obtained through this method is apparent resistivity. The actual rock resistivity and thickness of the rock structure can be interpreted based on apparent resistivity using the Robust Inversion method. Thus, the purpose of this study is to describe the rock structure (resistivity and thickness) which has the potential as a precursor for landslides in Solok Regency, West Sumatra. The results showed that there were 10 landslide precursor points in Sungai Lasi District and 6 landslide precursor points in Gunung Talang sub-district that had the potential for landslides.

1. Introduction

The term general landslide is used to describe the movement of soil, rocks and organic matter on a slope under the influence of gravity and the shape of the land surface that results from such movement. Various methods have been used for the identification and classification of landslides, including the type of movement, the type of material, the rate of movement, the geometry of the fractured area and the resulting sediment, the causes, the level of disturbance of the displaced mass [1]. Characterization and description of landslides must provide possible factors and trigger factors for landslides. So, in order to achieve the objectives, seven sites were selected according to the framework outlined the above and many field methods were combined, according to the form of field work. Characterization and description of landslide must provide possible conditioning and trigger factors and provide sufficient data to estimate the landslide pre cursor[2]. Activities can be carried out with a variety of techniques and the mechanisms involved should be covered.

Landslides disaster damaged infrastructure and the environment such as destroying residential housing, damaging agricultural land (rice fields and plantation), transportation facilities such as highway and bridges[3]. Damaging of the house has an impact on public health and education of the



younger generation. Therefore, landslides disaster is very influential to economic growth and the welfare of the people, it not only who live in the landslide area, but also the people who across this area. Mitigation of natural disasters is an effort made to reduce the risk of loss due to events in unwanted nature. Furthermore, natural disaster risk mitigation is a strategy prepared to reduce the impact of natural disasters such as landslides[4]. Risk reduction can be done by taking steps to reduce the negative effects of disasters on people's lives and the environment[3]. Risk mitigation is tasked with making plans to avoid the effects of disasters and steps that the steps that can be taken prior to the event occurring to reduce adverse, and potentially long-term[5]. The impact of landslides can be reduced by mitigating. Many mitigation techniques can be used to reduce the impact of landslides, such as community education and land use or space management. Land use can be optimized by knowing the structure of rocks in an area [6]. So, mitigating landslides are optimized by conducting research on these landslide precursors.

The frequent use of this method in the study of landslide areas is mainly due to the factors that can affect resistivity and its extreme variability in space and time domains. Indeed, this parameter is mostly influenced by the mineralogy of the particles, the ground water content, the nature of the electrolyte, the porosity and the intrinsic matrix resistivity with weathering and alteration[7]. Therefore, the landslide precursors are similar things that happened or existed before landslides, often something that leads to the existence or development of the conditions of the area being studied[8]. Landslide precursors can be studied through rock structures. Rock structure that has the potential as a precursor for a landslide can be studied through rock resistivity that forms a rock structure in the area to be studied [9],[10],[11]. Rocks that have low resistivity, but do not contain magnetite or metal minerals, indicate that the area will potentially cause landslides. So, if the precursor of a landslide is known, the impact of a landslide disaster can be reduced. This resistivity geoelectric method can be used to study the structure of subsurface rocks by studying the electrical properties of rocks at the measurement site. Data acquisition is carried out by injecting electric current into the ground surface through two current electrodes. Based on the results of measurements of currents and electrical potential differences can be obtained variations in the value of electrical resistivity in layers below the measuring point called apparent resistivity. The resistivity method is generally used for shallow exploration, around 300-500 m [12]. The depth of current penetration into the earth depends on the configuration of the electrodes used. Electrode configuration means the distance between the electrode and the sequence of the positive and negative poles, both current electrodes and potential electrodes.

The Wenner array is commonly used to profile rock's resistivity in literal directions, such as to distribute rock structures in horizontally. The disadvantage of Wenner's configuration is that it cannot detect the homogeneity of rocks near the surface which can affect the calculation results because all the electrodes are moved each time they are shaved [13]. Consequently, the near-surface lateral variations could potentially be misinterpreted in terms of depth variations in resistivity. The advantage of the Schlumberger configuration is the ability to detect the inhomogeneous nature of rock layers on the surface. The Schlumberger array is also used for mapping or profiling for lateral resistivity changes. However, it is possible to get a picture of the subsurface in terms of resistivity for finding the best-grounded location using methods such as electrical resistivity imaging (ERI) that are used in combination electrode arrays such as the Wenner-Schlumberger array[14]. The ERI method uses the same measurement, but in significantly more automated geometries to extend the method of measurement. The true resistivity of the subsurface can be estimated based on measurements at the earth's surface. The research objective was to describe the rock structure base on resistivity that have the potential as precursor landslides in Solok Regency, West Sumatra.

The obtained rock structure must be able to describe near-surface homogeneity, the literal profile of the structure and the reach of deep current penetration. The above requirements none of the configurations that can fulfill it, unless we use a combined configuration. Thus, this research uses the Wenner-Schlumberger configuration so that the above requirements are met, so that the research objectives can be achieved. Resistivity of rocks that play a role as a sliding field as an indication of a landslide precursor around (100-200 Ohm.meter) [15],[16]. The weathered part of the Rock block is

where the masses move (slip plots) or rock triggers into landslides [17]. The area with resistivity (<10 Ohm-m) at depth (1100 - 1500) meters is a combination of Clays and Chinshui Shale which is a fault zone. The electrical properties under the earth's surface (resistivity and thickness) can be studied based on the electrical parameters (true resistivity and layer thickness) of the subsurface structure [18]. So, the landslide precursors can be studied through the study of the electrical properties of rock parameters based on the associated electrical quantities (potential, current and dimensions of the measurement geometry). The variation in potential crossing a plane interface was established for a single current and potential electrode system, the potential $V(r,P)$ at a distance r from a point source I on a surface of a horizontally stratified terrain is given by the relationship [14],[19].

$$V(r, \mathbf{M}) = \frac{I}{2\pi} \int_0^\infty T(\lambda, \mathbf{M}) J_0(\lambda, r) d\lambda \quad (1)$$

where T is a kernel function as function transform of the apparent resistivity that depends on the integration variable λ and the parameter vector $\mathbf{M}$, which consists of the resistivity values (ρ_i) and the thicknesses (h_i) of the layers [20]. $J_0(\lambda, \mathbf{M})$ is the Bessel function of the first kind and zero order, which depends on the integration variable λ and the parameter vector $\mathbf{P}$, that consists of the resistivity values (ρ_i) and the thicknesses (h_i) of the isotropic layers that is related to the Kernel function through the Hankel integral and r is half the current electrode spacing such as Wenner-Schlumberger configuration. Base on Ohm principle for symmetrical array of four electrode on earth's surface, the apparent resistivity is given by:

$$\rho_a = \frac{K}{I} [V(r_2, \mathbf{M}) - V(r_1, \mathbf{M})] \quad (2)$$

where K is the geometri Factor that depend on electroda konfigurasion. For Wenner-Schulamberger konfigurasion Equation (2) can write as

$$\rho_a = 2\pi \frac{r_1 r_2}{(r_2 - r_1)I} [V(r_2, \mathbf{M}) - V(r_1, \mathbf{M})] \quad (3)$$

Parameter vector $\mathbf{M}$ at Equation (3) consists of the resistivity (ρ_i) and the thicknesses (h_i) that depend on the apparent resistivity (ρ_a). The true resistivity and the thicknesses of the layers are interpreted by inversion method. Prior assumptions and information about the underlying situation accounts for an equally important part of the problem [21]. While these conditions are rarely met, the application of the procedure is usually justified by the assumption that minor errors in the mathematical model and assumptions should cause only a small error in the final results [22]. There are a lot of inversion methods that used to interpreted Geophysics data, but the result of inversion is not unique value [10]. This concept is embodied in the continuity principle of robust estimation [9],[20]. Unfortunately, this is not always true. It has become apparent that solutions can be excessively sensitive to seemingly minor deviation from the underlying assumptions, even when the majority of the data errors correspond to the underlying assumptions [23],[21]. The conventional least-squares method, for example, will attempt to minimise the square of the difference between the measured and calculated apparent resistivity, such as

$$\mathbf{M}^{(k+1)} = \mathbf{M}^k - \beta^k (J^T J + \mu I)^{k-1} (J^k)^T \quad (4)$$

Least squares approaches are especially susceptible to these problems. Even when the majority of the data errors are approximated by a normal distribution, there may be contaminated by a small number of outlying points. An outlying point, or outlier, is an observation that deviates excessively from the "true" model, where the true model consists of the design matrix and the actual values of the unknown parameters, which can never be known[24]. The least squares approach to inversion minimizes the chi square merit function, which is the sum of the squares of the residuals between the model fit and input observations[8]. This leads to outliers having an excessive influence on the conventional least-squares, since the square of their residual is added to the conventional least-squares. However if the data set contains "outlier" data points (where the noise comes from non-random

sources such mistakes or equipment problems), this criteria is less satisfactory. To reduce the effect of such “outlier” data points, an inversion method where the absolute difference (or the first power) between the measured and calculated apparent resistivity is minimised can be used [24]. Such “outlier” data points could have a great influence on the resulting inversion model. If the robust model constrain inversion method is used on the model resistivity, the program will attempt to minimise the absolute changes in the resistivity. This constrain tends to produce models with sharp interfaces between different regions with different resistivities, but within each region the resistivity value is almost constant [23]. However, for outliers the merit function invokes a smaller penalty, then the sum of the squares. If the robust model constrain inversion method is used on the model resistivity, the we will attempt to minimise the absolute changes in the resistivity[17]. This constrain tends to produce models with sharp interfaces between different regions with different resistivity values, but within each region the resistivity value is almost constant. This results from their relative simplicity and flexibility. This type of robust inversion will be further discussed and applied to the inversion of the source receptor relationship.

2. Methodology

Data for an explorative research are interpreted by the Robust constrained inversion method. Resistivity data are used to obtain the rock structure in the location that potential landslide occurs [8],[31]. Therefore, data that results of interpretation are used to estimate the precursor of the landslide in Solok West Sumatra. Data was collected at coordinates ($00^{\circ}44.785' \text{ S} - 100^{\circ}44.153' \text{ E}$ to $00^{\circ}46.296' \text{ S} - 100^{\circ}45.261' \text{ E}$) at Sei Lasi and ($00^{\circ}59.304' \text{ S} - 100^{\circ}36.055' \text{ E} - 00^{\circ}59.434' \text{ S} - 100^{\circ}37.533' \text{ E}$) at Gunung Talang Solok. The location measurement such as Figure 1

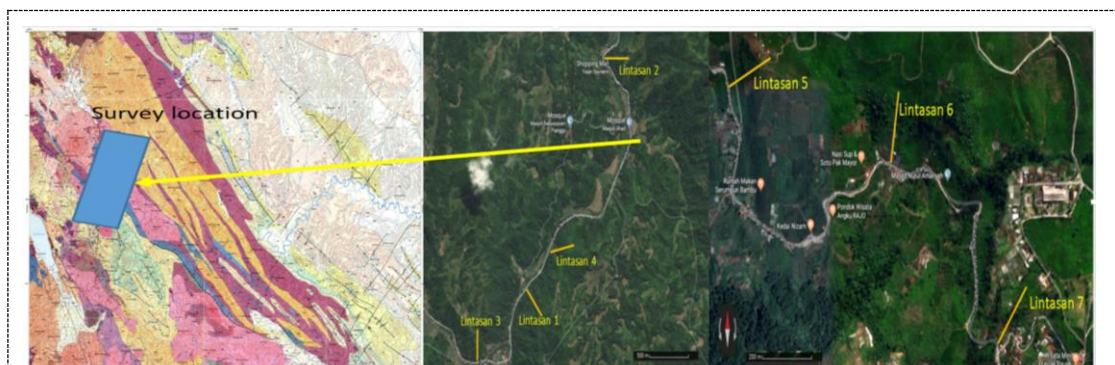


Figure 1: Measurement Locations in Kecamatan Sei Lasi and Gunung Talang Solok West Sumatra (Google Map, September 23, 2018) [25]

The main equipment used to obtain apparent resistivity is the multichannel Automatic Resistivity System GF Instrument (ARES) with the Ares-G4 model specification of Cheko production, belonging to the FMIPA UNP Padang. The arrangement of electrode array in the Wenner-Schlumberger configuration is shown in Figure 2

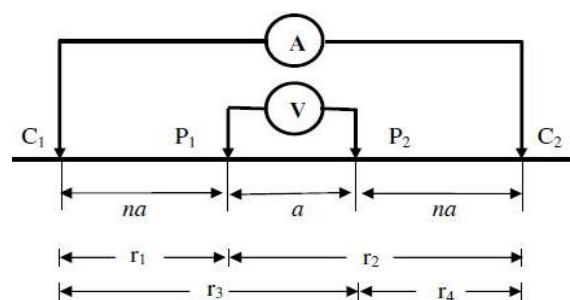


Figure 2. The Array of Wenner-Schlumberger configuration.

Therefore, the apparent resistivity of measurement is calculated by the equation:

$$\rho_a = n(n+1)\pi a \frac{\Delta V}{I} \quad (5)$$

The apparent resistivity data are interpreted using the Robust Inversion with damping factor such as Equation (5), in order to obtain a 2D resistivity cross section

$$\Delta \mathbf{m} = \mathbf{m}_{i+1} - \mathbf{m}_i = (\mathbf{J}^T \mathbf{W} \mathbf{J} + \mu \mathbf{I})^{-1} \mathbf{J}^T \mathbf{W} \Delta \rho_a \quad (6)$$

Where μ is the Marquardt-Levenberg or damping factor, and $\mathbf{I}$ is the identity matrix. Ordinarily, using the analogy with the damped least squares method, the expression damped least absolutes was used for this approach. Furthermore, there is a cut-off factor (μ) which controls the degree in which this robust data constraint is used[23]. In this case, if we use the value of cut-off factor 0.05, it means the effect of data points where the differences in the measured and calculated apparent resistivity values are much greater than 5 percent will be greatly reduced. This might be more suitable for areas where such a geological situation exists, such as the soil-bedrock interface over certain types of bedrock [4]. Notwithstanding, the result of interpreted are displayed on the 2D cross-section of true resistivity and we get the layer which has the contrast resistivity as the precursor of the landslide in West Sumatera can be estimated. The precursor of the landslide is identified based on two rock's layers that have contrast resistivity [2],[26],[19]. *In conclusion*, Structure of rock as the precursor landslide can be seen from the structure resistivity of rock

3. Results and Discussions

Based on, the objective of research that was to describe the rock structure base on resistivity that have the potential as precursor landslides in Solok Regency, West Sumatra. For this reason, at follow we will be explain interpretation of Geoelectric data in both at Sei Lasi Solok four tracks measurement and Gunung Talang Solok two tracks measurement.

3.1 The First Location Measurement.

The first location measurement was 00°46.053' S, 100°16,357' E, altitude 834 meters) to (00°25.488'S, 100°16,412' E, altitude 494 meters). Acquisition data this location were divided into fours sections such as (00°25.496 S, 100°16,357', altitude 834 meters) to (00°25.452 S,100°16,273' E, altitude 746 meters), and (00°44.785' S, 100°44.153' E, altitude 633 meters) to (00°25.488 S, 100°16,412' E, altitude 494 meters), and (00°46.439' S – 100°43.883' E, altitude 623 meters) to (00°25.488 S, 100°16,412' E, altitude 551 meters), and (00°45.753'S, 100°44.536' E, altitude 627 meters) to (00°45.784'S, 100°44.645'E, altitude 523 meters). The 2-D cross-section resistivity in the first location as shown in Figure 3 and Figure 4.

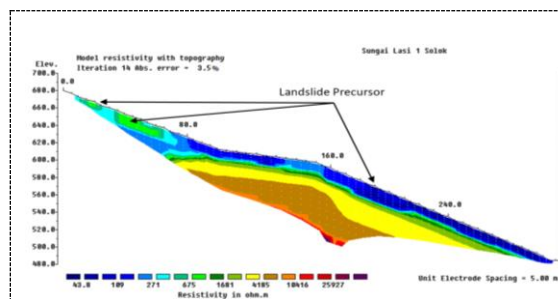


Figure 3: The 2-D cross section of the rock stucture as landslide precursor at (00°25.496 S, 100°16,357'E, altitude 834 meters) to (00°25.452 S,100°16,273' E, altitude 746 meters)

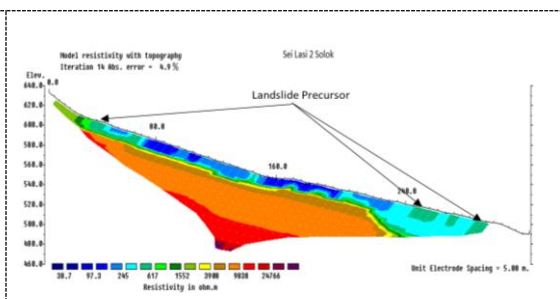


Figure 4: The 2-D cross section of the rock stucture as landslide precursor at 00°44.785' S, 100°44.153'E, altitude 633 meters) to (00°25.488 S, 100°16,412' E, altitude 494 meters)

Based on Figure 3 and 4 the rock structure in Sei Lasi Solok consist of sandy soil as top soil (Resistivity = 13 Ωm – 100 Ωm), Argileceous Clay (Resistivity = 101 Ωm – 500 Ωm), Schists (Resistivity = 505 Ωm – 1.050 Ωm , Tuffs (Resistivity = 1.060 Ωm – 4.185 Ωm , Gabro (Resistivity = 4.200 Ωm – 20.000 Ωm and Andesite (Resistivity = 20.100 Ωm – 40.000 Ωm) [21][6]. This rock layer structure shows that the sliding surface of the landslide is present in this position [5],[23]. According to the all Figure the above, the rock structure on the site can be written such as Table 1.

Table 1: The rock structure at (00°25.488 S,100°16,412', altitude 1182 meter) to (00°25.488'S,100°16,412'E, altitude 1300 meters)

	Coordinat / altitude	Resistivity (Ωm = Ohm.meters)	Type of Rock	Precursor landslide (meters in sea level)	The Degree of Landslide Slop
According to Figure 3	00°46.053'S, 100°44.353' E, altitude 760 meters to (S 00°25.488 S, 100°16,412' E, altitude 533 meters)	13 – 100 101 - 500 505 – 1.050 1.060 – 4.185 4.200 – 20.000 20.100 – 40.000	Top soil Argileceous Clay Schists Tuffs Gabro Andesite	655 – 665 620 – 645 440 – 500	46 degree, Clay under Schists (precursor landslide)
According to Figure 4	00°44.785' S ,100°44.153' E altitude 633 meters to (S- 00°25.488, E- 100°16,412', altitude 494 meters).	13 – 100 101 - 500 505 - 1050 1.060 – 4.185 4.200 – 20.000 20.100 – 50.000	sandy soil Argileceous Clay Schists Tuffs Gabro Andesite	585 – 600 450 – 510	45 degree, Sand top Soil above Gabro (precursor landslide)

Figure 3 and Figure 4 show that anomalies seen in the rock structures that have the resistivity (505 Ωm – 1050 Ωm) which is estimated due to the presence of the Schist rocks in this layer. The Schists are the metamorphic rock that consists of layers of different the minerals and can be split into thin irregular plates and hard which are weathering easily [17]. As a result, the Argileceous Clay (101 Ωm - 500 Ωm) was found between the top soil and Gabro (4200 Ωm – 20.000 Ωm) that indicate the existence of a slip plane. The comparison of the resistivity of two layers of the rocks allows us to determine the critical landslide criterion level, where this condition contributes to developing a landslide early warning system using the Geoelectrical method [7]. It is indicated of the precursor landslide. The Landslide precursors with Gabro rock landslide material are found at altitudes (620 meters – 680 meters) above sea level as shown in Figure 3. Landslides containing the Sandy soil are triggered by the rock structures at altitude (620 meters – 680 meters) above the sea level, such as Figure 3. Then, the another precursor is the Sandy soils lining the top of the Argillaceous Clay covering the Schists and the Tuffs. Therefore, the rock structures such as those located (440 meters – 500 meters) above the sea level also have the potential to cause landslides [3].

We were founded Gabro which has been weathering in this track, such as Figure 4. This structure was indicated of the precursor landslide. A low resistivity zone that forms a sloping arch consisting of the clay and has a high degree of saturation is a plane, as observed in the borehole [5]. The presence of clay reliefs above the Gabro aid has led to the formation of the sliding surface as the landslide precursor [18],[24]. Rock resistivity anomaly is estimated due to the presence of rock Schists. Schists are solid and hard rocks which are waterproof but easy to weather. As a result of Limestone that is cover the Schists rock that indicator of precursor of landslide (we call it the slip surface) [8],[29]. Landslides that contained the sandy soil are triggered by rock structures at altitude (450 meters – 510

meters) above the sea level, such as Figure 4. Then, the another precursor is the sandy soils that line Argillaceous Clay covering Schists [27]. Therefore, the rock structures such as those located (585 meters – 650 meters) above the sea level also have the potential to cause the landslides.

Based on, the all of the Figure at the above show that anomalies seen in the rock structures that have the resistivity ($505 \Omega\text{m}$ – $1050 \Omega\text{m}$) which is estimated due to the presence of the Schist rocks in this layer. Ordinarily, the Schists are the metamorphic rock that consists of layers of different the minerals and can be split into thin irregular plates and hard which are weathering easily [17]. As a result, the Argillaceous Clay ($101 \Omega\text{m}$ – $500 \Omega\text{m}$) was found between the topsoil and Gabro ($4200 \Omega\text{m}$ – $20.000 \Omega\text{m}$) that indicate the existence of a slip plane. Provided that, the comparison of the resistivity of two layers of the rocks allows us to determine the critical landslide criterion level, where this condition contributes to developing a landslide early warning system using the Geoelectrical method [7]. This condition indicating of the precursor landslide. The Landslide precursors with Gabro rock landslide material are found at altitudes (620 meters – 680 meters) above sea level as shown in Figure 3. As a result, Landslides containing the Sandy soil are triggered by the rock structures at altitude (620 meters – 680 meters) above the sea level, such as Figure 3. Then, the another precursor is the Sandy soils lining the top of the Argillaceous Clay covering the Schist and the Tuffs. Therefore, the rock structures such as those located (440 meters – 500 meters) above the sea level also have the potential to cause landslides [3]. We saw Gabro which has been weathering in this track, such as Figure 4. This structure are indicating of the precursor landslide.

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3.2 The Second Location Measurement.

The second location measurement was $00^{\circ}59.469'S$ – $100^{\circ}37.976'E$, altitude 1527 meters) to ($00^{\circ}59.434'S$ – $100^{\circ}37.533'E$, altitude 1379 meters). Acquisition data this location were divided into two sections such as ($00^{\circ}59.435'S$ – $100^{\circ}37.034'E$, altitude 1526 meters) to ($00^{\circ}59.434'S$ – $100^{\circ}37.533'E$, altitude 1379 meters), and ($00^{\circ}59.469'S$ – $100^{\circ}37.97 E$, altitude 1527 meters) to ($00^{\circ}59.304'S$ – $100^{\circ}36.055'E$, altitude 1415 meters). The 2-D cross-section resistivity in the first location as shown in Figure 5 and Figure 6.

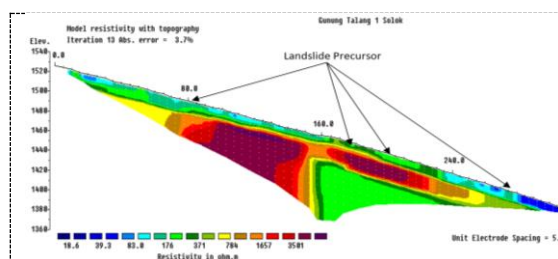


Figure 5: The 2-D cross section of the rock structure as landslide precursor at ($00^{\circ}59.435'S$ – $100^{\circ}37.034'E$, altitude 1526 meters) to ($00^{\circ}59.434'S$ – $100^{\circ}37.533'E$, altitude 1379 meters)

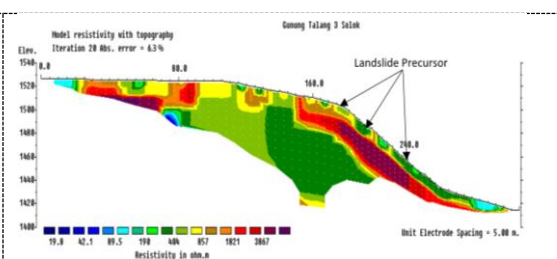


Figure 6: The 2-D cross section of the rock structure as landslide precursor at ($00^{\circ}59.469'S$ – $100^{\circ}37.97 E$, altitude 1527 meters) to ($00^{\circ}59.304'S$ – $100^{\circ}36.055'E$, altitude 1415 meters)

Base on the Figure 5 and 6, the rock structure in Gunung Talang Solok consist of sandy soil (Resistivity = $13\ \Omega\text{m} - 70\ \Omega\text{m}$), *Quartzporphyryt Clay* (Resistivity = $71\ \Omega\text{m} - 180\ \Omega\text{m}$), *Tuffs* (Resistivity = $190\ \Omega\text{m} - 410\ \Omega\text{m}$, Granite (Resistivity = $415\ \Omega\text{m} - 860\ \Omega\text{m}$, Albite (Resistivity = $900\ \Omega\text{m} - 3.000\ \Omega\text{m}$ and Andesite (Resistivity = $3.000\ \Omega\text{m} - 10.000\ \Omega\text{m}$)^{[6],[29]}. Sandy Soil. The rock structure found is slightly different from the global geological map of Solok Regency, West Sumatra [7]. This can occur because this study found more rock structures in certain areas. This rock layer structure shows that the sliding surface of the landslide is present in this position [4]. According to the all Figure the above, the rock structure on the site can be write such as Table 2.

Table 2 The rock structure at (00°25.488 S, 100°16.412', altitude 1182 meter) to (00°25.488'S, 100°16.412'E, altitude 1300 meters)

	Coordinat / altitude	Resistivity (Ωm)	Type of Rock	Precursor landslide (meters in sea level)	The Degree of Landslide Slop
According to Figure 5	(00°59.435'S – 100°37.034'E), altitude 1526 meters) to (00°59.434' S – 100°37.533'E, altitude 1379 meters)	13 – 70 71 - 180 190 - 410 415 – 860 900 – 3000 3000 – 10.000	Sandy Soil <i>Quartzporphyryt Clay</i> <i>Tuffs</i> Granite Albite <i>Andesit</i>	1470 – 1490 1400 – 1440 1360 - 1390	35 degree, Clay and Limestone under Lvas (precursor landslide)
According to Figure 6	(00°59.469'S – 100°37.97 E), altitude 1527 meters) to (00°59.304'S – 100°36.055'E), altitude 1415 meters)	13 – 70 71 - 180 190 - 410 415 – 860 900 – 3000 3000 – 10.000	Sandy Soil <i>Quartzporphyryt Clay</i> <i>Tuffs</i> Granite Albite <i>Andesit</i>	1500 – 1520 1420 – 1440 1380 - 1400	40 degree, Clay and Limestone under Lvas (precursor landslide)

The Figure 5 and Figure 6 show that the anomalies seen in the rock structures that have the resistivity ($190\ \Omega\text{m} - 410\ \Omega\text{m}$) which is due to the presence of the Tuffs in this layer. Therefore, Tuffs are the porous rock that formed by the consolidation of volcanic ash, such as the Talang mountain. The weathering of Tuffs is due to the changes of temperature and pressure in this area. Moreover, Tuffs that weathered thus forming the slip surface, known as the precursor of a landslide. Next, Argillaceous Clay ($71\ \Omega\text{m} - 180\ \Omega\text{m}$) was found between the Sandy soil ($13\ \Omega\text{m} - 70\ \Omega\text{m}$) and the Granite ($900\ \Omega\text{m} - 3.000\ \Omega\text{m}$) that indicate the existence of a slip surface. The structures which forming such as the above is indicating of the precursor landslide[7]. The landslides containing the Sandy soil and Quartzporphyryt Clay are triggered by the rock structure formed by Tuffs and Granite is found on at altitudes (1400 meters – 1440 meters) above the sea level, such as Figure 7 [8]. The same the rock structure is also found at altitudess (1445 meters – 1550 meters), and (1470 meters – 1490 meters) and (1420 meters – 1460 meters) above the sea level, such as Figure 8. Then, the another precursor is the Sandy soils lining the top of the Argillaceous Clay covering the Tuffs is also the potential to cause landslides is found at altitude (1370 meters – 1390 meters) above the sea level, such as Figure 5.

The presence of clay reliefs above the Granite aid has led to the formation of the sliding surface as the landslide precursor [2],[24]. The rock resistivity anomalies in this area are estimated due to the presence of Granite and Albite. Granite is solid and hard rocks which are waterproof, but easy to weather[17],[30]. As a result of the Argillaceous Clay that is covering the Tuffs that is the indicator of precursor of landslide (we call it the slip surface)[28]. The rock structures like the Sandy soils that line

Argillaceous Clay covering Tuff were seen at (1470 meters – 1500 meters) above the levels, such as Figure 5. The average of Landslide Slope is 38 degrees. Therefore, on the location of the large landslide possibility to occur, if in this location, washed by heavy rains [19]. Conversely, the sliding surface is the area where the landslide material moves on this surface. Thus, the movement of material is caused by disruption of soil stability that is the indicator of precursor of landslide.

Comparison of resistivity results allows us to determine the level of criticism for landslides, where these conditions contribute to the developing landslide early warning systems using the Geoelectric method. The low resistivity type zone that forms a tilted arch consisting of clay and has a high degree of saturation is a plane, as observed in boreholes [7]. In the location of possible large landslides, if in this region was washed with a large volume [19]. The rock resistivity anomalies in this area are estimated due to Tuff rock. Tuffs is a solid and hard stone which is a waterproof stone, but it is prone to weathering [18]. In conclusion, based on the list of rock resistivity [10], [4] in this pathway are sandy soil, Argillaceous Clay, Schists, Tuffs, Gabro and Andesite [27]. The sliding surface of the track has a slope of 44 degrees, with a layer thickness of 20 meters in the Sei Lasi and a slope of 46 degrees, with a layer thickness of 22 meters on Mount Talang. The effect of Clay on Dolomite assistance is as a sliding surface [26]. Rock structure like this is what triggers frequent landslides, when this area receives very high rainfall (Figure 6). Anomalies of the rock resistivities in this area are estimated due to Andesite rocks. Andesites are solid and hard rocks which are waterproof stones, but are prone to weathering. The effect of Clay on the Andesite hearing aid is the sliding surface. This is what triggers this area to experience landslides when the volume of rainfall is high [18], [8]. The rock structure in Sungai Lasi and Mount Talang Districts, Solok Regency consists of Sandy Soil, Quartzporphyryt Clay, Tuffs, Granite, Albite, Andesite. Granite, Albite, Andesite is the impermeable rocks, which means that there are in-kind rocks which are vulnerable in areas prone to landslides. However, there are several points of opportunity for large-scale landslides to occur, although small-scale landslides are still likely to occur.

4. Conclusions and Recommendations

Mostly the rock structure in Sei Lasi sub-district, Solok regency, West Sumatra consist of Sandy soil (as top soil), Argillaceous Clay, Schists, Tuffs, Gabro, Andesite. The Sandy Soil and Argillaceous Clay covering Schists and Gabro at the hill with slope 46 degrees were a precursor of landslide. We found ten rock structures which are indicating of precursor of landslide. The landslide precursor takes place at 440 meters to 665 meters in altitude above sea levels. Therefore, the implementation of the results of this study is at coordinates $00^{\circ}46.053'S$, $100^{\circ}16,357'E$, altitude 834 meters) to ($00^{\circ}25.488'S$, $100^{\circ}16,412'E$, altitude 494 meters must plan mitigation of the landslide disaster well. Next, mostly the rock structure in district Gunung Talang, Solok regency of West Sumatra is consist of Sandy Soil, Quartzporphyryt Clay, Tuffs Breccias, Granite, Albite and Andesite. The Sandy Soil and the Quartzporphyryt Clay are covering Granite and/or Albite was a precursor of landslide. Next, We found six rock structures which are indicating of precursor of landslide. The average of Landslide Slope in Solok regency, West Sumatra is 42 degrees. The landslide precursor takes place at 1360 meters to 1520 meters in altitude above sea levels. Moreover, the implementation of the results of this study is at coordinates ($00^{\circ}46.053'S$ – $100^{\circ}44.353'E$) to ($00^{\circ}25.488'E$, $00^{\circ}16,412'E$) must be planned mitigation of the landslide disaster well. Finally, related to this location was widely used for Cinnamomum zeylanicum plantations, when harvesting does not cut large trees simultaneously, so the roots of trees still grow in this location as the wood that grows to play a role as a reforestation tree.

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