



Geoelectric Interpretation of Wenner-Schlumberger Configuration Using Res2Dinv Software: A Case Study of 2D Mapping of Seawater Intrusion in a Landslide Potential Area, North Halmahera District, Indonesia

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Abstract

Research has been carried out on landslides in Saluta-Pelita Village, North Galela District, North Halmahera Regency, Indonesia using the Wenner-Schlumberger method using a Geoelectric Resistivity tool - Naunira NRD 300 HF. This research aims to determine the structure of the subsurface layer in the potential landslide area of Saluta-Pelita Village. In addition, this research aims to determine the slip plane (boundary layer) of sea water intrusion in the research area. The measurement results are processed using Res2Dinv software for 2D resistivity which describes the subsurface layer shown in color. The measurement results on track 1 show a clay layer with a resistivity value of 3.1 Ωm -27 Ωm at a distance of 1-80 meters (blue and green), a silt layer of 44.3 Ωm -184.1 Ωm at a depth of 1-20 meters (Yellow) which is a slip plane (boundary layer) of sea water intrusion with a path length of 40 meters, conglomerate 210 Ωm (red) at a depth of more than 7.50 meters. In track 2 there is a layer of clay with a resistivity of 1.4 Ωm -39 Ωm at a depth of 1-24 meters (blue and green), silt 43.1 Ωm -185.6 Ωm (yellow) is the slip plane (layer boundary) of sea water intrusion with a 95 meter long track, a conglomerate layer with a resistivity of 203.4 Ωm -407.8 Ωm (red) at a depth of more than 12.8 meters. On track 3 there is a layer of clay with a resistivity of 0.186 Ωm - 31.4 Ωm (blue and green) at a depth of up to 24 meters with a length of more than 120 meters, silt with a resistivity value of 44.4 Ωm -189 Ωm (yellow) which is a slip plane (boundary layer) sea water intrusion with a path of 65 meters at a depth of 2.50 meters-24.9 meters.

Keywords: boundary layer; geoelectric resistivity; north halmahera regency; res2dinv; sea water intrusion

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INTRODUCTION

Several factors like climate change, human activities, and geological conditions contribute to the collapse of coastal cliffs and the destabilization and retreat of sea cliffs. Increased marine erosion and retreat of the coast may lead to an increased frequency of rock falls and landslides. Sea level rise associated with climate change poses a significant risk to low lying coastal areas and islands. It has the potential to cause loss of land and exacerbate erosion (Bhat et al., 2018). Rising sea level is one of the most direct hazards resulting from anthropogenic climate change. It directly threatens low-lying areas and human activities by increased marine flooding and land submergence combined with more frequent and more severe storm surges (Marfai & King, 2007).

Considerable researches have been conducted using numerical methods since many decades to understand complex landslide process mechanics and failure modes (Pratiwi et al., 2019). Among several categories of landslides, how igneous rock slope failures behave under different boundary conditions and what are the modes of failures is an unexplored aspect of research for number studies yet. Knowledge on propagation, amplification, and/or attenuation attributes along with energy transferring characteristics of the above-mentioned landslides lead for a thorough investigation for different natural scenarios. It has much more challenges due to the variation in the compositions, textures and weathering degrees of igneous materials and many other respective parameters (Kimura, 1990).

Landslides

Landslides are the movement of rock, soil, and/or debris down a slope due to the influence of gravity or other ground-affected causes. They are natural geohazards, resulting in great impacts on humans, nature, society, and the economy (Grierson, 2007). The human and economic losses due to landslides have made it a global priority. Understanding the mechanisms of the initiation and propagation of landslides is the primary stage to be addressed. Several advances have been made through laboratory and/or field work. However, due to costing and many practical difficulties, field and laboratory-based works are limited in number, so the numerical models may provide a supplemental and cost-effective manner to retain the advancements in landslide mechanics under in-situ conditions (Abidin et al., 2011).

Landslides are one of the major natural hazards, which are known to cause significant economic losses and casualties. Many landslides develop due to combinations of geological conditions, precipitation, land use, seismically active, and climate change. Sea water intrusion also triggers and adversely affects the stability of landslides (Sari et al., 2020). Research on seawater intrusion and its impact on the stability of landslides is important for the assessment and management of future landslides. Sea water intrusion into land due to sea level rise is one of the catastrophic disasters which cause hazard to human life, settlements, agriculture, etc (Sabara et al., 2021).

Some opinions regarding the causes of landslides often only apply to certain areas and are not found in other areas, distinguishing between factors that come from outside and factors from within that are related to the physical properties of the soil or rock. Apart from these causes, it is influenced by excessive loading, vibration and shaking, changes in groundwater levels, and plant cover on the slopes (Muthamilselvan et al., 2019). Although the main cause of ground movement is gravity, which affects a steep slope, there are also influencing factors, namely erosion, weak rocks and soil, earthquakes and volcanoes, vibrations and additional loads, land use, landslides, and waste disposal areas (Datta et al., 2016).

Layers consisting of rocks that can pass water and impermeable rocks during the rainy season have the potential for landslides. Water that enters the soil until the layer is waterproof. Water will accumulate on the waterproof layer. The layer above the waterproof layer becomes rotten. The surface of the waterproof layer becomes slippery, so the weathered layer will move on the slippery part, which acts as a sliding surface. The slip plane is obtained from the resistivity contrast between two adjacent rocks, supported by high rainfall and a fairly steep plane. The slip surface usually consists of a hard layer and a soft layer. When it rains, the hard (waterproof) layer will become slippery. The soft layer moves through the impermeable layer. The impermeable layer acts as a sliding surface. The soft layer acts as a landslide material. Landslide material is characterized by low

resistivity values, and landslide areas are characterized by material that has high resistivity values (Aizebeokhai & Oyeyemi, 2015; Kumar et al., 2015; Sadjab et al., 2020). Slip areas are areas that hold water (low permeability) and are dense, causing weathered soil to move above them. Landslides often occur on slopes that have a layer of impermeable rock. Waterproof rocks usually have relatively small pores and a large resistivity value (Ibrahim et al., 2019).

In the North Galela District area, North Halmahera, Indonesia, there is a very important main road that connects the Tobelo and Loloda areas. North Galela has several areas prone to landslides due to sea water intrusion, especially on the road between Saluta Village and Pelita Village because it has mountains with wavy and steep relief so there is a high potential for landslides to occur. Therefore, it is necessary to make efforts to prevent road damage due to landslides by knowing the subsurface geometry (sea water intrusion). One effort to investigate and identify the surface layers that make up landslide areas is by using geophysical techniques to determine the characteristics of the surface layers that make up slopes and slopes using geological studies. The geoelectric resistivity method is a physical method that uses the properties of resistivity to determine conditions beneath the earth's surface. Using the Geoelectric Resistivity Method of the Wenner-Schlumberger Configuration Type, this research was carried out to determine the subsurface of the earth in landslide-prone areas using the Wenner-Schlumberger configuration to look for the existence of slip planes (boundary layer) of sea water intrusion.

METHOD

Research on the identification of landslide-prone areas on the road connecting Saluta Village and Pelita Village, North Galela District using the Wenner-Schlumberger Configuration Type Resistivity Geoelectric Method was carried out on 2022 in a Landslide Potential Area, North Halmahera District, Indonesia. The research was carried out at 3 measuring points with a track length of 150 meters each with a distance between tracks of 30 meters while the distance between the track and the road was 10 meters. Line 1 is at coordinates 2.086960, 127.994882, line 2 is at coordinates 2.086832, 127.994729, and line 3 is at coordinates 2.086660, 127.994580.

Wenner-Schlumberger Configuration

A configuration with a constant spacing rule system with a factor of "n" is a Wenner-Schlumberger configuration. Configuration is the comparison of the distance between AM and MN electrodes. If the distance between the MN electrodes is a then the distance between the current electrodes (A and B) is $2na + a$. Straight line is the process of determining resistivity on 4 electrodes (Aizebeokhai & Oyeyemi, 2015; Ibrahim et al., 2019; Kumar et al., 2015; Saparun et al., 2022). The geometric factors of the Wenner-Schlumberger configuration are: $k = n(n+1)\pi a$. Where a is the distance between electrodes M and N (Figure 1).

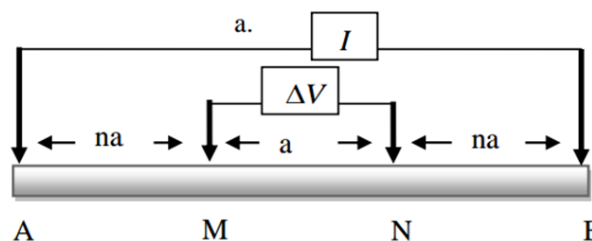


Figure 1. Wenner-Schlumberger configuration electrode

Data Collection Procedures

The first step taken is a location survey, if the location meets the requirements for conducting research, the next step is for researchers to prepare tools and materials to be used in the field, the tools used are geoelectric resistivity meters and other supporting tools. Install the electrodes and the potential of the Wenner-Schlumberger configuration with a predetermined distance, when taking current source data originating from the battery is injected into the earth through two current

electrodes that have been plugged into the earth's surface. The existence of the flow of electric current will cause an electric voltage. The voltage that occurs through the two potential electrodes is measured using a multimeter that is already in the geoelectric resistivity meter (Jamaluddin & Umar, 2018; Satriani et al., 2012).

Data analysis

Based on the data that has been obtained in the field, it is then processed using the Res2Dinv software. Res2Dinv software can describe or create 2-dimensional subsurface models from geoelectric survey data. The results obtained from data processing in the Res2Dinv software show conditions that are close to the actual subsurface if the inversion results produce very small error values. The smaller the error value obtained, the better the quality of the subsurface cross section based on the existing resistivity data.

RESULTS AND DISCUSSION

Geology of the Research Area

The research was carried out at 3 measuring points with a track length of 150 meters each with a distance between tracks of 30 meters while the distance between the track and the road was 10 meters. Line 1 is at coordinates 2.086960, 127.994882, line 2 is at coordinates 2.086832, 127.994729, and line 3 is at coordinates 2.086660, 127.994580. Measurements were carried out on Tuesday 17 May 2022. Measurements were carried out on uphill areas on the 3 routes. The weather conditions at the time of measurement varied, namely in the measurement of line 1 the weather changed from hot to cloudy while measurements in line 2 and line 3 were carried out in sunny conditions.

A general overview of the research area is dominated by volcanic rocks with quite complex geological structures. An overview of the rock structure and stratigraphy of the research area can be seen in **Figure 2** below.

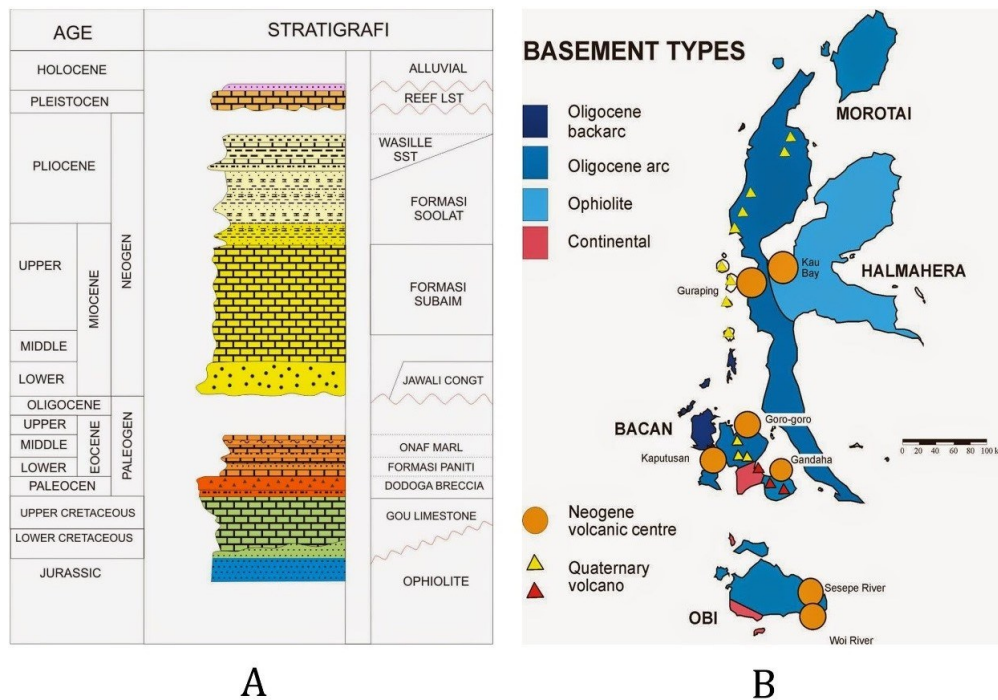


Figure 2. A. Geological map of Maluku Island; **B.** Stratigrafi regional Halmahera

Geoelectric Data Analysis

Based on the results of the resistivity cross-section in line 1 using Res2Dinv software (**Figure 3**) and the geological conditions, it can be seen that there is a dark blue contrast with a resistivity value of 3.1 Ωm to 5.8 Ωm to light green with a resistivity of up to 26.7 Ωm, which is thought to be a clay layer containing mixed sediment. water and is located at a distance of 1 to 80 meters so it is

vulnerable to landslides. The anomalous pattern due to the slip plane is shown in yellow which is thought to be silt rock with a resistivity of 44.3 Ωm to 184.1 Ωm at a depth of more than 20 meters, while below the layer there is a layer with a red contour consisting of hard rock which is suspected to be a conglomerate. When it rains, water will enter the surface of the soil and not enter the silt (the layer with yellow contours) so that it accumulates into a sliding area (boundary layer of sea water intrusion) above that layer. When there is high rainfall, there is the potential for landslides to occur because it has a sloping surface.

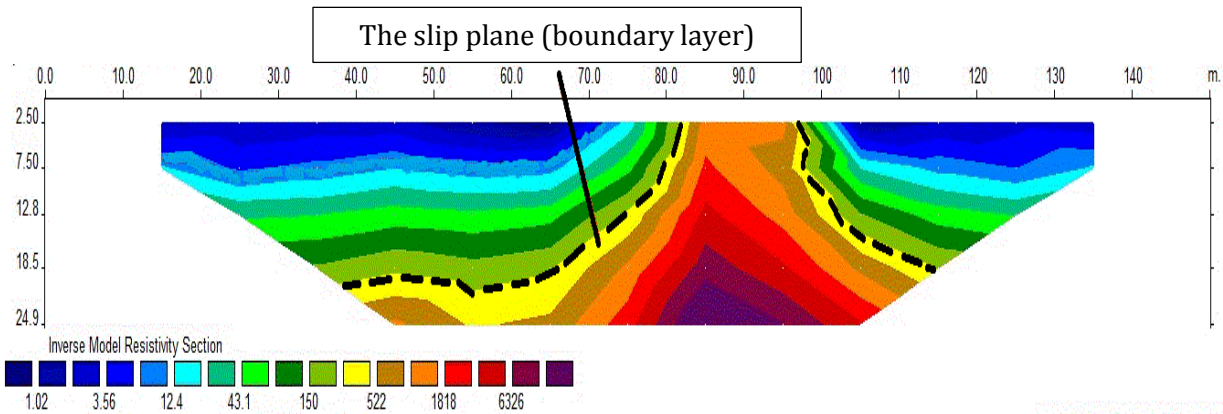


Figure 3. 2D cross section of resistivity contour results on line 1

Based on the results of the resistivity cross-section in line 2 using RES2DINV software (Figure 4) and the geological conditions, it can be seen that there is a dark blue contrast with a resistivity value of 2.5 Ωm to 6.8 Ωm to light green with a resistivity of up to 22.7 Ωm, which is thought to be a clay layer containing mixed sediment. water and is located at a distance of 2 to 90 meters so it is vulnerable to landslides. The anomalous pattern due to the slip plane is shown in yellow which is thought to be silt rock with a resistivity of 44.3 Ωm to 184.1 Ωm at a depth of more than 20 meters, while below the layer there is a layer with a red contour consisting of hard rock which is suspected to be a conglomerate. When it rains, water will enter the surface of the soil and not enter the silt (the layer with yellow contours) so that it accumulates into a sliding area above that layer. When there is high rainfall, there is the potential for landslides to occur because it has a sloping surface.

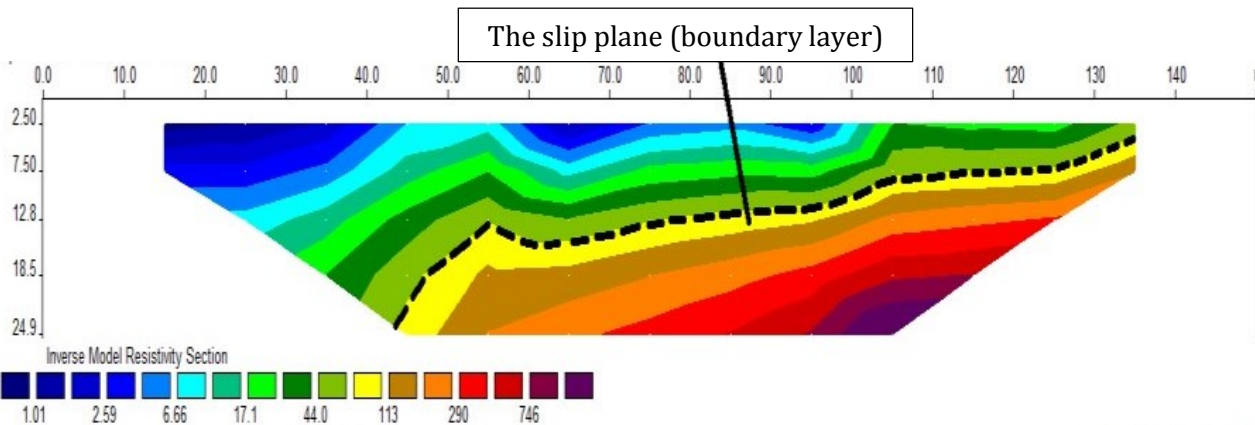


Figure 4. 2D cross section of resistivity contour results on line 2

Based on the cross-sectional results of the 2D resistivity contour in line 3 (Figure 5), several rock layers with different resistivities can be seen, which can be seen in dark blue with a resistivity value of 0.186 Ωm to a green layer with a resistivity value of up to 31.4 Ωm at a depth of up to 12.8 meters is a layer that can hold water because it consists of clay rock, this layer is above the slip plane or borders the yellow layer which has a resistivity value of 44.4 Ωm to 189 Ωm, this boundary is a slip plane because it is formed due to weathering and saturated with water or usually above a layer of silt. The silt layer itself is above conglomerate rock which has a resistivity value of more than 200 Ωm.

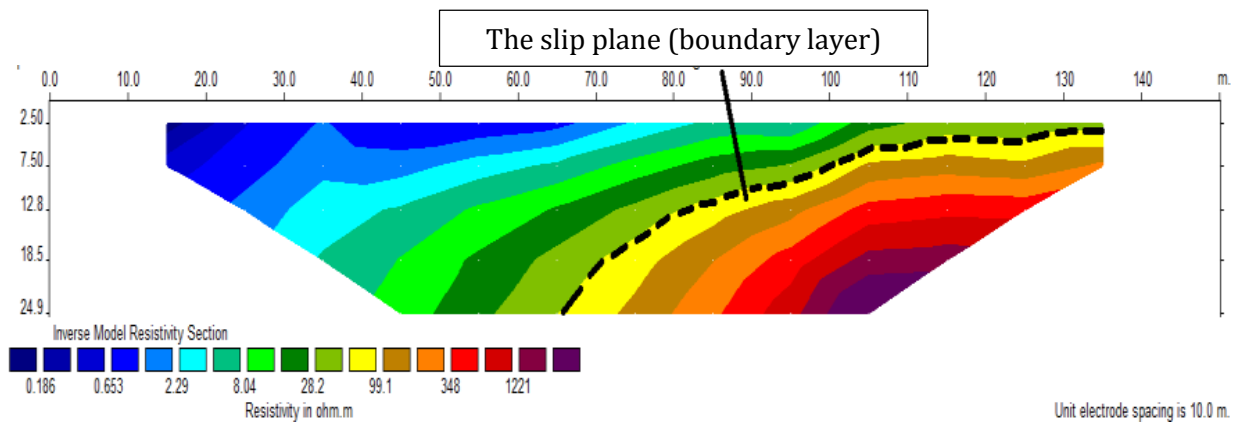


Figure 5. 2D cross section of resistivity contour results on line 3

CONCLUSION

In landslide-prone areas there are several layers that have different resistivity values. On track 1 you can see the resistivity structure of $26.7 \Omega\text{m}$ to $43.1 \Omega\text{m}$ at a distance of 0 to 80 meters and at a depth of up to 20 meters showing that the clay rock structure is located below. on the slip plane which is thought to be silt rock and at a distance of 70 meters to 100 meters at a depth of 1 meter to 24 meters there is a layer with a red contour which is thought to be conglomerate. On track 2 there is a resistivity value of $1.4 \Omega\text{m}$ to $39.6 \Omega\text{m}$, the clay layer is up to a depth of 24 meters and is above the silt layer which is at a depth of 1 meter to 25 meters which is at a distance of 40 meters to 140 meters and rocks. which is thought to be a conglomerate located at a depth of more than 17 meters at a distance of 70 meters to 125 meters. Meanwhile, on the 3rd track, there is a clay rock resistivity with a blue to green color contrast which is thought to be the clay layer at 0-130 meters at a depth of up to 24 meters, while the silt layer is at a distance of 65 meters to 130 meters with a depth of under 2.50 meters, and the red contour at a depth of 20 meters at a distance of 85 to 130 meters is Conglomerate. Based on the 2-D resistivity cross section, on each track there is a slip area on each track that is different, on track 1 there is a slip area at a distance of 35 meters to 80 meters with a depth of up to 20 meters, on track 2 there is a slip area at a distance of 40 meters to 130 meters with depths from 2 meters to 24.9 meters. Meanwhile, the 3rd route has a slip area at a distance of 70 meters to 130 meters at a depth of 2 meters to 24.9 meters so that it can cause landslides with quite large landslide intensity with the type of translational landslide.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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