INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2023, Vol. 4, No. 4, 1383 – 1390
http://dx.doi.org/10.11594/ijmaber.04.04.32

Research Article

Identification of Rock Resistivity and Slip Surface in the Ambon Volcanic Rock in the Kayu Putih Area of Ambon City

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Article history:
Submission March 2023
Revised April 2023
Accepted April 2023

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ABSTRACT

Research on rock resistivity and slip surface in the Ambon Volcanic Rock formation has been carried out through geoelectric mapping with the Wenner-Schlumberger configuration in the Kayu Putih area, Ambon City as one of the areas prone to landslides. Measurement of rock resistivity by Mapping was carried out on two tracks each 120 m long and 70 m long intersecting each other. The results showed that the resistivity values of the rocks ranged from 185 Ωm to 4,128 Ωm consisting of Top Soil, Unsaturated Landfill, and Loose Sand as the cover layer followed by Dry Sandy Soil and Gravel, and Breccia Dacite and Tuff at the bottom layer. Breccia Dacite rocks with a resistivity of greater than 2,000 Ωm are found at a depth of 11 – 13 m below the soil surface functioning as slip surface for the sand layer above them. The movement of the soil mass over the slip surface causes cracks in the surface of the road and houses.

Keywords*: Ambon volcanic rock, geoelectric, resistivity*

Introduction

Ambon as a small island in Indonesia is dominated by the Ambon Volcanic Rock Formation (Tpav) with Andesite, Dacite, Breccia and Tuff composition according to the Geological Map of The Ambon at a scale of 1:250.000 (Tjokrosaputro et al., 1993) or is loose material with a material composition of sand, silt, and gravel according to Map Geologische Kaart van Ambon Schaal 1:100.000 (Verbeek and Koperberg, 1898). One of the areas prone to landslides in Ambon City is Kayu Putih, Sirimau District, Ambon City. Several locations in this area show the presence of mass movement marked by cracks in surface roads and residential buildings, as well as landslides in several locations.

With the presence of several material components in this landslide-prone area, the resistivity of the constituent materials will vary. Groundwater has a resistivity of 0,5-300 Ωm, sand 1-1.000 Ωm, gravel 600-10.000 Ωm, tuff 2.000 Ωm, dacite 20.000 Ωm (Telford et al., 1990). This was proven in research on sandstone lithology that sand with a resistivity ranging from 15,1 Ωm – 87,9 Ωm is found at depths of 2 – 15 meters (Septiansyah et al., 2020). In Andesitic-Basal Breccia lithology, Breccia lava, Andesitic lava and Tuffaceous Sandstone inserts, water is found at depths of

How to cite:
Marthen, M. C., Puturuhu, F., & Latupapua, A. I. (2023). Identification of Rock Resistivity and Slip Surface in the Ambon Volcanic Rock in the Kayu Putih Area of Ambon City. *International Journal of Multidisciplinary: Applied Business and Education Research. 4*(4), 1383 – 1390. doi: 10.11594/ijmaber.04.04.32

5-25 m (Listyo et al., 2022). In another study it was also proven that material with a resistivity of 32,2 Ωm was thought to be water stored in limestone at a depth of 5,21-9,72 m (Latupapua, 2022a), while material with a resistivity of 8,82 Ωm was thought to be water stored in sand at a depth of 12 m (Latupapua, 2022b).

The difference in subsurface resistivity can not only indicate the availability of groundwater, but also indicate fractures and slip surface in disaster-prone areas. The existence of weak areas on the measurement path that cut the layers between rocks can be estimated as fractures (Jefriyanto et al., 2015). Meanwhile, the slip plane is in a layer of rock that is impermeable to water (Mulyasari et al., 2021). Ground slip surface, slopes, and vibrations at the top of densely populated are factors that trigger landslides (Miftahul and Rosid, 2022).

The resistivity of the rocks in the Ambon Volcanic Rock formation, especially in areas prone to landslides, is not known with certainty, because research on this matter has never been done.

Methods

The research was conducted in the Kayu Putih area, Negeri Soya, Sirimau District, Ambon City. Acquisition of rock resistivity data by Mapping using the geoelectric method with the Wenner-Schlumberger electrode configuration. Two tracks are made to intersect each other for 120 m and 70 m respectively with the smallest electrode distance on track 1 is 10 m and on track 2 is 5 m. Track 1 is located at coordinates 410.981 mE and 9.590.433 mS to 411.068 mE and 9.590.345 mS. While Track 2 is at coordinates 411.002 mE and 9.590.334 mS to 411.052 mE and 9.590.379 mS. The research location is at an altitude of 122 m to 135 m above sea level with rather steep slopes.

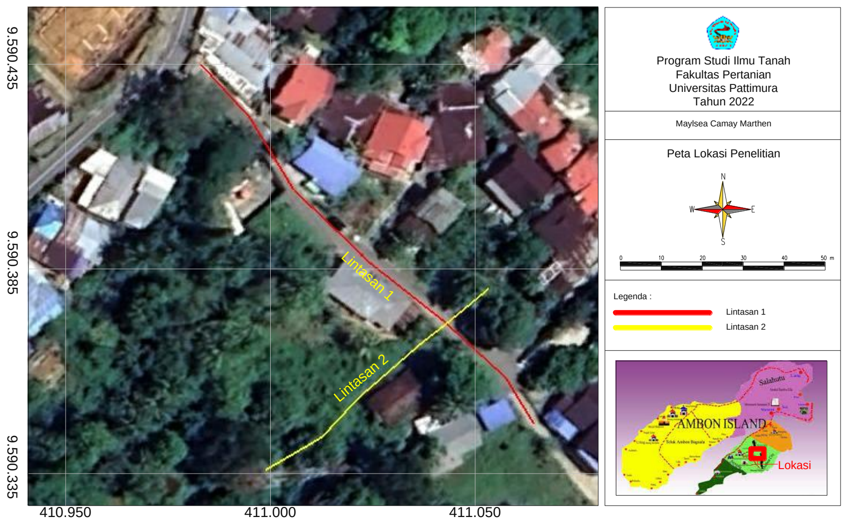

Figure 1. Research location

On track 1 there are 30 datum points with n value from 1 to 5, while on track 2 there are 42 datum points with n values from 1 to 6. From the distances of the installed electrodes, the geometric factor (K) of the Wenner-Schlumberger configuration can be obtained, namely :

$$K = n(n+1)\pi a$$

where n is the comparison factor, a is the smallest electrode distance MN. Furthermore, the apparent resistivity value can be calculated by the equation:

$$\rho = K\frac{\Delta V}{I} \quad \Omega m$$

where ρ is the apparent resistivity, K is the electrode geometry factor, ΔV is the electric potential difference, and I is the electric current which is read on the panel of the geoelectric device.

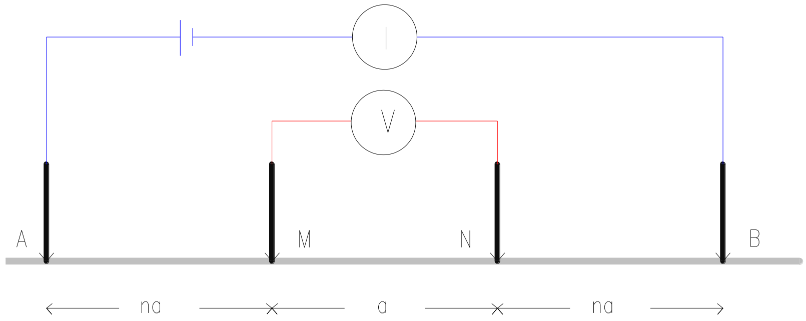

Figure 2. Wenner-Schlumberger electrode configuration

Data on *K* values, **Δ**V readings, and *I* are tabulated to obtain apparent resistivity values. Data that has been tabulated and considered to be of better quality is then processed through an inversion process using Res2Dinv. The inversion process uses the least square–constrained smoothness method which produces the apparent resistivity value of the field data, calculation results, and the inversion result pseudosection. The geological data of the research location is in the form of Ambon Volcanic Rock or its equivalent Loose Material and rock resistivity values (Telford et al., 1990; Milsom, 2003; Reynold, 1998; Loke, 2015 *in* Rizal et al., 2017) are used as references in interpretation data (Table 1).

Table 1. Rock Resistivity Value

Rocks	Resistivity (Ωm)
Dacite	2 x 10^4 (wet)
Andesite	4,5 x 10^4 (wet) – 1,7 x 10^2 (dry)
Tuff	2 x 10^3 (wet) - 10^5 (dry)
Limestone	5x10-10^7
Sandstone	200-8.000
Siltstone	1,5x10^4
Consolidated Shales	20-2x10^3
Loose Sand	500 – 5.000
Sand and gravel	30-225
Dry sandy soil	80-1050
Sand clay/clayey sand	30-215
Top Soil	250-1,700
Gravel	1.400 (dry) – 100 (Saturated)
Soil (40% Clay)	8
Soil (20% Clay)	33
Fresh Ground water	10-100
Conglomerat	2x10^3-10^4
Unsaturated landfill	30-100
Saturated landfill	15-30

Results and Discussion

Track 1

The data for Track 1 after being processed produces an overview of the horizontal and vertical distribution of Measured Apparent Resistivity Pseudosection, Calculated Apparent Resistivity Pseudosection, and Apparent Resistivity resulting from inversion with an RMS error of 16.7% (Figure 3).

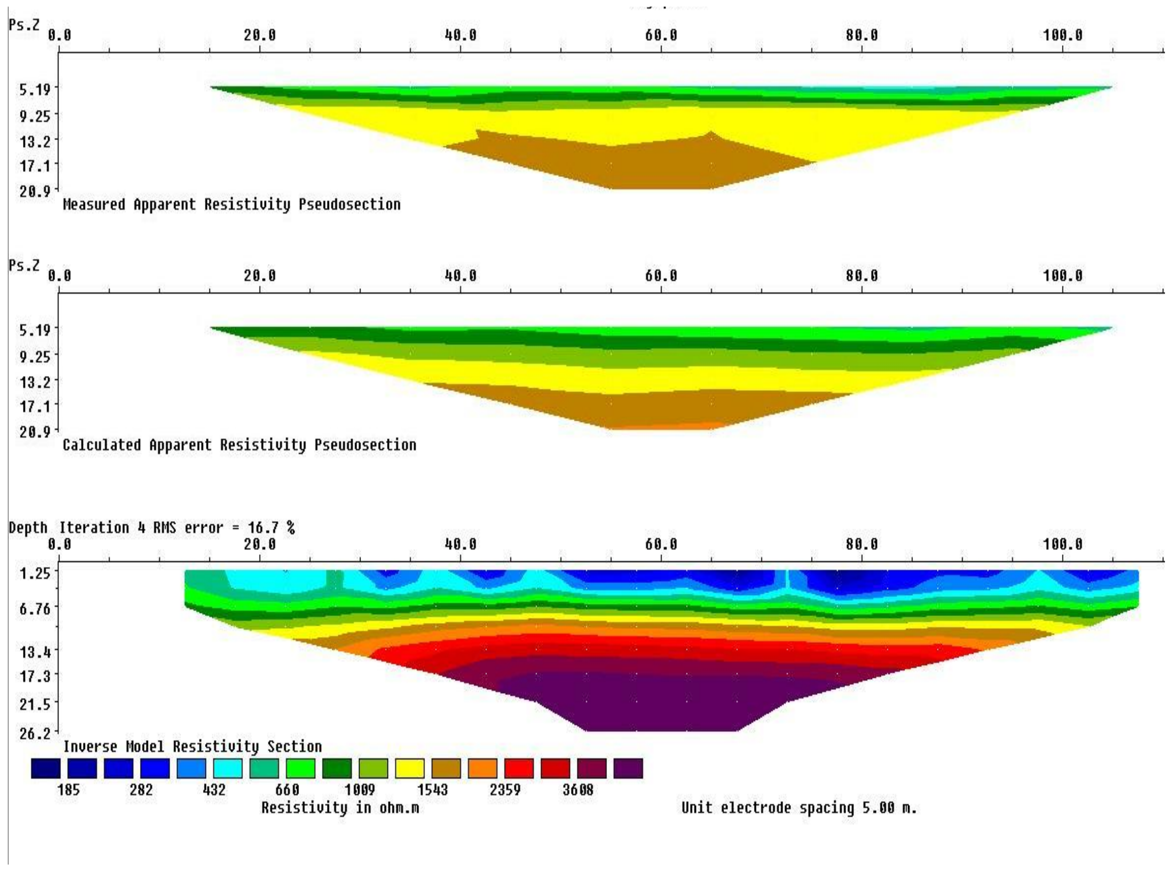

Figure 3. Measured, calculated, and iteration of apparent resistivity in Track 1

Based on Table 1, the resistivity of the rocks on Track-1 ranges from 185 Ωm – 3.608 Ωm can be grouped into low, medium and high resistivity. The contrasting resistivity values show differences in the physical characteristics of the rocks (Miftahul et al., 2022). Top Soil and Unsaturated Landfill cover layers are marked with blue to bright blue images that have low resistivity. This is caused by weak bonds between grains and there are cavities that are easily filled with water. With the presence of water in the pores, the electric current will easily flow so that the resistivity value becomes low. The Unsaturated Landfill layer is an embankment layer in asphalt road construction. The Sandy Soil and Gravel layers are characterized by a more compact sky blue to bright green image and moderate resistivity. This layer with low and medium resistivity is a saturated layer that can move on top of a hard layer with high resistivity, namely the Tuff and Breccia layers with Andecite fragments. This hard layer is characterized by a light green to dark purple image.

Table 2. Rock types based on the results of geological data correlation on Track-1

Resistivity Type	Value (Ωm)	Rock Type
Low	185 – 432	Top Soil; Unsaturated landfill
Medium	432 – 1.009	Dry sandy soil; Gravel
High	> 1.009	Breccia Andecite ; Tuff

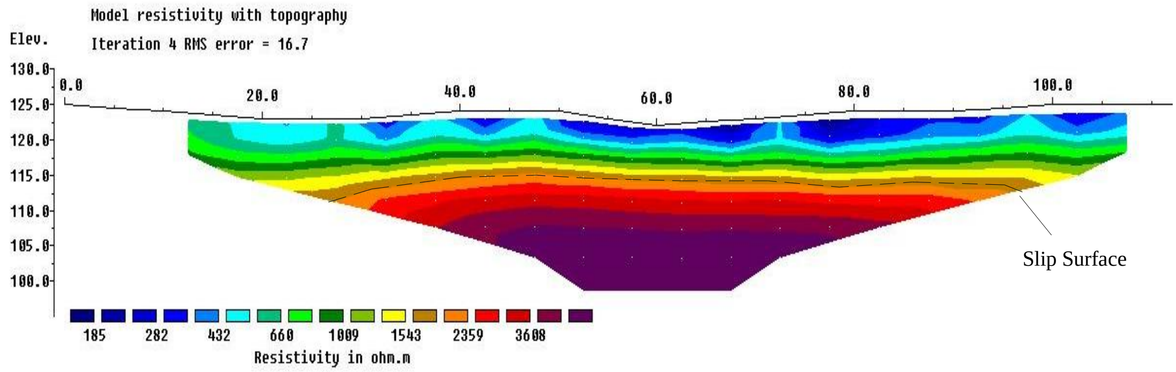

Figure 4. Resistivity section with topography on Track 1

Track-1 follows the contour so that the slope is flat all the way from point 0 to a distance of 120 m. The hard layer in the form of Breccia Andecite with a resistivity greater than 1.009 Ωm is found at a depth of 13 m. The resistivity value of Breccia Andecite according to the research results of Santoso and Hidayatulah (2017) ranges from 1.156 Ωm to 1.944 Ωm. The function of Breccia as a slip surface is also found in research to identify lithology and slip surface (Mulyasari et al., 2020; Mulyasari et al., 2021). The flat topography (Figure 4) shows that the movement of the soil mass is not significant horizontally even though the soft layer lies on top of the hard layer as a slip surface.

Track 2

After processing, Track-2 data produces an overview of the horizontal and vertical distribution of Measured Apparent Resistivity Pseudosection, Calculated Apparent Resistivity Pseudosection, and Apparent Resistivity resulting from inversion with an RMS error of 18.4% (Figure 5).

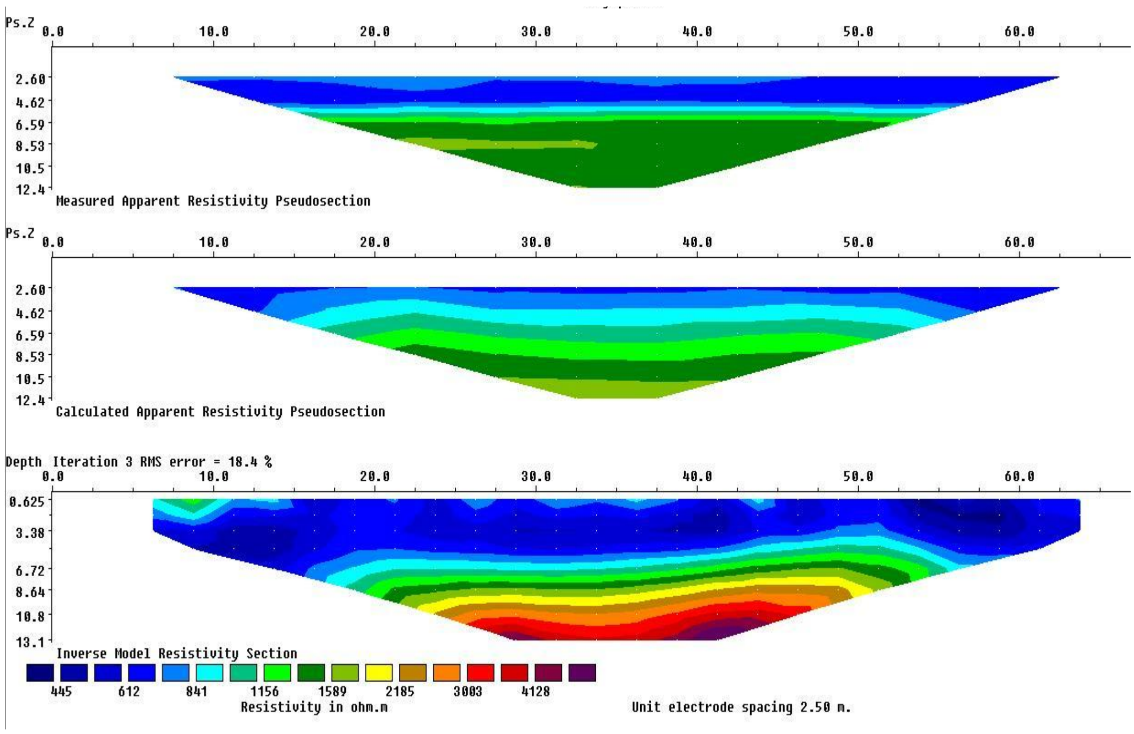

Figure 5. Measured, calculated, and iteration of apparent resistivity in Track 2

Based on Table 1, the resistivity of the rocks in Track-2 which ranges from 445 Ωm – 4.128 Ωm can be grouped into low, medium and high resistivity, especially at this location (Table 3). The cover layers in the form of Top Soil and Loose Sand are marked with blue to bright blue images that have low resistivity. This is according to the opinion of Debby Rahayu et al. (2019) that sand is classified as a material with low resistivity properties. Layers with low resistivity will be easily saturated with water. The Sandy Soil and Gravel layers are characterized by bright blue to green images, are more compact in nature and have moderate resistivity. The layers with low and medium resistivity are easily saturated and can move over the hard layers with high resistivity, namely the Breccia Andesite and Tuff layers. This hard layer is characterized by green to dark purple images.

Table 3. Rock types based on the results of geological data correlation on Track-2

Resistivity Type	Value (Ωm)	Rock Type
Low	445 – 841	Top Soil; Loose Sand
Medium	841 – 1.589	Dry sandy soil; Gravel
High	> 1.589	Breccia Andecite; Tuff

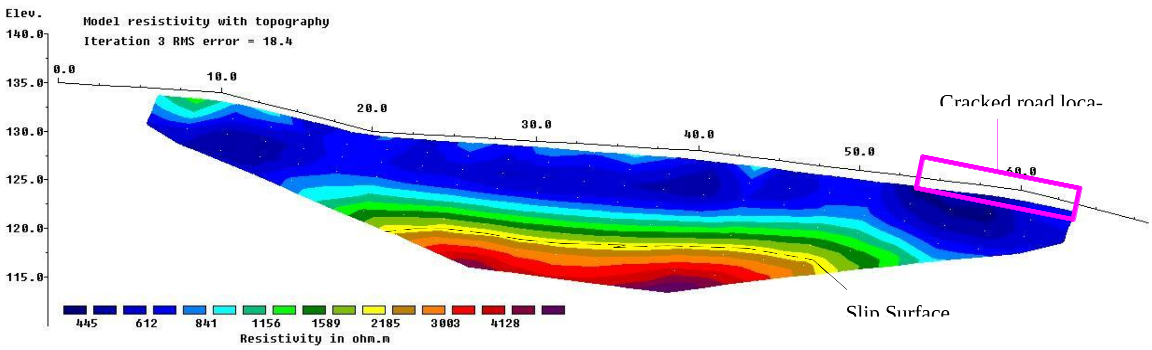

Figure 6. Resistivity section with topography on Track 2

Track-2 is located in an area with rather steep topography with a height of 135 m above sea level to 120 m above sea level (Figure 6). The difference in resistivity of subsurface rocks in the form of rocks with low to moderate resistivity and rocks that have high resistivity indicates differences in the compactness of the rock mass. The presence of soft rocks on top of hard rocks indicates the location of weak areas (Jefriyanto et al., 2015)

Figure 7. Cracks in the surface of roads and houses

The layer of hard rock with a higher resistivity than the soft layer above it functions as a slip surface. Breccia Andesite as a sliding plane is massive with poor porosity so that water is difficult to store (Mulyasari et al., 2020). If high rainfall allows water to accumulate in saturated layers, resulting in soil movement (Mulyasari, 2021). Saturation occurs because water infiltrates the fracture and the soil quickly expands. In addition, the less dense soil layer will be soft and very vulnerable to soil movement. Vibration due to earthquakes and vehicle traffic can also cause cracks in roads, floors and walls of houses. The movement of the soil masses that can cause landslides is supported by the research of Hendri et al. (2019) and Miftahul and Rosid (2022).

Conclusion

The resistivity values of the Ambon Volcanic Rock formation (Tpav) in Kayu Putih Area, Soya Village, Sirimau District, Ambon City vary between 185 Ωm to 4.128 Ωm with the constituent materials being Top Soil, Unsaturated Landfill, and Loose Sand as the cover layer followed by dry sandy soil and Gravel, as well as Breccia Dacite and Tuff in the lower layers. Breccia Dacite rocks with a resistivity of greater than 2.000 Ωm are found at a depth of 11 – 13 m below the soil surface functioning as a slip surface for the material above them. The movement of the soil mass over the slip surface causes cracks in the surface of the road and houses.

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