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Identification Lithology of Land Movement Zone using the Schlumberger Configuration Geoelectric Method in Samigaluh Distric Kulon Progo

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Abstract
Samigaluh Subdistrict in Kulon Progo Regency, Yogyakarta, is prone to landslides. The objective of this study is to determine the subsurface lithology in the land movement zone. The research was conducted using the Schlumberger configuration geoelectric method. Measurements were carried out deploying six lines with line lengths ranging from 100 to 150 m. The results identified a vertical distribution of subsurface rock resistivity values to a depth of 74.05 m with a value of 0.06-13749.51 Ωm. The lithology consists of soil (14.18-361.23 Ωm), clay (0.06-42.73 Ωm), sandstone (0.35-123.44 Ωm), conglomerate (1372.7-10168.66 Ωm), and andesite 13749.51 Ωm. Damage to buildings and roads were found around the formation boundary where the damage is located in the Kebobutak formation.

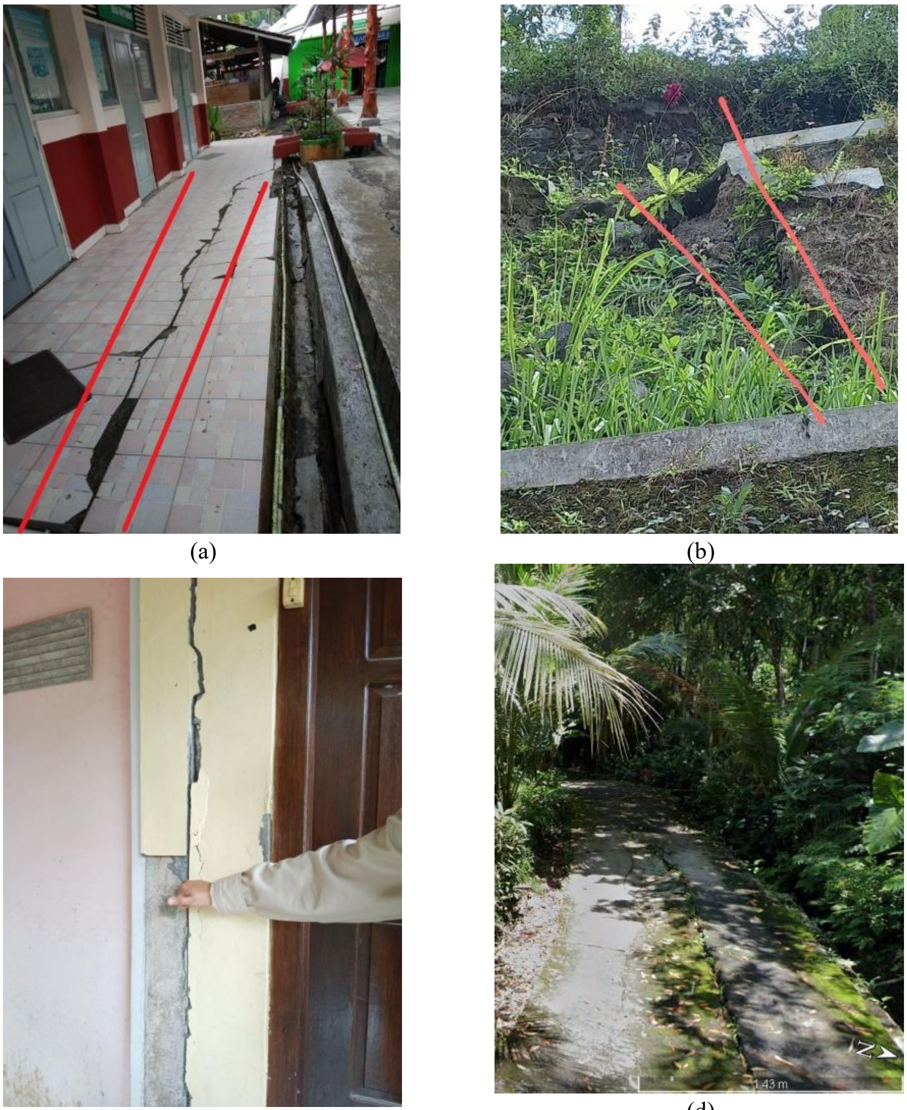
Keywords: Lithology, Samigaluh, Geoelectrical, Schlumberger Configuration.

1. Introduction

Land movement is the displacement of soil or rock masses from their original position, land movement includes creep and flow and avalanches [1]. The potential for ground movement on a slope depends on the condition of the soil and its constituent rocks, where one of the geological processes that is the main cause of ground movement is rock weathering [2]. Land movement that occurs in the form of landslides can be called landslides. Factors causing landslides are divided into two factors, namely internal factors and external factors [3]. Internal factors are factors related to rock lithology [4]. Internal factors that can cause soil movement are the weak binding force of soil or rock so that soil and rock grains can break away from their bonds [5]. The movement of these grains can drag other grains around to form a larger mass. Meanwhile, external factors that can accelerate and trigger land movement include slope angle, rainfall, changes in soil moisture, and land cover [6].

Landslides can occur if the slope has a driving or pulling force that is greater than the retaining force [7,8]. The driving or pulling force can be influenced by the slope, water content, and soil load, while the retaining force is influenced by soil density and strength. Samigaluh Subdistrict located in Kulon Progo Regency is an area prone to land movement. In the period 2018-2022, landslides occurred 2,186 times in Yogyakarta with the highest number of events in Kulon Progo Regency reaching 1,068, followed by Bantul, Gunungkidul, Sleman, and Yogyakarta City [9]. The ground movement caused cracks in several buildings, one of which was the SMP N 1 Samigaluh school building shown in Figure 1 (a), due to the cracks the building had to undergo rebuilding every time the cracks got worse. In addition to the school, there are other buildings that have cracks due to land movement, including residential buildings, roads, and fence foundations.

Besides causing damage to infrastructure, ground movements can also threaten human safety. An understanding of the subsurface lithology in ground movement zones is essential to address these risks. The application of resistivity geophysics method has been widely used for surveying and exploring natural resources, but it can also be used to determine slip areas that are estimated to be the cause of landslides. The resistivity geoelectric method can produce the image of the subsurface rock layer based on the resistivity value of the rock type that constitutes the layer which is estimated to be the cause of landslides [10]. The geoelectric method is a method that studies the nature of subsurface electricity and how to detect it on the earth's surface. The process includes measuring potential differences, electric currents, and electromagnetic fields that occur, both naturally and due to the injection of current into the earth [11].



(a) (b) (c) (d)

Figure 1. Cracks that occurred due to ground movement (a) cracks in the building of SMP N 1 Samigaluh, (b) cracks in the roadside wall, (c) cracks in houses, (d) cracks on the road.

There are various types of geoelectric method configurations, one of which is the Schlumberger configuration. The Schlumberger configuration geoelectric method can be used to identify rock layers and layer thickness. This can be done because rocks have electrical properties that depend on the constituent minerals. The Schlumberger configuration has the advantage of being able to detect the presence of inhomogeneous rock layers [12].

2. Method

The research conducted in Samigaluh Subdistrict, Kulon Progo Regency, focused on the land movement area, namely in Gerbosari and Ngargosari villages which experience land movement every year. Data were collected at six measurement points with a design as shown in Figure 2. Data acquisition in the field was carried out using a Naniura NRD 300 Resistivity Meter. This measurement was carried out by installing two potential electrodes (P1 and P2) and two current electrodes (C1 and C2) as shown in Figure 3.

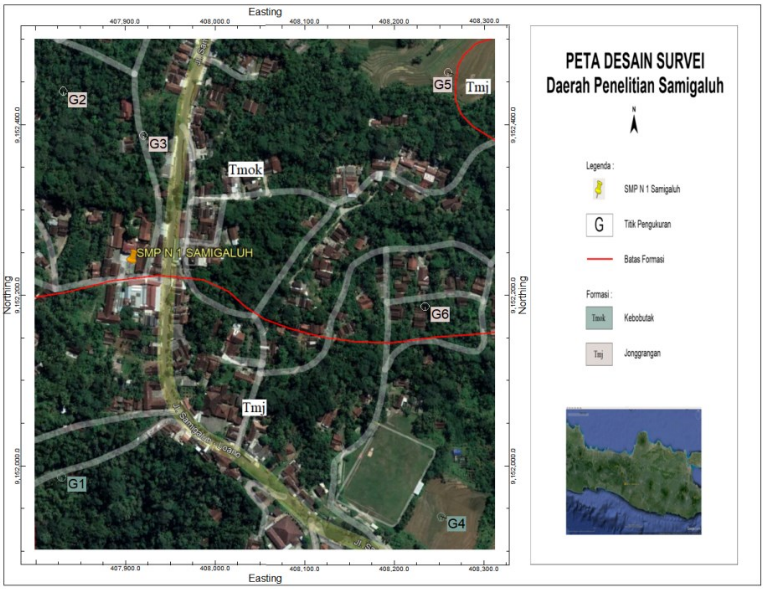


Figure 2. Map of research survey design

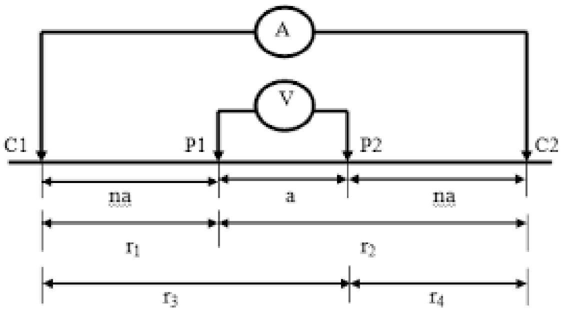


Figure 3. Current and potential electrode configurations *Schlumberger* [13]

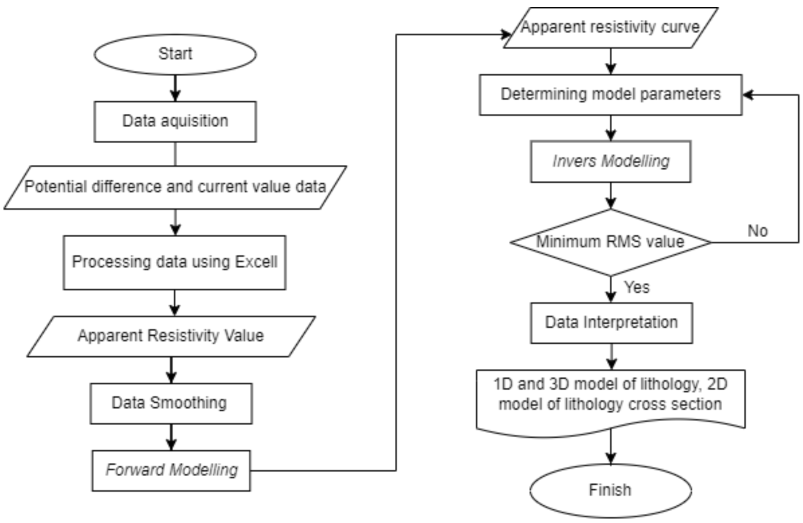


Figure 4. Research flowchart

After performing data acquisition, observation data will be obtained in the form of current (i) and potential difference (v) values. The data is then processed to get the average value of current and voltage, resistance, and resistivity. Then continue data processing using Progress software by forward modeling so as to get an apparent resistivity curve. Next, determine the model parameters to predict the actual resistivity value and depth, because the subsurface is layered so that the resistivity value is considered to vary with depth [14]. Then inversion (inverse modeling) is carried out until model parameters are obtained with a relatively small Root Mean Squared (RMS) error value. The iteration process in determining model parameters (resistivity and depth) continues until a model is found that is considered the closest to the actual situation.

3. Result and Discussion

Resistivity logs are the result of measuring the resistivity value of formation rocks and their contents measured using a resistivity meter, with a description of this resistivity value depending on porosity, formation water salinity, and the amount of hydrocarbons in rock pores. Formation resistivity is one of the main parameters needed to determine hydrocarbon saturation in a formation [15]. The results of data processing at the measurement points in the form of sounding resistivity logs and rock lithology are shown in Figure 5. The results of the six measurement points show that the subsurface lithology at the research site has several layers with different resistivity values at each depth as shown in Table 1. Layers interpreted as overburden generally have higher resistivity values [16]. While the layer interpreted as clay generally has a lower resistivity value [17]. This clay layer acts as a sliding plane in landslide-prone areas [18].

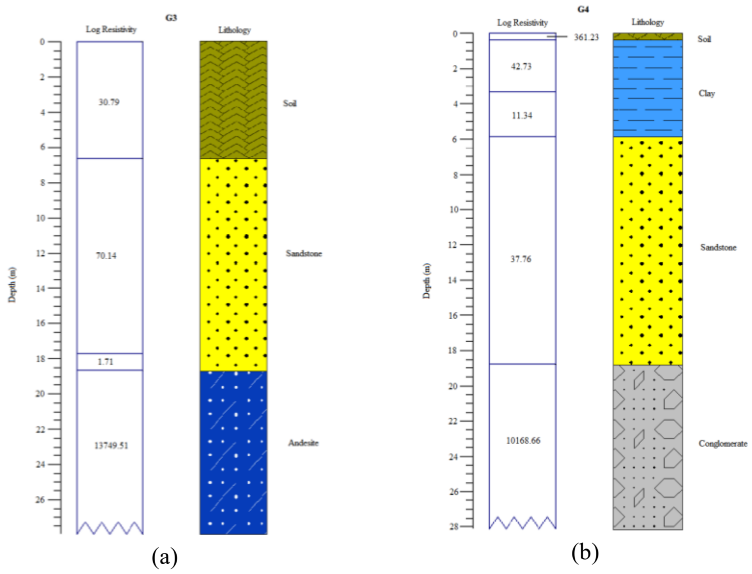


Figure 5. 1D subsurface lithology results based on resistivity log (a) point G3 (b) point G4

Tabel 1. Measurement results of subsurface lithology of Samigaluh Sub-district.

Point	Formation	Layer	Depth (m)	Resistivity (Ωm)	Lithology
G1	Jonggrangan	1	0-1.96	14.18	Soil
		2	1.96-24.2	5.59	Clay
		3	24.2	1372.70	Conglomerate
G2	Kebobutak	1	0-1.03	66.70	Soil
		2	1.03	123.44	Sandstone
G3	Kebobutak	1	0-6.61	30.79	Soil
		2	6.61-18.64	70.14	Sandstone
		3	18.64	13749.51	Andesite
G4	Jonggrangan	1	0-0.37	361.23	Soil
		2	0.37-5.58	11.43	Clay
		3	5.58-18.75	37.76	Sandstone
		4	18.75	10168.66	Conglomerate
G5	Kebobutak	1	0-1.3	30.42	Soil
		2	1.3	25.58	Sandstone
G6	Kebobutak	1	0-0.72	60.68	Soil
		2	0.72	12.20	Clay

The sounding resistivity distribution from six measurement points obtained subsurface lithology indicated as soil, clay, sandstone, conglomerate, and andesite with resistivity values and depths as in Table 2. The indication of the rock layer is in accordance with the reference [19] which says that the clay indication has a resistivity value range of 1-100 Ωm, sandstone has a resistivity value range of 1-6.4×108 Ωm, conglomerate has a resistivity value range of 2×103-104 Ωm, and andesite has a resistivity value range of 4.5×104 (wet) -1.7×102 (dry) Ωm. The subsurface lithology produced in this study is in accordance with research that has been conducted in the same area, namely soil, sandstone, conglomerate, and andesite [20], clay, sandstone, and andesite [21].

Tabel 2. Lithology of land movement zone

Lithology	Resistivity (Ωm)	Depth (m)
Soil	14.18-361.23	0-6.61
Clay	0.06-42.73	3.33-15.29
Sandstone	0.35-123.44	5.85-74.05
Conglomerate	1372.7-10168.66	18.75-24.20
Andesite	13749.51	18.64

Cross-sectional or 2D modeling of subsurface lithology intersects the area affected by ground movement. The cross-section of slice A-A' shown in Figure 6, starting from the south to the north, passes through the school building that cracks every year due to ground movement at coordinates -7°40'7.66" LS and 110°9'54.22" East. This cross section is a combination of data G1 and G3, point G1 on the left side of the cross section while point G3 on the right side of the cross section.

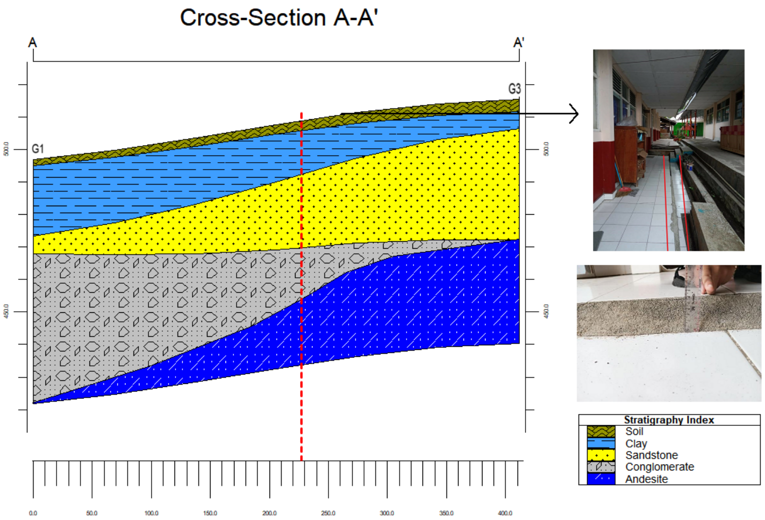


Figure 6. Cross section A-A' resulting from the intersection of points G1 and G3

The results in slice A-A' show five rock layers: soil, clay, sandstone, conglomerate and andesite. These rock layers have different thicknesses. The total length of slice A-A' cross section is 411.73 meters which crosses the formation boundary at 228.04 meters in the figure marked with a red line, Jonggrangan formation is on the left and Kebobutak formation is on the right. In addition to crossing the formation boundary, slice A-A' also passes through a damaged school building at 266.31 meters. The cross-section of slice B-B' shown in Figure 7 runs from south to north across the damaged road at the coordinates -7°40'10.60" N and 110°10°'04.88" East. This cross section is a combination of three data namely G4, G6, and G5. At measurement point G4 there are four rock layers while at points G5 and G6 there are two rock layers. This cross-section model does not find andesite rocks at points in the kebobutak formation.

The results in slice B-B' show five rock layers, namely soil, clay, sandstone, conglomerate, and andesite. These rock layers have different thicknesses. The total length of the B-B' slice cross section is 529.77 meters which crosses the formation boundary at 206.49 meters in the figure marked with a red line, the Jonggrangan formation is on the left and the Kebobutak formation is on the right. In addition to crossing the formation boundary, slice B-B' also passes through a damaged road at 248.59 meters

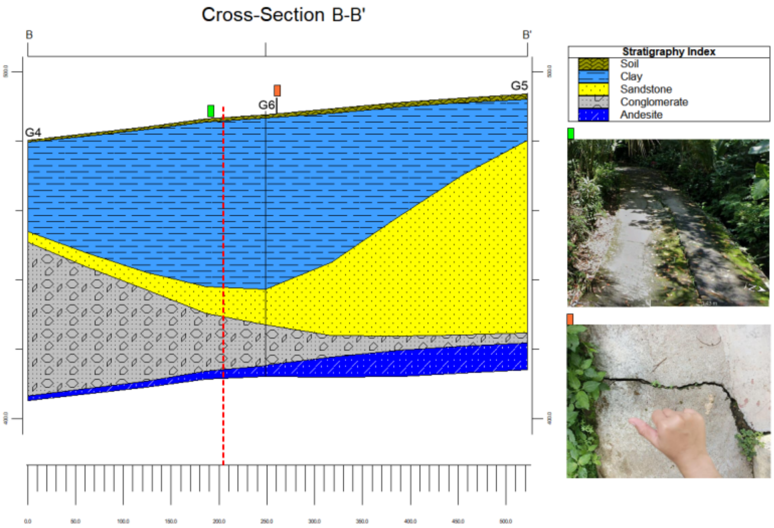


Figure 7. *Cross section* B-B' hasil dari perpotongan titik G4, G6, dan G5

The 3-dimensional modeling shown in Figure 9 shows five rock layers namely soil, clay, sandstone, conglomerate, and andesite which are interpolated so that the entire research area has five layers where at some points there are no specific rock layers. The layer on the west side of the study shown in the figure, on that side there are two different formations, namely the kebobutak formation on the west side of the northern part characterized by andesite rocks but in the 3-dimensional model inserted thin interpolated conglomerate rocks and the jonggrangan formation on the west side of the southern part characterized by conglomerate rocks inserted thin interpolated andesite rocks.

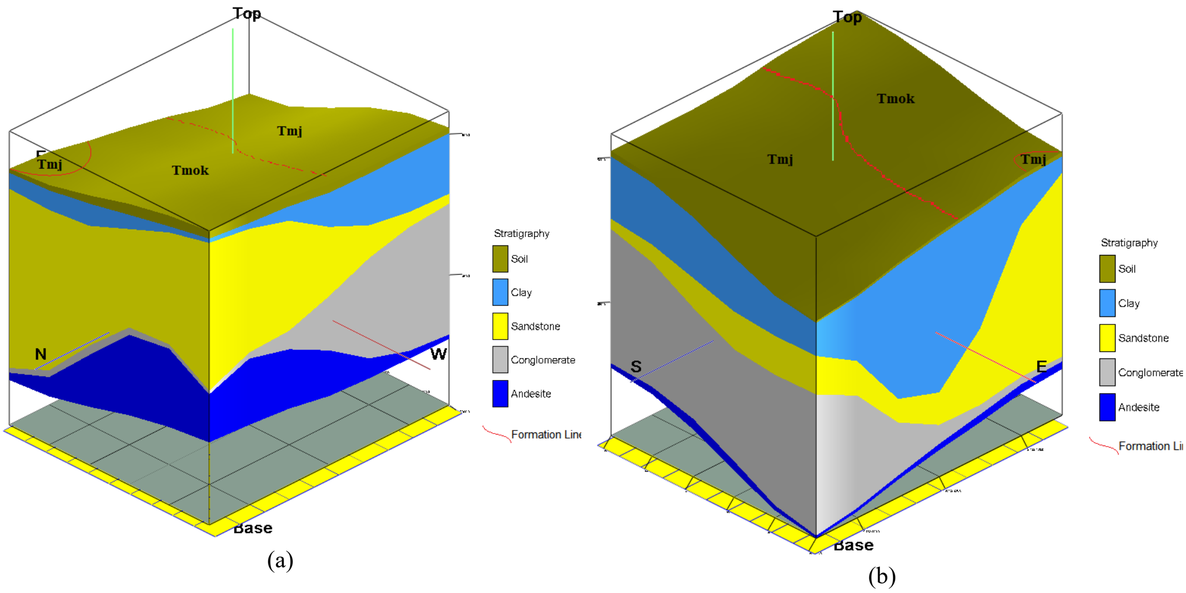


Figure 8. Results of 3D lithology modeling (a) North-West (b) South-East

The rock that causes the research area to experience land movement is clay because the rock acts as a sliding field. The results of this study show that the clay layer on the north side is thicker than the south side which is dominated by the Kebobutak formation. The cracks and damage that occur in this research area are located in areas that have clay subsurface lithology which is a sliding plane, especially in the formation boundary area.

4. Conclusion

Based on the results of research reviewed from geology, geophysics, and the field as well as several references that refer to the lithology in the research area by analyzing geoelectric data that has been measured using the Schlumberger method, it is concluded that the subsurface lithology in the research area consists of soil (14. 18-361.23 Ωm), clay (0.06-42.73 Ωm), sandstone (0.35-123.44 Ωm), conglomerate (1372.7-10168.66 Ωm), and andesite 13749.51 Ωm. The rock that becomes the sliding plane in this study is clay, where clay has a small resistivity value. Damage to buildings and roads were found around the formation boundary where the damage is located in the Kebobutak formation.

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