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SUBSURFACE MODELING USING GEOELECTRICAL RESISTIVITY METHOD IN JALIBAR AREA, ORO-ORO OMBO, BATU CITY, EAST JAVA

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ABSTRACT

This study aims to model subsurface structures based on resistivity values in the Jalibar area, Oro-Oro Ombo, Batu City, East Java. The geoelectrical survey was conducted using the Schlumberger configuration of Vertical Electrical Sounding (VES). Data interpretation was carried out with IPI2Win, RockWorks, and ProGRES software. The results identified three main layers: the topsoil of weathered material or sandy clay with low to medium resistivity (10–100 Ωm), an intermediate layer of compact tuffaceous sand or sandstone with moderate to high resistivity (100–300 Ωm) that potentially serves as an aquifer zone, and a basement rock layer with very high resistivity (>1000 Ωm), interpreted as fresh andesite or basalt. The consistency across software indicates reliable subsurface modeling. This research confirms the effectiveness of geoelectrical methods in delineating geological structures, supporting mineral exploration and groundwater studies in volcanic terrains.

Keywords: exploration, geoelectric, modeling, resistivity, subsurface

Introduction

The identification of subsurface structures is essential for mineral exploration and groundwater studies, particularly in volcanic terrains such as Batu City, East Java. Geoelectrical methods are widely applied due to their efficiency in determining resistivity distribution and interpreting lithological variations. Previous studies emphasize the effectiveness of resistivity methods in delineating aquifer potential and detecting bedrock boundaries [3], [7], [9]. This research focuses on subsurface modeling in Jalibar, Oro-Oro Ombo, to provide geological insights and evaluate potential resources using resistivity data.

Materials and Methods

The study area is located in Jalibar, Oro-Oro Ombo, Batu City, East Java, within a volcanic terrain dominated by Quaternary deposits. Electrical measurements at the research site were conducted to identify subsurface lithological variations based on the resistivity response of rocks to electric currents. The data obtained was then processed using 2D/3D modeling software, resulting in resistivity cross-sections that could be used for subsurface geological interpretation.

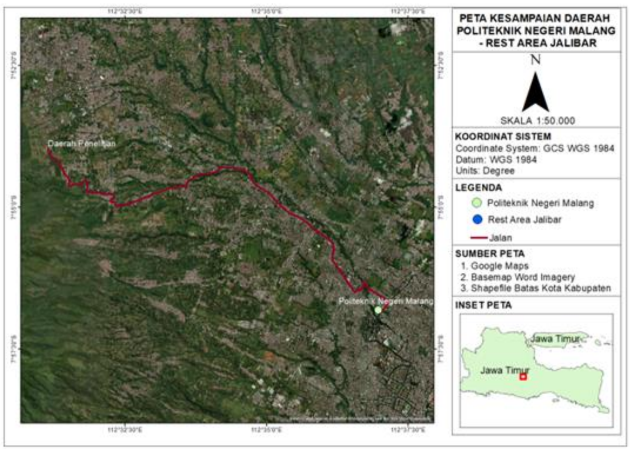

Figure 1. Regional accessibility map

The type of investigation used was Vertical Electrical Sounding (VES), a method based on resistivity properties [6], [8]. Resistivity is calculated from the electric current (I) and potential difference (V) in the field. The greater the resistivity of a material, the greater the electric field required to generate a current density. The configuration used in this practicum is the Schlumberger Configuration. In the Schlumberger configuration, the MN distance must be made as small as possible without changing the MN distance. However, due to the instrument's limited sensitivity, the MN distance must be adjusted if the AB distance is relatively large. The change in MN distance must not exceed 1/5 of the AB distance. To process the data from this configuration, IPI2WIN, Rockworks, and ProGRES software are used.

Results

In this study, three research coordinate points were taken in accordance with the number of geophysical testing routes conducted. The following are the coordinate data for each point:

Point 1: 7° 53' 57.38" S 112° 31' 8.18" E
Point 2: 7° 53' 56.976" S 112° 31' 8.706" E
Point 3: 7° 56' 20.23" S 112° 31' 52.44" E

The resistivity depth data is then used to indirectly interpret the conditions beneath the ground surface, enabling the identification of the physical properties of rock layers, the determination of the depth and thickness of each layer, and the mapping of geological structures such as groundwater aquifers, cavities, faults, and mineralization zones [5], [10]. This information is crucial in natural resource exploration activities, geotechnical investigations, and environmental studies, as it allows for an initial understanding of geological characteristics without the need for direct drilling. Resistivity and depth data for each survey line can be shown in Tables I, II, and III.

The Geology of the study area, based on the geological map, the main lithology in this area is marked in pink, representing young volcanic deposits in the form of lava, volcanic breccia, and tuff. This unit is the result of volcanic activity that produced relatively porous and permeable material, making it a potential shallow aquifer in its weathering zone.

Table 1. Resistivity data at point 1

mis	AB/2 (m)	MN/2 (m)	K	I (mA)	V (mV)	PS (mV)	r (O*m)	dev. st.
1	1.5	0.5	6.2	6.47	51.28	52.15	49.8	
2	2.5	0.5	18.8	17.85	42.22	32.62	44.5	
3	4	0.5	49.4	23.13	20.56	26	43.9	
4	6	0.5	112.3	18.74	8.23	23.41	49.3	
5	8	0.5	200.2	17.45	4.99	21.05	57.2	0.2
6	10	0.5	313.3	16.1	3.4	19.38	66.1	0.3
7	12	0.5	451.6	18.08	3	17.53	74.9	1.1
8	15	0.5	706	21.88	2.77	16.55	89.4	
9	15	5	62.8	22.09	28.69	-92.57	81.6	
10	20	5	117.8	18.24	16.13	-83.34	104.1	1
11	25	5	188.5	10.37	6.81	-78.05	123.7	2.2
12	30	5	274.8	26.1	12.99	-74.94	136.8	1.4
13	40	5	494.8	19.62	7.04	-71.56	177.5	9.3
14	50	5	777.5	21.4	5.53	-68.36	200.9	1.7
15	60	5	1123.1	13.46	3.01	-62.1	250.9	19.9
16	60	10	549.7	14.15	6.94	-75.18	269.8	7.8
17	75	10	867.8	15.07	5.73	-18.97	330.1	12.5

Table 2. Resistivity data at point 2

mis	AB/2 (m)	MN/2 (m)	K	I (mA)	V (mV)	PS (mV)	r (O*m)	dev. st.
1	1.5	0.5	6.2	12.92	104.05	-89.77	50.5	0.1
2	2.5	0.5	18.8	16.96	35.53	-71.6	39.5	0.3
3	4	0.5	49.4	15.79	12.68	-66.87	39.7	0.4
4	6	0.5	112.3	15.86	6.44	-63.9	45.5	0.9
5	8	0.5	200.2	16.51	4.6	-56.63	55.8	0.4
6	10	0.5	313.3	31.57	6.69	-50.18	66.3	0
7	12	0.5	451.6	12.63	2.17	-47.67	77.7	0.6
8	15	0.5	706	14.17	1.96	-42.79	97.7	0.1
9	15	5	62.8	14.89	18.39	-84.44	77.5	0.3
10	20	5	117.8	13.45	11.67	-74.76	102.1	0.4
11	25	5	188.5	13.6	11.58	-74.99	160.5	1.1
12	30	5	274.8	8.53	4.04	-67.82	130.3	1.3
13	40	5	494.8	31.82	11.53	-64.03	179.3	0.3
14	50	5	777.5	23.9	6.57	-57.58	213.8	8
15	60	5	1123.1	34	8.02	-52.47	265	6.5
16	60	10	549.7	33.95	16.72	69.16	270.7	3.5
17	75	10	867.8	25.62	9.37	32.1	317.4	7.9

Table 3. Resistivity data at point 3

mis	AB/2 (m)	MN/2 (m)	K	I (mA)	V (mV)	PS (mV)	r (O*m)	dev. st.
1	1.5	0.5	6.2	26.38	203.31	11.11	48.4	0.2
2	2.5	0.5	18.8	46.63	114.32	9.41	46.2	
3	4	0.5	49.4	22.3	20.13	9.06	44.6	
4	6	0.5	112.3	18.73	7	7.11	41.9	
5	8	0.5	200.2	33.93	8.75	6.66	51.6	
6	10	0.5	313.3	31.51	6.11	6.46	60.7	
7	12	0.5	451.6	24.86	3.89	6.14	70.7	0.3
8	15	0.5	706	18.49	2.31	5.74	88.2	1.9
9	15	5	62.8	18.15	23.54	42.46	81.5	0
10	20	5	117.8	22.89	21.81	29.73	112.2	
11	25	5	188.5	25.62	18.93	29.03	139.3	0

Figure 3. Lintasan 3

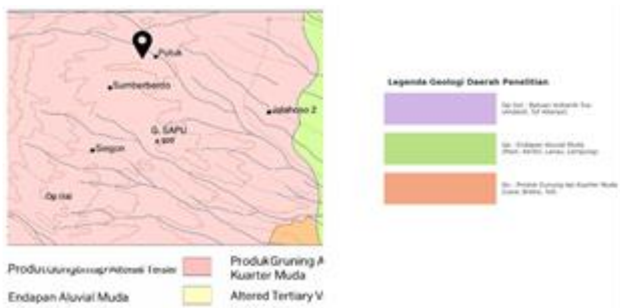

Figure 2. Local geological map

Discussion

The observation points in this study are marked as Point Location 1, Point Location 2, and Point Location 3, which are the points for collecting coordinate data and/or field samples. Based on the map, the elevation in the study area ranges from ±1111 meters to ±1144 meters above sea level. This elevation difference indicates morphological variations that may affect local geological and hydrological characteristics.

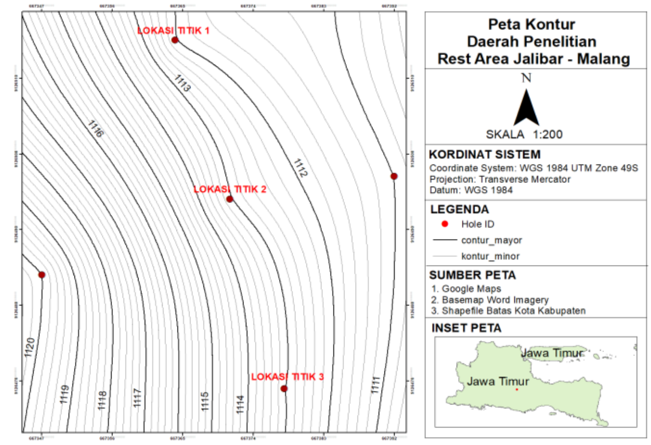

Figure 3. Topographic map

Electrical resistivity sampling at the research site in the Jalibar – Malang Rest Area was conducted to identify subsurface lithological variations based on the resistivity response of rocks to electrical current. The data obtained was then processed using 2D modeling software, resulting in resistivity cross-sections that can be used for subsurface geological interpretation.

The type of investigation used was Vertical Electrical Sounding (VES), a method based on resistivity properties [6], [8]. Resistivity is calculated from the electric current (I) and potential difference (V) in the field. The higher the resistivity of a material, the greater the electric field required to generate a current density. The configuration used in this practicum is the Schlumberger configuration. To process this configuration data, IPI2WIN and Progress software are used. Ideally, in the Schlumberger configuration, the MN distance should be kept as small as possible without altering the MN distance. However, due to the limited sensitivity of the instrument, the MN distance must be adjusted if the AB distance is relatively large. The change in the MN distance must not exceed 1/5 of the AB distance.

The following are some interpretation results using supporting software such as IPI2win, Rockwork, and Progress. :

Interpretation of *IPI2WIN*

IPI2Win is one of the software programs used in the interpretation of resistivity geophysical data, particularly the Vertical Electrical Sounding (VES) or Schlumberger method. The results of the interpretation using IPI2WIN software can be seen in Figure 4.

The interpretation of the resistivity cross-section shows that the aquifer potential is at a depth of ±10–25 m, bounded by sandy clay layers above and hard bedrock below. This information is important in planning well drilling for groundwater utilization, considering the optimal depth and avoiding penetration into unproductive bedrock layers.

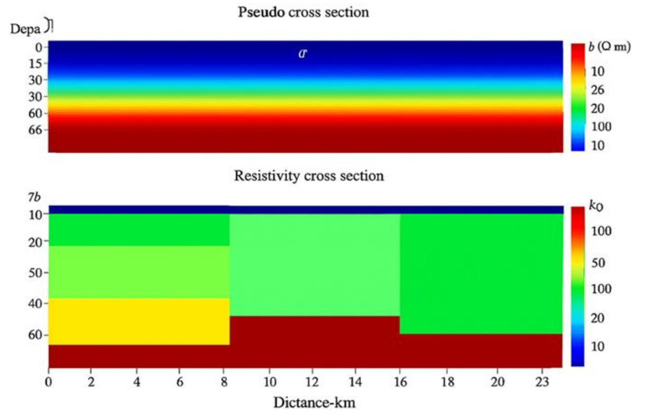

Figure 4. *IPI2WIN* interpretation results

Interpretation of *RockWorks*

The following are the results of interpretation using *RockWorks* software:

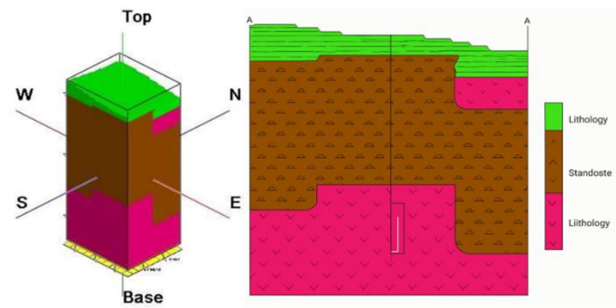

Figure 5. *RockWorks* interpretation results

Modeling of section A–A' using RockWorks software shows three main lithological segments. The top layer, colored green, is interpreted as thin weathered soil (±1–3 m) with uneven distribution. The middle layer, colored brown, is compacted sedimentary rock (sandstone or dense clay) that is widely distributed laterally as a transition zone. The deepest layer, colored pink, represents hard bedrock (igneous or metamorphic), with a sharp lithological boundary against the overlying layers. This lithological distribution is important for evaluating the potential of resources and the geotechnical stability of the study site [1], [4].

Interpretation of *ProGRES*

The following are the results of the interpretation in the research area:

Based on the results of Schlumberger geophysical data processing at point L1, six subsurface layers were obtained with varying resistivity values that indicate lithological differences. The first layer has a moderate resistivity value (54.87 Ωm), interpreted as moderately moist topsoil. The second and third layers show relatively low resistivity (34.30–33.36 Ωm), indicating the presence of sandy clay or water-saturated silt. The fourth layer has higher resistivity (186.01 Ωm), likely representing dense sandstone. The fifth layer shows high resistivity (682.26 Ωm), interpreted as bedrock composed of hard sediment. The sixth layer has extremely high resistivity (77,146.82 Ωm), indicating the presence of compact igneous or metamorphic rock with very high resistivity.

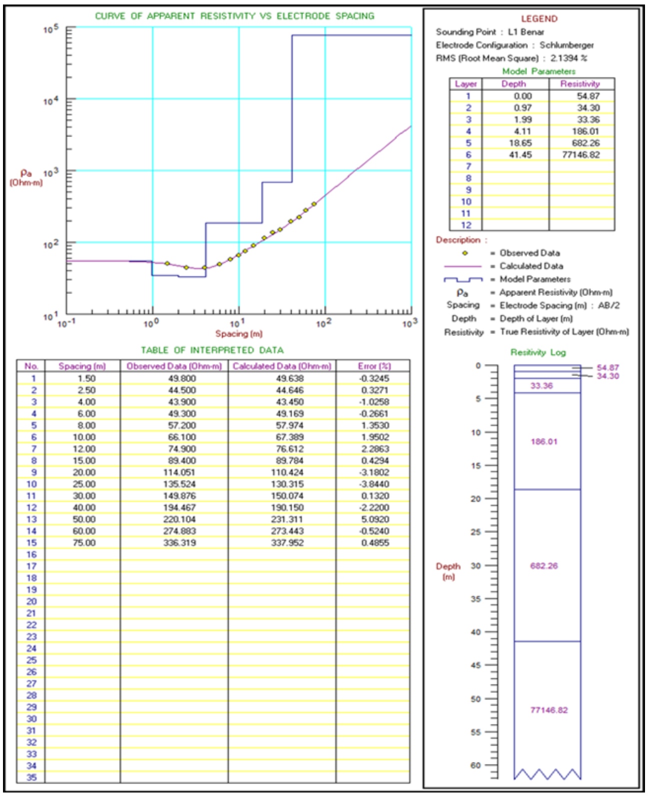

Figure 6. *Interpretation results for track 1*

Geophysical measurements using the Schlumberger configuration at point L2 resulted in an interpretation of the subsurface model consisting of five main layers. The Root Mean Square (RMS) error obtained was 7.287%, indicating a fairly good match between the measured data and the inversion model.

The first layer has a resistivity of 53.70 Ωm with a thickness of approximately 1.52 meters, possibly representing a relatively dry topsoil layer. The second layer has a low resistivity of 6.96 Ωm with a depth of up to 3.48 meters, indicating the presence of water-saturated clay material. The third layer has a resistivity of 3.86 Ωm, reinforcing the indication of a water-saturated zone or a denser clay layer. The fourth layer shows a high resistivity of 598.76 Ωm at a depth of approximately 33.49 meters, which may indicate hard rock or igneous rock formations. The fifth layer has a very high resistivity of 16,630.41 Ωm at a depth of more than 35 meters, which is potentially bedrock.

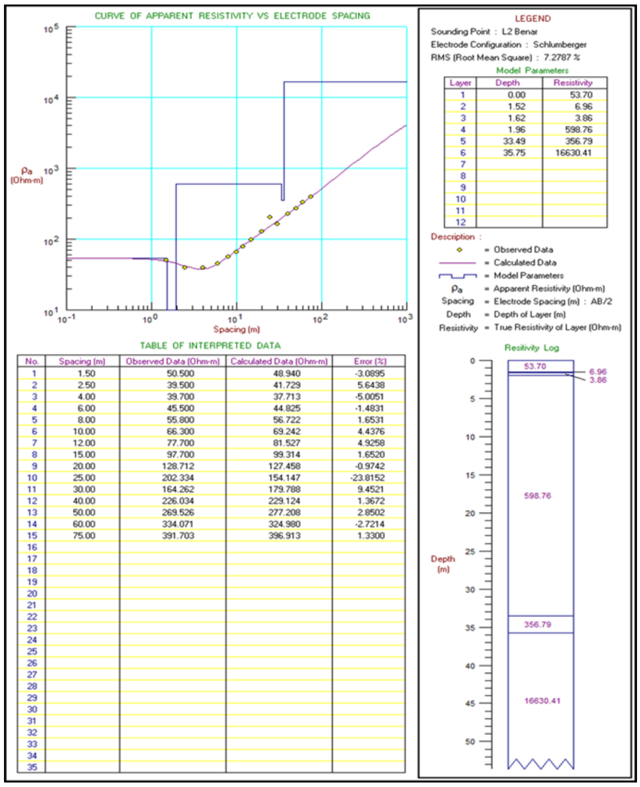

Figure 7. *Interpretation results for track 2*

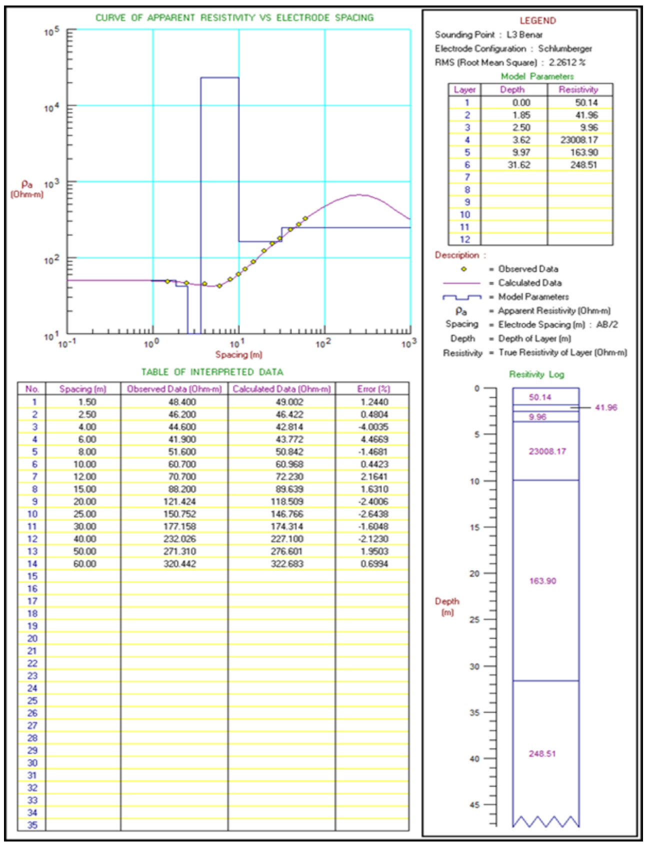

Figure 8. *Interpretation results for track 3*

The geoelectric measurement using the Schlumberger configuration at point L3 shows six rock layers with varying resistivity and depth values. Layers one through three have low to moderate resistivity, indicating clay or water-saturated weathered soil. Layer four has very high resistivity (23008.17 Ωm), which may indicate the presence of very hard rock or a dry layer. The fifth layer shows moderate resistivity (163.90 Ωm), while the sixth layer has relatively high resistivity (248.51 Ωm), which could potentially be a compact rock layer or aquifer zone.

Based on the integration of three interpretation software programs (IPI2Win, ProGRES, and RockWorks), it was found that the subsurface configuration of the research location consisted of three main layers, including :

1. Top Layer (Overburden /Weathering):

The top layer consists of cover soil and weathering material with low resistivity (10–100 Ωm) and needs to be well understood for field planning and risk mitigation in mining exploration. This layer functions as a natural cover or filter that influences measurement techniques and advanced exploration methods, and is a significant factor in determining drilling access points and environmental protection.

2. Middle Layer (Potential Aquifer Layer):

The middle layer, which has medium to high resistivity (100–300 Ωm) and is interpreted as tuffaceous sand, gravelly sand, or dense sandstone, is more commonly associated with aquifer potential in a hydrogeological context but is also important in mining exploration. This layer can be a transition zone that influences fluid mobility, facilitates secondary mineral deposition, or acts as a carrier for certain minerals associated with denser sedimentary rocks.

3. The bedrock layer (bedrock) is a hard and compact rock layer with very high resistivity (>1000 Ωm) identified as igneous or metamorphic rocks such as andesite or basalt, which is an important target in hard rock mining exploration or mineralization zone deduction. The presence of this massive, low-porosity bedrock indicates stable geological conditions and may serve as an indicator of potential intrusions or mineralization zones at lithological boundaries or faults.

The conclusions from the interpretation of subsurface layers based on the IPI2Win, RockWorks, and ProGRES software, which were adapted for mining exploration activities, can be seen in the following table :

Table 4. The results of the interpretation

Layer	Depth	Resistivity (Ωm)	Material Type	Relevance for Mining Exploration
Surface Layer / Overburden	0 - ±10 m	10-100 (IPI2Win), 54.87 (ProGRES L1), 53.70 (ProGRES L2), 50.14 (ProGRES L3)	Passive loam or weathered tuff with high water saturation. May also be overburden with moderate moisture or relatively dry. In RockWorks interpretation, interpreted as weathering material or overburden.	Important for planning surface infrastructure, slope stability and potential backfill material. Water-saturated conditions can affect mining methods and require water management.
Aquifer/Sedimentary Material Zone	±10 - 25 m	100-300 (IPI2Win), 186.01 (ProGRES L1), 163.90 (ProGRES L3)	Tuffaceous sand or gravelly sand with high porosity, potentially a productive aquifer. Also interpreted as compacted sandstone or compacted sedimentary rock (possibly sandstone or compacted clay).	Potential water source for mining operations. If above the deposit, requires careful dewatering to avoid stability and mining efficiency issues.
Bedrock	> 25 m	>1000 (IPI2Win), 682.26 (ProGRES L1), 16630.41 (ProGRES L2), 23008.17 (ProGRES L3), 248.51 (ProGRES L3), 77146.82 (ProGRES L1)	Compact bedrock, possibly igneous rocks such as fresh or metamorphic andesite or basalt. May also be hard sedimentary rock.	It is often the host rock for mineral deposits. Identification of the type of bedrock is essential for determining the potential for mineralization and planning appropriate mining methods (e.g., blasting). Being the limit of economic mining depth.

Conclusion

Based on the results of Schlumberger geophysical measurements in the Jalibar Batu area, Oro-Oro Ombo, Batu City, a subsurface structure model consisting of three main layers was obtained. The first layer consists of weathered soil/sandy clay with low to moderate resistivity, the second layer consists of tuffaceous sand or dense sandstone with moderate to high resistivity that has the potential to be an aquifer, and the third layer consists of compact bedrock with very high resistivity. The results of interpretation using the IPI2Win, RockWorks, and ProGRES software showed consistency, which is in line with previous works in similar volcanic terrains [2], [6], [8], and consistency, indicating that the subsurface model obtained is valid and can be used as a basis for further exploration.

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