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ISAR Journal of Science and Technology
Abbriviate Tittle- ISAR J Sci Tech
ISSN *(Online)*- 2584-2056
https://isarpublisher.com/journal/isarjst
Vol-2, Iss-4 (Apr- 2024)

OPEN ACCESS

Comparison of Robust Inversion and Least Square on Resistivity Data To identify the Presence of Andesite (Case Study: Tugu Area, Trenggalek- Indonesia)

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Article History

Received: 01.03.2024
Accepted: 17.03.2024
Published: 03.04.2024

Abstract: *Indonesia has quite large potential and reserves of non-metallic minerals, which are spread almost evenly throughout the region. Excavated materials include andesite, amounting to 18.98 billion tons, one of which is in the province of East Java. Estimating subsurface andesite reserves is urgent, as a first step in exploration. The presence of andesite below the surface is searched using Geophysical methods, one of which is Geoelectric. Processing geoelectric data using inversion produces inversion modeling, which is used to interpret geoelectric data. This research compares Least Square and Robust Inversion data to estimate andesite resources in the Tugu Area, Trenggalek Regency. The research results show that the Least Square inversion results have a smaller error than the Robust, but the cross-section of the Robust inversion is smoother than the Least Square inversion results. The Robust inversion cross-section has a higher resistivity value than the Least Square Inversion cross-section. Based on the resistivity range of the two inversion results, the areas are divided into three lithologies. Low resistivity values < 200 Ωm are soil, medium values (200–500) Ωm are indicated as weathered andesite, and high values > 500 Ωm are indicated as compact andesite*.

Keywords: *Andesite, Geoelectric, Inversion, Least Square, Robust*.

Introduction

Trenggalek Regency is one of the districts in East Java Province, with the potential and reserves of minerals one of the largest in the East Java region. Based on data from the Central Statistics Agency (BPS) of Trenggalek Regency in 2017, it was recorded that the excavation material with abundant reserves was Andesite with a total reserve of 163.6 million tons. in its exploration, andesite rocks are not all exposed to the surface, so further investigation is needed through measurements in the field using geophysical methods (Purwasatriya, 2013).

The geoelectric resistivity method is one of the geophysics methods that utilizes rocks' electrical properties. This method is carried out by injecting current and measuring the voltage or potential read on the surface so that the resistivity of 2 pole poles and azimuth dipole is obtained. (Santoso, 2002).

This study used the Wenner-Schlumberger configuration. The configuration is quite sensitive both horizontally and vertically, it is a good compromise between the Wenner (lateral) and Dipole-Dipole (vertical) configurations. This configuration is less sensitive to horizontal changes, has deep current penetration but poor resolution, and is best used for depth surveys. (Telford et al., 1990). Based on this, this research is expected to analyze the distribution of Andesite rocks and estimate the reserves in the research area. Resistivity data processing has an inversion process used to produce a cross-section that describes the surface medium resistivity value that matches the actual subsurface conditions. Least Square and Robust inversion are often inversions to process resistivity geoelectric data.

The inversions will be compared to determine the concepts' differences and results generated from the two inversions. Both inversion methods have differences in the concept and purpose of each inversion. Robust inversion interprets areas between boundaries at different layers of the earth's subsurface. However, the Least Squares method is less sensitive to large measurement errors (Bavitra et al. 2015). This research aims to compare the inversion results between Least Square and Robust inversion and analyze the response of resistivity values in the research area.

Geology of Research Area

The geology of this area is generally dominated by two intervening lithologies, namely the Mandalika Formation and the Arjosari Formation as shown in **Figure 1**. These formations include andesite lava, volcanic breccia, lava breccia flows, and sedimentary rocks. Then, above it stratigraphically deposited limestone and volcanic rocks consisting of sandstone, tuff, claystone, and siltstone. The tuff is interbedded with limestone and partly converted into silicified alteration in areas such as Dalangturu, Suruh, and Jati Prospect. Andesite intrusions in the form of sills and dykes cut these rocks. Some intrusions are 1-3 km in diameter with a cylindrical shape.

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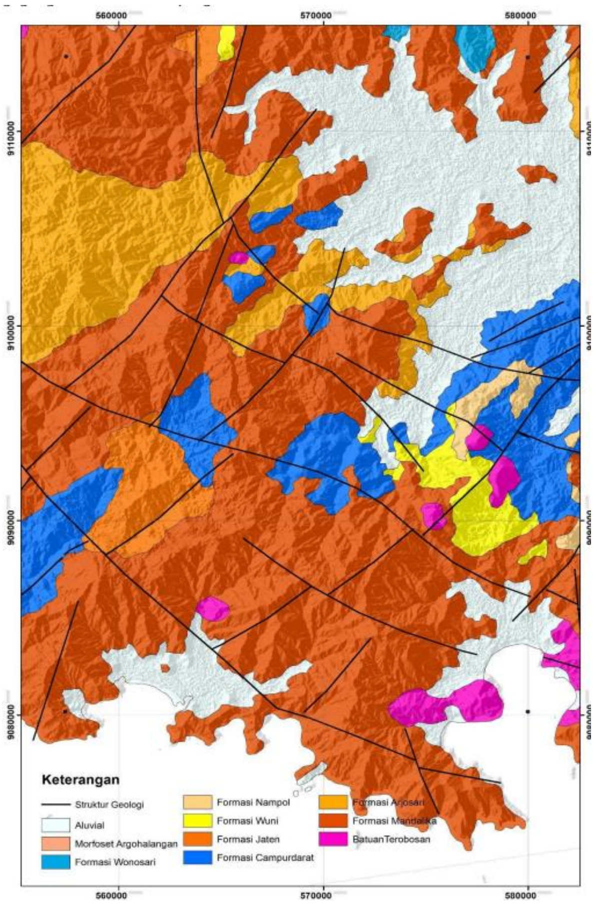

Figure 1 Geological map of the study area. The research location is shown with a yellow box in the Mandalika Formation.

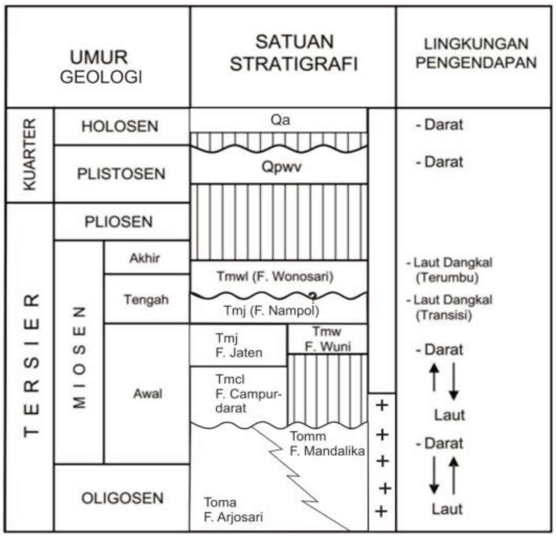

Figure 2 Stratigraphy of Research Area.

Figure 2 is the stratigraphic column of Trenggalek, based on the results of surface geological mapping of stratigraphic cross-section measurements, stratigraphic sequence analysis and confirmed and compared with the results of previous research, the stratigraphy of the research area from old to young includes (Samodra, 1992) :

1. Mandalika volcanic-breccia unit
2. Lithodem andesite Mandalika
3. Alluvial sédimenter unit

Methods

The basis of the geoelectric method is the assumption that the earth is considered an isotropic homogeneous medium or, in other words, has the same composition and physical properties. The measured resistivity is true and does not depend on the electrode spacing. In reality, the earth is not homogeneous but heterogeneous, consisting of layers with different compositional and physical variations. This heterogeneity assumes that the measured resistivity value is an apparent resistivity value that depends on the electrode spacing. Therefore, the measured resistivity value is not the resistivity value for one layer. The apparent resistivity value is formulated in the following equation (1):

$$\rho = k.\frac{\Delta V}{I} \quad (1)$$

The inversion process with the least square method aims to find the optimum model with the least square error criteria so that the difference between the calculation model and the field data is not much different. (Ferahenki, et al. 2018).

In general, the inversion problem in geophysical data processing can be simplified with the form d = Gm, where "d" is the data owned "m" is the model parameter sought, and "G" is the kernel matrix, so that get the value of m can be found by equation (2).

$$m = G^{-1}d \quad (2)$$

The above equation applies if the conditions are ideal, but in reality, the observational data is very difficult to resemble the model, so the equation can be written to be

$$d = Gm + e_i \quad (3)$$

the sum of squared residuals, to minimize the difference between the field data and the prediction model, the value must be as minimum as possible, the following is the formulation to minimize it

$$q = \ e^T\ e = (d - Gm)^T\,(d - Gm) \quad (4)$$

To get the minimum value, the derivative of q with respect to m must equal zero.

$$\frac{\partial q}{\partial m} = \frac{\partial\,[d^T\ d - d^T\ Gm - m^T G^T d + \ m^T G^T Gm]}{\partial m} = 0 \quad (5)$$

Robust inversion is an inversion method that is used if the error and data distribution are not normal and there are sharp data points. This Robust Inversion process can limit and minimize absolute changes in the specific gravity value and can minimize the effect of outliners in the data on the inverse model so that this inversion produces a sharp interface model between different areas with different specific gravity values (Hakim ; Rahma Hi. Manrulu, 2016). Robust inversion equations like Eq.

$$\acute{y} = \ \widehat{\emptyset}(x\,,u) + \ \Delta_{inv}\,(x,u\,) \quad (6)$$

$u = \ \widehat{\emptyset}^{-1}\,(x,\sigma)$ is the inversion controller and x is the state vector and y is the output containing two parameters, depth and specific gravity. σ denotes the pseudo-controller input of the inversion system.

The research location is in Jambu Village, Trenggalek Regency, East Java. Measurement trajectories used in this study were 13 lines spread throughout the study area, each length of 320m. The research was conducted using the Wenner-Schlumberger configuration of resistivity geoelectric to get good results on the subsurface geological configuration, such as knowing the lithology and identification of andesites in the study area.

Results and Discussions

A. Comparison of Inversion Results

This research uses two different types of inversion, namely Least Square inversion and Robust inversion. The Least Square inversion aims to find the optimum model with the least square error criteria so that the difference between the calculation model and the field data is not much different. As for Robust Inversion, it can limit and minimize absolute changes in the value of specific resistance and can minimize the effect of outliners in the data on the inverse model, so that this inversion produces a sharp interface model between different areas with different specific resistance values.(Hakim ; Rahma Hi. Manrulu, 2016)

Based on the results of Least square and Robust inversion in **Figure 3**, several differences are obtained, namely The first difference lies in the dominant resistivity value where at a depth of 20 meters to 40 meters, seen in **Figure 3 (a)** the resistivity value formed has a different range, where at this depth it is dominated by resistivity values> 506 Ωm to 1003 Ωm which spreads almost at the bottom of the cross-section while in **Figure 3 (b)** the resistivity value is dominated by the value> 1003 Ωm is dominant on the left side of the cross section..

The second difference is the error value of the two cross sections. **Figure 3 (a)** has an error value of while **Figure 3 (b)** has an error of as shown in **Table 2**.

The third difference is seen in the resistivity values generated from each inversion, where the Least Square inversion has a smaller resistivity value than the results of the resistivity value in the Robust inversion. the difference in the value of each path between the two inversions can be seen in **Table 1**.

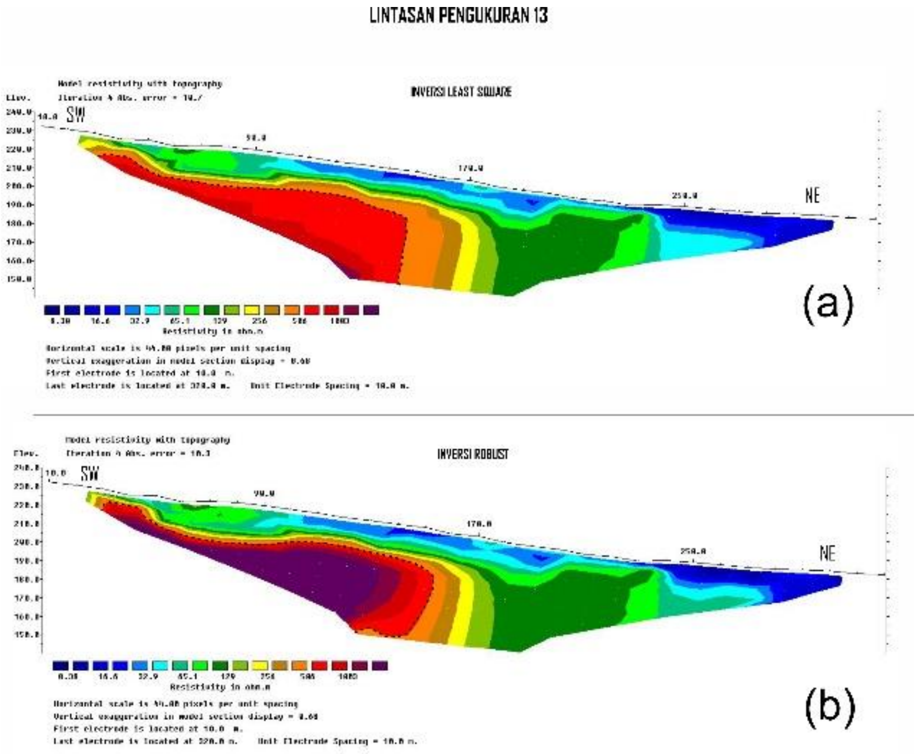

Figure 3 Results of Least Square Inversion and Robust Inversion. (a) Least Square inversion method (b) Robust inversion method Line 13

Table 1. Differences in Inversion Results

Parameter	LSQ	Robust
Error	Smaller	Largest
Smoothing	less smooth	Smoother
Range of resistivity	Smaller	Largest

Table 2. Differences in Inversion Results from all lines.

Line	Least Square			Robust		
	Rho min	Rho max	Error (%)	Rho min	Rho max	Error (%)
1	9.07	1087	13	7.74	2345	13.60
2	2.01	60.3	10.2	1.37	62.2	10.20
3	2.58	128	16.1	2.33	341	10.50
4	17.2	2514	10.1	14.3	5634	10.50
5	86.6	2035	9.5	83.8	2454	8.70
6	5.7	276	12.4	6.88	131	12.50
7	7.95	143	11.1	4.62	325	12.10
8	6.29	151	17.7	6.36	123	17.80
9	52.2	2180	4.8	54.1	1945	4.70
10	72.8	1413	6.2	67.9	1292	6.20
11	26.7	1042	11.5	23.8	1493	11.80
12	6.09	246	17.3	4.85	510	17.50
13	10.7	619	10.7	11.2	1445	10.60

Based on the inversion results analysis, it can be seen that the results of the Least Square Inversion better describe the actual conditions compared to the results of the Robust Inversion, which is seen from the comparison parameters that have been carried out starting from the errors generated from each inversion starting from the Least Square Inversion has a smaller error overall compared to the Robust Inversion as shown in Table 2. In addition, the resistivity value generated from the Robust inversion results is much greater than the Least Square inversion, where the results of the resistivity value generated from the Least Square inversion are close to the resistivity value of the existing data.

B. Resistivity Data Interpretation

The cross-section of Line 1, the interpretation of resistivity values in this study is divided into three categories, namely low resistivity values, medium resistivity values and high resistivity values as listed in **Table 4**.

Table 4. Rock Resistivity Values in the Study Area

Category	Resistivity Value (ohm)	Lithology
Low	< 200	Soil
Medium	200 - 500	weathered Andesite Mandalika formation
High	> 500	Fresh Andesite Mandalika formation

In **Figure 4** and **Figure 5**, the resistivity value can be divided into three: high, medium, and low. High resistivity has a value of more than 500 Ωm, as shown in **Table 4**. High resistivity values with a range of values > 500 Ωm are interpreted as compact andesite lithology with a red-to-purple symbol. In this track 1, andesite rocks begin to appear at a depth of 5 meters to a depth of ± 20 meters.

The high resistivity value in mandalika andesite rock is because andesite rock has a silica content of 52% - 66%, small porosity and small permeability make andesite rock has a high resistivity value. The low resistivity value of < 200 Ωm is interpreted as soil. The low resistivity value is soil because the soil has a large enough porosity and permeability the resistivity value lower.

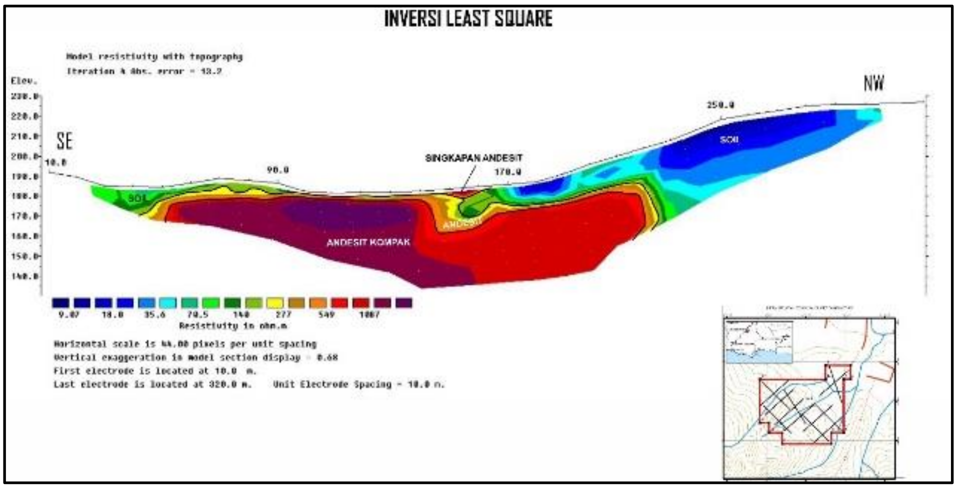

Figure 4. Inversion modeling results with Least Square of line 1

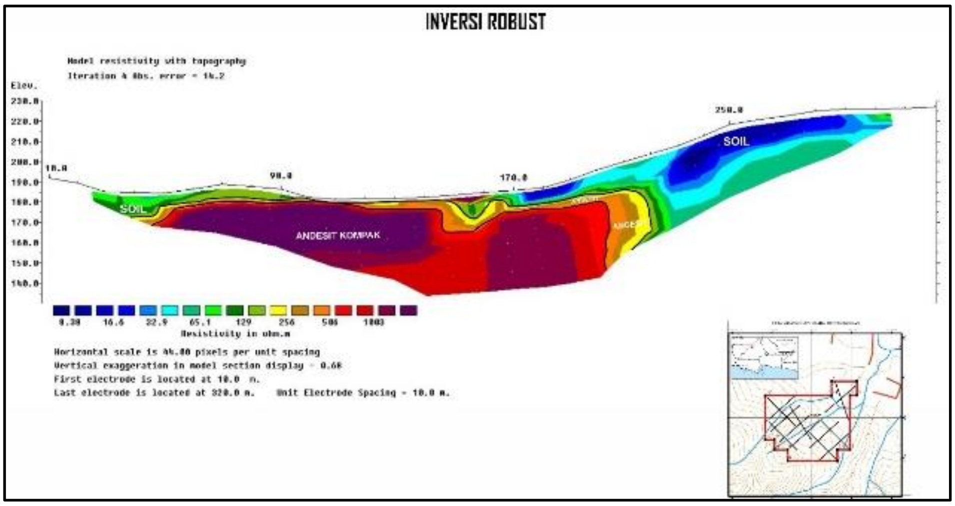

Figure 5. Inversion modeling results with Robust inversion of line 1

The andesite interpretation depicted in the Least Square inversion and Robust Inversion cross sections is a body of andesite rock, which, in the geological description of the research area, andesite in the area is an intrusive type of andesite that is below the surface. This opinion is supported by previous research, from the regional geological description of the research area. The Andesite rock is mandala pyroxene andesite lava, which is a volcanic rock resulting from convergent activity (subduction) in the form of subduction of the Indian Ocean-Australian Plate under the Asian Continental Plate in the Late Oligocene-Miocene.

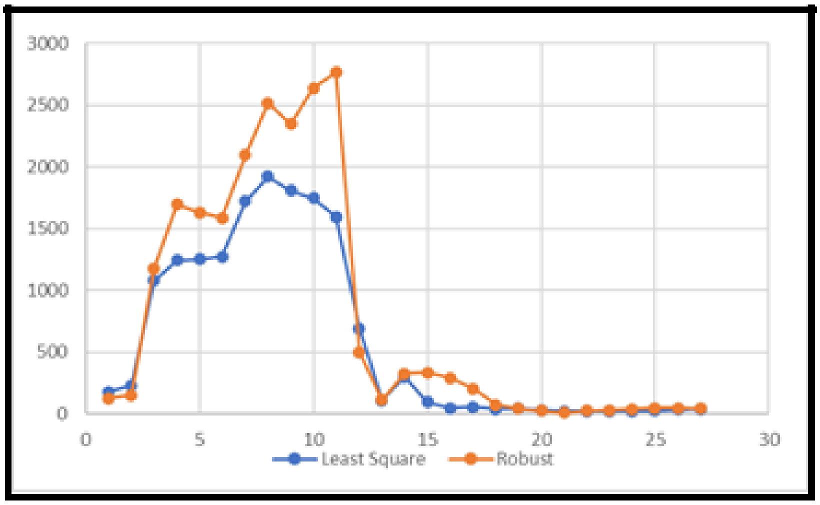

Figure 6 Difference in resistivity value of Line 1

The graph in Figure 6 shows that the resistivity value of the Robust inversion has a more volatile shape compared to the Least Square inversion, which has a more stable pattern and does not show sudden changes as in the Robust inversion, the Robust inversion has a higher resistivity value compared to the Least square inversion. The difference in the results of changes in resistivity values is due to the different concepts of the two inversions. Inversion is to see a response that matches the field measurement data so that the inversion model can be considered representative of the subsurface conditions of the measurement location. (Grandis, 2008)

Conclusions

Based on the results of data processing and analysis, Least Square inversion results have a smaller error than Robust. The Robust inversion cross section has a smoother picture than the Least Square inversion results. The Robust inversion cross-section has a higher resistivity value than the Least Square cross-section. The results of the Least Square inversion cross-section are more in accordance with the conditions of the research area because it describes the existence of andesite rocks based on resistivity values. The interpretation results on the 2D cross-section there are three ranges of resistivity values that can be interpreted, namely low resistivity values < 200 Ωm indicated as soil, moderate resistivity values (200 - 500) Ωm indicated as weathered andesite lava mandalika, and resistivity values > 500 Ωm indicated as compact andesite lava Mandalika (fresh).

Acknowledgments

The author would like to thank the Department of Geophysical Engineering, UPN Veteran Yogyakarta for providing facilities for this research.

REFERENCES

1. Badan Pusat Statistik(BPS). (2017). Potensi Bahan Tambang Dan Mineral Dirinci Menurut Kecamatan Di Kabupaten Trenggalek (Juta Ton).
2. Bavitra, B. (2015). *Estimasi Kedalaman Batuan Dasar Menggunakan Metode Inversi Robust 2-D Data Geolistrik Tahanan Jenis Konfigurasi Dipole-dipole di Bukit Apit Puhun Kecamatan Guguk Panjang Kota Bukittinggi* (Doctoral dissertation, Universitas Negeri Padang).
3. Bery, A. A., Nordiana, M. M., Ismail, N. E. H., Jinmin, M., & Amalina, M. N. (2018, April). Buried Man-made Structure Imaging using 2-D Resistivity Inversion. In *Journal of Physics: Conference Series* (Vol. 995, No. 1, p. 012075). IOP Publishing.
4. Sastrawan, F. D., Arisalwadi, M., & Rahmania, R. (2020). Identifikasi Lapisan Bawah Permukaan Berdasarkan Data Resistivitas 2 Dimensi. *JST (Jurnal Sains Terapan)*, *6*(2), 99-105.
5. Ferahenki, A. R., Ardi, N. D., Heditama, D. M., & Muttaqin, Y. A. (2018). Aplikasi pemograman inversi 2D menggunakan Matlab® pada data resistivity. In *Prosiding Seminar Nasional Fisika (SNF)* (Vol. 2, pp. 66-71).
6. Prameswari, F. W., Bahri, A. S., & Parnadi, W. (2012). Analisa Resistivitas Batuan dengan Menggunakan Parameter Dar Zarrouk dan Konsep Anisotropi. *Jurnal Sains dan Seni ITS*, *1*(1), B15-B20.
7. Grandis, H. (2008). Pemodelan Inversi Geofisika. Institut Teknologi Bandung .
8. Hakim, H., & Manrulu, R. H. (2016). Aplikasi Konfigurasi Wenner dalam Menganalisis Jenis Material Bawah Permukaan. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *5*(1), 95-103.
9. Hidayat, Wahyu. dkk. (2013). Geolistrik di Desa Girijati Kecamatan Purwosari Kabupaten Gunungkidul Provinsi Daerah Istimewa Yogyakarta. Seminar Nasional Kebumian-VII.
10. Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of instructional development*, *10*(3), 2-10.
11. Prastowo, R. (2017). Pemodelan 2D Resistivitas Batuan Andesit Daerah Gunung Kukusan, Kulon Progo. *Jurnal Kurvatek*, *2*(2), 87-93.
12. Purwasatriya, E. B. (2013). Studi Potensi Sumberdaya Andesit Menggunakan Metode Geolistrik Di Daerah Kokap, Kabupaten Kulonprogo, Daerah Istimewa Yogyakarta. *Dinamika Rekayasa*, *9*(2), 55-61.
13. Reynolds, J. M. (2011). *An introduction to applied and environmental geophysics*. John Wiley & Sons.
14. Santoso, D. (2002). Pengantar teknik geofisika. *ITB, bandung*.
15. Samodra, H., Gafoer, S., & Tjokrosapoetro, S. (1992). Peta Geologi Lembar Pacitan, Jawa, skala 1: 100.000. *Pusat Penelitian dan Pengembangan Geologi, Bandung*.
16. Surono, S. (2009). Litostratigrafi Pegunungan Selatan Bagian Timur Daerah Istimewa Yogyakarta dan Jawa Tengah. *Jurnal Geologi Dan Sumberdaya Mineral*, *19*(3), 209-221.
17. Swastika, A., Dipo, C., Pratama, A. Y., Kartanegara, S. M., Khorniawan, W. B., Sayyidi, M., & Natasia, N. (2018). POLA PERSEBARAN DAN ESTIMASI CADANGAN ANDESIT PADA DESA CILULUK, KECAMATAN CICALENGKA, KABUPATEN BANDUNG. *Bulletin of Scientific Contribution: GEOLOGY*, *16*(2), 81-88.
18. Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied geophysics*. Cambridge university press.
19. Wasillah, M. N. (2017). *Integrasi Metode Self Potential Dan Resistivitas Untuk Identifikasi Rembesan Air Pada Tanggul Lumpur Sidoarjo (LUSI)* (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).