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How to Identify the Subsurface Layer of Bangkam Hill - Mempawah Regency? Application of the Geoelectrical Resistivity Method

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ABSTRACT

Mapping the subsurface is essential in rock exploration for construction to minimize costs and guide adequate mining planning. This study aims to identify the subsurface layer of Bangkam Hill, a depot of various rocks for construction materials located in Sungai Kunyit District, Mempawah Regency. A resistivity method was applied to map the sub-surface using the Wenner-Schlumberger configuration. Data acquisition was performed at six measurement lines to cover the hill. The results show that the subsurface layers of the hill from the ground to 40 m in depth are composed of sand, laterite soil, gravel, and igneous rock, with resistivity varying from about 30 to 693,055 Ωm. Using the subsurface map, the stakeholder can assess shallow rock reserves in the study area and create a proper mining strategy.

INTRODUCTION

Urban development needs to be supported by the exploitation of local natural resources. These natural resources can be explored by mapping the subsurface of targeted areas. Here, the geophysics exploration methods are proven to handle this kind of task (Hörning et al., 2020; Karimah et al., 2022; Oguntade, 2022; Oyedele et al., 2022; Tapakis et al., 2022)

In general, several exploration methods can be implemented to provide subsurface information (Kinayung et al., 2014; Muhardi & Wahyudi, 2020). The distribution and potential of subsurface resources can be determined using a geological and geophysical method (Usman et al., 2017; Nordiana et al., 2018). Information on rock types can be used as a reference in the process of regional use planning and regional development (Septiansyah et al., 2020).

Bangkam Hill is a rich rock resources hill located in Sungai Kunyit District, Mempawah Regency. The subsurface rocks can be exploited as material for urban development in surrounding areas. The study to know the potential of subsurface resources can apply geophysical methods. The methods that can be used include geoelectrical resistivity (Masudi et al., 2021), seismic (Ismail et al., 2018), gravity (Abiyudo et al., 2021), magnetic (Maulidan et al., 2021), ground penetrating radar (Chhetri et al., 2020), very low frequency (Wulandari et al., 2018), and induced polarization (Muhardi et al., 2022). Geoelectrical resistivity can be used to identify subsurface geological conditions in the geoelectrical resistivity method (Setiadi

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et al., 2016). This method has been used to determine the subsurface layers, for example, the lithology (Wahyudi et al., 2021), landslide mapping (Sismanto & Nasharuddin, 2018), the distribution of igneous (Setiadi et al., 2016), subsurface structures (Anas et al., 2020), hard soil layers (Masudi et al., 2021), and identification of faults (Lutfinur et al., 2015).

The geoelectrical resistivity method can be implemented to depict the geological condition of a subsurface based on an electrical property, i.e., resistivity (Telford et al., 1990; Wahyudi et al., 2021). The resistivity describes the ability of a medium to block the flow of electric current. The subsurface composition is believed to have various resistivity values, which can be used as a reference in the interpretation process (Bayowa et al., 2022). This study will apply geoelectrical resistivity methods to identify the subsurface layer's potential in Bangkam Hills, Sungai Kunyit District, Mempawah Regency. The location is around the mining area, so this research is beneficial in providing an overview of the subsurface conditions around the mining area. In addition, previous research on the subsurface layer by the geophysical method in this area has never been done. This study is expected to provide an overview of the potential of subsurface geology so that it can be used as minerals for economic development in the area.

METHODS

This research uses the geoelectrical resistivity method with the Wenner-Schlumberger configuration. The research process carried out is field surveys, data acquisition in the field, data processing, inversion modeling, and interpretation of the results, as shown in Figure 1. Data acquisition was carried out using the Automatic Resistivity System (ARES). This equipment's measurement results will be stored automatically so that acquisitions in the field will be more effective and efficient. The measurement applied six paths, as shown in Figure 2. The length of each line is 240 m, and the electrode spacing is 5 m. The measurement design can identify the subsurface resistivity distribution to a depth of 40 m. The study location is in the Bangkam Hill area, Sungai Kunyit District, Mempawah Regency, West Kalimantan Province, Indonesia.

Based on the geological map, the study location is in the Sintang Intrusive Formation (Toms) and Alluvium Formation (Qa). The Sintang Intrusive Formation is composed of diorite, microdiorite, granodiorite, quartz diorite, gabbro quartz, and tonalite. Intrusive igneous rocks also dominate this formation. While the Alluvium Formation is composed of mud, sand, gravel, and plants (Pieter & Supriatna, 1990).

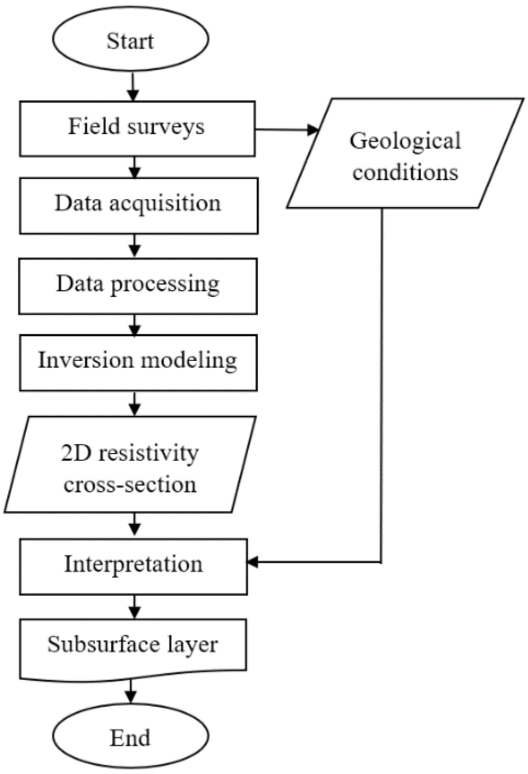


Figure 1. Flowchart of the research

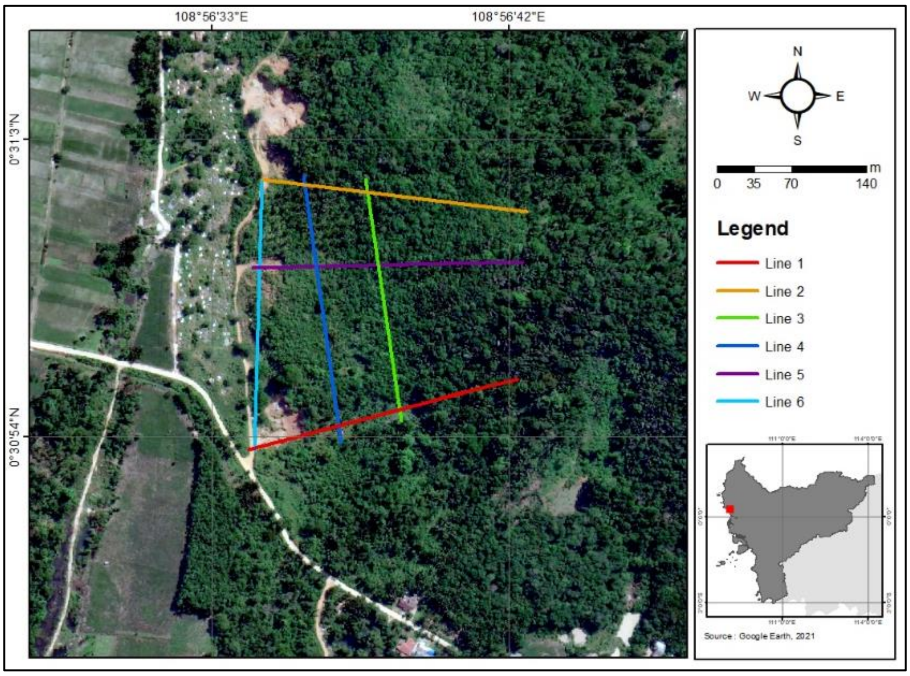


Figure 2. The Measurement design in the study location

The apparent resistivity values obtained from field measurements at the study site were processed using the Res2Dinv software. It is obtained in the form of a 2D resistivity cross-section of each measurement path. This section is used to interpret the type and distribution of the subsurface layer based on field conditions, geological maps, and the distribution of resistivity values, as shown in Table 1.

Table 1. The resistivity of materials (Dentith and Mudge 2014; Telford et al., 1990)

No	Materials	Resistivity (Ω*m*)
1	Laterite soil	120 - 750
2	Gravel	100- 10^6
3	Igneous	1.000 - 10^6
4	Sand	1 – 1.000
5	Sand and gravel	100 – 1.000

The application of Ohm's law is a fundamental concept in the geoelectrical resistivity method. This law states that the voltage of *V* of the two ends of the medium is equal to the product of the current of *I* and resistance of *R*, which is shown in Equation (1) (Everett, 2013)

$$V = I\,R \qquad (1)$$

If a medium is in the form of a cube that has a length of *L* and a cross-sectional area of *A* and is flowed by a current of *I*, as shown in Figure 3, then the resistance of *R* of the medium is shown in Equation (2) (Everett, 2013)

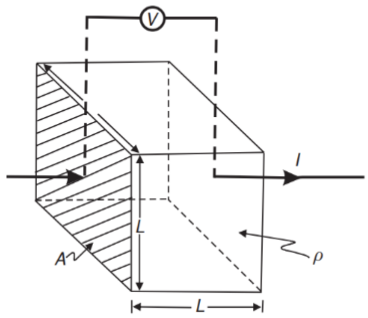


Figure 3. The illustration of resistivity is when an electric current passes through a cube of the length of *L* and a cross-sectional area of *A* (Reynold, 2011).

$$R = \rho\,\frac{L}{A} \qquad (2)$$

Measurements in the field were carried out using a pair of both current and potential electrodes arranged according to the Wenner-Schlumberger configuration, as shown in Figure 4. The ratio factor of *n* is the ratio of the distance between the electrodes of C_1-P_1 or P_2-C_2. At the same time, the distance a in this study is 5 m, with a line length of 240 m.

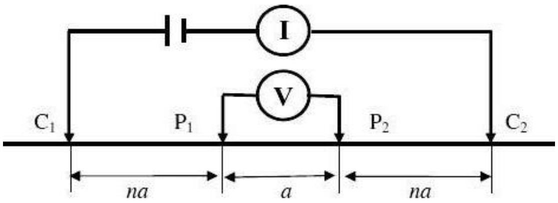


Figure 4. Electrode configuration of Wenner-Schlumberger (Loke, 2000)

The electrode configuration will affect the geometry factor of κ in the Wenner-Schlumberger configuration, which is shown in Equation (3) (Loke, 2000)

$$\kappa = \pi n\,(n+1)\,a \qquad (3)$$

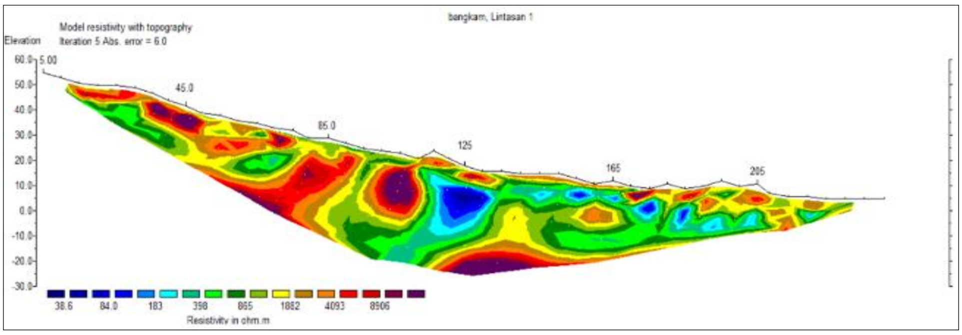
RESULTS AND DISCUSSION

The study location is in a hilly area with an elevation of 5 – 94 masl. Line 1, line 2, and line 5 are east-west oriented paths with the peak as the starting point of the measurement and the valley area as the endpoint of the measurement. While line 3, line 4, and line 6 are south-north oriented paths and intersect on the three before. The elevation of the lines and distribution of subsurface resistivity values on these six paths are shown by the results of measurements in the field in Table 2.

Table 2. Measurement results in the field

Line	Elevation (mdpl)	Resistivity (Ωm)
1	5 - 57	43.9 – 74,218
2	18 - 94	199 – 65,988
3	17 - 29	99.3 – 693,055
4	18 - 33	40,8 – 110,146
5	19 - 86	81 – 376,058
6	5 - 13	30.13 – 39,303

The field measurements show that the study location is at an elevation of 5 – 94 masl. Topography with a steep slope is found on lines 2 and 5, with angles of 18.46^0 and 16.21^0 each. While line 6 is in a flat area, the slope is 1.91^0. Relatively low resistivity values are found in lines 1, 2, and 6, namely 43.9 – 74,218 Ωm, 199 – 65,988 Ωm, and 30.13 – 39,303 Ωm, while relatively high resistivity values are found in lines 3, 4, and 5 namely 99.3 – 693,055 Ωm, 40.8 – 110,146 Ωm, and 81 – 376,058 Ωm.



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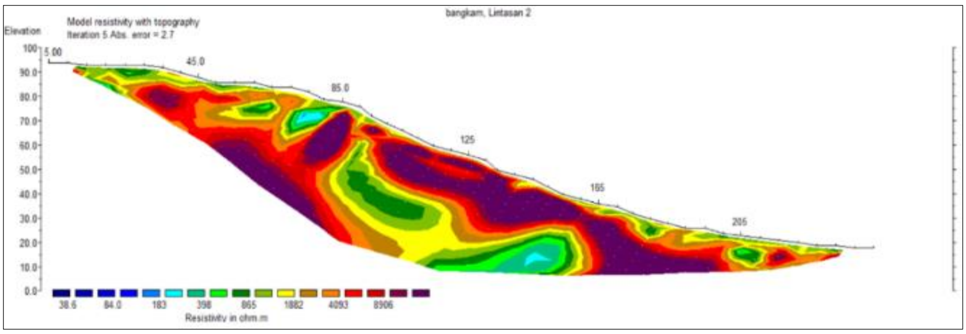

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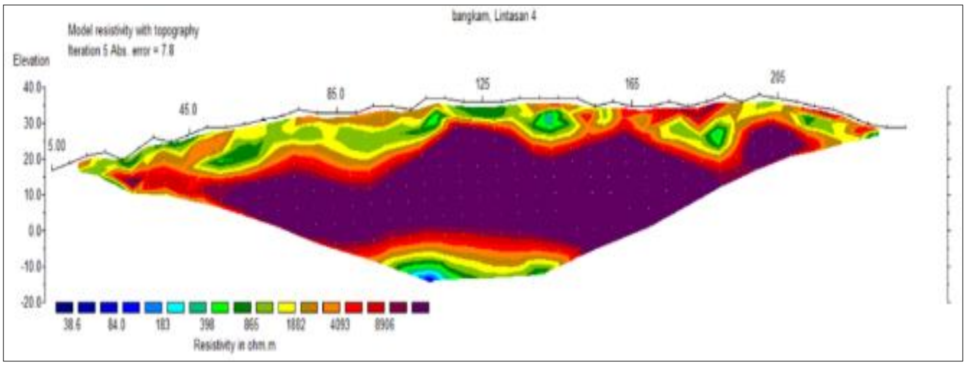

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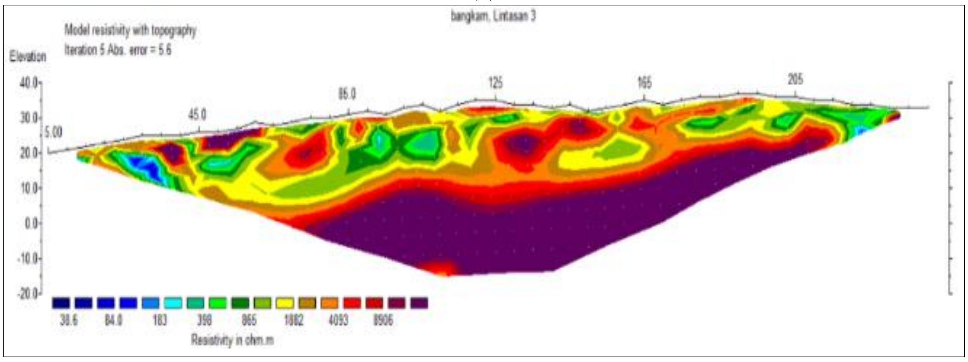

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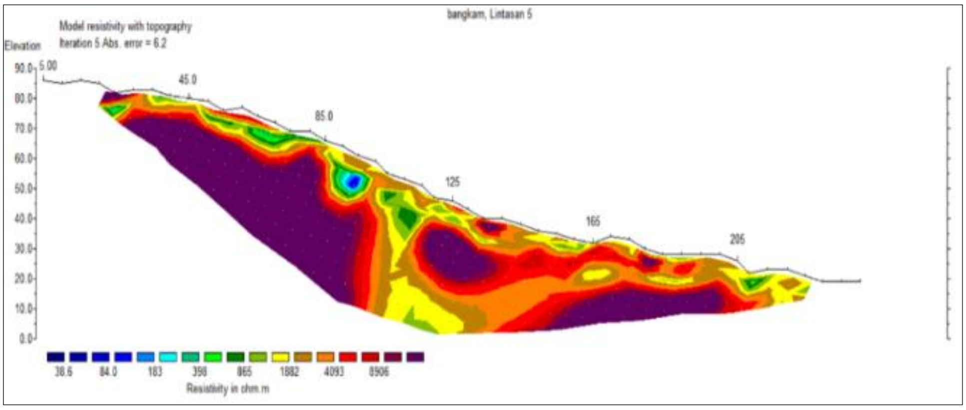

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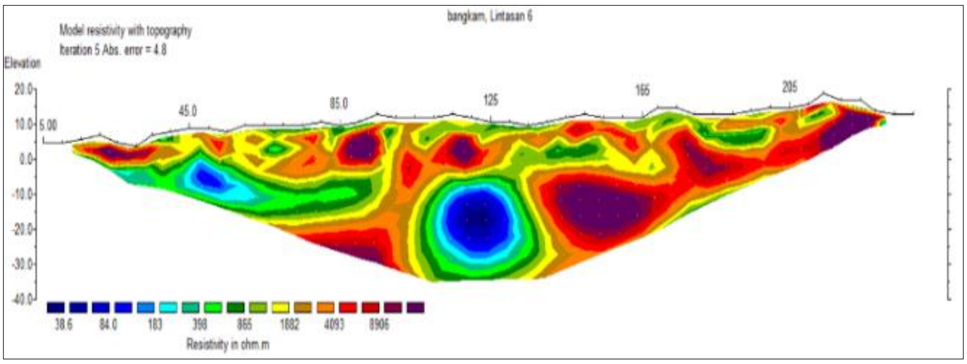


(f)

Figure 5. 2D resistivity cross-section; (a) Line 1, (b) Line 2, (c) Line 3, (d) Line 4, (e) Line 5, and (f) Line 6

Variations in subsurface resistivity values indicate variations in rock layers at the study location. The 2D resistivity cross-section can be shown in Figure 5, which presents the lateral distribution of resistivity values along the line to a depth of 40 m. This cross-section is obtained by the inversion process of the apparent resistivity.

Based on the distribution of resistivity values in Figure 5, the subsurface layer is interpreted as having four materials. They are sand, laterite soil, gravel, and igneous rock. These materials are thought to be at various depths. This refers to the resistivity values as shown in Table 1 (Dentith & Mudge, 2014; Telford et al., 1990). The resistivity value of 30.13 – 183 m is interpreted as sand material, resistivity 184 - 865 is interpreted as laterite soil, resistivity 866 – 4,093 m is interpreted as gravel, and resistivity 4,094 – 693,055 m is interpreted as igneous rock, as shown in Table 3.

Table 3. Resistivity value of materials in the field

No	Resistivity Value (Ωm)	Materials
1	30.13 - 183	Sand
2	184 -865	Laterite soil
3	866 – 4,093	Gravel
4	4,094 – 693,055	Igneous rocks

The results of the interpretation of the subsurface layer are shown in Figure 6. The three materials as sand, laterite soil, and gravel, are shown in brown. The combination of these three materials is based on field conditions and is also intended to make it easier to identify the presence of igneous rock that has the potential to be used as excavation material. In general, these igneous rocks are under sand, laterite soil, and gravel. There are several points whose existence is exposed to the surface because they may be caused by erosion. Figure 7 also shows that lines 1 and 6 have layers of sand, laterite soil, and gravel which is thicker than other lines. This information is needed for further utilization of minerals at the location.

Sand, laterite soil, and gravel are materials formed by the weathering process of the parent rock (in the form of igneous rock). This weathering process produces debris originating from the parent rock to produce smaller grains. This material is generally a place for water saturation so that electric current is easily flowed due to electrolytic conditions, causing the resistivity value of this layered material to be below. The accumulation of this material is marked with a red-brown color, as shown by the rock outcrops at the study location in Figure 6. The hilly conditions at the study site also contain many igneous outcrops that continue to the center of the hill. This rock is thought to be an intrusive igneous rock originating from the Sintang Intrusive Formation (Pieter & Supriatna, 1990).

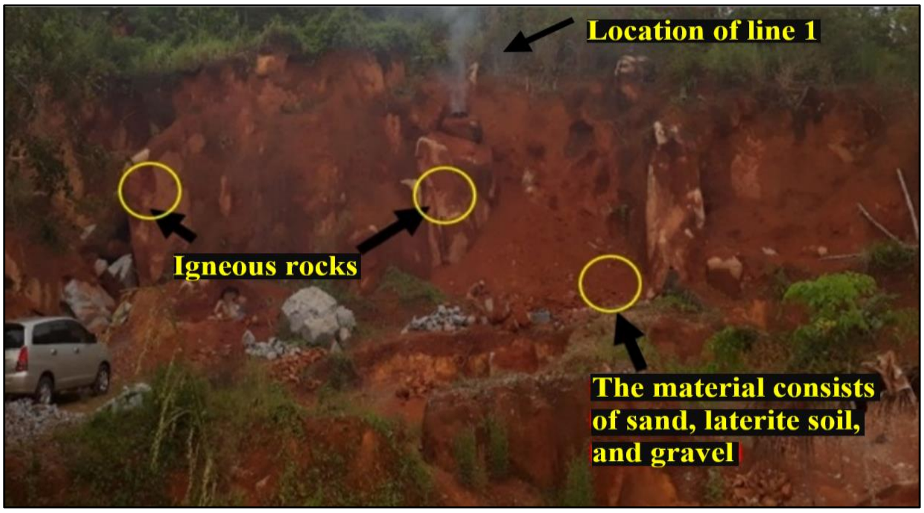
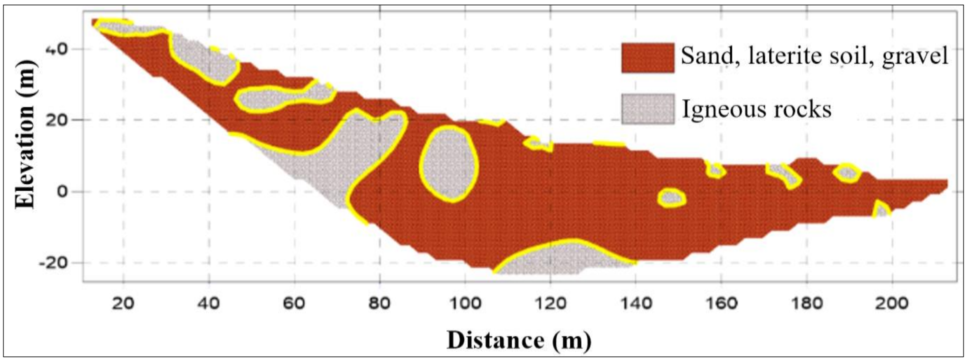


Figure 6. Rock outcrops in the study area

The rock formations at the study location consist of the Sintang Intrusive Formation (Toms) and the Alluvium Formation (Qa). Intrusive igneous rocks dominate the Sintang Intrusive Formation. While the Alluvium Formation is composed of mud, sand, gravel, and plants (Pieter & Supriatna, 1990). Intrusive igneous rocks are buried beneath the surface and cool from magma slowly. They have a phaneritic texture, so they have coarse-grained crystals and are more visible when compared to extrusive igneous rock. In addition, igneous rocks at the study location are seen in areas that experience erosion, so they are exposed to the surface.

The rock weathering process produces sand, laterite soil, and gravel from the materials that make up the Alluvium Formation. Sand and gravel come from rock and mineral particles that are broken up into smaller sizes, the result of weathering of igneous and sedimentary rocks. Based on the Wentworth scale, the diameter of the sand is 0.062 – 2 mm, and the diameter of the gravel is 2 – 256 mm (Nichols, 2009). Laterite soil in the study location is red to brownish-colored ground with a dense texture. Laterite soils are formed in tropical areas with humid environments.



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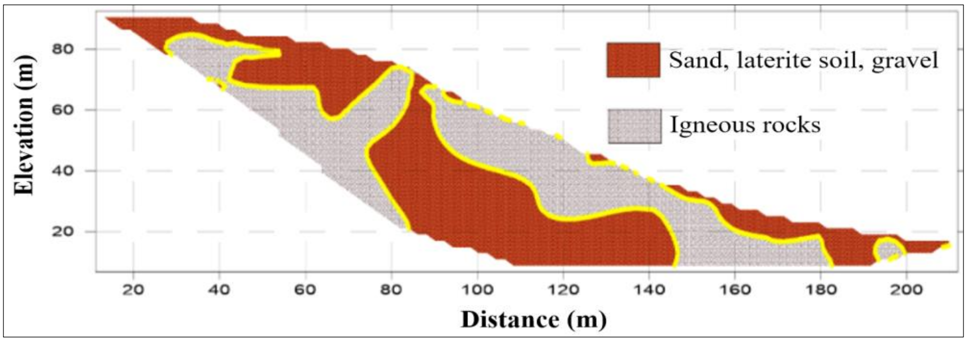

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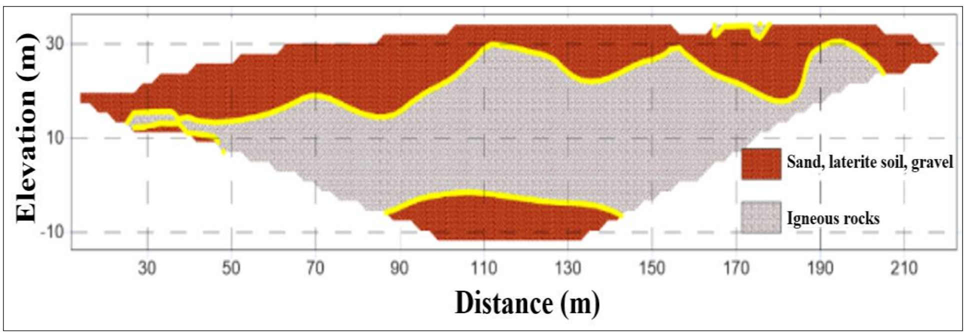

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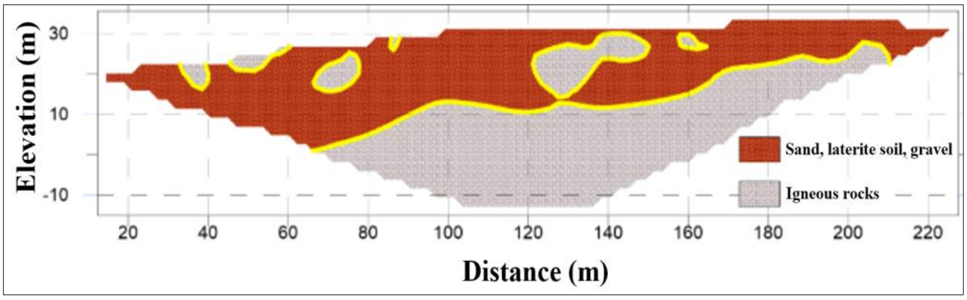

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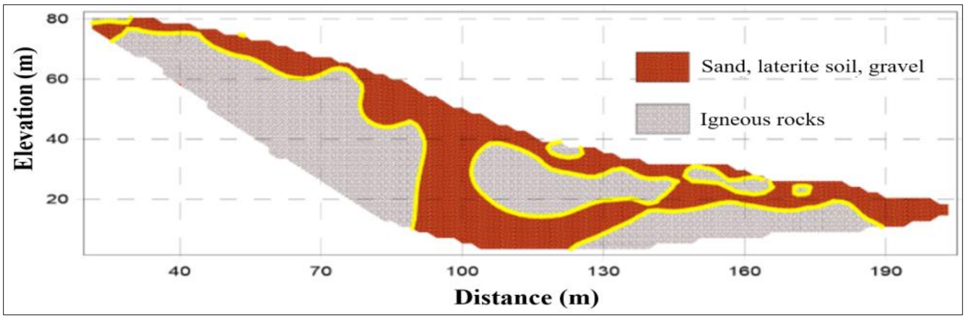

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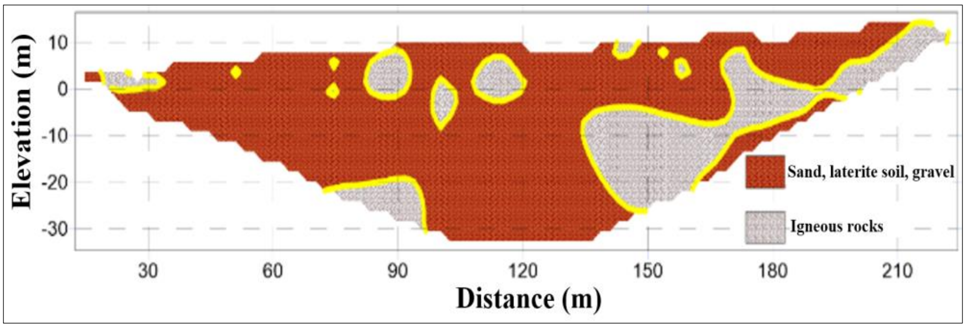

(f)

Figure 7. Interpretation of the subsurface layer; (a) Line 1, (b) Line 2, (c) Line 3, (d) Line 4, (e) Line 5, and (f) Line 6

CONCLUSION AND SUGGESTION

In this study, the subsurface of Bangkam hill has been successfully mapped using the resistivity method. The results show that the subsurface (from the ground to 40 m depth) has varying resistivity. Based on the resistivity distribution, it was then interpreted that the subsurface layers consist of sand (30.13 – 183 Ωm), laterite soil (184 – 865 Ωm), gravel (866 – 4,093 Ωm), and igneous rock (4,094 – 693,055 Ωm) with various depth. Using the subsurface map, the stakeholder can assess shallow rock reserves in the study area and create a proper mining strategy.

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AUTHOR CONTRIBUTIONS

In this study, each author has contributed to completing the stages. OI and FD carried out data acquisition in the field and data processing, while JS and MM conducted an interpretation of the results and discussion. All authors also contributed to compiling and reviewing this manuscript.

REFERENCES

Abiyudo, R., Daud, Y., & Satya, D. Y. (2021). Subsurface structure identification from gravity modelling of silangkitang geothermal field for future injection well targeting. *The 2nd Digital Indonesia International Geothermal Convention (DIIGC)*.

Anas, N. A., Syamsuddin, Harimei, B., & Nasri, M. (2020). Identifikasi struktur bawah permukaan di sekitar manifestasi panas bumi reatoa kabupaten maros menggunakan survey geolistrik resistivitas. *Jurnal Geocelebes*, *4*(1), 23–32. https://doi.org/10.20956/geocelebes.v4i1.8916

Bayowa, O. G., Adagunodo, T. A., Akinluyi, F. O., & Hamzat, W. A. (2022). Geoelectrical exploration of the coastal plain sands of Okitipupa Area, Southwestern Nigeria. *Journal of Environmental Science and Technology*, 1–18. https://doi.org/10.1007/S13762-022-04393-4

Chhetri, A., Bhusal, U., & Paudel, L. (2020). Investigation of sub-surface geological and man-made features in and around lazimpat-maharajgunj area, kathmandu valley using ground penetrating radar (GPR). *Lowland Technology International*, *22*(1), 123–136. https://cot.unhas.ac.id/journals/index.php/ialt_lti/article/view/796

Dentith, M., & Mudge, S. (2014). *Geophysics for the mineral exploration geoscientist*. Cambridge University Press.

Everett, M. E. (2013). *Near-Surface Applied Geophysics*. Cambridge University Press.

Hörning, S., Gross, L., & Bárdossy, A. (2020). Geostatistical electrical resistivity tomography using random mixing. *Journal of Applied Geophysics*, *176*, 104015. https://doi.org/10.1016/j.jappgeo.2020.104015

Ismail, M. A. M., Min, N. S., Abidin, M. H. Z., & Madun, A. (2018). Subsurface characterization using geophysical seismic refraction survey for slope stabilization design with soil nailing. *Journal of Physics: Conference Series*, *995*(1). https://doi.org/10.1088/1742-6596/995/1/012107

Karimah, K., Susilo, A., Suryo, E. A., Rofiq, A., & Hasan, M. F. R. (2022). Analysis of potential landslide areas using geoelectric methods of resistivity in the kastoba lake, Bawean Island, Indonesia. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 660–665. https://doi.org/10.29303/JPPIPA.V8I2.1414

Kinayung, S., Darsono, & Legowo, B. (2014). Aplikasi metode geolistrik resistivitas konfigurasi dipole-dipole untuk identifikasi potensi sebaran galena (PBS) daerah-X, Kabupaten Wonogiri. *Jurnal Fisika FLUX*, *11*(2), 140–148. https://doi.org/http://dx.doi.org/10.20527/flux.v11i2.2676

Loke, D. M. (2000). *Electrical imaging surveys for environmental and engineering studies*. Geoelectrical.com.

Lutfinur, I., Khumaedi, & Susanto, H. (2015). Identifikasi sesar bawah permukaan menggunakan metode geolistrik konfigurasi schlumberger (studi kasus sungai opak Yogyakarta). *Indonesian Journal of Applied Physics*, *5*(2), 10–24.

Masudi, Nurhasanah, & Muhardi. (2021). Identifikasi kedalaman lapisan tanah keras menggunakan metode geolistrik tahanan jenis (studi kasus: Jalan Perdana Kota Pontianak). *Jurnal Ilmu Dan Inovasi Fisika*, *5*(1), 59–64. https://doi.org/10.24198/jiif.v5i1.31227

Maulidan, I. F., Tri Suci, R., Mahendra, A., & Putra, A. (2021). Interpretation of subsurface structure based on the magnetic data at semurup geothermal area Kerinci. *Jurnal Ilmu Fisika |*

Universitas Andalas, *13*(2), 101–108. https://doi.org/10.25077/jif.13.2.101-108.2021

Muhardi, Anwar, M., & Kaharudin. (2022). Application of induced polarization and resistivity methods to identify subsurface layers in bauxite deposits area of Kendawangan, West Kalimantan. *Jurnal Pendidikan Fisika Indonesia*, *18*(1), 75–82. https://doi.org/10.15294/jpfi.v18i1.29230

Muhardi, & Wahyudi. (2020). Prediksi tipe longsor di desa clapar menggunakan metode geolistrik resistivitas konfigurasi dipol-dipol. *Jurnal Lingkungan Dan Bencana Geologi*, *11*(2), 115–123. https://doi.org/10.34126/jlbg.v11i2.290

Nichols, G. (2009). Sedimentology and stratigraphy. In *Syria Studies* (2nd ed., Vol. 7, Issue 1). A John Wiley & Sons, Ltd.

Nordiana, M. M., Bery, A. A., Taqiuddin, Z. M., Jinmin, M., & Abir, I. A. (2018). 2-D Electrical resistivity tomography (ERT) assessment of ground failure in urban area. *Journal of Physics: Conference Series*, *995*(1), 012076. https://doi.org/10.1088/1742-6596/995/1/012076

Oguntade, S. S. (2022). Subsurface investigation for road construction using electrical resistivity method along oloko road, Apatapiti, Akure, Ondo State, Nigeria. *Annals of Science and Technology*, *7*(1), 29–35. https://doi.org/10.2478/AST-2022-0004

Oyedele, A. A., Akinwamide, J. T., & Ogunyebi, S. N. (2022). Localized features in subsoil investigation and implications for foundation works: case study from ilora, Southwestern Nigeria. *ITEGAM-JETIA*, *8*(35), 14–19. https://doi.org/10.5935/JETIA.V8I35.816

Pieter, P. E., & Supriatna, S. (1990). *Peta geologi kalimantan barat*. Pusat Penelitian dan Pengembangan Geologi.

Reynold, J. M. (2011). An introduction to applied and environmental geophysics 2nd edition. In *Library of Congress*.

Septiansyah, M. R., Muliadi, & Zulfian. (2020). Identifikasi struktur bawah permukaan di daerah pariwisata ai sipatn lotup kabupaten Sanggau Menggunakan Metode Geolistrik Resistivitas. *Prisma Fisika*, *8*(3), 172–179. https://doi.org/10.26418/pf.v8i3.43669

Setiadi, M., Apriansyah, & Sampurno, J. (2016). Identifikasi sebaran batuan beku di bukit koci desa Sempalai kabupaten Sambas Kalimantan Barat Dengan Menggunakan Metode Geolistrik Resistivitas. *Positron*, *6*(2), 53–59. https://doi.org/10.26418/positron.v6i2.16879

Sismanto, & Nasharuddin. (2018). Landslide potential mapping in Penggung Purwosari village, district Girimulyo, Kulonprogo, Yogyakarta Province, Indonesia Using Dipole-dipole Resistivity Method. *International Journal of Civil Engineering and Technology*, *9*(6), 1141–1150.

Tapakis, U., Pariaman, P., Sumatra, W., Octova, A., Anaperta, Y. M., Febriandika, G., Febriandika, H. G., Martinus, H., Nazki, A., Razi, P., & Putra, A. (2022). Application of geoelectrical resisivity method for iron sand exploration in Ulakan Tapakis Padang Pariaman. *Journal of Physics: Conference Series*, *2309*(1), 012022. https://doi.org/10.1088/1742-6596/2309/1/012022

Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied Geophysics* (Second Edi). Cambridge University Press.

Usman, B., Manrulu, R. H., Nurfalaq, A., & Rohayu, E. (2017). Identifikasi akuifer air tanah kota Palopo menggunakan metode geolistrik tahanan Jenis Konfigurasi Schlumberger. *Jurnal*

Fisika FLUX, *14*(2), 65–72. https://doi.org/10.20527/flux.v14i2.4091

Wahyudi, A., Azwar, A., & Muhardi. (2021). Penggunaan metode geolistrik resistivitas untuk identifikasi lapisan bawah permukaan daerah Gunung Tujuh Kabupaten Kayong Utara. *Jurnal Fisika Unand*, *10*(1), 62–69. https://doi.org/10.25077/jfu.10.1.62-69.2021

Wulandari, A., Anggari, E. A., Dwiasih, N., & Suyanto, I. (2018). Estimation of existence geothermal manifestation using very low frequency (VLF) method in the pagerkandangvulcanic, Dieng, Central Java. *IOP Conference Series: Earth and Environmental Science*, *132*(1). https://doi.org/10.1088/1755-1315/132/1/012023