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Assessing The Impact of Lithological and Geological Features on Electrical Resistivity Tomography (ERT) at Kelantan River Basin, Malaysia

Z. M. Nizam[1,2]*, A. T. S. Azhar[1,2], M. Aziman[1], Z. M. N. Hidayat[3], J. A. Aziz[4], N. M. N. Amri[5]

[1] *Faculty of Civil Engineering and Built Environment*
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA
[2] *Geo-Structure Rehabilitation Centre*
Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA
[3] *Azurite Engineering PLT, 83300 Sri Gading, Johor, MALAYSIA*
[4] *Department of Electrical Engineering,*
Politeknik Mersing Johor, 86800 Mersing, Johor, MALAYSIA
[5] *Faculty of Earth Science*
Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, MALAYSIA

*Corresponding Author: mnizam@uthm.edu.my
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Abstract

The relationship between lithological and geological features, as assessed through Electrical Resistivity Tomography (ERT), is crucial for exploring subsurface characteristics. ERT is non-invasive and provides high-resolution images of subsurface electrical resistivity, closely linked to lithology and geological formations. This study aims to accurately delineate lithology, geological formations, and aquifer presence, whether in alluvial layers or bedrock. ERT measurements, employing Pole-dipole and Gradient-XL protocols, were conducted at At-Taqwa Mosque in Gua Musang, Mini Zoo in Kuala Krai, Kampung Sedar, and Kuala Jambu in Tumpat, Kelantan. Results indicated regions with high clay content exhibited low electrical resistivity (<100Ωm), whereas areas with sand and gravel deposits showed high resistivity (>500Ωm). Faults and fractures within hard layers significantly influenced resistivity values, revealing intricate connections between survey lines. Algorithmic analysis integrated with topographical data enhanced the identification of mineral exploration potential, paving the way for real-time monitoring. The Kelantan River Basin was selected due to its environmental importance, facilitating insights into groundwater dynamics, economic significance, and sustainable development practices. This study underscores ERT's role in ground management strategies, mineral exploration, and advancing ground exploration technologies.

1. Introduction

Kelantan River Basin is one of the major river basins in Malaysia, and it plays a critical role in supporting the livelihoods of millions of people who live in the region. The basin is in the north-eastern part of Peninsular Malaysia and covers an area of approximately 9,525 km^2. The geology of the region is characterized by the Main

Range Granite, which is overlain by sedimentary rocks of Mesozoic age. Electrical Resistivity Tomography (ERT) is a geophysical method that is widely used for investigating the subsurface geology and hydrogeology of a region. It involves measuring the electrical resistivity of the subsurface materials using an array of electrodes placed on the ground surface. ERT identifies the composition of subsurface and presence of water content. Granite properties indicate high electrical resistivity due to its low porosity and moisture content. In contrast, different levels of moisture content led to lower electrical resistivity. This contrast of electrical properties can be solved by ERT ability to distinguish and delineate geological properties and groundwater interfaces.

Kelantan River Basin, known for its diverse geological formations and potential near-surface heterogeneity, where well-suited for two common electrode configurations in ERT which are Pole-dipole and Gradient-XL arrays. A Pole-dipole array involves placing a current electrode and two potential electrodes in a linear configuration. This array is suitable for imaging deeper subsurface structures with good depth resolution. Meanwhile, Gradient-XL array involves placing electrodes in a linear array and measuring the voltage Gradient between adjacent electrodes. This array is suitable for imaging shallow subsurface structures with high lateral resolution. In this context, the use of the Pole-dipole and Gradient-XL arrays in ERT can provide complementary information about the subsurface resistivity distribution. The Pole-dipole array is suitable for imaging deeper structures, while Gradient-XL array resolves near-surface heterogeneities. By using both arrays, a comprehensive integrated two electrode configuration resistivity model of the substructure can be obtained.

This study aims to assess the impact of lithological and geological features on ERT at the Kelantan River Basin. Understanding the impact is crucial to understanding the accuracy and reliability of substructure imaging to determine potential areas for groundwater exploration and management. By identifying different types of underground structures that affect the resistivity value, ERT methods can be fine-tuned to align with cost-effectiveness and precision. The study involves conducting a field survey to collect ERT data at different locations along the river basin. Data is analyzed using geostatistical simulation to identify the intricate interactions between lithological and geological features that influence ERT measurements. The study findings extend beyond policymakers, water resources managers, and other stakeholders who are involved in sustainable management of groundwater resources in the region. This study represents an important contribution to the field of geophysics and hydrogeology. To be precise, the study elucidates substructure surface insights into unexplored lithological and geological features that have a direct bearing on groundwater storage and availability. Simultaneously, it aims to delineate an integrated relationship between geological formation and their influence on ERT within Kelantan River Basin. The study area consists of 4 sites which are in the state of Kelantan and are situated in the vicinity of the Kelantan River Basin.

2. Study Area

To gain insights into diverse geological conditions, the selection of area is based on significant environmental subsurface of river basin and its potential for groundwater recharge and discharge. The basin's geological landscape characteristic of 10 sites is selected with interrelationship and hydrogeological attributes are ideal to intricate the relationship between lithological and geological features and their impact on ERT value. A geophysical survey that applied the method of electrical resistivity and induced polarization (I.P) was carried out at At-Taqwa Mosque, Gua Musang, Mini Zoo Kuala Krai, Kampung Sedar, Tumpat and Kuala Jambu, Tumpat in the state of Kelantan. In this study, a total of eight (8) survey lines were conducted at the proposed site using Pole-dipole and Gradient-XL arrangements, as Pole-dipole provides insight deeper features, while Gradient-XL focuses on shallower subsurface heterogeneities, to obtain the most optimal subsurface information which were equal or greater than 120 m in depths.

This study was conducted using ABEM Terrameter LS2 equipment, which is designed to measure substructure electrical resistivity. The apparatus is capable of integrating with ERT to accurately determine variations in electrical properties of substructure, identifying most of rock type, soil composition and groundwater presence. The multi-electrode allows the data collection across 10 different site locations efficiently thus improving the coverage of data acquisition. The survey line that has been spread out has been in accordance with considering geological characteristic composition, topography feature elevation, accessibility, and the reading of designated guide as well as proposed location of the tube well to be installed. In addition, the environmental variables are considered in meticulous planning of the survey works such as faults and intricate composition of lithological formation that influence resistivity response due to changes in substructure properties that alter the resistivity value. Results obtained from the survey are then translated into pseudo cross-sections to provide a subsurface view of each proposed site. Fig. 1 and Fig. 2 show a map of the study location located in the state of Kelantan with detailed lithological data.

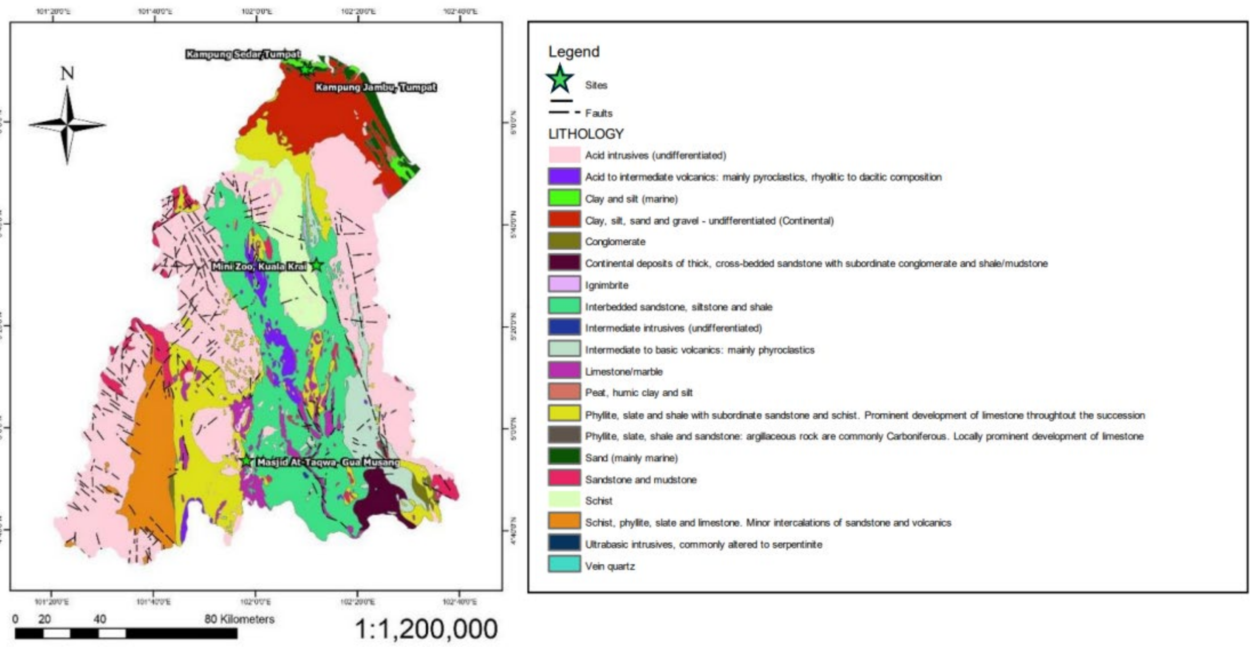

Fig. 1 *Location of the study area in Kelantan*

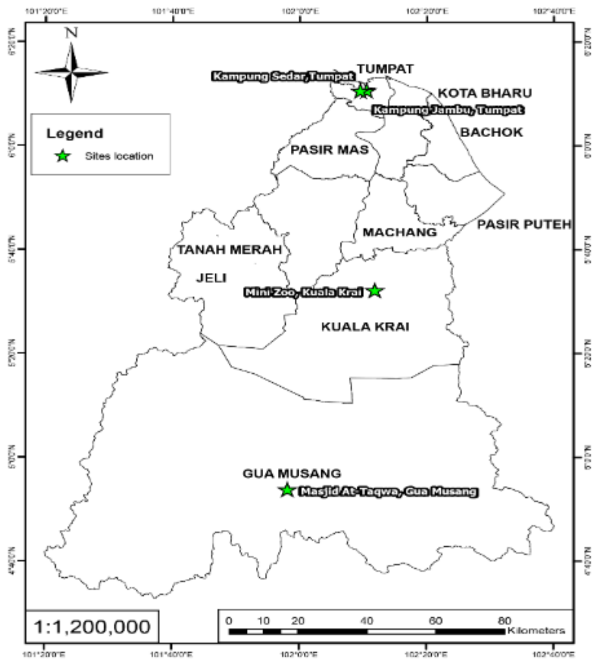

Fig. 2 *Location of the study area with the general geology*

In Gua Musang area, the rocks that can be found are argillite units that have mostly metamorphosed to low-grade either slate or phyllite, while limestone that has mostly recrystallized into marble, sandstone, and some conglomerate. Most of the argillite and sandstone units are tuffaceous and have the trace of volcanic origin. This rock unit is known as the "Gua Musang Formation", which is from the Early Permian to the Late Triassic age. Rock formations possess unique mineral compositions, porosities, and moisture content significant to determining ERT, where these variants generate lithological boundaries and geological structure that affect electrical resistivity value. For the locality in Kuala Krai, the geological aspect of the area consists of Gua Musang Formation rocks, Taku Schist and Complex Granite in the western region. The lithological units of study area consist of layers of sandstone, siltstone, shale and pyroclase that are in Triassic age, indicating that the geology of the Kampung Sedar and Kuala Jambu areas consist of Quaternary alluvial deposits. A profound grasp of the geological context is fundamental, as it enables the accurate interpretation of ERT data. Essentially, it enhances the capacity to discern subsurface structures, evaluate groundwater dynamics, identify valuable mineral resources, and implement effective environmental management strategies.

3. Methodology

ERT is a geophysical technique used to produce images of the subsurface via electrical resistivity distribution. Electrical resistivity values correlated with lithological and geological data obtained from borehole logs, geological maps, and surface observations. It has a wide application in environmental as well as engineering fields, such as groundwater exploration, contaminant plume mapping, and geological investigations. The ERT process encompasses several key steps:

- Injection of direct current (DC) into the ground via multiple electrodes.
- Measurement of voltage distribution on the surface or in boreholes.
- Inversion of collected data to generate a resistivity model.

This sequential process forms the backbone of this study into the impact of lithological and geological features on the ERT responses. The measured data was then inverted by computational software to obtain a resistivity model of the subsurface. In this research, the measurement of material resistance is using Pole-dipole and Gradient-XL to perform the data acquisition. This is due to the different path the electric current C2 passing through different soil types before reaching to the other side of the current electrode C1 [1]. The different types of soil such as clay, silt, sand, and gravel vary in electrical resistivity value. Pole-dipole configuration is sensitive to lateral variations in clayey soil due to higher ionic concentration, resulting the electrical resistivity becomes lower, whereas the Gradient-XL less sensitive to lateral variants and unable to receive any heterogeneity. In contrast, soil is composed of mineral grains and water with different distinct electrical conductivity impacting how the electrical current flows through the soil and interpretation of ERT results.

The main potential area for underground water in Kelantan is the north of Kelantan which is underlain by Quaternary alluvium [2]. According to MacDonald in 1967 [3], alluvium may be of marine or fluviatile origin and cannot necessarily be used to distinguish the two types of deposits. The alluvium under it is granite and sedimentary or metasedimentary rocks and the last layer consists of shale, sandstone, phyllite and slate. Alluvium contains high water content which influences lower resistivity that is easier to identify in survey but complex in vertical interpretation. Granitic rocks are usually found in the east and parallel to the Kelantan River which flows to the north, while sedimentary or metasedimentary rocks are limited to the foundation in the western part. Sedimentary and metasedimentary rocks consisting of shale, sandstone, phyllite and slate occur in the west. Rock properties manipulate ion movement of ERT value resulting from porosity, mineral content and fracture leading to higher resistivity. The thickness of quaternary alluvium is a few meters near the foot of the mountain up to more than 150m to the coast. This consists of clay, sand, silt, and gravel [4]. In a production well, pumping test with a screen which located approximately at 14-31m conducted by Noor in 1980 [5] at Kampung Chap, Bachok, it was found that the first and second aquifer systems in this area are hydraulically interconnected as they are only separated by a semi-permeable silt layer. Shallow aquifer is highly conductive due to water content, while deep aquifer is low conductive and contains a mineral that contrasts resistivity value. Two main aquifer aquifers can be divided [6]:

- Shallow aquifer - Mostly unconfined but sometimes semi-confined, thickness is usually 2 m to 3 m and can reach up to 17.5 m and is usually referred to as the first aquifer.
- aquifer - mainly confined, thickness usually more than 15 m. These deep aquifers consist of three distinct layers, separated from each other by semi-permeable silt layers, commonly referred to as the second, third and fourth aquifers.

Resistivity measurement is done by injecting current into the soil through two electrodes (C1 & C2) and the resulting voltage difference between the two electrodes (P1 & P2) is measured. By using the value of current (I) and voltage (V), the value of apparent resistance Δpa, is calculated.

$$\Delta \rho a = \frac{kV}{I} \tag{1}$$

As shown in Eq. (1), k is a geometric factor depending on the electrode arrangement; M resistivity usually gives the resistance value, $R = V/I$ and the apparent resistance value is measured as $\Delta a = kR$. The measured resistivity value is not the actual resistivity value but is the apparent resistivity value for a coating considered homogeneous which gives the same voltage and current values at the same electrode arrangement. Therefore, the actual resistivity value is calculated using computer software with the inversion method. Here, inversion method is a mathematical algorithm that reconstructs subsurface resistivity by generating accurate images allowing the interpretation of geological and hydrological features to minimize the difference between measurement and apparent resistivity.

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Fig. 3 shows a typical setup for a 2D survey with several electrodes along a straight line attached to a multi-core cable. Usually, a constant distance between adjacent electrodes is used. A multi-core cable is attached to an electronic switching unit connected to a resistivity meter. The sequence of measurements to be taken, the type of arrangement used and other survey params (such as when to use) are usually entered into a text file that can be read by the computer program built into the tetrameter. After reading the control file, the computer program then automatically selects the appropriate electrode for each measurement.

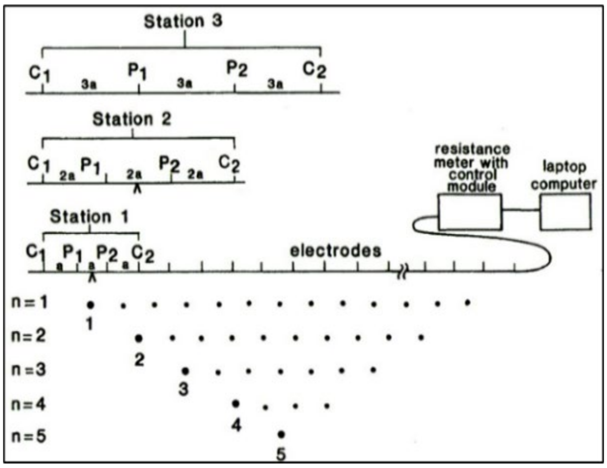


Fig. 3 *Arrangement of electrodes for electrical survey and sequence of measurements used for the section*

3.1 Pole-Dipole Arrangement

The Pole-dipole arrangement in which the current electrode has a fixed earthing in the conductor [7]. It contains three electrodes in line and requires one remote electrode, electrode C2, which must be placed at an "effective infinity" distance and perpendicular to the survey line. The distance of this electrode C2 must be placed at least 5 times between the largest distance C1-P1 used considering access and obstacles in the study area. The other current electrode (C1) is placed around the two potential electrodes (P1 and P2). Fig. 4 shows the arrangement of Pole-dipole electrodes.

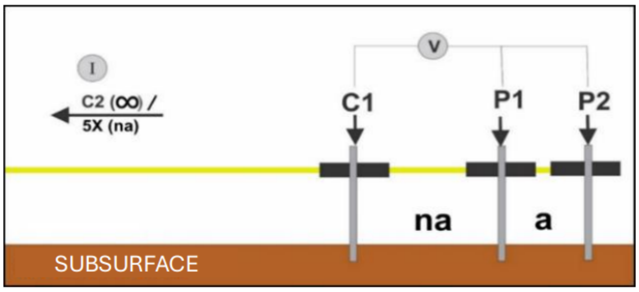


Fig. 4 *Pole-dipole electrode arrangement*

The Pole-dipole arrangement has better signal coverage and is less exposed to telluric noise because both potential electrodes are kept in the survey line. In addition, it is also able to take deeper data readings compared to the Wenner and Schlumberger arrays. Therefore, this arrangement is particularly suitable for surveys conducted in limited areas. The disadvantage of this arrangement is that it requires an electrode to be placed at a distance 5 times longer than the survey line which is at an "effective infinity" distance. This causes the signal to become weak and the ratio of signal to noise to become low (Signal to noise ratio) at the same time giving poor resolution of the profile. The Pole-dipole arrangement excels in high-resolution imaging ideal for fault detection, fracture mapping, and shallow subsurface. However, its complexity may limit suitability for rapid surveys due to a greater number of measurement considerations.

3.2 Gradient-XL Arrangement

The Gradient-XL electrode array has the same characteristics and settings as the Wenner - Schlumberger electrode array. The Gradient electrode arrangement contains 4 electrodes in a line containing C1, C2, P1 and P2. Potential electrodes P1 and P2 are used to account for access and obstacles in the study area. The current electrode will supply current into the ground so that electrodes P1 and P2 can take readings. Fig. 5 shows the arrangement of Gradient electrodes.

Since the Gradient-XL electrode arrangement allows the movement of the potential electrode, the results of the study obtained are very interesting. When the potential electrode set, P1 – P2, is moved from the centre of the array to the end of the array, the sensitivity contour pattern changes from the Wenner – Schlumberger pattern to the Pole-dipole pattern because the potential electrode set, P1 – P2, moves close to the current electrode, C2, which is at the end of the array. The results of the study obtained using the Gradient array are comparable to the results of the study using the Wenner - Schlumberger and Pole-dipole array but generally have a higher signal strength. The Gradient-XL offers faster data collection and broader survey, while its reduced sensitivity in broader scale geological structure and hydrological targets.

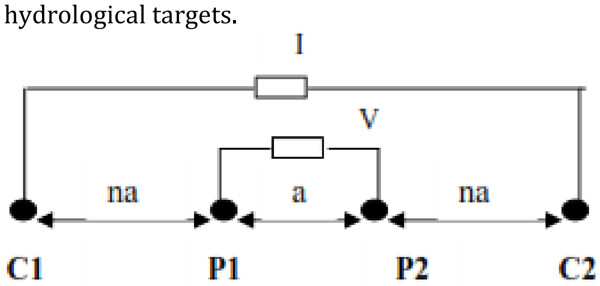


Fig. 5 *Gradient-XL arrangement*

3.3 Resistivity Values of Different Lithologies

Resistivity contour values are adjusted based on geological information corresponding to resistivity ranges. Table 1 shows the resistivity values of some rocks, soil materials and water [8]. Igneous and metamorphic rocks usually have high resistivity values. The resistivity of these rocks depends mainly on the degree of fracture. Due to groundwater filling the fracture zone, thereby lowering resistivity value of the rock. The soil above the water level is drier and has a higher resistivity value of several hundred to several thousand ohmms, while the rocks/soil below the water level generally have a resistivity value of less than 100Ωm. Moreover, clay has a much lower resistivity compared to sand.

Table 1 *Resistance of soil and rock types in the study area [8]*

Soil/ Rock Type	Resistivity Value (Ωm)
Alluvium	10 to 800
Sand	60 to 1,000
Clay	1 to 100
Groundwater (fresh)	10 to 100
Sandstone	8 to 4,000
Shawl	20 to 2,000
Slate/ quartz mica schist	500 to 50,000
Graphite schist	10 to 500
Limestone	50 to 4,000
Granite	50 to 10,000

4. Result and Discussion

Table 2 and Table 3 show the resistivity values range adopted in the groundwater interpretation. The interrelationship of ERT value and geological expectation reinforces the validity of the interpretation. Results showed that electrical resistivity values varied significantly depending on the lithology and geological features of the subsurface. The result of low resistivity values varies from less than 100Ωm. Low ERT corresponds to conductive material indicating presence of water [9]. This supports the hypothesis that the region is influenced by hydrological conditions, recent precipitations, and proximity of underground water. High resistivity values range between 500Ωm to 4,000Ωm associated with less conductive materials consisting of granite, sedimentary and metasedimentary rocks which create permeable soil layers. Rosa et al. [10] stated that formation of rock and consolidated soil layers exhibits higher resistivity due to low ability to conduct electrical currents. This supports the geological hypothesis that less permeable geological unit's influence groundwater flow and aquifer characteristics. The ERT value provides identification of presence of water-saturated zone and less permeable soil layers. The observation signifies the complexity of subsurface geology, identification of sedimentary layers and distinct lithological features. This study aligns with geological features stability of ground condition, identification of water-saturated, preserve hydrological balance and resource exploration.

The differences in variables of resistivity value influenced by lithology and geological features. Aquifer characteristics considered in terms of depth, porosity, saturation level and interconnection with water bodies contribute to variations in resistivity reading. Additionally, the arrangement of cable electrode in survey line impact depth and lateral resolution of the survey. The variants resulting from resistivity from different cable and survey lines indicate a complex subsurface that varies the formation of rock and water-bearing zone as well as aquifers in generating ERT profile. The result of resistivity varying depth from Pole-dipole and Gradient-XL allows identification subsurface features at difference on how lithological features relationship with depth. Therefore, the results align with ERT reliability on subsurface toward water management and reaffirm methodological consideration.

Table 2 *Electrical resistivity tomography (ERT) on survey line*

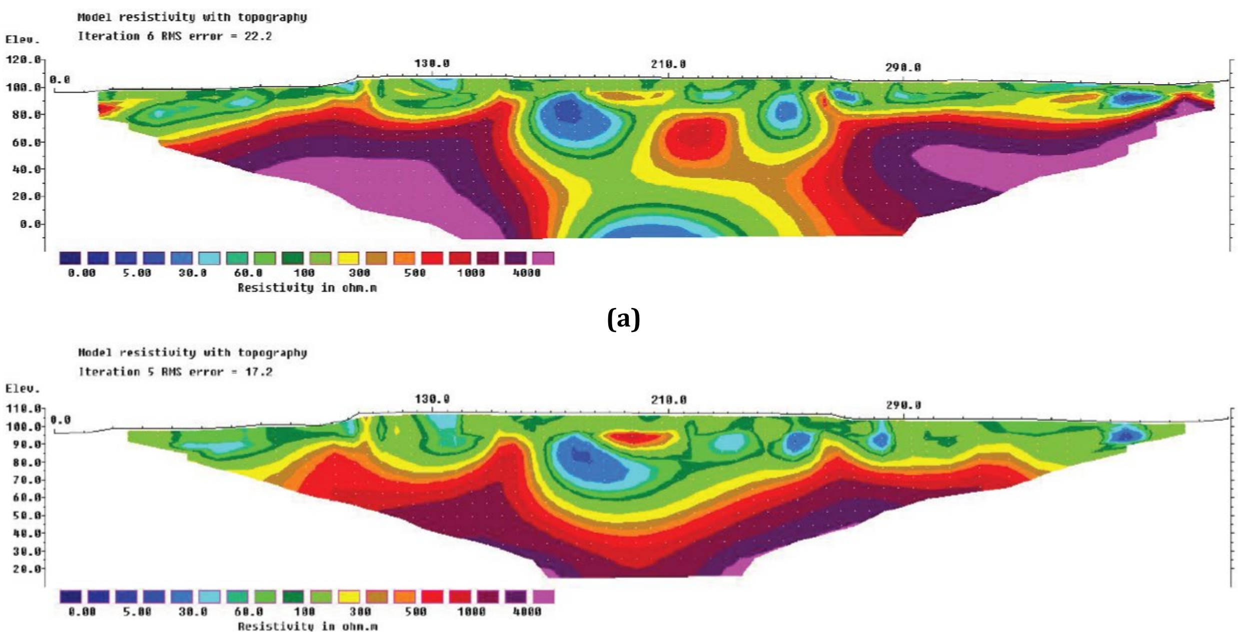
Survey Line	Depth Range of Resistivity Value (m)	
	Low Resistivity	High Resistivity
RL01 & RL02	≤ 25	25 to 100
RL03	100 to 210	210 to 260
RL05	≤ 20	0 to 75
RL07	≤ 10	0 to 70

Table 3 *The interpretation of resistivity value*

Resistivity Value (Ωm)	Legend	Interpretation
1 to 100	0.00 5.00 30.0 60.0 100	Zone of soil / rock saturated with water
>100	300 500 1000 4000	Zone of rock / soil of less saturated with water

4.1 Electrical Resistivity Study for Survey Lines at Masjid At-Taqwa (RL01 & RL02)

Fig. 6 shows the electrical resistivity profile for the RL01 survey line, 400 m for the Gradient-XL and Pole-dipole layout. The depth of the profile for both diagrams is not the same due to difference in the layout of the electrodes used.



(a)

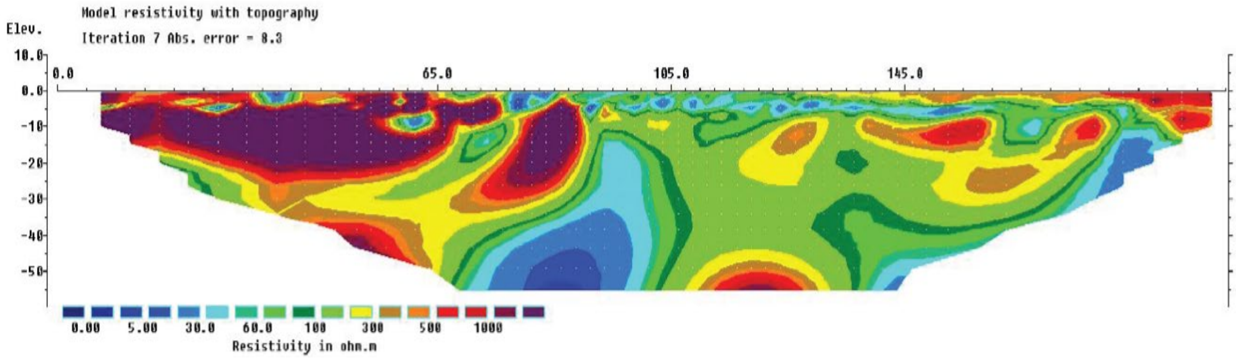
(b)

Fig. 6 *Resistivity data of (a) Pole-dipole; and (b) Gradient-XL at Masjid At-Taqwa, Gua Musang*

The Gradient-XL protocol can reach a depth of up to 80 m while the Pole-dipole can reach a depth of up to 120 m. RL01 is oriented North-South and is perpendicular to the survey line RL02. Based on the figure, a resistivity value of less than 100Ωm can be identified as the presence of surface water at a depth of 25 m. This aligns with the expectations that shallow areas contain moisture due to the influence of precipitation and hydrological condition. Meanwhile, high resistivity values ranging between 500Ωm to 4,000Ωm are at a depth of 25 m to 100 m located at between 40 m to 150 m and 270 m to 400 m distance. This distance is interpreted as a layer of rock or soil that is less saturated with the presence of water, preventing water from seeping further.

4.2 Electrical Resistivity Study for Survey Lines at Mini Zoo, Kuala Krai (RL03)

Fig. 7 shows electrical resistivity profile for the RL03 survey line, 200 m for the Gradient-XL and Pole-dipole. The majority of the subsurface for the study area has low to high resistivity values ranging between 30Ωm up to 1,000Ωm. A resistance value of less than 100Ωm is between 95 m to 210 m distance is a rock or soil zone that is saturated with the presence of water, while a high resistance value of more than 500Ωm is between 0 m to 90 m distance is a rock or soil that is unsaturated of water. For high resistance values between 210 m to 260 m distance, the saturated and unsaturated material varies with depth caused by sediment layers acting as aquifers at low resistivity value and aquitard at high resistivity value.



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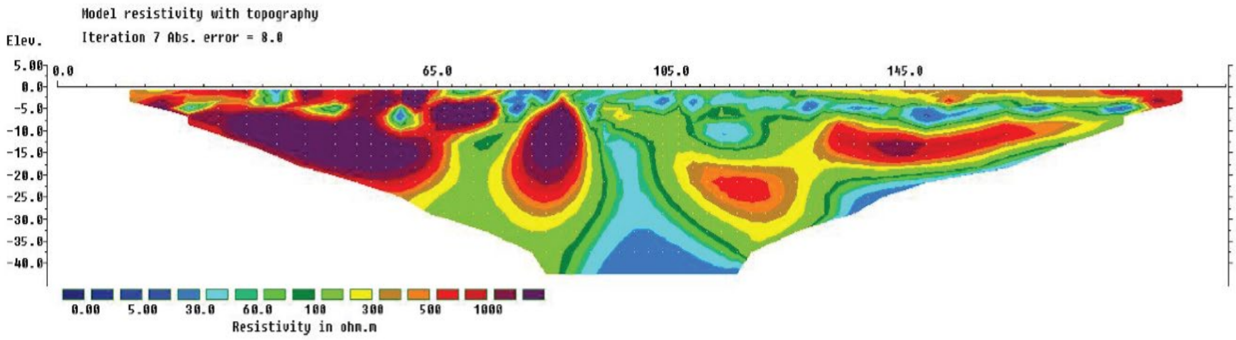
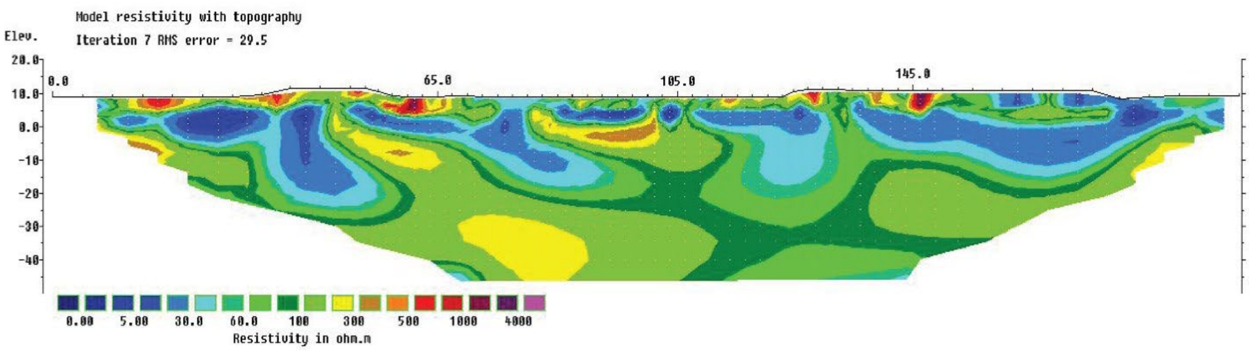


(b)

Fig. 7 *Resistivity data of (a) Pole-dipole; and (b) Gradient-XL at Mini Zoo, Kuala Krai*

4.3 Electrical Resistivity Study for Survey Lines at Kampung Sedar (RL05)

Fig. 8 shows the electrical resistivity profile of RL05, 200m for the Gradient-XL and Pole-dipole layout. In general, the resistivity for the RL05 line consists of a value of 0Ωm to 1,000Ωm and reaches a depth of up to 120 m. The majority of the subsurface has a resistivity value of less than 100Ωm. This low resistivity value can be observed at shallow depth from 0 m to 200 m distance which are from 0 m to 20m depth influenced by precipitation and surface hydrology, while the high resistivity value between 500Ωm to 4,000Ωm located between 80 m to 110m distance which is the depth of from 5m to 20m can be interpreted as a layer of rock or soil acting as compacted barrier to groundwater flow that is less saturated with the presence of water.



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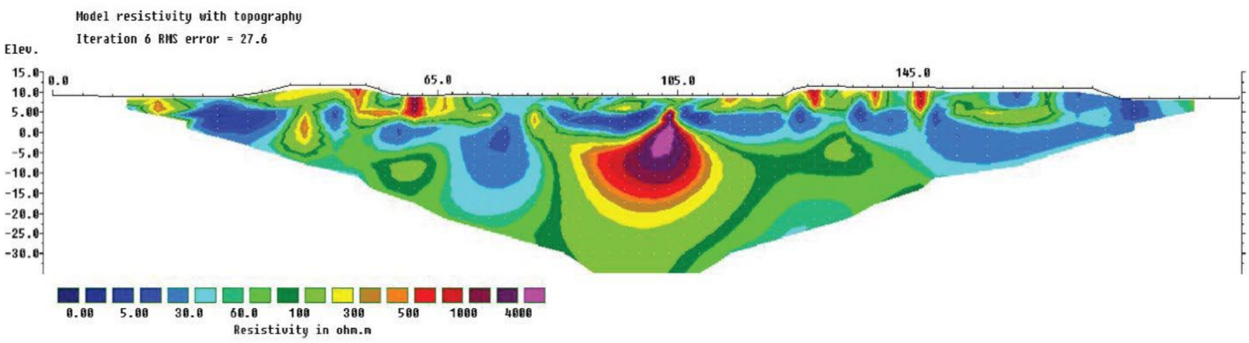
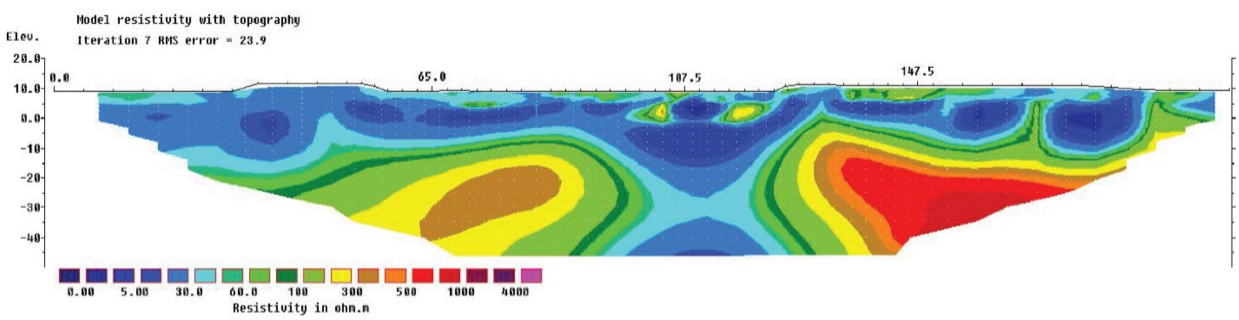


(b)

Fig. 8 *Resistivity data of (a) Pole-dipole and (b) Gradient-XL at Kampung Sedar, Tumpat*

4.4 Electrical Resistivity Study for Survey Lines at Kuala Jambu (RL07)

Fig. 9 shows electrical resistivity profile of RL07, 400 m array for the Gradient-XL and Pole-dipole layout. Majority of subsurface found that the study area has low resistivity value, which is less than 100Ωm, the area is interpreted as soil or rock saturated with the presence of water. High resistivity values ranging from 300Ωm to 1,000Ωm are seen from 20 m to 115.5 m distance, which is at a depth from 110 m to 200 m. The subsurface shows the study area majority consists of a low resistivity value between 0Ωm to 100Ωm. The formation of water areas for this area is extensive and the resistance value is moderately high which is up to 500Ωm shown at 30 m to 110 m distance. This area identifies as water table and an aquifer that more porous and allow water storage.



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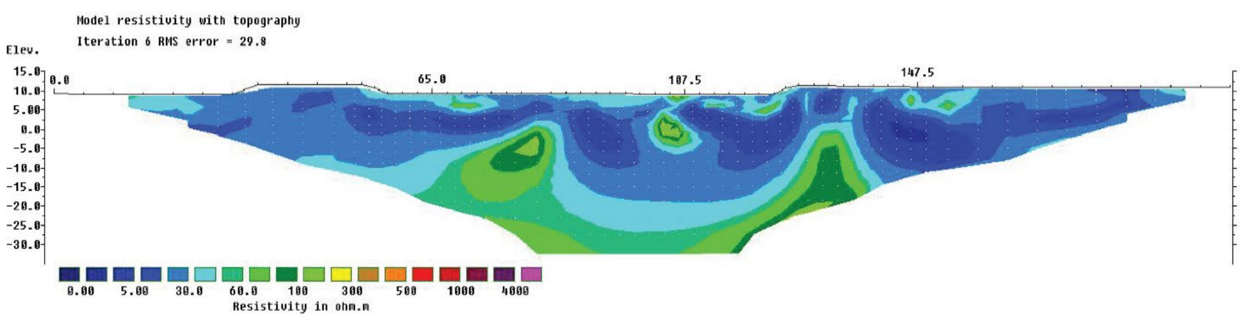

(b)

Fig. 9 *Resistivity data of (a) Pole-dipole and (b) Gradient-XL at Kuala Jambu, Tumpat*

5. Conclusion

Masjid At-Taqwa, Gua Musang (RL01 & RL02 - Based on resistivity value at Masjid At-Taqwa, it can be concluded that this geological unit exhibits resistivity values ranging from 500Ωm to 4,000Ωm, depending on the lithology. The Gua Musang Formation is a sedimentary unit that consists of sandstone, siltstone, and shale, and is widely distributed in the Malaysia Peninsula. Resistivity of the area is influenced by various factors, including mineralogy, porosity, and water content. Sandstone generally exhibits higher resistivity values due to its lower porosity and higher quartz content, while siltstone and shale typically exhibit lower resistivity values due to their higher porosity and presence of conductive minerals such as clay.

Several studies have reported resistivity values for the Gua Musang area in different geological settings. For example, in a study conducted in Hulu Kelantan area of the Malaysia Peninsula, sandstone lithologies within the Gua Musang Formation exhibited resistivity values ranging from 1,000Ωm to 4,000Ωm, while siltstone and shale lithologies exhibited resistivity values ranging from 500Ωm to 1,500Ωm. The finding of sandstone resistivity value aligns with objective in characterize the electrical properties subsurface by understanding the resistivity variants within this geological Gua Musang formation. The high resistivity value associated with rich mineral deposits has a high potential target region with similar resistivity profile for geological exploration.

Mini Zoo, Kuala Krai (RL03) - Based on research on the resistivity value of schist and granite lithology, it can be concluded that these rock types exhibit a wide range of resistivity values, typically ranging from 30Ωm up to 1000Ωm. Schist and granite are both common types of metamorphic and igneous rocks, respectively, that can be found in a variety of geological settings. Resistivity of schist and granite is influenced by several factors, including mineralogy, porosity, and moisture content. In general, rocks with higher percentage of conductive minerals, such as graphite or sulphides, tend to exhibit lower resistivity values, while those with a higher percentage of resistive minerals, such as quartz or feldspar, tend to exhibit higher resistivity values.

Several studies have reported resistivity values for schist and granite in different geological settings. For example, in geothermal fields, resistivity values for granite typically range from 30Ωm to 100Ωm, while resistivity values for schists can range from 10Ωm to 1,000Ωm, depending on the degree of metamorphism and presence of sulphides. In addition to geothermal fields, resistivity of schist and granite has important implications for a range of geological and engineering applications, including mineral exploration, groundwater exploration, and geotechnical engineering. Resistivity surveys can be used to identify areas of high or low resistivity, which may indicate presence of mineral deposits, groundwater resources, or potential geological hazards.

Kampung Sedar (RL05) and Kuala Jambu (RL07) - It can be concluded that resistivity values of less than 100Ω are commonly observed in alluvium deposits. Alluvium is a loose sedimentary deposit composed of gravel, sand, silt, and clay, which are typically formed by the erosion and deposition of weathered rocks, soil, and other materials by water or wind. Resistivity of alluvium is influenced by a variety of factors, including grain size distribution, porosity, saturation, and mineralogy. Generally, alluvium with a higher percentage of clay and silt tends to have lower resistivity due to presence of conductive minerals such as iron sulphides and graphite. These findings are pivotal to water resources management as alluvium deposits with low resistivity potential as groundwater recharge and discharge. The result enriches insight on how sediment composition and hydrology relationship influence the ERT characteristic underlying sediment layers.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Z. M. Nizam, A. T. S. Azhar;* ***data collection:*** *Z. M. N. Hidayat;* ***analysis and interpretation of results:*** *M. Aziman, J. A. Aziz;* ***draft manuscript preparation:*** *Z. M. Nizam, N. M. N. Amri. All authors reviewed the results and approved the final version of the manuscript.*

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