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Electrical resistivity and induced polarization techniques for groundwater exploration

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Abstract: Electrical resistivity and induced polarization surveys have been conducted for groundwater exploration at two different sites of geological aged i.e. Carboniferous and Quaternary. This study discussed the earth materials resistivity and chargeability for metasedimentary rock and unconsolidated sediment for groundwater exploration at Kampung Jongok Batu, Dungun and Kampung Paya Rawa, Besut, respectively. For this study Terrameter LS2, cable, electrode, cable connector, battery and remote cable are tools for measurement. The spacing between electrodes is 5 m, maximum length of spread line is 400 m and using Pole-Dipole protocol. Via comparing between the resistivity and chargeability values able to provide better interpretation for ground water exploration for metasedimentary rock and unconsolidated quaternary sediment. The result shows the important of chargeability for refining the resistivity value for locating the groundwater position.

Keywords: Groundwater, Geophysics, Electrical resistivity, Induced Polarization

1. Introduction

Groundwater source exists beneath the subsurface in soil pore spaces and the fractures in rock formations [1]. It can be obtained for the use of the peoples for domestic or agricultural use [2]. The underground water contains and transmits in aquifer, which are characterized either unconfined aquifer or confined aquifer. Typically, unconfined aquifer is found an upper layer of confining layer such rock layer whereby confine aquifer is found between confining layer. The occurrence of this aquifer can be determined by electrical technique survey, one of the geophysical applications for underground survey [3,4,5]. The electrical survey commonly adopted resistivity and induced polarization methods. By combining these methods, subsurface can be modelled and thus the groundwater bearing can be detected. Electrical resistivity and induced polarization methods provide resistivity and chargeability values of the subsurface for entire survey line [6,7]. The principal of electrical resistivity technique is in term of how current is opposed to flow between two electrodes. Meanwhile induced polarization is measuring the time of the earth material can store the charges. This paper will have discussed about induced polarization characteristics between two distinct type rock formations and compared with resistivity values for groundwater exploration at Jongok Batu and Besut, Terengganu.

2. Literature Review

2.1 Electrical resistivity method

The electrical resistivity survey is the oldest application of geophysical survey techniques used for determining water existence underground [8]. This main purpose of this technique is to determine the subsurface resistivity distribution by making measurements on the ground surface [9]. By injecting electrical current to the ground through electrode [10], it provides estimated resistivity value of ground which is affected by ground parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock [7,10]. The electrical resistivity method has followed the fundamental physical law of Ohm's Law and determined the value of resistivity in Ohm meter (Ωm) [10].

2.2 Induced Polarization Method

The induced polarization (IP) method has been recently development of multiple electrode data acquisition and used to identify chargeability of subsurface materials. This method used the same survey configuration as resistivity method. Loke *et. al* [10] stated that the resistivity measurement are conjunction with induced polarization measurement for complex mineral exploration. Using recent geophysical electrical tools of terrameter, both resistivity and induced polarization method can be performed at the same time. The induced polarization method uses parameters of time and frequency domain to show the induced polarization effect [6,11]. Induced polarization effects are caused by the two main effects such as the membrane polarization and electrode polarization effects. Membrane polarization is mainly caused by the existence of clay mineral in the sediment or rock. Meanwhile electrode polarization is caused by conductive minerals in rocks where electrical current flow through partly electrolytic (groundwater) and partly electrocnic (conductive mineral). Induced polarization have two type of measurement taken in time-domain or frequency domain where most often measurement taken using latest terrameter LS2 are in time-domain. The induced polarization effects were measured by the residual decay voltage after the current switch off, this is called induced polarization measurement taken in time-domain which given in per volt (mV/V) or in milliseconds (ms).

3. Geological Setting

Geologic formation at Kampung Jongok Batu, Dungun belongs to Paleozoic sedimentary rock at aged of Carboniferous which known as Sungai Perlis Beds as shown in Fig. 1. The Sungai Perlis Beds sediment consists of shallow marine sediment with several isolated limestone at thickness about 1500 m and usually argillaceous interbedded carbonaceous slate, argillite, phyllite, variably metamorphosed siltstone and sandstone. However, in study area only phyllite is observed. The second location is at Kampung Paya Rawa, Besut covered by unconsolidated Quaternary sediment of marine deposit consists of clay, silt and gravel as shown in Fig. 2. The study area is located about 5 km of shoreline and organic soil is observed on the top layer.

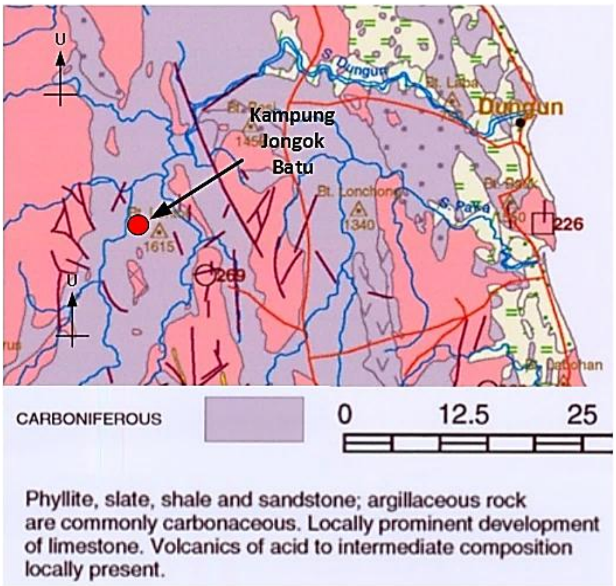

Fig.1 Geology map of Kampung Jongok Batu, Dungun. [12].

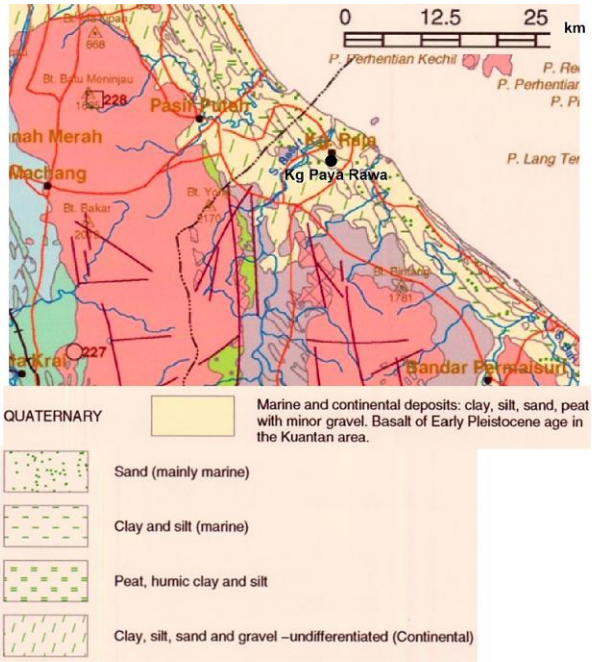

Fig. 2 Geology map of Kampung Paya Rawa, Besut.[12]

4. Methodology

4.1 Equipment Setup

For this study, authors are using latest Terrameter LS2 manufactured by ABEM including several equipments such as 4 units of multi-purpose cable, 64 units of jumper cable, 61 units of stainless steel electrode, 2 units of cable connector, 1 unit of 12 volt battery and 1 unit of remote cable. Fig. 3 shows the equipment used for electrical resistivity and induced polarization survey. Fig. 4 shows the equipment arrangement for electrical methods survey. The spacing between electrodes is 5 m and maximum length of profile lines are 400 m. Both study locations used Pole-Dipole protocol with remote cable setup about perpendicular from spread line with a distance of 300 m. During data acquisition, the LS2 terrameter is configured to take resistiviy and induced polarization measurement at the same time.

Fig. 3 The ABEM Terrameter LS2 resistivity meter and supported equipment.

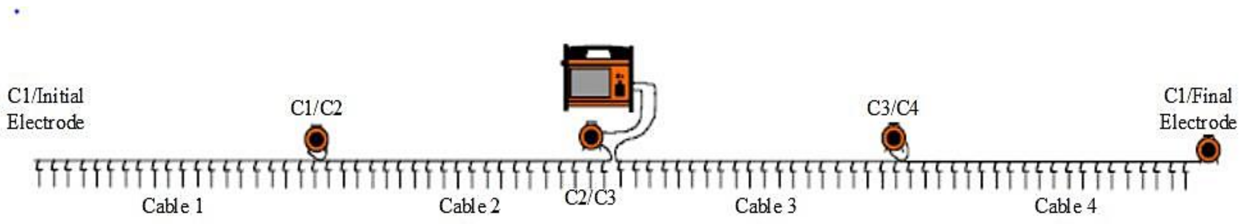

Fig. 4 The arrangement of ABEM Terrameter LS2 resistivity meter and other equipments.

4.2 Interpretation Technique

RES2DINV program was used to converted raw data in the extension of the DAT format. The earth materials resistance measurements are reduced to apparent resistivity values by inversion process. RES2DINV used a least-squares inversion scheme to determine the appropriate resistivity value so that the calculated apparent resistivity values agree with the measured values [13]. The inversion process is carried out to obtain three types of resistivity section which consist of the calculated apparent resistivity, measured apparent resistivity and inverse model resistivity. The misfit between measured and calculated apparent resistivity produce root mean square (RMS) values. The resistivity contour value is adjusted based on geological information that fit the resistivity range with different colours [14].

5. Result and Discussion

For groundwater exploration, the resistivity and induced polarization parameters are suggested to utilize and thus able to give a realistic subsurface model for groundwater interpretation. In resistivity measurement, it is recommended to differentiate fresh groundwater based on resistivity value from 10 to 100 Ohm.m. Meanwhile, in induced polarization measurement, chargeability for water is 0 ms. Table 1 and 2 separated the resistivity and chargeability values for Kampung Jongok Batu and Kampung Paya Rawa, Besut for ease the interpretation. Fig. 5 and Fig. 6 show the 2-dimensional tomography of resistivity and induced polarization for Jongok Batu and Kampung Paya Rawa, Besut, respectively.

The 2-dimensional tomography at Carboniferous rock formation at Kampung Jongok Batu was differentiating based on the contrast of resistivity values, i.e. less than 100 ohm.m and above 100 ohm.m. Below 100 ohm.m is the zone considered saturated rock with groundwater. Meanwhile, above 100 ohm.m is suggested as a zone of weathered and fractured phyllite. The chargeability from induced polarization tomography is separated between the value of below 1.0 ms and above 1.0 ms. It is expected at phyllite rock mass has above 1.0 ms due to ability to retain the electrical charges. It is worth noting that the phyllite contains minerals of quartz and biotite. Meanwhile, in water zone is 0 ms chargeability due to inability to retain the electrical charges. Therefore via combining resistivity and chargeability values the groundwater bearing zone can be well predicted. The potential groundwater is detected at a depth of 60 m at two (2) possible locations at distance of 40 to 125 m and 195 to 370 m from scan line in Fig 5.

Table 1 The resistivity and chargeability value at Kampung Jongok Batu, Dungun and its interpretation.

Resistivity value (Ωm)	Resistivity legend	Interpretation
1 – 100	1.00 30.0 60.0 100	Saturated soil at sediment layer
> 100	600 800 1000 4000 6000	Fractured rocks of phylitte
Chargeability value (millisecond, ms)	Chargeability Legend	Interpretation
0.0 - 1.0	0.00 0.300 0.700 1.00	Saturated soil layer contains fresh and saline water
> 1.0	3.00 5.00 9.00 12.0	Fractured rocks of sandstone and siltstone

The 2-dimensional tomography at Quaternary unconsolidated sediment at Kampung Paya Rawa, Besut is shown in Fig. 6. The resistivity values are divided into three which are under 10 ohm.m, 10 to 100 ohm.m and above 100 ohm.m. Below 10 ohm.m is considered as a saturated marine sediment, meanwhile between 10 and 100 ohm.m is soil with groundwater bearing layered and above 100 ohm.m is saturated soil layer. The chargeability from induced polarization tomography is separated between the value of below 1.0 ms and above 1.0 ms. It is expected at sand and clay has above 1.0 ms chargeability due to ability to retain the electrical charges. It is worth noting that the sand and clay contains minerals of quartz, kaolinite and other clay minerals. In water zone is 0 ms chargeability due to inability to retain the electrical charges. The potential groundwater is detected at a depth of 5 m across the scan line in Fig 6.

Table 2 The resistivity and chargeability value at Kampung Paya Rawa, Besut and its interpretation.

Resistivity value (Ωm)	Resistivity Legend	Interpretation
1 – 10	1.00 3.00 5.00	Saturated soil contains saline water
10 - 100	30.0 100	Saturated soil contains fresh water
> 100	300 500 700 1000	Sandy and gravel sediment layer

Chargeability value (millisecond, ms)	Chargeability Legend	Intepertation
0.0 - 1.0	0.00 0.300 0.700 1.00	Saturated soil layer contains fresh and brackish water
> 1.0	3.00 5.00 9.00 12.0	Sandy, gravel mixed with clay

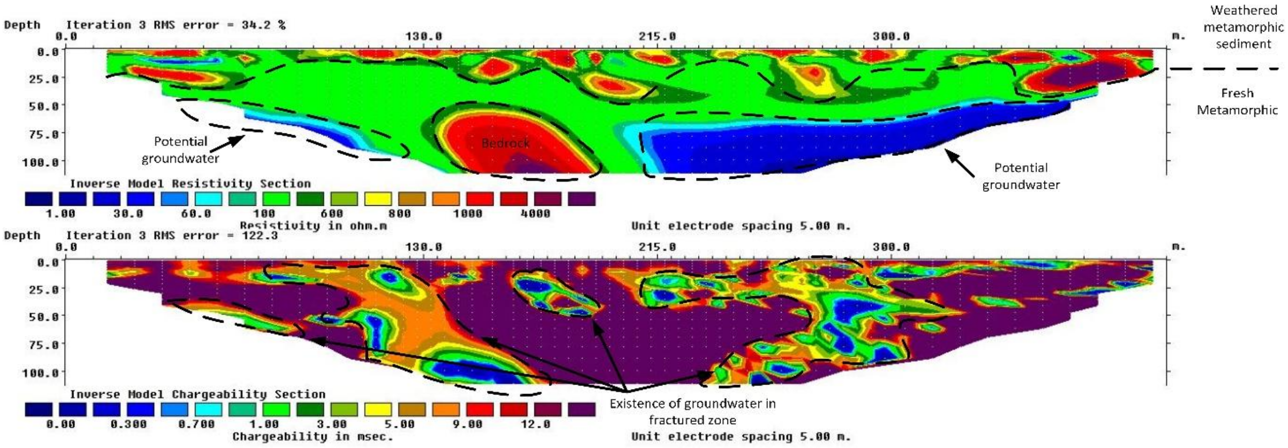

Fig. 5 Resistivity and induced polarization results at Kampung Jongok Batu.

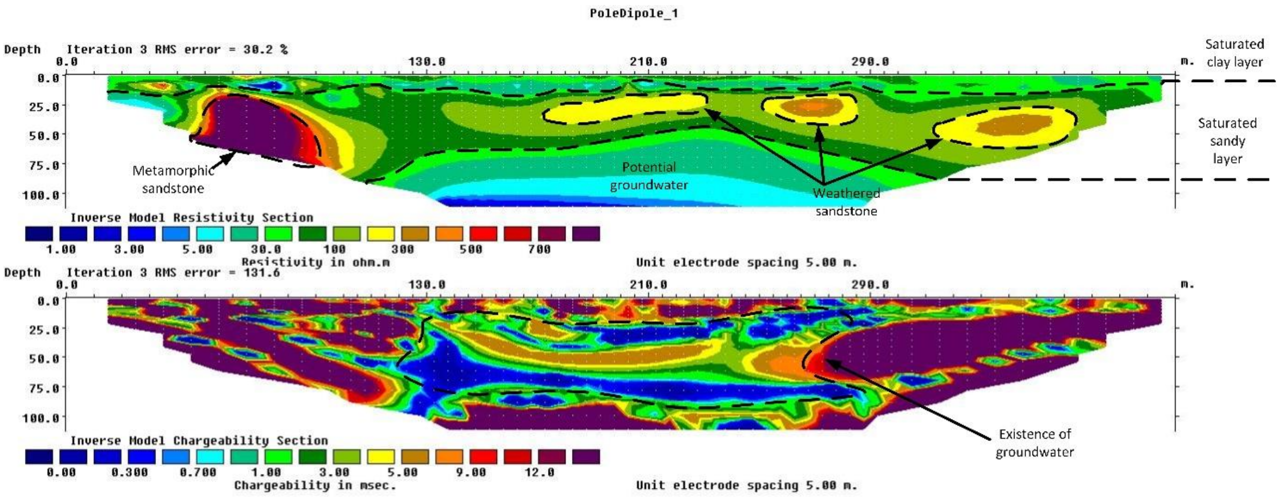

Fig. 6 Resistivity and induced polarization results at Kampung Paya Rawa.

The resistivity measurement could determine the location of groundwater in older rock formation in distinct compared in unconsolidated Quaternary sediments due to the high ground water table and saturated condition. Via combining chargeability value is able to differentiate between earth material and groundwater in saturated conditions. Therefore induced polarization measurement is important in groundwater exploration in metasedimentary rock and unconsolidated Quaternary formations.

6. Conclusion

This study used a geophysical electrical survey to determine the groundwater by combining resistivity and induced polarization techniques for different geology aged formation of Carboniferous metasedimentary rock and unconsolidated Quaternary sediment. The result shows the importance of chargeability for refining the resistivity value of locating the groundwater position.

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