Groundwater Exploration in Granitic Rock Formation Using Electrical Resistivity and Induced Polarization Techniques

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Abstract: Electrical resistivity and induced polarization surveys have been conducted for groundwater exploration at granitic formation. This study discusses the earth materials resistivity and chargeability of granitic for groundwater exploration at IIUM campus. In this study Terrameter model LS2, cables, electrodes, cable connectors, battery and remote cable were used as the tools for measurement. The spacing between electrodes is 5 m and maximum length of spread line is 400 m by using Pole-Dipole protocol. By comparing the resistivity values and the chargeability values, it would be able to provide better interpretation for ground water exploration for granitic rock. The result also shows the important of chargeability to verify the resistivity value for locating the groundwater position.

Keywords: Groundwater, Geophysics, Electrical resistivity, Induced Polarization

1.0 Introduction

There are two (2) source of waters can be obtained in the earth, such as surface water and groundwater. In many urban areas, the most common source of water is surface water which provided by the water supply department of government or private sectors. There are certain situations happen lately when the surface water is not sufficient to supply for the locals especially during drought season and worst case scenario during floods due to water contamination. Therefore, source of groundwater is essential as a secondary source or alternative for local usage. 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 people for domestic or agricultural use [2]. The underground water contains and transmits in aquifer, which are characterized either unconfined aquifer or confined aquifer. 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 is commonly adopted by using resistivity and induced polarization methods. By combining these two methods, subsurface can be modelled and 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 discusses the induced polarization characteristics between two distinct type rock formations and compare it with resistivity values for groundwater exploration at Universiti Islam Antarabangsa Malaysia, Gombak, Selangor, Malaysia.
2.0 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]. According to Hazreek et. al [10], this technique is sensitive to the variations of earth materials with the existence of water. By injecting electrical current to the ground through electrode [11], it provides estimated resistivity value of ground which is affected by ground parameters such as the minerals, fluid content, porosity and degree of water saturation in the rock [7,11]. Asry et.al [12] stated that the resistivity can be used to investigate boundary between crystalline and sedimentary rocks, compact quartzite rocks with schist or phyllite where differentiation between rocks can be interpreted in horizontal direction meanwhile the maximum resistivity value can change in vertical direction. The electrical resistivity method has followed the fundamental physical law of Ohm’s Law and determined the value of resistivity in Ohm meter (Ωm) [13].

2.2 Induced Polarization Method

The induced polarization (IP) method is recently development of multiple electrode data acquisition and has been used to identify changeability 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. By using recent geophysical electrical tools of terrameter, both resistivity and induced polarization method can be performed simulteneously. 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 electronically (conductive mineral). Induced polarization have two types of measurement taken in time-domain or frequency domain where most often measurement is taken using latest terrameter LS2 are in time-domain. The induced polarization effects were measured by the residual decay voltage after the current was switch off, this is called induced polarization measurement taken in time-domain and reading in milivolt per volt (mV/V) or in milliseconds (ms).

2.3 Geological Setting

Geology formation in Universiti Antarabangsa Islam Malaysia is classified as an intrusive rock of granite as shown in Figure 1. It is near boundary between Chert-Argillite formation as known as Gombak Chert and Selut Schist formation which consist of quartz-mica schist and some metaquartzite. The Gombak Chert is an olistostromal block of interbedded chert, mudstone and siltstone within group near Genting Sempah. The study location is also near to the Kuala Lumpur fault line where may have a broad fracture rock zone that may contain groundwater.
Figure 1. Geology map of Universiti Islam Antarabangsa Malaysia, Gombak [14].

3.0 Methodology

3.1 Equipment Setup

For this study, the latest Terrameter LS2 manufactured by ABEM was used for measurement 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. Figure 2 shows the equipment used for electrical resistivity and induced polarization survey whereas, Figure 3 shows the equipment arrangement for electrical methods survey. The spacing between electrodes is 5 m and maximum length of profile line is 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 resistivity and induced polarization measurements at the same time.

Figure 2. The ABEM Terrameter LS2 resistivity meter and supported equipment.

Figure 3. The arrangement of ABEM Terrameter LS2 resistivity meter and other equipments.
3.2 Interpretation Technique

RES2DINV program was used to convert 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 are in agreement with the measured values [13,15]. It will produce a smooth boundary which is recommended to differentiate between soil material and rocks. The inversion process is carried out to obtain three types of resistivity section which consist of 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 colors [16].

4.0 Result and Discussion

For groundwater exploration, the resistivity and induced polarization parameters are suggested to utilize thus would be able to give 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. There are three (3) profiles lines have been conducted electrical survey around study location. Table 1 shows the resistivity and chargeability values for Universiti Islam Antarabangsa Malaysia (UIA) for ease the interpretation. Figure 4 shows an overview of three (3) profile lines of results on google map at Universiti Islam Antarabangsa Malaysia. Figure 5, Figure 6 and Figure 7 show the 2-dimensional tomography of resistivity and induced polarization at each profile lines.

Figure 4. An overview of resistivity and induced polarization results at UIA.
Table 1. The resistivity and chargeability value at Universiti Islam Antarabangsa Malaysia and its interpretation.

| Resistivity value (Ωm) | Resistivity legend | Interpretation                      |
|------------------------|-------------------|-------------------------------------|
| 1 – 100                |                   | Fractured rock saturated with water |
| > 100                  |                   | Fractured to Fresh solid rocks      |

Chargeability value (millisecond, ms) Chargeability Legend Interpretation

| Chargeability value | Chargeability Legend | Interpretation |
|---------------------|----------------------|----------------|
| 0.0 - 1.0           |                      | Fractured rocks contain fresh water |
| 1.0 – 12.0          |                      | Fractured rocks zone to solid rocks |
| >12.0               |                      | Fresh solid rock zone               |

The 2-dimensional tomography at Permian granite rock formation at Universiti Islam Antarabangsa Malaysia was separated based on the variation of resistivity values i.e. less than 100 ohm.m and above 100 ohm.m. Below 100 ohm.m is the zone which can be considered as saturated fractured rock with groundwater. Meanwhile, above 100 ohm.m is suggested as a zone of dense rock. 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 granitic rock mass has the value above 1.0 ms due to its ability to retain the electrical charges. Meanwhile, in water zone, the value is 0 ms chargeability due to its inability to retain the electrical charges. Therefore, by combining resistivity and chargeability values, the groundwater bearing zone can be well predicted and detected.

Based on Figure 5, Figure 6 and Figure 7, all the profile lines have shown potential of groundwater around the study areas based on the contrast of resistivity value and chargeability value. For profile line 1, the potential groundwater zones are very large within the distance from 134 to 340 m with the depth from 10 m until more than 80 m at fracture zone. The most potential groundwater zone is at profile line 2. The groundwater is mainly located at rocks formation which indicated volume of water are less than in fractured zone at distance of 155 to 320 m. Figure 7 shows potential groundwater zone at profile line 3 at the distance from 180 to 350 m and the depth more than 25 m.

Figure 5. Resistivity and induced polarization results for profile line 1.
Resistivity measurement could determine the location of groundwater in older rock formation in distinct between fractured or solid rocks. Through induced polarization method, the results affected by the electrode polarization effect which caused by conductivity of rocks material thus the current will flow in partial electrolytic (groundwater) and partly electronic (conductive mineral). By comparing resistivity method and induced polarization method, existence of groundwater can be predicted and detected either the water is exists in fractured zone or in dense rocks zone. The high chargeability value (more than 12 ms) in the potential groundwater zone has shown their existence of water in dense rock zones in the resistivity result. This is probably the indication of low volume of groundwater. While, the chargeability value between 0 – 9 ms are the evidence of the existence of water in fractured rock zones which have higher concentration of groundwater.

5.0 Conclusion
This study used geophysical electrical survey to determine the groundwater by combining resistivity and induced polarization techniques in granitic formation. There were three (3) profiles lines of measurements have been conducted at Universiti Antarabangsa Malaysia and all the results have shown potential groundwater zones. From the results, there are potential groundwater zones of 10 – 120 Ohm.m at dense rock formation with chargeability more than 12 ms. Meanwhile, the fractured rock formation has the chargeability value ranging between 0 – 9 ms.
Acknowledgement
The authors would like to thank to Ministry of Higher Education and Universiti Tun Hussein Onn Malaysia for their financial support on FRGS vot. 1455.

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