The Implementation of 2-D Resistivity Method in Verifying Paleozoic Aquifer Properties at Bukit Chondong, Perlis (Malaysia)

Umi Maslinda 1, M.M. Nordiana 1, A.A. Bery 1, Muhamad Afiq Saharudin 1, Hazrul Hisham 1, Z.M. Taquiddin 1, Nabila Sulaiman 1, M.K.A. Nur Amalina 1 and A.N. Nordiana 1

1 Geophysics Section, School of Physics, 11800 Universiti Sains Malaysia, Penang, Malaysia.
E-mail: umimaslinda@gmail.com

Abstract. The research was conducted using 2-D resistivity in verifying Paleozoic aquifer. Since most geologic materials behave as electrical insulators, surface measurements of earth resistivity are controlled by the electrolytic ability of interstitial water. The subsurface distribution of water is controlled by the porosity of the formations. The study area is at Bukit Chondong, Beseri, Perlis. Bukit Chondong is made of sedimentary rock which mostly is sandstone. Bukit Chondong is from uppermost of the Kubang Pasu Formation that represented by a thick unit of grey mudstone interbedded with sandstone. The Kubang Pasu Formation was influenced by shallow marine during the early age. Paleocurrent and fossils traces were found on the mudstone at the study area. The area is suspected to be a Paleozoic aquifer because the sandstone can be a productive aquifer with diffuse flow. The water movement in sandstone is through the fractures and joints. Most of the water stores and transmits in sandstone. The interbedded sandstone and mudstone is one of the aquifer characteristic. Sandstone and mudstone are water-bearing rocks and low-permeable rocks respectively. The data was processed according to the geological information of the study area since there was an outcrop. The study area have low resistivity value which both sandstone and mudstone give less than 800 Ohm-m due to the water content (Sulphide and clay).

1. Introduction
The aquifer is an underground layer of water bearing permeable rock, rock fractures or unconsolidated materials such as gravel, sand, or silt from which the groundwater can be exploited using water well. Bukit Chondong is mostly consists of sedimentary rocks where mostly is sandstone. The outcrops in Bukit Chondong have been studied by geologist until today. Bukit Chondong is from uppermost Kubang Pasu Formation represented by a thick unit of grey mudstone interbedded with sandstone. The Kubang Pasu Formation consists of coarsening upward cycles of clastic during Kungurian age which representing shallow marine, wave- and storm-influenced shoreline [1]. Thus, geophysics plays important roles to identify the outcrops and to prove the area was the shallow marine influenced.

The 2-D resistivity method is related to different geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. The method also referred to as galvanic electrical method which sometimes useful for determining shallow and deep geologic and hydrogeologic conditions [2]. Electrical resistivity is measure the electrical resistance to a direct
current applied at the surface. Resistivity method is a non-destructive ground survey method and its main advantage is produced the subsurface resistivity distribution. Resistivity method has many applications in a number of fields. It provides accurate depth information of uncertain target through visualization. The depth information is important to detect the aquifer. The sedimentary rocks usually are more porous and have a higher water content, which result in lower resistivity values. Wet soils and fresh ground water have even lower resistivity values [3].

2. Study Area
The study was carried out at Bukit Chondong, Beseri, Perlis, Malaysia. Bukit Chondong is located at east of the Maktab Rendah Sains Mara (MRSM) and the line is facing MRSM as shown in Figure 1. The line starts with coordinate of N 6.55299°, E 100.23647° and end at N 6.55265°, E 100.23638°. Chondong is a small steep hill forming part of the N-S trending Chuping Hills in central Perlis. The study area was a quarry and the quarry exposes the uppermost of the Kubang Pasu Formation which mostly consist of mudstone that interbedded with sandstone.

![Figure 1. The survey line was conducted on top of the outcrop.](image)

3. Methodology
The 2-D resistivity survey was conducted using Pole-Dipole and Wenner-Schlumberger array with one meter electrode spacing. The total length of the survey is 40 meter with 41 electrodes. The survey used two cables, ABEM SAS4000 System and a remote cable for Pole-Dipole array. The processing was performed using Res2Dinv and Surfer10 software. The results are then interpreted by referring to the geological information of the study area.

4. Results and Discussion
The survey area is mostly made of brownish red colour sandstone and dark grey colour mudstone. The outcrop shows both sandstone and mudstone are interbedded to each other as shown in Figure 2. The depth of the top sandstone is about 5.8 m and followed by mudstone with depth about 7.5 m. The third and fourth layer is sandstone and mudstone with depth about 8.8 m and 10.5 m respectively. The thickness of the layer of mudstone is same with 1.7 m. A productive aquifer can be comprised of sand and gravel, sandstone and limestone. Thus, this study area that composed of sandstone has potential to be an aquifer.
Figure 2. The outcrop of mudstone interbedded with sandstone.

Moreover, there are also presence of sulphur (Figure 3) and black shales in this study area. The presence of sulphur provides information that the area was influenced by marine because the sulphur ion is stable in aqueous solution, where the polar water reduces the energy of the charge [4]. The sulphur is made from the oxidation of sulfide. The main pathways of sulfide oxidation in marine sediments associate with complex interactions of chemical reaction and microbial metabolism. The black shale is a fine-grained, indurated detrital sedimentary rock formed by the consolidation of clay, silt or mud.

Figure 3. Presence of sulphur at the survey area.
Around the survey area also found mudstone with ripples mark and fossils traces on the mudstone surface as shown in Figure 4. It is also known as paleocurrent. Paleocurrent is a geological feature that helps determine the direction of flowing water in the geologic part which typically a sedimentary structure [5]. This is the other evidence that prove the area was influenced by marine. The water current cause ripples to move by erosion and deposition. Ripples grow up in either one direction or oscillatory currents. Oscillation ripples form by wave movement and tend to be symmetric in shape with straight crests. Besides that, fossils traces is found on mudstone surface at the survey area or known as bioturbation. The bioturbation process is from organism activities that disturbed the formation of the rock. Organism may disturb soft sediment after deposition such as mudstone. The bioturbation of the mudstone happened after deposition. Bioturbation features can be seen as trace fossils and include the tracks, trails and burrow of animals, as well as root casts, bark impressions that left by plants [6].

![Figure 4. Paleocurrent and fossils traces on mudstone surface.](image.png)
Figure 5. 2-D resistivity results from (a) Wenner-Schlumberger and (b) Pole-Dipole arrays.

Figure 5 is the interpreted results from both Wenner-Schlumberger and Pole-Dipole arrays that show the layering of the subsurface. The different of the arrays are only the depth of penetration. Pole-Dipole array can penetrate deeper than Wenner-Schlumberger array. The different in depth is not significant in this study, but both results produced the same contour maps that show the layering of the different rocks. A standard value of resistivity range is used for both arrays according to the type of rock that found at the study area, sandstone and mudstone. The range of resistivity value for sedimentary rock is 5 to 1000 Ohm-m [7]. This is due to sedimentary rocks are usually porous and have pores that filled with fluids which mainly water causing the rocks become electrolytic conductors. Electrical current is passing through a rock mainly by the passage of ions in pore of waters. The sedimentary rocks tend to be conductive due to their high fluid content [8]. The standard value used is in the range of aquifer resistivity value from 50 to 2000 Ohm-m [9]. Therefore, the study area has potential to be an aquifer.

Both outcrop and the 2-D resistivity results show a better correlation as can be seen from the outcrop, the top layer is sandstone with depth about 5.8 m while from the 2-D resistivity result, the top layer has interpreted as about 4-6 m thick from the surface with the resistivity value range of 8.00 to 80.0 Ohm-m. The second layer is mudstone with resistivity value between 100 and 130 Ohm-m which about 1 m thick. It is almost same depth as the measurement from the outcrop which is 1.7 m thick. The third layer of sandstone was measured at depth of 8.8 m from the outcrop. Similarly, the third layer sandstone that interpreted from the 2-D resistivity results lies between 5-8 m depth with resistivity value of less than 150 Ohm-m which has different resistivity value with the top layer of sandstone. The value for this layer is higher than both two layers above it though the resistivity value for mudstone usually is lower than sandstone. It is because the sandstone at the top layer was affected by weathering process due to the physical, chemical or biological activity. Then at depth about 8 m, it is interpreted as mudstone with resistivity value range same as the second layer of mudstone.
Aquifer occurs in porous or fractured rocks and moves within them when there is a pressure difference. Fractured porous rocks are characterized by presence of fissure and weakly cemented sandstone. According to their ability to transfer water, rocks are classified as either water bearing or well-permeable, low-permeable and practically impermeable or water resistant. The water-bearing and low-permeable rocks usually occur as alternating layers of deposits or zones with different thickness [10]. The outcrop shows that the sandstone layer is alternate with mudstone layer. Both sandstone and mudstone are high porosity but only sandstone is high permeability. Between the grains of sand in sandstone, there is space that can store the fluids. Thus, the sandstone may acts as water-bearing rocks while mudstone acts as low-permeable rocks. The lower permeability of mudstone can be an effective seals for an aquifer.

5. Conclusion
The 2-D resistivity is a very effective method to estimate the hydraulic properties of aquifers. This method successfully differentiate sandstone and mudstone. The study area have low resistivity value and expected as aquifer. The resistivity value of both sandstone and mudstone less than 800 Ohm.m. Sandstone and mudstone are acting as water-bearing rocks and low-permeable rocks respectively and the layering of sandstone and mudstone can be an effective aquifer. The outcrop and the 2-D resistivity results show a good correlation.

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