METEORITE IMPACT CRATER SUBSURFACE STUDY AT BUKIT BUNUH, LENGGONG, PERAK USING 2-D ELECTRICAL RESISTIVITY METHOD

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by

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LIST OF SYMBOLS

ΔV	Potential difference
ρ_a	Apparent resistivity
$>$	More than
I	Current
V	Voltage
R	Resistance
R	Rebounds/Uplifts
A	Area
ρ	Electrical resistivity
ℓ	Length

LIST OF FIGURES

LIST OF ABBREVIATIONS

1-D	One Dimension
2-D	Two Dimension
2-DERI	2-D Electrical resistivity imaging
3-D	Three Dimension
BH	Borehole
C	Current electrode
IP	Induce Polarization
NE	North-East
NW	North-West
P	Potential electrode
PDP4L	Pole-dipole (Long)
PDP4S	Pole-dipole (Short)
SE	South-East
SP	Self Potential
SW	South-West

CHAPTER 1

INTRODUCTION

1.0 Background

Impact cratering plays a huge pioneering research in planetary bodies. It is also rarely choose by most geoscientist due to other dynamic endogenic processes and yet it is a very rare event by human time scale (Philip, 2004). Lenggong Valley has a long history of human occupation covers the Paleolithic, Neolithic and Metal age cultures. This represents one of the longest culture sequences in Southeast Asia. The subsurface structure have been discovered and thoroughly studied during last 1.8 million years ago. Studies on impact craters provide important knowledge about planetary and terrestrial environment, including the biosphere (Tiiu, 2011).

Geophysical surveys in archaeology can be defined as a ground based physical sensing methods used for imaging and mapping. It is neither invasive nor destructive methods for an environmental study. For this reason, preservation and avoiding of the disturbance are always the goal. Geophysical results used to guide practitioners insight view and provide evidence of non-excavated site. Many geophysical methods which are subsurface geophysics have been introduced (Bullock, 1988). This includes GPR, IP, SP, seismic, 2-D resistivity, magnetic and gravity which has been used as tools for subsurface study for better understanding of the geophysical responses. Geophysical methods also improved its data acquisition technology in order to obtain precise data for processing.

Geophysical method used in this study was to elucidate the underlying structures, identifies features such as faults, folds and intrusive rocks, to identify and map subsurface thickness for archaeological identity. Identity are the non-portable part of the archaeological evidence, whether standing structures or traces of human activities lest in the soil. Geophysical methods are indirect method which perform the shallow subsurface study and maintaining the environment.

Seismic refraction and reflection are the most widely used methods in geophysical survey. These methods able to identify rock rip ability, thickness of overburden, rock velocities and bedrock depth. The technique are also applied in environmental cases for mapping thickness of the layer, cavities and abandon mines. The limitation is the resolution will decrease with the distance. The other restriction in this method is high electrical conductivity provide strong velocity contrast (Hermann, 2004).

Ground Penetrating Radar (GPR) is one of the useful geophysical method. GPR gives evidence in archaeological insight which are difficult to see with naked eye (Conyers, 2004). It utilized the reflection of radiowave to microwave electromagnetic frequency in materials of varying dielectric permittivity and low electrical resistivity to map manmade features (Conyers, 2004).

Magnetic is useful geophysical method which were used in large survey areas for underground steel and iron objects such as tanks. Gradient measurements are less sensitive to deeper objects than total field measurements and the magnetic method does not give exact depth information (Grauch and Lindrith, 1987).

Gravity method measure variations in gravitational field of the earth and usually employed in mapping sinkhole, bedrock and groundwater flow. Hence, a gravity survey provides a measures of change in subsurface density. There are limitation for this method which is external sources of vibrations and earthquakes which can allow interference (Butler, 1984).

2-D resistivity imaging method is yet more powerful geophysical technique which is important to identity or to estimate the depth of bedrock including identify the thickness of the layer for shallow subsurface. The method measure apparent resistivity (ρ_a) using a pair of potential electrode (P_1 and P_2) and current (C_1 and C_2) by measuring the potential difference (ΔV). This technique is widely applied in evaluation of aquifers, well, plumes and groundwater exploration, environmental aspects of landfills, detection of voids and boulders.

1.1 Problem statement.

Planetary exploration has shown that virtually all planetery surfaces are cratered from the impact of interplanetary bodies. The Planetary and Space Science Centre (PASSC) is recognised body by National Aeronoutics and Space Administration (NASA) to apporve and register all meteorite craters of the world. PASSC outlintes six criteria to be fulfill in order to claim that a crater is truly formed by a meteorite impact. One of the criteria is crater morphology, in which geophysical methods and borehole drilling play the important roles. The meteorite impact crater provides subsurface features such as faults, fractures, rebound structures and undulating bedrock. Mapping such features using conventional method such as geotechnical is time consuming, costly and destructive which is not suitable in presenting the evidence. The 2-D resistivity method is non destructive geophysical method which apply for the purpose. It provide an evidence such geological features and contour the case study area with less time and cost. The resistivity value for bedrock and overburden might be different at different continental site. Hence, this research is to provide different value of resistivity for bedrock and overburden in Malaysia compared with other region study area for meteorite impact subsurface features.

1.2 Study objectives

The objectives of this research are:

i. to identify the thickness of overburden and bedrock of Lenggong, Perak and its vicinity with support of borehole records.

ii. to map the subsurface features associate with meteorite impact at Bukit Bunuh and its vicinity.

iii. to predict the impact crater in Bukit Bunuh and its vicinity, Lenggong, Perak

1.3 Scope of the study

The research employed 2-D resistivity imaging method for subsurface features study to identify a possible impact crater. Previous studies show other geophysical methods unable to delineate the alluvium and bedrock contact and other impact related structures in geo-environment. The method provides excellence result and enhances horizontal resolution image with deeper penetration and low noise level (Nordiana, 2013). The 2-D resistivity technique with Pole-dipole array was applied using 5 m minimum electrode spacing together with 20 mA and 1 mA max & min current respectively. The results correlated with borehole records provided.

1.4 Thesis layout

Generally, the arrangement of this thesis organized as follows ;

Chapter 1, contain background of the geophysical methods, the problem statements in this research are in this chapter with the study objectives and scope of the study related to type of geophysical method been used.

Chapter 2, contain literature review which related to meteorite impact using various geophysical methods in other countries.

Chapter 3, is included the research methodology of 2-D resistivity imaging method and Borehole techniques. The chapter included the general theory, study area, data acquisition and data processing. Location of the study area including the history and geomorphology of study area are also discussed.

In Chapter 4, the results of 2-D resistivity imaging survey for the study area is shown and discussed. This chapter also shows drilling borehole records assimilation with 2-D resistivity imaging for correlation and interpretation on the results.

The last chapter, which is Chapter 5 contain of recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In order to identity the subsurface features and signatures of the area that is to be investigated, preliminary study needed, to avoid future hazards. Desk study is very important to ensure the data acquisition provide optimum information. Processing and analyzing the geophysical data is crucial in order to extract information such as depth of rock head and subsurface thickness of the study area. The geomorphology of some typical impact craters is illustrated to show the characteristic of the pre-impact and post-impact deformation. Hence, geophysical dates for meteorite impact studies, the in-situ acquistion of electrical resistivity imaging (ERI), seismic, gravity, magnetic and drilling borehole records are utilized and produce with case studies from complex craters and simple craters.

2.1 Previous study

In Malaysia, studies related with planetary object such as meteorite impact in archeological are not as much as other countries. Acheampong et al (2013) written in research paper stated that the 10.5 km diameter Bosumtwi meteorite impact was formed about 1.07 million years ago. The crater is occupied by a lake of diameter 8.5 km. 2-D electrical resistivity imaging (2-DERI) survey using multi electrode gradient array was carried out along sixteen radial profiles around the lake to determine the sediment and bedrock contact, impact related structures and the impact direction of the meteorite. The data were corrected for topography and the subsurface images highlighted areas that are characterized by faults, fractures, lake sediments and impact related breccias such as allochthonous and parautocthonous breccias and dikes. The sediment and bedrock contact, which marks the crater geometry, was successfully mapped and it shows symmetry in the NE-SW direction and the dips between 16° in the NE to 36° in the SW. The faults were mostly delineated in the west and they dip averagely 60° to the east and 80° to the west. The dips of the faults were statically treated and were found to have a preferred direction. The results of the crater geometry and the orientation of the faults indicate that the meteorite came from the NE.

Backstrom (2005) published a paper of research of electric resistivity and impact fracturing related to the Lockne impact structure in Sweden. The fracture frequency and the electric of outcrops of crystalline basement rocks at the Lockne meteorite impact site have been studied in order to investigate the extent and radial changes of impact induced fracturing. By measuring the electric resistivity and the fracture frequency at the same outcrops, the effect of fracturing on the electric properties of the rock is estimated and correlated with the fracture frequency.

Ernston et al. (2011) documented a paper on resistivity measurement of soil liquefaction features in quaternary sediments of the Alpine Foreland, Germany. The study gave insight into a geological underground liquefaction process that must have released energies leading to the assumption that the liquefaction, because of absent earthquake activity in the region, has been induced by the recently proposed Holocene so called Chiemgau meteorite impact event. It is suggested that this application measurements is an important tool for the investigation of subsurface studies.

A study had presented by Tong et al. (2012) about electrical imaging of impact structures. Electrical tomography imaging gives crucial subsurface evidence for the construction of hypervelocity impact models. It provide an overview and evaluation of the current electrical imaging methods used in impact studies. Although apparent resistivity models are commonly used in the geoelectrical imaging of impact structures, the reliability of these models has not been determined. In order to assess these imaging approaches in impact, the discrepancies between the apparent resistivity and true resistivity models of an impact structure. The results of the study propose the importance of inversion of resistivity tomography data in impact studies, and include data modelling and for cost effective subsurface imaging of impact structures in the future.

Masero et al. (1997) study provide information about the deep structure of large meteorite craters by electrical conductivity and crustal deformation in the region of the Araguainha impact, Brazil. The magnetotelluric responses in the short period range from 0.001 to 1 s show one-dimensional behavior, in contrast to the longer periods where data are multi-dimensional. The results of two and three dimensional modelling reveal a disk-shaped body embedded within a layer of 5000 Ωm. The resistivity value of the body, 20-500 Ωm, lies significantly below the bulk value of the upper crust. The anomaly is believed to be caused by impact-induced faulting and brecciation of the crust, reaching to depths of 3-7 km.

Mazur (1999) had documented a thesis department of geology and geophysics in Calgary, Alberta. The research was carried out at Steen River impact feature in northwestern Alberta, Canada and examines the seismic characteristic of three possible impact craters and one confirmed impact structure. Using established seismic methods and impact crater scaling relations, an investigation of these features is undertaken. The largest structure examined is the 24 km diameter, Steen River impact feature in northwestern Alberta, Canada. This astrobleme has been imaged by more than 130 seismic lines to date.

Koeberl et al. (2005) shows the result from site investigation using borehole drilling log correlate with seismic profile at Bosumtwi impact crater centered in Ghana, West Africa. Bosumtwi is one of the 170 meteorite impact craters currently known on Earth and one of only four known impact craters associated with a tektite-strewn field (Koeberl et al., 1997). It is a well preserved, complex impact structure with a pronounced rim, surrounded by a slight, near circular depression with 20 km diameter of outer ring and minor topographic highs. The crater is excavated in 2 Ga metamorphosed and crystalline rocks of Birimian system. Only limited petrographic studies of rocks found along the crater rim and of suevitic brecciasare available so far (Koeberl et al., 1998). Insights into the deep structure of the crater, the distribution of nature ejected material and post-impact sediments were obtained by geophysical work over the past seven years. The research concludes that borehole drilling log correlated with geophysical method shows supportive and accurate in data interpretation.

Gumede et al. (1998) developed a research on the 20 km diameter Highbury meteorite impact structure in northern Zimbabwe. The gravity study indicates a central high with a large offset anomaly coinciding with the granophyres surrounded by concentric gravity lows. This is interpreted to be the result of a central uplift cored by denser material from the underlying Chinhoyi greenstone belt. Magnetic studies show that a prominent magnetic anomaly is centred on the Munwa Granophyre, while other anomalies are due to dipping mafic dykes. Resistivity studies show the limited extent of the Munwa Granophyre, and support its interpretation as a downwardly-injected impact melt. The research on gravity, magnetic and resistivity data were chosen for this research because of the cost and time effectiveness and produced good and accurate results.

A study had presented by James Hutton (1795) about potential fields for detecting buried impact structures. The crater was known as Chicxulub crater. North America turned out to be the most likely location, because of the large number of microscopic tektite and shocked quartz fragment was found. The specific site was first discovered using potential field methods. During an aeromagnetic survey conducted by a petroleum company over the Yucatan Peninsula and the Gulf of Mexico, a candidate impact site was located. Later, gravity surveys made this crater even more obvious and the buried Chicxulub crater was found. Note that the study using geophysical methods was successfully identifying the meteorite impact.

2.2 Chapter summary

This chapter discussed about the overview of this study and the previous study done for meteorite impact from other countries. The chapter included about geophysical methods used for impact study using 2-D electrical resistivity imaging and geotechnical method.

CHAPTER 3

MATERIALS AND METHODS

3.0 Background

Geophysical data provide information about the subsurface features. It's contain information about the identity of physical properties such as locations of natural resources, artificial object and event. This information is acquired by measuring the parameters which caused by variations in one or more physical properties. Hence, geophysical methods were introduced to be a tool in collection geophysical data. Most geophysical methods have been used approximately 80 years ago although it was dominantly in the mineral and natural explorations. Over the past decades, the used in geophysical methods has been increased due to the needed on geotechnical and geophysics engineering study. The additional aid and design in geophysical methods help in construction needs for development project (Sirles, 2006). The participation of geophysics in civil engineering and environment has been widely well known in their study cases. Geophysical methods are applied in wide range of applications includes ground investigation, dykes, determining the explorations of geological subsurface features and the determination of geophysical parameters of rock formations (Othman, 2005).

Geophysical methods can be defined as ground based physical sensing which are able to imagine and to map geological features as evidence in the study. The methods are destructive and environment friendly. Hence, it is often used where preservation and environment disturbance are the goal. As there are lots of geophysical methods that can provide such promising information, this study utilized 2-D resistivity imaging method to detect and solve archaeological problems in Bukit Bunuh, Lenggong , Perak.

3.1 Electrical resistivity method

Geophysics studies the properties of the earth and its distribution from the physical identity correlate with it by applying the basic principle of physics. The most commonly used is electrical resistivity method which measurement of electrical resistivity is made with circuit in which the subsurface is one of the components, the resistance. The direct current is injected to the ground surface using electrode stainless steel and then calculate the potential difference associated with the current. From the measurement of the distribution, the physical property of materials or segment of the earth is measured and calculated. The measurement made by using another pair of electrodes connected to a sensitive voltmeter which later provide information on subsurface layers. Geophysical interpretations are mostly remote inference about the observed physical property. The electrical resistivity imaging method is to identify the resistivity value by making measurement in the ground to determine the true resistivity of the subsurface.

In 1920s, the technique was perfected by Conrad Schlumberger for the first experiments in the field of Normandy (Keofoed, 1979). For many decades, electrical resistivity imaging methods applied in mining, hydro geological, geotechnical investigation and nowadays, it has been used for environmental purposes (Loke, 1999).

3.1.1 Resistivity theory

It is crucial to understand how to measure electricity. The parameters used in measuring electricity are amperage, voltage and resistance. Amperage is the parameter for measuring electric current. This unit used is amperes or simply amps. An amp is the amount of a coulomb of charge passing any point in the circuit in 1 second. A coulomb is equal to 6.25 x 10^{18} electrons. Voltage is the electrical pressure hat needed to move the charge around a circuit. Hence, it is called potential difference or pressure difference. It is measured in unit volts. Electric charge moves by giving an imbalance charge to the circuit. It provides excess electrons to the circuit causing the electrons in a circuit to flow from negatively charged area to positively charged area.

Established by Georg Simon Ohm, a German scientist, Ohm's law suggests that the electric current, I in a conducting wire is proportional to the potential difference, across it (Burger, 1992). The linear relationship is expressed by Ohm’s law (Equation 3.1).

$$V = l.\ R \tag{3.1}$$

Where;

l = Current
V= Voltage
R= Resistance

Since various geologic materials are expected to have different resistances to current flow, the current and voltage are measured directly to measure resistance and determine the material in the subsurface. Resistivity of a material is defined as the resistance (ohm) between the opposite faces of a unit cube of the material. Figure

3.1 shows a cylinder with resistance, *R* while resistivity depends on the length and cross sectional area, given by Equation 3.2 and 3.3 (Kaerey and Brooks, 1991).

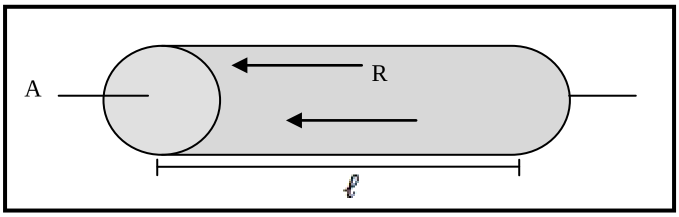

Figure 3.1: Electrical resistivity with relation of resistance (*R*), area (A) and length (ℓ).

$$R = \rho \frac{l}{A} \qquad (3.2)$$

Where;

l = Current
ρ = Electrical resistivity
A= Area
R= Resistance

By rearranging the formula, resistivity can be written as

$$\rho = \frac{RA}{l} \qquad (3.3)$$

Where;

l = Current
ρ = Electrical resistivity
A= Area
R= Resistance

The resistivity measurement are made by injecting current into the earth between two outer electrodes, C_1 and C_2 and measuring the resulting voltage difference at two potential electrodes, P_1 and P_2 (Figure 3.2).

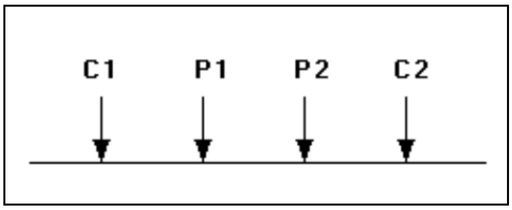

Figure 3.2: A conventional four electrode array to measure the subsurface resistivity (Loke, 1999).

The current, *I* and voltage, *V* values and an apparent resistivity, ρ_a is calculated using Equation 3.4.

$$\rho_\alpha = k\frac{V}{I} \tag{3.4}$$

Where;

ρ_α = apparent resistivity
k = geometric factor

Resistivity meter usually give the resistance, $R = V / I$ and therefore the apparent resistivity is calculated using Equation 3.5

$$\rho_\alpha = kR \tag{3.5}$$

For 2-D electrical resistivity imaging, there are few common arrays used in this method (Figure 3.3). Figure 3.4 shows the current flow in homogeneous subsurface. When current is injected through two current electrodes, the current will flow radically outer of the electrodes and between the electrodes. Potential differences between two potential electrodes are measured using voltmeter. The greater the electrode spacing, the deeper the current flow.

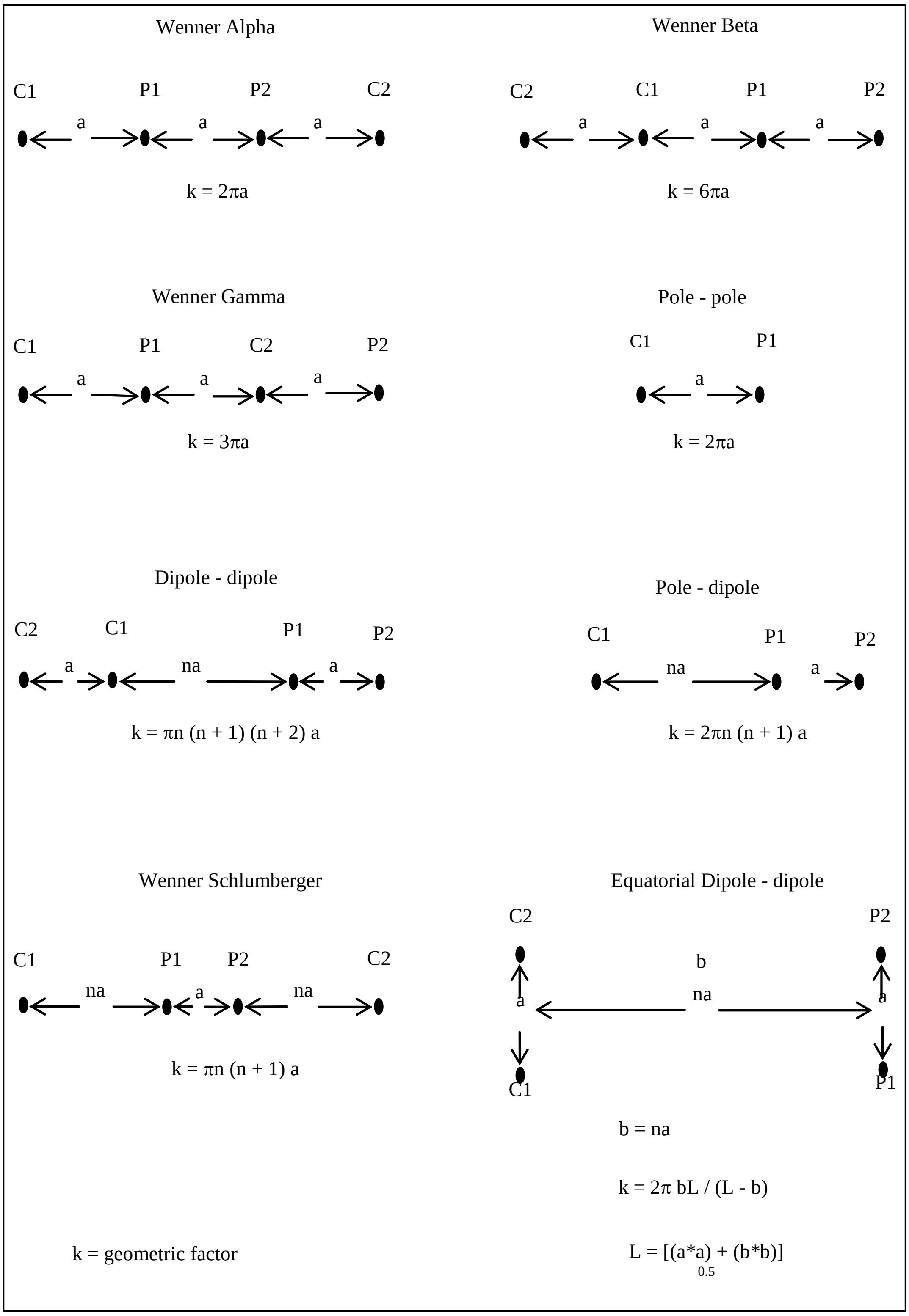

Figure 3.3: Common arrays used in resistivity surveys and their geometric factor (Loke, 1999).

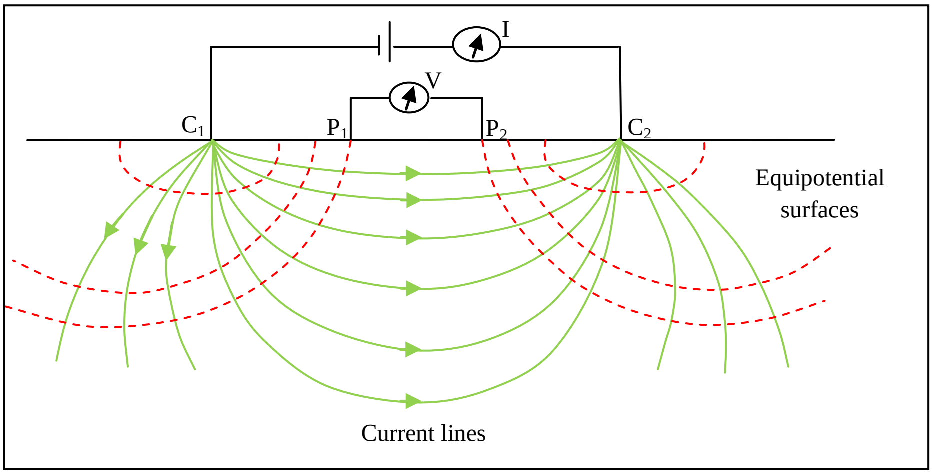

Figure 3.4: Current, I is induced between paired electrodes C_1 and C_2. Potential difference, ΔV between paired voltmeter electrodes, P_1 and P_2 is measured (Anderson and Croxton, 2008).

3.1.2 2-D resistivity imaging

An accurate 2-D model describes the resistivity changes in the horizontal and vertical direction. No changes of resistivity value assumed in the direction which is perpendicular to the resistivity line. Theoretically, 3-D resistivity imaging study and data intrepratation will be precise. Nowadays, the used of 2-D and 3-D resistivity imaging surveys to map areas with lateral and vertical changes in resistivity have been developed (Dahlin and Bernstone, 1997; Li and Oldenburg, 1992; Loke and Barker, 1996).

Typically, 1-D resistivity sounding method and 2-D resistivity usually involve about 10 to 20 readings and 100 to 1000 respectively. In comparison, 3-D resistivity imaging surveys involve a total of thousand measurements. Rather than using one set of current and measuring electrodes, a series of 20 or more electrodes are used in 2-D resistivity imaging survey while 256 or more electrodes are used in a

3-D resistivity imaging method (Robert, 2000). Nowadays geophysics case study, 2-D resistivity imaging method provide precise results which is crucial as the evidence obtained by other geophysical methods.

The measurement apply a series number of electrodes planted into the ground along a straight line with fix spacing between adjacent electrodes and clipped to a multi-core cable. The multi-core cables are then connected to an automated computer operated switch box known as electronic switching unit that selects the four electrodes to be used. The switching unit and the resistivity meter are then connected to a laptop computer (Figure 3.5). After laying all the cables and electrodes, the data measurement are taken and will stored into the laptop. The data sets obtained from field are inverted for the true resistivity using 3-D or 2-D inversion algorithms and the resulting estimated models are interpreted (Papadopoulus et al., 2006).

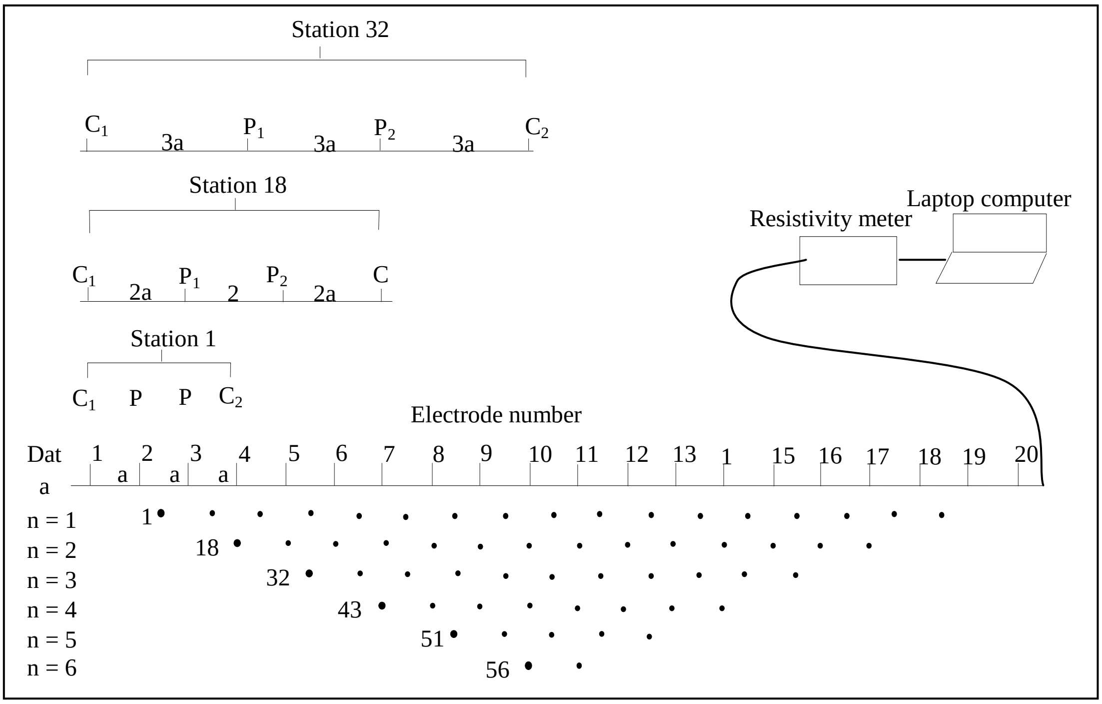

Figure 3.5: The arrangement of electrode for 2-D resistivity imaging survey and the sequence of measurements used to build up the resistivity section (Loke, 1999).

The first measurement starts by considering electrode 1, 2, 3, and 4 to be the current and potential electrodes, C_1, P_1, P_2, and C_2 with spacing “1a”. The measurement is continued with second measurement by allowing electrodes 2, 3, 4 and 5 to be C_1, P_1, P_2, and C_2 respectively. These steps are repeated to the last electrode with constant spacing of “1a”. After completing the first sequence of measurement “1a”, the measurements are continued with the second sequence of measurements with “2a” electrode spacing. Therefore, the first measurement starts with electrodes 1, 3, 5 and 7 followed by second measurement with electrode 2, 4, 6 and 8. These procedures are repeated until the last electrode used with “2a” spacing down the line of electrodes. The continuation of this method utilized for measurement with “3a”, “4a”, “5a” and “6a” spacing. The number of measurements will decrease as the electrode spacing increased, depends on the array type (Loke, 1999).

For an extension of the area, the roll along techniques was used to cover by a survey horizontally predominantly for a system with limited number of electrodes. After a sequence of measurement is complete, the cable is roll towards end of survey line by several unit electrodes spacing (Figure 3.6). Roll-down is defined when the cable is moved towards the first electrode while roll-up is delineate when cable is moved towards the last electrode. The technique is useful to produce detailed data at the center of resistivity section with the intention of better resolution (Loke, 1997).

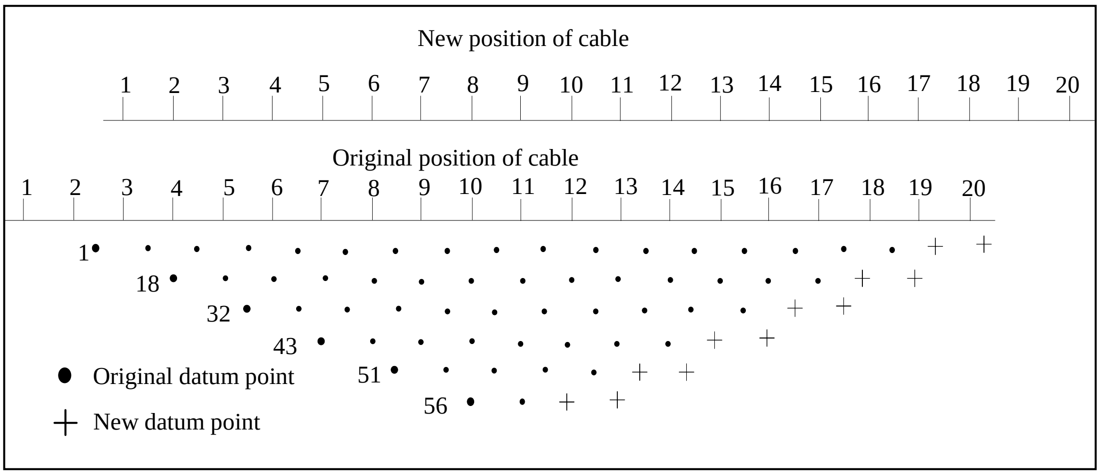

Figure 3.6: Roll-along technique to extend the area covered by a survey (Loke, 1997)

Since 1950's, there are a lot of electrode array been used in the electrical explorations such as Pole-pole, Pole-dipole, Dipole-dipole, Wenner-α, Wenner-β and Wenner-Schlumberger which produce different sensitivity (Figure 3.7).

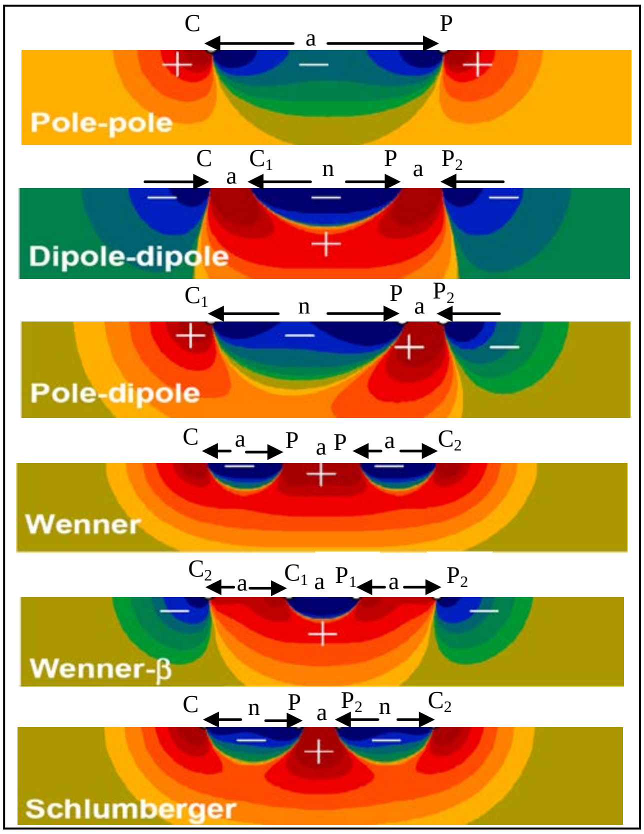

Figure 3.7: Electrode array sensitivity pattern for different electrode array (Loke, 1997).

The arrays provide eligble options for sounding, profiling and scanning survey with different study cases although there have advantages and limitations. Some of these electrode arrays are now often employed for the 2-D resistivity imaging and 3-D resistivity imaging applications (Dahlin, 1996; Chambers et al.,1999; Storz et al., 2000). Selection of the best electrode array depends on background noise level, sensitivity and the type of structure to be mapped. After data acquisition, for high resolutions and reliable results, data with maximum anomaly information, reasonable data coverage and high signal-noise ratio are the important part to choose the electrode array (Dahlin and Zhou, 2003).

The Pole-dipole array uses two potential electrodes, P_1 and P_2 separated with spacing "a" which moves along the line for "n" spacing from current electrode C_1. This array requires current electrode, a remote electrode C_2 , is placed suffiently far from the survey line. The C_2 electrode effect can be stated as approximately proportional to square of ratio distance between C_1-P_1 and C_2-P_1. Pole-dipole array is not as sensitive to telluric noise as Pole-pole array and has considerably higher signal strength compared to Dipole-dipole array. This array also has moderately good horizontal coverage. Pole-dipole array is an asymmetrical array which produces asymmetrical apparent resistivity anomaly in the resistivity section. Therefore, the measurements are repeated with the electrodes arranged in the reverse manner to eliminate the effect of the asymmetry by combining the forward and reverse measurements (Figure 3.8).

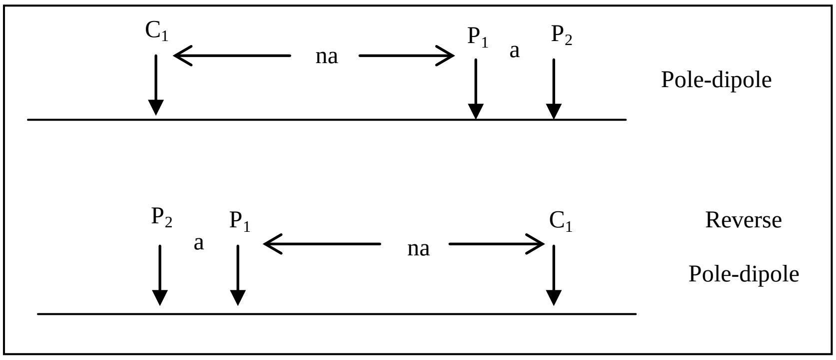

Figure 3.8: The forward and reverse Pole-dipole array (Loke, 1999).

3.1.3 Factors affecting resistivity of earth's material

Electrical resistivity value of earth's material shows a greatest variation for all rocks and minerals. It has a huge range compared to other physical quantity mapped by other geophysical methods. For a particular soil and rock, the resistivity value depends on geological parameter such as degree of water saturation, concentration of dissolved salt, porosity, physical composition and degree of fracturing (Pokar, 1998). These factors change the resistivity value of earth materials (Figure 3.9).

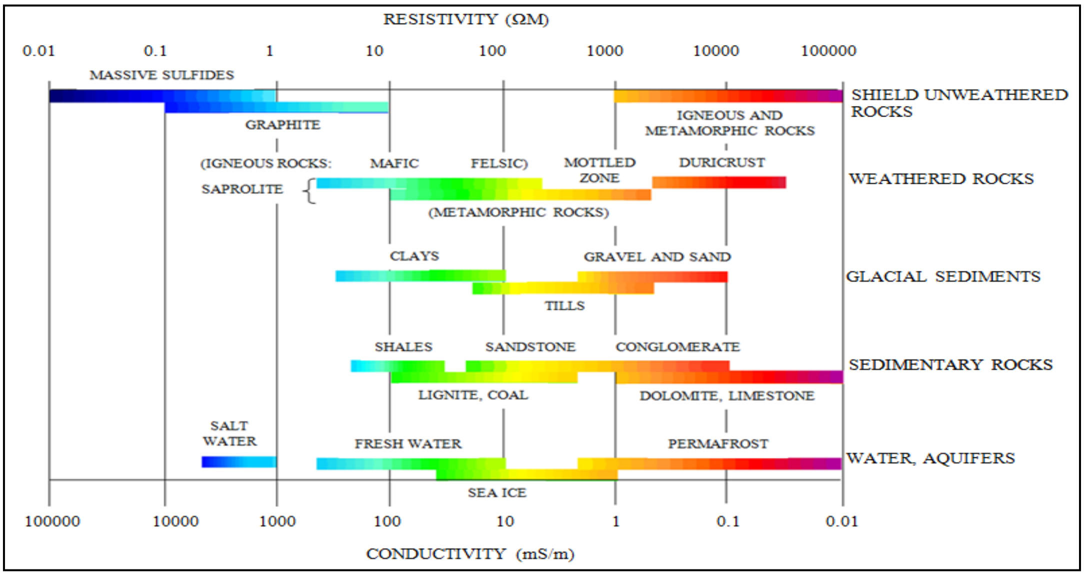

Figure 3.9: Resistivity values for some common rocks (Keller and Frischknecht, 1996).

Porosity is related to the distribution of grain size in a soil. It can be define as a ratio between the volume of pore space and the total volume of soil. Filled pore or saturated pore will result in low resistivity value while air-filled pore will have higher resistivity value.

Distribution of grain size is related closely to water saturation in soil and rock which has a big influence on resistivity value. Saturation of water will decrease the resistivity value of soil and rock. For different composition of soil gives different resistivity value. For example, the resistivity of clay is 1-100 Ωm whereas for metal is well above 9.074×10^{-8} Ωm. Clay is known as an exchangeable ions because during the formation of clay through weathering, cations are absorbed to the surface and can subsequently be essentially go into solution if the clay is mixed with water. Therefore, more ions are released and thus increase its conductivity. The resistivity value of soils and rocks vary from 1-30 Ωm for some clay and shales to over 1000 Ωm for limestone, intrusive rocks such as granites, and some metamorphic rocks. However for sedimentary rocks where resistivity value is from 10-1000 Ωm, resistivity is also significantly affect by the porosity and salinity of the water in the pore space. Igneous rocks generally have higher resistivity values. The resistivity of this rock is greatly dependent on the degree of fracturing and percentage of the fractures filled with groundwater. Resistivity value will be lower as the fracture size increased. Granite has resistivity value of 5000-10000 Ωm in wet and dry condition respectively. When fracture in this rock is saturated, the resistivity will reduce to less than 100 Ωm (Loke, 1999).

3.2 Study area

The study conducted on granite formation and oriented from North to South of Lenggong. It is covered five main villages which are Kampung Bukit Sapi, Kampung Luat, Kampung Chepor, Kampung Beng and Kampung Raja Intan Suraya with about 30 kilometers in length. The study is divided into two stages, which are regional study and detail study (Figure 3.10).

The study area is approximately 132.25 km^2 and with coordinate of 5.117022º, 100.910857º, 5.123884º, 101.034228º, 5.023540º, 100.917481º and 5.021796º, 101.031081º with mainly agriculture land (palm estate) meanwhile towards the West of the survey area is primary jungle. Generally, Lenggong valley consists of few unit lithologies, such as alluvium, tetra dust and granite rock. Granitic rock was represented by Late Jurassic-Lower Carboniferous which dominates the whole of Lenggong valley which also originated of Bintang Range on the west of Lenggong (Mokhtar, 1993).

3.2.1 Regional study

The regional study using 2-DERI study was conducted at Lenggong, The preliminary study is to justify the features and environmental subsurface geological due to meteorite impact. The resistivity equipment comprises with 5 m minimum spacing, covering an area of 64 km^2. The survey lines were carried out using 'roll-along' technique. A total of 4 survey lines consists of North-South line; 8 km length, West-East line; 8.01 km length, Northwest-Southeast line; 6.61 km length and Southwest line; 1.84 km length (Figure 3.11).