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GEOPHYSICAL APPLICATIONS FOR BUKIT BUNUH CRATER EVIDENCES

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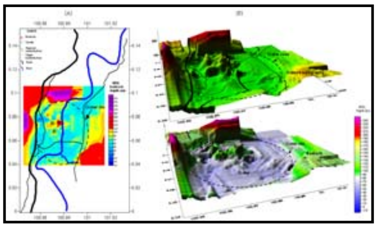
Graphical abstract



Abstract

Geophysical surveys were conducted in Bukit Bunuh area, Perak to study an hypothesis of the existence of an impact crater and if so, to identify the perimeter of the crater. Four (4) geophysical methods were applied; seismic refraction, 2-D resistivity imaging, gravity and magnetic methods over approximately 132.25 km² of developed agricultural land, primary jungle and villages of Bukit Bunuh, Perak and its vicinities. The surveys were conducted from May 2011 until July 2013 and have successfully proven the existence of an impact crater. The crater is about 6 km in diameter with a depth of 5 m – 50 m. There are lots of unusual fractured bedrock which represent features associated with impacted event.

Keywords: Bukit Bunuh crater; gravity; magnetic; 2-D resistivity imaging; seismic refraction

Abstrak

Kajian geofizik telah dijalankan untuk mengkaji hipotesis kewujudan kawah hentaman di kawasan Bukit Bunuh dan sekiranya ada, untuk mengenal pasti perimeter kawah. Empat (4) kaedah geofizik telah digunakan; pembiasan seismik, pengimejan resistiviti 2-D, kaedah graviti dan kaedah magnet ke atas kira-kira 132,25 km² tanah pertanian, hutan asal dan kampung-kampung Bukit Bunuh, Perak serta kawasan sekitarnya. Kajian telah dijalankan dari Mei 2011 sehingga Julai 2013 dan telah berjaya membuktikan kewujudan sebuah kawah hentaman. Diameter kawah dianggarkan kira-kira 6 km dengan kedalaman 5 m – 50 m. Terdapat banyak patahan luar biasa yang dikenal pasti berlaku pada batuan dasar yang mewakili ciri-ciri berkaitan dengan kesan hentaman.

Kata kunci: Kawah Bukit Bunuh; graviti; magnetik; pengimejan resistiviti 2-D; pembiasan seismik

1.0 INTRODUCTION

Earth processes change and hide original ground surface features. The original features of an impact crater on Earth's surface are identified by topographic characters; circular hills, bowl shape with an upturned rim and sometimes uplifted centre. The impact craters are classified as simple or complex based on the size and morphology. Simple crater with bowl-shaped cavity partially filled with breccias lens, well-defined rims and regular shapes (Figure 1). The depth of rim-to-floor is about one-fifth of the rim-to-rim diameter, and the rim height is about 4 % of the total diameter. The maximum diameter is influenced by surface gravity of the impacted body and strength of the impacted surface, such as igneous rock is about 4 km and sedimentary rock is about 2 km [1].

Complex crater with central uplift and slump blocks, which arranged within an annular synform with smaller diameter (Figure 2). The central peak originated from central uplift of a rock from below the crater floor could change into a concentric ring of peaks, as crater size increases. The stratigraphic uplift is approximately 8 % of the crater's final diameter. Both craters are common with ejecta and the raised rim structure caused by ejected deposits and structural uplift of the underlying pre-impact surface. The uplift is upmost at the rim crest and vanishes at about 1.3 to 1.7 centre radii from the centre [1]. As the crater grows, an enormous radial force tends to push the rock units upwards [3-4]. The overturned stratigraphic features observed around the simple craters rim or on top of the slumped blocks for complex crater. The peak ring does not surpass half the rim-to-rim diameter.

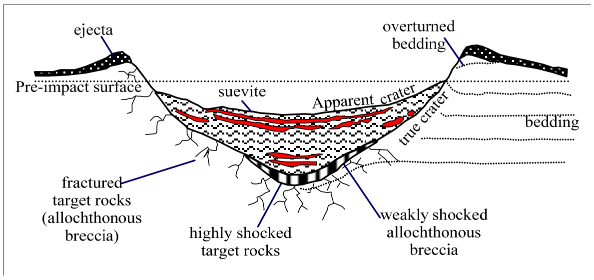


Figure 1 A schematic cross-section of simple crater [2]

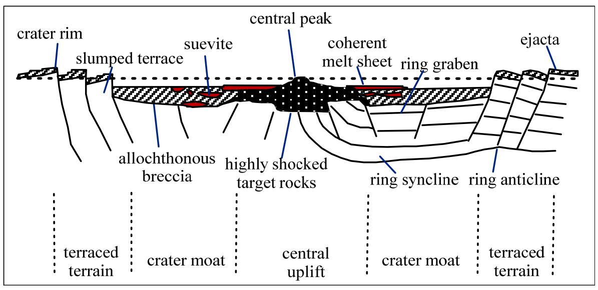


Figure 2 Schematic cross-section of complex crater [2]

2.0 METHODOLOGY

In this study, the evidences of the crater were investigated at Bukit Bunuh, Perak. Geophysical methods employed for the study were magnetic, gravity, seismic refraction and 2-D resistivity imaging. Water content, porosity, mineral content and density can enhance geophysical results accordingly. Identifying the subsurface thickness, fractured area and faults will lead to good conclusion of the earth process.

Magnetic fields measurements depend on the accuracy of regional magnetic anomaly which induced by rock/soil magnetization intensity induced by earth magnetic force and remnant. Magnetometer measures horizontal/vertical magnetic force and declination angle [5]. The magnetic force sometime interrupted by magnetic storm [6]. The magnetic survey can be used for ore exploration and geology features; i.e. faults, contact zone and intrusion [7]. Proton precision magnetometer was used in this study (Figure 3).

Figure 3 Magnetometer and barometer

Gravity method is extensively used for ore exploration, hydrocarbon, non-metallic minerals, groundwater, engineering and environment. It measures relative gravity value between survey station and base station which to identify absolute gravity value at each survey station. Results from the gravity survey provide density of rock/soil after corrections.

2-D resistivity imaging used to determine subsurface structures for bedrock depth estimation, minerals and groundwater exploration. Electrical resistivity is the characteristic of earth materials to inhibit the flow of electrical current. Electrical resistivity is measured by inducing a current between two electrodes and measuring the resulting potential at other electrode pairs. The calculated resistivity value is not true resistivity of the subsurface but an apparent value. To determine the true resistivity values, an inversion of the measured apparent resistivity value using a computer program must be carried out. In this study, 2-D resistivity imaging carried out using multi-electrode resistivity meter system (Figure 4).

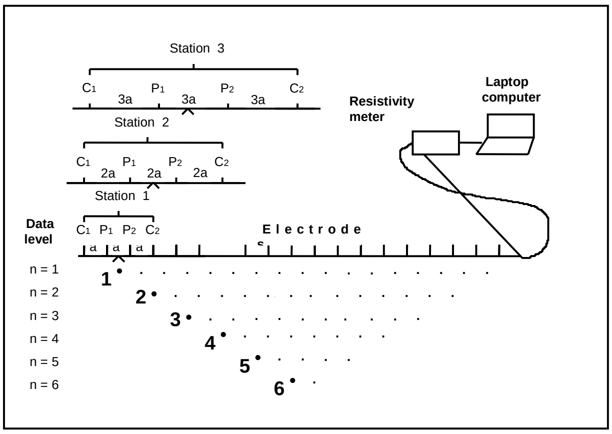


Figure 4 The arrangement of electrodes for a 2-D electrical survey and the sequence of measurement used to build up a pseudosection [8]

Seismic refraction in this study use seismograph, geophones and non explosive seismic source. This method utilizes refraction of seismic waves (Figure 5). It provide rock intrinsic characteristics such as porosity, density, particle size and shape, anisotropy, mineralogy, degree of cementation and moisture effect.

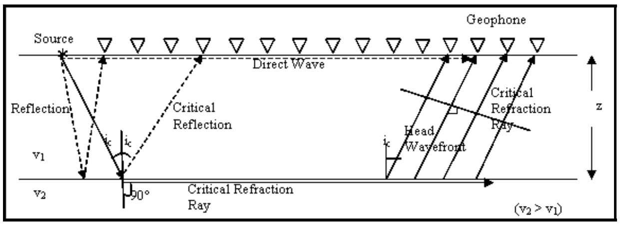


Figure 5 Direct wave, reflection and refraction ray in seismic refraction study [9]

3.0 GENERAL GEOLOGY

The survey area covered approximately 132.25 km^2 with agricultural, primary jungle and undulating area. The survey situated between two ranges, Bintang Range and Titiwangsa Range. Generally, it consists of few unit of lithology, such as alluvium, tefra dust and granitic rock. The Quaternary sedimentation was represented by alluvium unit and tefra dust. The granitic rock was represented by Late Jurassic-Lower Carboniferous which dominates the whole of the study area which is originated from Bintang Range [10].
Granite intrusion has occurred all over Malaysia in Triassic age which is about 200 million year (m.y) ago [11]. The top layer of Bukit Bunuh consists of alluvium layer and scattered along the Perak River which settled down on the Quaternary era (> 2 m.y). At elevation less than 180 m, there are lots of fractured rocks and faults. From the physical aspect, the rocks are angled and crushed including chert, flint and agate (Figure 6).

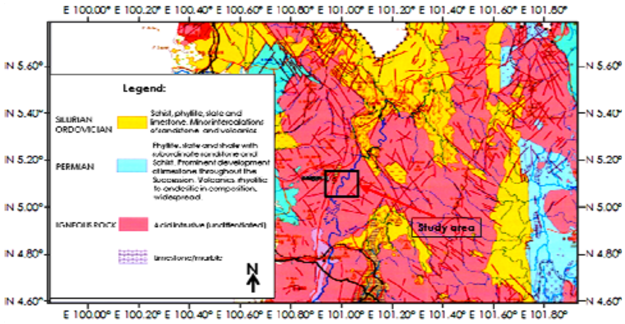


Figure 6 Geological map of Bukit Bunuh [12]

4.0 STUDY AREA

Bukit Bunuh is located about one kilometer from Kota Tampan, Lenggong, Perak and the survey area is shown within the square box shown in Figure 7.

Figure 7 The study area

Bukit Bunuh archaeological site in Perak (Malaysia) has been discovered as the world archaeological heritage site since the area has one of the oldest prehistoric settlements in the world. The most significant finding so far is an axe preserved in a suevite rock dated at least 1.83 million years old through fission track dating. Bukit Bunuh lies between Titiwangsa Range and Bintang Hill where it is believed to be a valley long time ago. Bukit Bunuh shows an indication of meteorite impact based on the surrounding geological characteristic and rocks characteristics such as suevite breccia [13-14]. This location appears as valley vicinity with several ascending topography and the crater ring formation has been confirm via aerial photograph [1].

5.0 DATA ACQUISITION AND PROCESSING

The study employed four geophysical methods; magnetic, gravity, seismic refraction and 2-D resistivity imaging. The surveys were conducted in stages, from May 2011to July 2013. For the early stage, the survey was conducted in a big scale, which is regional study.

Detail study was conducted based on the regional study results (Figure 8-9).

Magnetic data processing used MAGMAP and SURFER 8 software to analyze the anomaly for qualitative interpretation. Diurnal and IGRF correction applied prior to modeling and interpretation. The gravity processing includes drift, free air (FAC), bouguer, latitude and terrain correction for modeling and interpretation. 2-D resistivity data was processed using RES2DINV software to produce inversion model resistivity while the seismic refraction data was process using FIRSTPIX, GREMIX15, OptV1.5 and V3.5 software.

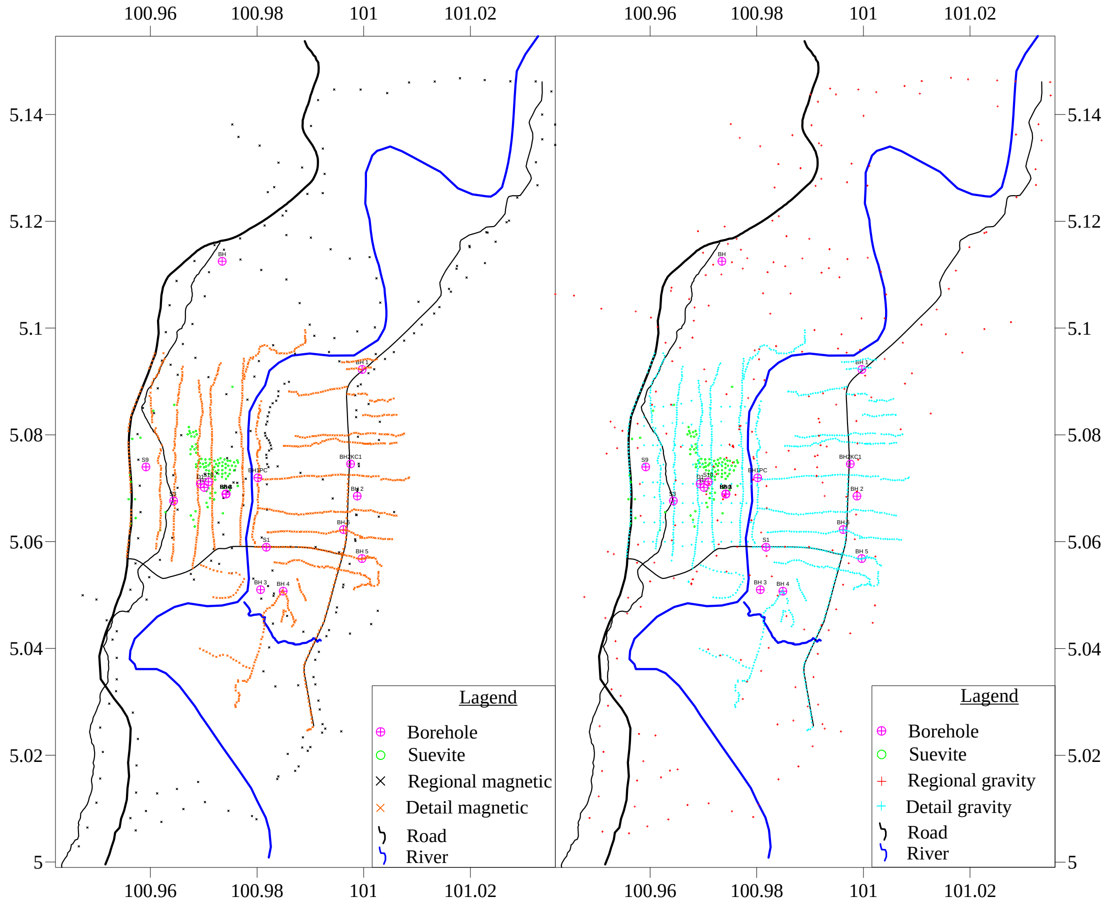


Figure 8 Magnetic and gravity stations at Bukit Bunuh, Perak for regional and detail study.

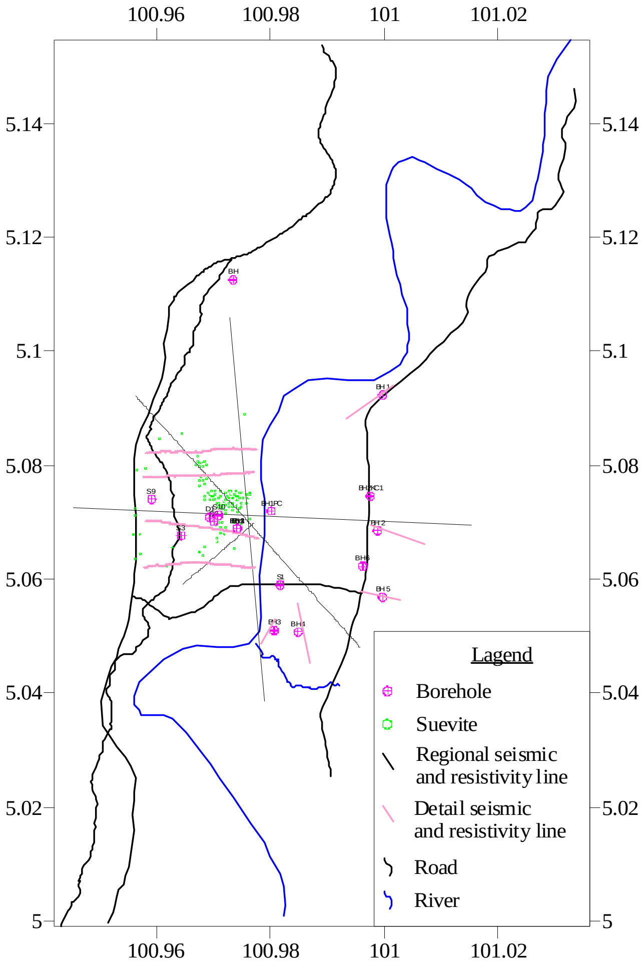


Figure 9 Seismic refraction and 2-D resistivity survey lines at Bukit Bunuh, Perak for regional and detail study

6.0 RESULTS AND DISCUSSION

Final magnetic residual contour map of the study area (regional and detail) generally divided into two main zones, high (positive values) and low (negative values) magnetic anomaly (Figure 11a). The scattering of low magnetic anomaly is associated with magnetic minerals or sedimentation/ overburden and fractures. High anomaly is associated with shallow bedrock which situated at the north and south parts. Few high anomalies scattered around the middle of the study area with certain shape. The dotted line is interpreted as the crater rim and the rebound zone is label as R.

Final bouguer anomaly contour map (regional and detail) generally divided into two main zones, high (positive values) and low (negative values) bouguer anomaly. The high anomaly is scattered throughout the study area, and the low anomaly appear only at one area, which, it is surrounded by high anomaly (Black dotted circle) and interpreted as crater rim. Few sports of high anomaly (R) appear at the centre of the low anomaly, which interpreted as rebounds zone (Figure 10b).

2-D resistivity results generally shows the study area was divided into two main zones, overburden with resistivity value of 10-800 Ωm and bedrock with resistivity value of >1500 Ωm and depth of 5-70m. Figure 12a shows a 2-D view of bedrock topography map with respect to ground surface topography and Figure 11b shows a 3-D view of bedrock topography map with respect to ground surface topography. It is clearly seen the crater rim (dotted line) and rebound effect (R).

Seismic refraction results show the study area was generally consist of two main layers. The first layer is predominantly consists of alluvium mix with boulders with velocity of 400-1100 m/s while the second layer with velocity of 2100-4400 m/s with depth of 5-50 m is interpreted as bedrock. Figure 12a shows a 2-D view of bedrock topography map with respect to ground surface topography and Figure 12b shows a 3-D view of bedrock topography map with respect to ground surface topography. It is clearly seen the crater rim (dotted line) and rebound effect (R).

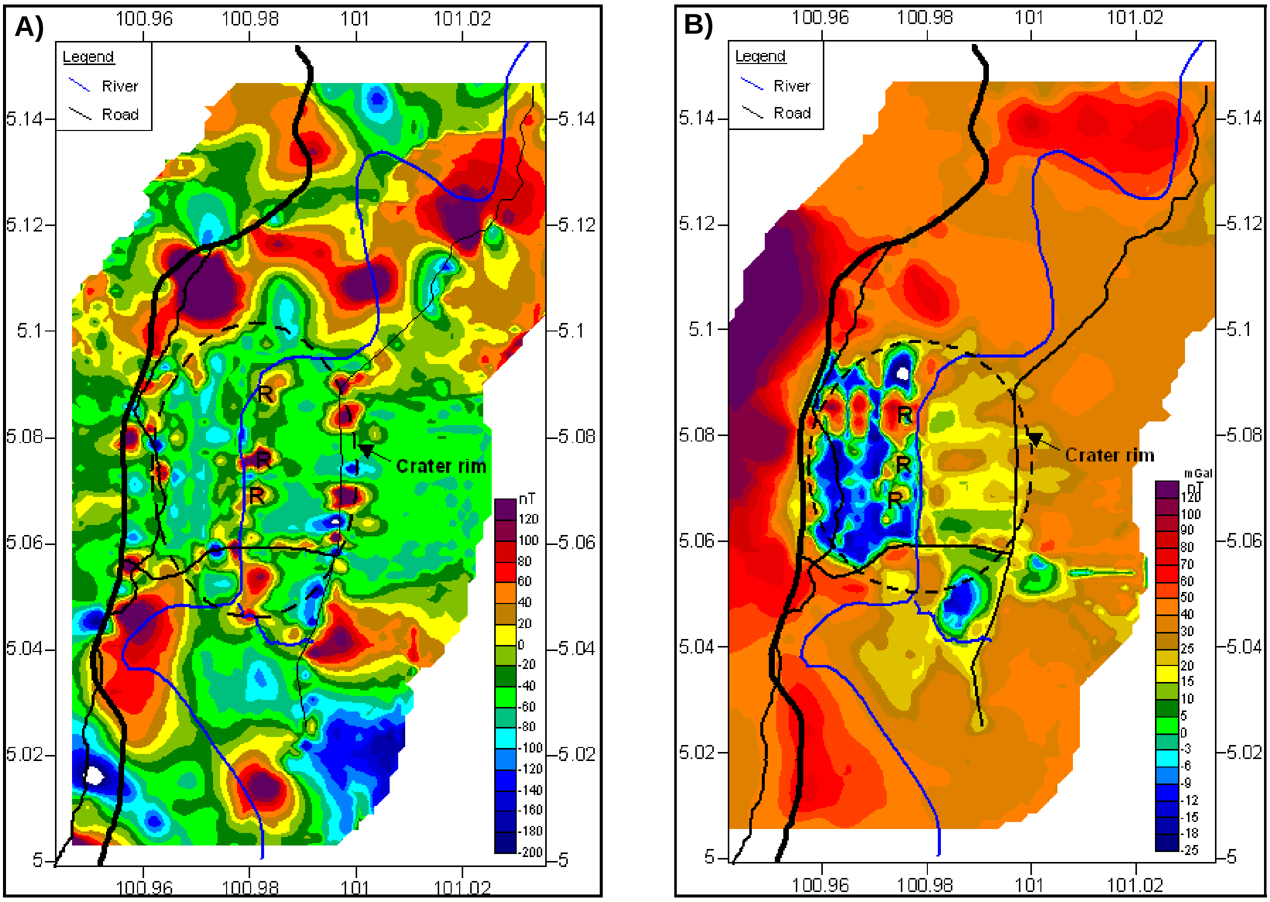


Figure 10 Contour map; a) magnetic residual, b) bouguer anomaly of Lenggong, Perak

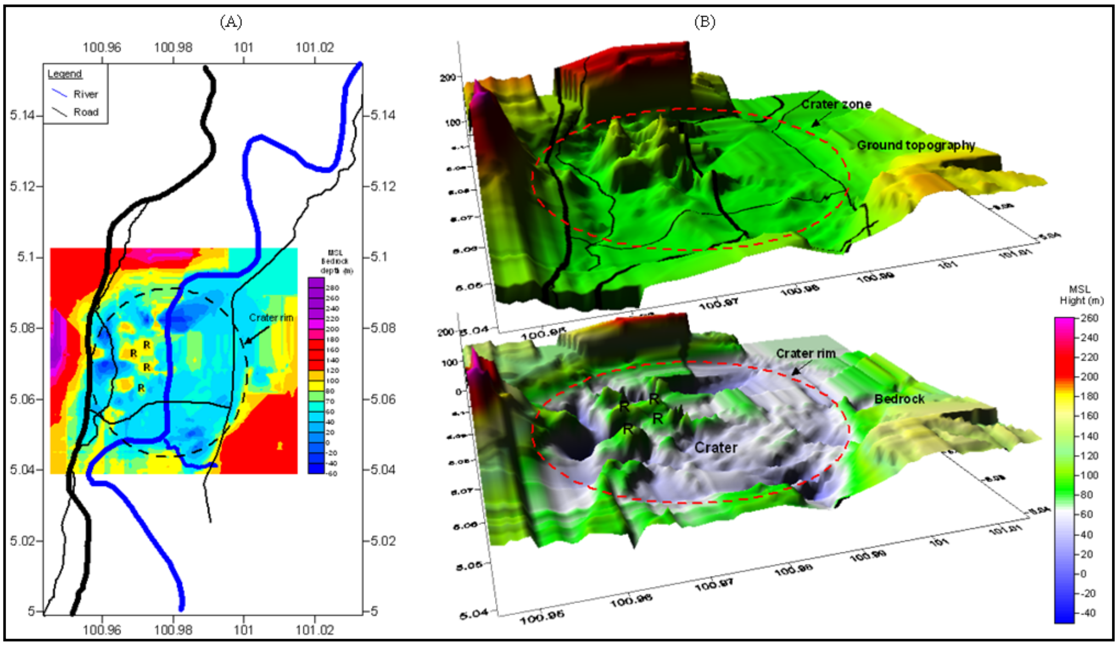


Figure 11 Resistivity topography map of bedrock with crater rim and rebound effect (R); a) 2-D view of bedrock depth, b) 3-D view of bedrock depth

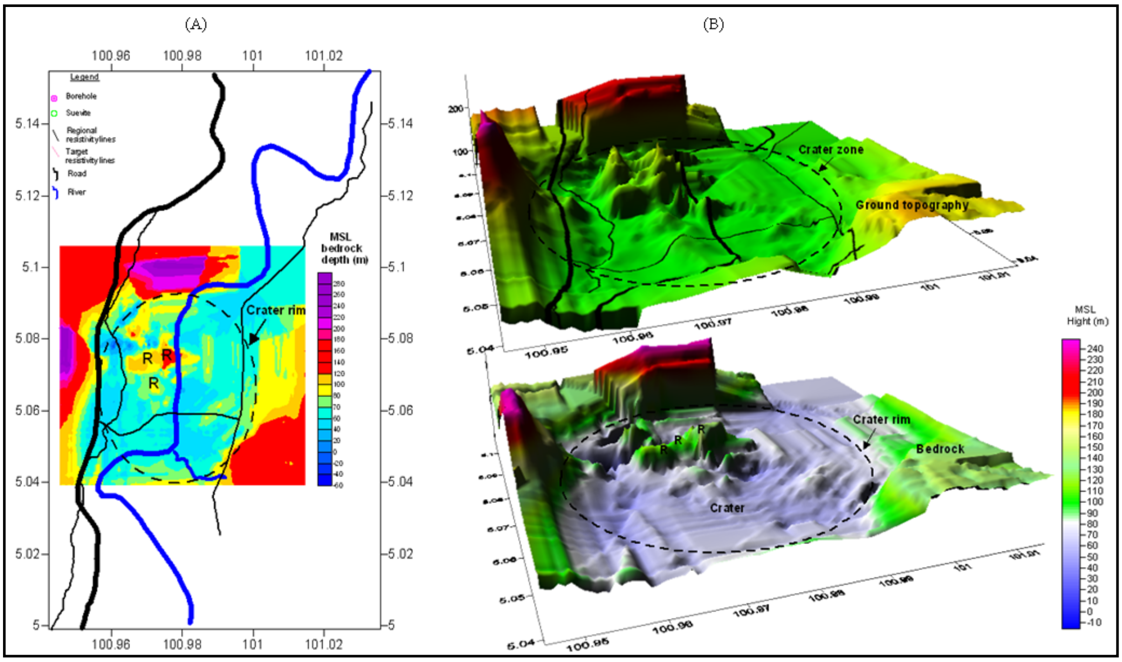


Figure 12 Seismic topography map of bedrock with crater rim and rebound effect (R); a) 2-D view of bedrock depth, b) 3-D view of bedrock depth

7.0 CONCLUSION

Geophysical methods proved that Bukit Bunuh is highly fractured granitic bedrock with depth of 5 m - 50 m (from ground surface). It shows one interesting zone with highly fractured bedrock surrounded by competent highly elevated bedrock. The area was filled with sediments and interpreted as an impacted crater of about 6 km in diameter. Thus, the geophysical methods had successfully proven on the existence of an impact crater at Bukit Bunuh.

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