Geophysical Modelling Using Gravity Data Of Meteorite Impact Crater At Bukit Bunuh, Lenggong, Perak, Malaysia

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Abstract

A geophysical survey using gravity method was conducted at Bukit Bunuh, Lenggong, Perak, Malaysia, to determine the occurrence of a subsurface impact crater, based on the discovery of meteorite impact rock, suevite, in the study area. A standard correction was applied to all the gravity data to produce Bouguer gravity anomaly of the study area. The Bouguer gravity anomaly was used to produce several maps of gravity anomalies by filtering processes and relate them to the geological structure and tectonic history of the study area. Data processing and interpretation were conducted using geophysical software, Oasis Montaj. This software was used in a number of gravity data filtering processes, such as Low Pass Filter (LPF) and the Total Horizontal Derivative (THD). Bouguer gravity anomaly map shows a circular structure in Bukit Bunuh area which is interpreted as a remnant of meteorite impact crater. The gravity anomaly appears to decrease from the edge of the crater and increases at the center. This feature indicates a complex crater structure which has central uplift. The Total Horizontal Derivative map of residual gravity anomaly shows structural trend such as lineaments and faults that dominant to the northwest-southeast direction. A model was produced using GM-SYS 3D software to determine the geometry of the impact crater. The interpreted 3-D model shows a diameter of the impact crater was approximately 2368 m and depth of about 400 m. The model of the crater appears to tilt toward southeast, which illustrates the ancient meteorite that hit this area about 1.83 million years ago possibility came from northwest direction.

Keywords

Keywords: Geophysics; Gravity; Bukit Bunuh; Impact Crater; Model

1. Introduction

Gravity survey is a measurement of the gravitational potential field in a series of different locations for a particular purpose. The objective of this survey is to relate the density differences to anomaly gravity changes (Parasnis, 1986). The anomaly gravity changes shows horizontal density differences of subsurface rocks or materials and could be used to determine the subsurface structure (Samsudin, 1990).

A gravity survey was conducted in Bukit Bunuh, Perak, Malaysia. The study was initiated by a discovery of meteorite impact rock, called, suevite (Fig. 1), around Bukit

Bunuh area. The presence of suevite provides an evidence of possible ancient meteorite impact that had taken place in the study area.

Figure 1: Meteorite impact rock, suevite discovered in Bukit Bunuh area

Bukit Bunuh area (Fig. 2) was initially a rubber plantation until it had been replanted with palm oil plantation in 2001. During the replanting period, some suevite boulders and artifacts of archaeological significant were exposed, which was then confirmed by a palaeo-environmental mapping of Lenggong Valley. Since then the area has been set as a centre for archaeological and meteorite impact research lead by Universiti Sains Malaysia. Bukit Bunuh area is believed to be impacted by a meteorite around 1.83 million years ago, which developed an impact crater. However due to tropical weather and erosion, the geomorphology condition of the crater has been destroyed and the crater structure buried by a relatively new sediments.

Figure 2: Location map of Bukit Bunuh area

Based on Lenggong topographic map, sheet number 3464, series L7030, scale 1:50 000, issued by Department of Survey and Mapping Malaysia, 1986, Bukit Bunuh is situated at longitude $100^{0}58.5'$ East and latitude $5^{0}4.5'$ North. The study area is a hilly region that could be seen in the topographic map (Fig. 3), indicated by closed contour lines on the eastern and the western part. On the southern part, Bukit Bunuh is border with Raban Lake and Perak River flows on the eastern area.

Geophysical gravity survey can contribute a supporting evidence for meteorite impact structure in Bukit Bunuh. The fulfillment of all criteria would help the study area to be recognized as a World Heritage Site by UNESCO.

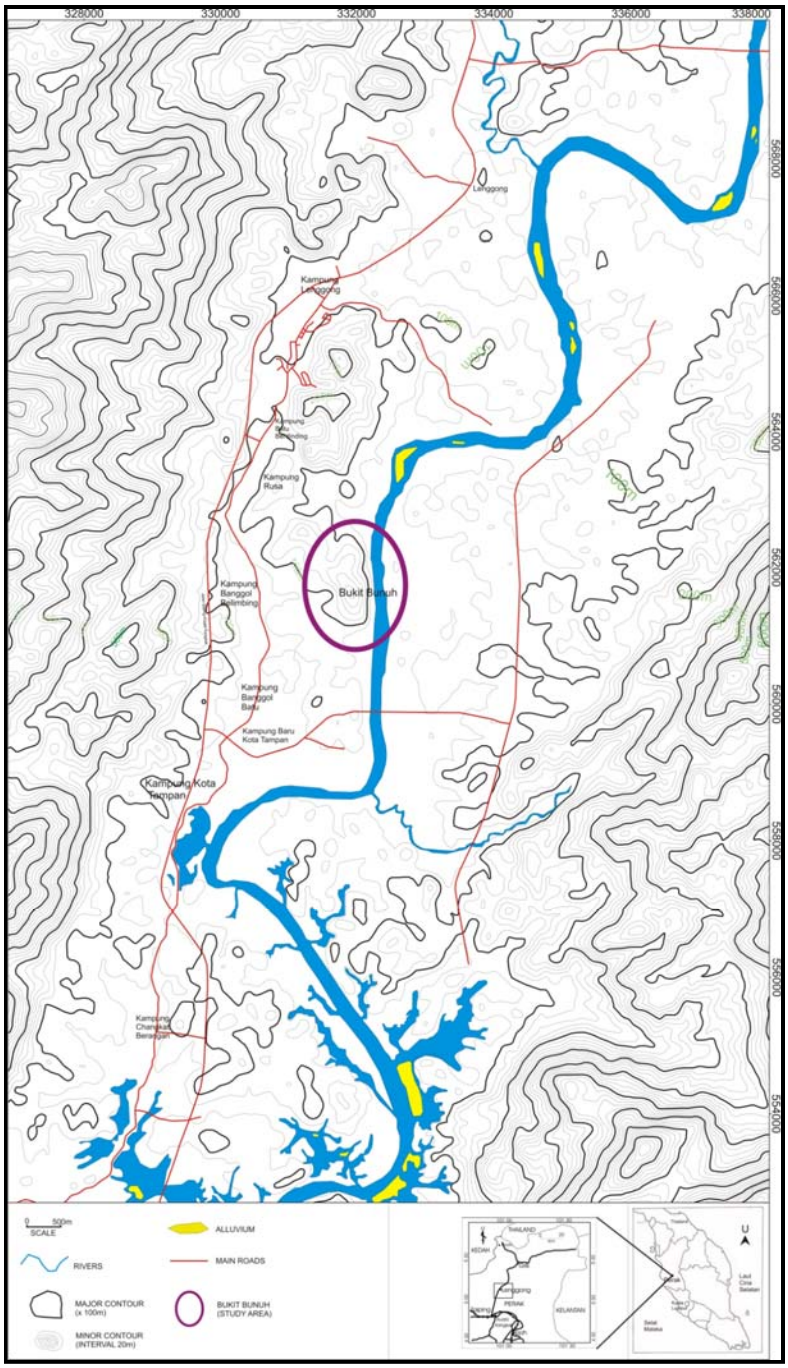

Figure 3: Topographic map of study area

Based on Geological Map of Lenggong valley issued by Mineral and Geoscience Department Malaysia in 2007, scale 1:200 000 (Fig. 4), the study area consists of

Quaternary sediment and small lithology unit of Tertiary tephra ash and metasediments. While, it basement were dominated by Mesozoic granitic rocks as a concurrence of regional granitic intrusion in Peninsular Malaysia during Triassic (Alexander, 1962). Suevite breccias in form of variable size boulders were found well scattered in the southern area of the Bukit Bunuh (Fig. 5).

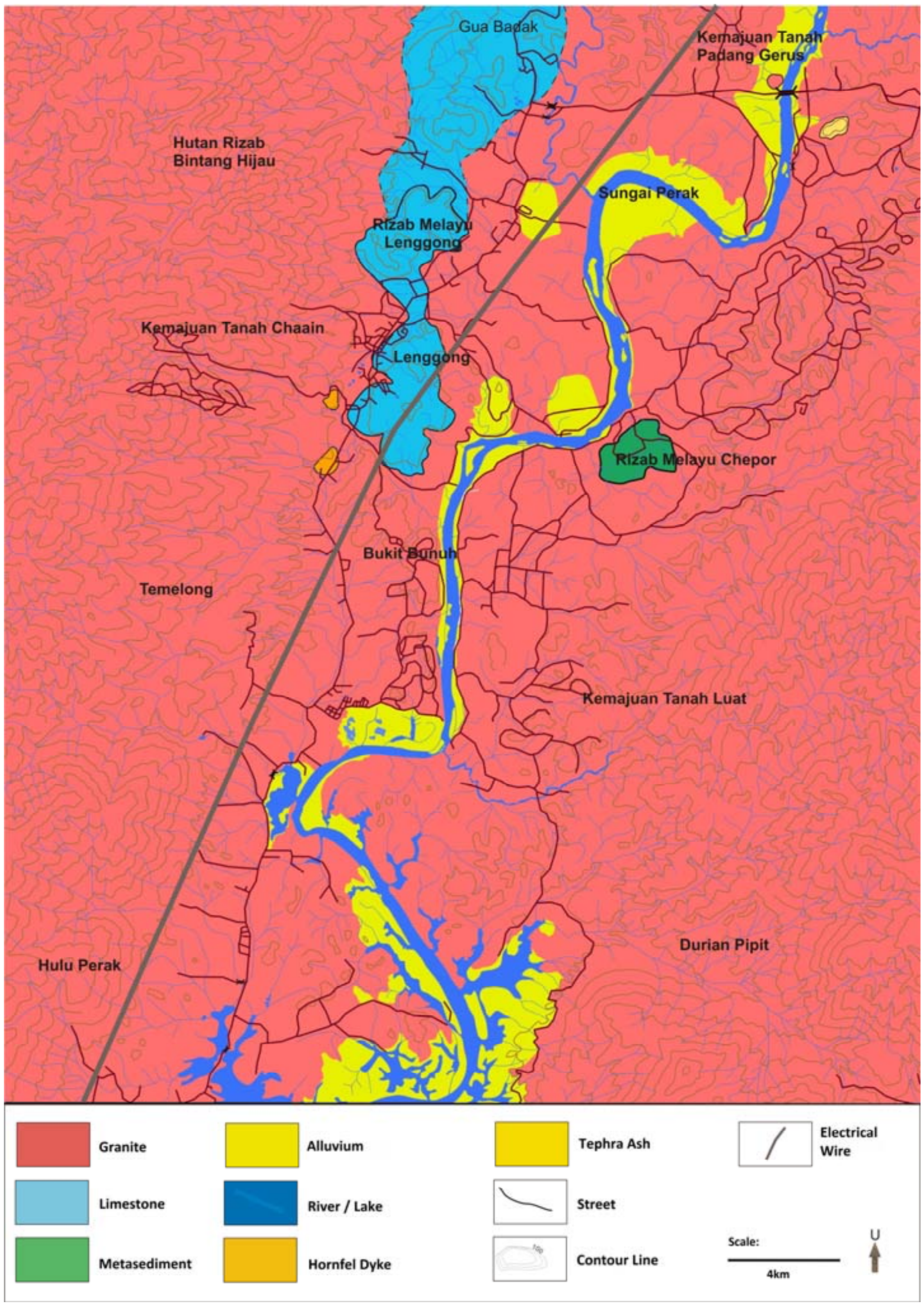

Figure 4: Geological map of Lenggong valley

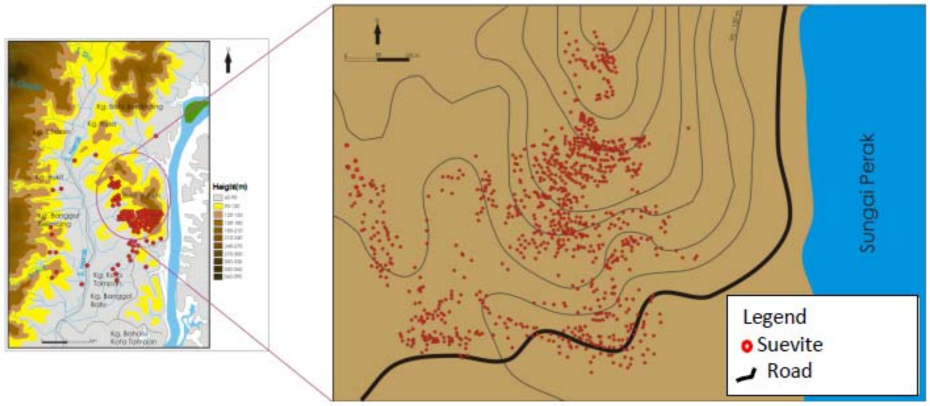

Figure 5: Map of suevite boulders

2. Methodology

The gravity survey was conducted using CG5 Scintrex Micro-Gravitimeter. A total of 544 gravity stations had been established with approximately 500 m spacing in surrounding area and 50 m spacing in Bukit Bunuh (Fig. 6). The observed gravity data has been tied with an established gravity station (Loke, et al 1983). Wallcae and Ternian altimeters had been used to measure the elevation of gravity stations and the station coordinates determined by using global positioning system (GPS) instrument.

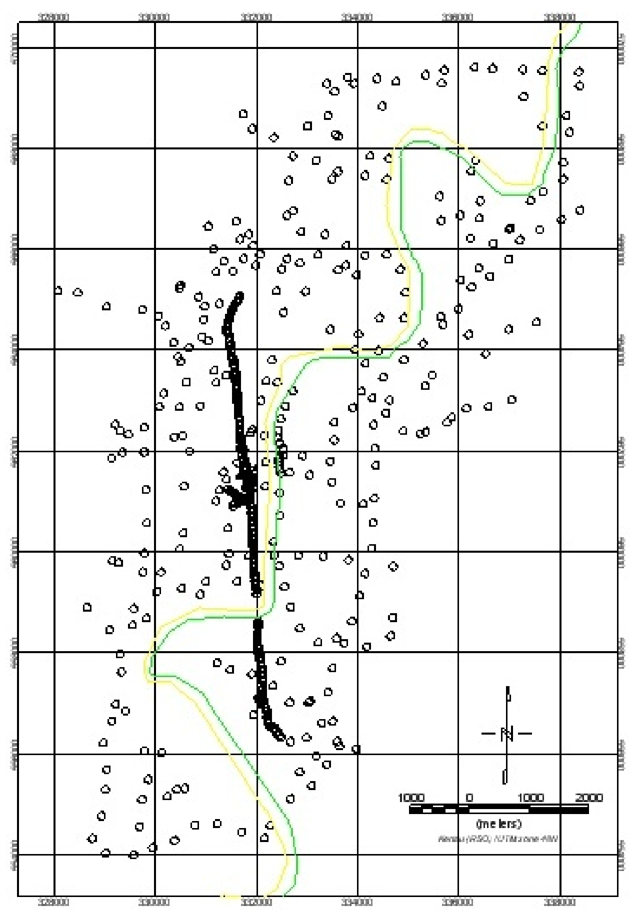

Figure 6: Map of observed gravity stations

The gravity data were corrected for drift, free air, bouguer, latitude and terrain in order to produce corrected bouguer anomaly data of the study area. The gravity data were then processed and analysed using Geosoft Oasis Montaj software to produce several gravity anomaly maps such as, bouguer, regional, residual, THD residual and THD regional anomaly maps, for qualitative and quantitative interpretation. Since about one fifth of known impact craters on Earth are covered with sediments, gravity is the major tool for investigation of theses craters (Grieve and Pesonan, 1992). The gravity signature of impact craters is relatively distinctive and the relationship between impact effects and density is somewhat straightforward (Pilkington and Grieve, 1992).

3. Result and Discussion

Several anomaly gravity maps had been produced and interpreted by qualitative and quantitative analysis.

3.1. Qualitative Analysis

The bouguer gravity anomaly map (Fig. 7) shows a negative low anomaly and some circular shaped in the study area.

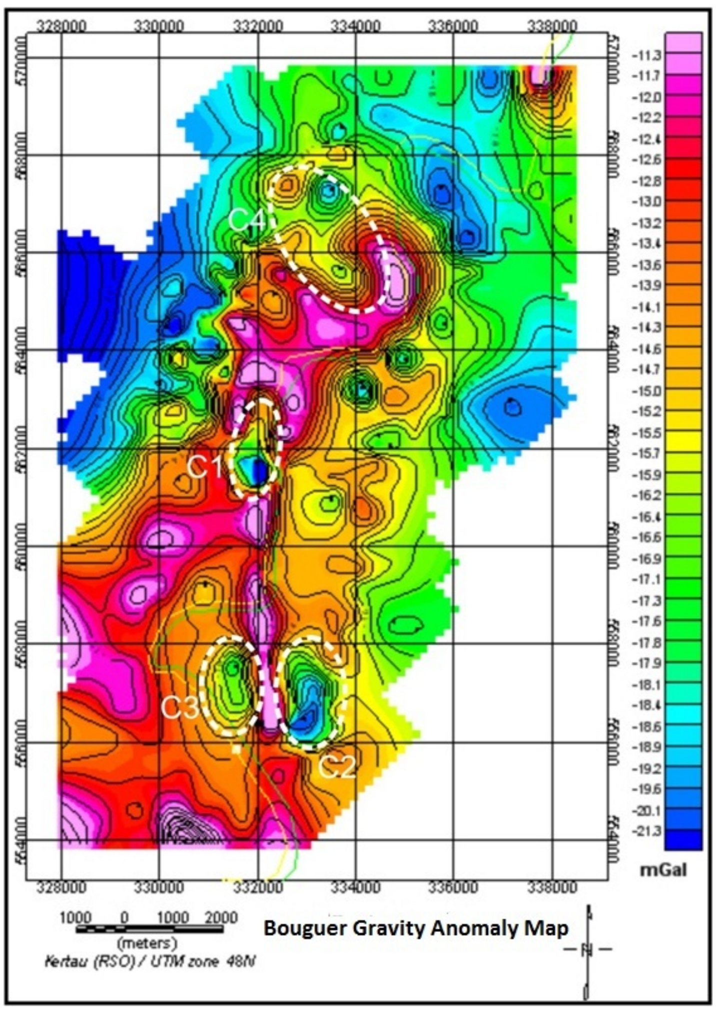

Figure 7: Bouguer gravity anomaly map of the study area

The map shows the occurrence of circular shaped in Bukit Bunuh area (C1). It surrounded by high anomaly with a diameter around 2.5km and interpreted as a remnant of meteorite impact crater. The low gravity anomaly is interpreted to be associated with low-density sedimentary fill, ejecta, and brecciated Suevite. Information from borehole data indicates that the subsurface geology at Bukit Bunuh area comprises of remnant of impact brecciated rocks (suevite) and weathered metasediments which are underlain by granitic rock basement. The bouguer anomaly map also shows the possible occurrences of three others impact craters (C2, C3, C4) located not very far to the northeast and southeast of the Bukit Bunuh impact crater. However, these structures need further detail investigation for confirmation.

Regional and residual gravity anomaly map had been produced to analysed subsurface structures. These maps were derivation of bouguer gravity anomaly map. Regional gravity anomaly map (Fig. 8a) shows the condition of basement. The anomaly tends to decreased in southwest-northeast direction. This indicated either the basement was shallower or alluvium sediment was thinner. Based on the surface geological condition, granite had been found in the southwest part of study area, therefore the first possibility is likely to be acceptable.

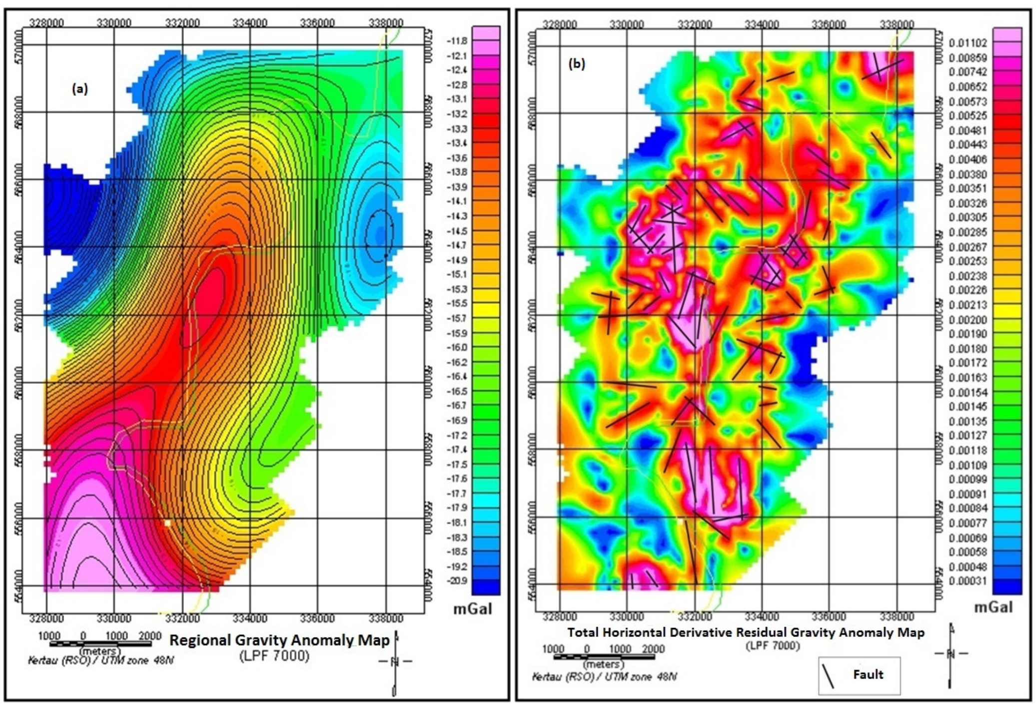

Figure 8: (a) Regional gravity anomaly map shows the condition of basement; (b) THD residual gravity anomaly maps shows the structure of shallower subsurface layer

Residual gravity anomaly map had been derived to produce Total Horizontal Derivative (THD) gravity anomaly map (Fig. 8b) that shows the structural condition of shallower subsurface layer. THD map shows the occurrence of lineaments and fault structures that concentrated in Bukit Bunuh and the direction is dominant to northwest-southeast. This data were supported by the result of rose diagram (Fig. 9) analysis that indicated the same dominant direction of the structures.

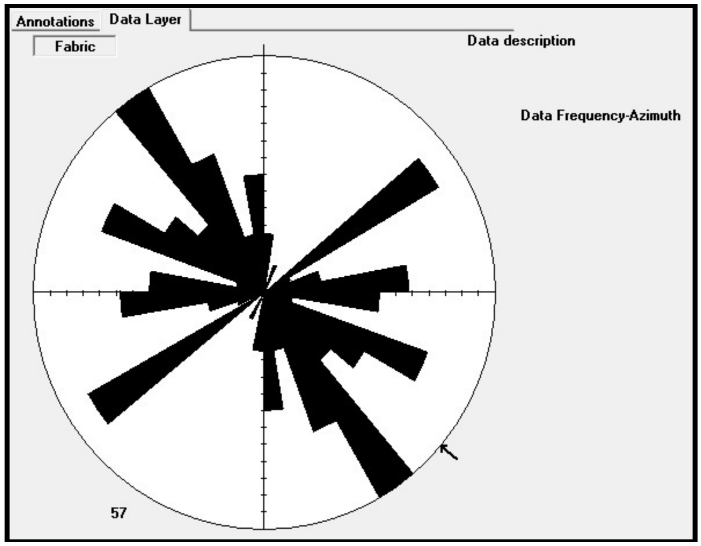

Figure 9: Rose diagram analysis indicated the dominant direction of lineaments and fault structures is northwest-southeast

3.2. Quantitative Analysis

An interpreted gravity model had been generated using GM-Sys 3D software. The model constructed based on several borehole data and bouguer gravity anomaly map of the study area. The 3D model (Fig. 10) shows the structure of impact crater is complex because of the occurrence of central uplifts.

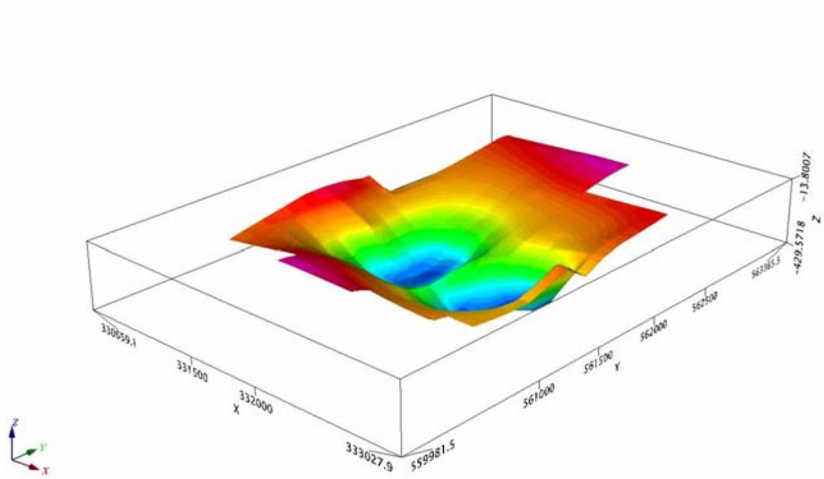

Figure 10: A 3D gravity models shows a complex crater structure with central uplifts

Based on this model, the diameter of impact crater approximately 2368 m and low density material including alluvium sediment, impact breccias (suevite) and metasediment with thickness about 400 m. The thickness of impact crater also could be determined from power spectrum analysis (Fig. 11) and the result had been displayed in a graphic that indicated the estimated layer and depth of impact crater. The graphic shows the subsurface structure divided into four section, 100 m, 130 m, 380 m and 400 m. The basement or the deepest part of impact crater had been interpreted belong to the last section. The 3D model of impact crater appears to tilt toward southeast direction (Fig. 12) suggesting the ancient meteorite that hit Bukit Bunuh area about 1.83 million years ago came from northwest direction.

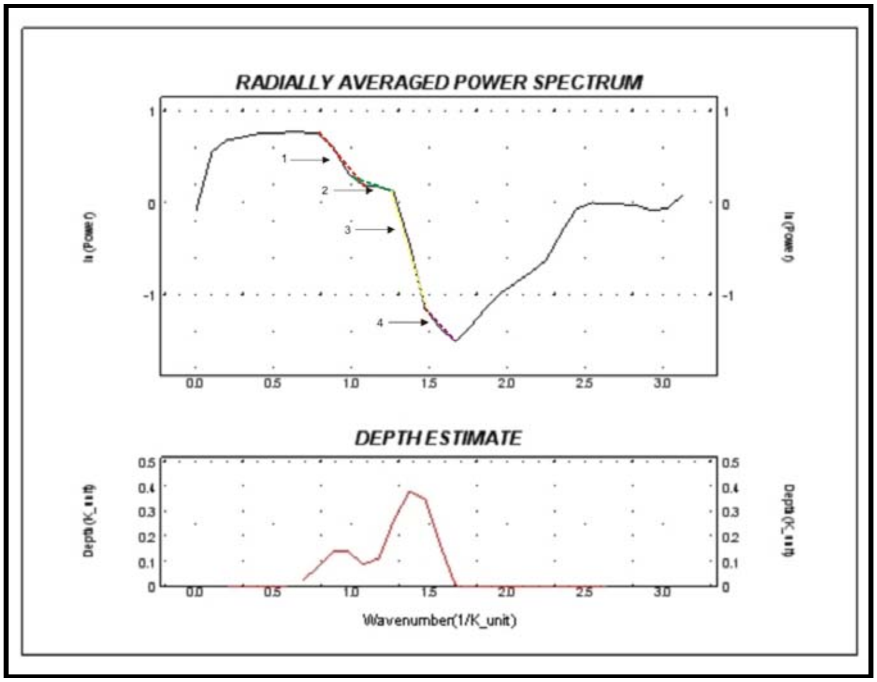

Figure 11: Power spectrum analysis to determined the estimated depth of impact srater

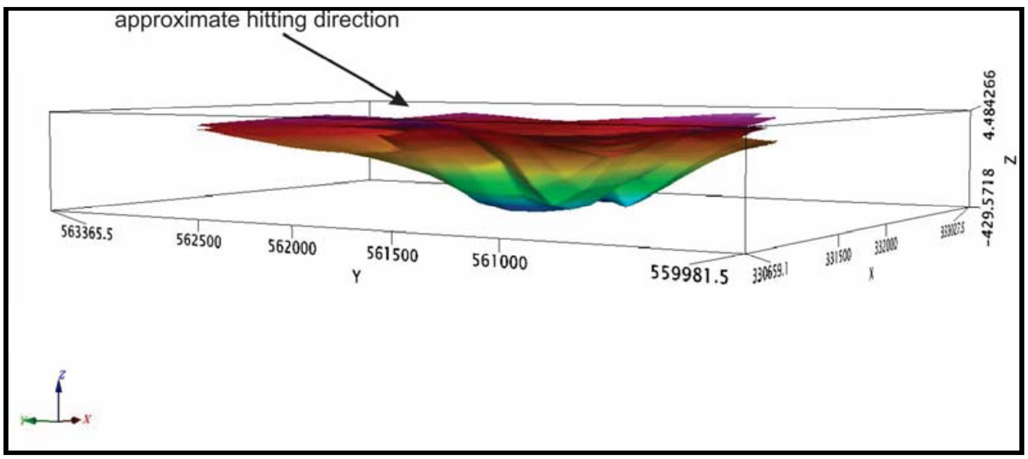

Figure 12: The direction of ancient meteorite that hit Bukit Bunuh 1.83 million years ago approximately came from northwest resulting the impact crater appears to tilt towards southeast direction

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