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Analyses of Magnetic and Gravity Data in Search for Meteorite Impact Crater at Bukit Bunuh, Lenggong, Perak, Malaysia

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ABSTRACT: *Analyses and interpretation of magnetic and gravity fields data acquired at Bukit Bunuh, Lenggong, Perak, Malaysia have been carried out in this study. The objective is to identify the meteorite impact crater and possible rebound locations. This study was instigated by an archaeological investigation carried out by the Centre for Global Archaeological Research, Universiti Sains Malaysia. The investigation suggested evidences of shock metamorphisms (suevite breccia) and crater morphology at Bukit Bunuh in Lenggong area of northern Perak, Malaysia. To justify the occurrence of the impact crater, ground magnetic and gravity surveys were conducted first as regional study in the entire area, followed by detailed study at the suspected crater region. Data from both surveys were compiled and corrected. The residual magnetic data ranged between −272 nT and +134.2 nT, whereas the Bouguer gravity data were between −25 mGal and 120 mGal. Both the magnetic and gravity data were gridded and plotted for qualitative interpretation. It was found that low magnetic and gravity region, believed to be an impact crater which is now filled with sediments and surrounded by a highly magnetised shallow bedrock, exists at the mid-part of the study area. Other high magnetic and gravity key features located within the central regions are interpreted as rebounds. In conclusion, the impact structure was successfully modelled as a complex impact crater.*

Keywords: Magnetic, gravity, meteorite impact crater, rebounds, Bukit Bunuh

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1. INTRODUCTION

Geophysics applies fundamental principles of physics to probe the earth's subsurface. It covers everything from experiments to determine the thickness of overburden or sediments (which is important in hydrocarbon exploration) to the studies of shallow structures for exploring minerals, groundwater and other economic resources. In addition, it is concerned with surveys to locate narrow mine shafts and other forms of buried structures such as pipes, cables and cavities, or mapping of archaeological remains.[1] Detection of structures beneath the surface will therefore depend upon those properties that distinguish them from the surrounding media. Different methods may thus be applied to wide range of investigations depending on their suitability to resolve the targeted structure in relation to its surrounding environment. For example, seismic method takes the advantage of contrast in velocity of acoustic waves as they propagate through the subsurface to distinguish between rocks and soils of varied materials.[2] Ground Penetrating Radar (GPR) is also another powerful tool used for very shallow studies, particularly when subsurface structures are distinguishable by their conductivity or reflectivity to radar pulses.[3] In the same manner, electrical resistivity method uses contrast in resistivity distribution to distinguish between subsurface materials.[4]

The magnetic method involves measuring the earth magnetic field at specific locations on earth's surface to determine locations of subsurface magnetic contrasts. The magnetic method works only when buried objects have different magnetic susceptibilities, which are caused by the object having a greater or lesser magnetism than the surrounding material.[5,6] The gravity method involves measuring the earth's gravitational field at specific locations on earth's surface to determine the points of subsurface density variations. The gravity method works well when buried objects have different masses, which are caused by the object having a greater or lesser density than the surrounding medium.[7,8]

Potential fields (magnetic and gravity) survey has received enormous attention from various survivors and researchers for many years.[9,10] Advancements have also made it possible to acquire and utilise data in air, at sea and on land.[11–13] Cost effectiveness and resolution obtained from ground surveys, especially for small scale projects, have made it very attractive for prospecting mineral deposits, ground water and study of localised (low magnetic or gravity) sedimentary infill in a (high magnetic or gravity) bedrock.[14–16]

Previous works in the area have applied active geophysical methods such as resistivity and seismic for the same objective.[17,18] Others have even applied the gravity and the magnetic methods separately to model the Bukit Bunuh impact crater.[7,16] The outcomes of these researches have showcased the crater model in reasonably different patterns. This is for the fact that each of these methods is distinct in the way data is acquired, processed and analysed, and most importantly how target structures are modelled in relation their surrounding environment. For the fact that a typical impact crater (Figure 1) can be viewed as a bowl-shaped cavity (within a bedrock) partially filled with breccias lens and other sedimentary materials, the present study thus applied magnetic and gravity methods to model the target structure in the study area.[18]

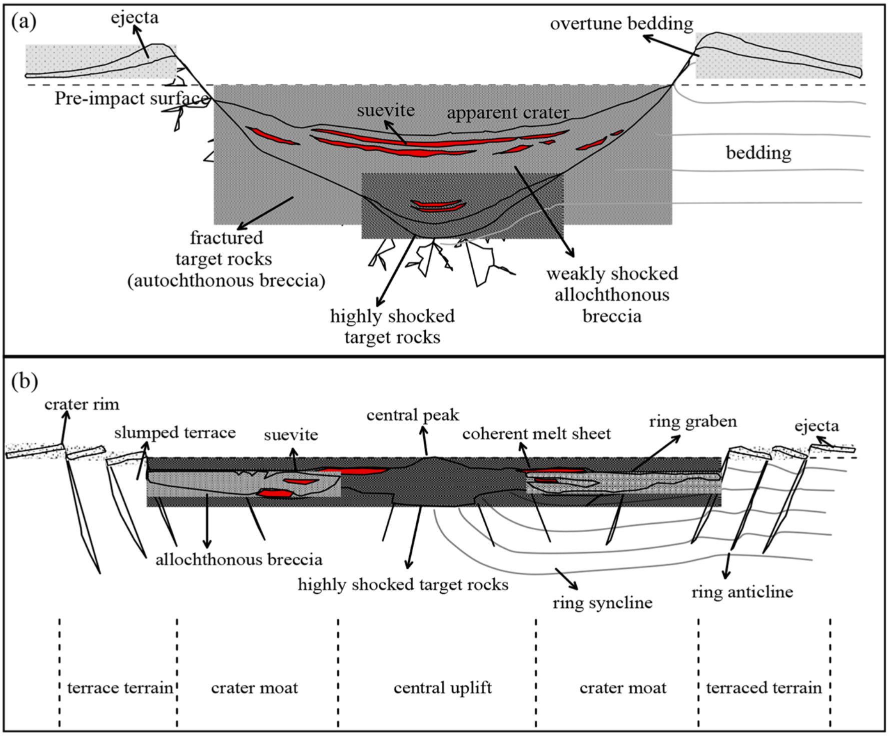

Figure 1: Crater cross-sections of (a) simple crater and (b) complex crater.[9]

The study objectives are to identify meteorite impact crater and redefine its rebound locations, typically indicated by high magnetic and gravity anomalies within the crater region. This is particularly useful if the impact crater is to be classified as simple or complex. In doing so, one form of data may not be adequately enough to accomplish this task, as anomalies which may arise due to magnetic field may differ from those due to gravitational field of the source. Therefore, this research combines the two forms of data to extract more information about the target structure. Both forms of data are used to check one another to reduce ambiguity in interpretation; as unwanted anomalies due to shallow ensembles and noise in the gridded data may pose similar signatures as those of the desired deeper sources.

2. EXPERIMENTAL

In this section, a brief account of geology and general description of the study area is provided. An account of experimental procedures conducted in relation to data acquisition and processing is also provided.

2.1 Study Area

Bukit Bunuh is an integral part of Lenggong district of Perak, Malaysia. It encompasses a total land area of about 132 km^2, between Lenggong town to the north and Kampung Raban to the south. Topography of the study area is generally undulating with thick vegetation from jungles, rubber and oil palm estates. Lenggong is underlain by granitic rocks of possibly Jurassic to Carbonaceous era.[19] Prominent lithology is made up of alluvium—which is found along river banks as quaternary sediment—and granite (Figure 2). Suevite rocks of various shapes and sizes, pebbles and cobbles classified as impacted rocks, suggested an evidence of meteorite impact, dated to about 1.83 million years back.[20]

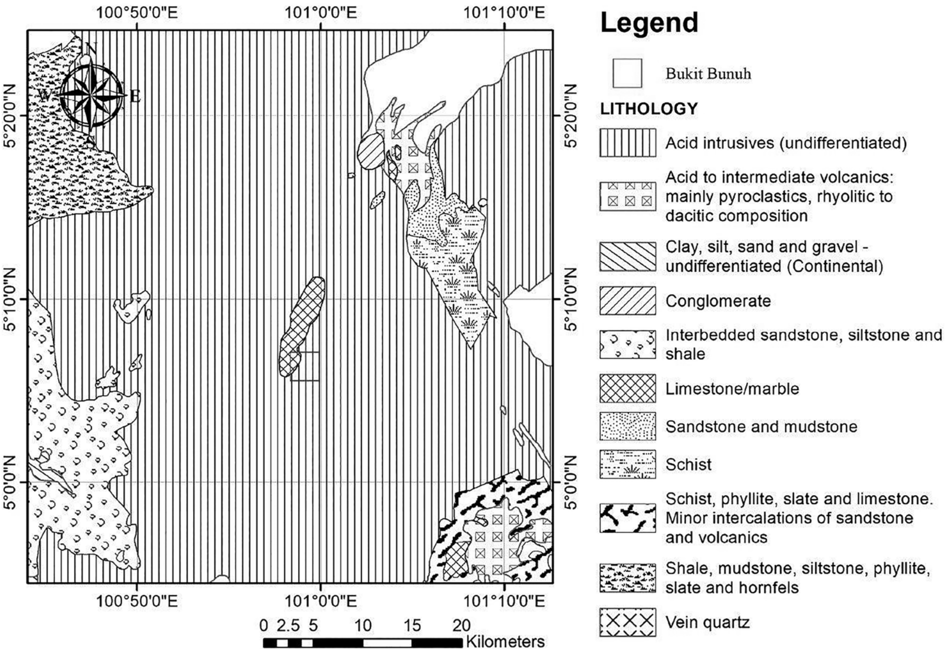

Figure 2: Geology map of the study area.[17]

Suevite is a rock consisting partly of melted material, typically forming a breccia containing glass and crystal or lithic fragments formed during an impact event. It forms part of a group of rock types and structures that are known as impactites.

Suevite is thought to form in and around impact craters by the sintering of molten fragments together with unmelted clasts of the country rock. Rocks formed from more completely melted material found in the crater floor are known as tagamites. Suevite is distinct from the pseudotachylite in an impact structure as the latter is thought to have formed by frictional effects within the crater floor and below the crater during the initial compression phase of the impact and the subsequent formation of the central uplift. Suevite is one of the diagnostic rock types for significant impact structures. It has been described from many of the larger impact structures identified on earth.

2.2 Data Acquisition and Analyses

Ground magnetic data were acquired using Geometrics G-856 proton precession type magnetometer and GPS navigation equipment at the study area in two phases: regional and interest. The regional phase was the first stage of the survey, conducted to cover the entire study area at relatively larger station spacing, while the interest phase was the second stage of a more detailed data acquisition after roughly analysing the results of the regional stage (regional phase). The regional stage covers an approximate area of about 132 km^2 from Lenggong town at the northern region until Kampung Raban at the southern region.[7,21] The total magnetic field intensity readings were taken at 580 stations in the study area, with stations spacing of about 200–500 m. The stations spacing was chosen to be at least five times less than the expected target size or dimeter. A layout map showing the data acquisition points is given in Figure 3. The data acquired were first preprocessed to identify the interest area, giving rise to the second phase of the work in which data was acquired at 50 m stations spacing. During the data acquisition, suitable base station was established close to the study area to take readings at 1-minute interval for diurnal data corrections. Elevation data were also recorded with the aid of an altimeter. The magnetic data were corrected for International Geomagnetic Reference Field (IGRF) and diurnal variations of the earth magnetic field. The IGRF was subtracted to obtain a corrected magnetic anomaly data for the area.

The gravity survey was similarly conducted in two stages at the same stations spacing as the magnetic (for both regional and interest). Gravity measurements were carried out with CG5 Scintrex microgravity meter using looping technique, to monitor and eliminate the potential drift effect. The observed gravity data were tied to an established gravity station. Station coordinates and elevation were determined using global positioning system (GPS) instrument. The raw gravity data were then corrected for drift, latitude, free air and Bouguer to produce corrected Bouguer anomaly data. Both residual magnetic field and the Bouguer gravity datasets were then gridded and plotted using Oasis montage software package. Patterns of anomalies shown in contours were observed and interpreted.

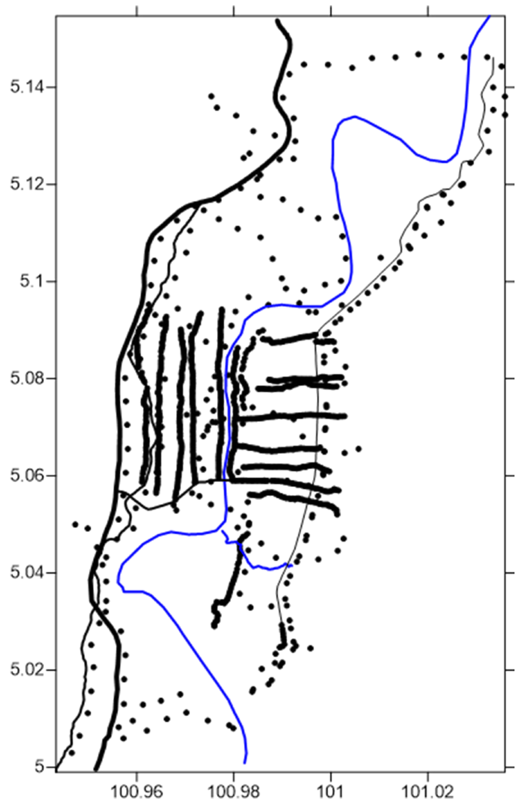

Figure 3: Survey layout for magnetic and gravity data acquisition.

3. RESULTS AND DISCUSSION

Figure 4 presents contour plot of the residual magnetic field intensity data of the study area. The residual magnetic field intensity data are obtained with values from −272 nT to +134.2 nT. Magnetic high anomaly features (> −40 nT) are predominant at northern and southern parts of the figure. These are interpreted as signatures of relatively shallow bedrock.[16] Conversely, the mid part of the figure (region of the interest covered in the second phase of data acquisition) is of low magnetic background (< −40 nT) with noticeable magnetic high anomalies distributed everywhere, especially in the regions marked A, B and C. The magnetic low anomaly is an indication of deeper bedrock covered by low magnetic infill materials; typically breccias lens and other sedimentary materials, and thus the suspected impact crater region.[21] The suspected crater rim is marked by a circle (Figure 4). The magnetic high anomalies at the regions A, B and C are also indications of shallow bedrock, suspected to be the rebound areas.[22]

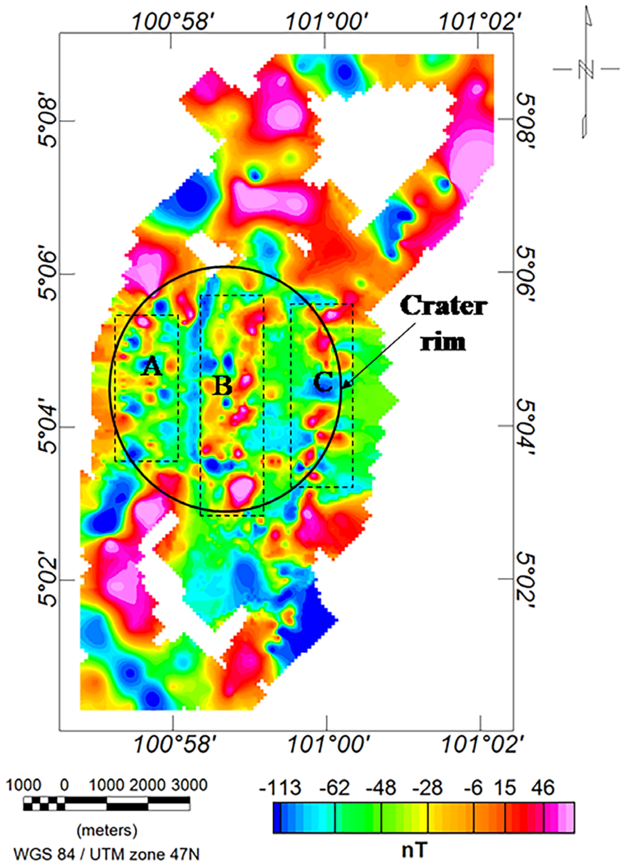

Figure 4: Residual magnetic field intensity data of the study area.

Figure 5 shows the Bouguer gravity field intensity data of the study area. The Bouguer gravity values are generally between −25 mGal and 120 mGal. Low (negative) values of Bouguer gravity indicate low density beneath the measurement points, whereas high (positive) values of indicate high density beneath the measurement points. The fractured rock is less dense than the unaltered target rock (forming the ring) around the structure. Higher values (> 40 mGal) are found at the northern and southern parts as well as at the western edge of the area. This is interpreted as shallow granite bedrock compared to the middle area with lower bouguer gravity values (< 40 mGal), interpreted as overburden or fractured area.[7,23] The low gravity region indicates deeper bedrock covered by low gravity thick sediment or overburden, and thus the suspected impact crater region.[24] The crater rim is also marked (Figure 5) as in the magnetic map. The high gravity anomalies observed at the portions marked A, B and C in the Figure 5 are also indications of shallow bedrock suspected to be the rebounds.

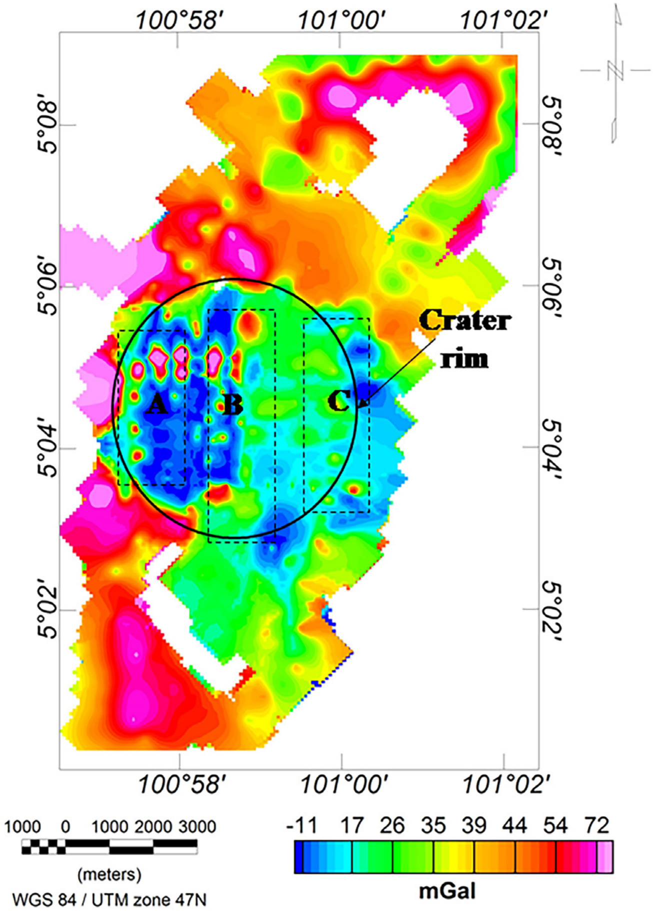

Figure 5: Gravity field anomaly contour map of the study area.

To confirm exact rebound locations, both magnetic and gravity field anomalies are visually correlated with one another. It is observed that most of magnetic high anomalies located in region C of Figure 4 do not correlate well with gravity anomalies in the same region (Figure 5). These anomalies may therefore indicate signatures of shallow ensembles and noise in the grids, but do not extend to the bedrock. Most anomalies in regions A and B of both magnetic and gravity field data maps are however clear and common in both regions, signifying that they may extend to the bedrock. The presence of these rebounds has thus indicated that the impact crater is a complex type. It can be deduced from the magnetic anomaly map that a diameter of approximately 5 km is obtained for the impact crater.

4. CONCLUSION

Ground magnetic and gravity data covering part of Bukit Bunuh area in Lenggong district of Perak, Malaysia has been acquired, analysed and interpreted in this study. Both methods identified the interest area as a circular shaped portion, with shallow bedrock around the edge and deeper bedrock at the inner part of the circle. This region was interpreted as an impact crater, having lower magnetic and gravity intensity relative to the surrounding regions. Few shallow bedrock units, interpreted as rebounds, were identified at the inner of the circle. The presence of these rebounds as central uplifts from the bedrock favoured the conclusion that the impact crater is a complex type. It is recommended that all the four geophysical methods (resistivity, seismic, magnetic and gravity), previously used in isolation to map the study area, be put together to come up with a more precise impact crater model.

5. ACKNOWLEDGEMENTS

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