Internal Architecture of Meteorite Impact Crater at Bukit Bunuh, Lenggong – Perak, Malaysia Inferred from Upward Continuation of Magnetic Field Intensity Data

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Abstract. 2-D upward continuation of magnetic field data acquired at Bukit Bunuh, Lenggong – Perak, Malaysia, with the objective to ascertain the impact crater and possible rebounds, has been carried out and interpreted in this study. Ground magnetic survey was conducted first as regional study in the entire area followed by a detailed study at the suspected crater region. Data from both studies were compiled, corrected and separated (regional – residual). The residual magnetic data ranged between -272 and +134.2 nT. 2-D upward continuation at various planes of observation was carried out on the gridded residual magnetic field data after coordinates were converted (from degrees to meters) to undestate anomalies due to shallow features. The planes were at 250 m, 500 m and 750 m above the ground level. The continuation at 500 m revealed a low magnetic region, believed to be an impact crater, which is now filled with sediments, surrounded by a high magnetic shallow bedrock. Other high magnetic key features interpreted as rebounds (R) also remained after filtering out the ambiguous anomalies.

1. Introduction

Magnetic survey has received enormous attention from various survivors and researchers for many years [1], since it provides a handy means for investigating subsurface structures based on magnetic susceptibility contrast of the underlying materials [2]. Advancements have also made it possible to acquire and utilize magnetic data in air [3], at sea [4] and on land [5]. Cost effectiveness and resolution obtained from ground magnetic surveys especially for small scale projects, have made it a very attractive tool for prospecting mineral deposits [6], ground water [7] and study of localized (low magnetic) sedimentary infill in a (high magnetic) bedrock [8]. Since 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 [9], the present study has thus adopted ground magnetic survey to investigate the study area. The study objective is to identify and redefine the rebound areas indicated by high magnetic anomalies within the crater region. This is particularly useful if the impact crater is to be classified as simple or complex. Unfortunately, using only the contour plots of the acquired data without recourse to filtration techniques will make difficult to accomplish this task, because undesirable anomalies due to shallow ensembles and noise in the data may also pose similar signatures.

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as the deeper sources. Upward continuation is one such filters capable of reducing the effect of short wavelength features due shallow sources and noise in grids to a certain level, thereby enhancing large scale (usually deep) features in the survey area [10].

![Diagram of impact craters](image)

**Figure 1.** Crater cross – sections (a) simple and (b) complex impact craters [9].

2. **Study area**

Bukit Bunuh is an integral part of Lenggong district of Perak, Malaysia. It encompasses a total land area of about 132 km², 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 underlaid with granitic rocks of possibly Jurassic to Carbonaceous era. Prominent lithology is made up of alluvium – which is found along river bank 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 [11].
3. Methodology

Ground magnetic data were acquired using Geometrics G-856 proton precession type magnetometer and GPS navigation equipment at the study area in two phases; i.e. regional and interest. At the regional phase, station spacing of 200 – 500 m was used. The data acquired were first preprocessed to identify the interest area, giving rise to the second phase of the work, whose data was acquired at 50 m station 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 altimeter. Residual magnetic field data was then gridded and plotted after regional – residual separation and coordinates conversion (degrees to meters) in preparation for the upward continuation, using Oasis montaj software package.

It is convenient to implement upward continuation on magnetic field data for the fact that potential fields generally obey Laplace’s equation. This permits us to determine the field over an arbitrary surface if the field is known completely over another surface, which is known as continuation [12]. To reduce the effect of short wavelength features due shallow sources and noise in grids to a certain level, thereby enhancing large scale features of the study area, upward continuation of the residual magnetic field intensity data was carried out at various planes of observation. The planes were at 250 m, 500 m and 750 m above the ground level. The method tends to accentuate anomalies caused by deeper sources at the expense of anomalies caused by shallower sources [13]. Following the method of Grant and West [14], the upward continuation is given by the following Equation (1)

$$ F(x',y',-h) = \frac{h}{2\pi} \int \frac{F(x,y,0)dx\,dy}{\left[(x-x')^2+(y-y')^2+h^2\right]^{3/2}} $$

(1)
The left side of the equation is the total field at point \(F(x',y', - h)\) above the surface on which \(F(x,y,0)\) is known. The calculation procedure is to replace the integral with a weighted sum of values taken on a regular grid.

The empirical formula of Henderson [15] from Equation (2) provides the field at the elevation \(h\) above the surface in terms of values \(F(r_i)\), the average value \(\overline{F(r_i)}\) over a circle of radius \(r_i\) centred at the point \((x,y,0)\)

\[
F(x,y, - h) = \sum \overline{F(r_i)} K(r_i, - h) \tag{2}
\]

Where \(K(r_i, - h)\) are weighting coefficients. These coefficients when calculated, give the upward continued field within 2% error [12].

4. Result and discussion

Figure 3 presents contour plot of the residual magnetic field intensity data of the study area. The residual magnetic field intensity data were obtained with values of -272 to +134.2 nT. Magnetic high anomaly features are predominant at northern and southern parts of the map. They are interpreted as signatures of a relatively shallow bedrock. Conversely, the mid part of the map (region of the interest covered by the second phase of data acquisition) is of low magnetic background with noticeable magnetic high anomalies distributed everywhere, especially in the regions marked; A, B and C. The magnetic low is an indication of deeper bedrock covered by low magnetic infill materials, and thus the suspected impact crater region. The crater rim is marked by the circle. The magnetic highs at the A, B and C regions are also indications of shallow bedrock suspected to be the rebound areas.

To confirm exact rebound locations, the field was continued at various planes at heights above the earth surface. Figure 4 shows map of the continued field at 250 m, in which most of magnetic high anomalies located in regions A and C have almost completely disappeared, indicating that they are only signatures of shallow ensembles and noise in the grids, and therefore did not extend to the bedrock. Anomalies in region B, however, are persistent and clear, signifying that they may extend to the bedrock. To reaffirm this, the field was further continued at 500 m (Figure 5), in such a case all the anomalies in regions A and C completely vanished, and the anomalies in region B are further filtered and redefined to four distinct signatures, interpreted as the rebounds \(R_1, R_2, R_3\) and \(R_4\). It may also be possible for \(R_4\) to be part of the crater edge, since it is located just in-between two other major magnetic high anomalies believed to form the southern edge of the crater. The upward continuation map at 750 m (Figure 6) revealed that even the most prominent among the minor anomalies can disappear when the continuation plane is too high. Even as such, \(R_1\) and \(R_4\) are still present and clearly seen, which are more prominent than \(R_2\) and \(R_3\). The presence of these rebounds has further indicated that the impact crater is a complex type.
Figure 3. Magnetic field anomaly contour map of the study area.

Figure 4. Upward continuation of the magnetic field data at 250 m.

Figure 5. Upward continuation of the magnetic field data at 500 m.

Figure 6. Upward continuation of the magnetic field data at 750 m.
Conclusion
Ground magnetic data covering part of Bukit Bunuh area in Lenggong district of Perak, Malaysia has been acquired, analyzed and interpreted in this study. It is established that an impact crater, characterized with low magnetic anomaly and surrounded by high magnetic anomaly due to shallow bedrock, exists at the mid part of the study area. The presence of three to four rebounds as central uplifts from the bedrock, identified after filtering the gridded data by upward continuation, supports the conclusion that the impact crater is the complex type.

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