

Enhancing Magnetic Interpretation Towards Meteorite Impact Crater at Bukit Bunuh, Perak, Malaysia

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Abstract. Bukit Bunuh is the most popular area of suspected meteorite impact crater. In the history of meteorite impact hitting the earth, Bukit Bunuh has complex crater of a rebound zone of positive magnetic anomaly value. This study area was located at Lenggong, Perak of peninsular Malaysia. The crater rim extended 5 km outwards with a clear subdued zone and immediately surround by a positive magnetic residual crater rim zone. A recent study was done to enhance the magnetic interpretation towards meteorite impact crater on this study area. The result obtained is being correlated with boreholes data to determine the range of local magnetic value. For the magnetic survey, the equipment used is Geometric G-856 Proton Precision magnetometers with the aids of other tools such as compass and GPS. In advance, the using of proton precision magnetometer causes it able in measures the magnetic fields separately within interval of second. Also, 18 boreholes are accumulated at study area to enhance the interpretation. The additional boreholes data had successfully described the structure of the impact crater at Bukit Bunuh in detailed where it is an eroded impact crater. Correlations with borehole records enlighten the results acquired from magnetic methods to be more reliable. A better insight of magnetic interpretation of Bukit Bunuh impact crater was done with the aid of geotechnical methods.

1. Introduction

Magnetic methods on meteorite impact have a long history in the meteorite impact study. Among the geophysical methods which had been previously applied in the meteorite impact crater investigation, magnetic field measurements around impact structures may have given the poorest response over the other methods such as seismic, electrical resistivity, and gravity. Magnetic low is a signature for some of the craters found, for example, Mien crater [1], Dellen crater [2] and Kärddla crater [3]. The dominant effect of magnetic low anomaly or subdued is closely related to the major impact structures [4][5], which generally distinguish as a truncation of the regional magnetic indication. However, the other impact structures on a strong local magnetic anomaly either positive or negative may be produced by the remanent magnetization. Hence, these types of magnetization are occurred due to the units of impact melt within the structure or also could be found by the uplift of more magnetic units from depth into the central uplift [6].



The magnetic method has seldom had been used in correlation with borehole data for interpretation compared with other geophysical method such as seismic and resistivity. It provides potential field measurement which does not relate directly to depth. A study of tectonic features and subsurface in the Thrace Basin using the integration of magnetic, borehole data, gravity, and seismic reflection had been done [7]. Sediment thickness in Thrace Basin is accurately determined, and magnetic response towards intrusion and metamorphic basement outcrops is identified. The exact depth is hard to obtain in the magnetic modeling where the anomalies are only caused by the lateral magnetization contrasts [8]. Geology survey and mapping in the area surrounded of Bukit Bunuh have found many block of rocks with angular and variety of sizes from 0.3 m till more than 9.0 m. Rock types found are classified into suevite, impact rock, and shock gneiss. Even though the original rocks have undergone an impact, the rocks found on the site were still comprised of clastic rock and igneous rock. Most of the impact rock is distributed at the west of Bukit Bunuh where a variety of sizes [9]. The distribution of rock sometimes concentrated with size in between 1 m to 2 m. Round shapes of rock indicate that the rock was produced from the meteorite impact. There is the distribution of some suevite rock, which covers less than 5 km² area and could be an indication of the diameter of meteorite impact not less than 2 km. The appearance of the rocks with a hole that resembles looks like vesicle present around the rocks due to the recrystallization occurs within the structures. The ejecta blanket that exists at the outer part of the crater is due to the fraction of rock that settles or falls after the impact, and it settled down as small sizes of the angular shape of rock [10]. Borehole records correlate well with magnetic residual value where the thicker sediment infilling has lower magnetic residual and vice versa. From the record, it is shown that the depth of bedrock at the crater rim and rebound area is shallow to only 3.00 m and the interior of crater is found with the depth of 18.0 m. The delineation of fault and fracture at this study area has been map by [11] with using magnetic response mapping and proven by the borehole records. Parameters like sediment thickness and range of magnetic residual values were extracted to correlate with the defined crater from previous studies.

2. General Geology

Bukit Bunuh was bounded between Titiwangsa Range and Bintang Range. The Lenggong Valley covered with a few of lithology which is alluvium, tephra dust, and granitic rock. Alluvium is the mostly found along the river area. Meanwhile, the granitic rock is from Jurassic to Carbonaceous were also dominated in the whole of Lenggong area which is originated from Bintang Range at the west of Lenggong [12]. In addition, the nearby area to the river also covered with Quaternary deposits such as clay and sand.

3. Study Area

This study was carried out in the area of Bukit Bunuh, located 1 km away from the town of Kota Tampan, Lenggong, Perak which is about 17×10 km². This study was dividing into two parts which are regional study and detailed study. The direction of the magnetic survey is towards the southwest. Figure 1 shows the map of Lenggong, Perak from front-view of Google map and pointed area represented the study area. There are about 18 boreholes were done around the rebound zone to reduce the ambiguity of magnetic data interpretation. Hence, crater interior and crater rim that defined from the magnetic results.

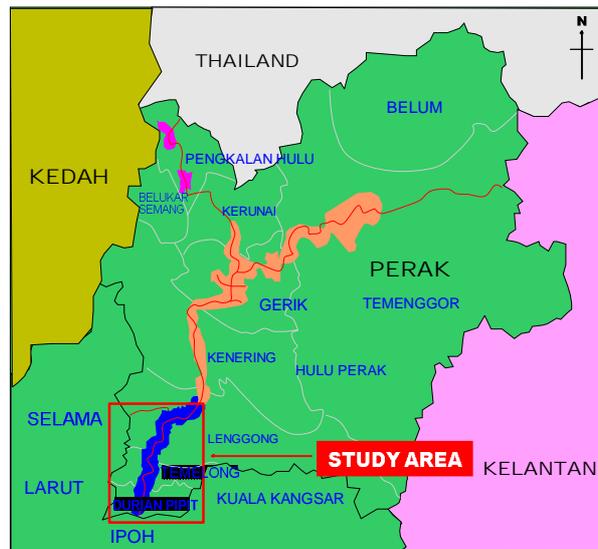


Figure 1. The study area at Lenggong, Perak.

4. Research Methodology

The magnetic surveys were conducted using Geometric G-856 Proton Precision magnetometers with the aids of some accessories such as GPS and compass. The moving station of this survey was set at 250 m to 500 m for regional study and 50 m for detailed study interval or in whichever distance permitted to cover the whole of the survey area. The location of the base station was set at the same spot throughout the survey and relatively far away from the magnetic disturbance. The reading of base station was set to auto function and taken for an interval of 1 minute. The magnetic data processing started with applying data reductions before deducting with the base reading to get magnetic residual values. Finally, a magnetic residual contour map is generated using Surfer 8 software. To supervise the interpretation, the records from four existing boreholes and addition of 14 new boreholes (Figure 2) are used to integrate with the magnetic response of Bukit Bunuh area.

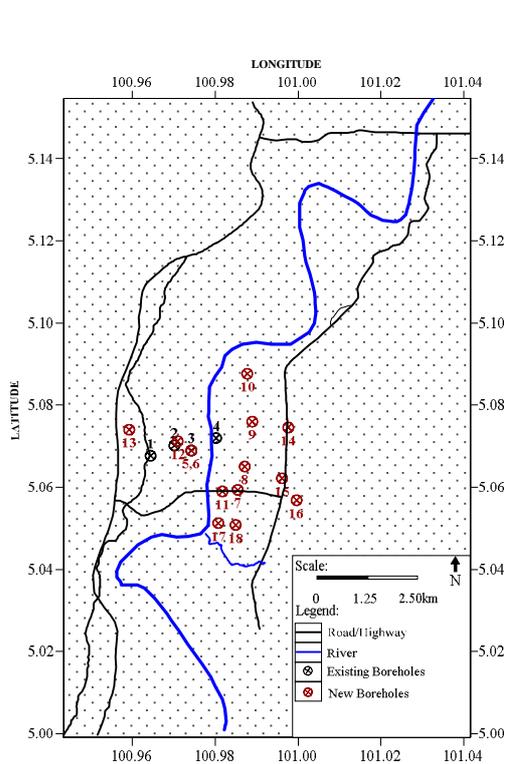


Figure 2. Existing and new boreholes located around Bukit Bunuh area.

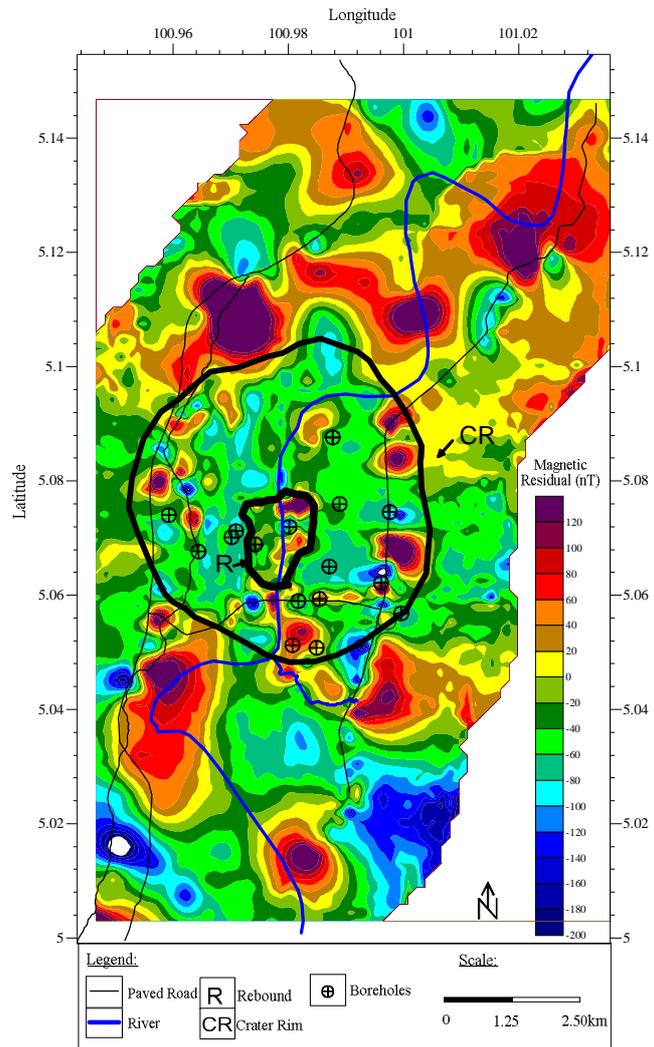


Figure 3. Map of Boreholes positions with crater rebound and crater rim identified.

5. Result and discussion

An additional of 14 boreholes which make the total number of 18 boreholes accumulates at the Bukit Bunuh impact crater area. The additional boreholes record will enhance the interpretation towards the subsurface utilizing the magnetic survey. The location of the boreholes is overlaid on top on the residual magnetic map of Bukit Bunuh impact crater (Figure 3) for better understanding and aid in interpretation at ease. Table 1 shows the sediment thickness and magnetic residual value for existing and new boreholes records.

Table 1 Sediment thickness and magnetic residual value for existing and new boreholes records.

Existing / New	Location	Borehole (BH)	Sediment thickness before reaches impact/weathered granite (m)	Magnetic residual value range (nT)
Existing	Crater rim	1	3.00	-20 to 0
Existing	Crater interior	2	18.00	-100 to -80
Existing	Rebound zone	3	3.00	0 to 20
Existing	Rebound zone	4	7.50	-60 to -40
New	Rebound zone	5	1.50	-20 to 0
New	Rebound zone	6	3.00	-20 to 0
New	Crater interior	7	12.50	0 to 20
New	Crater interior	8	13.00	-120 to -100
New	Crater interior	9	15.00	-60 to -40
New	Crater interior	10	12.00	-60 to -40
New	Crater interior	11	15.00	-60 to -40
New	Crater interior	12	12.00	-80 to -60
New	Crater rims	13	18.00	-60 to -40
New	Crater rims	14	13.50	-100 to -80
New	Crater rims	15	13.00	-20 to 0
New	Crater rims	16	13.60	-80 to -60
New	Crater rims	17	10.50	60 to 80
New	Crater rims	18	15.00	0 to 20

The suspected area of crater rim or the edge of the crater rim is located at the location of boreholes 1,13 – 18 with sediment thickness of 3 – 18 m and may residual values of -100 to 80 nT. Borehole 1 and 6 shows a characteristic of shallow sediment or also known as ejecta layer deposited of 3.00 m with the magnetic residual value of -20 to 0 nT. Boreholes 1, 17 and 18 showed a positive magnetic response while the other boreholes were in the negative magnetic response area. The inconsistent variation of sediments thickness with respect to magnetic residual value may be due to a few effects. Bukit Bunuh impact crater is located at the tropical region which exposes to extreme erosion condition due to weathering processes. At present, thick sediment was found as a result of the downwards gravity pull due to a collapse of an initially deep transient crater causing rock units near the rim slumping downwards. During the excavation event, the collision caused tensional stress exceeds the mechanical strength of the target rocks which cause them to be fractured and shattered. The original crater rim may not preserve well at these conditions. The low magnetic residuals value spotted around the crater rim is identified as the deeply eroded structure with thick sediments measured.

While borehole 2, 7 – 12 show sediment depth of 12.00 – 18.00 m to drill through before hitting impact/weathered granite and have the low magnetic residual value of -120 – 20 nT. These boreholes were in the suspected crater interior, which has the deepest sediment infilling and the authigenic breccia formation area. The magnetic response of this area is low due to the reduction of the magnetic intensity field by the sediments.

Boreholes 3 – 6 were identified with the depth of 1.5 – 7.5 m. Before reaching granite rock with the magnetic residual value range of -60 – 20 nT. Borehole 3, 4 and 5 located at the suspected rebound area that shows a characteristic of shallow bedrock depth. Negative anomaly zone was suspected as the zone of a fractured cause by the impact. Hence, borehole 4 shows negative anomaly and bedrock depth of 7.5 m.

Meteorite impact is a near-surface activity and the magnitude deformation and shock metamorphism associated with impact structures reducing with depth. Most of the impact structures found are relatively shallow, and subsurface rock metamorphism produced from the activity is comparatively thin units of the earth crust. The top soils of the target area are removed during the excavation stage and causes the impact structures are now uncovered and extremely vulnerable to erosion before the new layer of top soil. In the early stage of erosion, the near-surface ejecta deposits with the distinctively shocked and melted materials contain are preferred to be removed. Thus, the most convincing and comprehensive evidence of impact is rapidly destroying, and the crater is now camouflaged.

6. Conclusion

The additional boreholes data had successfully described in detail the structure of Bukit Bunuh the impact crater where it is an eroded impact crater. Correlations with borehole records enlighten the results acquired from magnetic methods to be more reliable.

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