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Delineation of basement structure of Bukit Bunuh impact crater, Lenggong Valley Perak, Malaysia inferred from ground magnetic data

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Abstract
Ground magnetic residual data were acquired to delineate the subsurface basement structure of some parts of Bukit Bunuh impact crater, covering an area of 1.5 km². The data were collected on six profiles each 2 km long running in the North-South orientation with 0.15 km interline spacing at 30 m station interval. Data reduction and correction were carried out using Microsoft Excel, while krigging gridding method was applied on the data to produce contour, 3D surface and 3D wireframe maps. The contour map shows the study area has varying magnetic residual intensity with maximum and minimum values at 80 and -60 nT. Magnetic high intensity is interpreted as response from strongly remanent magnetized impactites (suevite rocks), while magnetic low is interpreted as response due to sediments from authigenic breccia. Long and parallel dislocations of magnetic low and high in the North-South orientation are interpreted as geological faults. Short dislocations with circular pattern of intermittent low and high magnetic residual intensity observed are interpreted as shear zones.3D surface map shows varying amplitudes on the surface map represented by peak in red and low in blue colours. The shear zones are depicted by undulating surfaces predominantly along longitudes 100.970, 100.973, and 100.976°E respectively. 3D wireframe displays gradationally coloured lines that show elevation. The maximum and minimum amplitudes observed on the map in pink and blue colours correspond to effects of suivite rocks, faults and shear zones. The study concludes that ground magnetic residual data could successfully delineate subsurface affected by meteorite impact.

Key words: Ground magnetic, basement structure, Bukit Bunuh, impact crater

1. Introduction
Bukit Bunuh impact crater at Lenggong valley Perak, Malaysia, was discovered in the year 2000 (Saidin, 2006) following the findings of research conducted by Nawawi *et al* (2004). The crater has a diameter of 2.5 km and categorized as a complex crater (Saad *et al*., 2013). Impact crater events are catastrophic phenomena that shaped the Earth, deformed its crust, altered its chemical composition and geological history (French, 1970, 1990; Shoemaker, 1977; Grieve *et al*., 1987, 1991; Henkel & Pesonen, 1992; Dressler & Sharpton, 1999). Crustal deformation linked to impact cratering process produce basement structures which are host to minerals and hydrocarbons resources. The economic importance of impact crater has escalated research into finding clues associated with crater area, which are recognized by

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landmarks and petrographic features which are degraded over the years by weathering process such as erosion and sedimentation; making it difficult to be identified (Henkel & Pesonen, 1992). Geophysical signature provides a good tool in tracing terrestrial impact crater (Pilkington & Grieve, 1992). Application of geophysical methods in the study of meteorite impact is founded on geophysical principles: identifying contrast in physical properties between background medium and anomalous zone. The anomalous zones are recognized by pattern of anomalies caused by change in the physical properties of rocks at the vicinity of impact (Henkel & Pesonen, 1992) Pilkinton & Grieve, 1992). Past studies on meteorite impact using geophysical applications such as gravity, magnetic, electrical resistivity, and seismic have produced good results (Unsworth, 2002; Delgado-Rodriguez *et al.,* 2001; Bäckström, 2004; Adepelumi, 2004; Morgan *et al.,* 2000; Westbroek, 1997; Stierman, 1997; Danuor, 2013; Ortiz-Aleman & Urrutia-Fucugauchi, 2010; Ugalde e*t al.,* 2007; Muundjua *et al.,* 2007; Ismail, 2014) since impactites respond well to geophysical signals and thus making it an indispensable tool. Bukit Bunuh impact crater has been investigated using geophysical applications to shed more light on its existence and the researches produced good results (Kiu *et al.,* 2013; Nordiana *et al.*, 2013; Saad e*t al.,* 2013; Ismail, 2014; Saad, 2016).

In this study, a portion of Bukit Bunuh impact crater areawas studied using ground magnetic residual data with the objective to delineate the subsurface structure in the study area. The method was chosen because it alone can give a general idea about the subsurface structures affected by the impact.

2. Location of the study area

The study location Bukit Bunuh (Fig.1) is on coordinates of 5º4.5'00'' N and 100º58.5'00'' E within oil palm estate and about 10 km from Lenggong valley in the upper part of Perak. It lies between two mountain ranges, Titiwansa Range and Bitang Hill in a rugged terrain

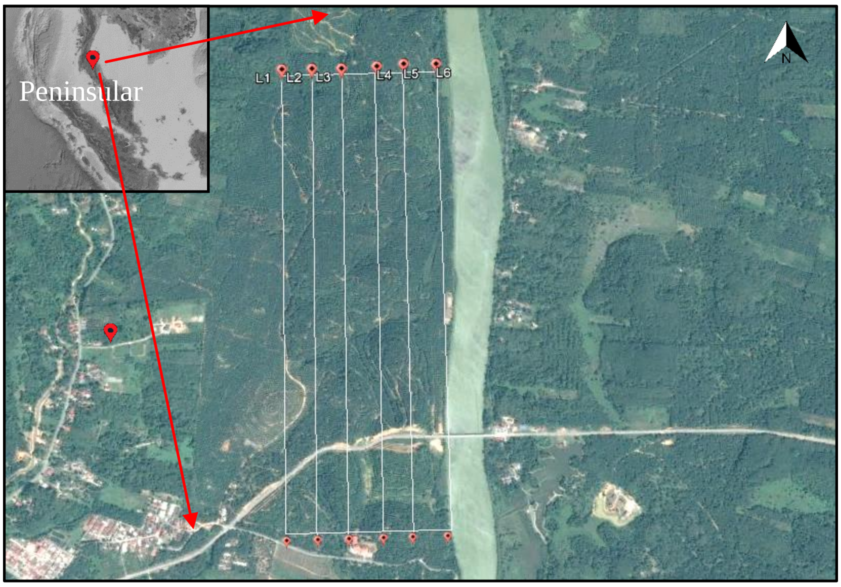
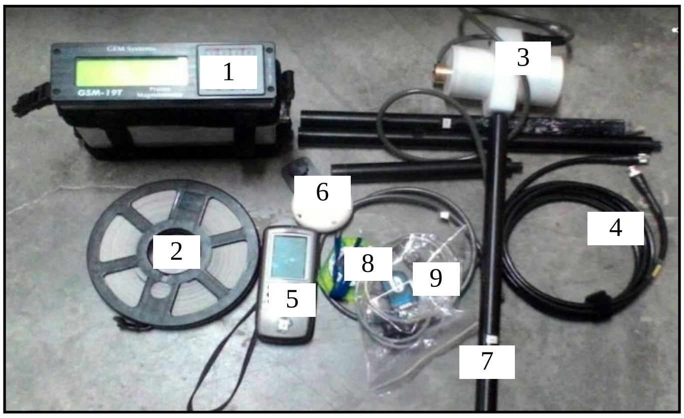


Figure 1: Location and layout at Bukit Bunuh, Perak Malaysia
(Google Earth, 2017)

covering an area of about 3 km². The portion of the area to be investigated has an area of about 1.5 km². Generally, Bukit Bunuh is made up of Quaternary sediments and pockets of lithology unit of Tertiary tefra ash and metasediments. The entire Lenggong valley is underlain by granitic rock from Mesozoic era which gives rise to regional granitic intrusion of Peninsular Malaysia during Trias (Alexander, 1962). The survey was conducted on six profiles each 2 km long with 0.15 km interline spacing at 30 m stations interval in the North-South orientation.

3. Methodology

A ground magnetic survey was conducted on six profiles of length 2 km long each, and 0.15 km interline spacing at 30 m station spacing. Two sets of GEM system 19T proton precision magnetometers (Figure 2) were used for both rover and base stations with a hand-held Garmin Global Positioning System (GPS) for real time measurement. A base station was carefully selected at a location free from magnetic noise and readings were recorded continuously at sixty (60) seconds interval. At the end of the survey, data from both magnetometers were downloaded, synchronized, corrected for diurnal variations of the Earth's magnetic field and other interference, and regional-residual separation was carried out to isolate anomaly of interest (Breiner, 1999) using Microsoft Excel application software. Thereafter, kriging gridding method was applied to the data and contoured using Surfer 8 Golden software to produce magnetic residual contour, 3D surface, and 3D wire frame maps.



Accessories:

1. Console
2. Measuring tape
3. Sensor
4. Connection cable
5. Hand held Garmin GPS
6. Magnetometer GPS
7. Staff pole
8. Magnetic compass
9. Data transfer cable

Figure 2: GEM 19T Magnetometer

4. Result and discussion

Figure 3 shows magnetic residual maps of the study area presented in three different forms. Figure 3a shows contour map of the area with varying magnetic residual intensities in nanotesla. It has maximum and minimum magnetic residual intensity values at 80 and -60 nT respectively. High intensity values observed could be associated with strong remanent magnetized impactites such as suivite rocks, while low magnetic pattern with subdued anomaly amplitude could be presence of sediments from authigenic breccia(Henkel, 1992).Long trend of magnetic low along longitudes 100.975 and 100.977^{o}E,which are parallel to another long high and medium intensity anomaly on longitudes 100.973 and 100.976^{o}E can be observed on the map.The features indicate subsurface conditions and depict magnetic anomaly pattern of a geological faults (Saad *et al.*, 2013; Akanbi and Mangset 2011). Intermittent high and low intensity anomalies dominate longitude 100.970^{o}E and represent dislocations suspected to be shear zone.

Figure 3b shows 3D surface map of the area. The varying amplitudes on the surface map are indicated by peak in red and low in blue colours. The shear zones are depicted by undulating surface predominantly along longitudes 100.970, 100.973, and 100.976°E. Long depression of magnetic low corresponds to geological faults.

Figure 3c shows 3D wire frame map of the area, which displays gradationally colored lines that show elevation. The maximum and minimum amplitudes on the map are represented in pink and blue colours. Depression with blue colour corresponds to geological faults, while undulating surfaces corresponds to shear zones on the contour map. Therriault *et al.* (2002) reported meteorite impact events alter the magnetic character of rocks in its surroundings leading to magnetic high and low as observed in this study. The result of this study also agrees those from previous studies conducted around the area by Ismail (2014); Jimmin *et al.* (2013); Kiu *et al.* (2013); Nordiana *et al.* (2013); Saad *et al.* (2013) & Saad (2016) where properties of rocks associated with impact events were reported.

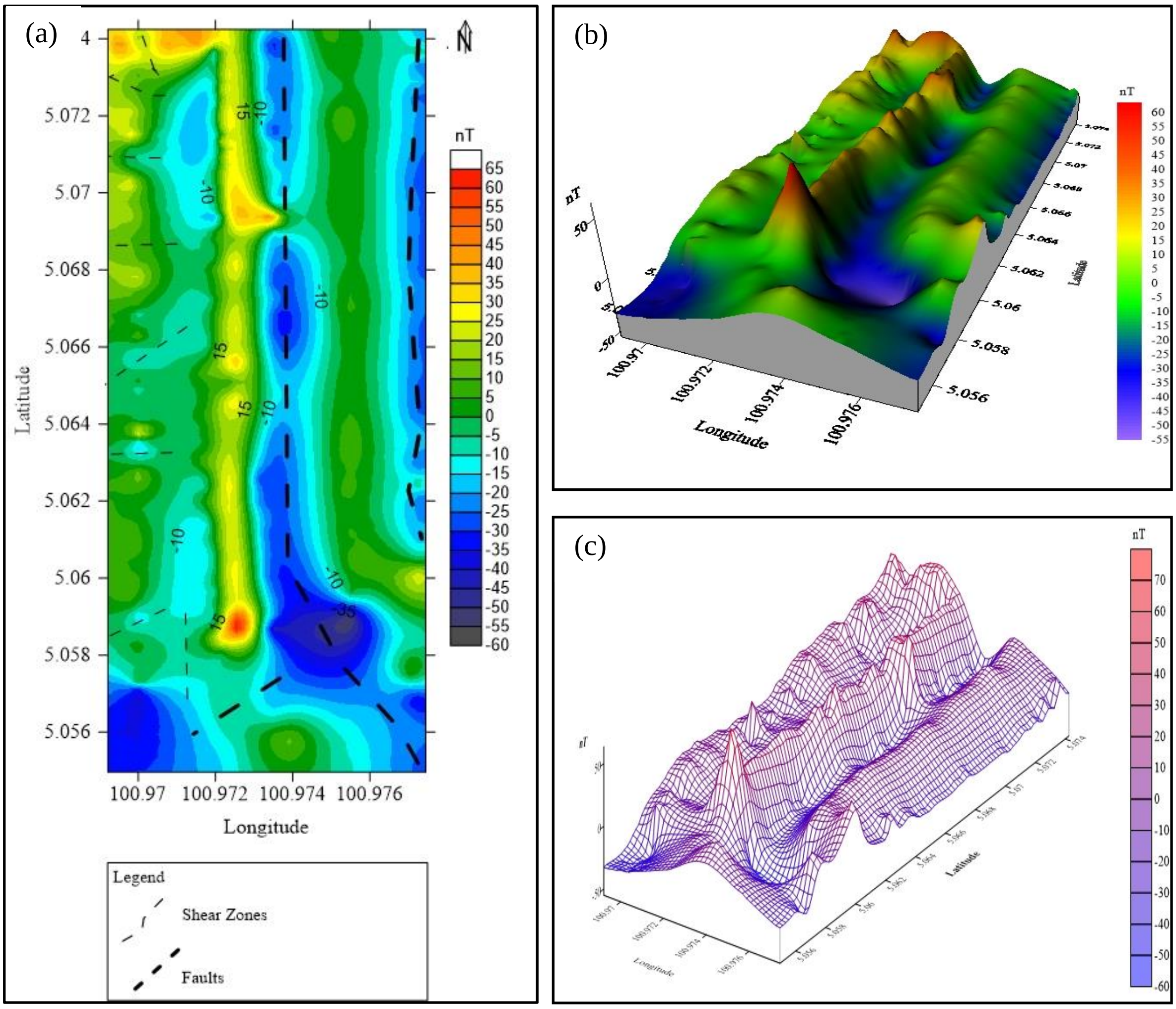


Figure 3: Magnetic residual maps of section of Bukit Bunuh impact crater
(a) Contour map (b) 3D surface map (c) 3D wire frame map.

5. Conclusion

In this paper, we applied ground magnetic residual data collected on six profiles in some parts of Bukit Bunuh impact crater area to analyze its basement structure. Maximum and minimum magnetic residual intensity values were observed at 80 and -60 nT. Strong remanent magnetized impactites such as suivite produced for high magnetic residual intensity indicated in red colour, while sediments from authigenic breccia account for magnetic low indicated in blue colour. The analysis identified faults and shear zones based on the pattern magnetic of anomalies produced by these features. Long and short linear dislocations were identified as geological faults, while intermittent circular features with low and high amplitude anomalies were interpreted as shear zones. Conclusively, the objective of the study was achieved and shows ground magnetic data alone could identify subsurface structure produced by effect of meteorite impact.

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