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Ground Magnetic Data Assessment of the Geology and Structural view of Bukit - Bunuh impact crater area, Malaysia.

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Abstract

Ground magnetic data obtained at Bukit Bunuh area was analyzed using several magnetic data (signal)-processing (magnetic derivative) techniques that include vertical derivatives, total horizontal derivatives, and analytic signal. The study was aimed at providing an insight on Bukit Bunuh geology, structures, and their patterns. The magnetic derivative anomaly maps obtained showed an enhanced high frequency signature related to the surface or sub-surface causative geological bodies. The maps showed the pattern of emplacement of granitic plutons within the Bukit Bunuh crater zone. The research outcome (results) showed a clear distinction between the edges of the granitic plutons from Quaternary sediments as well as the weathered overburden anomalies which were previously not known. The

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findings of this research were used to update the current lithological/structural map of the Bukit-Bunuh crater area of Peninsular malaysia

Keywords: Bukit Bunuh, Ground magnetic data, vertical derivatives, total horizontal derivatives, analytic signal

INTRODUCTION

Magnetic technique is an ancient geophysical exploration procedure. It is among the most extensively applied methods for the investigation of the earth's subsurface (Anudu et al., 2014, Danour et al., 2013, Ghazala et al. 2018, Yusuf et al. 2022a, Yusuf et al. 2022b). This is because magnetic measurements gotten especially for small-scale surveys are quite easy and cost effective with few corrections that need to be applied to the data.

The study area (Bukit Bunuh) was described as an impacted crater area (El-Hidayah et al. 2015, Rosli et al. 2014, and Samsudin et al. 2014). Impact crater produce a distinct magnetic anomalies due to large variation in the magnetic properties of rocks (Plado et al. 2000). The dominant magnetic effect over impact structures is a magnetic low (Plado et al 1996). However, complex impact structures, especially larger ones may show high amplitude (Plado et al 1996). The process of impact crater formation is highly dynamic and complex in which high-energy shock waves are propagated into the target rocks (Plado et al 1996). Thus, subjecting the impacted area and its environs to several kinds of deformation mechanisms.

It is worth noting that quite a number of research have been carried out at Bukit Bunuh with respect to the impact crater (El Hidayah et al. 2018, Samsudin et al. 2014, and Arifin et al. 2010). However, most of these researches are focused on establishing the occurrence of the impact crater and the soil moisture content of the impacted area (Mohammed et al. 2019, Mohammed et al. 2020, and Azwin et al. 2014). Since the occurrence of Bukit Bunuh, impact crater has been ascertained, and the subsurface geology and structural trends of the impacted area are bound to change. However previous studies did not examine the geology and the structural deformation found in the area, which is considered as an incomplete study gap. Therefore, this research tends to uncover new information on Bukit Bunuh geological structures and their structural trends. It therefore serves as the first attempt that focussed on the geology, and the structures of the crater area. In light of this, the ground magnetic data acquired were subjected to several processing techniques such as vertical derivatives (VD), total horizontal derivatives (THDR), tilt derivatives (TDR) and analytic signal (AS) in order to achieve the stated objective.

Geology of the Study Area

Bukit Bunuh is a fundamental portion of Lenggong district of Perak, in Peninsular Malaysia which is located at the coordinate of $5^0 4.9'00''N$ and$101^0 58.2'00''E$. The area has an undulating landscape which is covered by thick vegetation. It is underlain with basement rocks and quaternary sediments (Samsudin et al. 2014) (Fig. 1). The basement rock is Jurassic to Cretaceous in age (150 Ma – 100 Ma) mostly dominated by granite which is considered to originate from Bintang Range found at the west of Lenggong (Mohammed et al. 2020, Azwin et al. 2014, and Saidin, 1993). Quaternary sediment underlies part of the study area which consists of limestone, tertiary tefra ash and metasediments.

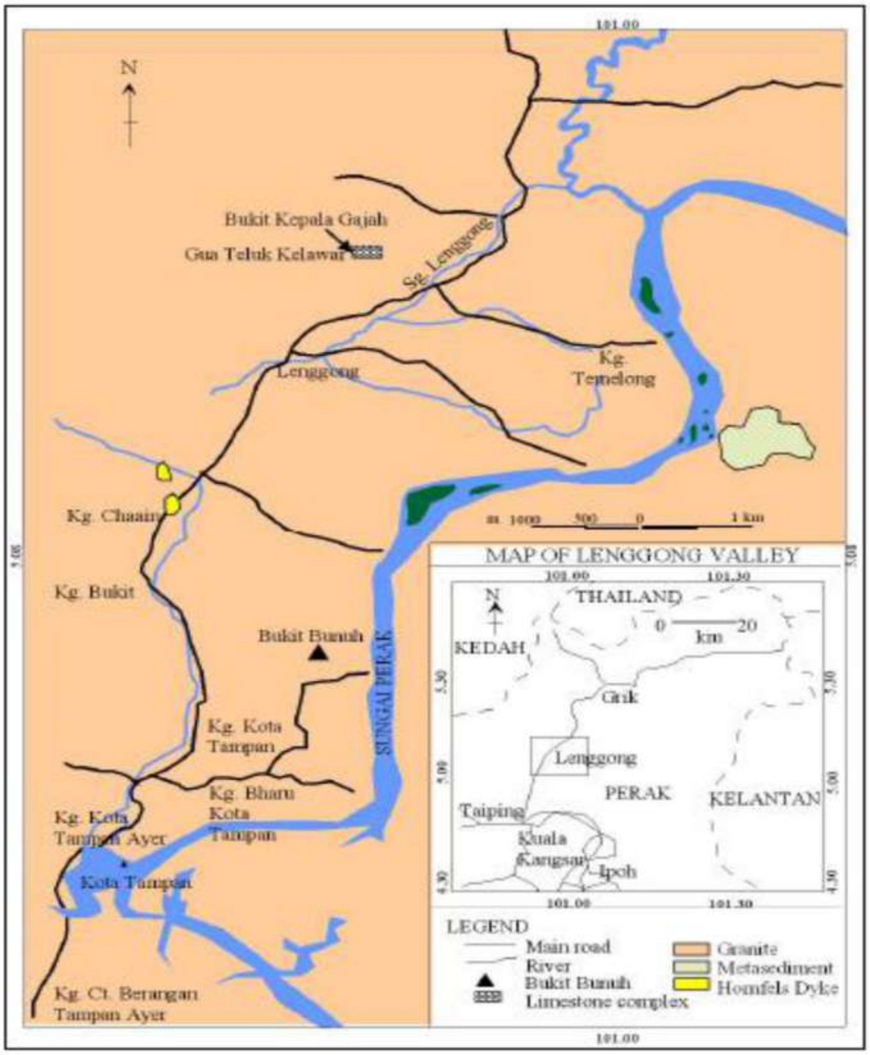

Figure 1. Geology map of Lenggong Basin indicating the position of Bukit Bunuh area (Adopted from Azwin et al. 2014).

MATERIALS AND METHODS

Ground Magnetic Data Acquisition and Processing

Proton precession magnetometer (Geometrics G-856) and Garmin Global Positioning System (GPS) were used for the data acquisition at the study area. The data were acquired in two phases; regional and small scale (detailed) surveys. The regional survey phase (1st stage of data acquisition) was conducted using a station interval of range 200 m – 500 m. The data collected was then preprocessed to pinpoint abnormal areas. The magnetically perturbed areas were subsequently investigated during the 2nd phase of the data acquisition events using stations whose intervals are 50 meters apart. A base station was strategically chosen and located closer to the surveyed site. Magnetic field measurements were continuously read after every one minute in order to correct for diurnal variations. Consequently, Geosoft software was applied in the processing and analysis of the collected magnetic field data. Having corrected the data for diurnal effect, the magnetic data was earlier imported into Oasis Montaj environment and converted to the Universal Transverse Mercator (UTM) coordinate system to allow subsequent analyses.

The total magnetic field intensity (TMI) anomaly map computed for the Bukit-Bunuh area is displayed in Fig. 2. The TMI values showed the maximum and minimum field measurements of -103 nT and 83 nT respectively. It indicates the presence of long, medium, and short-wavelengths anomalies. Most of the anomalies depicted in Fig. 2 showed the preponderance of NE-SW and E-W trends. The reduction to the equator (RTE) algorithm was applied to the TMI grid to align the magnetic signals to their causative sources. This is due to the fact that the research location is situated within the low magnetic latitude (LML) regions with geomagnetic inclination below $+/-30^{0}$, where reduction to pole (RTP) becomes somewhat unstable, producing anomalies smeared in a north-south direction (Sheriff 2002, Fairhead and Williams 2006). The factors applied for the RTE filters are geomagnetic declination(-0.19^{0}), geomagnetic inclination (-6.14^{0}) and amplitude correction(-20). Butterworth low-pass algorithm was also used alongside the RTE to remove short wavelengths related to noise components of the data. In the case of the Butterworth low-pass filtering, a cut-off wavelength of 200 m and a filter order of 8 were used. Moreover, when the reduced to equator total magnetic field intensity (RTE_TMI map) produced is viewed; it can be seen that the peaks of magnetic anomalies are centered over their causative sources (Fig. 3).

The RTE_TMI grid data was thereafter analyzed to further enhance the magnetic anomalies. The techniques applied include vertical derivatives (VD), total horizontal derivatives (THDR), tilt derivative (TDR) and analytic signal (AS).

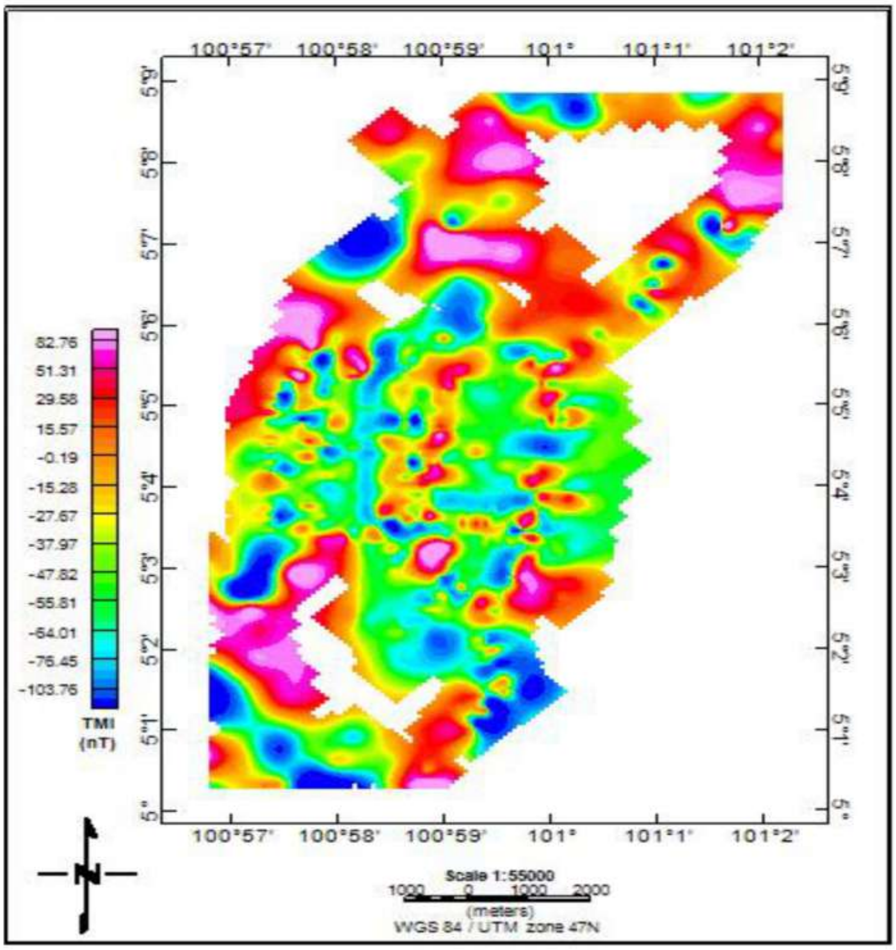

Figure 2. Total Magnetic Intensity Map (TMI). The blank areas in our survey are inaccessible (e.g. rivers)

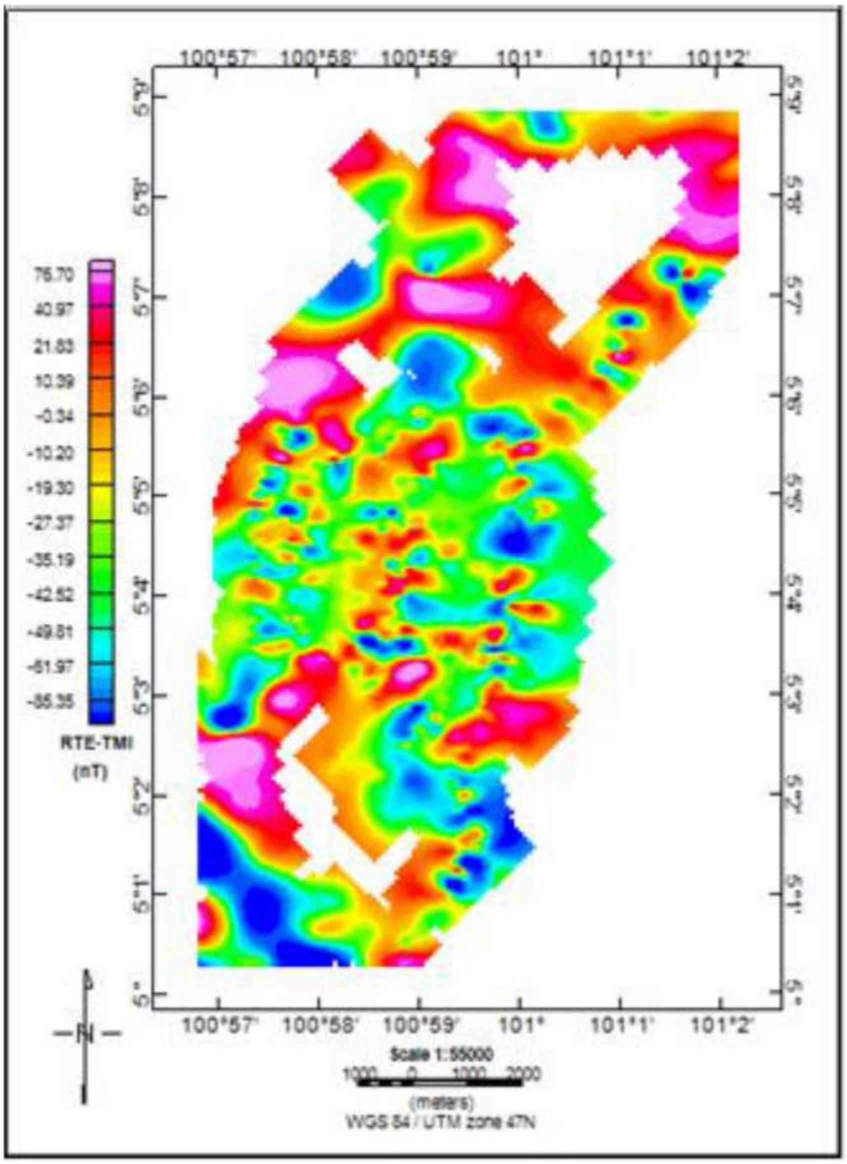

Figure 3. The total magnetic field intensity reduced to magnetic Equator (RTE_TMI) map

Vertical Derivatives

This technique tends to enhance the ends of anomalies and highlights shallow causative geological bodies (Telford et al., 1998). That is, it enhances high frequency and subdues low frequency anomalies in the magnetic data. The high frequency anomalies are usually caused by shallow geological bodies, while low frequency anomalies are mostly produced by deeply buried causative geological features. The vertical derivatives (VD) maps have their zero contour values situated directly over the edges of their causative bodies (Reynolds, 2011), if their magnetic field measurements were originally reduced to the equator or to the pole. The 1st and 2nd vertical derivatives (FVD & SVD) are the most commonly applied methods (Telford et al., 1998). As such, they were also applied in the present study and are expressed as in equation 1 and 2:

$$FVD = \left(\frac{\partial T}{\partial z}\right) \quad (1)$$

$$SVD = \left(\frac{\partial^2 T}{\partial z^2}\right) \quad (2)$$

Where, FVD, SVD, denotes the 1st and 2nd vertical derivatives of the magnetic field respectively, and $\frac{\partial T}{\partial z}$, and $\frac{\partial^2 T}{\partial z^2}$ represents the derivatives of the magnetic field meatured at 1st and 2nd degrees respectively.

The RTE _ TMI grid computed were transformed to 1st and 2nd vertical derivatives. A Butterworth low-pass filter using a cut-off wavelength value of 200 m plus a filter order of 8 was similarly used when calculating the vertical derivatives. The FVD and SVD applied to the RTE-TMI maps created are presented in Fig. 5a and 5b, respectively. The vertical derivative filters promote high frequency parts of the anomalies, while the Butterworth low-pass filter removes the low frequency (noise) parts of the data.

Total Horizontal Derivative (THDR)

THDR filter is commonly deployed to detect edges of both near surface and deeply buried sources (Anudu et al., 2014, Arisoy and Dikmen 2013). It is also suitable for identification of linear structures such as faults, veins, and contacts. The major significance of this technique is that it is less sensitive to noise components of the data since, it only needs the two 1st-order horizontal derivatives for its computation (Ibraheem et al. 2018). Cordell and Grauch, 1985 defined THDR as the square root of the totality of the squares of the 1st horizontal derivatives of the magnetic field measured along x- and y- directions (as in equation 3):

$$THDR = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2} \qquad (3)$$

The RTE _ TMI grid generated were subjected to 1st horizontal derivatives (along x and y axes) and thereafter to total horizontal derivative. The THDR of RTE_TMI map of the Bukit Bunuh area (Fig.6) depicted highly accentuated structures and projects the amplitudes of magnetic measures owing to high frequency anomalies.

Analytic Signal (AS)

Analytic signal is used in detecting the boundaries of magnetic source bodies, especially where remnant and/or low magnetic latitude confounds the analysis. It is independent of geomagnetic inclination, declination, and remnant magnetization (Roest et al. 1992). An analytic signal of an acquired magnetic data can simply be estimated as the square root of the summation of squares of the individual derivatives measured along the x, y and z axes. It involves the 1st-degree vertical derivative (z) and horizontal (x, y) derivatives. The amplitude of the 3 -D analytic signal at any given position can be estimated from the 3 orthogonal gradients of the computed magnetic field via the relation (equation 4) ;

$$|AS(x, y)| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \qquad (4)$$

Where, $|AS(x, y)|$ denotes the amplitude of the analytic signal measured along (x, y), T indicates the total magnetic field observed at (x, y) axis, and $\left({\partial T}/{\partial x},\ {\partial T}/{\partial y},\ {\partial T}/{\partial z}\right)$ represent the two 1st horizontal and vertical derivatives of the observed field, respectively.

A 3-dimensional analytic signal calculation was performed on the TMI data to generate the analytic signal map of the total magnetic field intensity (AS_TMI) of the area. The AS_TMI map created was consequently continued upward at 200 m to subdue surface signal sources and noise components of the data (Fig. 7).

RESULTS AND DISCUSSION

According to Reynolds 2011 and Parasnis 1962, qualitative interpretation of magnetic data involves visual demarcation of outlines of anomalies in magnetic maps and the explanation for the probable causative geological structures. An indispensable section of qualitative analysis is 'zoning.' Zoning encompasses an act of delineation of regions with separate patterns of magnetic anomaly on a magnetic map (Reeves, 2005). 'Zoning' is an essential instrument applied in lithological mapping that aids in enhancing the information on the geology map, particularly in locations with scanty or devoid of base rock outcrops.

In the qualitative interpretation, RTE of TMI anomaly map was adopted instead of the TMI anomaly map, because the form of the magnetic anomalies had been freed from the effect of magnetic inclination due to the RTE transformation.

The present area had been segmented into four (4) magnetic zones (B, G, S and Y zones) based on the magnetic characteristics (such as magnetic susceptibilities) of the emplaced rock types (Fig. 4).

Zone B and G are predominant in both the central and northern portion of the research location respectively. Both zones are also sparsely observed in the southern portion of the research location. The B and G zones are underlain by basement rock (granite). They show short wavelength anomalies with varying magnetic intensity amplitudes of 10 to 76 nT. Zone S occupies a huge area of the central portion of Fig.4. It is underlain by weathered overburden. Zone S shows small (negative) magnetic anomalies with amplitude of the magnetic strength ranging from -49 to -0.3 nT. The magnetic anomaly identified and labelled as zone Y in Fig. 4 depicts very low (negative) magnetic anomalies which possibly indicate the manifestations of Quaternary sediments. The amplitude of the magnetic intensity of zone Y is in the range of -85 to -49 nT.

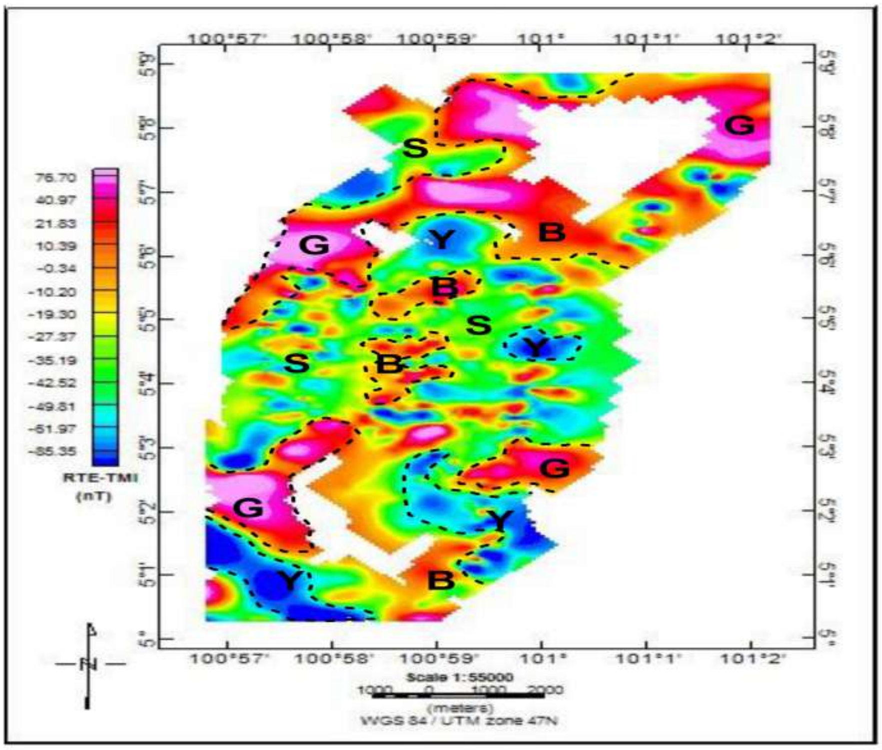

Figure 4. Zoning of the RTE-TMI anomaly map showing four main magnetic zones (B, G, S, and Y)

Furthermore, several analytical and interpretation procedures (e.g. magnetic derivatives) were applied to identify and demarcate many geological bodies with their trends, sizes and limits in the study area. The reddish to pinkish-coloured (high magnetic susceptibilities) anomalies observed on the AS, THDR, FVD and SVD anomaly maps could be linked to the occurrence of near-surface intrusions of granitic plutons around the crater area. The presence of anomalies that are of moderate to low magnetic susceptibilities, (greenish blue) on the maps show the occurrence of shallow and thin deposits of weathered overburden, overlying the highly magnetic granitic rocks.

In addition, the FVD and SVD anomaly maps (Fig. 5a & 5b) enhance high-frequency aspects of the anomalies (shallow geological bodies) which are interpreted/inferred to be Quaternary sediments overlying the crystalline basement (granite). The inferred sediments have magnetic intensity ranging from -0.16 to -0.36 nT/m and -0.0011 to -0.0042 nT/m² for FVD and SVD respectively. The THDR anomaly map was able to provide the pattern of emplacement of granitic intrusions within the study area (Fig. 6) with magnetic intensity amplitude ranging from 0.186 to 0.535 nT/m. The AS anomaly map clearly distinguishes the edges of the granitic plutons from the Quaternary sediments as well as the weathered overburden anomalies as shown in Fig.7. These results affirm the statement made by (Anudu et al. 2014, Arisory and Dikimen 2013 and Roest et al. 1992) on the application of THDR and AS. Based on the results obtained from the application of the various edge-enhancement techniques, an updated geological map of the Bukit-Bunuh area has been produced (Fig. 8).

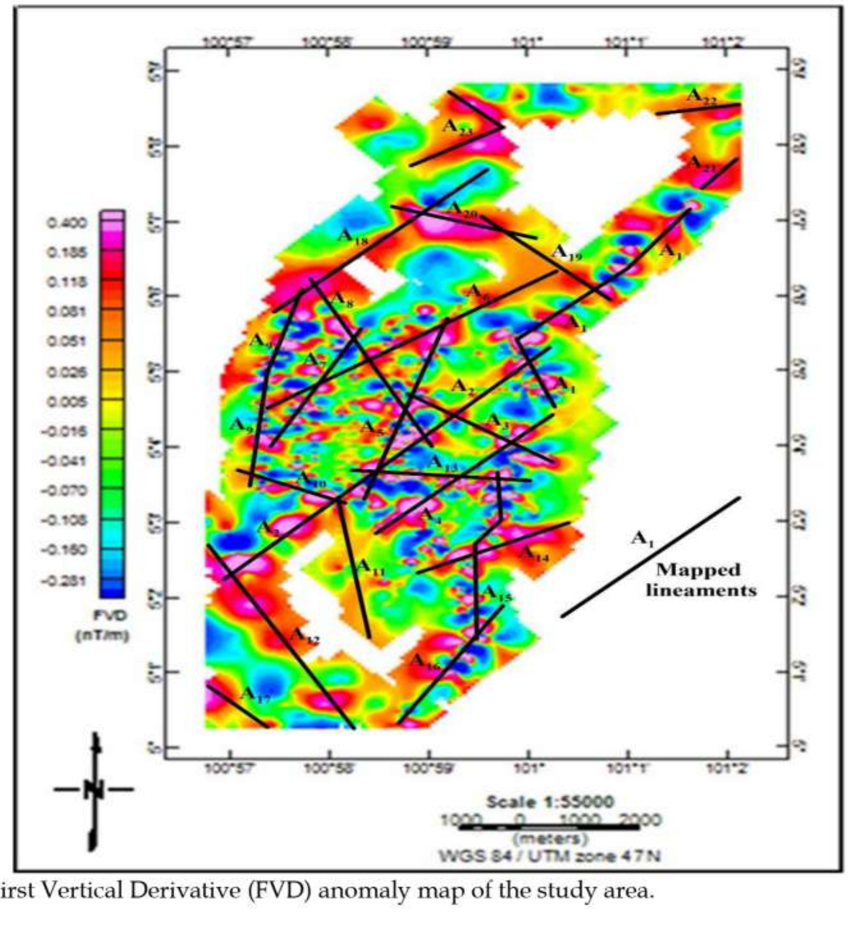

Figure 5a. First Vertical Derivative (FVD) anomaly map of the study area.

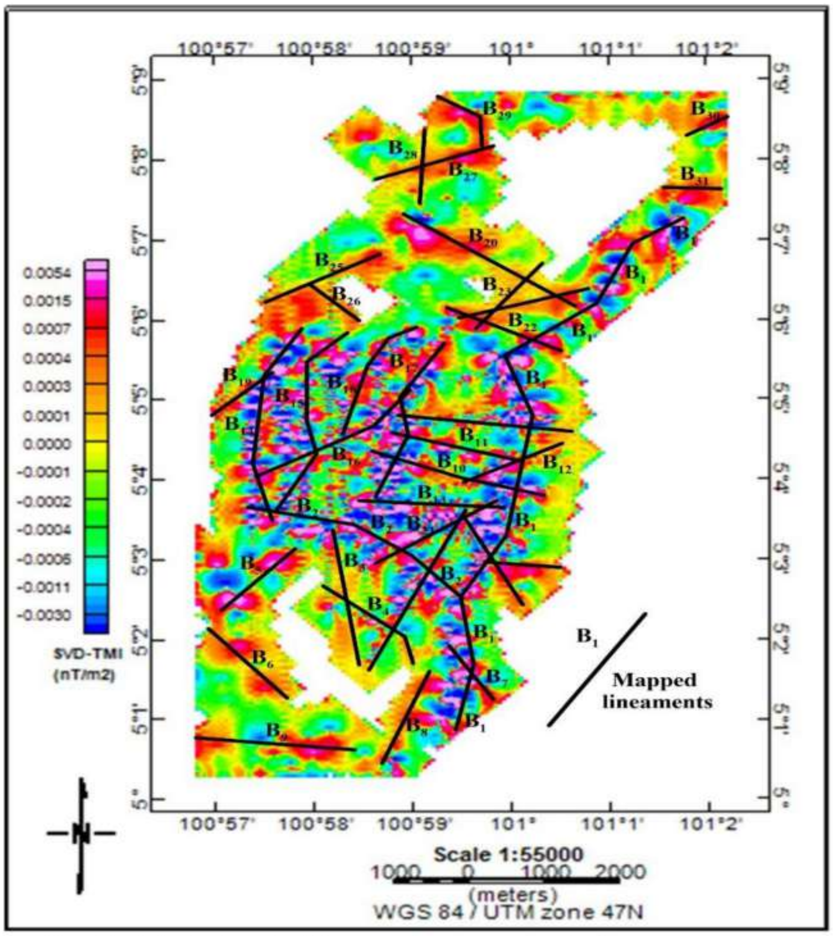

Figure 5b. Second Vertical Derivative (SVD) anomaly map of the study area.

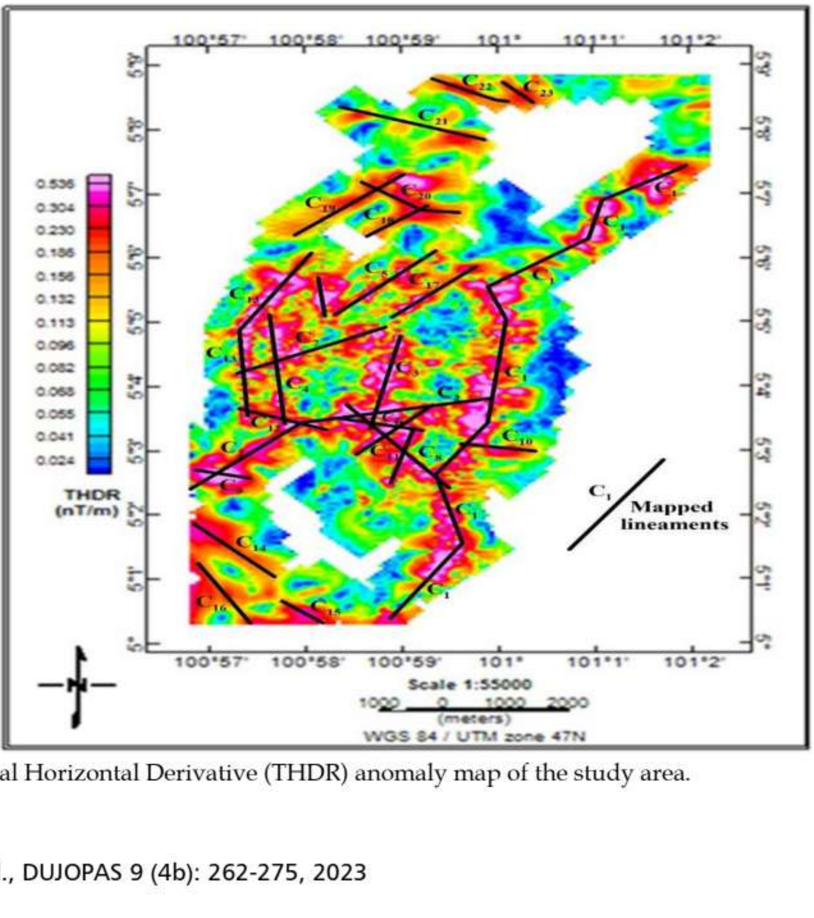

Figure 6. Total Horizontal Derivative (THDR) anomaly map of the study area.

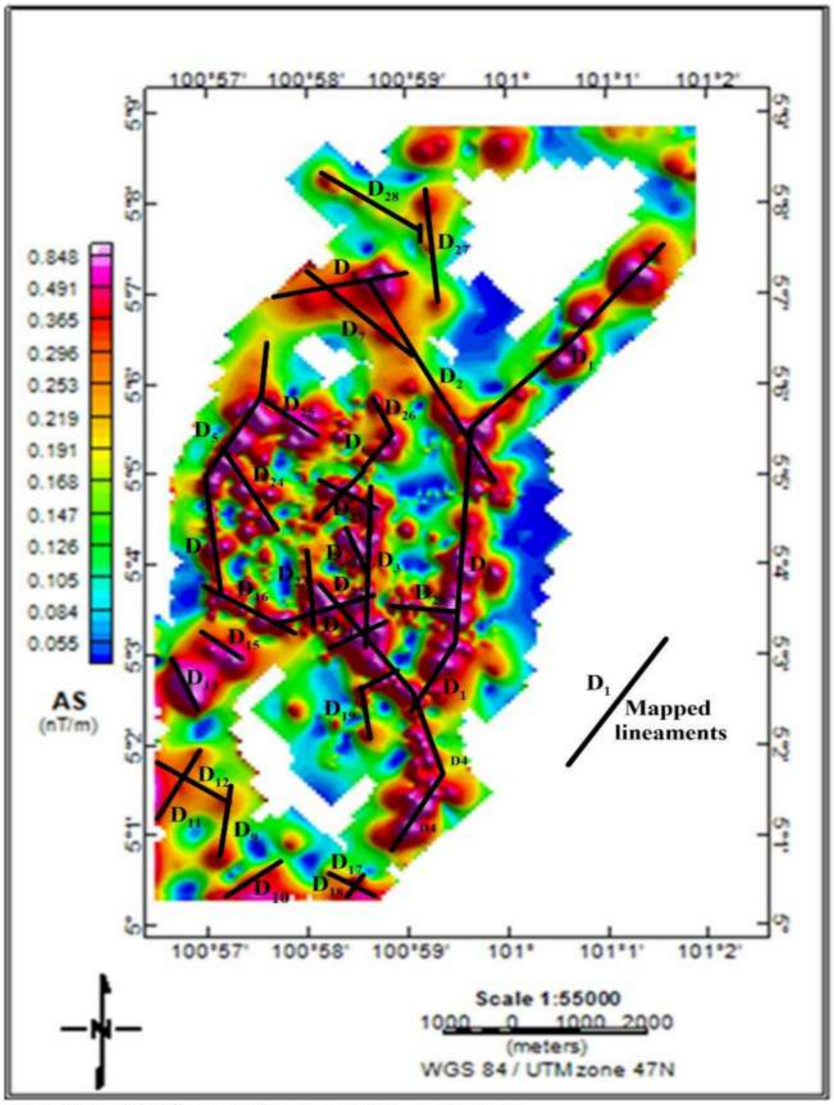

Figure 7. Analytic Signal (AS) anomaly map of the study area

The structural features such as faults, Joints, fractures, veins, and linear granitic intrusions (plutons) are some of the geological lineaments deduced from the magnetic data that was subjected to (THDR), FVD, SVD, and AS processing (Fig. 5 - 7). An observation of the updated geology map of Bukit-Bunuh impacted crater location (Fig.8) shows the distribution of lineaments in the following clusters: NE-SW, WNW-ESW, NNW-WSE, and NW-SE trends (Fig. 9). Further check on Fig. 9 revealed a predominance of NE-SW structural patterns. The NE-SW trend conforms to the pattern of emplacements of the near-surface granitic intrusions (plutons) mapped within the crater vicinity. Moreover, this trend further conforms to the regional orientations of rivers/streams of the Bukit-Bunuh area (Mohammed et al. 2019). This suggests the structural control of the streams/river channels.

The structural lineaments mapped could be very useful in terms of preliminary search for minerals manifestations, geotechnical investigations, and groundwater studies. The structures mapped could also be useful in terms of understanding the tectonic history of this crater impact area based on the kinds of deformations recorded within the area.

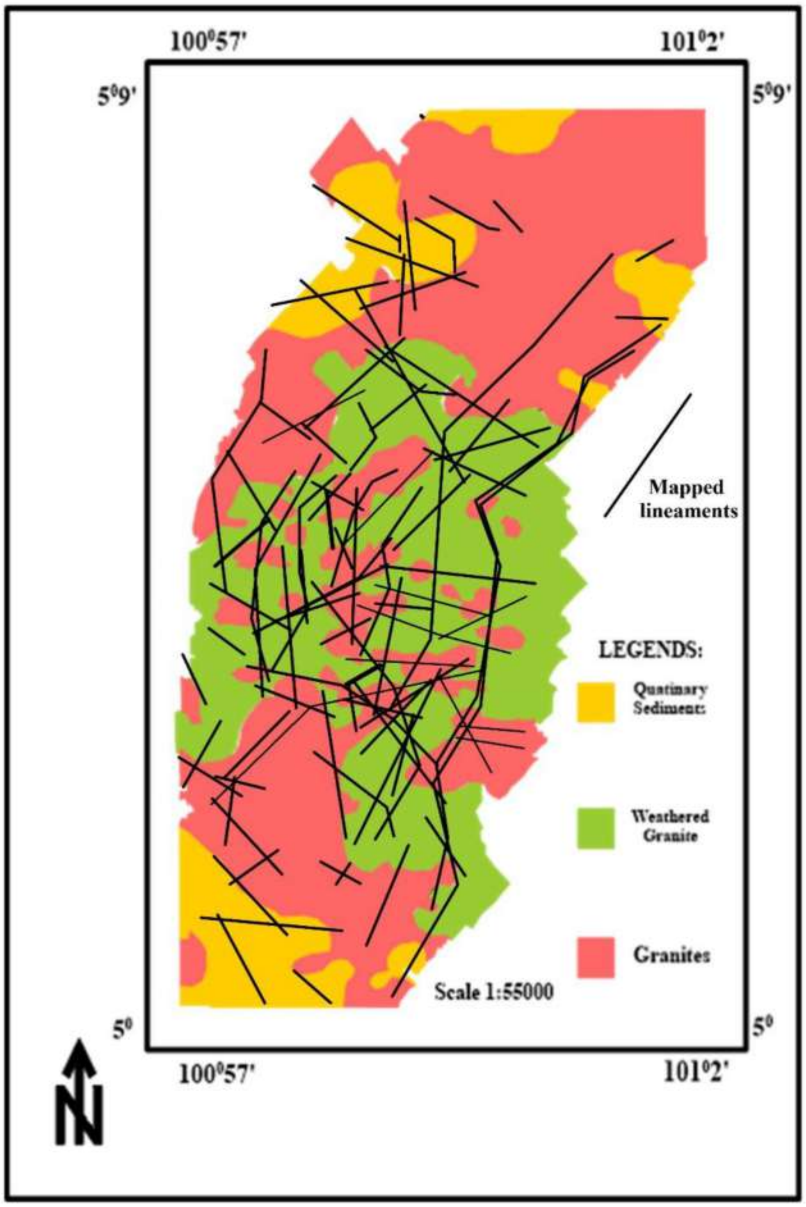

Figure 8. Updated geological map of the study area (Bukit Bunuh impact crater area).

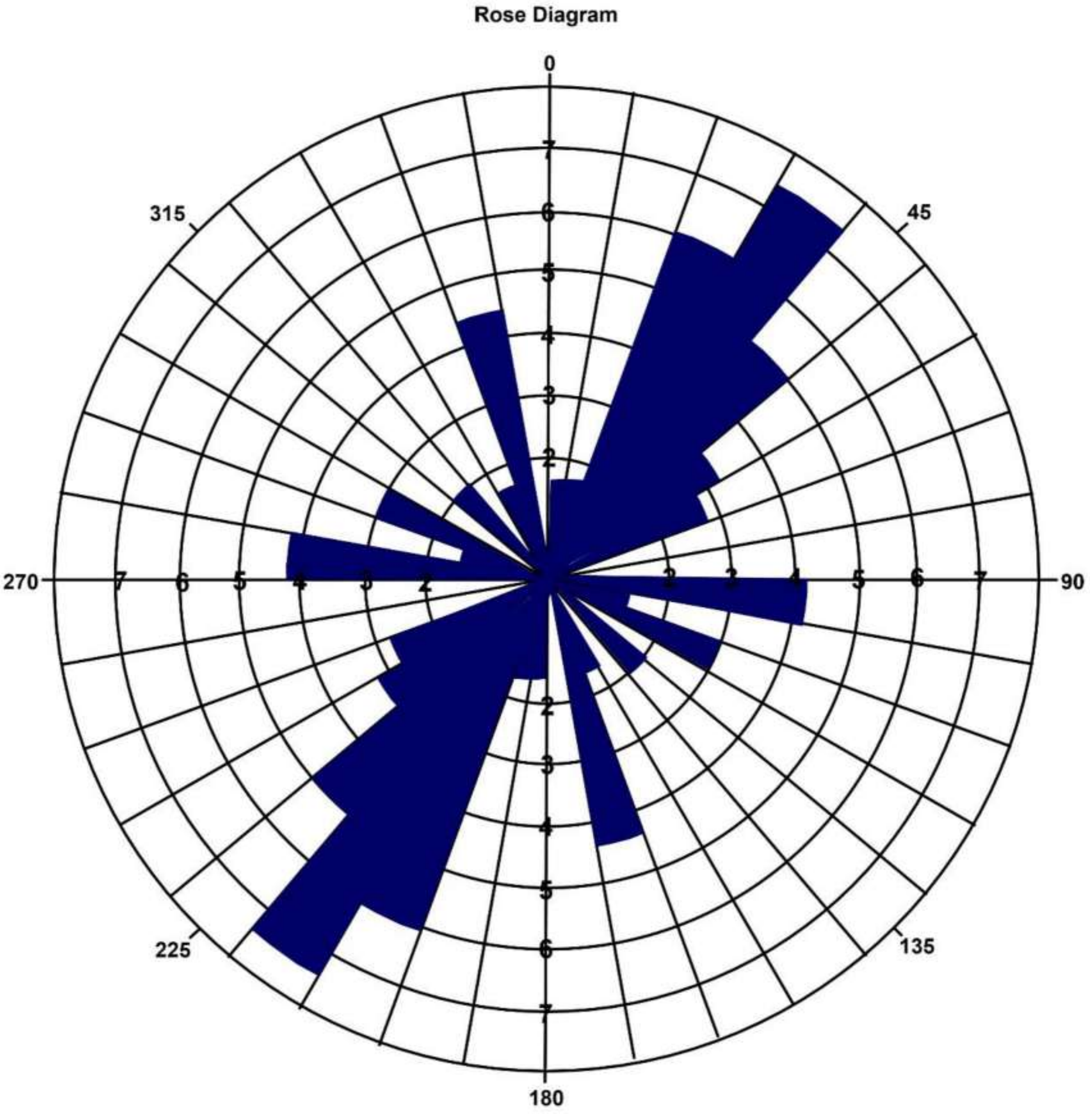

Figure 9. An overall distribution pattern of the structural lineaments mapped from Bukit Bunuh impact crater area.

CONCLUSION

The acquired and processed magnetic data over Bukit-Bunuh impact crater area has enabled a successful mapping of near surface lithologies (granitic plutons), quaternary sediments, weathered overburden, and structural lineaments within this impact crater location. The mapped plutons, quaternary sediments as well as the weathered overburden are mostly found within the central part of the impact crater. The structural lineaments pattern recorded include the NE-SW, WNW-ESW, NNW-WSE, and NW-SE trends, with the NW-SE pattern dominating. The mapped structures could provide a very significant guide in terms of the preliminary search for minerals, groundwater, and tectonic studies of the study area.

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