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DELINEATION OF SUBSURFACE STRUCTURES OF SEMANGGOL FORMATION, NORTH PERAK USING MAGNETIC DATA

*Ooi Wei Chian[1], Muhammad Noor Amin Bin Zakariah[2], Abdul Ghani Bin Md Rafek[3] and Muhammad Azfar Mohamed[4]

[1,2,3] Department of Geosciences, Universiti Teknologi PETRONAS, Malaysia; [4] Department of Petroleum Engineering, Universiti Teknologi PETRONAS, Malaysia

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ABSTRACT: The Semanggol Formation has been studied widely and published by many, but only focus on areas of northern and southeast Kedah. Limited data have been studied and published on Perak area, especially Gunung Semanggol. The research is aimed to augment the presently limited knowledge on the hill, particularly the subsurface structure. In addition, new lithology such as a breccia formation with tens of meters width of what appears to be a breccia granitic matrix was identified in an abandoned quarry. Therefore, a study on the application of geophysical methods covering the Semanggol Formation located at Semanggol area has been carried out. The main aim of this study was to conduct a magnetic survey to study the subsurface and possibility of granitic bodies in Gunung Semanggol. The total magnetic field data were obtained by using a proton free-precision magnetometer, recording the total ground magnetic field along the transverse. There was a total of 184 magnetic stations established during the survey with a 500 m to 1 km spacing. Data reduction was processed using Oasis Montaj software to produce Total Magnetic Intensity (TMI), Reduction to Pole (RTE), Regional Anomaly and Residual Anomaly maps for qualitative interpretation. The interpreted field data gave the results of total component measurements of magnetic anomaly varying between minimum negative value around 180 nanoTesla (nT) and maximum around 510 nanoTesla (nT) as shown in TMI map. Besides, the regional magnetic map shows a gradual decrement of magnetic intensity towards east and southeast. And residual magnetic map reveals that the dominant orientation for magnetic lineaments in the NE-SW direction. However, geochemical tests have to be conducted to study the possibility of granitic bodies.

Keywords: Semanggol, Magnetic Intensity, Regional, Residual, Anomaly Map

1. INTRODUCTION

The magnetic survey is one of the oldest and widely used geophysical investigation techniques to delineate the geology such as lithology and subsurface structure of basement. It involves the measurement of the magnitude and the orientation of Earth's magnetic field. When there is a ferrous material located within the Earth's magnetic field, it will produce an induced magnetic field where the induced field is superimposed on the Earth's field at that area, thus, it will create a magnetic anomaly. Generally, the anomaly depends on the size of magnetic bodies and their distance from the sensor. The variations in concentrations of ferromagnetic material within geologic strata containing in the vicinity of the magnetometer's sensor results in local variations or anomalies of the geomagnetic field of Earth [1].

The magnetic anomalies can be originated from the changes in lithology, variations in the size of magnetized bodies, faults presence and topographical relief [1]. A significant quantity of information obtained can lead to a qualitative interpretation of regional and residual magnetic anomalies map of the total intensity magnetic field.

Generally, the variation magnetic content of rocks depends on the rock types. Most of the rocks are not magnetic, yet there are few types of rocks containing enough minerals to produce magnetic anomalies. The common causes of magnetic anomalies are mafic dikes, faults and lava flow [2]. Sedimentary formations are usually non-magnetic and have smaller variation while mafic and ultramafic igneous rocks exhibit greater effect and they are useful to indicate the bedrock geology concealed below cover formations [3]. Hence, the interpreted information that reflects variations in local abundance of magnetization is useful in mapping the geological structures on or inside the basement rocks. Moreover, it helps in understanding and testing the various tectonic models. Therefore, the structural and the tectonic evolution of geological features can be contrasted with different tectonic and geographic provinces.

The aims of this research are to investigate the subsurface structures over Gunung Semanggol and its surrounding area and the possibility of granitic body's existence based on the anomalies of the geomagnetic field of Earth. Gunung Semanggol, Bukit Merah is part of the Semanggol Formation that stretches from the northern border of Kedah southwards to north Perak. This study only focuses on the Semanggol Formation in north Perak.

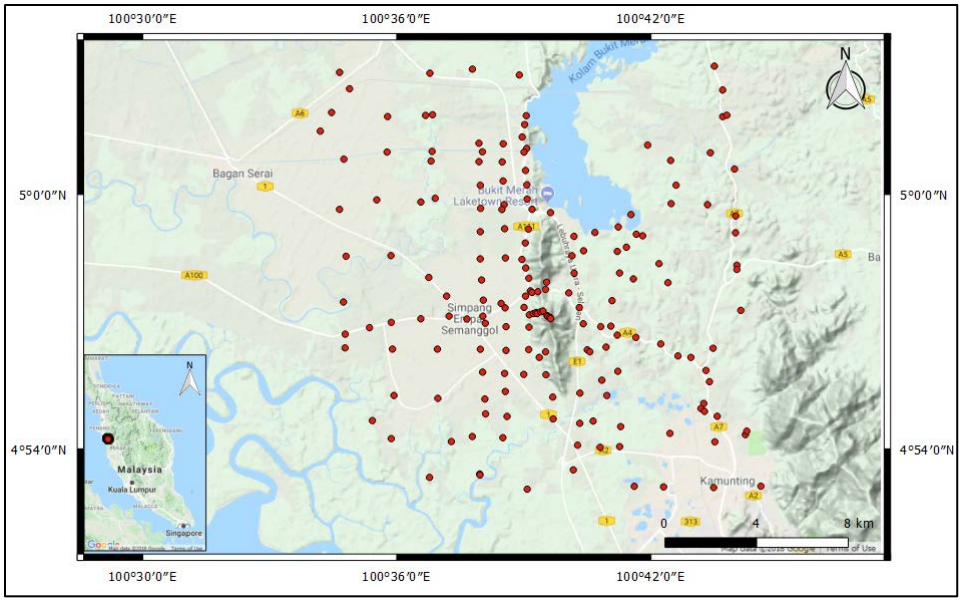

Fig.1 Study Area with magnetic stations located (Google Map)

2. GEOLOGY OF STUDY AREA

Semanggol Formation has been studied widely and published by many, yet, just covering areas of the northern and southeast Kedah. Limited data have been studied and published on Perak area, especially Gunung Semanggol. There is no study about the igneous and volcanic evidence around the Gunung Semanggol. But the new evidence that was found by UTP around the Gunung Semanggol complex relatively gave a possibility of the existence of igneous and volcanic rocks.

Semanggol Formation was first introduced by [5] as Middle Triassic argillaceous-arenaceous rocks that are exposed in Semanggol, north Perak. In 1973, Burton divided Semanggol Formation into three informal members namely as chert, rhythmite and conglomerate members. [6] stated that the formation young towards the southeast or east, suggesting the Chert Member is the oldest rocks, followed by the Rhythmite and Conglomerate Member. According to [6], the rocks at Gunung Semanggol consist of two dominant facies which are a rudaceous-arenaceous facies of intraformational conglomerate and sandstone, and an argillo-arenaceous facies of rhythmically bedded sandstone and shale. Recently most of them are surrounded by alluvium and paddy fields.

The Semanggol Formation is located at the three-separate fault-displaced areas in Padang Terap (north Kedah), Kulim-Baling (south Kedah) and Gunung Semanggol (north Perak) [7]. Referring to [6], the formation at Gunung Semanggol does not represent a complete succession of Semanggol Formation due to the absence of top and bottom of the formation. [6] also agreed that the base of the formation cannot be determined and the top is eroded.

The 3 members of Semanggol Formation were initially thought to be deposited in succession, yet few pieces of evidence in subsequent studies reject the idea [8, 9]. Instead, tectonic activities were suggested to have preceded the deposition of Rhythmite and Conglomerate members. According to [8, 9], the Chert member was deposited in Paleo-Tethys below carbon compensation depth in a foredeep basin. The ocean basin became part of the accretionary wedges during Sibumasu-Indochina collision, during which the S-type granitoids intrusion coincides. The subaerial exposures of the accretionary wedge became the source of the clastic sediments associated with Rhythmite and Conglomerate members that were deposited in a forearc basin.

3. METHODOLOGY

3.1 Magnetic Data Acquisition

In this research, a proton magnetometer (Scintex ENVI) which measures the horizontal and vertical components of the magnetic field or the total field was used to detect the total field intensity that is within vicinity by means of discrete measurement at sampling intervals of few seconds. When the magnetic field of rock is measured, it is the measurement of the field as it is being influenced by the earth's geomagnetic field and any other large magnetic bodies which are nearby as well. GPS and compass were used to obtain the bearing and coordinates at each station as well.

The magnetic survey was acquired by loop

technique along Semanggol area. The main base station was set up before and after data acquisition which consists of few base stations. Along the transverse, there were 184 magnetic stations 0.5 to 1 km apart. The collected readings included coordinates of the station, altitude, the time taken and magnetic variations in nano-Tesla (nT). Repetition measurements of a base station at frequent intervals were carried out to correct the diurnal drift. During the acquisition, all surface noises like man-made metal materials have been considered and avoided.

3.2 Magnetic Data Processing

3.2.1 Diurnal Variation Correction

Temporal changes in Earth's field during the survey must be considered in order to obtain an accurate result. Earth's magnetic varies during the day and night times, due to the interactions of the solar wind with Earth's ionosphere. This variation is called diurnal variation. Hence, repetition measurement of a base station at frequent intervals was conducted for diurnal effect correction. After data collection, the drift effect was calculated and the magnetic data was obtained by applying the equations as shown below.

$$\text{Drift} = \frac{B\ base,f - B\ base,i}{T\ base,f - T\ base,i}$$

where Drift is the measure of drift in a loop; B base,f and B base, i are the final and initial total magnetic field at the base station; t base,f and t base, i are the final and initial time taken at the base station. Then, the corrected drift data at the station in the loop was obtained by:

$$Bdrift,\ n = B_n - drift\ (i_n - t_{base})$$

where *Bdrift, n* is the corrected magnetic field at the nth station of the loop; B_n is the total magnetic field at the nth station; t_n is the consumed time at the nth station; t_{base} is the consumed time at the first station of the loop.

3.2.2 Removal of Normal Field (Geomagnetic Field)

After subtracting the diurnal correction from the raw magnetic data obtained, the regional field was obtained by applying the standard mathematical model of Earth's main magnetic field, known as International Geomagnetic Reference Field (IGRF). It is calculated based on the dates, elevation, latitudes and longitudes of the obtained magnetic data, generating the result of geomagnetic field 41,638nT, inclination -6.155 and declination -0.21. In order to determine the residual magnetic field, the IGRF value was subtracted from the obtained magnetic data for each station.

3.2.3 Reduction to Pole (RTE)

RTE is one of the common filters applied to transform the anomaly caused by a body with non-zero inclination into an anomaly that would be caused by the same body with zero inclination. In general, reduction to the pole (RTP) is the best and general method used to remove magnetic distortion, yet it can be only applied to the data that were acquired at magnetic latitudes greater than approximately 20° north or south. Hence, RTE is more applicable in this study where the study area. The declination of -0.184° and inclination of 5.683° which could be considered relatively small that were determined from IGRF calculations were used.

4. RESULTS AND DISCUSSION

The result was interpreted qualitatively based on the pattern of anomalies shown in contour map and depth of the anomaly bodies.

4.1 Total Magnetic Intensity (TMI)

TMI generally a reflection of the average magnetic susceptibility of broad and large-scale geologic features, indicating the lithology and basement topography. To minimize the dipolar nature of the field, the TMI map has been reduced to the north magnetic equator (RTE). The TMI map as shown in Figure 2 has a maximum anomaly about 510nT and minimum anomaly around -180nT. The center part of the study area is characterized by high magnetic intensity whereas the eastern part is dominated by low magnetic intensity value.

4.2 Reduction to Equator (RTE)

The obtained RTE map as shown in Fig. 3 has an intensity ranging from 470nT to -270nT. High and low magnetic anomalies can be observed overall of the map. These magnetic intensity variations can be attributed to the presence of rock types and their mineral composition. High magnetic anomaly value indicates the high susceptibility of rocks and strong metallic features that are located far from the surface. The low magnetic intensity in the eastern part may be attributed to the S-type granite of Main Range which is composed of mainly quartz, silicate and feldspar minerals. Meanwhile, the high magnetic anomalies are concentrated in the north-west and the center part of the study area which is the Gunung Semanggol. This might be the result of the presence of rocks with high iron content in Semanggol area such as shales. Furthermore, the magnetic intensity at the peak of Gunung Semanggol is lower than its surrounding. This is believed that the granitic bodies might occur which is the extension of the S-type granitoids of Main Range.

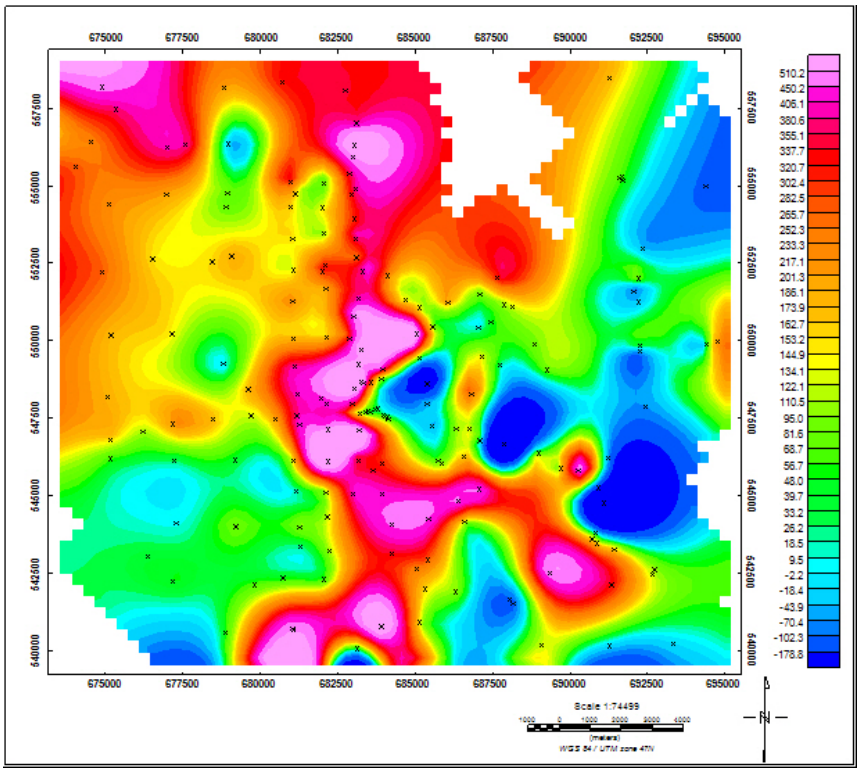

Fig. 2 Total magnetic intensity (TMI) map with located stations of the study area

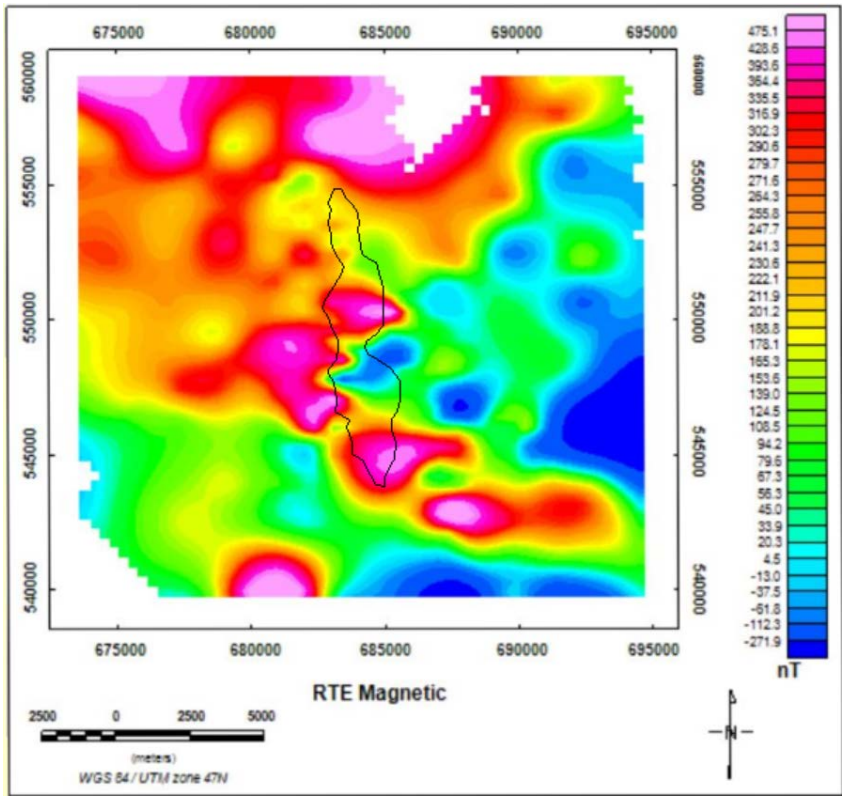

Fig. 3 Reduction to Equator (RTE) map after IGRF reduction and the black line represents Gunung Semanggol

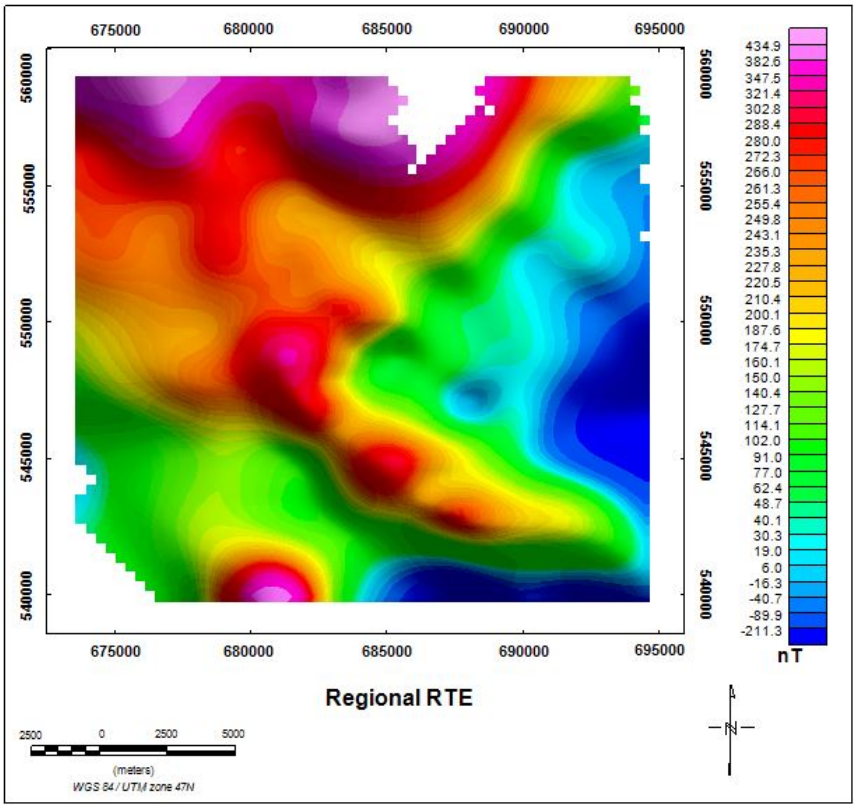

Fig. 4 Regional Magnetic Map

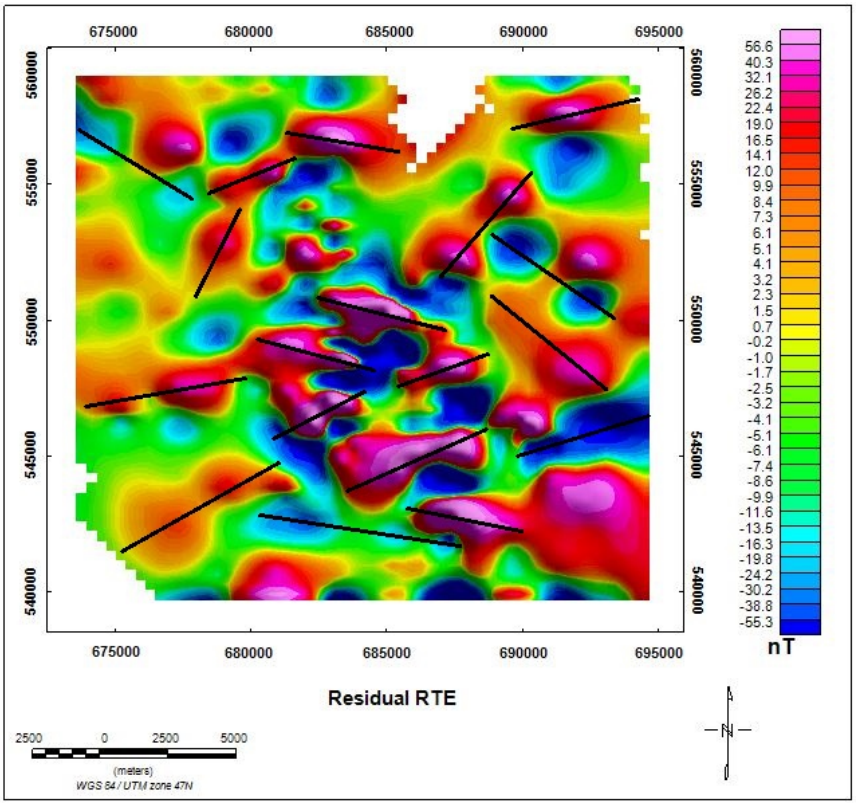

Fig. 5 Residual Magnetic Map

4.3 Regional Magnetic Map

Regional magnetic intensity map is produced after an extremely low pass filter is applied, masking the high-frequency anomalies and noise from the map and leaving only the low-frequency anomalies that reflects the deep-seated magnetization of Earth. Fig. 4 illustrates the regional magnetic anomaly map that has been undergone low pass filter with an intensity range of between 430nT to -210nT. The cutoff for the map is 5000m in order to produce a clear deep-seated basement rock. There is a gradual decrement of magnetic intensity towards east and southeast. The low magnetic anomalies are as a result of deep-seated bodies, indicating that there is a huge depth of basement rocks in the east and southeast of the study area. The decreasing of magnetic anomalies reflects the basement is thickening towards east and southeast area. This suggests that the basement extends to the Main Range granite in the east area which has a thicker crustal. Therefore, it also results that Semanggol area has fewer sediments filling. The regional magnetic trend of the study area is in a northwest-southeast direction.

4.4 Residual Magnetic Map

The residual map is generated after applying a high pass filter. It enhances the data by isolating the shallow-depth anomalies (high frequency) from the cumulative nature of TMI. The high pass filtered magnetic intensity map as shown in Fig. 5 with an effective cutoff at 2500m has a magnetic intensity range of between 57nT to -55nT. There are several positive and negative closure sets can be observed in the residual magnetic map. These anomalies indicate the variations of the magnetic susceptibility of the rock types that relate to the geological features. As shown in Fig. 5, those black line represents the possible shallow subsurface features such as weak zones and structures zones. In the residual magnetic map, there are few linear features with different trends can be observed. The orientations of these features are towards NW-SE and NE-SW directions. The main positive anomalies are trending NE-SW direction while the negative anomalies have the trend of NW-SE direction. Hence, it can be concluded that the dominant orientation for the weak zone features is towards NE-SW direction.

1. CONCLUSIONS

Based on the analysis and interpretation of the magnetic data, it can be concluded that the RTE map showed a relatively low magnetic intensity in the eastern part of the study area, indicating a gradual increase in the thickness of the crust. This might be due to the basement rock of Main Range Granite. Besides, around the peak of Gunung Semanggol illustrates low magnetic intensity. It suggests the existence of possible granite which is the extension of S-type granitoids of Main Range. However, certain geochemical laboratory investigations must be conducted to study the mineral and chemical composition of the rock types at Gunung Semanggol. Moreover, from the residual magnetic map, it can be concluded that the major orientation of the subsurface zones is in NE-SW direction.

2. ACKNOWLEDGMENTS

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