Implementing gravity method on geological contacts in Bukit Bunuh, Lenggong, Perak (Malaysia)

I N E Hidayah¹, Rosli Saad¹, Mokhtar Saidin², M M Nordiana¹, I N Azwin¹ and Andy Anderson Bery¹

¹Geophysics Section, School of Physics, 11800 Universiti Sains Malaysia, Penang, Malaysia
²Centre for Global Archaeological Research Malaysia, 11800 Universiti Sains Malaysia, Penang, Malaysia

Email: noerelhidayah@yahoo.com

Abstract. Using gravity method, a study of responses of different geological settings towards gravity was conducted in Bukit Bunuh, Lenggong, Perak (Malaysia). Gravity method provides different responses towards different rock types depending on the rock density. The survey area cover an area of 12 km², with a total 404 survey stations with stations interval of approximately 50 m and 500 m. The Bouguer anomaly map identifies the shallow granite rock with a value of -6 to -10.5 mGal while shallow limestone is -11 to -15 mGal. The sediment/overburden was identified with value of < -15.5 mGal. Few fractures are also identified and the boundary between limestone and granite rocks identified at the north part of the study area.

1. Introduction

The study implemented gravity method which involves in measuring the Earth’s gravitational field at specific locations on the Earth’s surface to determine the subsurface density variations [1]. A geological contact is the surface along which one rock touches another and a boundary between two rock units which identified on the basis of a textural, compositional, temporal difference or structural between rocks [2]. Drilling, application of geophysical methods or geological mapping can infer a geological contact. Common geophysical methods used to delineate these features are magnetic, gravity, seismic refraction and electrical resistivity methods. The study is to perceive the geological contacts’ response using gravity method. As different rocks gives off different gravity value, gravity method was chosen to delineate the existence of different geological settings at the same place. Generally, granitic rock have higher gravity value if were to be compare with limestone rock. Granitic rocks are composed of minerals rich in silicon and aluminium (felsic) which is denser than minerals contains in limestone rock, thus resulting in higher gravity value. Furthermore, gravity method is cost and time effective where it can cover over large areas in a short time. By doing the desk study and visiting the interested survey area, the different geological settings of granitic and limestone were found existed at the same place (N 5.09112° E 100.9724°) in Bukit Bunuh, Lenggong, Perak (Malaysia).

2. General Geology

Predominantly the Lenggong valley comprise of few lithologies which are tefra dust, granitic rock and alluvium (figure 1). The entire of Lenggong valley is dominated with granitic rock which is from
Jurassic end-Carbonaceous low era and originated from Bintang Range at the west of Lenggong [3]. Almost all of alluvium units in which the quaternary sediments contain of alluvium and tefra dusts are located along the river area. The topography of the Lenggong valley is exceeding 600 ft MSL. Situated at the east of Bukit Bunuh is Sungai Perak which flows from north to south and located at 61ft MSL while Bukit Bunuh consists of the older granitic rock. 200 million years ago at Mesozoic era the granite intrusion was happened all over Malaysia [4]. In Lawin, Bukit Jawa, Kampung Telemong and Kota Tampan, pebbles which is dominated by quartz and quartzite are found at the elevation 200-350 ft. At the lower zone of <600 ft, there exists colluviums which are characterized by a lots of fractures and fault zones. The rocks physical features exhibits that they are fractured and angled fractured comprise of chert, flint and agate.

Figure 1. Geology map of Lenggong, Perak, Malaysia with study area marked in the purple box [5].

3. Theory of gravity method
Gravity method utilized to study the figure, composition and structure of the Earth. Density variations of bedrock and soil in the immediate vicinity of measuring points influence the force of gravity in a discernible way. Influenced primarily by the mass and figure of the Earth, local and regional topography and centrifugal force due to the Earth’s rotation is total gravity [6].

Density is the parameter which control and determine the Earth’s gravity value. The changes of the density value horizontally will change the gravity or the anomaly gravity horizontally. Thus, the gravitational attraction of a body of non-homogenous density will vary from point to point, in react to the distribution of density within the body. Due to the reason, measurements of the variation, with location of the gravitational attraction of the Earth can provide valuable information of subsurface geology [7]. Rock types and minerals have their own characteristics range of densities. The dispersal in the subsurface of the constituent rock types and minerals will reflect through changes in the local
gravitational field. The variation of the gravitational field of the Earth from place to place may therefore, be interpreted in terms of subsurface geology – with certain assumption and limitations. Table 1 shows the density value for some of different materials [8]. In gravity anomaly interpretation, the measuring of the difference in density between different rock types should be done before determining its structure. The bulk density of the rock is controlled by the mineral content which forms rock mass, porosity and type of fluid in the cavity.

| Materials        | Density , ρ (g/cm³) |
|------------------|---------------------|
| Overburden       | 1.92                |
| Granite          | 2.50 – 2.81         |
| Limestone        | 1.93 – 2.90         |
| Gravel           | 1.70 – 2.40         |
| Shale            | 1.77 – 3.20         |
| Sedimentary rocks| 2.50                |

4. Data acquisition
Similar with any other geophysical survey, this study also started with desk study by studying the geological settings of the interested area. The lines and stations spacing were also decided depending on the area that need to be cover and the accessibility. After all of the decisions being made and all the preparations for the gravity survey were done, the gravity measurements were conducted using gravimeter Scintrex CG-5. The equipment measure differences in gravity from station to station [7] in miliGals (mGal). The survey conducted using loop principal to monitor and eliminate the potential drift effect. Base readings were taken at the beginning and end of the survey for that particular day at a fixed area where it is noise-free. The gridding survey stations were design to cover 12 km² areas. The northern traverse distance is 6 km with 50 m station spacing and eastern traverse distance is 2 km with 500 m station spacing. The total gravity stations for the study area are 404 (figure 2). Note that all of these stations are not taken on the same day but taken on different but continuous days. The global positioning system (GPS) instrument used for stations coordinates and stations elevations. The surveys were conducted in Bukit Bunuh, Lenggong valley (Perak) where meteorite impact was suspected million years ago [9]. After data acquisition, all the readings taken on that day will be transfer from the equipment to computer for data processing and interpretation. All the data collected were compiled and corrected using several standard procedures such as drift correction, elevations correction and free air correction to produce corrected Bouguer anomaly and contour map of Bouguer anomaly. Several filtering scheme were apply such as low pass filter and then the patterns of anomalies in contour map are observed and interpreted.
5. Result and discussions

Figure 3 shows Bouguer anomaly map of the study area with a value of -6 to -18 mGal. The high value (-6 to -10.5 mGal) is identified at northeast part and scattered at the center of the study area. This is due to the shallow level of granitic rock. The shallow level of granitic rock is validated from the borehole record which was done scattered in the survey area. The borehole records denoted granitic bedrock as impact granite with depth of 5-40 m. The rest of the study area was identified with a value of -11 to -15 mGal. The northern part is suspected due to the shallow limestone rock while the rest is due to sediment/overburden. Fractures also identified with the value of less than -15.5 mGal. The gravity low indicates rock fracturing as fractured rock is less dense than the unaltered rock. Previous studies conducted in the survey area using other geophysical methods such as seismic refraction, 2-D electrical resistivity method and magnetic method also show result with a lot of fractures zones due to the impact meteorite [10, 11; 12].
6. Conclusion
Based on the Bouguer anomaly map produced, the difference of responses of different geological settings is significance which in this case granitic (-6 to -10.5 mGal) and limestone (-11 to -15 mGal) while fractures zone indicated with much lower value of less than -15.5 mGal. As the result shows distinct differences in the values between two different geological settings, it shows that gravity method is capable to map the study area with density respond and identifies shallow or deep bedrock, fractures and boundaries/contact.

7. Acknowledgments
The authors wish to thank the member of Geophysics group of USM for their cooperation in the geophysical field data collection and Centre for Global Archaeological Research (CGAR), Universiti Sains Malaysia for sponsoring the project.

References
[1] Reza T 2010 Application of gravity method in fault path detection Aus. J. B. & Appl. Sc. 4(12) 6450-60

Figure 3. Bouguer anomaly map in Lenggong, Perak with fractures represented by the black lines.
[2] Howe R C 1997 Geologic contacts J. Geosc. Edu. 45 133-6
[3] Mokhtar S 1993 Kajian perbandingan tapak Paleolitik Kampung Temelong dengan Kota Tampan dan sumbangannya terhadap kebudayaan zaman Pleistosein akhir di Asia Tenggara Msia. Museum J. 32
[4] Alexander J B 1962 A short outline of the geology of Malaya with special reference to Mesozoic orogeny: crust of the Pasific Basin Geophy. Mono. 6 81-6
[5] Geological Map of Malaysia 1985 Geological survey department of Malaysia
[6] Elo S 1997 Interpretation of the gravity anomaly map of Finland Fin. Geophy. Soc. 33(1) 51-80
[7] Seigel H O 1995 A guide to high precision land gravimeter surveys Scientrex Limited
[8] Linsley R K, Kohler M and Paulhus J 1982 J. Geosc. Edu. 45 133-6
[9] Mokhtar S 2006 Bukit Bunuh, Lenggong, Perak : Sumbangannya kepada arkeologi dan geologi negara J. Arkeo. Msia 19 1-14
[10] Mark J, Rosli S, Mokhtar S, Kiu Y C and Andy A B 2013 Second stage subsurface study of meteorite impact crater at Bukit Bunuh, Malaysia using 2D electrical resistivity survey Elec. J. Geotech. Eng. 18 1199-204
[11] Rosli S, Kiu Y C, Mokhtar S and Shyeh S K M 2013 Identifying subsurface features using magnetic residual in Bukit Bunuh, Perak, Malaysia Elec. J. Geotech. Eng 18 1367-74
[12] Kiu Y C, Rosli S, Mokhtar S, Nordiana M M and Andy A B 2012 Characterization of Bukit Bunuh ground subsurface by 2D resistivity for meteorite impact study Elec. J. Geotech. Eng 17 3575-83