# GEOPHYSICAL SUBSURFACE GRAVITY SURVEY MODELING OF SEGAMAT- KUANTAN USING MATLAB

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**UNIVERSITI SAINS MALAYSIA**

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by

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# DECLARATION

I hereby declare that I have conducted, complete the research work and written the dissertation entitled **“Geophysical Subsurface Gravity Survey Modeling of Segamat- Kuantan Using MATLAB”.** I also declare that it has not been previously submitted for the award of any degree or diploma or another similar title of this for any other examining body or university.

Name of student : Mohamad Razif Bin Khazali Signature:

Date : 25 June 2018

Witness by,

Supervisor : Assoc. Prof. Dr. Kamar Shah Bin Ariffin Signature:

Date : 25 June 2018

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## ABSTRAK

Dalam projek ini, kaji selidik graviti geofizik dijalankan untuk mengkaji profil graviti geologi di sepanjang jajaran Lebuh Raya Tun Abdul Razak (Segamat-Kuantan). Kawasan kajian terletak di bahagian tenggara Pahang dan sebahagian utara Segamat. Secara amnya, struktur litologi bagi kawasan ini terdiri daripada mendapan sedimen, basalt, meta-sedimen dan terluluh hawa kuartenari yang merujuk kepada lempung. Profil data graviti untuk setiap stesen adalah kurang tepat kerana getaran dan bunyi yang disebabkan oleh lalu lintas di lebuh raya. Kaedah barometrik yang digunakan untuk mengira asas ketinggian pada pembezaan tekanan dan data yang diterima tidak tepat disebabkan oleh suhu di sekelilingnya. Tinjauan graviti dilakukan dengan menggunakan Gravimeter untuk mengukur perubahan graviti yang disebabkan oleh perubahan pecutan graviti di bawah permukaan topografi muka bumi. Selain itu, data graviti juga ini dipengaruhi oleh ketumpatan batu di bawah permukaan kawasan ini. Ketumpatan sampel batu untuk kawasan kajian ini direkodkan untuk mendapatkan data ketumpatan dan digunakan untuk permodelan 2-dimensi. Pelbagai graviti diperhatikan antara 0.89 hingga 6.62 miligal ke arah Kuantan. Pembacaan boleh dipengaruhi oleh julat geologi bawah permukaan ketumpatan antara 2.9 ($g/cm^3$) hingga 3.0 ($g/cm^3$). Bacaan graviti menunjukkan graviti minimum disebabkan oleh granit dan ketumpatan ia adalah (2.65 $g/cm^3$) dan minimum di Sg. Kawasan Rompin (65 km) terjejas oleh meta-sedimen (2.74 $g/cm^3$) yang lebih padat berbanding dengan granit di sekitar kawasan ini. Untuk analisis graviti yang lebih tepat, disarankan agar lebih banyak faktor perlu dipertimbangkan seperti bunyi bising, getaran, dan ralat instrumen.

# GEOPHYSICAL GRAVITY SURVEY SUBSURFACE MODELING OF SEGAMAT- KUANTAN USING MATLAB

## ABSTRACT

In this project, geophysical methods of gravity survey are conducted in order to study subsurface geology profile along Tun Abdul Razak (Segamat-Kuantan) Highway. The area of study is generally located in the southeastern Pahang region and the northern Segamat region. Generally, the lithology structure for this area consists of sedimentary, basalt, meta-sediment and quaternary unconsolidated deposit which refers to loose materials. Gravity data profile for each station is less accurate due to the vibration and noise caused by the traffic on a highway. A barometric method used to calculate the elevation base on pressure differential and the data received is not accurate cause by the temperature at surrounding. A gravity survey was carried out using Gravimeter to measure a change in gravity acceleration due to the gravitational acceleration on subsurface materials. Furthermore, the gravity data for this project influenced by the density of underlying rock subsurface and topography of this area. The density of rock along this survey area was recorded to obtain density data and requirement for 2-dimension modeling. The range of observed gravity between 0.89 to 6.62 milligal toward Kuantan. The highest observed gravity is 6.62 milligal at station number two. The reading may be affected by the density subsurface geology range between 2.9 ($g/cm^3$) to 3.0 ($g/cm^3$). The reading of gravity observed indicates minimum gravity is indicated by Granite and density is (2.65 $g/cm^3$) and the minimum at Sg. Rompin area (65 km) affected by meta-sediment (2.74 $g/cm^3$) which more dense compare to granite around this area. For accurate gravity analysis is needed, it is recommended that more factors need to be considered such as noise, vibration, and instrument drift.

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Geophysical methods are used to determine the physical properties of sub-surface geology from a surface measurement. Example of geophysical technique measure such as gravity, resistivity, seismic and magnetic. Gravity survey is one of the geophysical surveys usually second-hand for geophysical investigation which survey uses a natural method which the survey will measure gravity without providing equipment. Usually, gravity survey will measure the acceleration due to gravity and gravitational attraction depend on rocks with their density. Application of geophysical methods includes oil and gas exploration, geomechanics investigation, and hydrogeological investigation. The variation of physical properties affects the implementation of geophysical methods for a particular situation.

Based on the data profile, a good outcome depend on the real-time situation but cannot be used for high accuracy or multi-gravimeter project. Thus, to achieve high accuracy result in gravity survey, the data correction is required to data profile such as free air ($gfa$), latitude ($gn$), Bouguer (gb) and terrain correction ($gt$) to estimate the errors and the value of gravity anomalies. The correction of data profile will representations on graphical and an output using the MATLAB graphical user interface tool. MATLAB software is a new computer language which advance and easier to use compared to Visual Basic, Java and C++ programming. Data profile from the survey will be an input to the coding system and all gravity correction base on formula will calculate the function that transfer in MATLAB code language. From the interpretation data, the model can create with more accurate and easy to analyses.

## 1.2 Problem Statement

Location for this gravity survey project involved a N-S alignment along Tun Abdul Razak highway (Segamat-Kuantan) which the total length is 103.6 kilometer. The data profile along the survey is not accurate due to topography landscape (elevation). For gravity data modeling, the survey needs to be conducted with more database for 3-dimension modeling. 3-dimension modeling involved information distance, depth, and width of the study area which for a graphical presented with more data and make easier to interpretation gravity data. But, modeling for this survey only use X-axis and Y-axis as an input data to plot and create a model of gravity profile. Besides that, a barometric method used to calculate the elevation base on pressure differential and the data received is not accurate cause by the temperature at surrounding.

Gravity data profile for each station is less accurate due to the vibration and noise caused by the traffic on a highway. Selection of station point near to highway because to increase the accuracy of the distance between two stations.

## 1.3 Objectives

The objectives of this project:

- To develop subsurface geology gravity data profile along Tun Abdul Razak Highway (Segamat - Kuantan) area using gravity geophysical survey data.
- To understanding implementation of the method in mathematical modeling for solving the optimal problem.
- To use 4$^{th}$ generation MATLAB in processing and interpretation the geophysical data profile on programming software tool.

### 1.4 Survey Location

Geophysical gravity survey is carried out along 105 KM Tun Abdul Razak Highway. The survey starts from Segamat district to Kuantan, Pahang. This highway line is located between the latitude 2˚30' and longitudinal lines 102˚ 45' T – 103˚ 10' T. 25 KM from a total distance for this project located at Segamat district and the rest in South-East Pahang. Figure 1.1 shows the location of Tun Abdul Razak Highway (Segamat-Kuantan).


Figure 1. 1 Location of Tun Abdul Razak Highway (Segamat-Kuantan)

The study area comprises are highland and lowland topography landscape, with estimated elevation above sea level between 41- 43 meters. The road alignment generally running through a palm plantation area, surrounding of forest and agriculture which mainly belong to FELDA, FELCRA, and RISDA.

## 1.5 Geology

Generally, the area along the survey route is underlying sedimentary, basalt, meta-sediment and quaternary unconsolidated deposit which refers to loose materials. According to geological formation map of Peninsular Malaysia 2018 , the area generally comprises cretaceous-Jurassic, Permian, and acid intrusive rock formation.

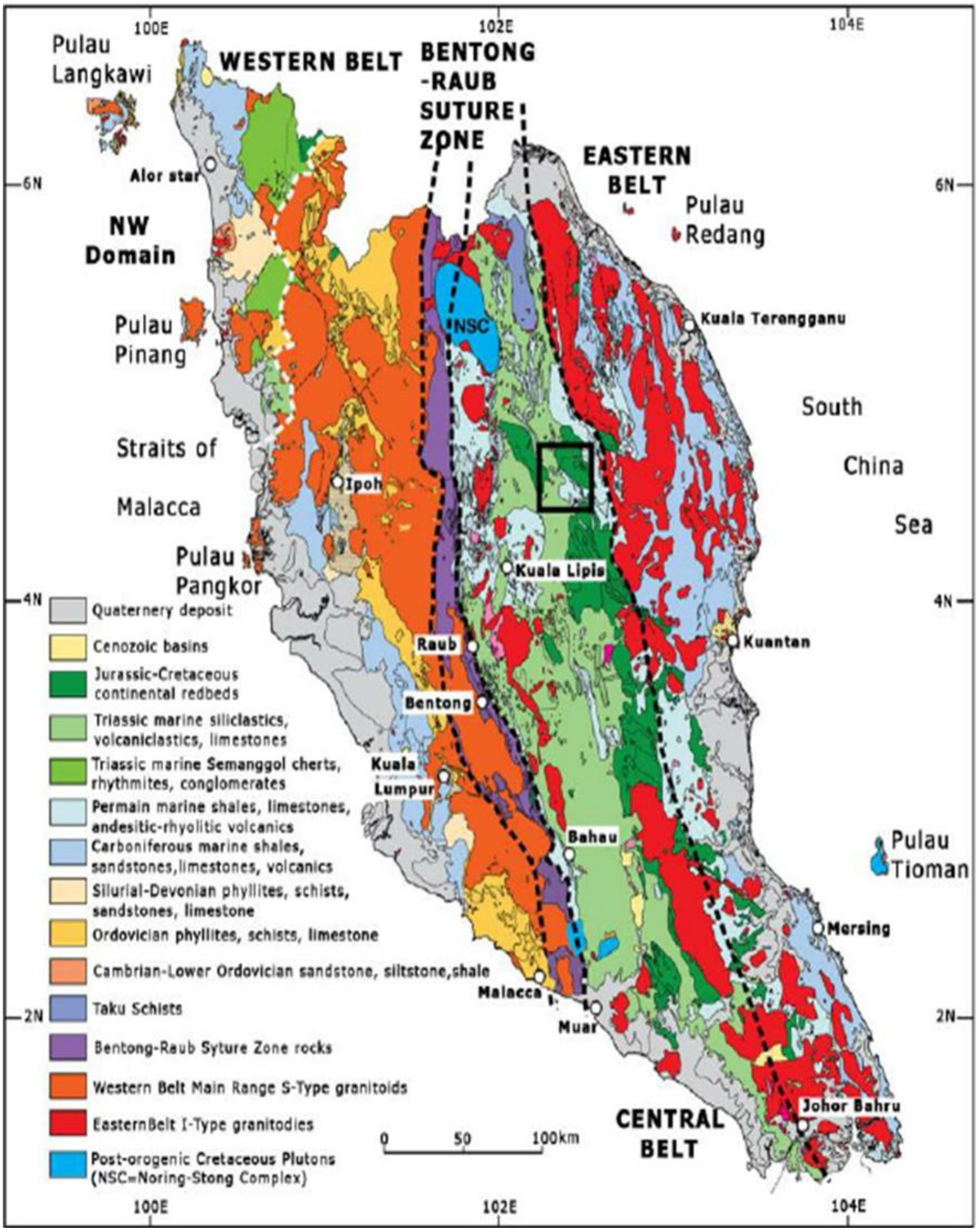


Figure 1.2 Geological Formation Map of Peninsular Malaysia 2018

Granite intrusive have formed a very thick and homogeneous soprolite due to the granite has a rough and compacted grain size. Similarly to Segamat basaltic rocks, it is rich in the rock composition. This situation is different for meta-sediment and sediment areas, soils are more shallow and less homogeneous. This is because the rocks are of various types and are resistant to weathering.

Lithology is the most effective factor in controlling the properties of soil that is formed relative to climate and vegetation, relatively much the same. The area of study is generally located in the southeastern Pahang region and the northern Segamat region. The study area also has a climate of the equator where rain and temperatures are high throughout the year. it is also one of the factors that have a direct relationship with the active impulse process and land-based patterns in the study area. Its annual rainfall ranges from 2000-2300 mm for the southern region of Peninsular Malaysia (Malaysian Meteorological Department,2018).

Weathering is the process of decomposition rocks by the action of process chemistry, physical and biogenetic. In engineering term, weathering and erosion that activities will continue to affect the stability of the slopes and rocks which relate throughout the geology of study area. Slopes and rock movement on land at the area clearly showed that the intensity of weathering is different depending on the type of rocks. Lithology is the most effective factor to control the properties of the land formed compared to climate and plant relative.

Weathering of granite has a resulted in a very thick and soprolite homogeneous because granite has a rough and size details fault compact. The composition of rich minerals that easily weathering as well as heavy and compact is the factors that lead to the formation of thickness and homogeneous soil. This is different for sediment, soil caused and produced more shallow and less homogeneous.

This primary drainage system can generally describe the geology of the bedrock and structures in this area. The main fault system in this area is oriented in the northwest, north and southeast directions. The secondary drainage system, drainage pattern is not affected by the fault. This area has generally reached a relatively mature stage of formation, where the rocks are controlling drainage patterns because the flow is not controlled by the structure or the rocks. Typical patterns are dendrites (branch) and sub dendrites (Ariffin, 1984).

Almost 90% slopes found along the study area consists of slope instability, designed specially to always be in a State of the stable. Unfortunately, geomorphology processes that are active in this area are quite unstable. landslides, creep and dropping rocks is a geomorphology process activities happen especially when rainy season (Ariffin, 1984).

## 1.6 Outline of Thesis

This project was being held for about 13 weeks, starting from February until May after the research proposal was approved. To achieve this project objective, the work outline and task had carried out first. Literature reading will help to obtain a basic knowledge before proceeding to research work. A literature review is the assessment of available scholarly paper of the chosen research from any project. This research assessment help from the data and analyses the formation from a particular topic in summary.

After study the theory, site investigation need an arrangement and plan all the work frame for field investigation. For gravity survey, the methods used are geophysical techniques which involve gravitational acceleration over varieties of density subsurface materials. Data acquisition is done during this stage after considering all parameters that will affect the survey result.

This project involves outdoor and indoor activities. Outdoor activities include field work such as gravity observed, measuring elevation and pressure. For indoor activities involve data analyzed and interpreted data profile. All the data will transfer to selected software to be analyzed.

The application of software such as Microsoft Excel and MATLAB software helps to process the data. The result will process by the software after programming and the result are able to be assessed and interpreted. The result obtained is analyzed first to ensure the objective of this project achieves the target. This software chooses for building the new programming to calculate all the correction involve and affected by gravity survey.

Flowchart represents three main component for gravity processing involves input, processing, and output. Gravity model, barometric measure and gravity measure will use as a database for input and all the correction for this survey will set as the processing in programming. After all the step done, research conclusion has to be stated and summarizing all about this project relate to an objective. Lastly, to improve these project recommendations were suggested.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Geophysical Survey

The geophysical survey usually applies on subsurface to obtain information by responses that are measured physical properties and contrast in the earth. In oil exploration, the geophysics involve the measure of gravity gradients to locate salts piercement (Bedard *et al.*, 2000). Mathematics framework by inversions data will construct physical property models consistent with the data profile. Deterministic inversion aims to find a model that consistent with the data and to find the best model that will consistent with the data (Cockett *et al.*, 2015). Geophysical overviews react to the physical properties of subsurface materials. it can be grouped into two type :

a) *Active*: For example, those utilized as a part of investigation seismology, in which misleadingly created signals are transmitted into the ground, which at that point changes those flag in ways that are normal for materials through which they travel.
b) *Passive*: Techniques that distinguish varieties inside the characteristic field related to the earth, for example, a gravitational and attractive field.

Each geophysical system measures a particular parameter, which relies upon at least one physical properties of the earth. Since not every single physical property will fluctuate in a specific circumstance, certain methods are not appropriate for all issues. The case of geophysical studying with its separate physical properties to be estimated is demonstrated as follows :

- Magnetic study estimation relies upon the thickness of the attractive weakness of subsurface materials.
- Seismic refraction overview relies upon P wave and S wave.
- Electrical resistivity or instigates polarization review strategy measure electrical conductivity or electric capacitance.
- Gravity overview strategy relies on thickness and size of earth gravitational field (Ariffin, 1984).

Data of geophysical survey method is normally prepared somehow after securing. One of the advantages of this system is that it is non-ruinous and makes no unsettling influence subsurface materials. Geophysical survey is fast and financially understanding in covering an extensive scale region and furthermore can induce properties of substance from surface data.

The fundamental use of geophysical techniques is for the mineral, oil and gas exploration. The variety of physical properties impacts the gravity filed to the survey data profile. Gravity gradient data are measured in 3-dimension where measure obtain in change gravity field in three directions (Qin *et al.*, 2016). Relative gravimeters are usually used in geoscience exploration such as oil and mineral explorations, water storage, volcanology, geothermal monitoring (Balia *et al.*, 1984) or geodynamical studies with high precision (Cattin *et al.*, 2015).

Gravity geophysics survey technique has proven that the application is useful in survey industries such as locating a number of common oil trapping environments, including salt domes, major anticlines and structures that have fault-block (Bedard *et al.*, 2000).

## 2.2 Geology

According to Ariffin (1984), a maximum magnetic anomaly for Basalt between 200 to 240 gamma and minimum is -120 gamma for the sedimentary area. For Segamat region, basalt consists of leucite basalt and basalt-potassium which in potassium area. Granite in the south of Segamat known as granite adamellite, biotite and granodiorite usually slightly hornblende. Granite as a result of metamorphism and metasomatism rocks and sedimentary rocks arenite (Harun and Samsudin, 2014).

Based on granite formation for Peninsular of Malaysia, granite for this area shows the lowest gravity anomaly (-11.8 mgal) compare to another granite area. From gravity survey profile modeling, the granite layer between 1.0 to 1.5 km thickness. Formation of the conglomerate layer at Rompin similar to a conglomerate layer near to Murau hill relates to properties and geological formation (Ariffin, 1984).

Highly weathered basaltic rock was exposed along the profile of Kuantan, Segamat Highway. The weathering profile from fresh rock soil can be observed at profile at Kg. Jabi Quarry. The concentration of major elements contain $TiO_2$, $Al_2O_3$ and $Fe_2O_3$ appear to be increased with the increasing of the degree of weathering whereas the concentration of $SiO_2$and CaO are decreased (Baba Musta & Mohamad Md. Tan, 1996).

There is a pure correlation between $Al_2O_3 + Fe_2O_3$ , L.O.I as well as between $Fe_2O_3$ with $Al_2O_3$. Behaviour of the trace elements such as Ni, Co, Cr and Zn against the weathering process are absolutely different. The secondary minerals such as kaolinite, hematite, nactire, and gibbsite are appear to control the behaviour of the major and trace elements (Baba Musta & Mohamad Md. Tan, 1996).

## 2.3 Gravity Method

### 2.3.1 Concept

Aim for gravity data survey is to studying details and providing a better understanding of subsurface geology. The gravity is one method that inexpensive and non-destructive remote sensing method. This method is a passive means no energy required into the ground in order to obtain gravity data (Harun and Samsudin, 2014).

The gravity measure density of rocks below subsurface. This method includes measuring the gravitational attraction between two point station on the surface toward to Earth. Gravity attraction strength directly proportional to the mass of geological structures. Therefore, gravity will affect by subsurface geology. Figure 2.1 shows the illustrations the relative surface variation of Earth's gravitational acceleration over geology subsurface structure.

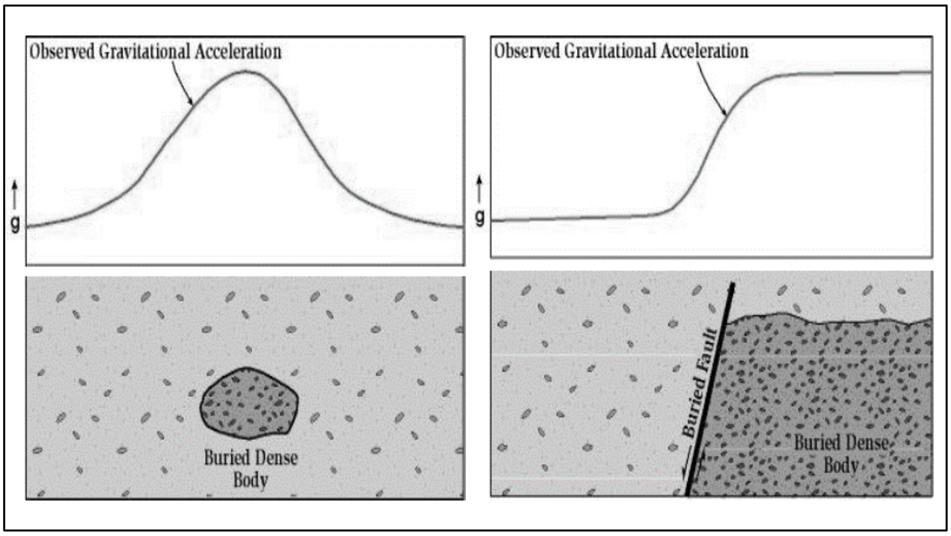


Figure 2. 1 Illustrations The Relative Surface Variation Over Geology Structure (Shen and Na, 2017)

Figure 2.1 shows the gravitational acceleration to the earth is distracted because of the buried density below the surface. Gravity method can infer the location of the fault and detect the movement of hydrothermal.

### 2.3.2 Gravity Properties of Earth

The gravity of an object is directly proportional to its mass. Gravity on earth effect by the gravitational attraction and value of gravity earth's surface is 9.8 $ms^{-2}$. For geophysical gravity survey, the method is measure gravity variations at stations around loop or station. Gravity measurement usually use worldwide to investigations such as topography mapping for bedrock, thickness, offshore exploration and microgravity investigations (Li and Nabighian, 2015).

Newton's laws by Isaac Newton (Plastino and Rocca, 2018), Second law state that acceleration force will produce when an object acts on the mass. The greater the force required to accelerate an object, the greater the mass of the object. Law of Universal Gravitational state that the force of attraction every point mass relate to other point mass connecting by an intersection point for both point. Force is directly proportional to the mass of product and inversely proportional to the square to the distance between to masses (Moustafa, 2016). The formula to approve this story can be expressed as:

$$\boldsymbol{F = G\frac{m_1 m_2}{r^2}}$$

where :

F = Force acts between two point

G = Gravitational constant

$m$ = Mass of two product and respectively

$r^2$ = Distance between to an object

The shape of the earth is a Uniform spherical, therefore the gravitational attraction on small mass will be simplified as :

$$\boldsymbol{F} = \frac{\boldsymbol{GM}}{\boldsymbol{R}^2}\boldsymbol{m} = \boldsymbol{gm}$$

Where :

$m$ = Weight of mass and object

$g$ = Acceleration due to gravitational force to the earth.

The gravity field is a potential field where is a signature reflecting the interior structure of the Earth and used for geophysical and geodynamical investigation. The geodynamical phenomenon is a study by observed of gravity and change caused by the different properties of the underlying rock. For example, Satellite Gravity Gradiometry (SGG) one of the techniques that use accelerometry at satellite level to measure geopotential by the second-order partial derivatives. This method will recover the gravity data field more homogeneously, precisely and to a higher resolution than other satellite (Eshagh and Sjöberg, 2011).

Gravity field can be measured by using a gravimeter which measures relative gravity variations with standard deviation as low as 5 µGal without the noise and vibration surrounding. High-resolution can reach by with a mean gravity and standard deviation. The measurement standard sampling between 1-10 Hz rate and be corrected in real-time corrections, temperature, Earth tide, seismic noise and instrument drift (Cattin *et al*., 2015).

### 2.3.3 Correction

Input data from gravity meter measurements need to recalculate based on the correction that involves and affected the reading of gravity field data. Among of the corrections are latitude correction, free air correction, terrain correction, Bouguer correction, instrument drift correction, earth, and tide correction. All the correction will affect the gravity data profile and the accuracy gravity value (J. Xia, D. R. Sprowl, 1991).

a) Instrumental Drift Correction

Gravimeters are very sensitive to surrounding especially noise and vibration (Sokolov, 2011). The change in temperature will affect the elastic creep in spring cause the data reading not accurate. Usually, correction of gravimeter drift can reach up to 1mGal per day and this will affect the significant to be accuracy data profile in gravity survey (Cattin *et al.*, 2015). Drift correction value is typically less than 10 gu per hour and large or value indicate because of instrument problem. Elevation measurement for this project uses a barometric method which use a different pressure to calculate the elevation by whirling. The formula can be expressed as:

$$\boldsymbol{h_c = \frac{(dh)(T - T_0)}{T_0}}$$

Where :

$h_c$ = Temperature correction

$dh$ = Height

$T$ = Average temperature ($K^o$)

and the height actual expressed as :

$$\boldsymbol{Dh = dh + h_c}$$

and the equation for $\boldsymbol{dh}$ expressed as :

$$\boldsymbol{dh = 29.348 \times T \times \ln \frac{P_1}{P_n}}$$

Where :

$Dh$ = Actual Height

$P_1$ = Pressure at the aim station

$P_n$ = Pressure at survey location, n = 1, 2,3….,n

Another cause of drift correction is the gravitational attraction of sun and moon will affect when the position change toward earth. This usually calls as a tidal correction. Figure 2.2 shows the example instrument drift correction for each station gravity point due to time.

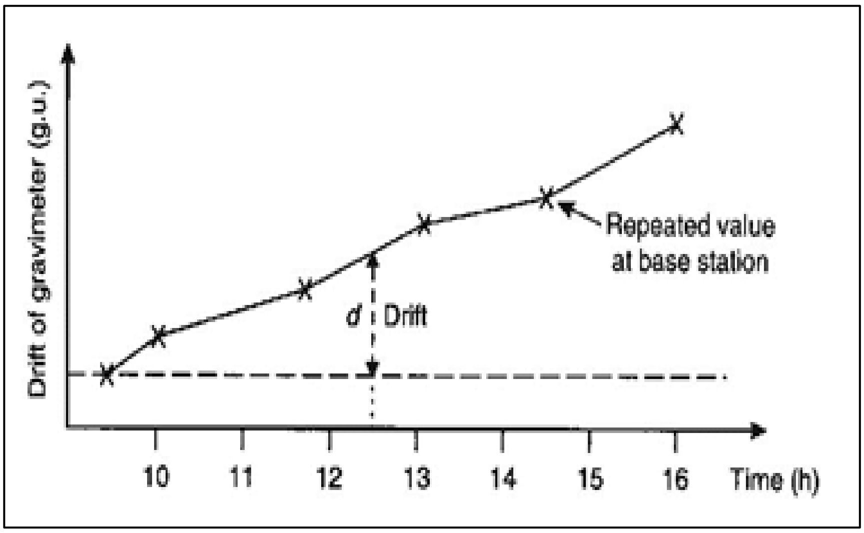


Figure 2. 2 Example Instrument drift correction for each station

b) Topography Correction

Aims for topography correction to minimize gravity field caused by topography or earth surface and all the gravity data will refer to one datum. Topography correction includes free-air correction, terrain correction, and Bouguer correction.

i. Free air Correction

Free air correction is performed to eliminate the effect of station altitude difference on the center of the earth. The bigger the difference is that the gravitational force is decreasing and that is the opposite. Correction for free air will add when the location for stations is above the datum and will be subtracted from the stations below the datum.

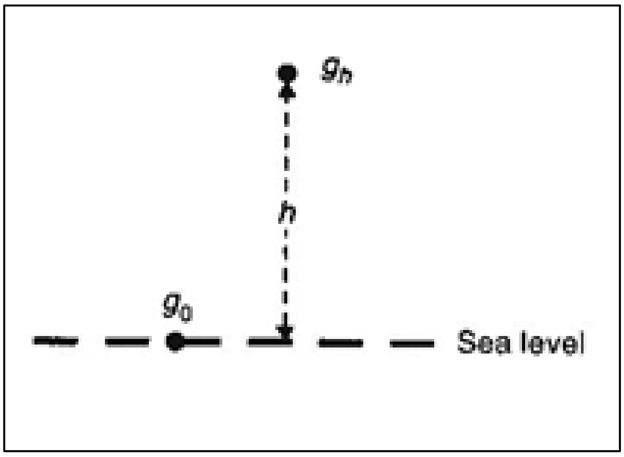


Figure 2. 3 Free-air corrections

Figure 2.3 shows the application difference between gravity measured at sea level and at an elevation, h, with no rock in between. The elevation difference between the base station and the measurement point affected by the different gravitational acceleration due to gravitational attraction. The free air correction uses to measure the different gravity due to the different elevation on the earth surface (Allen and Fratta, 2015). The free air formula can be expressed as:

$$\boldsymbol{\delta_{gh} = -(0.3087691 - 0.0004398 sin^2 \emptyset) h + 7.2125 \times 10^{-8} h^2}$$

Where :

$\delta_{gh}$ = Free air correction in milligal

$h$ = Elevation of measurement stations in meter

$\emptyset$ = Latitude point station respectively to ellipsoid

Free air correction depends on latitude so that, the gravity gradient is varied due to the position and shape of the Earth. The changed elevation between the base gravity station and the reference ellipsoid is measure as h, where effect the correction (Chasseriau and Chouteau, 2003).

For example, If the measure station located higher than reference ellipsoid, gravity at the station will increase due to apply to free air correction. Another case, if the base station is located higher than the measure gravity station, gravity will reduction at measure gravity station after the free air correction is applied to reduce the measure gravity station position to the base station. From that, the formula can simplify as :

$$\boldsymbol{\delta_{gh} = -0.3086\ (h)}$$

where h is the elevation of gravity station is above the datum in meters. The total value different between a corrected value and standard gravity is called as 'free air anomaly'. The value that involves observed gravity (gobs) and latitude correction (gn) to evaluate anomaly for that location. Free air corrected gravity (*gfa*) formula can be expressed as :

$$\boldsymbol{gfa = gobs - gn + 0.3086(h)}$$

Where :

$gfa$ = Free air corrected gravity

$gobs$ = Observed gravity

$gn$ = Latitude correction

$h$ = Elevation of gravity station is above the datum in meters.

Free air anomaly is important because this value will use to calculate the other correction and will affect the gravity anomaly at a station. The higher location of gravity station, the higher value gravity corrected due to the different distance between two station point refer to ellipsoid.

ii. Bouguer Slab Corrected Gravity

The Bouguer correction accounts for the mass which underlying the point station or reference ellipsoid and the measurement point located at the elevation higher than the elevation datum. For the measurement gravity which the reference ellipsoid is below the Earth's surface and the gravity point station on the surface, the mass of rock between the reference point and gravity point station has the effect of the gravity (Allen and Fratta, 2015)

The reading of meter will be related to the position where the measurement station and reference ellipsoid location. Based on the theoretical, this will pull up on the meter, measurement station will have a reducing gravity. The aim of Bouguer correction is to remove the effect of mass between the measurement point and a base station using a formula (Connor *et al.*, 2012) expressed as :

$$\boldsymbol{\delta_{gb} = 0.04193\rho h}$$

Where :

$\delta_{gb}$ = Bouguer gravity

$\rho$ = Density (average) of the rocks underlying station

$h$ = Elevation of gravity station and reference ellipsoid

Elevation different between the reference ellipsoid and gravity point station has a part to minimize the correction. For example, a location of gravity point station is higher elevation than the reference ellipsoid and gravity will decrease after the applied Bouguer correction due to the different elevation. Thus, the form of the Bouguer gravity anomaly based on theoretical can express as :

$$\boldsymbol{gb = gobs - gn + 0.3086(h) - 0.04193\rho(h)}$$

Where :

$gb$ = Bouguer slab corrected gravity

$gobs$ = Observed gravity

$gn$ = Latitude correction

$\rho$ = Density (average) of the rocks underlying station

$h$ = Elevation of gravity station and reference ellipsoid

The density of rock between the gravity point station and reference ellipsoid will affect the gravity location. According to the density of granite is less than the Precambrian rocks (Chandler, 1994) of surrounding area and give a low gravity (Choi *et al*, 1999).

iii. Terrain Correction

Terrain correction negligible in Bouguer correction because due to the topography around at survey area. Terrain correction basically measures the variation of gravity acceleration near to the gravity point station caused by topography. The gravity will reduce when the measurement of gravimeter near to mountain caused by the force and if the gravity point station near to valley (Bahrami *et al*., 2016). Thus, the form of the Terrain corrected can express as :

$$\boldsymbol{gt = gobs - gn + 0.3086(h) - 0.04193\rho(h) + TC}$$

Where :

$gb$ = Bouguer slab corrected gravity

$gobs$ = Observed gravity

$gn$ = Latitude correction

$\rho$ = Density (average) of the rocks underlying station

$h$ = Elevation of gravity station and reference ellipsoid

TC = Value of terrain correction

Figure 2.4 shows terrain correction is applied which gravity point located at a different elevation. The purpose of this correction to reduce the error of different topography structures that may be affected by geological and formation.

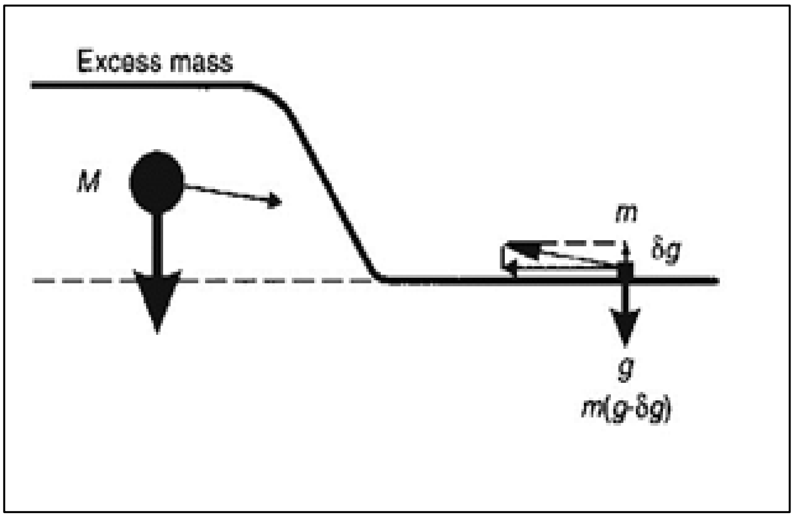


Figure 2. 4 Terrain Correction

Terrain correction is added to Bouguer anomaly by assuming the terrain correction is positive whether the measurement of gravity near to mountain or valley. Terrain correction can be computed by applying the Sigmund Hammer (Hammer, 1974) technique which uses a Hammer chart transparent template or uses topography at fine-scale digital value. The Chart use as the center of gravity point station and off at the center of chart segment will be read as topography. Terrain correction will be obtained after tabulation each segment and this is applied to the gravitational attraction of cylindrical segment formula.

c) Latitude Correction

The error involved in the topography correction is a function to balance the point between station point and reference point. Correction can be maximized when the optimum elevation achieve and help to smooth anomaly calculation for gravity survey (J. Xia, D. R. Sprowl, 1991). Usually, the correction will be applied to small-scale survey less than 100 km. Latitude correction applied to eliminated influence latitude  to gravity anomaly by using the following equations:

$$gn = 978031.85(1.0 + 0.005278895\, sin^2(lat) + 0.000023462\, sin^4(lat))$$

where:

$gn$ = Latitude correction

$lat$ = Latitude of gravity station

Latitude correction subtracted from the observed gravity that relates to elliptical shape and rotation. The gravity of Earth different due to the position on the surface. If the shape of Earth is constant, the value of gravity will constant respectively. The shape of Earth is flattened due to the rotation is shown in Figure 2.5. The bigger radius of Earth when the greater centrifugal force tends to pull outward at the equator position.

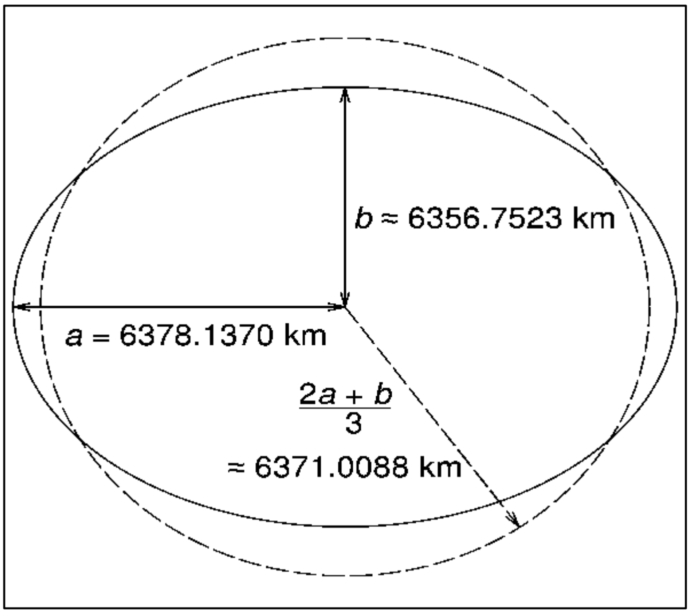


Figure 2. 5 Shape of Earth

Figure 2.6 shows reference ellipse rotation and geoid which represent a surface on which the gravitational field has a similar value and known as the equipotential surface. Water level also corresponding to the geoid surface and imaginary canal.

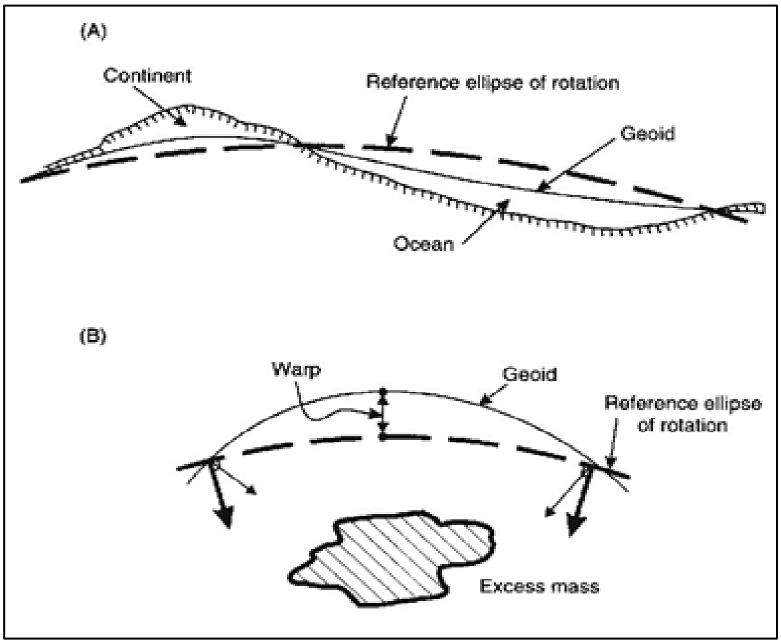


Figure 2. 6 Geoid and Reference ellipse

Bouguer anomaly is a relatively different gravity from the result of gravity point station after all the correction is applied. Bouguer anomaly using the following equations:

$$\Delta \boldsymbol{g} = \Delta \boldsymbol{g}_{obs} \pm \Delta \boldsymbol{g}_{n} - \Delta \boldsymbol{g}_{fa} + \Delta \boldsymbol{g}_{b} + \Delta \boldsymbol{g}_{t}$$

For the point station below the datum, but if the point station above the datum can use following equations:

$$\Delta \boldsymbol{g} = \Delta \boldsymbol{g}_{obs} \pm \Delta \boldsymbol{g}_{n} + \Delta \boldsymbol{g}_{fa} - \Delta \boldsymbol{g}_{b} + \Delta \boldsymbol{g}_{t}$$

Where:

$\Delta g$ = Gravity different between station

$\Delta g_{obs}$ = Different gravity before correction

$\Delta g_{n}$ = Latitude correction

$\Delta g_{fa}$ = Free-air correction

$\Delta g_{b}$ = Bouguer correction

$\Delta g_{t}$ = Terrain correction

The Bouguer anomalies are used in map interpretation of land gravity and modeling (Hinze *et al.*, 2005). Variations of the Bouguer gravity anomaly caused by the density of rocks that varies due to geological structure. This method is not unique because the result of mass possible produces a pattern of anomalies due to the mass distribution. With this method and skillful hands, this method will be useful to oil and gas exploration when the combination data between other geological and physical skill will improve the accuracy of data. Bouguer anomalies also widely used in general on land and at sea with respect to geological studies.

### 2.3.4 Geophysical Gravity Application

Gravity survey is a method which applied in drill holes to the measured mean density value of rocks with varieties of depth by means of gravimeters. Located iron-rich accumulations in engineering application can be carried out by gravity survey. Application of gravity method survey includes the shape of the earth, determination of isostatic compaction and the major in hydrocarbon exploration (Haldar, 2013)

Sedimentary basin formation or the accumulation of hydrocarbon is an important role in management and acquisition for exploration by mapping. In the oil industry, reconnaissance scale geophysics important to eliminate the possibility of success for exploration. However, accurate and high resolution of gravity data will involve the large-scale surveys which affect time and the cost totally increase due to surveys area.

According to Bedard, Creer and Asten (2000), Airborne geophysical survey in petroleum exploration have a major role in initial reconnaissance of continental shelf areas. Gravity survey method will involve magnetic survey to determine the position and size of the major structures underlying rock which contain accumulations of