Gravity Method

Contents

Geophysics (Definition)

- Geophysics is the application of method of physics to the study of the Earth.
- On the other sense, it is a subject of natural science concern with the physical processes and the physical properties of the earth and it's surrounding space environment and the use of co-ordinary methods for the analysis.
- It involves the application of physical theories and measurements to discover the properties and processes of the earth.

Geophysics

- Geophysics has contributed significantly in the understanding of many physical processes that lead to scientific and economic contribution to our society.

Branches of Geophysics

- **Solid Earth Geophysics :**
  - Earthquakes, Tsunamis, Tectonics
  - Geodynamics

- **Exploration Geophysics :**
  - Oil and Gas exploration
  - Minerals exploration

- **Environmental & Engineering Geophysics :**
  - Groundwater exploration
  - Contaminant delineation
  - Utility or object detection

Scopes of Geophysics

- **Natural hazard studies:**
  - Earthquake
  - Landslide

- **Resource explorations:**
  - Oil and gas exploration
  - Mineral prospecting
  - Geothermal exploration
  - Groundwater exploration

Scopes of Geophysics(Cont.)

- **Engineering:**
  - Underground utility locating
  - Concrete inspection
  - Rebar locating
  - Pavement evaluation
  - Underground void locating
  - Ground strength testing

- **Environmental application:**
  - Underground storage tank locating
  - Contamination delineation
  - Landfill delineation
  - Bedrock depth mapping

Geophysical Methods

- **Potential Fields:**
  - Gravity
  - Magnetics
- **Diffusive Fields:**
  - Electrical
  - Heat Flow
  - Electromagnetics(EM)
- **Wave Propagation:**
  - Seismic (Sound Waves)
  - Radar (EM Waves)

Geophysical methods

- **Gravity method:**

- Gravity method is a non-destructive geophysical technique that measures differences in the earth's gravitational field at specific locations.
- The gravity method is a relatively cheap, non-invasive, non-destructive remote sensing method.

Gravity method

- In gravity surveying, subsurface geology is investigated on the basis of variations in the Earth's gravitational field arising from differences of density between subsurface rocks.
- An underlying concept is the idea of a **causative body,** which is a rock unit of different density from its surroundings.

Gravity method

- The basis on which the gravity method depends is encapsulated in two laws derived by Newton, namely his **Universal Law of gravitation** and his **Second Law of Motion**.

$$F = G\frac{Mm}{R^2} \quad ....(1) \qquad F = mg \quad ....(2)$$

$$g = \frac{GM}{R^2} \quad ....(3)$$

This shows that the magnitude of acceleration due to gravity on Earth (g) is directly proportional to the mass (M) of the Earth and inversely proportional to the square of the Earth’s radius (R)

Gravity method

Units of gravity

- The mean value of gravity at the Earth's surface is about 9.8ms-2.Variations in gravity caused by density variations in the subsurface are of the order of 100 mms-2.
- This unit of the micrometer per second per second is referred to as the *gravity unit (gu). In gravity surveys on land an* accuracy of ±0.1 gu is readily attainable, corresponding to about one hundred millionth of the normal gravitational field.
- At sea the accuracy obtainable is considerably less, about ±10 gu.The c.g.s. unit of gravity is the *milligal* (1 mgal = 10-3 gal = 10-3cms-2), equivalent to 10 gu.

Gravity method (Process)

- Gravity techniques measure ***minute variations in the earth's gravity field***. Based on these variations, subsurface density and thereby composition can be inferred.
- These variations can be determined by measuring the earth's gravity field at numerous stations along a traverse, and correcting the gravity data for ***elevation, tidal effects, topography, latitude***, and ***instrument drift***.

Gravity method (Process)

- The gravity field on the surface of the Earth is not uniformly the same everywhere. It varies with the distribution of the mass materials below. A Gravity survey is an direct means of calculating the density property of subsurface materials.
- ***The higher the gravity values, the denser the rock beneath.***

Gravity method (Equipment)

- Modern instruments capable of rapid gravity measurements are known as ***gravity meters*** or ***gravimeters***. Gravimeters are basically spring balances carrying a constant mass. Variations in the weight of the mass caused by variations in gravity cause the length of the spring to vary and give a measure of the change in gravity.

Gravity method (Equipment)

- There are ***two types*** of gravimeters:
  1. ***Relative*** and
  2. ***Absolute***.

Absolute gravimeters measure the ***local gravity in absolute units***, ***gals***.

Relative gravimeters compare the value of gravity at one point with another. They must be calibrated at a location where the gravity is known accurately, and then transported to the location where the gravity is to be measured. They measure the ratio of the gravity at the two points.

Gravity Anomalies

- A causative body represents a subsurface zone of anomalous mass and causes a localized perturbation in the gravitational field known as a gravity anomaly.
- Gravity anomaly map yield the difference between the observed gravity values and the theoretical gravity values for a region of interest.

Gravity Anomalies(Cont.)

- A very wide range of geological situations give rise to zones of anomalous mass that produce significant gravity anomalies.
- On a small scale, buried relief on a bedrock surface, such as a buried valley, can give rise to measurable anomalies.

Gravity Anomalies(Cont.)

- Depending on what we want to emphasize there are **3** anomaly map:
  - Free-air or Faye anomaly
  - Bouguer anomaly and
  - Isostatic gravity anomaly maps

Faye anomaly:

- Is defined by applying only normal, free-air, terrain and tidal corrections to the measured gravity value.

Gravity anomalies(Cont.)

- **Bouguer anomaly:**
- Is defined by applying normal, free-air, terrain and tidal correction to the measured gravity value.
- The difference between the Bouguer and the Faye anomaly arises from the Bouguer plate correction.
- Bouguer anomalies are usually negative in region of large elevation and are mainly in positive in oceanic regions.

Gravity anomalies(Cont.)

- **Isostatic gravity anomaly:**
- Is defined by applying isostatic correction to the Bouguer anomaly.

Gravity reduction

Before the results of a gravity survey can be interpreted it is necessary to correct for all variations in the Earth's gravitational field which do not result from the differences of density in the underlying rocks. This process is known as ***gravity reduction***.

Gravity reduction

- **Drift correction**

Correction for instrumental drift is based on repeated readings at a base station at recorded times throughout the day. The meter reading is plotted against time and drift is assumed to be linear between consecutive base readings.

Drift Correction

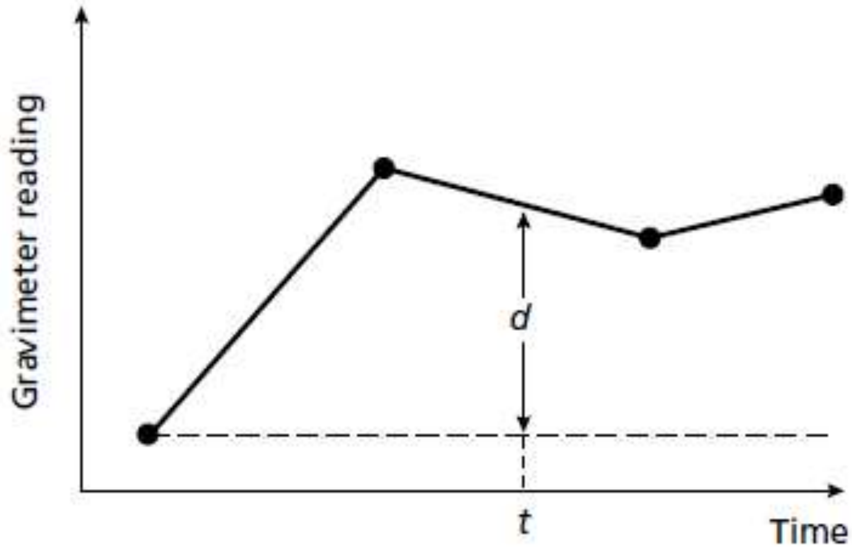


Fig. 6.10 A gravimeter drift curve constructed from repeated readings at a fixed location. The drift correction to be subtracted for a reading taken at time *t* is *d*.

From the figure drift is assumed to be linear between consecutive base readings. The drift correction at time *t is d, which is subtracted from the observed value.*

Eötvös correction

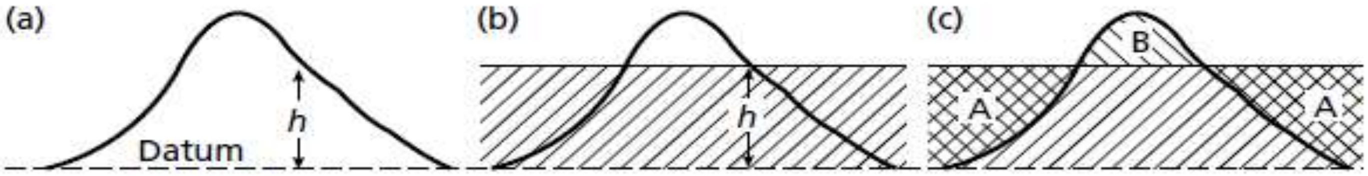
The Eötvös correction (EC) is applied to gravity measurements taken on a moving vehicle such as a ship or an aircraft. Depending on the direction of travel, vehicular motion will generate a centripetal acceleration which either reinforces or opposes gravity.

Gravity reduction

Elevation corrections

Correction for the differing elevations of gravity stations is made in three parts :

- Free air Correction
- Bouger Correction
- Terrain Correction



. 6.12 (a) The free-air correction for an observation at a height h above datum. (b) The Bouguer correction. The shaded region responds to a slab of rock of thickness h extending to infinity in both horizontal directions. (c) The terrain correction.

Elevation Correction

- **The free-air correction (FAC)** corrects for the decrease in gravity with ***height in free air*** resulting from increased distance from the centre of the Earth. The FAC is positive for an observation point above datum to correct for the decrease in gravity with elevation. The free-air correction accounts solely for variation in the distance of the observation point from the centre of the Earth; no account is taken of the gravitational effect of the rock present between the observation point and datum.

Elevation Correction

Bouguer correction

On land the Bouguer correction must be subtracted, as the gravitational attraction of the rock between observation point and datum must be removed from the observed gravity value. The Bouguer correction of sea surface observations is positive to account for the lack of rock between surface and sea bed. The correction is equivalent to the replacement of the water layer by material of a specified rock density r.

Elevation Correction

Terrain corrections

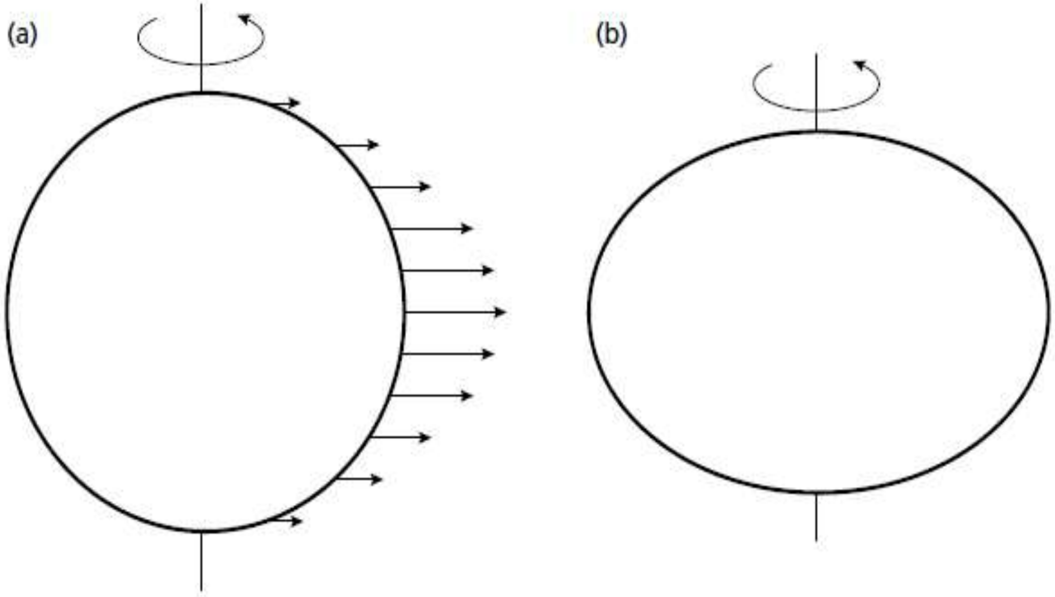
A correction applied to observed values obtained in geophysical surveys in order to remove the effect of variations in the observations due to the topography near observation sites.

Latitude Correction

Gravity varies with latitude because of the non-spherical shape of the Earth and because the angular velocity of a point on the Earth's surface decreases from a maximum at the equator to zero at the poles. The centripetal acceleration generated by this rotation has a negative radial component that consequently causes gravity to decrease from pole to equator. Consequently, points near the equator are farther from the centre of mass of the Earth than those near the poles, causing gravity to increase from the equator to the poles.

Latitude Correction

Fig. 6.11 (a) The variation in angular velocity with latitude around the Earth represented by vectors whose lengths are proportional to angular velocity. (b) An exaggerated representation of the shape of the Earth. The true shape of this oblate ellipsoid of revolution results in a difference in equatorial and polar radii of some 21 km.



Tidal Correction

Gravity measured at a fixed location varies with time because of periodic variation in the gravitational effects of the Sun and Moon associated with their orbital motions, and correction must be made for this variation in a high precision survey. In spite of its much smaller mass, the gravitational attraction of the Moon is larger than that of the Sun because of its proximity.

Tidal Correction

- These *solid Earth tides* are considerably smaller than oceanic tides and lag farther behind the lunar motion. They cause the elevation of an observation point to be altered by a few centimeters and thus vary its distance from the centre of mass of the Earth. The periodic gravity variations caused by the combined effects of Sun and Moon are known as *tidal variations*.
- They have a maximum amplitude of some 3 gu and a minimumperiod of about 12 h.

Application of Gravity method

- Determine shape of the Earth
- Hydrocarbon exploration
- Regional geological studies
- Iso-static compensation determination
- Detection of sub-surface cavities (microgravity)
- Location of buried rock-valleys
- Determination of glacier thickness
- Tidal oscillations
- Basin Geometry