

GRAVITY SURVEY

The basic concept behind Gravity survey is to investigate variation (gravity anomalies) in the Earth's gravitational field generated by differences of density between subsurface rocks. The variation in density is induced by presence of causative body such as salt domes, granite pluton, sedimentary basins, heavy mineral like chromite, manganese, faults and folds, etc., within the surrounding subsurface rocks. The size of the anomalies mainly depends on difference in density between host rocks and causative body, their geometrical form and depth of occurrence. The method is capable to carry survey on ground, air and marine environment.

TABLE 5.2 Densities of Common Rocks and Minerals

Rocks	Density (10^3 kg/m^3)	Minerals	Density (10^3 kg/m^3)
Alluvium	1.96–2.00	Cassiterite	6.80–7.10
Amphibolites	2.79–3.14	Chalcopyrite	3.90–4.10
Anorthosite	2.61–2.75	Chromite	4.30–4.80
Basalt	2.70–3.20	Coal	1.11–1.51
Clay	1.63–2.60	Galena	7.40–7.60
Dolomite	2.28–2.90	Gold Native	19.30
Gabbro	2.85–3.12	Gypsum	2.30–2.80
Gneiss	2.61–2.99	Hematite	5.10
Granite	2.52–2.75	Magnetite	4.90–5.20
Limestone	2.60–2.80	Mercury Native	13.60
Peridotite	3.10–3.40	Platinum Native	14.00–19.00
Quartzite	2.60–2.70	Pyrite	4.90–5.20
Rhyolite	2.40–2.60	Pyrrhotite	4.50–4.80
Sandstone	2.05–2.55	Silver Native	10.10–11.10
Schist	2.50–2.90	Sphalerite	4.10–4.30
Shale	2.06–2.66	Quartz	2.59–2.65

The bulk density of a rock depends on its mineral composition, porosity and fluid in the pore spaces. Variation of one or all will change the density locally.

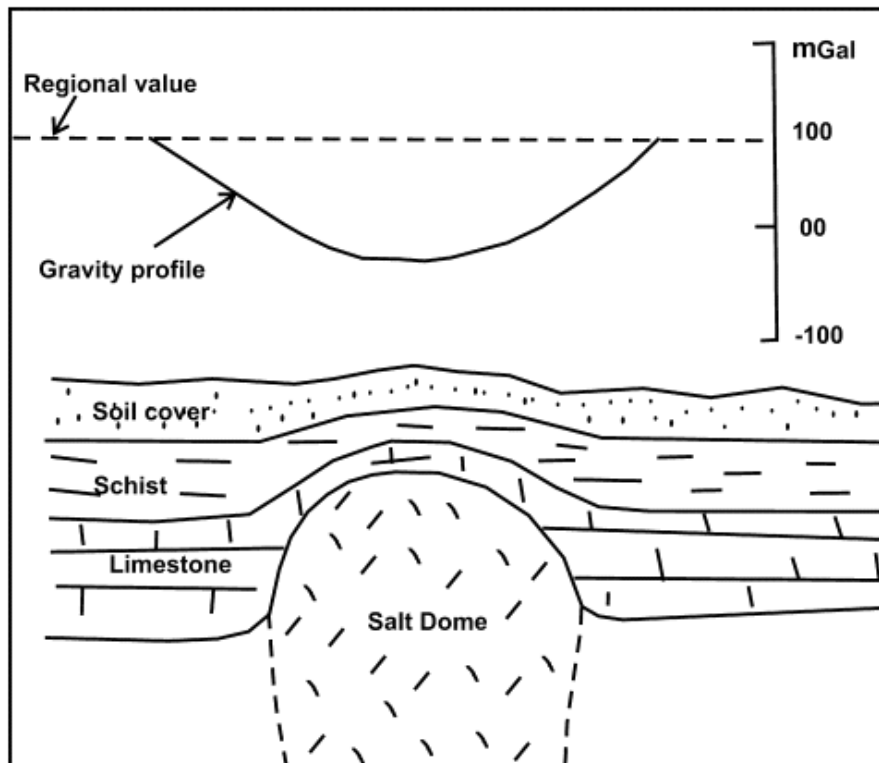


FIGURE 5.10 Gravity profile across a buried salt dome showing lower density compared to the surrounding country rocks.

Measurement of Gravity

"Gravimeter" is the measuring instrument of gravitational field of the Earth at specific location. The instrument works on the principle of measuring the constant downward acceleration of gravity. There are two types of gravimeters: absolute and relative. Absolute gravimeters measure the local gravity in absolute units ("Gal" after "Galileo"). Absolute gravimeters are compact (Autograv CG-5 model) and used in the field. It works by directly measuring the acceleration of a mass during free fall in a vacuum. The accelerometer is rigidly attached to the ground. Relative gravimeters are spring based. It is a specially assembled extremely sensitive spring balance carrying a fixed mass. The basic principle is that the changes in gravity will result change in weight of fixed mass with change of location.

The progressive spacing of the instrument in a gravity profile (Fig. 5.10) changes from few meters for detailed mineral investigation to several kilometers in regional reconnaissance survey. Ship-borne system is widely used in marine gravity survey for mapping the ocean floor. Satisfactory tests of airborne helicopter gravity survey are getting prominence.

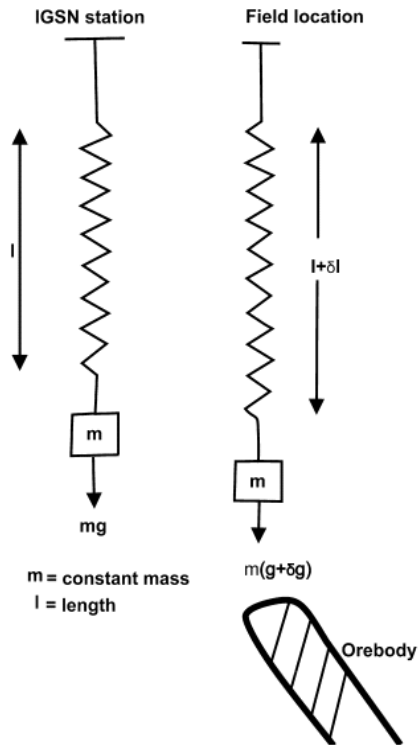


FIGURE 5.9 Schematic diagram showing the principle of stable relative gravimetry survey in the field.

Corrections to gravity observations

“Gravity reduction” is the process of routine correction of field gravity contrast data between an arbitrary reference point and a series of stations that are influenced by various extraneous effects, which are not related to subsurface geology. No interpretation should be attempted before correcting the field data. The reduction processes are due to the following.

1. Instrumental drift

Gravimeter readings change (drift) with time as a result of elastic creep in the springs, producing an apparent change in gravity at a given station. Instrumental drift is corrected by repeated readings at a base station at fixed time interval through out the day.

2. Latitude Correction

The earth is a nonspherical body with equatorial bulging. Points near the equator are farther from the center of mass of the earth than those near the poles causing gravity to increase from the equator to the poles. The correction must be subtracted from, or added to, the measured gravity contrast, depending on whether the station is on higher or lower latitude than the base station.

3. Elevation Correction (Free Air)

The inverse square dependence on the distance of Newton’s law causes the vertical decrease of gravity of the survey point with increase of elevation in the air from the

center of the earth. An amendment factor is used in gravitational surveys that take into account the decrease in the force of gravity with increasing altitude. It assumes interference of air between the observation point and sea level. It is equal to 0.3086 mGal/m above sea level.

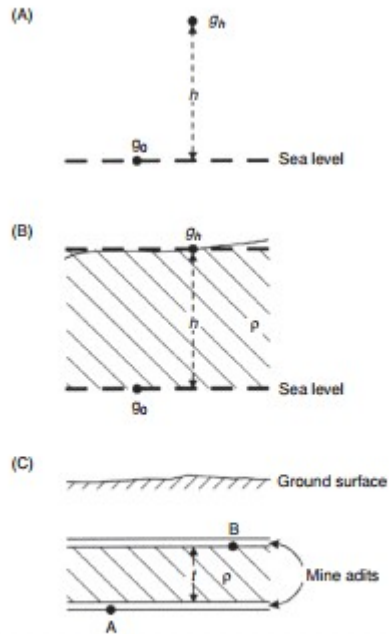


Figure 2.22 Schematic showing (A) the free-air correction, (B) the Bouguer correction, and (C) the Bouguer correction for measurements made underground.

4. Bouguer correction

Whereas the free-air correction compensates for the reduction in that part of gravity due only to increased distance from the centre of mass, the Bouguer correction (δg_B) is used to account for the rock mass between the measuring station and sea-level (Figure 2.22B). The Bouguer correction calculates the extra gravitational pull exerted by a rock slab of thickness h metres and mean density ρ (Mg/m^3) which results in measurements of gravity (g_{obs}) being overestimated by an amount equal to $0.4192\rho h$ g.u.

5. Elevation Correction (Terrain)

The “elevation correction” or “terrain correction” accounts for the topographic relief in the vicinity of the gravity station. The effects are always positive. It is low in the flat areas, but high in steep sided valleys, at top of the cliffs and summits of the mountains.

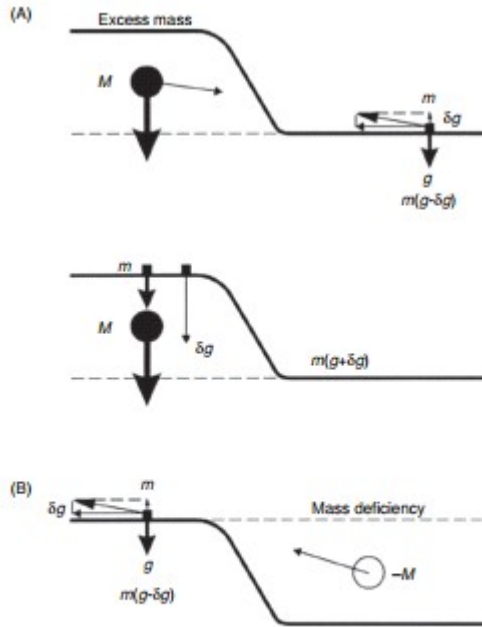


Figure 2.25 The effects of (A) a hill and (B) a valley on the measurement of gravity, illustrating the need for terrain corrections.

6. Tidal Correction

The periodical gravitational effects of sun and moon create Earth's tides in the same way as ocean tides behave due to celestial attraction. It is considerably smaller than oceanic tides. Therefore, the distance between observation point and center of the earth will vary periodically caused by the combined effect of the Sun and Moon by few centimeters. This is known as tidal variation and needs correction for high precision survey.

7. Building corrections

One additional aspect of terrain corrections is the effect of buildings adjacent to the gravimeter during data acquisition in built-up areas.

8. Eotvos correction

For a gravimeter mounted on a vehicle, such as a ship or a helicopter, the measured gravitational acceleration is affected by the vertical component of the Coriolis acceleration, which is a function of the speed and direction in which the vehicle is travelling. To compensate for this, gravity data are adjusted by applying the Eotvos correction.

9. Isostatic correction

If there were no lateral variations in density in the Earth's crust, the fully reduced gravity data, after application of all the corrections so far outlined, would be the same. However, where there are lateral

variations, a gravity anomaly results which is known as the *Bouguer anomaly* (discussed in more detail in . The average Bouguer anomaly in oceanic areas is generally positive, while over mountainous regions it is usually negative. These effects indicate that the rock beneath the oceans is more dense than normal while that beneath the mountains is less dense.

10. Bouguer anomaly

The main end-product of gravity data reduction is the Bouguer anomaly, which should correlate only with lateral variations in density of the upper crust or near-surface environment and which are of most interest to applied geophysicists and geologists. The Bouguer anomaly is the difference between the observed gravity value (g_{obs}), adjusted by the algebraic sum of all the necessary corrections, and that at some base station (g_{base}). The variation of the Bouguer anomaly should reflect the lateral variation in density such that a high-density feature in a lower-density medium should give rise to a positive Bouguer anomaly. Conversely, a low-density feature in a higher-density medium should result in a negative Bouguer anomaly. The Bouguer anomaly is related to the observed gravity.

The Bouguer anomaly is related to the observed gravity g_{obs} as follows:

$$g_B = g_{obs} - g_\lambda + \delta g_F - \delta g_B + \delta g_T$$
$$g_B = g_F - \delta g_B$$

Here,

- g_B is the Bouguer anomaly;
- g_{obs} is the observed gravity;
- g_λ is the correction for latitude (because the Earth is not a perfect sphere);
- δg_F is the free-air correction;
- δg_B is the Bouguer correction which allows for the gravitational attraction of rocks between the measurement point and sea level;
- g_F is the free-air gravity anomaly.
- δg_T is a terrain correction which allows for deviations of the surface from an infinite horizontal plane

11. Miscellaneous factors

Such factors are: meteorological loading produced by atmospheric pressure changes; inertial acceleration caused by seismic and microseismic waves, including the effect of wind pressure on the gravimeter, and vibration from traffic and industrial machinery; and electrical noise from the gravimeter itself. Changes in atmospheric pressure can be corrected for using an atmospheric pressure coefficient

Applications

1. Mineral exploration

Gravity surveys fulfil two roles in exploration for minerals: (1) for search and discovery of the ore body; and (2) as a secondary tool to delimit the ore body and to determine the tonnage of ore.

Discovery of the Faro lead-zinc deposit, Yukon .Discovery of deep-seated Neves-Corvo massive multimetal sulfide orebodies. There was no surface signature.

2. Engineering applications

The size of engineering site investigations is normally such that very shallow (<50 m) or small-scale (hundreds of square metres) geological problems are being targeted.

3. Detection of natural and man-made cavities

Hidden voids within the near-surface can become serious hazards if exposed unwittingly during excavation work, or if they become obvious by subsidence of the overlying ground.

4. Archaeological investigations

Gravimetry is increasingly of interest to archaeologists searching, for example, for ancient crypts or passages within **Egyptian pyramids**,

5.Detection of massive ice in permafrost terrain

6.Hydrogeological applications

Gravity methods are not used as much as electrical methods in hydrogeology, but can still play an important role **Location of buried valleys** Buried Pleistocene subglacial valleys are important geological structures in northern Germany and are used extensively for groundwater production .

7.Microgravity monitoring in the oil industry

8.Volcanic hazards

With the advent of highly accurate surveying equipment and methods, and the availability of very sensitive gravimeters, it is possible to monitor small changes in the elevations of the flanks of active volcanoes .

9.Glaciological applications

For a regional gravity survey to be complete in areas such as Antarctica and Greenland, measurements have to be made over ice sheets and valley glaciers. Very often, these areas have incomplete information about the depth or volume of ice.