جامعة الانبار

كلية العلوم -قسم الجيولوجيا التطبيقية

اسم المادة بالعربي: الجيوفيزياء الجهدية - الطريقة الجذبية

اسم المادة بالإنكليزي: Potential Geophysics- Gravity Method

عنوان المحاضرة بالإنكليزي: Rock densities

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Rock densities

Gravity anomalies result from the difference in density, or density contrast, between a body of rock and its surroundings. For a body of density ρ_1 embedded in material of density ρ_2, the density contrast $\Delta\rho$ is given by

$$\Delta\rho = \rho_1 - \rho_2$$

The sign of the density contrast determines the sign of the gravity anomaly. Rock densities are among the least variable of all geophysical parameters. Most common rock types have densities in the range between 1.60 and 3.20Mgm-3 . The density of a rock is dependent on both its mineral composition and porosity. Variation in porosity is the main cause of density variation in sedimentary rocks. Thus, in sedimentary rock sequences, density tends to increase with depth, due to compaction, and with age, due to progressive cementation. Most igneous and metamorphic rocks have negligible porosity, and composition is the main cause of density variation. Density generally increases as acidity decreases; thus there is a progression of density increase from acid through basic to ultrabasic igneous rock types. Density ranges for common rock types and ores are presented in Table 6.2. A knowledge of rock density is necessary both for application of the Bouguer and terrain corrections and for the interpretation of gravity anomalies. Density is commonly determined by direct measurements on rock samples.A sample is weighed in air and in water.The difference in weights provides the volume of the sample and so the dry density can be obtained. If the rock is porous the saturated density may be calculated by following the above procedure after saturating the rock with water. The density value employed in interpretation then depends upon the location of the rock above or below the water table

Table 6.2 Approximate density ranges ($Mg\,m^{-3}$) of some common rock types and ores.

Alluvium (wet)	1.96–2.00
Clay	1.63–2.60
Shale	2.06–2.66
Sandstone	
Cretaceous	2.05–2.35
Triassic	2.25–2.30
Carboniferous	2.35–2.55
Limestone	2.60–2.80
Chalk	1.94–2.23
Dolomite	2.28–2.90
Halite	2.10–2.40
Granite	2.52–2.75
Granodiorite	2.67–2.79
Anorthosite	2.61–2.75
Basalt	2.70–3.20
Gabbro	2.85–3.12
Gneiss	2.61–2.99
Quartzite	2.60–2.70
Amphibolite	2.79–3.14
Chromite	4.30–4.60
Pyrrhotite	4.50–4.80
Magnetite	4.90–5.20
Pyrite	4.90–5.20
Cassiterite	6.80–7.10
Galena	7.40–7.60

NB. The lower end of the density range quoted in many texts is often unreasonably extended by measurements made on samples affected by physical or chemical weathering.

It should be stressed that the density of any particular rock type can be quite variable. Consequently, it is usually necessary to measure several tens of samples of each particular rock type in order to obtain a reliable mean density and variance. As well as these direct methods of density determination, there are several indirect (or in situ) methods.These usually provide a mean density of a particular rock unit which may be internally quite variable. In situ methods do, however, yield valuable information where sampling is hampered by lack of exposure or made impossible because the rocks concerned occur only at depth. The measurement of gravity at different depths beneath the surface using a special borehole gravimeter (see Section 11.11) or, more commonly, a standard gravimeter in a mineshaft, provides a measure of the mean density of the material between the observation levels. In Fig. 6.14 gravity has been measured at the surface and at a point underground at a depth h immediately below. If g1 and g2 are the values of gravity obtained at the two levels, then, applying free-air and Bouguer corrections, one obtains location and an upward attraction at the underground location. The density r of the medium separating the two observations can then be found from the difference in gravity. Density may also be measured in boreholes using a density (gamma–gamma) logger.

$$g_1 - g_2 = 3.086h - 4\pi G\rho h$$

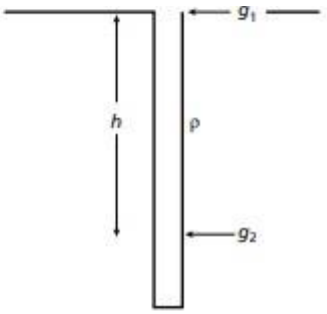

Fig. 6.14 Density determination by subsurface gravity measurements. The measured gravity difference $g_1 - g_2$ over a height difference h can be used to determine the mean density ρ of the rock separating the measurements.

Nettleton's method of density determination involves taking gravity observations over a small isolated topographic prominence. Field data are reduced using a series of different densities for the Bouguer and terrain corrections (Fig. 6.15).The density value that yields a Bouguer anomaly with the least correlation (positive or negative) with the topography is taken to represent the density of the prominence. The method is useful in that no borehole or mineshaft is required, and a mean density of the material forming the prominence is provided. A disadvantage of the method is that isolated relief features may be formed of anomalous materials which are not representative of the area in general. Density information is also provided from the P-wave velocities of rocks obtained in seismic surveys.

Figure 6.16 shows graphs of the logarithm of P-wave velocity against density for various rock types (Gardner et al. 1974), and the best-fitting linear relationship. Other workers (e.g. Birch 1960, 1961, Christensen & Fountain 1975) have derived similar relationships. The empirical velocity–density curve of Nafe and Drake (1963) indicates that densities estimated from seismic velocities are probably no more accurate than about ±0.10Mgm-3 . This, however, is the only method available for the estimation of densities of deeply buried rock units that cannot be sampled directly

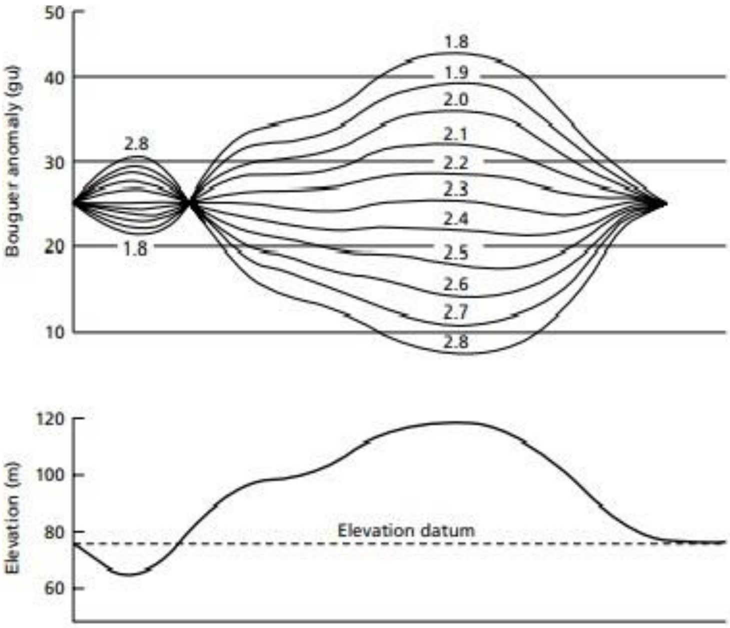

Fig. 6.15 Nettleton's method of density determination over an isolated topographic feature. Gravity reductions have been performed using densities ranging from 1.8 to 2.8 $Mg\,m^{-3}$ for both Bouguer and terrain corrections. The profile corresponding to a value of 2.3 $Mg\,m^{-3}$ shows least correlation with topography so this density is taken to represent the density of the feature. (After Dobrin & Savit 1988.)

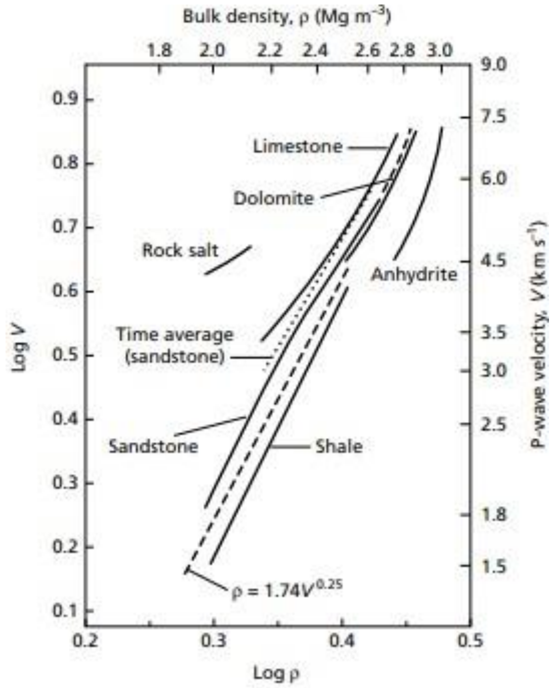

Fig. 6.16 Graphs of the logarithm of P-wave velocity against density for various rock types. Also shown is the best-fitting linear relationship between density and log velocity (after Gardner *et al.* 1974).

References

Kearey, P. An Introduction to Geophysical Exploration. Department of Geology University of Leicester, Michael Brooks, 2002.