Micro-gravity

Principle of operation

All matter exerts a gravitational field in direct proportion to its mass. Dense earth materials will exert a stronger localised gravitational field than less dense ones and this can be measured using extremely sensitive gravity meters. These instruments are essentially highly sophisticated spring balances. A simplified gravimeter design consists of a precisely measured mass suspended by a spring. Locating the instrument above higher density material causes the downward component of the local gravitational field (*g*) to increase and the spring extends under the additional force. The relative increase in *g* is determined through measurement of spring extension. In engineering and environmental applications, it is more usual to use the micro-gravity technique to locate the absence of material due to buried voids, mine shafts and wells. In these situations the mass deficiency results in shortening of the spring due to a relative and very localised decrease in *g.* Data are acquired on a grid at intervals designed to ensure detection of targets at the desired resolution (*e.g.* 0.5 m-1 m spacing for a 2 m^2 buried mineshaft). It is vital that the position of every data point acquired is surveyed accurately and that short-term changes in the gravitational field of the Earth (known as *drift*) are monitored throughout the survey period. See Reynolds (1997) for further details.

Gravity data acquired are dominated by the gravitational field of the Earth. Numerous corrections are required in order to isolate the local (*residual*) signal cleanly and accurately from all background effects. The process of removing all background effects is termed *data reduction*. If field measurements and corrections are performed properly then the localised variations in the gravitational field caused by buried sub-surface structures can be determined extremely accurately. The most sophisticated gravimeters are capable of measurement accurate to ±3 µGal (~1 part in 10^9), although the best realistic tolerance is ± 5 µGal allowing for field conditions.

Figure 1: Acquisition of micro-gravity data in a built-up area.

A gravimeter is positioned precisely on a predetermined survey point and values of *g* are measured repeatedly to produce an average value and standard deviation. A maximum standard deviation may be set before the survey commences, then the instrument will continue sampling until the measured value falls within the given limits. Alternatively, the instrument samples for a set duration and the standard deviation is then calculated for subsequent filtering of the data set. Measurement repeatability is determined by sampling for two periods of 20 seconds duration and comparing the results. With a Scintrex AutoGrav (CG-5) gravimeter up to 100 data stations can be occupied in one day. An advantage of the gravity technique is that it can be deployed in buildings and inside mine galleries, provided that the effects of the surrounding structures and earth material can be modelled subsequently and corrected for their gravitational effects.

Data processing

All gravity measurements require application of corrections to compensate for background effects such as Earth tides, instrument drift, latitude effects, elevation and local topography. Data remaining after correction is termed the Bouguer Anomaly. Initial processing up to this stage is standard for all gravity survey techniques; study of micro-gravity anomalies requires significant additional refinement to remove short-wavelength noise and the effects of localised smaller features and any adjacent buildings from the data.

Interpretation

Data are usually presented in 2D plan view maps. Plots of the residual field can be interpreted qualitatively, leading to estimates of the mass deficit associated with features interpreted as voids. Spatial trends can be identified, allowing mapping of laterally extensive features such as dissolution void networks in karst landscapes or abandoned mine workings beneath urban developments. Interpretation is often supported by forward modelling in two or three dimensions, using dedicated software packages. Examples of residual gravity anomaly data acquired in a built-up urban environment are presented in Figure 2 with a modelled transect with its interpretation.

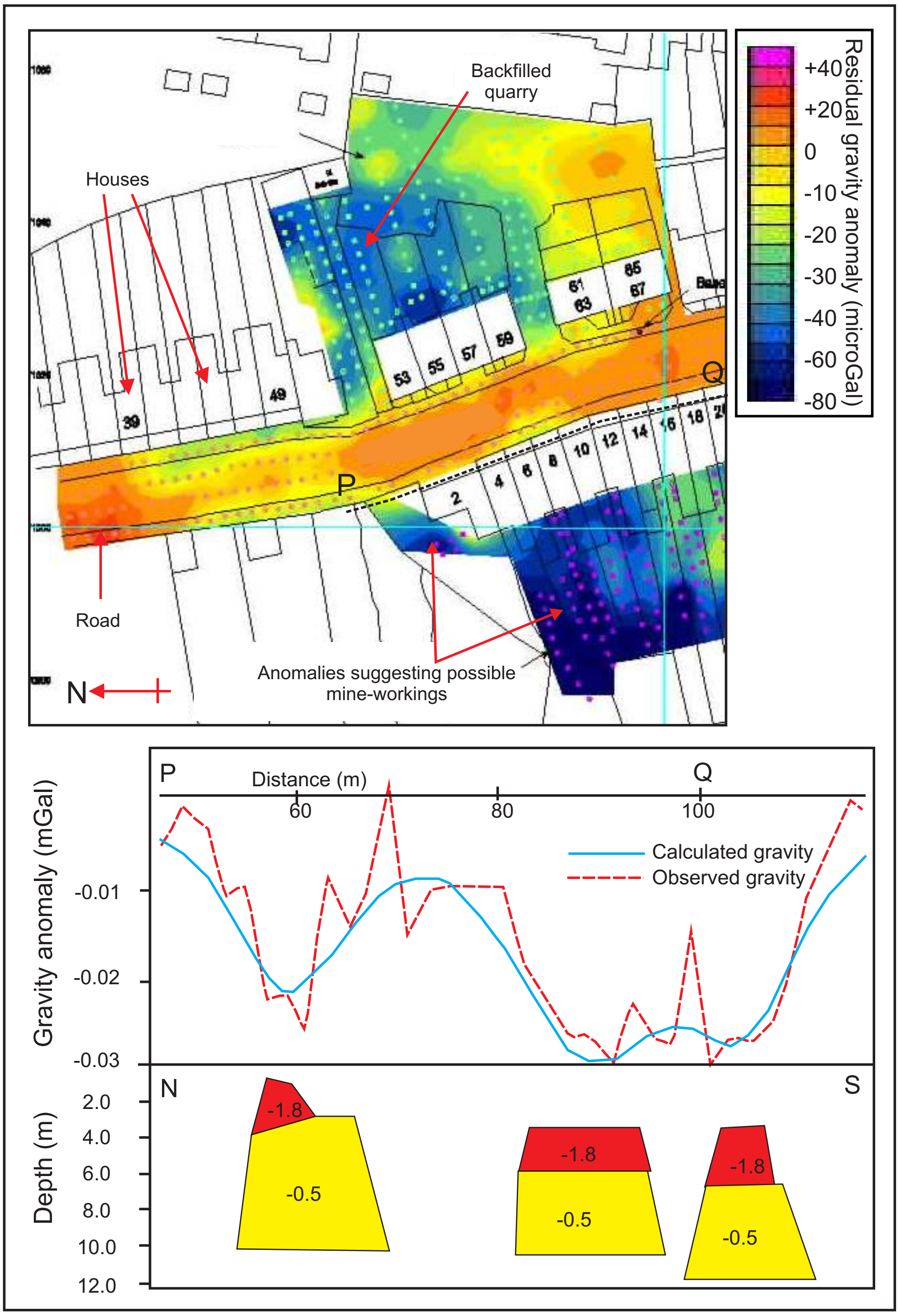

Figure 2:

Top: Micro-gravity residual field plot of data acquired in a residential area known to overlie old mine workings.

Bottom: Profile showing gravity data and model results for a line of observations recorded along the central road. Forward modelling of the micro-gravity profiles suggested that the road was underlain by several low-value anomalies likely to represent disused mine workings. Blocks have been labelled with density contrasts in Mgm^{-3} relative to the background density of chalk (1.8 Mgm^{-3}); the red blocks represent voids and the yellow blocks loosely infilled mine galleries. The interpretation was confirmed subsequently by probe drilling.

Reference

Reynolds, J.M. 2011. *An Introduction to Applied and Environmental Geophysics*. John Wiley & Sons Ltd, Chichester, 2nd ed., 712 pp.