Aeromagnetic surveys

Aeromagnetic surveying is the process of carrying out comparatively rapid, large-scale magnetic surveys using magnetometers attached to or suspended from aircraft. Aeromagnetic surveying has several applications, including as a reconnaissance tool before 3D seismic surveys to estimate depths to basement, to inform geological maps and to map mineral deposits. More detialed information is given by Reynolds (2011).

Principles of operation

The Earth's magnetic field is generated predominantly in the Earth's core. It is complex in structure, but can be simply approximated by a dipole field, like that of a bar magnet. Some materials become magnetised when in the presence of a magnetic field and develop an induced magnetic field, while others posses their own intrinsic magnetic fields. The interaction of such fields with the Earth's primary field gives rise to the field at the Earth's surface. The parts of the field that are considered to be 'background' and the parts considered to be 'signal' vary, depending on the survey target.

Magnetic fields are measured using magnetometers. A single sensor is normally used to measure the magnitude of the Earth's magnetic field, or the magnetic field intensity (in units of nano-Tesla; nT), but two sensors mounted either vertically above or horizontally adjacent to each other can be used to derive the vertical or horizontal magnetic gradient (in units of nano-Tesla per metre; nT/m). The advantage of gradiometers is that temporal variations in the magnetic field are essentially cancelled out by subtracting the signal from one magnetometer from the signal of the other.

Figure 1: Aeroquest Ltd instruments. *Right*: stinger (single magnetometer). *Left*: TAG (triaxial gradiometer).

The measured magnetic field is the resultant of the Earth's magnetic field and the anomaly field. The shape and amplitude of a magnetic anomaly depends on the location, shape, size, strike, burial depth, magnetic susceptibility and intrinsic magnetisation of the causative body, and the angle at which the survey lies relative to both the Earth's magnetic field and to the causative body. Additionally, the Earth's magnetic field varies in time on a scale of minutes to centuries. Typically, a normally magnetised object (one with no intrinsic field of its own) located in the northern hemisphere produces a characteristic N-S anomaly.

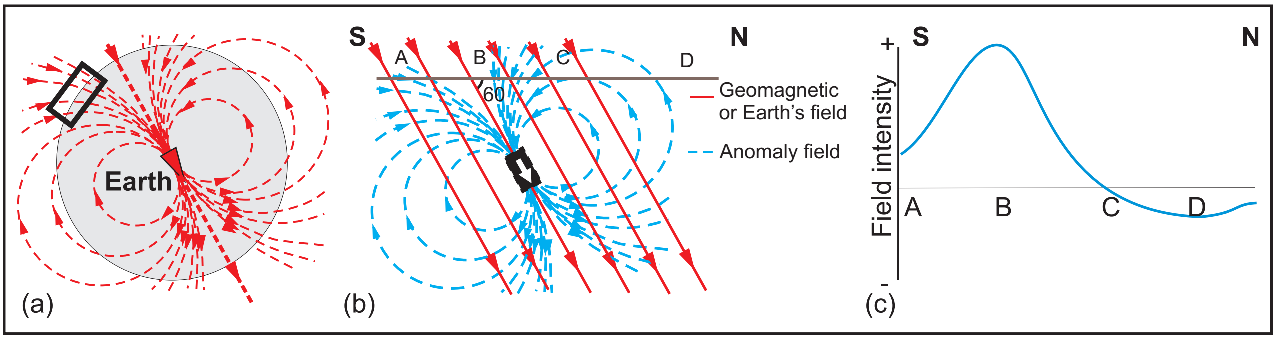

Figure 2: (a) Magnetic survey location. (b) A N-S cross-section of the induced field due to a magnetisable body. (c) The N-S magnetometer data (geomagnetic field removed).

Processing and interpretation

Magnetic data may be used not only to map anomalies, but also to determine the depth at which the causative bodies lie. For shallow, ground-based investigations for which relatively simple, semi-quantitative interpretation methods are available, the time and cost of carrying out complicated processing is not justified when the targets are within digging range. For the larger, deeper and often more economically important aeromagnetic targets, such as ore deposits, advanced processing techniques should be used. There are several processing methods available to aid the interpretation of magnetic anomalies. If a single magnetometer has been used, the effect of the daily variations in the magnetic field are removed, as is the Earth's background field, the International Geomagnetic Reference Field (IGRF). The data may also be *upward continued* or *downward continued* (made to appear as if the field was measured at a higher or lower elevation respectively) in order to mitigate the effects of rough terrain and noise. Magnetic anomalies are complicated and their maxima do not lie directly over the causative body, so processing must be carried out in order to recover the true position and depth of the survey target; such processing is carried out on 2D data.

Different methods are more suited to different targets and areas; for example the *reduction to pole* (RTP) method, which alters the data so that peaks lie directly over causative bodies, does not work well in lower latitudes where the magnetic field lies at a shallow angle to the Earth's surface. Powerful methods to determine target depths include *deconvolution* (Euler and Werner), *depth slicing* and taking the *radial power spectrum*. Direct observation of the horizontal gradients can reveal the locations of the boundaries of anomalies. The horizontal and vertical derivatives can be combined in different ways to better detect anomaly boundaries, as in the *complex gradient* and *analytic function* methods. It is important that the most appropriate processing techniques are used, based on the nature of the data and the target, so that the data can be interpreted sensibly.

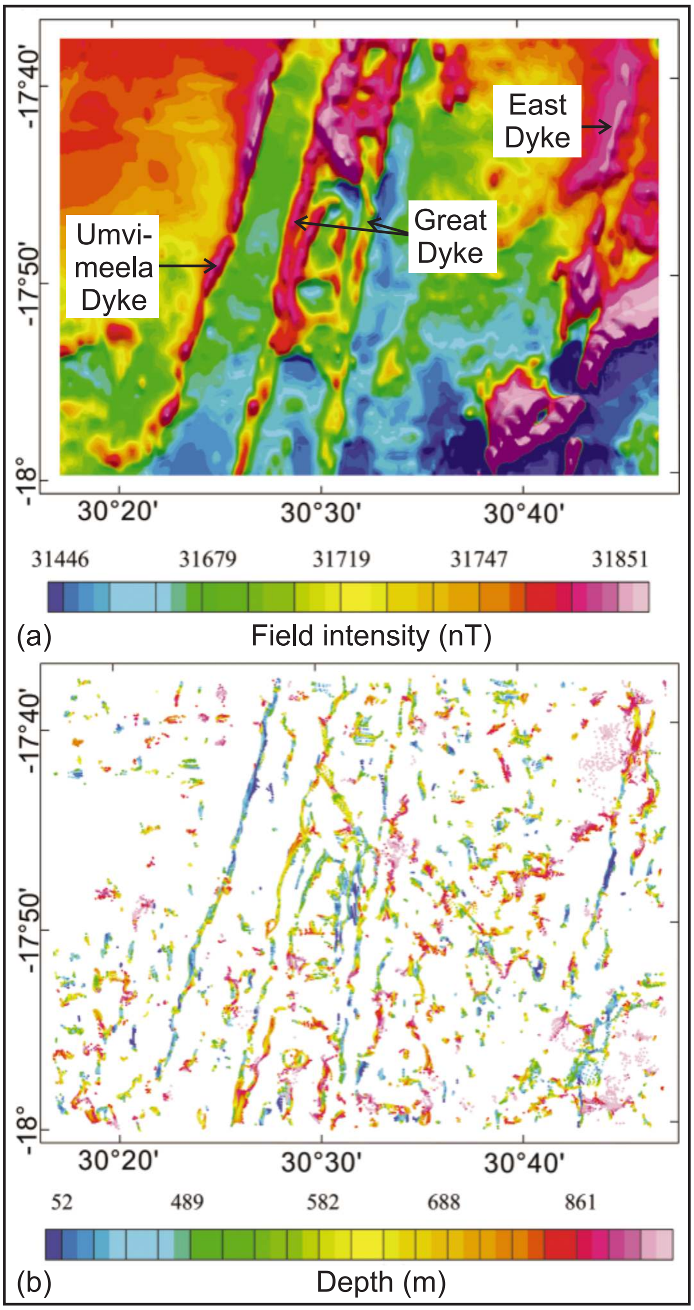

Figure 3: An example of advanced processing on aeromagnetic data from the Great Dyke, Zimbabwe (after Mushayandebvu *et al*., 2004, by permission). (a) Total magnetic intensity. (b) After grid Euler deconvolution; the dyke structures are clearly delineated.

References

Mushayandebvu, M.F, Lesur, V., Reid, A.B. and Fairhead, J.D. 2004. Grid Euler deconvolution with constraints for 2D structures. *Geophysics*, **69**(2):489-496.

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