Ground-based magnetic prospecting for iron ore

Prospection for iron ore has been carried out using magnetic methods since the early 1900s. Both aerial and ground-based magnetic and radiometric techniques are commonly used for the detection of iron ore. Aerial techniques tend to be used at the reconnaissance stage, whereas ground-based techniques may be used for target appraisal.

Principles of operation

The basic principles of operation are based upon detecting the disturbance to the Earth's magnetic field by buried objects. The method is entirely passive in that the instrumentation does not have to generate a field itself. The Earth's magnetic field causes a magnetic field to be generated within any magnetisable object that lies within its influence. Additionally, any material that contains some form of iron oxide (*e.g.* a ferromagnetic substance), such as iron ore, records the strength of the Earth's magnetic field at the location where the material acquires its magnetisation.

A magnetised body in the Earth's magnetic field (Figure 1) distorts the field. The measured magnetic field is the resultant of the Earth's magnetic field and the anomaly field. The former must therefore be removed in order that the anomaly field may be identified. Typically, a normally magnetised object located in the northern hemisphere, *e.g.* in the UK, produces a characteristic N-S anomaly. A magnetic low lies to the north of a high to the south, as indicated in the profile in the Figure below. Modern environmental magnetometers are capable of detecting distortions in the Earth's magnetic field as small as 1 part in a billion (1×10^{-9}).

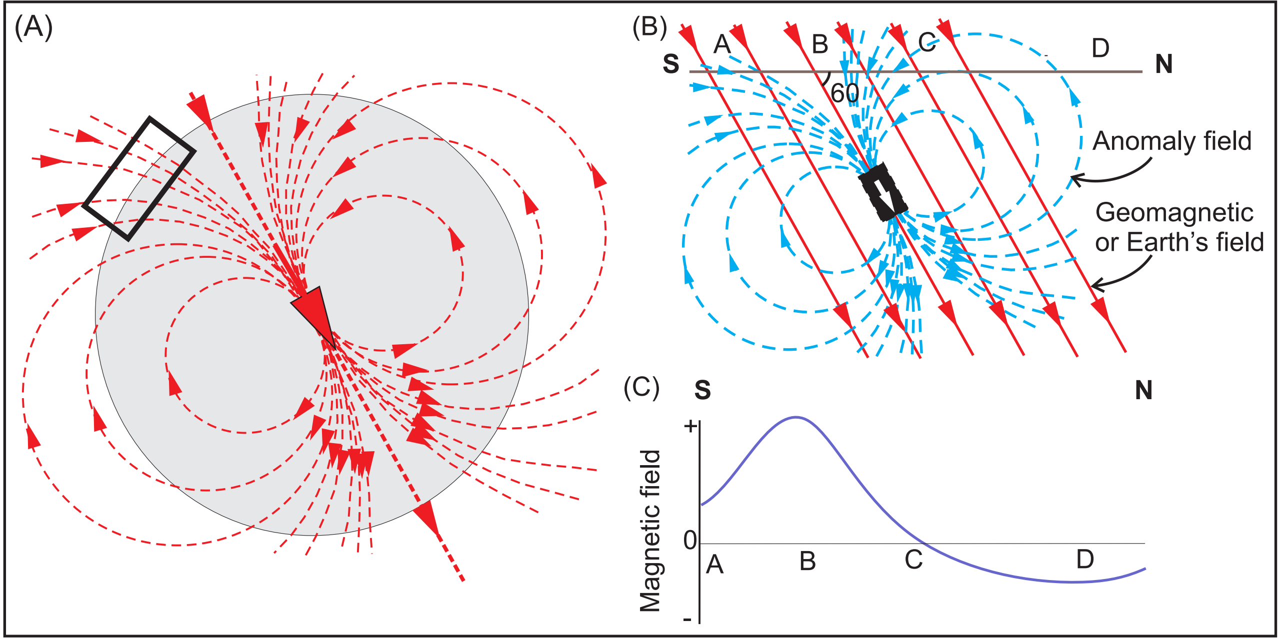

Figure 1: The magnetic field generated by a magnetised body (whose field is entirely due to the Earth's magnetic field) inclined at 60° parallel to the Earth's field (A) would produce the magnetic anomaly profile from points A-D shown in (B). (After Reynolds, 2011).

A single sensor is normally used to measure 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. This is simply the difference in the magnetic field intensity as measured at each sensor corrected for the physical separation of the two sensors (in units of nano-Tesla per metre; nT/m). The magnetic gradients provide information on the location of the edges of anomalies and on the depth at which the causative body lies.

Data are acquired by walking the magnetometer along north-south oriented lines. The line orientation is maintained either by walking along survey lines that have previously been marked out, or by connecting a differential global positioning system (DGPS) to the magnetometer.

Processing and interpretation

The Earth's magnetic field fluctuates during the day, even in the absence of magnetic storms. A static base station magnetometer is used to record these variations, which can then be subtracted from the total field. There is no need for this processing stage in magnetic gradiometry, since the temporal variations affect both sensors equally, and cancel out. The Earth's 'baseline' magnetic field can be determined for a given site latitude, allowing removal of the International Geomagnetic Reference Field (IGRF) to expose any residual anomalies. Interpretation of the anomaly field allows identification of known features (*e.g.* pipes, cables) and any remaining anomalous regions in the data set can subsequently be prioritised for further investigation.

Figure 2: Ground-based magnetic gradiometry survey in progress.

Certain types of 'standard' anomaly are known, including thin vertical sheets of magnetisable material, analogous to dykes. Basic interpretation involves attempting to identify such shapes and hence determine the type of causative body. The next stage of interpretation is semi-quantitative, where established relationships between the amplitude and shape of an anomaly and the shape of the causative body are used to estimate the depth to the body.

More sophisticated processing techniques such as Reduction To Pole (RTP) are not usually used for small scale, ground based magnetic data. However, modelling is often carried before a survey, in order to predict the size and shape of magnetic anomaly that might be observed in a given location for a given causative body, such as a dyke of a certain orientation and dip. Location matters as the shape of an anomaly for a given body changes depending on the local magnetic inclination and declination.

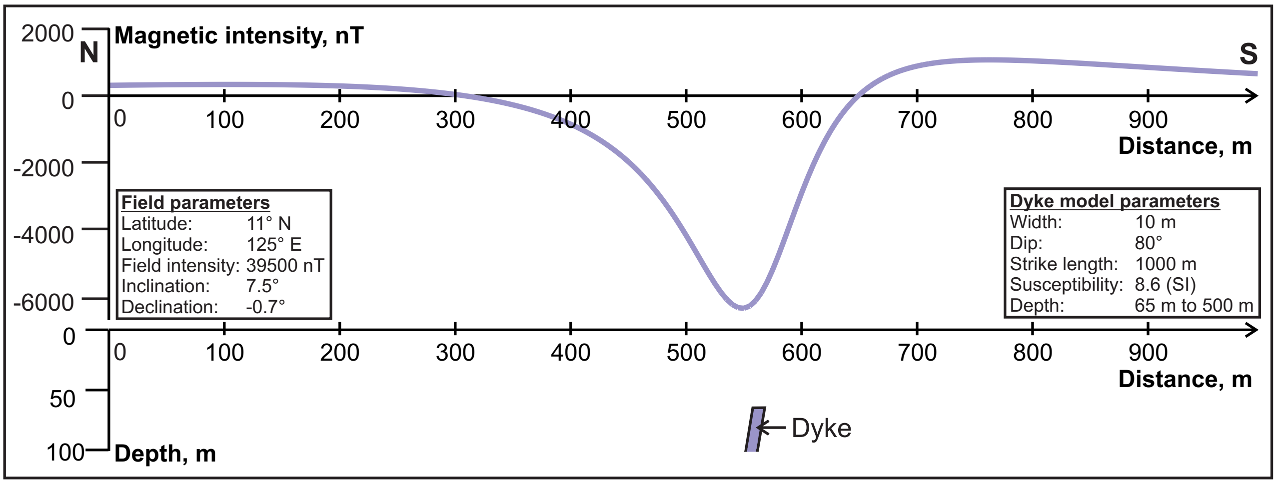

Figure 3: *Left*: a model of a typical magnetic dyke, striking east-west. *Right*: the N-S magnetic anomaly profile that would be observed over this dyke for a location in the Philippines.

Modelling can also be used in interpretation. The interpreter makes an educated guess about the size, shape and magnetic characteristics of the causative body. The interpreter makes a computer model of that body, then generates the synthetic magnetic anomaly that would be seen if a magnetic survey was carried out over that body. The real and synthetic data are compared and the model adjusted until the differences are minimised. This can be done manually or automatically (inversion).

Reference

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