Magnetic suvrveys

Principles of operation

The basic principles of operation are based upon detecting the disturbance to the Earth's magnetic field by buried magnetised materials. The method is entirely passive in that the instrumentation does not have to generate a field itself. The types of materials that affect the Earth's magnetic field include basic igneous rocks, certain forms of mineralisation, and a wide variety of man-made materials and fabrications such as metal pipes, reinforcement bars, electric cables, types of furnace ash. Indeed any material that contains some form of iron oxide (*e.g.* a ferromagnetic substance) or other material that is susceptible to magnetisation records the strength of the Earth's magnetic field at the location where the material acquires its magnetisation. For example, a volcanic lava flow acquires its magnetisation when the lava cools below the Curie temperature; this permanent magnetisation is known as Thermal Remanent Magnetisation. The same thing applies to bricks when they are fired in a kiln, or to metal pipes when they are extruded and then allowed to cool. Metal pipe segments represent individual bar magnets so that when a pipe line is constructed the magnetic response is akin to that arising from a line of bar magnets. Consequently, it is possible to determine the approximate length of individual segments of buried metal pipes from their magnetic signatures.

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}).

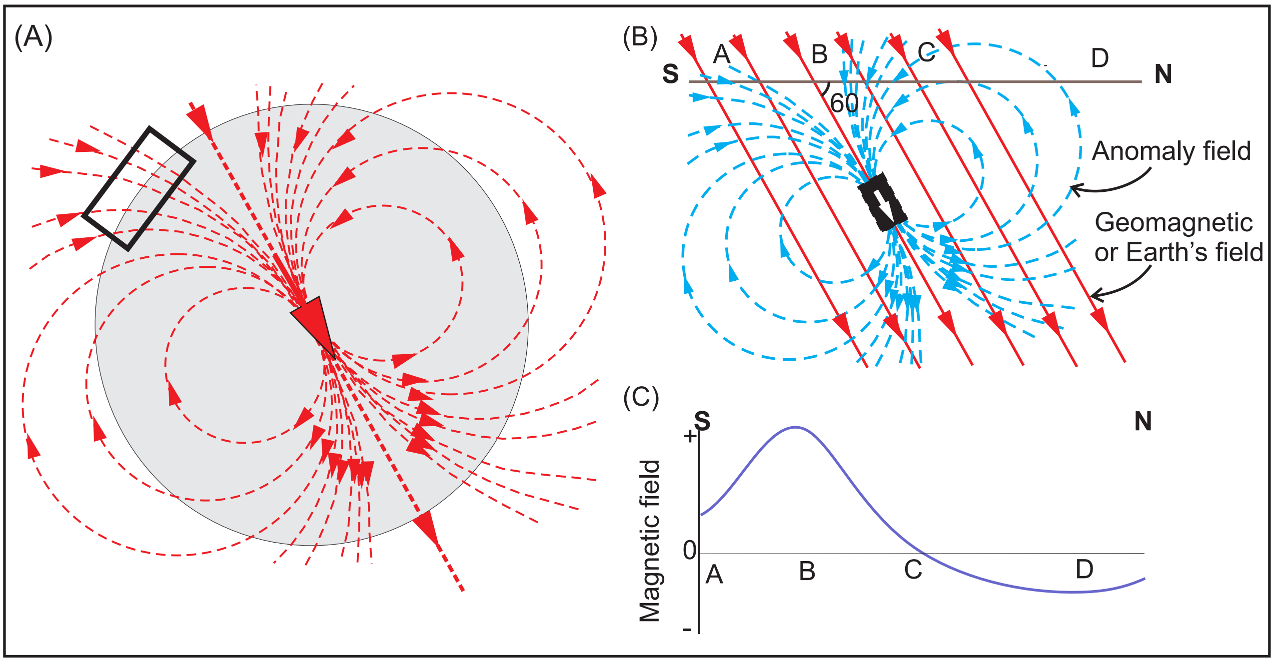

Figure 1: The magnetic field generated by a magnetised body (whose field is entirely due to the Earth's magnetic field) inclined at 60° parallel to the Earth's field (A) would produce the magnetic anomaly profile from points A-D shown in (B). (Reynolds, 1997, fig. 3.29).

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; nTm^{-1}).

Processing

The Earth's 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. The combination of magnetometry and ground conductivity mapping provides a very powerful method for identifying different types of buried materials without having to excavate and disturb them. Such a combination may enable the interpreter to differentiate magnetic from non-magnetic objects (*e.g.* Pulverised Fuel Ash, clinker, *etc.*). In areas of contaminated ground, this can be used to focus invasive ground investigations onto anomalous areas, optimising their efficiency.

Applications

The most common applications of geomagnetic mapping (including gradiometry) include:

- Locating pipes, cables and metallic objects, including metal drums and UneXploded Ordnance (UXO);
- Locating concealed mineshafts, mine adits and Underground Storage Tanks (USTs);
- Mapping archaeological remains;
- Mapping geological features, *e.g.* concealed basic igneous dykes and metalliferous mineral lodes; and
- Geological boundaries between magnetically contrasting lithologies, including faults.

Example: Llwyneinion Lagoon, Wrexham

Magnetometry is very suitable tool for safely locating buried or submerged metallic waste drums containing toxic materials. The 2D plot below demonstrates contouring of residual magnetic field strength applied to data acquired over a tar pit containing several hundred waste drums. Initial inspection of the data facilitated classification into single drums, clusters and mass drum graves. Subsequent modelling and analysis of individual anomalies at selected orientations allowed more detailed interpretations, such as size of clusters and depth of drum burial.

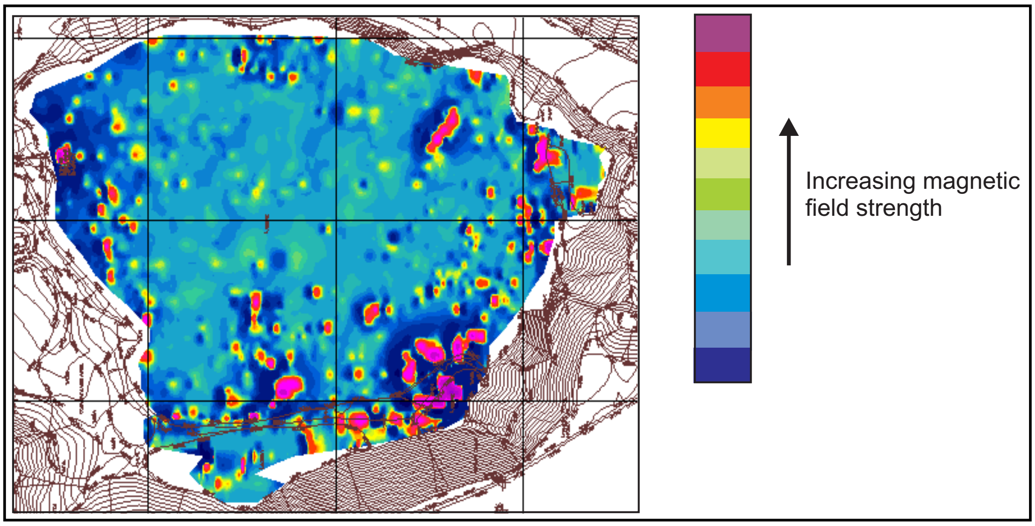

Figure 2: Anomaly field image plotted from data acquired over flooded tar pit (see Reynolds, 2002).

References

Reynolds, J.M. 2002. The role of geophysics in the investigation of an acid tar lagoon, Llwyneinion, North Wales, UK. *First Break*, **20**(10):630-636.

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

