01-02 AEM surveys in the UK

David Beamish, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK dbe@bgs.ac.uk

Introduction

Most countries would regard National Scale Mapping of magnetic and gravity data as a required geoscientific asset baseline. Airborne magnetic data were acquired in the UK over 45 years ago and our gravity data were obtained in accumulated ground surveys. It is possible therefore to make a case that there is geoscientific knowledge gap in terms of modern, high-resolution geophysical data. Assessment of priority items has lead to the joint acquisition of radiometric, active electromagnetic (EM) and magnetic data as a practical means of providing a cost-effective scientific framework of value to a wide range of stakeholders.

Our multi-parameter surveys, follow a lead set by the Geological Survey of Finland (GTK) in their long-established national airborne mapping program. In the UK, these High resolution Resource and Environmental Surveys (HiRES) have been carried out at a preferred line-spacing of 200 m. We have formed a shared capability (JAC) with GTK to perform airborne geophysical survey work, processing and interpretation. The JAC capability together with the current AEM system are described by Leväniemi et al. (2008). Regulatory CAA airborne activity permits typically restrict UK surveys to twin-engine operation and elevations of between 100´ and 180´, with mandatory fly-high (800´) above conurbations.

Trial surveys in the UK

Initial trial surveys were conducted in 1999, in the East Midlands, primarily to evaluate the performance of the EM system in the UK context. The remarkable ability of the data to detect pore fluid concentrations and their movement in association with typical UK legacy zones (coal-mine spoil and both open and closed landfills) led to the conclusion that this was a must-have airborne capability. Figure 1 shows 14kHz conductivity contours across a 13 x 9 km sandstone aquifer in northern Nottinghamshire. Only values > 20 mS/m (i.e. significantly above background) are shown. Black contours (>90 mS/m) delineate all the existing coal spoil zones, and one legacy landfill.

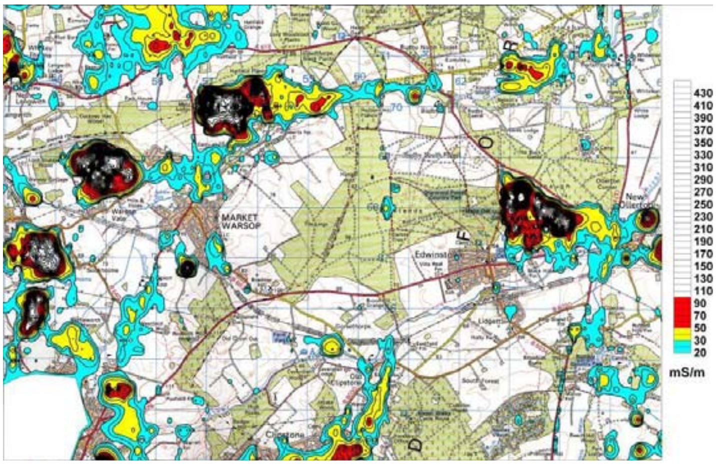

Figure 1. 14 kHz half-space conductivity map acquired across a 13 x 9 km area. 200 m E-W line spacing.

At-surface total dissolved solid concentrations enter the sandstone matrix (~ 30% porosity) and their movements are detected at decreasing levels of conductivity. The conductivity plume associated with the eastern-most colliery was subjected to confirmatory ground geophysical and borehole geochemistry follow-up investigations (Beamish and Klinck, 2006).

UK Geology and EM

The AEM data acquired, in a spatially coherent manner, has enabled the conductivity of UK geological formations to be assessed for the first time. This has taken place by surveys in southern Scotland and Northern Ireland. The latter, in particular, is a microcosm of UK type formations. Figure 1 is an example of conductivity mapping across a 10 x 15 km, largely Carboniferous, terrain in Northern Ireland. Figure 1a displays half-space conductivity (3 kHz) image using a linear colour range from 0.15 (black) to 50 (pink) mS/m. Shaded relief (NW) is used to emphasise gradients. Three cultural disturbances (due to towns) are circled.

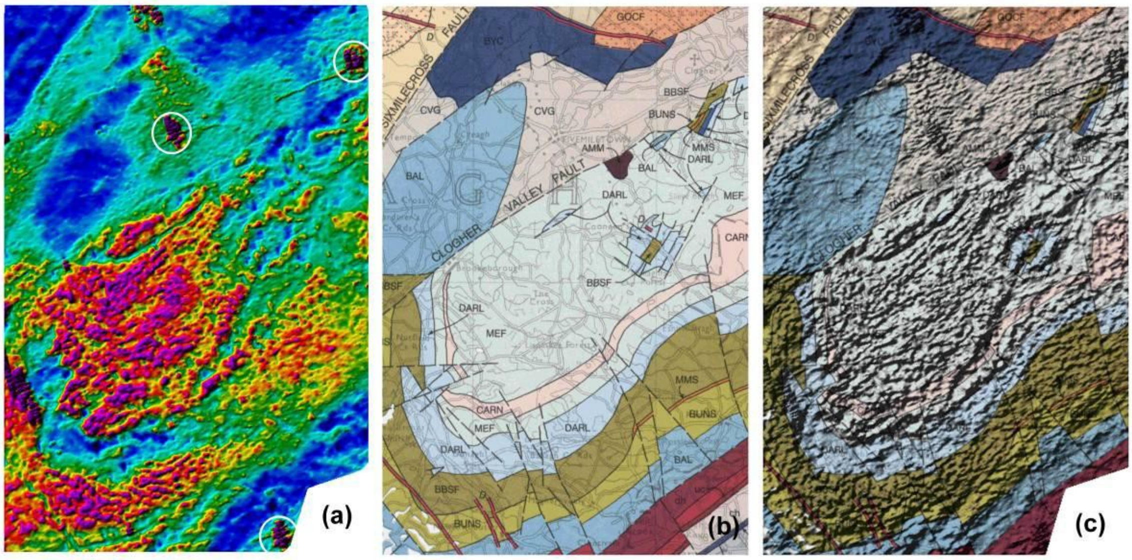

Figure 2. (a) 3 kHz half-space conductivity map across a 10 x 15 km area. (b) 1:250k geological map. (c) Blend of geological map (colour) and grey-scale shaded-relief (NW) of data in (a).

Comparison with the 1:250k geological map (Fig. 1b) reveals some broad associations however it is the high wavenumber content of the conductivity image that it is most intriguing. Figure 1c is an image formed by taking the colours of the geological image and blending them with a grey-scale shaded-relief image of the conductivity map. We believe that this information content revealed in the detail of the conductivity gradients is new and can be interpreted in terms of the mapping of the lithological fabric (e.g. such as degree of cementation i.e. porosity) of the formations. It is self-evident that EM responds to material properties rather than geological classification; in broad terms the geological utility of AEM can be extended from the familiar territory of resource investigations (e.g. sand and gravel, clays and minerals) into new information concerning the depositional and deformation framework of the formations.

Site-scale investigations and EM

The acquisition of coherent EM data sets with a line-spacing of 200 m provides for a reasonable investigation scale in relation to environmental responses. As suggested in Fig. 1, small-scale features in the landscape then provide bulls-eye responses. The degree to which the general UK land surface provides detectable conductive features is worth remarking on. Our extensive industrial legacy, appears to have led to a wide-range of anthropogenic conductivity gradients within the subsurface. With the subsequent redevelopment of sites, these features may go unrecorded. Although many features are of low amplitude, many highly significant conductivity discoveries have been made. Figure 3 shows a conductivity map (values above 125 mS/m are shown) for a 3x2 km zone within a detailed (50 m N-S flight lines) survey across an estuary site in southern Scotland. The site is due for redevelopment. In order to understand the anomaly it was necessary to consult historical maps dating back to the 1860's. The earliest maps show a range of existing mine-shafts used for small-scale coal extraction. The major environmental impact appears to be associated with the introduction of a chlorine works as shown on the background map for 1897. The works was situated in the vicinity of an existing mine-shaft. Chemicals production continued into mid-20'th century by which the mapped locations of previous mineshafts had disappeared.

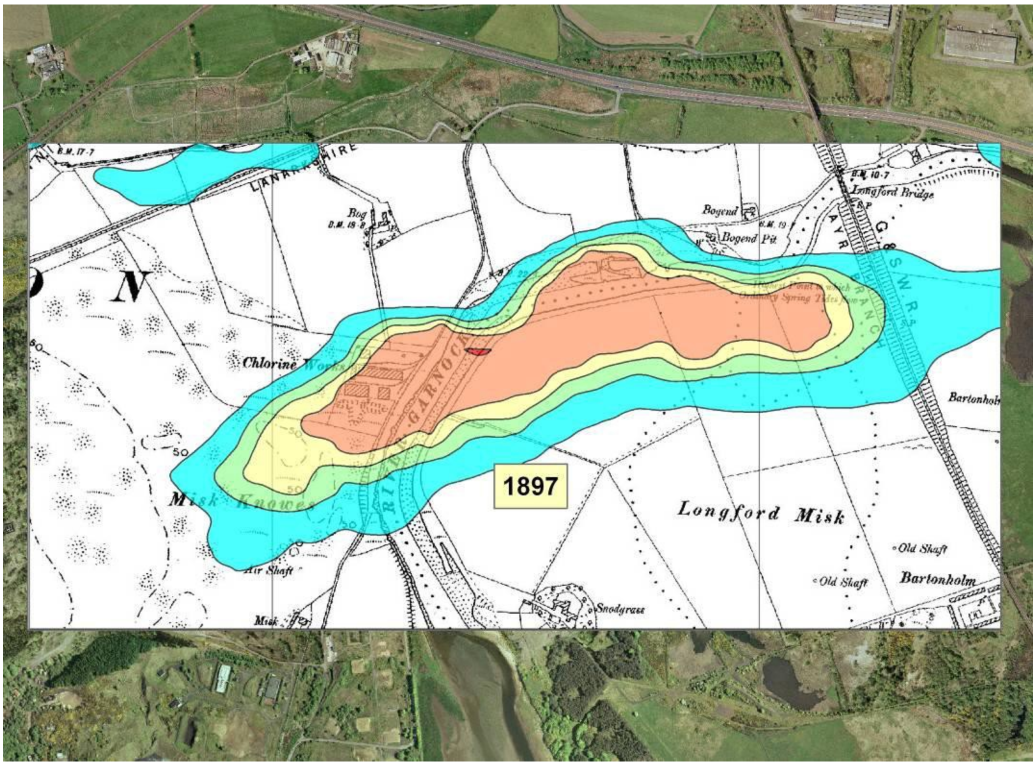

Figure 3. (a) 3 kHz half-space conductivity contours (>125 mS/m, in 100 mS/m increments) on background map from 1897 (3 x 2 km). Both on modern air photo.

Descriptions of AEM UK surveys applied to environmental and landfill investigations are provided by Beamish (2003, 2004). Many UK landfills are legacy sites, often former quarries, operating according to the dilute-and-disperse principle. We observe detectable conductivity anomalies many decades after closure. Conductivity data map Total Dissolved Solids by virtue of the fluid conductivity dependence. The conductivity data may be used by non-scientists and it has been important to provide an understanding of the linkage between maps of conductivity contours and the likely volumetric subsurface distribution of conductivity.

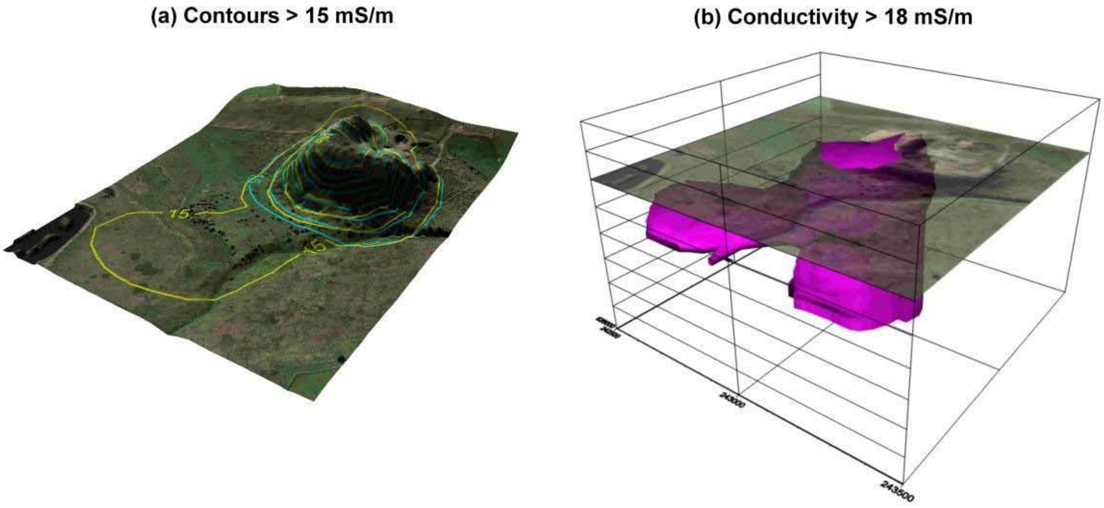

Figure 4. (a) 1x1 km area containing an active landfill. (a) conductivity contours > 15 mS/m, 14 kHz (yellow), 3 kHz (cyan). (b) Volumetric conductivity model of the same area to a depth of 80 m. Ariel photo (transparent) placed at a depth of 20 m as a reference.

A detailed (1 x1 km) example of the relationship between half-space conductivity mapping at 2 frequencies and the distribution in the subsurface conductivity determined from the same data is shown in Figure 4. The area contains an active landfill outlined as a topographic feature.

Summary

In the UK the AEM data compete with a wide-range of existing geoscientific data. Multi-parameter airborne data acquired at high-resolution are a *de facto* requirement. Three of the key roles of AEM which *uniquely* define its value in the UK context are:

- Lifting the lid. AEM provides subsurface information on geological and fluid processes throughout the near-surface.
- Fluid geochemistry. AEM provides bulk resistivity information, which exhibits a high degree of sensitivity to pore water geochemistry.
- Site-investigation scale. AEM, at high resolution, has the potential to provide continuity across regional and local scales of information.

References

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