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Use of magnetics for the location of environmental contamination

Timothy D.J. Pippett
ADI Services
Sub Surface Imaging
Ground Floor, 77 Parramatta Road
Silverwater NSW 2141

Paul O'Donnell
ADI Services
Sub Surface Imaging
Ground Floor, 77 Parramatta Road
Silverwater NSW 2141

Stuart I. Hankin
ADI Services
Sub Surface Imaging
Ground Floor, 77 Parramatta Road
Silverwater NSW 2141

Craig A. Blundell
EPA, N.S.W.
Citadel Towers (Block B)
799 Pacific Highway
Chatswood N.S.W. 2067

ABSTRACT

ADI Services, in conjunction with the Geophysical Research Institute of the University of New England, have been utilising the TM-4 Imaging Alkali-Vapour Magnetometer to locate and validate the presence of buried ferrous items in contaminated areas. Unlike many conventional systems, the TM-4 enables the rapid collection of high resolution magnetic data. The data can be displayed as colour images and interpreted semi-automatically and/or manually. Flexibility within the TM-4 system enables irregular blocks to be surveyed without requiring the user to know the exact beginning and end coordinates of the survey lines.

Two case studies are presented which demonstrate the effectiveness of high resolution magnetic surveys for contamnated site assessment. The first case study shows how the TM-4 system has been used for the detection of unexploded ordnance, associated ammunition components and fragmentation. The objective for the second case study was to locate one edge of a former waste burial pit which was known to contain significant quantities of ferrous waste. The contrast in the total magnetic field between the burial pit and the surrounding bedrock was easily recognised.

Keywords: high resolution, magnetics, buried waste, environmental contamination.

INTRODUCTION

Land owners seeking to rezone or redevelop their land are under growing pressure to perform site audits to satisfy local councils and other government authorities that their land is free of contamination. Geophysics has the potential to play a major role in these audits including defining the local geology and mapping subsurface contaminants.

Environmental applications of geophysics typically require high levels of accuracy. For example, it may not be satisfactory to locate 99 of a total of 100 objects when searching for unexploded ordnance (UXO). This means that the geophysical tools used for environmental applications must be capable of producing images of the subsurface that are both well resolved and accurate. A great deal of effort will be required by the geophysical community to develop subsurface imaging tools and techniques that meet the challenges presented by environmental problems.

Conventional magnetometers have been used for some time for environmental audits where there has been a need to locate buried ferrous items (Cohen et al., 1992; Emerson et al., 1992; Gillekson et al., 1992). For ferrous ordnance detection, instruments such as fluxgate gradiometers which give an audio or visual indication of the presence of ferrous items have been used, however these do not give a picture of the subsurface for future validation. Other magnetometers suffer from the disadvantage of being prohibitively time consuming, and hence expensive, when gathering data at the resolution required for the definition of small items on or near the surface of the earth. Even instruments such as proton proecession magnetometers which have a memory unit included in their components are unsuitable for such activities.

The ideal magnetometer system for environmental applications should enable the rapid collection of high resolution magnetic data. An example is the TM-4 system developed by the Geophysical Research Institute (GRI) of the University of New England (Stanley et al., 1991). ADI Services, in conjunction with TM-4 system for a variety of environmental audits.

The TM-4 system has proved to be particularly useful for locating unexploded ordnance. Detailed analysis of the performance of the TM-4 system by GRI has enabled ADI and GRI to define 100% quality assurance levels for various forms of UXO under certain geological conditions (Stanley, 1994). This level of quality assurance is essential to satisfy the requirements of regulators and the community at large.

Details of the TM-4 system and the procedures used for data collection and data processing are outlined in the sections that follow. Two case studies are presented which demonstrate the effectiveness of high resolution magnetics for locating buried ferrous objects.

THE TM-4 SYSTEM

The TM-4 is a man portable magnetometer system with a typical operating rate of 100 measurements per second with an accuracy of 0.01 nT (Stanley et al., 1992). The TM-4 in its simplest configuration consists of a two person crew, the first carrying a wand mounted caesium vapour sensor connected to the main TM-4 console which is operated by the second person. The pair maintain a separation of approximately 5 metres to reduce instrument noise to the sensor. Distance along the survey line is measured by means of a cotton-thread odometer which is anchored prior to starting each traverse.

An alternative configuration for the TM-4 consists of using a multi-sensor, with multiple caesium vapour magnetic sensors mounted in an aluminium 'bedframe' and again carried by the first crew member. Conducting surveys in this mode allows a production rate of up to 2 - 3 hectares/day at 5 samples-square-metre. There is also the option of utilising a quad-cycle-trailer mounted unit for more open areas. This configuration makes use of a DGPS for positioning the sensors. It is also possible to incorporate the system into less conventional modes, such as small watercraft for flooded areas.

FIELD PROCEDURES

Geophysical surveys in and around industrial sites often need to contend with irregular survey boundaries. The TM-4 system has been designed to minimise the effort required by the users when surveying irregularly shaped blocks. The field personnel are not required to know with any accuracy the start and end positions of survey lines (they do need to know, however, that they are on the survey line). The need for this information is avoided by using markers within the survey area whose locations are accurately known. These markers typically consist of tapes laid out perpendicular to the survey direction along known eastings or northings. A note is recorded when these markers are crossed together with the total magnetic field measurement in a data-file. The marker information is used in subsequent data processing to correctly position the data.

A base station magnetometer is set up in the vicinity of the survey area to record diurnal variations in the geomagnetic field. The location of the base-station is chosen to minimise the effects of cultural noise. These base station measurements are used in data processing to remove diurnal variations from the data.

DATA PROCESSING AND INTERPRETATION

Data processing and interpretation consists of the following main steps:

- Base station corrections - remove diurnal variations in the total magnetic field;
- Correctly positioning the data by incorporating field marker information;
- Spike removal;
- Removal of the local median value - to remove low frequency geological effects;
- Data enhancements such as upward continuation, second vertical derivatives, and reduction-to-the-pole to enhance various features;
- Histogram equalisation; and
- 2D and 3D modelling of anomaly profiles.

The processing sequence outlined above is easily adapted to suit the objectives of each particular survey.

The data processing and interpretation software developed by GRI facilities the rapid interpretation of magnetic images. The software produces a written record of all interpreted anomalies including the estimated positions (eastings and northings), depths and masses of the objects producing the anomalies. The written records and paper displays can then be used for further validation work.

CASE STUDIES

Positioning Drill Holes

This site, located in northern Germany, was extensively bombed during the Second World War. The objective of the survey was to locate any unexploded ordnance (UXO) to safely position oil exploration drill rigs.

High resolution magnetic surveys were performed over an area around each of the proposed drill sites. This enabled the site either to be cleared for drilling, or for a clear area to be selected nearby. The TM-4 system was operated in a single sensor mode at its highest resolution to successfully clear several thousand drill-holes. The low geomagnetic background noise of this region enabled UXO to be detected to a depth of 12 metres.

The total magnetic field data for one area are shown in Figure 1a. The UXO items are readily identifiable from the distinct magnetic anomalies.

Location of a Waste Burial Pit

This site, located in the Sydney region, is a former quarry used as a landfill. The fill consists of a large proportion of ferrous waste including, from conversations with site personnel, whole car bodies. The requirement was to define the southern edge of the landfill as the area was marked for redevelopment.

A high resolution magnetic survey was conducted using the TM-4 system in the simplest mode utilising a single sensor. The length and orientation of the survey lines were designed to optimise the location of the southern edge of the pit. The lines were sufficiently long to obtain a contrast between the waste pit and the surrounding host material.

The total magnetic field data are shown in Figure 1b. The contrast between the landfill and the surrounding bedrock is easily recognised along -105 metres. This feature was

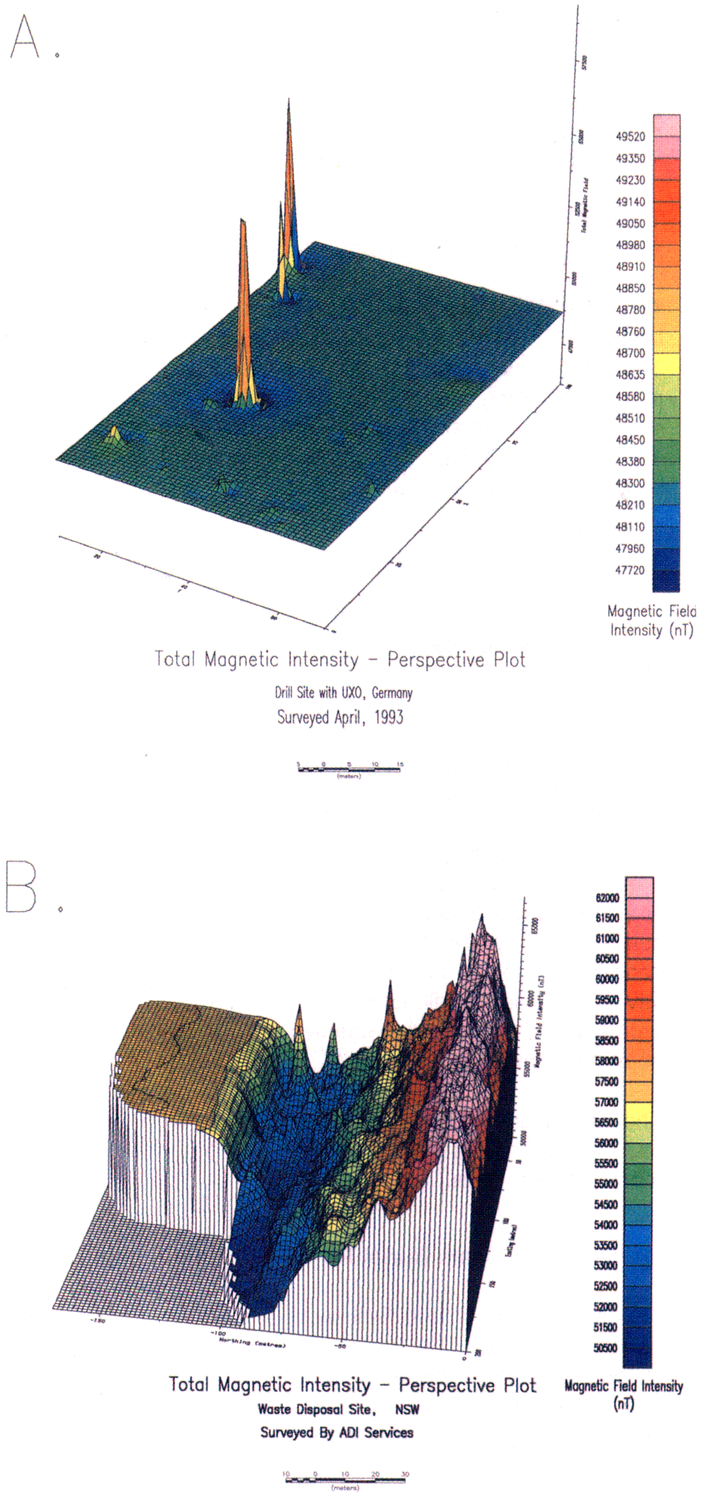

Fig. 1. (a) Total magnetic field data over a region containing unexploded ordnance (UXO). The UXO items are readily identifiable from the distinct magnetic anomalies. (b) Total magnetic field data over a region known to conceal a former waste pit. The edge of the waste pit is marked by the rapid change in the total magnetic field at the northing of approximately - 105 metres.

enhanced by calculating the second vertical derivatives and reduction-to-the-pole. The landfill showed significant variation in the total magnetic field, which contrasted with the surrounding subsurface material.

CONCLUSIONS

High resolution magnetics surveys, and the TM-4 system in particular, have proven to be a very powerful tool for locating buried ferrous objects as part of contaminated site assessment programmes. The TM-4 system has been designed so that high resolution total magnetic-field data can be rapidly collected, even for irregularly shaped survey areas. Two case studies were presented which demonstrated how high resolution magnetic surveys can play an important role in mapping subsurface contamination.

Regulators and the community at large require accurate mapping of subsurface contaminants. In many cases traditional geophysical tools and field methods are of limited use for accurate mapping of subsurface contaminants. The TM-4 system is an example of a recently developed geophysical technology that has been designed to meet these challenges.

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