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Archaeomagnetic prospection: A tool for near-surface hidden treasures

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ABSTRACT

Some manmade features may be under soil cover as a result of flooding, erosion, gradual sedimentations over a long period of time, or even sudden natural phenomenon such as earthquakes and tsunamis. Because of the inherent problems associated with conventional archaeological search, the magnetic profiling method has become a major tool in searching for such concealed features if they have contrasting magnetisation with the host soils. To establish the level of uncertainty in the method of locating the cultural features or lost items, we created an artificial site on a flat land in the Kogi State University Campus, Anyigba, Nigeria. Here, objects such as a short iron rod, a steel cylindrical pot, a fired stone and a clay pot were buried at known locations and at different depths, varying between 0.5 m and 1 m. The site was allowed to pass through one season of rains for the sake of re-arrangement of the disturbed soils. Thereafter, vertical gradient of the total field data were acquired on a 25m by 25m grid using proton precession magnetometer (Geometrics model G-856AX). The readings were taken at interval of 0.5m along profiles that were also spaced 0.5 m apart. The lower and the upper sensors were positioned at 1.25m apart, with the lower sensor fixed at 0.3m above the ground. We analysed and inverted the gridded data using 3D Analytical Signal Technique and obtained the plan positions and depths of the known sources with maximum errors of 11.39% and 35.29% respectively.

Key words: Cultural features, Experimental site, gridded data, analytical signal

INTRODUCTION

Many features that are of archaeological origin and other manmade features may be under soil cover due to some natural phenomenon such as flooding, erosion, gradual sedimentation, natural disasters such as earthquakes and tsunamis, etc. Such items may be recovered through archaeological excavations in search of historical evidence or treasure hunt (Binford [2]; Clark [3]). The practice which is of diverse scale can be highly destructive, and in most cases, faces environmental restrictions because to an environmentalist it is a disruption to nature even when an archaeologist may view as an unavoidable evil. The inherent problems associated with conventional archaeological practice has paved way for the more environmentally friendly approach (Scollar et al. [12]; Clark [3]), the geophysical methods which have become the usual practice in the developed and some developing countries of the world.

The magnetic method of geophysical exploration has been widely applied in the search for archaeological and other concealed features which display appreciable magnetisation contrast between them and the surrounding soils. The method offers the best combination of resolution and speed of mapping. Despite these interesting attributes, the geophysical method requires validation of the method of interpretation, the purchased or the developed software. One way to achieve this is to test run such software or method using sources of known parametric values (Tsokas and Papazachos [15]; Piro et al. [7]; Godio and Torino [4]). Once the error limit of the method of interpretation has been established, it can be easily and reliable applied in searching for similar features under soil cover. In this study, we created an experimental site on a 25 m by 25 m plane land to the south-east of the Kogi State University campus, Anyigba, Nigeria. A few objects of known shapes and some few physical properties were buried with definite surface locations and depths. The materials include a 60 cm iron rod having diameter of about 6 cm, a steel pot having volume of about 7 litres, a medium size fired stone and a fired clay pot of estimated volumes of about 12 and 10 litres respectively. The site also contains two known refuge dumps made up of old metallic wares, mostly cans, which were burnt severally at the period of dumping which was about six years ago.

The main aim of this study was to assess the possibility of using the available magnetic method to delineate the locations of the buried materials and to map any other source of magnetic anomaly within the experimental site. The study was expected to determine their depths and compare the results obtained for the sources of known spatial locations with the chosen values. Small error margins in such attempt would be regarded as validation of the interpretational technique which is not only used in delineating locations of artefacts in an archaeological site but can also be used in locating buried ferrous objects such as underground tanks, buried pipes and similar lost treasures of high magnetisations.

We measured the vertical gradient of the total field on a regular grid of 0.5 m by 0.5 m using proton precession magnetometer (Geometrics model G-856AX) having accuracy of 0.1 nT. The sensor separation was 1.25 m with the lower sensor positioned at 0.3 m above the ground so as to increase its sensitivity to the very near surface sources. Analytic signal method was deployed in inverting the acquired magnetic data. The results obtained put the uncertainty in the known depths and plan positions as 35.29 % and 11.39% respectively.

MATERIALS AND METHODS

Two refuge dumps were made (one after the other) in the south-eastern part of the Kogi State University, Anyigba campus between 2006 and 2007 for the purpose of evacuating refuge dumps from a house in the campus. Both of them were dug to depths of about 1 m, filled with house wastes which included many metal cans and other ferrous objects and covered with top soil. These two locations were included in the 25 m by 25 m portion of land used as experimental archaeological site. In order to enrich the site, four other sources of the magnetic field including a metal rod, a steel cylindrical pot, a fired stone and a fired clay pot were buried in the site with the following spatial coordinates in metres (5.25, 10.5.50, 0.70), (15.25, 7.50, 0.55), (19.00, 17.00, 0.50) and (10.00, 5.00, 0.70) respectively. The site was then properly gridded at intervals of 0.5 m along the profiles which were also spaced 0.5 m apart.

In order to acquire the magnetic readings, the magnetometer sensors were positioned 1.25 metres apart while the lower sensor was fixed at 0.3 m throughout the survey. The gradient data which were acquired in unidirectional method were downloaded into a digital computer directly from the console memory using the software, MagMap2000, thus avoiding transcription errors. The data displayed by the MagMap2000 software were sorted, filtered using spline smooth filters of the golden software (surfer) and contoured with contour intervals of 10 nT (figure 1).

To invert the magnetic data, analytic signal component of the processing software, the MagPick, was deployed. The software was used to first compute the two horizontal gradients followed by the vertical gradient of the total magnetic field from which the analytic signal amplitudes were obtained (figure 2). It was observed after the application of the analytic signal method that two anomalies at locations D and E of figures 1 disappeared in the analytic signal results using contour interval of 50nT/m. To view their anomalies in order to compute their spatial locations, attempt was made to amplify the signal by reducing the contour intervals (in stages) to 10nT/m. This change revealed the boundary of the source of the anomaly numbered D, but with different contour interval from the other sources in figure 2. Further amplification to display the presence of the source of the anomaly numbered E (the cooking stone) amplified the noise component so much that proper identification of its location became very difficult and uncertain.

In order to calculate the plan locations and depths of sources of anomalies at locations A to J (excluding E) profiles were drawn across each analytic signal anomaly in figure 2 and surfer digitizing facilities were used to obtain digital values for each anomaly. Using "width of the analytic signal anomaly at half the maximum amplitude" method (Atchuta et al. [1]; Roest et al. [10]), the depths of the causative magnetic bodies were computed. The plan location of each source was also obtained by scanning for the position of maximum amplitude of the analytic signal around the centre of each anomaly. The results obtained are displayed in the table 1.

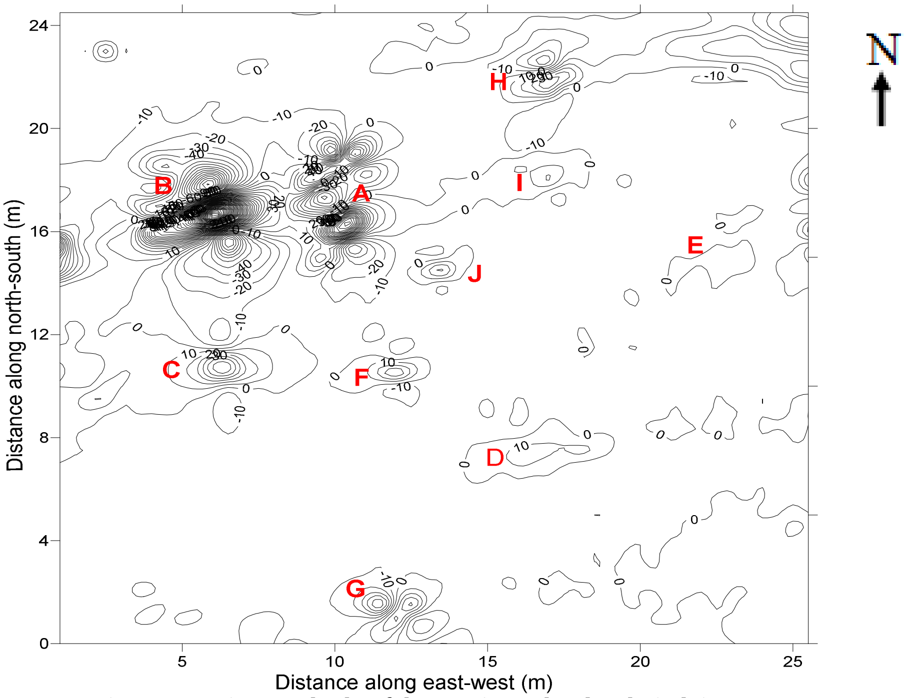

Fig. 1: Magnetic anomaly plot of the experimental archaeological site
(A to J are labels for anomalies of interest)

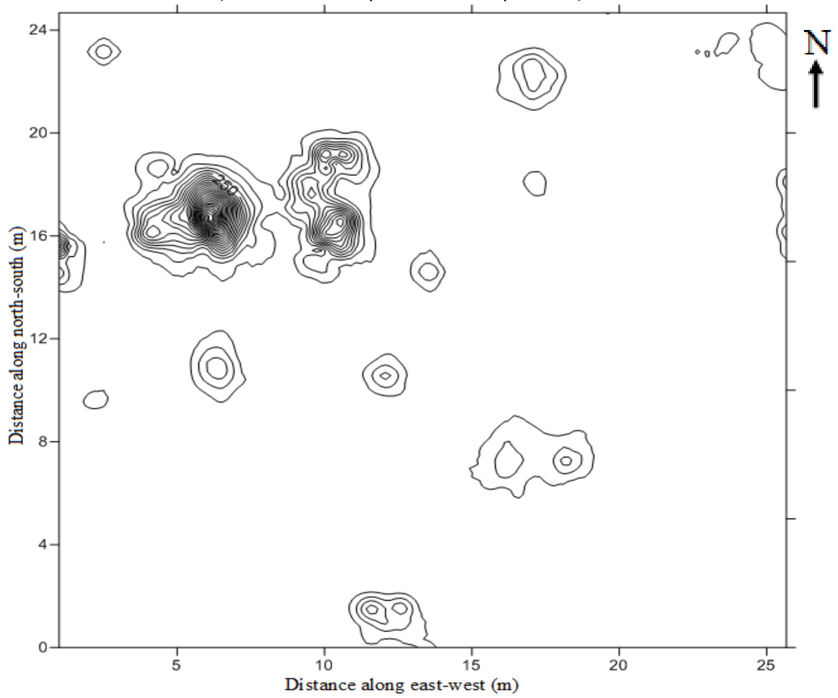

Fig. 2: Analytic signal anomalies of the experimental site

Table 1: Calculated spatial locations of the sources in the experimental site
(Known values recomputed contain the relative percentage errors)

Anomaly Number	Calculated locations of sources			Known locations of sources		
	x (m)	y (m)	Depth (m)	x (m)	y (m)	Depth (m)
A	10.55	16.57	0.48	-	-	-
B	6.14	16.79	0.38	-	-	-
C	5.40±02.78	10.92±03.85	0.85±17.65	5.25	10.50	0.70
D	17.21±11.39	7.49±00.13	0.85±35.29	15.25	7.50	0.55
F	11.03±09.34	10.60±05.66	0.68±11.76	10.00	10.00	0.60
G	10.58	1.50	0.63	-	-	-
H	16.10	22.65	0.75	-	-	-
I	16.10	18.11	0.38	-	-	-
J	12.55	14.60	0.43	-	-	-

RESULTS AND DISCUSSION

The magnetic profiles were numbered along the east-west direction beginning with number 1 while the sample points along the north-south direction began with the number 0. This format has affected the scaling of the maps of figures 1 and 2. The anomaly locations C, D, E and F correspond with the known (buried) sources; that is, the iron rod, the steel cylinder, the cooking stone and the fired clay pot respectively. The sources of the rest anomalies (except those of A and B which were refuge dumps) are unknown.

The computed spatial locations of the magnetic sources using the analytic signal technique has been displayed in the table with the anomaly numbers recorded according to the labels in figure 1. The shapes of the three known sources were used in the analytic signal amplitude-depth relationship as given by Atchuta et al. [1] and Roest et al. [10]. The results obtained for the buried sources of known spatial locations reveals that the plan locations of the known sources were recomputed with percentage errors varying between 0.13 and 11.39. On the other hand, the known depths of the sources were recomputed with percentage error between 11.76 and 35.29. These error margins as compared to the acceptable uncertainty of 20% used by MacLeod et al. [5] and the error of about 18% accepted for depth computation in a field example by Salem [11], may be tolerated. The only outlier may be that of 35.29% obtained in the computation of the depth of the source labelled D in figure 1. The reason for such large percentage error is enshrined in the small magnetisation contrast of less than 14 nT between the magnetic source in question and the host soil in the site with very high magnetic gradient, varying from less than 1 nT at some locations to over 300 nT at others (figure 1). The analytic signal depths computed for the other two sources at locations C and F have percentage errors of 17.65 and 11.76 respectively which are within the tolerant limit used by Salem [11]. The depths of 0.48 m and 0.38 m computed for the old refuge dumps at locations A and B respectively also appear reasonable and acceptable.

CONCLUSION

Many artefacts, including some manmade prehistoric treasures and treasures of the present era, concealed under soils can be recovered using geophysical techniques. Magnetic method is very important in this regard since many of such items display detectable magnetic properties. In order to ascertain reliable results, the method of analysis (or the software used) has to be validated by using either synthetic data (Talwani [13]; Rao and Babu, [8]; Ogah, [6]) or an experimental site with known parametric values of the causative bodies.

The error margins in the applied technique of the analytic signal method determined in this study can be used as a guide in preparing excavation plan in future exploration for artefacts or lost treasures. In the worst case; that is, a magnetically weak source in a high gradient field, the error margins can be as high as 11.39% and 35.29% in the plan location and depth respectively. For the sources of moderate to high magnetisations, the error margins are less than 10% and 18% in plan locations and depths respectively. It therefore means that the other spatial locations obtained for the unknown sources having moderate to high magnetisation contrasts should be within acceptable limits. However, results of another interpretational technique such as Euler deconvolution method (Thompson [14]; Reid et al. [9]) are required for correlation purposes at this experimental site.

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