Applications of field geophysics within the habitation area of a slave village at Marshall's Pen, Mandeville, Jamaica

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INTRODUCTION

The site studied in this project is a former coffee plantation located in Mandeville, Jamaica, in an area called Marshall's Pen. At its heyday, from about 1790 to the late 1830s when slavery was abolished in Jamaica, the plantation contained nearly 1000 acres of land and at least 200 slaves. The plantation included a slave village built over a hill in this karst region. Most of the houses and living areas existed on the hill, while the slave cemetery was placed in an area of lower elevation on the flanks of a sinkhole. The Great House for the plantation owner and a smaller overseer's house are located beyond a hill to the west of the slave village.

Focus for this project was placed on the slaves' living and domestic labor areas located at the top of the hill and along its slope. On the hill, it was possible to discern multiple terraces cut into the sloping land to form flat platforms for the floors of houses. In addition to the platforms, recent and historic rock walls and rock piles were abundant; some rock-walled enclosures should have contained livestock or gardens.

The site chosen for detailed study was selected to include both known structures at the top of the hill and less well understood structures on the hill's southern slope. Study was conducted on a grid of 49 x 50 meters with lines spaced at 1-m intervals. A variety of geophysical tools, including conductivity and resistivity profiling, susceptibility, and magnetometry, was used to locate areas of possible archaeological significance. Use of these geophysical instruments was intended to maximize the success of the follow-up archaeological excavation, and to provide a non-invasive and cost-efficient method of survey.

MATERIALS AND METHODS

Two perpendicular test lines were laid out at the site, one 25-m long and the other 50-m long. These test lines were set up so that they would be contained in the final 49 x 50 meter grid, and four geophysical instruments were run along them: a Bison Earth Resistivity meter, a Geonics EM-31 electromagnetic conductivity meter, a Bartington MS2 magnetic susceptibility meter, and a Geometrics G-858 cesium vapor magnetometer. A second magnetometer, a Geometrics G-856 proton procession magnetometer, was also set up as a base station to correct for diurnal variations.

The resistivity meter was run along both test lines using the Wenner array and an a-spacing of 1 m, except at one point where an a-spacing of 2.5 m was employed due to the presence of a wall. The conductivity meter was also used on both test lines with readings recorded at 1-m intervals. The instrument was held parallel to the line at a height of about 1 m and the readings were collected in an Omnidata Polycorder data logger. The susceptibility meter was used on both test lines and readings were also recorded at 1-m intervals. The instrument was zeroed every 10 m to correct for instrumental drift. Finally, the magnetometer was used along both test lines with readings recorded every 0.1 seconds. The position of the sensor was marked every 2 m and the instrument was held about 70 cm above the ground, parallel to the line.

Having run all four instruments along these test lines, it was determined that the magnetometer and susceptibility meter produced the most useful results. Therefore, these two instruments were used for the data collection over the 49 x 50 meter grid. The use of susceptibility and magnetometry as successful geophysical tools for archaeological study is supported by the findings of Batt *et al.* (1995), who state that a detailed survey with both instruments is often ideal.

The method for data collection over the grid using the susceptibility meter remained the same as along the two test lines. The method for data collection with the magnetometer, however, varied over the grid from that along the test lines. The position of the sensor was still marked every 2 m, but the magnetometer was now held perpendicular to the lines of the grid for surveying ease. In addition, the interval of readings was changed from 0.1 s to 0.5 s, as the rough terrain of the area slowed down the operator.

Data collected in the field during the day was reduced and interpreted nightly while in Jamaica. Two Dell laptops, an Inspiron 3200 and an Inspiron 7000, and a Macintosh Powerbook G3 were used to run programs for data reduction. These included Dat31, MagMapper, Surfer, and Microsoft Excel. Upon returning to the U.S., project study continued at Franklin & Marshall College where iMacs, PowerMacs, and PCs were used to run Adobe Photoshop, Canvas, Microsoft Excel, Surfer, KaleidaGraph, and ClarisWorks in order to further reduce data and prepare material for presentation.

RESULTS

Data collected using the magnetic susceptibility meter and the magnetometer were formatted in a number of different ways to display results. Figure 1 shows a contour map of the magnetometry data collected over the 49 x 50 meter grid. This map presents magnetometry data that was collected over three consecutive days. The data collected using the base station magnetometer for these three days showed unexplained jumps in the readings, and thus could not be used to correct for diurnal variations as planned. Therefore, for each day, an average of all readings from that day was calculated and then subtracted from the initial results. In this way, it was possible to normalize for some of the effects of the earth's magnetic field on the mobile magnetometer readings.

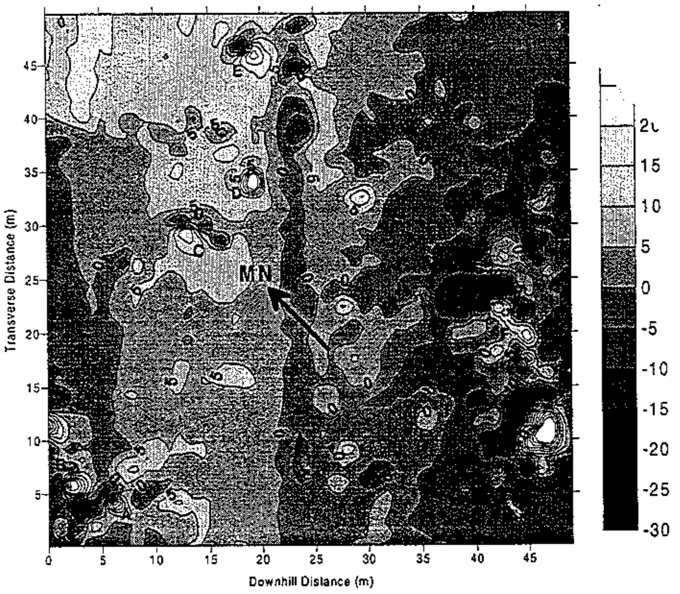

Figure 1. Corrected magnetics (nT). Magnetic north is shown.

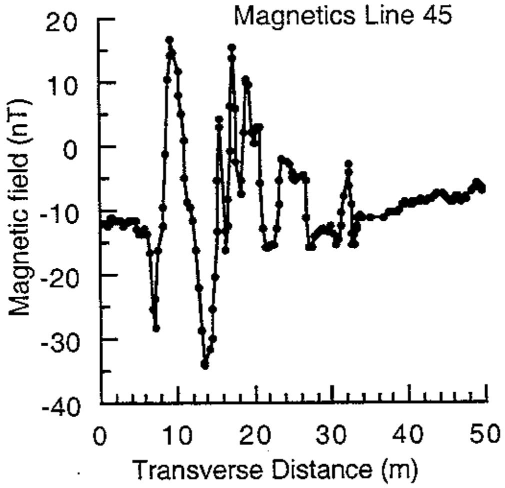

Figure 2. Profile of magnetics data of line 45.

The contour map in Figure 1 shows many magnetic anomalies of both monopoles and dipoles; many dipoles are aligned with magnetic north-south. These anomalies represent sub-surface sources that display a magnetization different from that of the surrounding soil (von Frese, 1984). Reading the map as an X-Y grid, dipoles are located at coordinates (3,4), (7,4), (13,30), (18,45), (42,23), and (45,12). These dipoles are labeled A, B, C, E, F, and G respectively. A profile of anomaly G is further exhibited in Figure 2, clearly visible from about 5 m to 17 m.

One monopole anomaly is visible in Figure 1 at coordinates (19,34) and is labeled anomaly D. There is also a an apparent linear anomaly that runs down the middle of the map. However, this strip is actually the result of readings that were recorded on a separate day from the rest of the map's data, and for which day-to-day geomagnetic differences were inadequately normalized.

The contour map in Figure 3 displays data collected with the susceptibility meter over the grid. There are three areas of susceptibility highs on the map which correspond with the magnetic anomalies seen in Figure 1. These areas are located in the lower left-hand corner of the map, the upper left-hand section of the map, and the right-hand edge of the map. A somewhat linear arrangement of susceptibility highs can further be discerned running N-S from 0 to 25 m in the downhill direction in the lower left-hand corner of the map. Readings on limestone are zero.

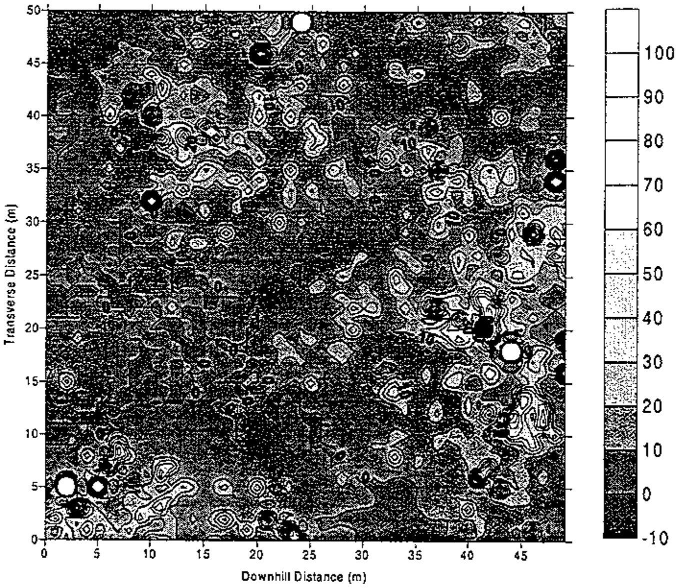

Figure 3. Bartington SI susceptibility readings.

DISCUSSION

Dipoles B, E, and G in Figure 1 represent subsurface features with a magnetization contrast that may result from induced magnetization, since the dipoles line up well with magnetic north, where high readings occur to the south and lows lie to the north. Dipoles A, C, and F do not line up as well parallel to magnetic north. These are thought to represent buried objects that possess a remanent magnetization and are no longer in the same position as when remanence was acquired.

The subsurface features represented by the former three dipoles are likely to be pits dug into the rock and then filled with soil during burial, as cultural soil features tend to exhibit enhanced induced magnetization (von Frese, 1984; Sternberg, 1987). One or all of these dipoles could also represent a buried hearth, or another *in situ* object. A hearth possesses remanent magnetization, but as the site may be as young as 160 years old, the orientation of the earth's magnetic field then would be roughly the same as it is now. Therefore, the magnetic anomaly of an *in situ* object with remanence would look like the anomaly of an object with induced magnetization.

Dipole G in Figure 1 is somewhat elongate in the E-W direction, suggesting the possibility that the magnetic signature may result from a buried trench. However, anomalies B and E do not exhibit such an elongate quality and are therefore more likely to be buried pits or hearths. None of these dipolar anomalies have very large amplitudes, which is consistent with Sternberg's (1987) results for magnetic anomalies of hearths in the American Southwest.

The features represented by dipoles A, C, and F in Figure 1 are thought to be remanence-bearing objects such as buried iron artifacts or pieces of fired pottery (von Frese, 1984; Sternberg, 1987). Since, once again, the amplitudes of the anomalies are not very large, it is possible that the objects they represent are buried a bit deeper, as the intensity of the dipole varies as $1/r^3$, where r is the distance from the sensor to the source of the anomaly. It is also possible that these relatively weak anomalies represent materials that possess remanent magnetization but are no longer *in situ,* such as ashes from a hearth that have been spread out over a large area and then buried.

Depth estimates of buried objects can be useful for interpretations of magnetic data. Using profiles of magnetometry data, it was possible to estimates depths to objects using the straight-slope (SS) method and Peters' half-slope (PHS) method (Milsom, 1989, p. 58). Examples of these two methods are shown in Figure 4, and Table 1 lists our depth estimates. Negative values signify that the source of the anomaly is located below the surface. Positive values mean literally that the source is located above the surface, but as the methods are only accurate to about 20%, these depth can be interpreted as very shallow.

TABLE 1. DEPTH ESTIMATES OF MAGNETIC ANOMALIES

Anomaly	Line	Width	Depth (SS) meters	Depth (PHS) meters
C	12	2.7	0.2	0.1
D	19	4.9	0.1	0.5
G	45	7.4	-3.2	-1.1
G	46	6.1	-3.9	-1.7

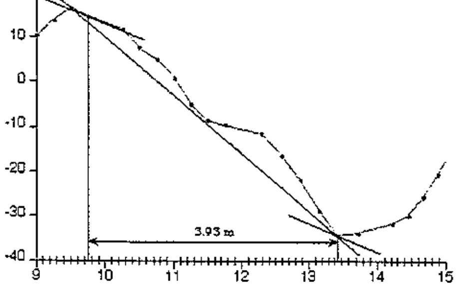

Figure 4. Straight-slope depth estmate for G.

Contrast in magnetic susceptibility can occur for filled pits, trodden roads, or heated and burned soil (Tite and Mullins, 1971). The contour map in Figure 3 shows three major areas where the soil on which the reading was taken possessed a higher susceptibility than that of the surrounding soil. According to Tite and Mullins (1971), these areas of susceptibility highs quite often represent patches of soil where material was heated to a temperature of 450° C or higher, as would occur with fires on an archaeological site. The figure also shows areas of low susceptibility where rock walls were present at the surface, as the limestone which made up the walls had a susceptibility of zero. These walls most likely formed pens for animals or gardens. Two pens are easily seen in Figure 3 along the left-hand side of the map as two adjacent rectangular features with susceptibility of zero.

The task of discovering such archaeological features as a path or road has also previously been addressed (Papamarinopoulos et al., 1993; Tite and Mullins, 1971). Figure 3 shows a somewhat linear arrangement of susceptibility highs in the lower left-hand corner of the map. These susceptibility highs may correspond with what appeared to be the surficial expression of a path on the hill. However, since the site is now part of a cow pasture, it is unknown whether this path was created during the site's archaeological history, or in more recent years as part of the cows' grazing route.

CONCLUSION

The studies at Marshall's Pen, and countless other areas, have shown that geophysical instruments can be used as part of a non-invasive and cost-efficient method for approaching an archaeological site. Through study at the slave village, it was possible to compare the utility of different geophysical instruments and methods. It was further possible to recognize the particular value of the magnetometer and the susceptibility meter. The data collected using the magnetometer allowed for plots of very useful contour maps. This is predominantly due to the excellence of the G-858 in terms of ease and accuracy. Susceptibility is a less commonly used geophysical instrument, yet it worked surprisingly well in terms of its ability to recognize clear anomalies that corresponded with magnetic anomalies. Initial interpretations of magnetometer and susceptibility data proved successful at finding similar clusters of anomalies which could have resulted from activities that generally occur in habitation areas. The data collected using the conductivity and resistivity meters were not as useful as originally anticipated. This is attributed to the abundance of outcrop and scattered rock at the site which made useful electrode placement and detection of cultural stone features nearly impossible. The researchers would certainly benefit from the results of the follow-up archaeological excavation in order to compare interpreted data to actual archaeological evidence collected at the site.

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