Geophysical Investigation of a former landfill and brickworks area, Baker Woodlands Research Site Lancaster, Pennsylvania

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INTRODUCTION

In the last fifty years geophysical methods have become increasingly important in site investigation, since mastering the equipment is fairly simple, large amounts of data can be quickly obtained and processed, and scientists can study subsurface areas of interest without physically altering the landscape. Geophysical results do not produce conclusive, explicit results, but rather show subsurface variations in physical properties (Breiner, 1973). Magnetic and conductivity surveys are among the most commonly used methods. The magnetometer, which penetrates the ground down to 6 meters, is designed to measure the total field magnetic intensity, which includes the magnetivity of subsurface features as well as background magnetization from the Earth. Subsurface variations cause anomalous readings that fall above or below background levels of 55,000 nanoTeslas (nT) in Pennsylvania. A dipole anomaly, a combination of a low measurement directly north of an abnormally high measurement, could indicate metallic objects below the surface. Ground conductivity surveys are useful in studying subsurface variations. A conductivity meter utilizes a transmitter which produces a magnetic current that is sent, about 1 meter into the ground, and is measured by a receiver at the other end of the instrument. Changes in the subsurface are detected by differences in conductivity readings; for example, metallic objects effectuate higher values (Bevan, 1983).

The Baker Woodlands research site is a 60-acre tract of land approximately one mile west of Franklin and Marshall College in Lancaster, Pennsylvania. In the past, varying sections of the site were used: for agriculture, by a brickworks company, as a landfill, and as open woodlands. Today, most of the site is a woodland area, with some grassy zones, and a small wetland. Four sites of varying sizes were selected for geophysical analysis, two in the industrial landfill (Grids 1 and 2) and two in the former brickworks area (Grids 3 and 4). The two sites in the landfill are adjacent to the previously studied transect L-4 (de Wet et al., 1998).

METHODS

Field Work. After excessive brush was cleared, a grid with one-meter transect spacing was created at each site. Each grid was surveyed using: a GeoMetrics G-858 proton procession magnetometer and a Geonics EM31 conductivity meter. The magnetometer gathered information every 0.5 seconds and points were marked at 2-meter intervals. The EM31, held parallel to the grid transects, collected data every meter. The data was processed into contour maps. In Grids 1 and 2, three 0.5 meter by 1 meter pits were dug in areas identified by the contour maps as the locations of large magnetic anomalies. A total of 10 samples were taken from different stratigraphic layers in the pits.

Lab Work. The samples were prepared in the lab and analyzed by x-ray fluorescence (XRF) to determine their composition. Three samples of slag collected from the kiln in Grid 3 were also analyzed using the XRF. The magnetometer data was integrated into a Geographic Information System (GIS) for future reference.

DISCUSSION

Landfill. In Grid 1 the magnetic anomalies are randomly distributed throughout the locality, while only one large anomaly is present in Grid 2. Differences in anomaly distribution are attributed to variations in subsurface composition. As discovered through excavation, Grid 1 has a heterogeneous layer of wood, bricks, tile, and other demolition debris capped by about 10 cm of fine-grained, crushed limestone and 3 cm of soil and organic matter. Metallic objects are the cause of the anomalies spread throughout the site. In contrast, Grid 2 has a homogeneous composition of approximately 75 cm of the same limestone material capped by about 5 cm of soil. Here the excavation did not reveal the source of the large anomaly, which most likely lies beneath the depth of the excavation. The vegetation also provides evidence of differing subsurface conditions; Grid 1 is covered by more dense vegetation supporting large trees and bushes, whereas Grid 2 is sparsely vegetated by grasses and scrubby plants. Clearly, the tightly packed limestone material found there is not conducive to rootstock. In Grids 1 and 2 the EM31 readings, like the magnetometer data, peaked above metal objects. The EM-31 data shows a thinning of slag material as one moves southward in the landfill, giving increasingly lower positive values. This is congruent with the excavation of the pits, which showed the slag material in much greater amounts, and at deeper depths, moving North along L4.

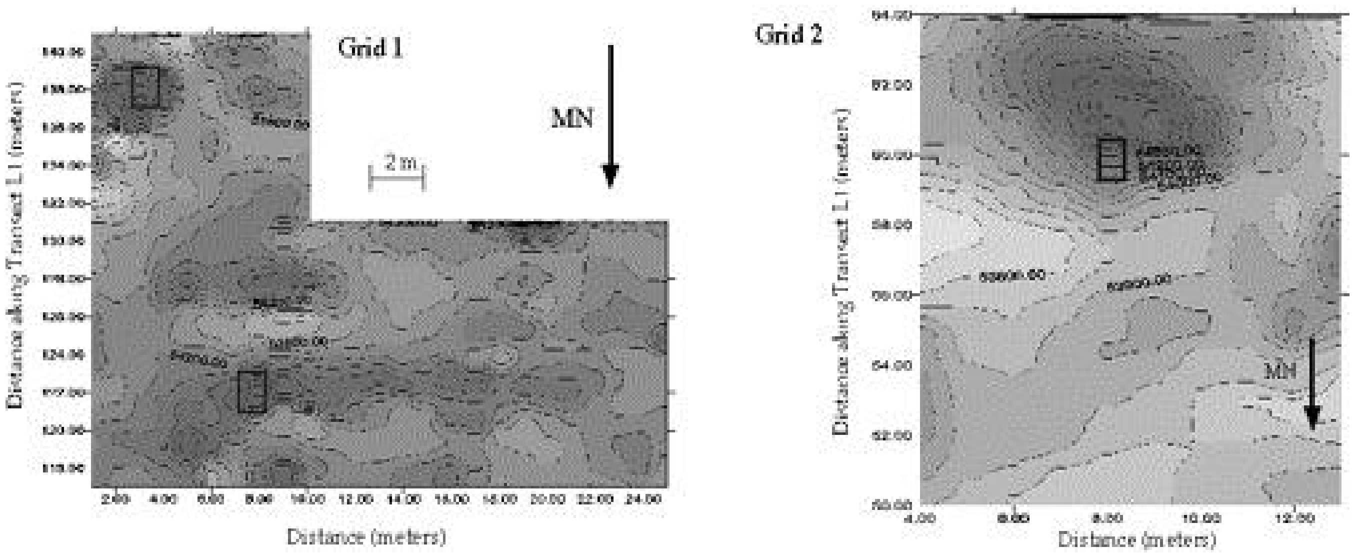

Figure 1: Total field magnetic intensity from grids 1 and 2.

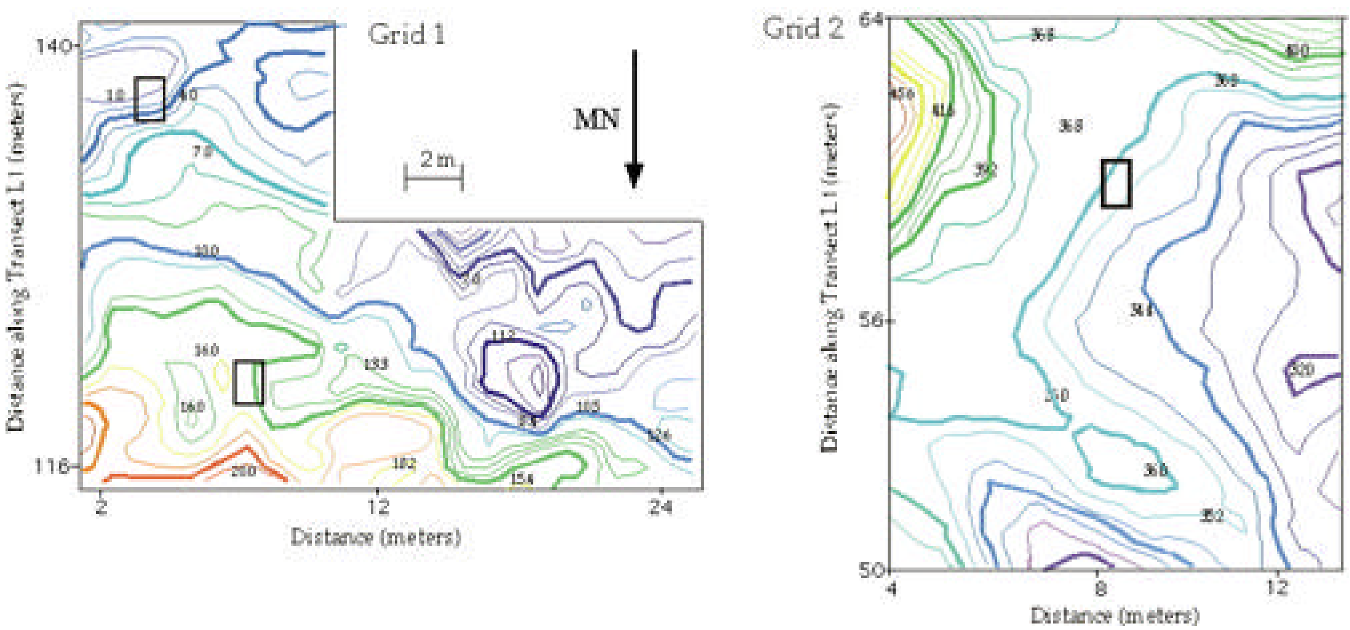

Figure 2: Conductivity from grids 1 and 2.

Geochemistry. Based on limited sampling that is representative of the soils in the landfill, the XRF analysis supported the hypothesis that the landfill is heterogeneous (Figure 3). Although amounts of some trace elements are similar between the landfill grids, there are large differences in percent composition of elements such as Barium, Lead, and Zinc.

High traces of barium can be linked to the abundant amount of linoleum tile pieces found in Grid 1; the large lead percentages are attributed to lead based paints in building demolition debris and the zinc values are due to metal plated industrial waste (Sparks, 1995). The sources of these elements did not exist in Grid 2. Even though the bulk composition of the slag examined from Grid 2 and from the kiln in Grid 3 was comparatively similar, there is too much variation in elements such as Fe_2O_3, K_2O, MnO, Strontium, and Rubidium for them to be the same slag. Figure 4 shows these variances in trace elements.

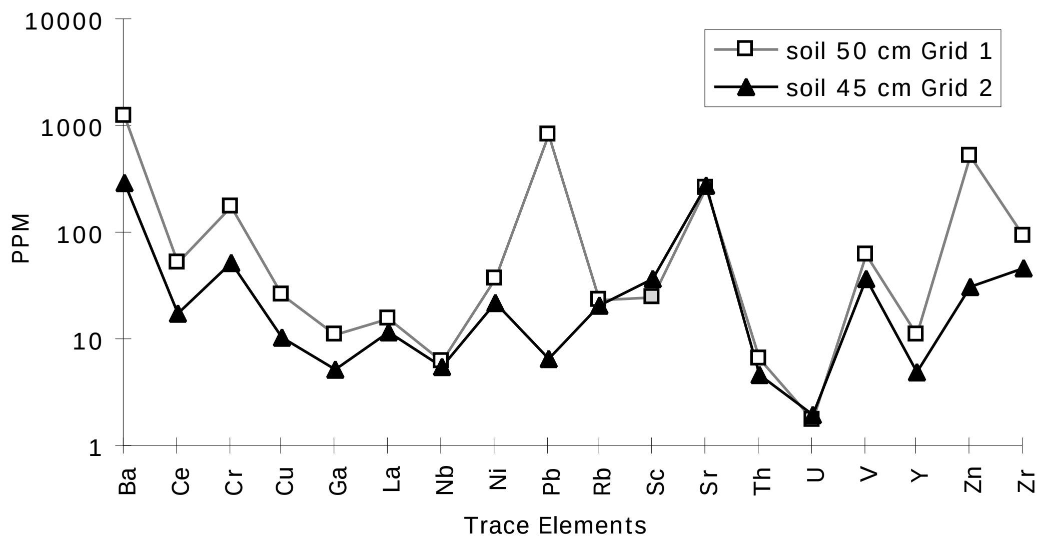

Figure 3: Trace elements concentrations of soils from grids 1 and 2.

Figure 4: Trace element composition of slag from grid 2 (landfill) and grid 3 (Brickworks kiln).

Brickworks. The two anomalies indicated by the geophysical data in the landfill area are markedly different from those found in the former brickworks area. The huge dipole anomalies in Grids 3 and 4 varied as much as 100,000 nT, whereas they differed at most by 3,000 nT in Grids 1 and 2. Surface metallic objects increased the magnetic signatures detected by around 10x. Negative values recorded by the EM31 correspond with the dipole magnetometer readings in Grid 3 and 4, where multiple sets of partially exposed cart tracks are located.

CONCLUSION

Together the geophysical data excavation, geochemistry data, and vegetation of the sites verify that the landfill is heterogeneous. Surface metal, such as the cart tracks in the brickworks area, produce enormous anomalies not comparable to those caused by the buried objects in the landfill. The EM-31 data corresponds with the data obtained by the magnetometer in locating anomalies, but also provides information about the moisture and salinity of subsurface material. No correlation exists between the materials at the brickworks and those disposed of in the landfill.

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