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Lawrence B. Conyers

Ground-penetrating Radar and Magnetometry for Buried Landscape Analysis

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Preface

For more than a decade, archeologists and cultural geographers have appreciated how important it is to place ancient people into their cultural and natural environment. When sites can be studied in this context, people's adaptation to environmental factors, changes in those environments, and human interactions with each other can become part of a holistic examination of human behavior. This has fostered the subfield of landscape archeology, which takes into consideration not just artifacts and features left behind by past people, but analyzes them within their overall environmental context. When important remains of human activity and aspects of the ancient landscape and environment are buried and no longer visible at the surface, geophysical analysis becomes an obvious choice for this type of large-scale analysis.

Two commonly used landscape-scale geophysical techniques are magnetometry and ground-penetrating radar (GPR). Magnetometry gained an early recognition for these types of studies as the instruments can be moved across broad areas quite readily, producing large-scale images of features within the upper few meters of the ground surface. This is a passive method that measures changes in the earth's magnetic field and is especially useful for the discovery and mapping of ditches and berms, large structures, and other features of the built environment, especially those that have been burned, or contain ferrous objects. As magnetometry instruments are extremely sensitive, even small changes in the amount of organic matter, which is often very slightly magnetic, can be mapped over large areas producing dramatic images of buried cultural and natural landscapes. In this way, large-scale constructions such as ditches, property boundaries, and other built features are visible. GPR data are somewhat slower to collect as the antennas that transmit and receive radar waves must be kept in contact, or very near, the surface. The GPR method, however, is capable of a three-dimensional analysis of buried layers as long as the interfaces between those buried units and objects reflect energy. While the properties of the materials in the ground are important to understand what is visible in GPR images, the GPR method is usually not capable of determining much about the composition of those specific materials. An integration of GPR and magnetometry is therefore symbiotic, as the results of one technique can readily inform interpretations made with the other, and vice versa.

Most magnetometry and GPR results are often displayed in map view, allowing for a visual analysis of differences in the ground that may be the result of buried features of interest. In ground that is suitable for one or the other method, these images can often be highly informative, displaying striking large-scale maps of buried features. However, in many cases, map images are less distinct, with some features effectively invisible for reasons that can often remain obscure. A common interpretation method is to overlay, or directly compare GPR and magnetometry maps of the same area, looking for common trends of buried anomalies, or perhaps direct correlations. While this comparison of results derived from the two techniques can sometimes yield good results, a different interpretation technique is presented here. It begins with an analysis of individual GPR reflection profiles over small two-dimensional slices within a larger study area to identify buried strata that can be interpreted using standard GPR techniques. Then, individual magnetic readings are extracted from a larger dataset and compared directly to the GPR profiles, helping to define the composition of the features that are visible with GPR. A variation on this method is to look for important features visible in magnetic maps and then use GPR profiles to determine what about the units in the ground is producing those magnetic readings. Both these types of direct comparisons can be applied in an iterative way, gaining even more utility by correlation to known units visible in excavations or outcrops.

This type of initial small-scale GPR and magnetic interpretation can begin in just a corner of a larger grid of data, and those results become a way to understand what it is about the various units in the ground that are providing the contrasts visible with each technique over the larger area. When this is done, both small- and large-scale features become understandable, and the origins of all can be mapped spatially using both methods in conjunction. The images produced from both GPR and magnetometry therefore become less "anomaly maps" and more "geophysically defined feature maps," displaying understandable and more readily interpretable images of buried materials that make up buried landscapes.

At a Roman site in Croatia, the buried walls of a structure were readily visible in the magnetic map, but invisible using GPR. At this site, the stones that had been used for building the house walls had mostly been recycled in the past, and only the foundations of the building, visible as composition changes were imaged with magnetics. In contrast, buried Roman structures in England could be readily mapped using GPR, as much of the stones were still in place and readily reflected radar energy. There was not enough magnetic contrast in the buried architecture at this site to be readily visible in the magnetic maps. In Ireland, magnetic mapping defined roads, ditches, and property boundaries in a buried village associated with a Medieval castle. The GPR profiles clearly defined house floors and other stone features associated with living structures, with the magnetic readings being useful for interpreting which areas had been burned, and where the central hearths of houses were located. A seventeenth-century English farmstead in Connecticut associated with a Native American village was discovered using GPR mapping, as the house cellars and other structures filled with homogeneous sediment were readily visible in amplitude maps. The magnetic maps over the large study area were cluttered with anomalies produced from recent metal trash and were almost useless in mapping the buried farming village. However, individual magnetic readings, when compared to the GPR profiles, showed which houses had been burned and where metal objects were located. At a 6000-2000 year old hunter-gather site in Colorado magnetic mapping was capable of locating hearths and ovens, which are invisible in GPR images as they were small in size and compositionally too similar to the surrounding ground. The GPR profiles were quite effective at locating packages of sediment deposited during different environmental changes in this dynamic landscape over millennia, and therefore, the subtle features left by these mobile people, and their artifacts, could be placed within that changing ancient landscape.

The overall purpose of this book therefore is to recommend methods not commonly employed in geophysical landscape analysis where small areas of larger grids are analyzed first using both GPR and magnetometry. Only when an understanding of what each method is capable of measuring regarding the specific properties of materials in the ground can the larger features in the landscape-scale maps generated by each method be more readily defined and interpreted.

Denver, USA Lawrence B. Conyers

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Chapter 1
Introduction

Abstract Artifacts, architecture and other remains of human use and adaptations to environmentally-defined landscapes are generally termed cultural landscapes. These are often buried and difficult to find and study, especially over broad areas. Geophysical tools, when accompanied by and correlated to information obtained from excavations is one way to expand knowledge of human activities over these large areas. Ground-penetrating radar can produce images in two and three-dimensions that define geological and anthropogenic units and features if those materials in the ground generate radar reflections from layer surfaces. The composition and extent of those materials is often discernable using magnetometer analysis, as that method produces images and discrete measurements of differences in the magnetic properties of some of the units that reflect radar energy. If the two methods are merged and evaluated in small areas first, where much can be determined about units and features of interest, this information can be projected over a wide area in order to understand broad natural landscapes and human activities in the past that occurred on and within them.

1.1 Introduction

This book presents methods and interpretations on how two commonly used near-surface geophysical techniques can be used in conjunction. The goal of this methodological integration is to study historic and prehistoric human uses of and adaptations to past environments and buried landscapes. These two methods are ground-penetrating radar (GPR) and magnetometry, which produce complementary but not directly correlative analyses of materials preserved in the ground. The GPR method produces three-dimensional images of complex layers of sediment and soil, and often architectural and other human-produced materials within those layers. The magnetic method measures changes in the Earth's magnetic field as a function of the magnetic properties of materials in the ground. It is only indirectly a three-dimensional method, but complementary with GPR as it can often determine the composition of buried materials, which is difficult with most GPR analyses. By

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