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# Innovative Ground-penetrating Radar Methods for Archaeological Mapping

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**ABSTRACT** The three-dimensional complexity of ground-penetrating radar (GPR) data can be one of its strengths, as multiple factors are included in “cubes” of radar wave reflections. These parameters are time that can be converted to depth, wide bands of wave frequency that are capable of differing feature resolution and wave amplitudes that are a function of material differences at buried interfaces. When GPR data are filtered and corrected to enhance aspects of these factors, many otherwise invisible buried features become visible in the resulting maps and images. This can allow for buried archaeological feature resolution even in the most cluttered and noisy urban environments, as demonstrated by GPR maps from Santa Fe, New Mexico. Copyright © 2006 John Wiley & Sons, Ltd.

*Key words:* GPR; image production; three-dimensional resolution; urban environments

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## Introduction

As ground-penetrating radar (GPR) has gained an ever growing number of users, its range of applications for archaeological mapping are increasing as well. One past criticism of the method was that it was applicable only in certain environments, or for certain types of buried materials. These critiques are slowly being challenged as some practitioners push what used to be thought of as the bounds of GPR. Although the method is still the most complex of the near-surface geophysical methods for archaeological mapping, its complexity is now being viewed more as one of its strengths. The many variables that affect radar transmission, reflections and recording, as well as those inherent in the GPR equipment itself are slowly being appreciated, understood, and then applied to specific problems. For instance, GPR reflection data are measuring both magnetic and electrical properties of the ground while simultaneously using multiple

frequencies of energy within a three-dimensional cube of data. Each of those variables are potentially measuring something about the material in the ground. But only when each can be identified in the database, resolved using processing software and then made into images that the human brain can process, are they useful. This type of analysis has only recently become available with the increased power and speed of data processing and software developed to meet a variety of problems (Conyers, 2004).

All GPR reflection data present within each individual reflection trace contain information regarding strength of reflection (measured in amplitude), depth in the ground (in two-way travel time), as well as energy from a wide range of frequencies above and below the antennae’ centre-frequency. Each of those factors potentially can be used to measure variables of geological or archaeological materials in the ground, but only if one can relate them directly to the material in the ground and the geometry of features. When reflection profiles are collected in closely spaced transects, and reflection traces are also spaced closely along transects, a very detailed ‘three-dimensional cube’ of information

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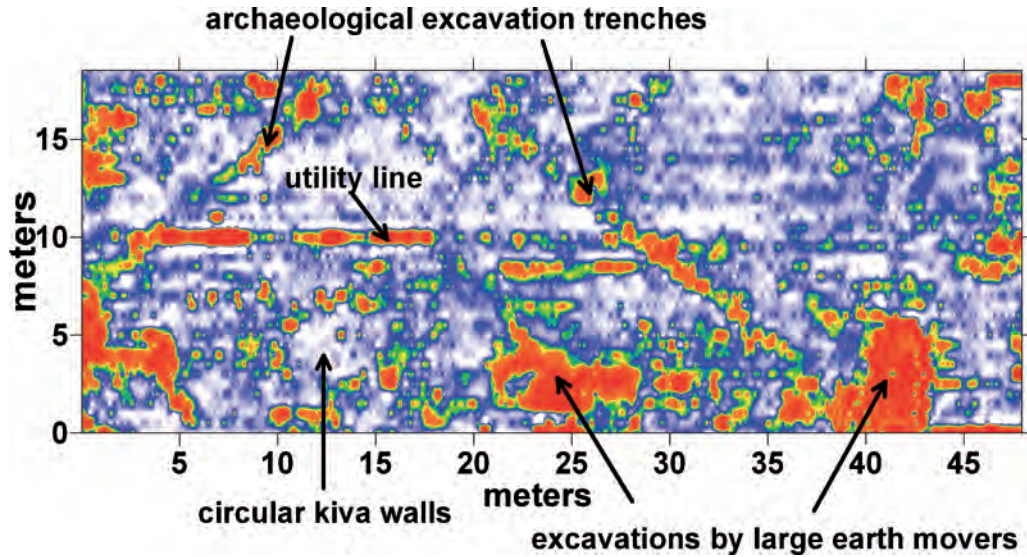


Figure 1. Amplitude slice-map from 20 to 40 cm in a parking lot in Santa Fe, New Mexico.

exists, which if understood and interpreted correctly can produce very precise images of otherwise invisible features.

### An example of archaeological site complexity resolved using GPR

An example of the type of precision possible with GPR, in what would be considered an extraordinarily 'cluttered' urban environment, illustrates one utility of detailed GPR mapping. In a parking lot in Santa Fe, New Mexico a  $50 \times 20$  m grid of data was collected using the GSSI SIR-2000 system and the 400 MHz centre frequency antennae. The urban clutter just below the ground surface was immediately apparent during collection as reflections from recent earth-moving activity, numerous buried pipes and other utility lines as well as recently excavated archaeological test trenches that crossed the study area (Figure 1). The area appeared so hopelessly disturbed that there was initially given little hope of success in finding the remains of what historians suggested was the original prehistoric pueblo of Santa Fe, occupied long before the arrival of the Spanish in 1541.

Amplitude slice-mapping quickly produced images of the ground, but high amplitude reflections from the large amount of buried metal,

rubble from various constructions activities, and the back-fill from recent trenching obscured much of the images. A very simple amplitude filter, which removed only those values greater than one standard deviation above the mean, left the medium- and low-amplitude values, producing a map that was much more readily interpretable (Figure 1). An image of the parking lot from about 20 to 40 cm below the pavement surface showed the remains of a well preserved circular kiva wall amidst the noise and clutter. Kivas are semi-circular subterranean rooms that were used for ceremonial as well as domestic activities by the ancient Puebloan people, and are still used by their descendants that live in the area (Conyers and Cameron, 1998). In this study it is doubtful that any other near-surface method would have been capable of this degree of resolution, especially given the complexity of the area.

### The following papers

The following short articles in this special addition of *Archaeological Prospection* briefly detail other results of the GPR technique that illustrate its broad utility of the method for archaeological mapping. The authors show how knowledge of the method and what it is potentially resolving

can allow for data collection and processing methods that are not typically used by many GPR practitioners. The discoveries that were made in these short articles were produced from reflection data that probably would have been discarded just a few years ago as unusable, or at least obscure. In all cases these short reports illustrate a diversity of examples showing the method's ability to image the ground in novel ways. This kind of analysis can be accomplished only by an understanding of both GPR's method and theory but most importantly a comparison of

the final geophysical results to the ground and the features preserved within it.

## References

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