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Ground-penetrating Radar Mapping of Non-reflective Archaeological Features

A case study from southern Arizona, USA

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Abstract*—Ground-penetrating radar mapping scientists have long stressed how a visualization of the three-dimensional placement of high amplitude reflections is the key to finding and understanding buried archaeological features. However, in some areas, the similarity in feature composition to the surrounding matrix, produces no reflections and therefore areas of no reflection are actually denoting the location of buried features of interest. In southern Arizona, USA, the archaeological remains are often "puddled adobe", a mixture of local earth that was made into walls and floors of substantial structures by the ancient Hohokam people between about AD 400 and 1400. These structures were often above-ground room blocks and other substantial earthen buildings. As the architectural components are chemically and physically almost identical to the surrounding site matrix these walls and floors are not visible in reflection profiles or amplitude images. The only buried discontinuities that produce reflections are the eroded and re-deposited "melt" units adjacent to walls, which are interbedded layers of eroded architecture and naturally deposited sediment. Only when areas of no reflection are mapped can the intact walls and floors become visible. In this way non-reflective areas are the key to understanding these subtle architectural features.

Keywords-Ground-pentrating radar; non-reflective features; Hohokam; southern Arizona

I. Introduction

The necessity for locating, mapping and understanding buried cultural materials with GPR, where the strongest reflections are produced from walls and floors and other features, has long been appreciated by archaeologists in much of the world [1]. High amplitude reflections are usually generated at the contact of archaeological features and surrounding sediment or soil that is much different in composition, which becomes an effective reflection surface. However, in some instances areas of no reflection can denote the location of walls and other features, especially when earthen architecture is the target of research. Adobe and compacted earthen walls will often quickly erode after abandonment, and their remains re-deposited as adobe "melt" adjacent to the remaining architecture. The melt units are often interbedded with wind-blown or alluvial sediment, creating a burial environment that places reflective units adjacent to non-reflective earthen walls. Ground-penetrating radar is the only near-surface geophysical method that produces a data set in three-dimensions that can potentially map these buried and stratigraphically complex features.

Figure 1. Casa Grande Ruins National Monument structure composed of earth, which is covered by a roof to protect it from erosion. In the foreground are walls that have been preserved with modern coating material to protect them from natural erosion.

In southern Arizona the ancient Hohokam people produced above ground adobe buildings that often reached four stories high between the years AD 400 and 1400 [2]. When these buildings were abandoned and the roofs destroyed, the earthen walls and floors quickly "melted" in the rain and their remains were quickly covered and preserved adjacent to the remaining walls. The few standing structures still visible today for archaeological study are either covered with modern roofs to protect them from the rain (Fig.1) or are encased in a complex series of natural sediment and eroded earth that was once part of the uppermost architectural units. In most of the hundreds of Hohokam sites in southern Arizona the only surface evidence of possible buried architecture is broken pottery or subtle color changes in the soil that might indicate what is below the surface (Fig. 2).

Ground-penetrating radar, which can effectively map the nature of this complex stratigraphy can play a

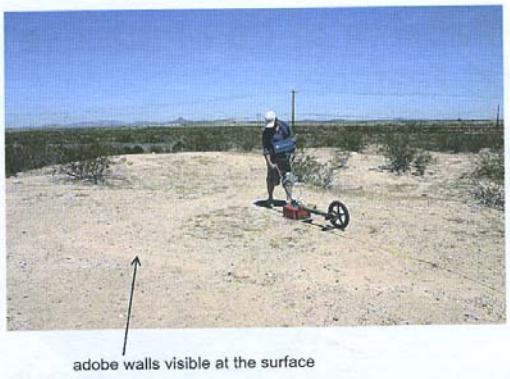

Figure 2. Adobe walls are visible as subtle color changes on the surface, but there is almost no composition change between the architecture and the surrounding matrix.

significant role in finding and mapping ancient structures in the ground. While a challenging medium for the GPR method, an understanding of the archaeology, abandonment and burial history, and the geological history can be incorporated with geophysics to help understand the ancient history of this archaeologically-rich area of the world.

II. The GPR Method in Southern Arizona

At sites near Tucson, Arizona, USA, abundant Hohokam features are covered with minor amounts of aeolian material, with most of the matrix that surrounds cultural features consisting of adobe melt from what were once above-ground compacted earthen structures [3, 4]. The GPR method has been rarely applied in this area because the few geophysical studies conducted have produced complex and often confusing results. This is likely because of the un-reflective nature of the features of interest and the complex burial history. The few published results of GPR have noted that only distinctly compacted floors and sometimes in-ground ovens for cooking are visible. The less reflective walls have been considered almost invisible in typical GPR reflection profiles or amplitude maps. In addition, when buried walls are exposed in standard excavations they are often less than about 20-30 cm or so in dimension and are not readily differentiated from adjoining layers of naturally deposited sediments.

The buried Hohokam walls are effectively invisible to GPR because they are composed of the same material as the surrounding ground and when they were constructed this earth was homogenized and therefore contains no internal layers that could reflect radar energy. In addition the standing walls encased in sediment are mostly vertical and therefore to not provide a surface from which to reflect energy transmitted from the ground surface. Using a GSSI SIR-3000 and the 400 and 900 MHz antennas to produce reflection profiles, walls are not readily visible, but can be delineated as areas of little or no

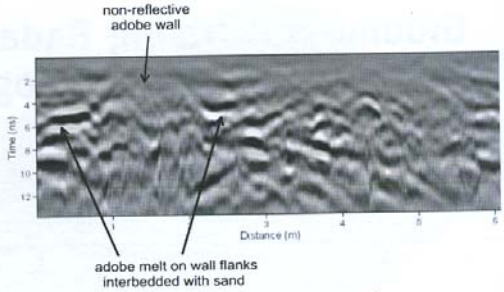

Figure 3. GPR reflection profile showing walls as areas of no reflection.

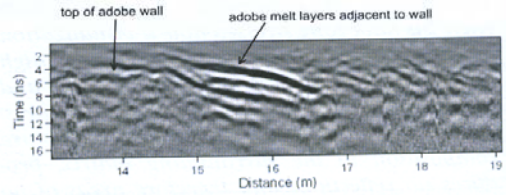

Figure 4. GPR Reflection profile showing layers of adobe melt and naturally-deposited sediment adjacent to non-reflective walls.

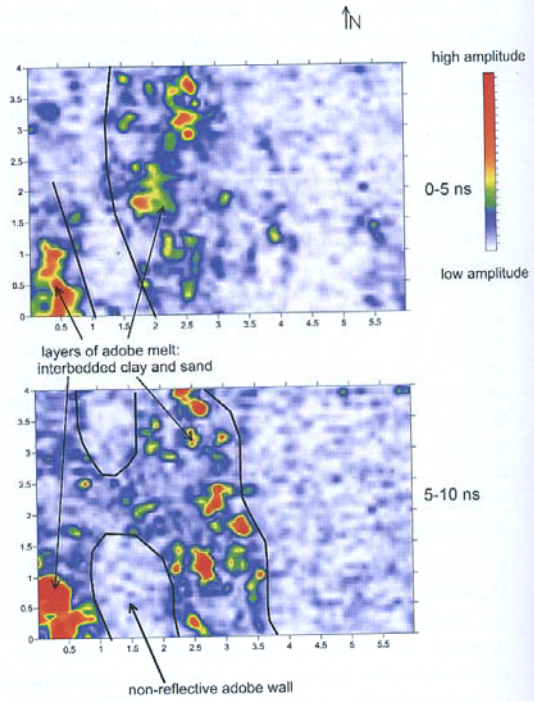

Figure 5. Amplitude maps showing the areas of no-reflection denoting the location of walls, with the high reflection areas being the layers of adobe melt and natural sediment.

reflection (Fig. 3). In these profiles the only prominent reflections are generated from the materials that were eroded from them and deposited along their sides (Fig. 4). These strong reflections were generated from the contacts between adobe melt layers

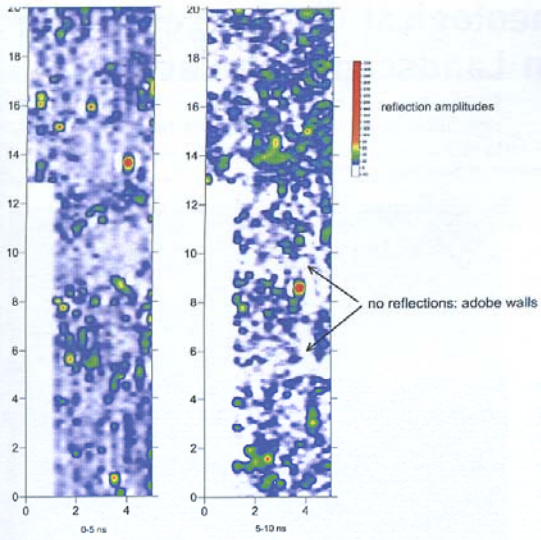

Figure 6. Reflection amplitude map showing the location of walls as areas of no reflection (white).

and naturally-deposited sediment layers that were deposited after abandonment.

When all reflections in a grid of tightly spaced profiles (25 cm spacing or less) are mapped spatially (Fig. 5), the areas of no reflection (usually the walls) are distinct from the adjacent areas of adobe-melt, which produce the higher amplitude reflections.

While most geophysical archaeologists concentrate on the high amplitude reflections when interpreting amplitude maps, it is actually the areas of no reflection that are important (Fig. 5). The areas of high amplitude reflections are complex layers of eroded walls and floors adjacent to what remains of the walls.

In amplitude maps the slices closest to the ground are often complex and show little indications of the features that are buried below (Fig. 6). The re-sampled amplitudes used to make deeper slice maps must be colored and highlighted in a way so that maps will illustrate areas of no reflection as well as higher reflections. In this way the human eye can visualize the subtle walls (Fig. 6).

III. Conclusion

Geophysical archaeologists using GPR have at their disposal all the tools necessary to produce important maps of earthen walls, even when they are "invisible" in standard profiles and amplitude maps [5]. In the Hohokam area of southern Arizona the remains of walls constructed of earth produce few if any radar reflections and appear as areas of no reflection in profiles and amplitude slice maps. These walls were constructed of earth that was taken from the same ground as the matrix of the site and therefore produce few if any reflections. When an understanding of the burial conditions and nature of the architectural and sedimentary layers is incorporated with an interpretation of the GPR images, these features become visible. Mapping using GPR in this area of the world can then become more than just a discovery tool but also a method for interpreting the ancient past in this archaeologically-complex are of the American Southwest [6].

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