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Advances in the Use of Ground-Penetrating Radar at Archaeological Sites in Southern Arizona

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Excavated adobe walls at University Indian Ruin
Photograph courtesy of Paul R. Fish, University of Arizona

Well-preserved masonry architecture is common at prehistoric sites in the northern Southwest. These features can be fairly easily identified and mapped using standard archaeological methods. In contrast, earthen architecture was the norm across much of the southern Southwest. Unfortunately for archaeologists, earthen architecture quickly erodes after abandonment, is re-deposited as adobe melt, and then often covered and obscured by windblown or river sediment. Cultural features constructed in active floodplains can also be quickly buried and become largely invisible today on the ground surface.

Researchers in southern Arizona have traditionally determined the extent of buried sites by recording surface artifact scatters, or using random shovels tests or backhoe trenches. These common discovery methods are problematic for a number of reasons. First, there are many natural (e.g., flooding, dust storms) and cultural (e.g., plowing, urban sprawl) processes that can obscure surface artifact distributions, or in some instances make them virtually invisible if artifacts are buried by sediment and have not been brought to the surface by some post-depositional process such as erosion or burrowing animals. These potential biases can, in turn, result in misleading or inaccurate characterizations of subsurface deposits. Although backhoe trenching or shovel testing can help resolve some of these issues, they tend to be costly and destructive, as well as "hit-or-miss" propositions in many instances.

In this article, I discuss some of the ways that ground-penetrating radar (GPR), a well-tested, non-destructive geophysical survey method, has been recently used to discover and map buried features at archaeological sites in southern Arizona. The sites that I discuss are located in a variety of environmental settings across the Tucson Basin, including the Santa Cruz River floodplain and adjacent terraces, as well as along the bajada slopes of the Tortolita Mountains. The sites also contain a wide variety of cultural features (e.g., canals, agricultural fields, adobe walls) and cover a wide time span, ranging in age from the San Pedro phase of the Early Agricultural period (ca. 1200–800 B.C.) to the Hohokam Classic period (ca. A.D. 1150–1450). These examples not only illustrate how GPR can compliment traditional archaeological

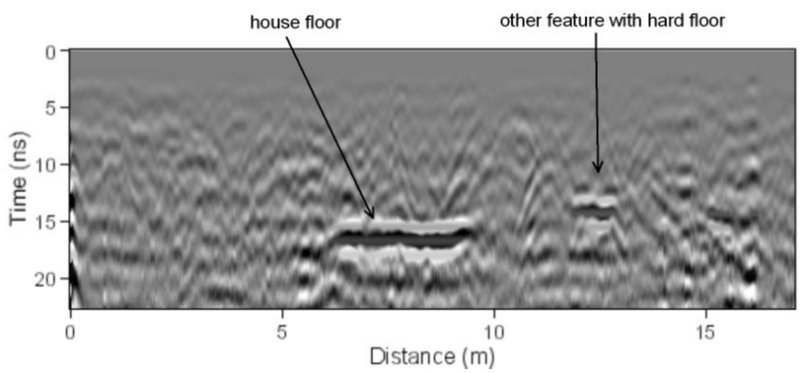
Collecting GPR data with a 400 MHz antenna, located in orange box, attached to a survey wheel for horizontal distance calibrations

discovery methods, but they also show how GPR can provide a viable alternative to traditional methods when ground disturbance is not an option.

Ground-Penetrating Radar: How it Works

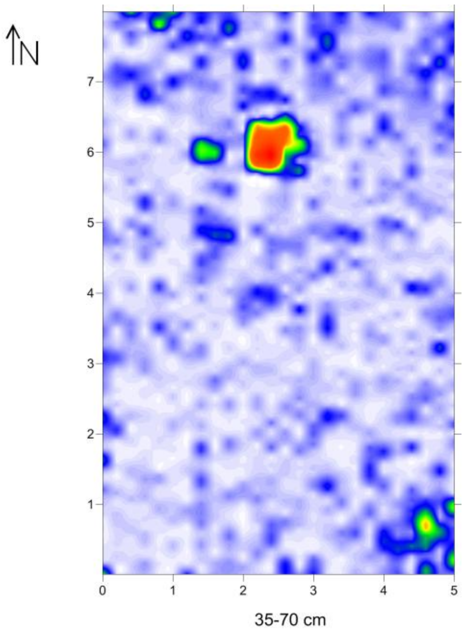
GPR uses radar antennas to transmit pulses of high frequency electromagnetic energy (radio waves) into the ground to measure the elapsed time between when they are sent and then received back at the surface. Buried contexts where radar energy is reflected might be any changes in the ground constituents such as contacts between cultural features and surrounding material, or water differences due to variations in material properties. When the distribution and strength of those radar wave reflections can be related to certain aspects of archaeological sites such as the presence of architecture, ancient use areas or other associated cultural features, high definition three-dimensional maps and images of buried archaeological remains can be produced.

Most typically in archaeological projects, GPR radar antennas are moved along the ground in transects (see above) and two-dimensional profiles of a large number of reflections at various depths are created, producing profiles of subsurface stratigraphy and buried archaeological features along lines. This produces profiles of radar reflections, with strong reflections shown in black and little or no reflection in white, as shown in the figure on the right.



Floors made of compacted earth, plaster, or burned layers generate very high amplitude reflections that are visible in profile.

The depth of potential features is measured in elapsed time from when radar pulses are sent from the surface, and then received back after having been reflected in the ground. Horizontal distance is measured by the calibration wheel attached to the antenna. In turn, when radar reflection data are acquired in a closely spaced series of transects within a grid, and reflections are correlated and processed with a computer, an accurate three-dimensional picture of buried features and associated stratigraphy can be constructed in map view, as illustrated in the figure on the left, which shows the results of a GPR map of a distinctive Hohokam earth oven (*horno*).

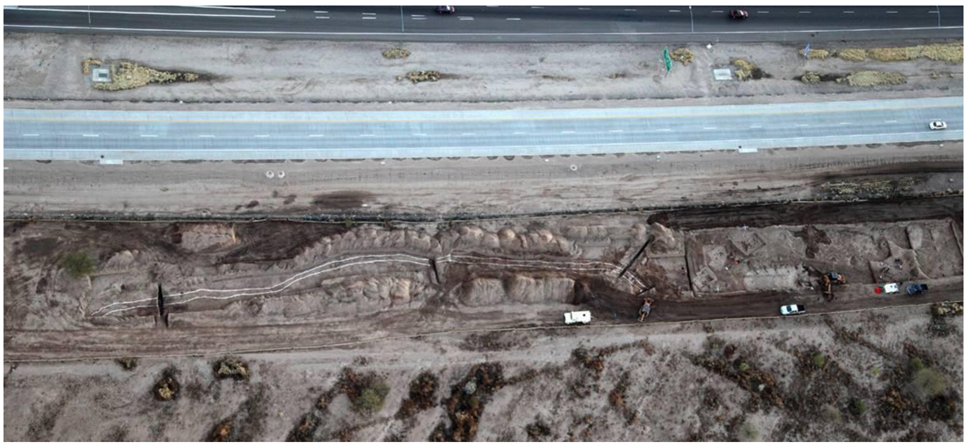


Example of a horizontal amplitude map showing a Hohokam horno in a 35–70 cm depth slice; the strong reflections of the horno are colored red and yellow, and areas of weak or no reflection are white and blue.

GPR Applications in Southern Arizona

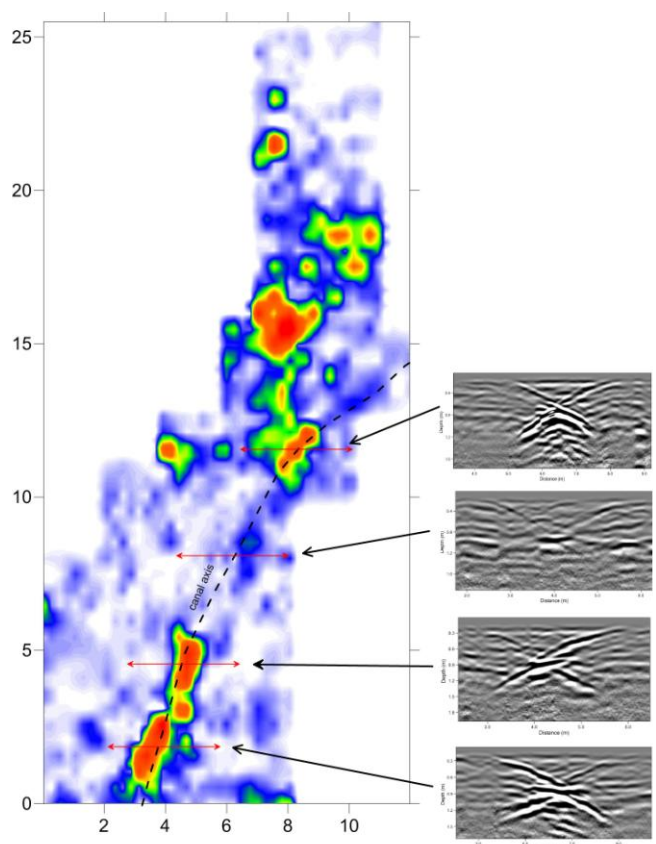
At the Marana Mound site, a Hohokam platform mound settlement in the northern Tucson Basin, cultural features were covered with about 50–100 cm of alluvial silts and sands and floors of houses were especially visible using GPR. The house floor shown in the profile figure above is an example of how a plastered and burned floor looks in a reflection profile. The floor surfaces readily reflect radar energy, and are visible as very high amplitude reflections. This floor feature was particularly visible using GPR because it was plastered and contrasted in composition with the overlying fine sand that covered it.

At the Rillito Fan and Las Capas sites along I-10, the method was used to image Early Agricultural period irrigation canals and associated agricultural fields that were buried below about a meter or so of silt and sand deposited along the eastern bank of the Santa Cruz River. At these sites a number of ancient irrigation channels were superimposed and associated with agricultural fields and other natural river features. This was a particularly challenging area for GPR, because depending on the amount of sand that had been retained in the channels, they appeared very differently along their courses in both profile and in the horizontal amplitude maps.



Early Agricultural Period canal at the Rillito Fan site (outlined in white)
Photograph courtesy of Northland Research, Inc.

As indicated in the figure on the right, the horizontal amplitude map of the Rillito Fan canal shows that areas with preserved sand produced strong reflections that could be readily seen. However, channel sections that had the same general sediment as that which surrounded it were almost invisible in the horizontal amplitude maps. The amplitude maps were a good way to image the channel, but only when it had sand in it. Areas that were less reflective for radar energy had to be interpreted from an analysis the individual profiles and the channel mapped in that way. When all reflections in many transects in a grid are sampled on the computer and the strength of the reflections is colored in a horizontal map, the aerial extent of features can be seen.



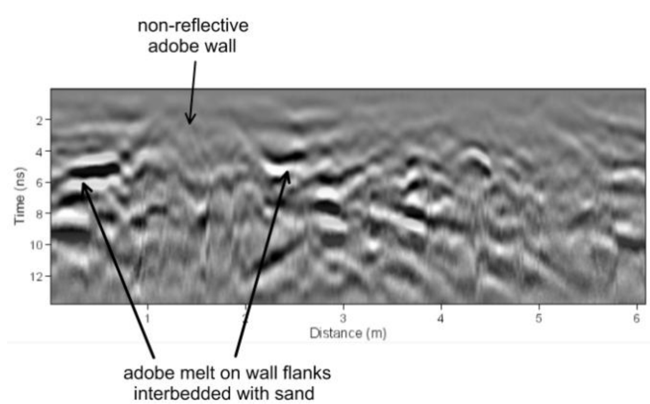
Horizontal amplitude map displaying irrigation channel at the Rillito Fan site; note that the canal is visible when it contains sand, but almost invisible when filled with the same material as the surrounding ground. Examples of the reflection profiles along this reach of the channel are shown on the right of the amplitude map, demonstrating the variability of reflections.

A very different situation was encountered at University Indian Ruin (UIR), a Classic period platform mound settlement in the eastern Tucson Basin. At UIR, cultural features made of local earth (adobe) were covered with minor amounts of windblown material, as opposed to river deposits. Consequently, sections of walls are often preserved just a few centimeters deep, though no evidence of them is visible on the ground surface today. Additionally, most of the sediments surrounding the walls consist of adobe melt from what were once above-ground earthen structures. In many instances, the adobe melt extends for a considerable distance beyond the wall.

Among the features recently discovered by students from the University of Arizona field school was small platform mound, located due east of a much larger platform mound excavated by Julian Hayden more than 70 years ago. The small mound contains at least one room on top, and possibly several additional rooms on adjacent sides. The mound in general is a very complex amalgamation of architecture that was built, abandoned, and then built upon by later inhabitants, now mostly melted and re-deposited over the centuries into a complex series of intact and erosion units.

Excavations of small platform mound at UIR
Photograph courtesy of Henry D. Wallace, Center for Desert Archaeology

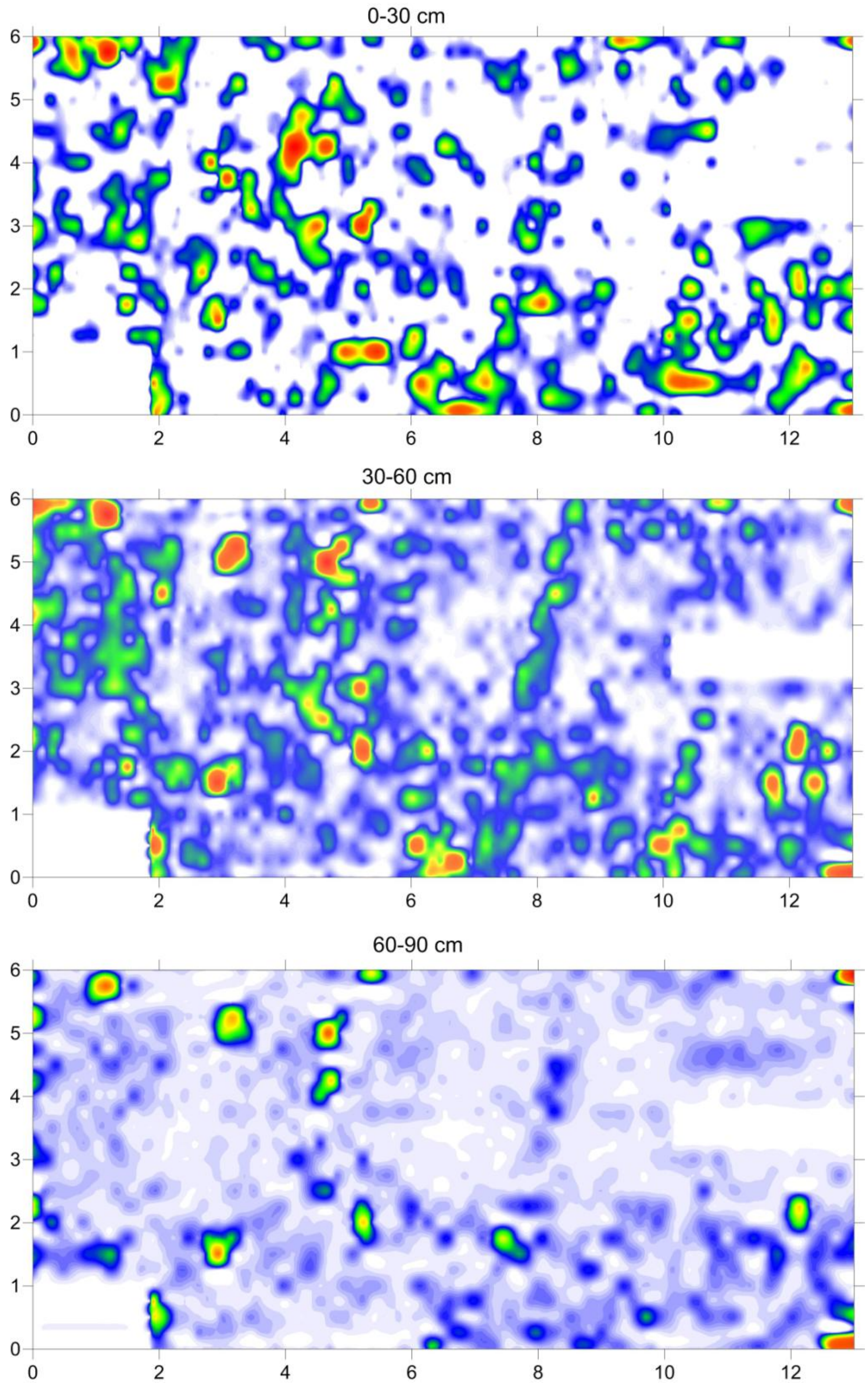
Several GPR test profiles were collected perpendicular to known earthen walls on the mound in order to determine how Hohokam walls of this sort appear in GPR images. As indicated in the reflection profile below, the location of walls could be seen as areas where there were no reflections, while the adjacent adobe melt layers produced strong visible reflections. The adobe melt layers were highly reflective because they consist of layers of adobe and sand, each of which contrast in composition, and therefore produces a strong reflection. The Hohokam constructed their walls from homogenized local earth, and as a result there are few distinctive interfaces within intact adobe walls to reflect radar energy.



Adobe walls at the University Indian Ruin site are composed of homogenized earth that produces no reflections when viewed in profile. The adjacent melted adobe layers produce very strong radar reflections.

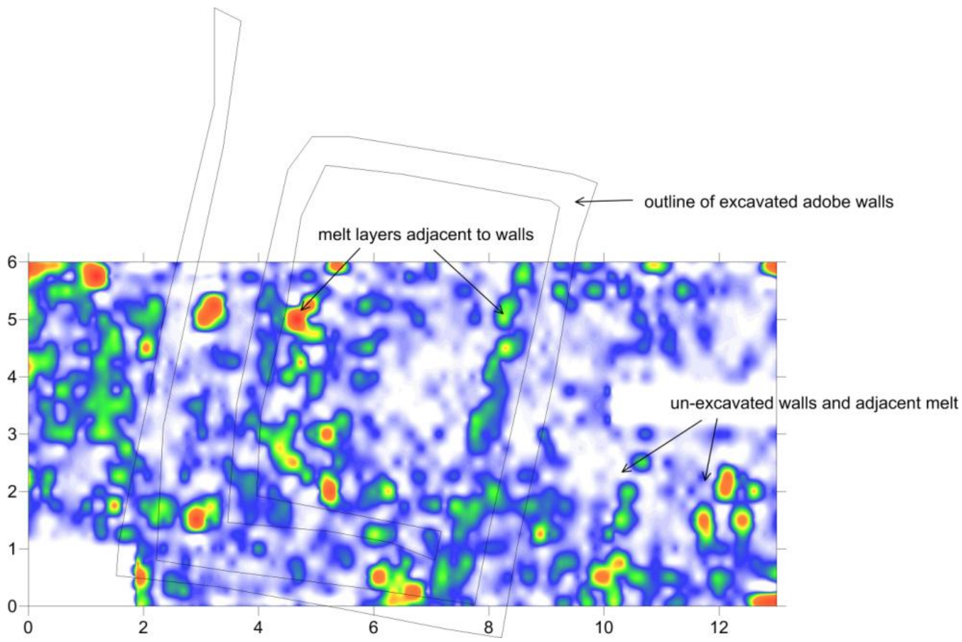
When many reflection profiles are collected in a grid over the top of possible buried walls, the complex nature of the ground at University Indian Ruin became apparent. As indicated in the amplitude maps below, the strong reflections, colored as the “hotter” shades of red and yellow in the maps are displaying the location of the adobe melt layers adjacent to the walls.

Note in the amplitude maps that the walls themselves are not reflective and therefore appear as white or light blue in these horizontal maps. Additionally, when the amplitude maps are viewed in horizontal slices, the upper slice from 0–30 cm depth is very complex and appears to show a jumble of materials from many depositional episodes over the last 500 years or more. There are only a few linear alignments in that shallow slice corresponding to walls. When the strength of radar reflections is displayed in the 30–60 cm depth slice, the walls are much more apparent, and are visible as the areas of no reflection with the adobe melt layers next to them as the strong reflections.



Horizontal amplitude maps of the strength of reflections over what turned out to be two complex Classic period structures built in the same location as the mound was renovated and changed over time.

When these earthen features were excavated, two buildings were found constructed in the same general location, with the intact walls of both apparent in the GPR maps. A comparison of the exposed walls with the amplitude map from the 30–60 cm slice demonstrates how the walls are non-reflective and the linear bands of adobe melt show up well in the radar wave strength map (see below).



Conclusions

Each environmental setting encountered in southern Arizona required different GPR data collection and processing procedures. Floors of compacted earth or clay from house floors were the most readily visible features in reflection profiles as distinct high amplitude reflections. Standing walls constructed of earth produce few radar reflections and are therefore the most challenging feature to see with GPR. They are often non-reflective, but can be discovered by mapping the high amplitude melt layers that commonly occur in linear bands parallel to them. Canals also generate complex reflections from their sides of canals and reflections from them are dependent on the type of sediment that was preserved within them.

Depending on the depth of burial, composition of the archaeological features and the surrounding burial material and the geometry of these features, GPR can be of great value in discovering and mapping cultural resources in southern Arizona. While the method cannot be applied to all areas of interest, with considered and knowledgeable collection, processing and interpretation, GPR has a wide range of applications.

About the Author

Lawrence B. Conyers is a Professor of Anthropology at University of Denver, Colorado. He received his Ph.D. in 1995 from University of Colorado, Boulder, where he developed the use of ground-penetrating radar for archaeological applications. Since that time he has worked on all continents of the world using GPR in many environments and archaeological applications. He is the author of three books on the subject, the latest *Interpreting Ground-penetrating Radar for Archaeology* published by Left Coast Press in 2012.

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