ACQUISITION, PROCESSING AND INTERPRETATION TECHNIQUES FOR GROUND-PENETRATING RADAR MAPPING OF BURIED PIT-STRUCTURES IN THE AMERICAN SOUTHWEST

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ABSTRACT

Ground-penetrating radar was used successfully to discover and map buried archaeological sites containing pit-structures in the American Southwest. Sites tested contained different archaeological features, geological matrix, and varying deptlis of burial. These varying site conditions necessitated the application of different acquisition, data processing and interpretation techniques. With pit-structures buried between 50 cm and 2 m, high frequency antennas were used to collect data with 50 cm spaced transacts. Amplitude slice-maps were constructed that delineated floors, floor features and other related archaeological materials. In Bluff, Utah buried Anasazi pit houses were identified using the slice-map method and confirmed with subsurface coring. At the Valencia Site in Tucson, Arizona Hohokam pit dwellings were identified and mapped in caliche impregnated terrace gravels. At this site filtering techniques were applied during data processing because of the abundance of system and external noise. Manual mapping of features from two-dimensional sections was essential because of the abundance of metal garbage in the area that obscured much of the reflection data, precluding batch computer processing.

Key words: ground-penetrating radar, archaeology, pit structures, American Southwest

INTRODUCTION

Ground-penetrating radar offers a rapid and inexpensive method for identifying subsurface archaeological features without excavation. Although the technique has been used for archaeological exploration and mapping since the 1970s, recent advances in GPR equipment and the computer processing of geophysical data have revolutionized its effectiveness. Ground-penetrating radar maps that illustrate buried features in three dimensions have become not only a tool for discovering buried archaeological materials, but a key part of archeological data recovery and a part of the overall assemblage of a site.

Previous researchers have reported on the effectiveness of GPR in the Southwest in some preliminary surveys (e.g., Sternberg and McGill 1995, Vickers and Dolphin 1975). This study builds on this research by using the amplitude slice-map data processing method to create images of the depth and aerial extent of subsurface reflections. Archaeological sites were chosen for GPR testing that had been excavated before GPR data were collected, or could be tested immediately afterward so that the accuracy of images created could be evaluated. At both sites excavations confirmed that GPR images accurately replicated the buried features.

TESTING THE GPR MIETHOD IN THE AMERICAN SOUTHWEST

Ground-penetrating radar techniques are especially useful in the southwestern United States because many archaeological features are deeply buried and are recognizable only as surface scatters of artifacts or, occasionally shallow depressions. For example, domestic architecture among the ancient Hohokam of southern Arizona consisted of shallow, ephemeral pit structures. These structures are rarely visible on the ground surface and can only be observed in profile after trenches have been cut, often destroying much of the feature. In the northern Southwest, domestic architecture consisted of deep pit structures, constructed until about A.D. 700. Even after the development of above ground structures, pit houses and other semi-subterranean structures (called kivas) continued to be used for ritual and domestic purposes. Sometimes these structures are visible as depressions, but often they leave no surface indications.

Valencia Site

The Valencia site is located within the southern city limits of Tucson, Arizona and includes almost five kilometers of archaeological remains along the east bank of the Santa Cruz River. Ground-penetrating radar tests were conducted in a portion of the Valencia Site that was soon to be subject to disturbance by development. A 29 m x 40 m GPR grid was established in an area where four backhoe test trenches had previously encountered 14 pit structures and a number of other extramural features. The ground surface of the GPR grid was covered with recent trash consisting of metal objects and concrete blocks. Much of the trash was partially buried, indicating intense recent surface disturbance. No subsurface features were visible on the computer screen during data acquisition. Immediately after collection the data were filtered to remove all frequencies above 900 MHz and below 250 MHz, the Fifty-nine transacts of reflection data, spaced 50 cm apart, were collected using dual 500 MHz frequency antennas as transmitter and receiver with a

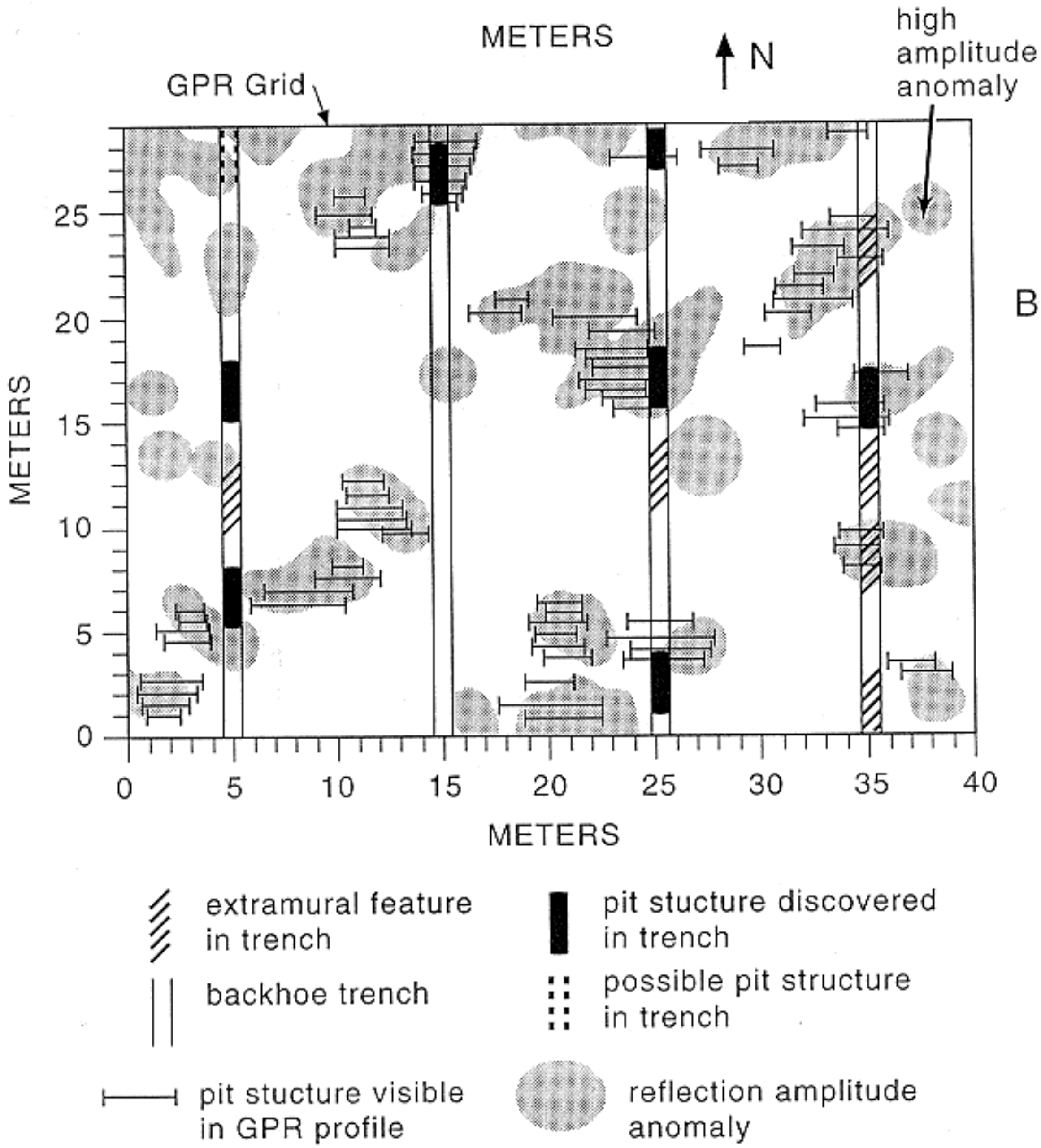

Figure 1. GPR Grid at Valencia Site, Arizona. High amplitude reflections from the 50-100 cm depth slice are shown with location of pit structures and backhoe trenches.

GSSI SIR10 system (Figure 1). The background was arithmetically removed from all reflection profiles, and travel times converted to approximate depth. The amplitude slice-map processing technique (Conyers and Goodman 1997: 149-194, Goodman, Nishimura, and Rogers 1995) was then applied to the processed data set in order to identify all significant high amplitude reflections between 50 and 100 cm depth within the grid. This is the depth at which the pit structure floors and other features were typically encountered in the backhoe trenches.

The presence of high amplitude anomalies within the defined slice was compared to the location of archaeological features discovered earlier in the backhoe trenches. Using this method 11 of the 14 known features were identified, although some were offset away from the test trenches because in most cases the backhoe did not encounter the middle of each feature. Numerous other amplitude anomalies were mapped between trenches that could be archaeological features, but could not be confirmed by the excavation data.

Ground-penetrating radar mapping at the Valencia Site highlights many of the problems, and offers some possible solutions, that have plagued all types of geophysical archaeological mapping. The initial results obtained in the field were very discouraging because the data were extremely "noisy" and reflections were non-coherent. Only when the digital data were filtered and processed were reflections derived from the archaeological features identifiable. When the processed data were interpreted by computer using the amplitude slice-map technique, many more anomalies were produced than could be accounted for by the archaeological features known to exist. In this case a reliance on only computer interpretation would have produced a very misleading site map. To solve that problem, and to understand what the computer generated map was producing, each individual line was also manually interpreted and each mapped feature judged individually. When a comparison of the final computer and manually produced GPR maps were compared to the excavations, 85% of the known features were visible by GPR and their orientations in the ground precisely mapped (Figure 1). In addition, at least 10 additional pit structures were visible by GPR that were not found in the trenches and would likely not have been discovered by any other means.

Coder Site

The Coder Site is located in southeastern Utah in the small town of Bluff. Local archaeologists had noticed surface scatters of ceramic and chipped stone here, as well as very low relief depressions that might be pit structures. A 30 m x 50 m grid was established in an open area where abundant surface ceramics were visible. The subsurface sediment consisted of friable, slightly calcareous crosslaminated fluvial sand and silt. Data were collected with a SIR-10 system using 500 MHz anteiuias.

During GPR surveying unprocessed reflection profiles were viewed on the computer screen as they were collected. Significant horizontal reflections that resembled pit structure floors were discovered in a portion of the grid. All data were processed to remove background noise, remove frequencies between 900 and 200 MHz and converted to depth using velocity estimates obtained from metal bar tests conducted in a nearby excavation (Conyers and Lucius, 1996). The reflection data were then processed using the slice-map technique to produce an amplitude anomaly map from 80 cni-100 cm depth. The western portion of the resulting map is shown in Figure 2. The orientation of the high amplitude anomaly indicates a roughly circular floor outline, with a possible antechamber projecting to the north.

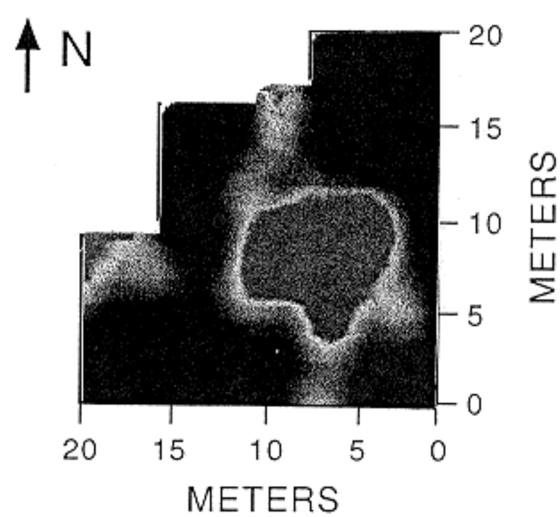

Figure 2. Amplitude anomaly generated from a pit-structure floor at the Coder Site. Slice is from 80 to to 110 cm depth.

To test the origin of this high amplitude horizontal anomaly 8 auger holes were drilled in and around the possible pit structure floor (Figure 3). Three auger holes (holes 2, 3 and 6) penetrated aeolian sand that contained scattered ceramics and abundant charcoal and fire cracked rock from near the surface to just above the floor of the probable pit structure. Auger holes drilled away from the GPR anomaly (Figure 4) encountered only a thin layer of aeolian sand with scattered broken ceramics, sitting directly on calcareous sand (probably a weak Bk soil horizon).

Ground-penetrating radar testing at the Coder site clearly revealed a pit structure with a small antechamber. Similar pit structures are common in the northern Southwest, especially during Basketmaker III period and later. The extent of the artifact scatter and one additional untested anomaly in the GPR maps suggest that there may be other pit structures nearby.

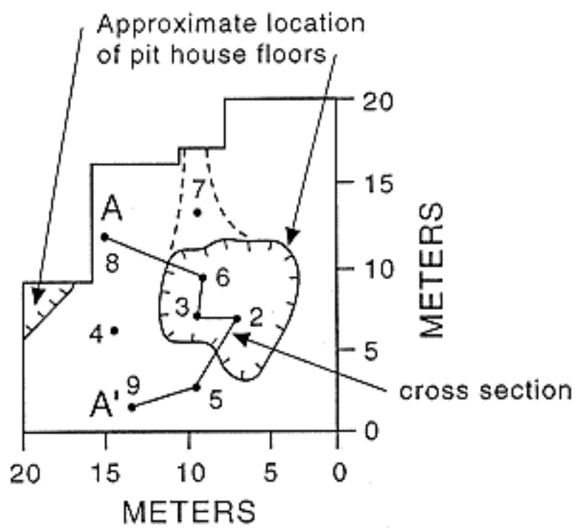

Figure 3. Location of auger holes and cross section at Coder Site pit-structure.

The importance of local climatic conditions to GPR collection were vividly illustrated when the Coder site was resurveyed after a heavy rain. The night before the resurvey was conducted, about 1/2 inch of rain fell and the area had received more than 2 inches of rain in the previous 2 weeks. Data from this survey was processed in the same way as the earlier survey, but the pit structure floor was not visible. Instead the amplitude slice-map consisted of many high amplitude reflections at different depths, which were probably generated by pockets of water differentially retained in sediments with varying compositions or pooled above impermeable layers. If the original survey had been conducted in similar conditions, the pit structure would never have been discovered.

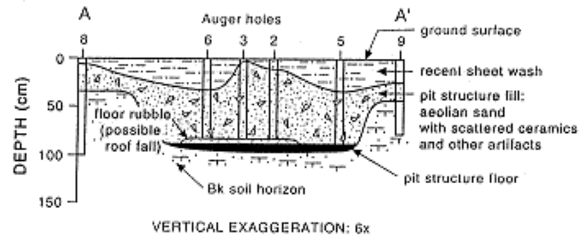

Figure 4. Cross section through auger holes at Coder Site showing the location of the pit-structure floor.

CONCLUSIONS

Ground-penetrating radar surveys can be of tremendous value for the rapid, nondestructive determination of the number and character of subsurface features at archaeological sites. Many parts of the Southwest have conditions that are ideal for the use of GPR, including dry sandy soils and deeply buried sites. The American Southwest is experiencing explosive population growth and development. If GPR is used in advance of development projects, archaeological features can be assessed and often avoided, resulting in an enormous savings of time, money and damage to archaeological deposits. Even where sites cannot be avoided, by learning the full extent of subsurface features, more appropriate excavation sampling can be developed and contract archaeologists will not be "surprised" by more extensive remains than they had budgeted for.

Ground-penetrating radar can have significant benefits also for research archaeological projects. Few research archaeologists have the funding to excavate more than a tiny fraction of most sites and they must interpret prehistoric cultures and behaviors based on limited knowledge of site size, layout and feature characteristics. The GPR mapping method can be used to identify the number, size and character of buried features yielding a far more complete picture of a site than would be possible using excavation alone. Furthermore, where features are known to exist, GPR surveys conducted prior to excavation can delineate the location and approximate depth of features of interest. Excavation strategies can then be formulated to efficiently test only targeted features, preserving others.

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