GROUND PENETRATING RADAR SURVEY: RESULTS FROM FOUR SITES IN CALIFORNIA

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ABSTRACT

Non-invasive geophysical survey was utilized as a remote sensing tool at two prehistoric and two historic sites in California. The sites were investigated with Ground Penetrating Radar (GPR) to identify anomalous signals (targets) which might correspond with subsurface archaeological features. Results of GPR testing at SOL-356 are presented in detail discussing depth of penetration, identification of targets, and the feasibility of future use of GPR technology in cultural resource studies.

INTRODUCTION

Ground Penetrating Radar (GPR) has been utilized by geologists and civil engineers for several decades: military personnel use GPR for underground tunnel detection; utility companies use it for subsurface tank and pipe locating; and GPR was utilized on the moon for lunar sounding experiments during Apollo 17. GPR depth penetration ranges from a few centimeters to hundreds of meters in electrically resistive materials such as dense granite or basalt.

Evidence from four sites in California indicates that GPR can be an effective archaeological tool. Surveys at both prehistoric and historic sites were undertaken to determine the feasibility of GPR survey as part of archaeological investigations. GPR was found to be effective at a range of sites with different remote sensing needs.

GEOPHYSICAL METHOD

The concept of GPR is based on the use of high frequency radar pulses to penetrate and reflect off subsurface materials. The downward attenuation of the pulse is dependent upon the electrical properties of subsurface materials. At the interface of electrically different materials, a

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small portion of the electrical pulse will be reflected back to the surface. Receivers located on the surface can intercept this reflected pulse and record the signal. Buried cultural materials, naturally-occurring ground water, and varying soil horizons can provide excellent reflecting interfaces for radar pulses in the subsurface environment. The recorded data, in profile form, allows for the non-invasive investigation of the subsurface.

EQUIPMENT

The surveys reported below utilized a Geophysical Survey Systems Inc.'s Subsurface Interface Radar 10 System (SIR-10). An array of antennas ranging from 100 MHz to 900 MHz were utilized. Best results for optimal profile data were achieved with a 300 MHz antenna at all sites investigated. It should be noted that higher frequency antennas deliver higher resolution profiles, though with less depth penetration, while lower frequency antennas produce lower resolution profiles but with greater depth penetration capability. During all surveys the GPR unit was powered by an ordinary vehicle battery. Generators can be utilized for remote areas where access by vehicle is not possible. A SIR-10 control unit using RADAN III software, equipped with digital tape recording capabilities, was used to acquire field data for further processing. The SIR-10 is equipped with a color monitor for viewing profiles in the field. All the antennas were equipped with handles and were dragged by hand over the ground surface. Antennas were attached to the SIR-10 control unit with one or more 30 meter cables.

FIELD INVESTIGATIONS
SUNOL VALLEY

The first site investigated using GPR survey was located in an agricultural area in Sunol Valley. The site was being investigated by an archaeological field school from San Francisco State University. This late period prehistoric/ historic site was primarily located in a recently plowed field. The purpose of the survey was to determine if GPR would achieve sufficient depth penetration to assist with characterization of subsurface materials. Due to time limitations none of the anomalies identified on GPR profiles were excavated, but the survey did establish that GPR equipment could achieve penetration depths up to two meters; culverts buried 76 cm below ground surface were located and provided a means of depth calibration. GPR profile materials have been provided to the principal investigator and await further investigation.

PALACE OF THE LEGION OF HONOR

The Palace of the Legion of Honor (hereafter Palace) in San Francisco has been undergoing extensive renovation and seismic retrofitting. Holman and Associates, an archaeological consulting firm, is monitoring construction to identify and remove coffin burials from a historic pioneer cemetery (in use from 1878 to 1910) located under the Palace. Failure Analysis Associates, Inc. (FaAA) was invited to conduct a GPR survey of the Palace courtyard. The courtyard was excavated down to approximately 30 feet, which allowed excavation of anomalies identified by GPR. Twenty-seven transect lines ranging from 5 to 12 meters long were surveyed. Numerous anomalies and three distinct strata were identified. Depth of penetration was estimated to be approximately 30 feet, extending to bedrock. Over 500 historic burials have been recovered to date from various areas of the cemetery, with approximately 20 interments showing up on radar profiles as anomalies (see Figure 1 for example). This site has provided the first opportunity to identify anomalous radar signals in an archaeological context that were actually tested through excavation.

HISTORIC MARTINEZ CEMETERY

Our third test site is a historic cemetery in

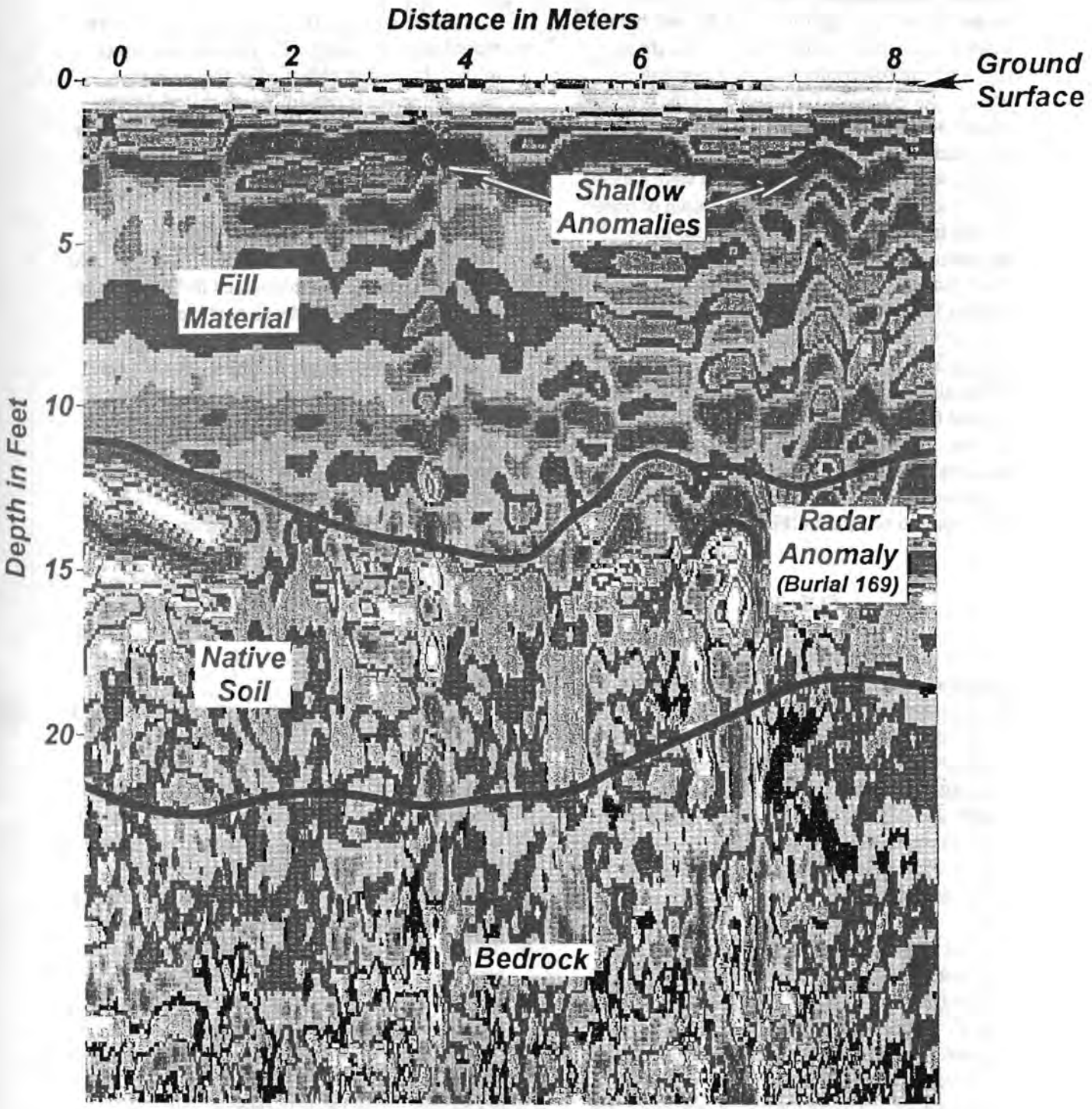

Figure 1. Ground penetrating radar survey at the Palace of Legion of Honor, San Francisco, California, May 1993. Profile number SFL-V115 showing burial 169.

Martinez, in service for approximately 131 years, which was undergoing landscape and other ground surface modifications. Records of some burial locations had been destroyed over the last hundred years and the owner of the cemetery sought to complete improvements without disturbing any graves. An extensive GPR survey of the proposed impact area was undertaken. GPR transect lines were laid out on a three-foot grid; approximately 4380 linear feet of GPR profile data were collected to plot subsurface anomalies. Depth of penetration, in silty clay soil, was estimated to be approximately six feet. Burials associated with grave markers were used to characterize GPR profiles for predictive purposes (see Figure 2). The GPR survey was quite successful in identifying graves in areas that were thought to be free of burials. A ferrous metal survey was also incorporated to identify any coffin material with iron content. No archaeological excavation was undertaken to test targets, but a map prepared subsequent to the GPR survey was used to direct renovation to avoid disturbing graves.

SOL-356

Our last case involves a late period prehistoric midden site in Green Valley, California. Potential development impacts to the site included scarification and keying in of structural fill. Holman and Associates contracted to evaluate the significance of the site under the California Environmental Quality Act (CEQA). FaAA was given the opportunity to conduct a GPR survey, in order to identify anomalies that might be investigated during field testing.

The survey consisted of eight transect lines 140 meters long; 1120 linear meters of GPR profile data were collected and plotted (Figure 3). Four GPR anomalies were chosen for investigation based on anomaly characteristics and sampling needs. Three GPR anomalies were investigated because they were located in strategic areas of the site and one was tested due to its large anomalous profile. It should be noted that great control must be taken when laying out transect lines for GPR surveys so field investigators can precisely locate and investigate potential targets.

Three 1x1 m units and one 1x2 m unit were placed over anomalies. Two of the units either missed the targets identified or the anomalies represented electrically different material composition from surrounding soils. One of the units revealed a large inverted mortar located in an ash lens.

The fourth anomaly investigated was most interesting in profile, covering an area of over five meters (Figure 4). Based on the GPR profile, the anomaly looked like and was predicted to be a compacted layer distinct from surrounding soils. The control unit investigating this anomaly was started as a 1x2 m, but was later expanded to include four additional 1x1 m units separated by 20 cm balks. The hard packed layer identified in the profile turned out to be a house floor, located between 60 and 70 cm below ground surface. A hearth, post holes and several artifacts including clam disk beads, an *Olivella* sp. spire-ground bead, a *Haliotis* sp. ornament/pendant, and a fragment of an obsidian serrated projectile point were recovered in association with the compacted layer.

It was determined from excavating these units that the feature was a probable pithouse structure with a diameter of approximately 5 m. The packed earth and gravel floor was slightly dish-shaped and rimmed with seven postholes, located around the periphery of the structure on a raised berm. Two discrete concentrations of ash, possible hearths or ovens, and a possible entrance were recorded, although no artifact caches were discovered. Testing exposed only portions of the housefloor, and excavation was terminated to preserve this unique and important structure. A layer of breathable outdoor synthetic fabric (Solarex/Molon) was placed over the floor and postholes were filled with plastic film containers prior to backfilling to help relocate this feature in the future.

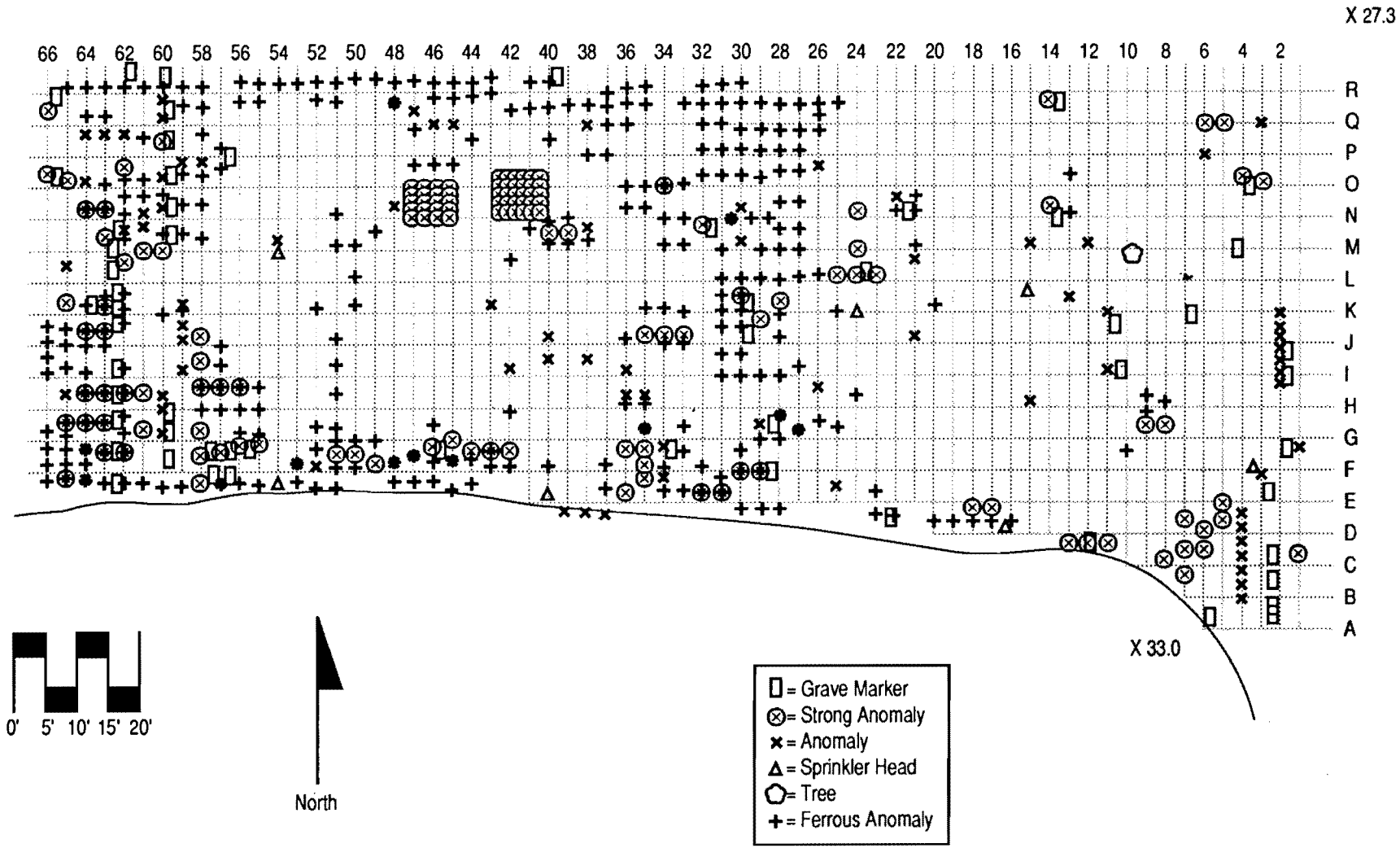

Figure 2. Martinez Cemetery, ground penetrating radar and ferrous metal survey, 11/165/93 and 12/13/93, Failure Analysis Associates, Inc.

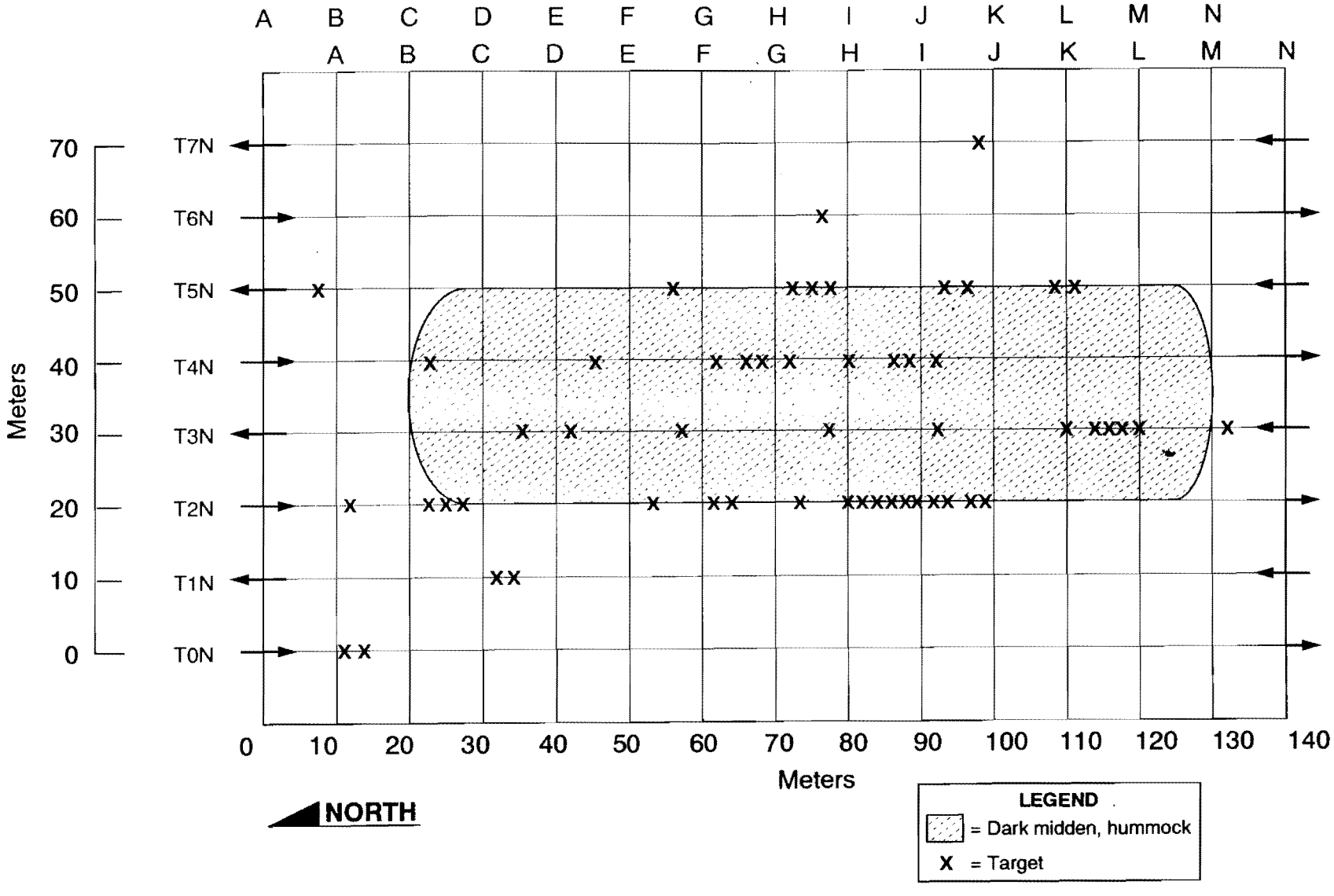

Figure 3. SOL-356, Green Valley Parcel, ground penetrating radar survey, June 24, 1993.
(Note: Penetration depth of GPR, approximately 2.5-3 meters; 300 Mhz antenna; target and midden locations approximate.)

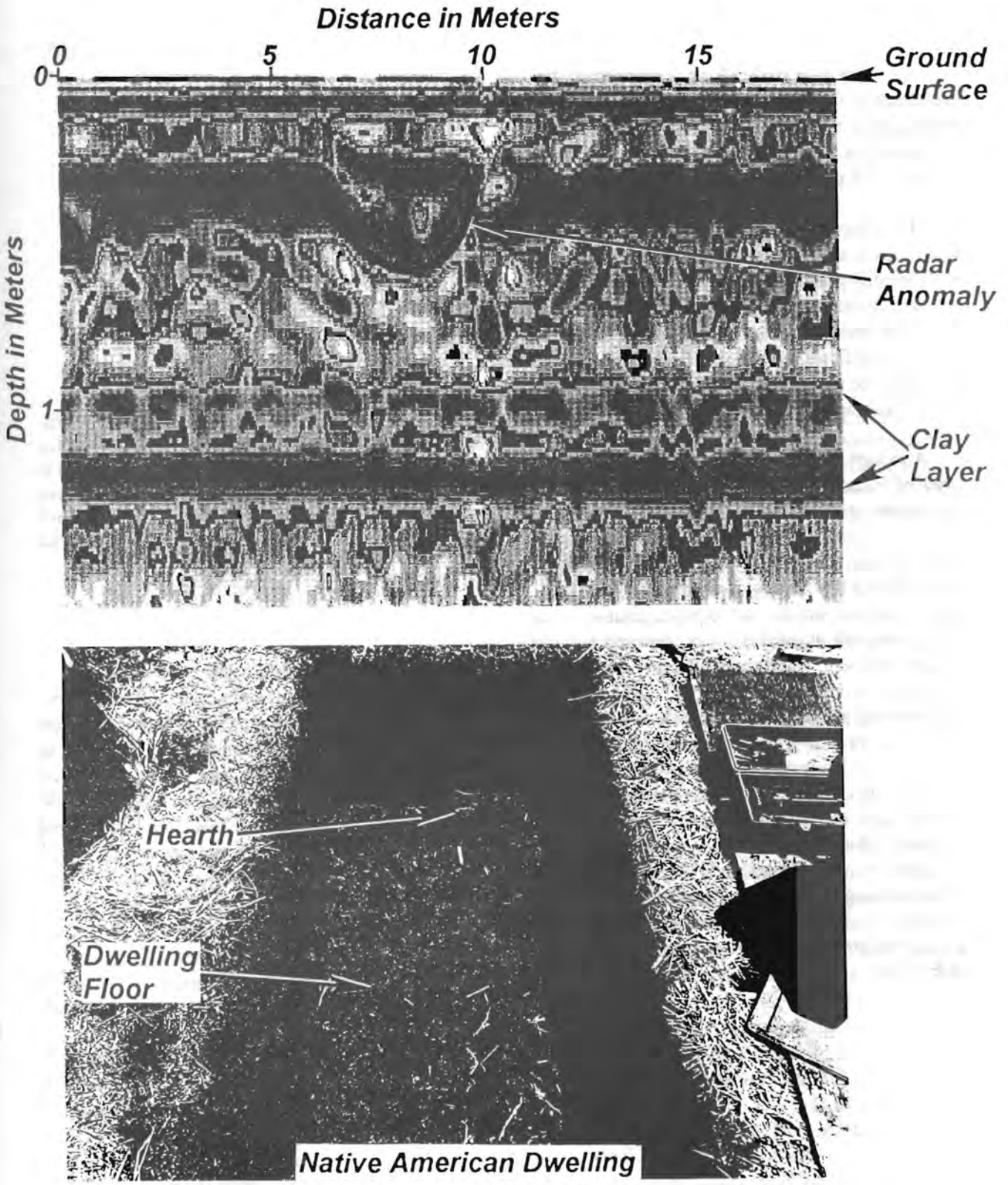

Figure 4. SOL-356, Native American dwelling, ground penetrating radar.

DISCUSSION

The above case studies have demonstrated the usefulness of GPR surveys for archaeologists and developers in a number of ways. By investigating archaeological sites during initial phases of investigation GPR profile data can:

- Characterize soil strata non-invasively
- Locate subsurface features non-invasively
- Identify potential materials or disturbed areas to be avoided
- Map anomalous signals that could represent significant features
- Be used in specific situations to predict and characterize specific features

Although data were acquired from various types of features/anomalies, the specific pattern of an anomaly is often hard to predict without background knowledge. For instance, at the Martinez cemetery where targets were known to be graves, the profiles differed from one another to such a degree that it would be hard to predict that a similar anomaly at another site represented a human interment. With these limitations in mind, we believe anomalies identified with GPR can be useful to archaeologists, using the data as a predictive survey tool when trying to determine areas of a site useful to test. Conversely, GPR data, coupled with other sampling considerations, can suggest areas to avoid due to lack of anomalies/ features. It has become a reality that sites cannot be (fully) excavated, nor should they, but it is in the archaeologist's interest to test those areas containing artifacts and features that contribute to a better understanding of the cultural resource under study.