THE USE OF GEOPHYSICAL SURVEYS FOR ARCHAEOLOGICAL EXCAVATION PLANNING AT THE MITCHELL SPRINGS RUINS IN CORTEZ, COLORADO

John A. Mundell, Mundell & Associates, Inc., Indianapolis, IN
Gregory B. Byer, Mundell & Associates, Inc., Indianapolis, IN
Harvey Henson, Southern Illinois University, Carbondale, IL
Vince Gutowski, Eastern Illinois University, Charleston, IL
Donald E. Dove, Mitchell Springs Ruins, Cortez, CO

Abstract

In the spring of 2001, a detailed geophysical survey using magnetics, 2-dimensional resistivity imaging and ground penetrating radar techniques was conducted at the prehistoric archaeological complex of Mitchell Springs Ruins in Cortez, Colorado. The purpose of this survey was to test the efficacy of geophysical methods for pre-evaluating suspected Anasazi ruins within selected areas of the site prior to archaeological excavation. These methods provided significant insight into the shallow subsurface material characteristics, and were valuable aids in guiding excavation activities during the summer of 2001 field school. This paper presents the results of this survey, with special attention to how these results were used to develop an archaeological exploration strategy. Field verification of various geophysical anomalies was completed during the summer 2001 field program at seventeen two meter by two meter grid locations, and identified a pueblo with connecting rooms, several deep storage pits, and three burials.

Introduction

The Mitchell Springs ruins are a prehistoric archaeological complex located just beyond the southern city limits of Cortez, Colorado (Figure 1). Positioned on and around a slight rise at an elevation of 6000 ft, the site overlooks the Montezuma Valley and faces the broad expanse of Mesa Verde, a few kilometers to the southeast. A meandering McElmo Creek cuts a canyon that forms much of the northern and western boundary of this prehistoric community (Figure 2). Mitchell Springs is representative of a prehistoric Anasazi pueblo culture of the Colorado Plateau region, and was occupied from at least the Basketmaker III period (AD 500 – 750) until the mid 13th century, with an apparent population peak occurring during the Pueblo II period (AD 900 – 1100).

Mitchell Springs has been historically recognized since the last 1800s as a significant prehistoric occupation with numerous structures, including many pueblos, kivas or pit-houses, and towers. The verbal and written records regarding the history of the Mitchell Springs ruins, accompanied by present day observations, make it clear that many of the surface remains have been significantly disturbed during the 19th and 20th centuries due to pot-hunting. However, recent studies during the 1990s conducted by archaeological field classes (Dove, 1997) have mapped a number of undisturbed structures, including three significant pueblos with associated kivas (see Figure 2).

In the spring of 2001, a multi-technique geophysical survey employing magnetics, two-dimensional resistivity imaging and ground penetrating radar was conducted at the site over several selected areas of interest. The survey was to be completed in less than a one week 'window' of time available at the site prior to the commencement of the summer archaeological field school. The survey

results were then to be used by the site archaeologist to aid in planning the distribution of excavations in areas thought to contain culturally significant features. As such, the purpose of this survey was to significantly increase the likelihood of finding human-produced features that would be reflected in observed variations in subsurface material and field properties. A number of recent papers have

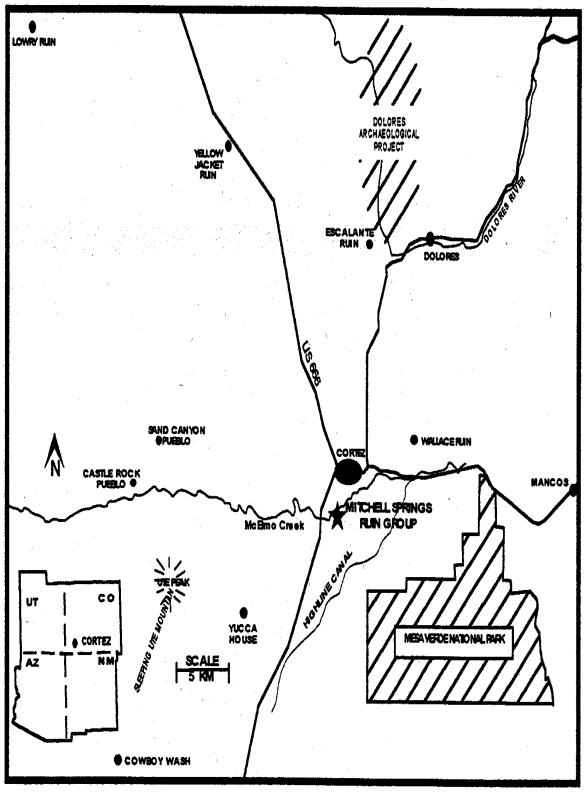

Figure 1. Site Vicinity Map.

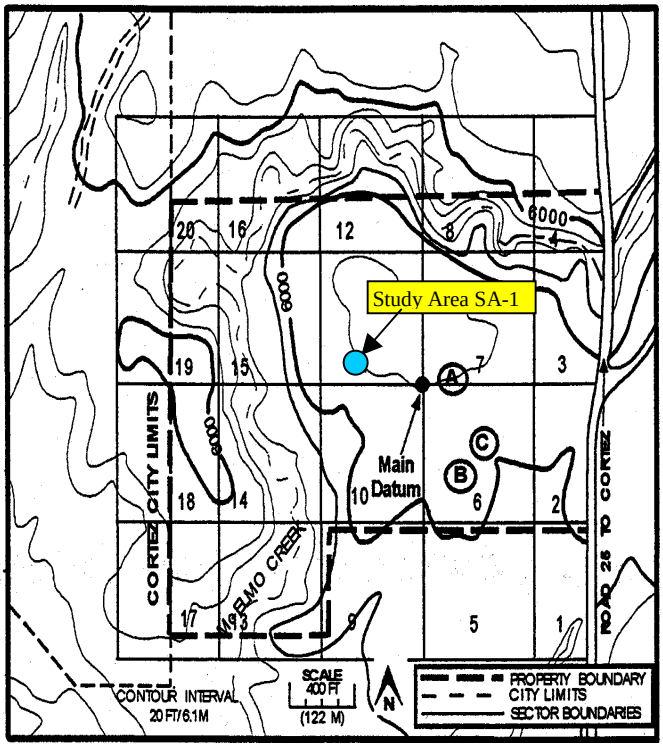

Figure 2. Mitchell Springs Ruins. Letters A, B and C indicate pueblos previously found at the site. Study Area SA-1 is discussed in the paper.

demonstrated the usefulness of various geophysical techniques in identifying anomalous areas of potential archaeological significance (e.g., Conyers, 2001; Versteeg et al., 2001; Eppelbaum et al., 2000; Mankowski et al, 2000; Kutrubes et al., 1997; Luke et al., 1997; Skokan et al., 1996; Bauman et al., 1995).

Site Geologic and Cultural Setting

As part of the development of the conceptual site model, it is necessary to understand the site geological context on which human habitation occurred. Mitchell Springs is located at the northern limits of the San Juan Basin in southwestern Colorado. The area is generally overlain by a windblown fine sandy loam covering a calcareous caliche layer, through which the prehistoric people often constructed pit structures and hearths. Dakota Sandstone underlies these upper soils and is the basal formation for much of this area, the nearby Ute Mountains and Mesa Verde. The sandstone is observed to outcrop across the site, and was used extensively as prehistoric construction material for the pueblo structures built by Anasazi communities.

Around a central knoll area, a few large pueblos were prehistorically established at the Mitchell Springs Ruins. Two pueblo structures, A and B located on Figure 2, make up part of this cluster and were investigated during the 1990s. These central structures were massive, multi-story buildings. The surrounding areas within which the geophysical survey was conducted appear to contain structures of the smaller, "unit pueblo" configuration.

Geophysical Surveys

Within the 110-acre site, five areas (SA-1 through SA-5) were selected for detailed geophysical surveys based on previous archaeological finds at the site, topographic expressions, and artifacts found at the surface. The results of only Study SA-1 will be presented in this paper. Prior to site geophysical work, these areas were cleared of sagebrush for ease of conducting the surveys. Survey grids were then placed over the study areas, with a 1-meter by 1-meter grid spacing marked prior to survey initiation. The grids were surveyed in with a total station and aligned so that data were collected in a north-south and an east-west orientation, consistent with the archaeological survey coordinates used during the confirmation field school excavations. For the results presented herein, SA-1 was a 25 m by 22 m area located in a gently westward sloping portion of the central part of the site, with less than a 0.64 m elevation difference across the area (see Figures 2 and 3).

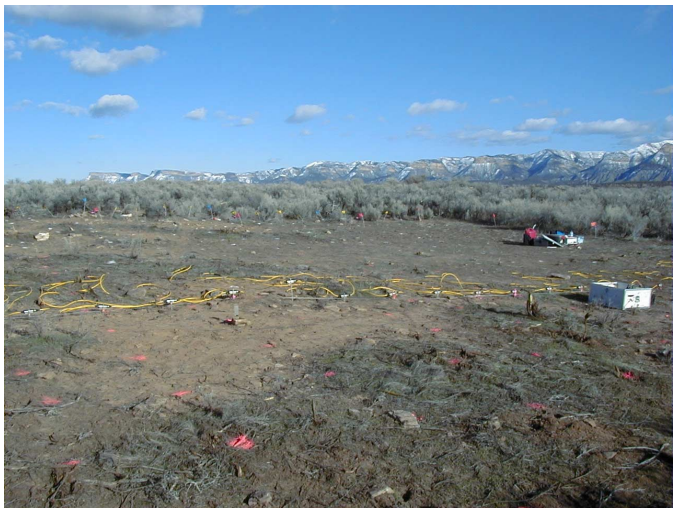

Figure 3. Southeast View - Study Area No. 1.

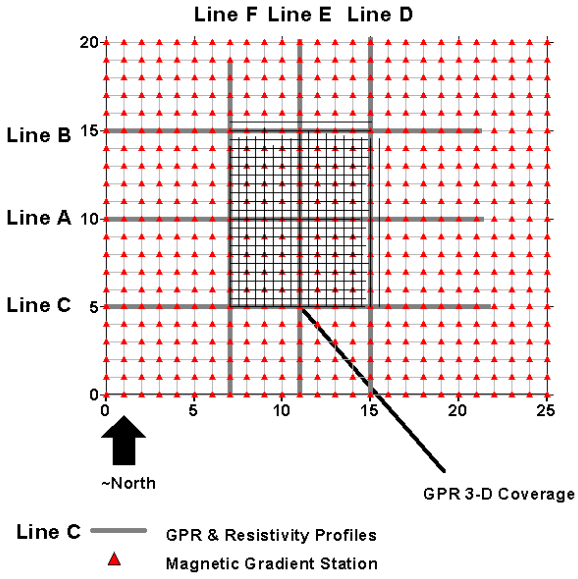

Figure 4. Geophysical Survey Grid in SA-1.

Magnetics, 2-dimensional resistivity imaging and ground penetrating radar were then conducted over selected portions of the study area during an intensive, three-day study period. Figure 4 shows the geophysical survey grid locations within SA-1.

Geophysical Methodology and Results

Magnetics

Magnetic data were collected with an *EG&G Geometrics Gradiometer* at a 1-meter grid spacing. The results were contoured using Surfer Version 7.0 and are presented in Figure 5. As shown in the figure, the most intense magnetic anomaly (about 25 nT/m) is in a 2 m by 3 m area (6N to 8N, and 1E to 4E) in the southwest quadrant of SA-1, and also has the greatest areal extent. Other smaller, lower intensity anomalies (about 15 nT/m) are clustered in several east-central areas of SA-1 (*e.g.*, 9N to 15N, 11E to 22E), and also within the northwest quadrant (*e.g.*, 15N to 17N, 5E to 8E).

2-D Resistivity

The evaluation of the vertical and lateral resistivity characteristics of the subsurface materials encountered were determined using a 2-dimensional *Advanced Geosciences, Inc.* (*AGI*) *Sting R1* portable resistivity imaging system. This resistivity instrumentation consists of a *Sting R1* resistivity meter with internal memory storage connected to an *AGI Swift* automated electrode switching system equipped with switchable electrodes.

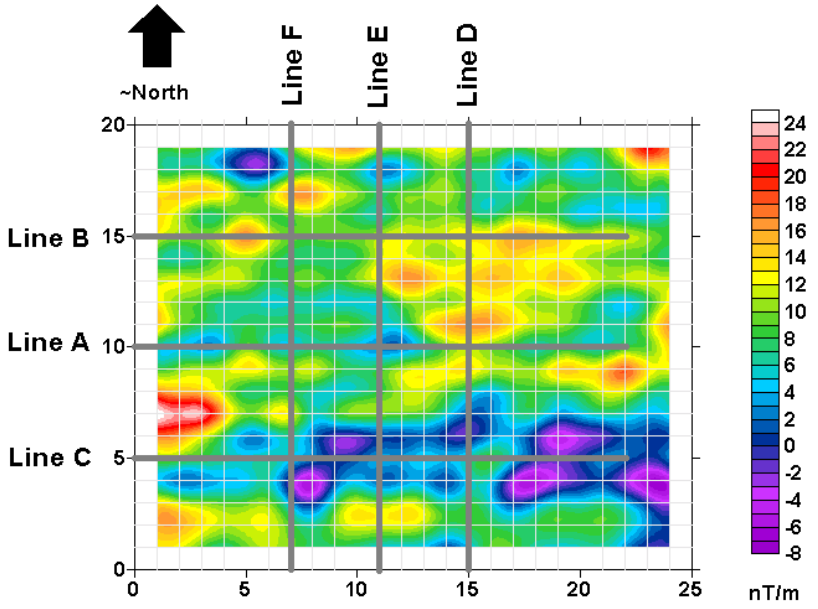

Figure 5. Vertical Magnetic Gradient over Study Area No. 1.

SA-1 was evaluated using six profile lines: three east-west profiles (Lines A, B and C shown in Figure 4) placed at a 5-meter line separation, and three north-south profiles (Lines D, E and F) with a 4-meter line separation. Using the *Sting R1* resistivity meter, *Swift* automatic electrode switching system, and 30 switchable electrodes, electrical resistivity readings were acquired along these profiles. Stainless steel electrode stakes were driven into the ground at a 0.75-meter spacing with an anticipated effective modeling depth approximately 5 meters below the ground surface. Once the electrode stakes and switchable electrodes were emplaced and adequate ground contact established with brine, the automated data acquisition system was programmed to acquire electrical resistivity readings using a standard pole-dipole array with a forward and reverse setup. This asymmetrical array configuration was chosen because of its sensitivity to lateral changes in electrical resistivity and improved signal to noise ratio relative to the dipole-dipole array. This array was chosen with the desire to provide as much detail in the upper shallow soils as subsurface material types varied. Once the initial forward and reverse pole-dipole setup was completed, half the electrodes were moved down-line in a roll-along process to increase the effective line length.

The resulting apparent resistivity data sets were subsequently merged and downloaded in the field to a laptop computer for 2-dimensional inversion modeling. Using the RES2DINV program written by Dr. Meng Heng Loke, a 2-D model of the subsurface was produced through calibration of the apparent resistivity field data with a modeled apparent resistivity data set. To develop geologically reasonable resistivity cross-sections, sensitivity analysis (*e.g.*, varying layer thickness and damping factor) was performed for each data set to minimize the root mean square error within the six cross-sections developed. RES2DINV also allows the simultaneous inversion of the forward and reverse pole-dipole data to eliminate bias from the array asymmetry.

Figure 6 illustrates the results of the three parallel, east-west 2-dimensional resistivity cross-sections (Lines A, B and C). The range of resistivity values spanned about two orders of magnitude from about 10 to 1,000 ohm-meters. It is presumed that soil, particularly below about one meter, has a relatively low resistivity, probably in the range of 10 to 40 ohm-meters (dark blue to cyan). Large

accumulations of stones, whether natural or anthropomorphic in origin, would be anticipated to have high resistivity, perhaps 100 to 1,000 ohm-meters (warm colors, i.e., yellow, red, and purple).

The lower section (Line C) shows a significant high resistivity area (denoted in red and purple) at the far western extent of the profile from 0E to 5E to a depth of 1.2 m below the ground surface. Several

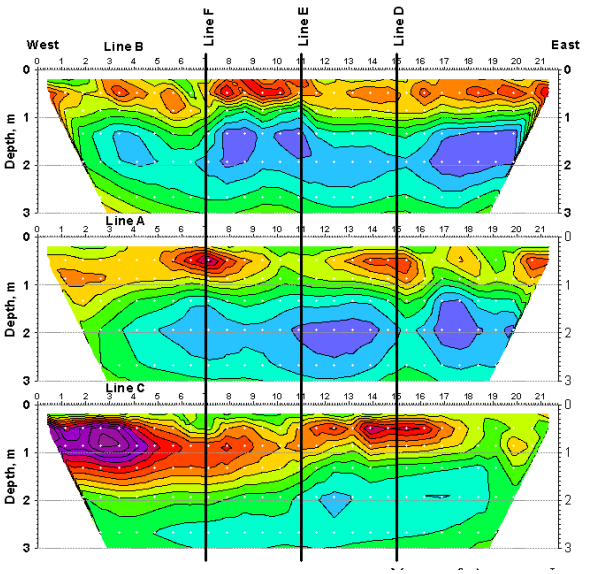

Figure 6. 2-D Resistivity Profile Lines: A, B, C.

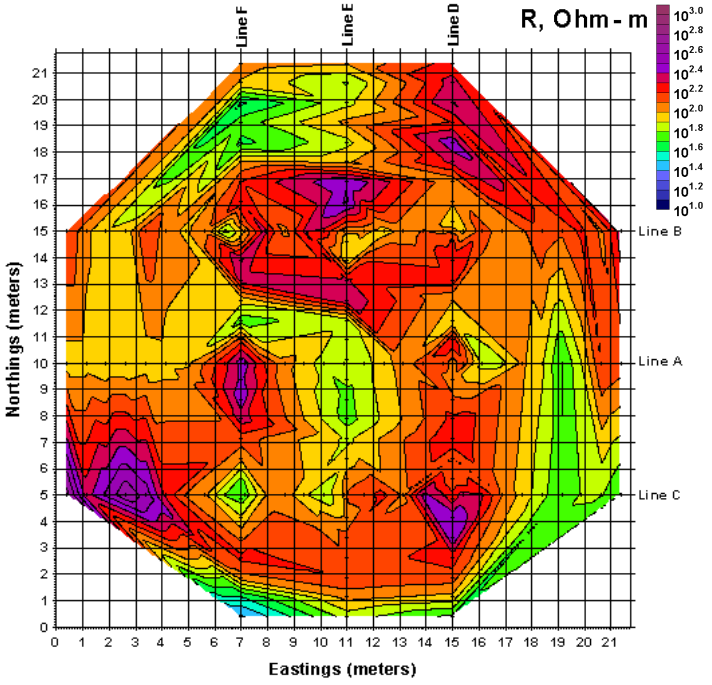

Figure 7. Resistivity Map at 0.48 m Depth.

shallow (approximately 0.5 m in depth), smaller high resistivity anomalies are shown in the upper portions of all profiles that may be indicative of residual rock walls or dwelling foundations.

Six resistivity plan-view maps were constructed using the six 2-dimensional resistivity cross-sections at depths of 0.15 m, 0.48 m, 0.86 m, 1.33 m, 1.93 m, and 2.67 m. Surfer Version 7.0 was used, and the simple triangular interpolation algorithm was used to grid the data. As shown in the plan-view map for the 0.48 m depth presented in Figure 7, high resistivity (red and purple) anomalies with a unique geometric texture are present in the northern portion of the study area (north of 12N). Three significant, higher resistivity anomalies are also present in the southwest (4N-7N, 0E-4E; 8N-10N, 6E-8E) and southeast (3N-5N, 14E-16E) quadrants of the study area, indicating potential unique buried features that may be of interest.

Ground-Penetrating Radar

Ground-Penetrating Radar (GPR) profiles were acquired using a *Sensors & Software Noggin* with shielded *250* MHz center-frequency antennas. The antennas were mounted to a *Smart Cart* with an odometer wheel for accurate positioning. A Noggin Plus digital video logger (DVL) was used to monitoring the data in real time. Data were collected at a 0.5-meter line separation along selected lines in areas of interest within SA-1. Six profiles were recorded and stored along the same north-south and east-west lines as the 2-D resistivity (*i.e.*, Lines A through F). In addition, GPR data were also collected along two, orthogonal grids at a 0.5-meter grid spacing for quasi 3-D analysis (see Figure 4). GPR data were downloaded using the PXFER software, and the results were processed for plotting with IxeTerra.

For comparison to the earlier 2-D resistivity profile lines, Figure 8 contains the results of the three east-west profile Lines A, B and C for the *Noggin 250*. As shown, some of the GPR lines have

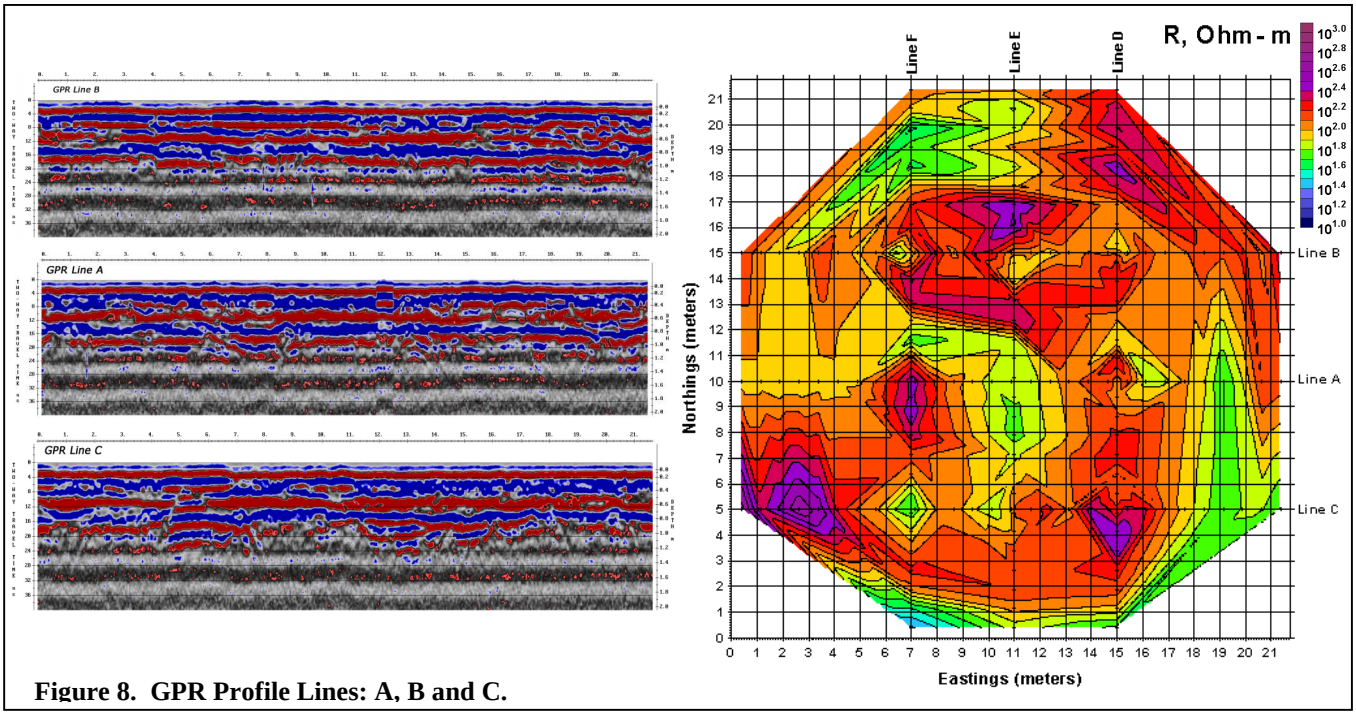

Figure 8. GPR Profile Lines: A, B and C.

reflection events that correspond to features seen on the 2-D resistivity cross-sections. Depth of penetration of the GPR appears to have reached a limit of about 1.2 m. Additional spatial analysis of the amplitude distribution in three dimensions is currently being conducted on the 3-D GPR grid. Comparison of amplitude variations within horizontal time slices has been shown to provide an excellent indication of the location of subsurface discontinuities and interfaces often associated with buried features of interest (Conyers and Goodman, 2001; Campbell et al, 2001). Preliminary analysis indicates a strong correlation with the results of the 2-D resistivity plan view maps.

Summer 2001 Archaeological Field School

The summer 2001 field school for the Mitchell Springs Ruins was conducted from May 21st to June 28th. A plan map of SA-1 is shown in Figure 9, showing the locations of the 17 excavation units and archaeological interpretations of the key findings. The 2-meter by 2-meter units fall along the same 1-meter grid lines

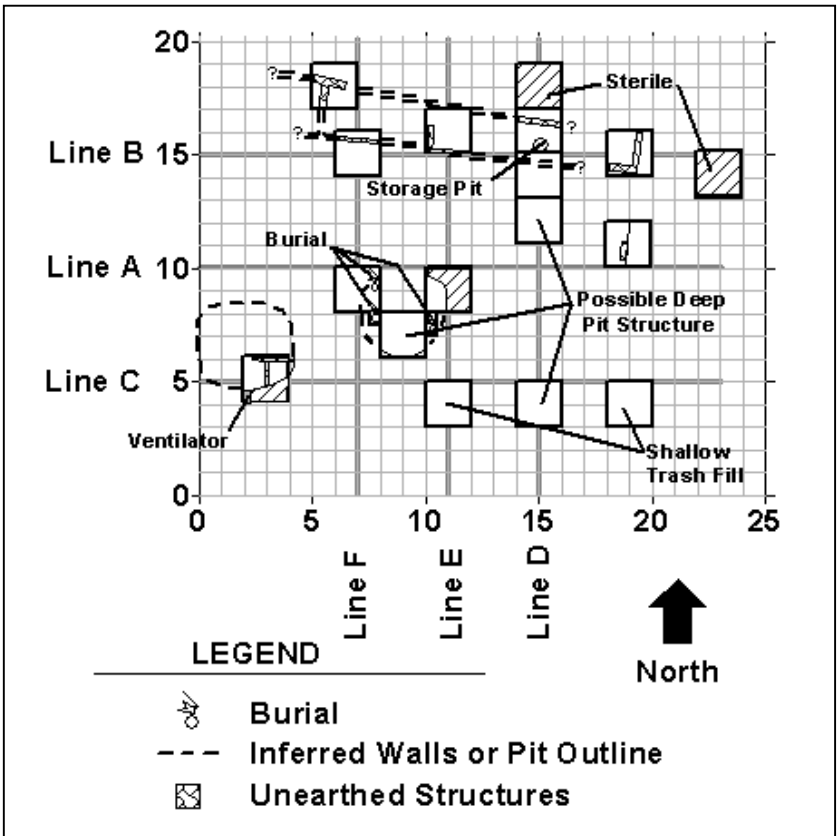

Figure 9. Archaeological Interpretation of Study Area Findings.

used in the geophysical survey. The reference datum for each excavation unit is at the southwest corner. For example, the southwestern pit in SA-1 has its reference point at 4N, 2E.

Prior to the commencement of the field camp, excavation units selection criteria were based on: 1) groupings of geophysical anomalies, which included areas of extreme resistivity or magnetic values; 2) synergy between two or more geophysical techniques (e.g., areas where two or more techniques exhibited anomalous readings); and 3) the geometrical configurations of anomalous areas relative to the forms associated with archaeological features. In some cases, the anomalous areas had no surface expression to indicate a reason for the observed readings, whereas in others, subtle surface characteristics (e.g., slight topographic variations or material changes) were present.

As described in the following sections, a high percentage of features of archaeological significance were encountered during the summer field school excavations within the anomalous geophysical areas.

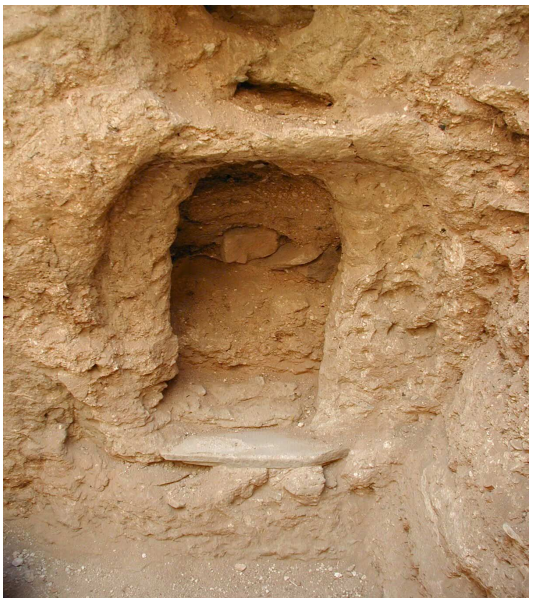

Figure 10. Ventilator Shaft Opening within Southwestern Deep Pit Structure.

Southwestern Deep Pit Structure - Resistivity High; Elevated Magnetic Gradient

Excavation 4N, 2E

In the far southwest corner of SA-1, the southeastern part of a 3-meter deep pit structure was exposed (see Figure 9). At floor level, a divided wingwall and a ventilator shaft opening was noted (Figure 10). The size of the pit is estimated to be about 4 to 5 meters in diameter. This pit corresponds to a resistivity high (Figure 7) and an elevated magnetic field gradient (Figure 5) observed at this location.

Human Burials Within Pit Structure - Central Elevated Resistivity

Excavations 8N, 6E; 6N, 8E; 8N, 10E

Figure 11. Wall Structures for Pueblo (15N, 10E).

Indicated by a significant resistivity high at a depth of 0.48 meters over a 4 m by 4 m area (see Figures 6 and 7), these three 2 m by 2 m excavations yielded the presence of three inhumations at a depth of about 65 cm. All were buried face down with legs flexed (one male adult, and two children about 9 and 11 years old). Excavation was stopped after removal of the burials, but it appears the burials are associated with a pit structure approximately 1 m in depth.

Pueblo With Associated Features - Northern Resistivity Highs

Excavations 17N, 5E; 14N,6E; 15N, 10E; 15N, 14E

As shown on the electrical resistivity plan-view map at a depth of 0.48 m (Figure 7), a large higher resistivity area on the order of more than 10 m long by 6 m wide extends across the northern portion of SA-1. Most of the overburden north of the 14N or 15N line contained numerous Dakota sandstone blocks that were determined to be from fallen walls of a pueblo located in this area. Several

of the excavations relating to resistivity highs contained low-standing wall remains that are resting on a sterile soil base at about 30 to 50 cm depth (see Figures 11). The pueblo appears to be a series of adjacent rooms, perhaps one room in width (Figure 9). However, based on an unexplored resistivity high that runs from 12N-14N and 7E-11E, there could possibly be another parallel wall structure over an extended distance. A storage pit was also exposed to a depth of about 1 m within one of the small rooms (Figure 12).

Figure 12. Storage Pit with Pueblo Wall (15N, 14E).

Northeastern Deep Pit Structure - Deep, Resistivity High; Elevated Magnetic Gradient

Excavation 11N, 14E

Excavation down to a depth of 40 cm at the end of the season by students had only indicated a hard sterile layer with nothing of significance at this location. However, based on adjacent features and the deeper, higher resistivity noted along 2-D Profile Line D (Figure 13) and elevated magnetic field in this area, a continuation of a test trench by the site archaeologist across the center revealed a large pit structure based on finding a number of masonry blocks beneath the upper sterile layer. Continued excavation during the 2002 field school will further expose the characteristics of this structure.

Southern, Deep Pit Structure/Shallow Trash Fill - Extended Resistivity High

Excavation 3N, 14E

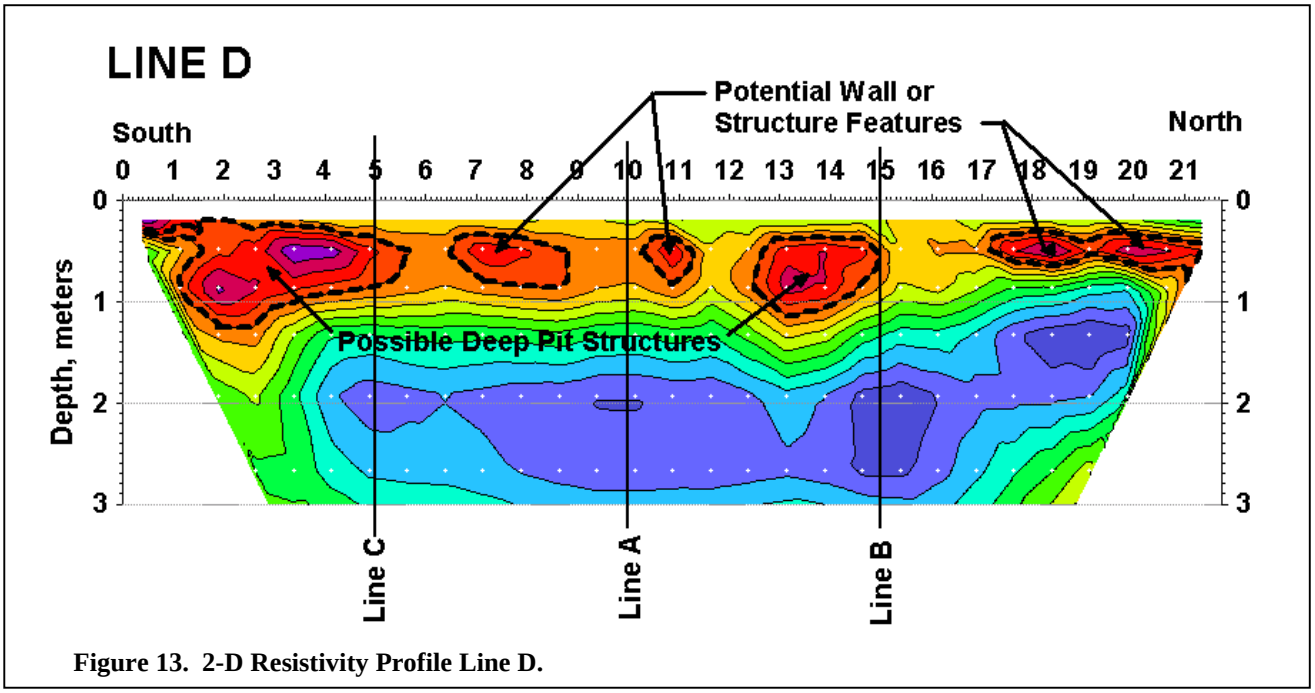

Figure 13. 2-D Resistivity Profile Line D.

Digging was halted at a shallow depth when it was thought that a hard, sterile soil had been encountered; however, based on later discoveries, it appears that this area is most likely over a deep pit structure (see Figure 13). On the electrical resistivity plan-view map depicting a depth of 0.86 meters (not shown) and on the south end of the 2-D resistivity profile for Line D (Figure 13), a significant

elongated resistivity high area extending more than 4 m across (2N-3N, 11E-15E) is immediately south of this area. The slightly elevated magnetic gradient (see Figure 5) also suggests a change in material type, and the potential for a significant feature.

Unexplored Geophysical Features

Time constraints during the 2001 field school did not allow the excavation at all areas of interest shown by the geophysical survey. Examination of potential pueblo walls south of those uncovered in an area of elevated resistivity (*e.g.*, 12N-13N, 7E-11E) and magnetic gradient (*e.g.*, 13N, 12E) should be confirmed by selected test pits. A 2 m by 2 m deep pit structure appears to be located at 13N, 14E to a depth of almost 1 m (Figure 13). In addition, excavation of additional resistivity highs along the 15E profile Line D between the two deep pit structures may yield additional features of interest.

Conclusions

Based on the geophysical survey results, significant archaeological structures were disclosed at a high percentage of anomalous areas exhibiting elevated resistivity and/or magnetic field gradient, or changes in the shallow material properties observed in the ground penetrating radar profile lines. Use of multiple geophysical techniques allows for cross-correlation of anomalous areas, enhancing the likelihood of finding features of significance. The 2-D resistivity approach with a relatively close electrode spacing (0.75 m) proved effective in identifying features at depth that most likely would not have been pursued otherwise. However, because of the longer time period necessary to collect data at sufficient density for archaeological features of interest, the use of other more rapid geophysical methods (*e.g.*, magnetics, GPR) is strongly recommended to help selectively locate detailed study areas. In addition, the use of a multichannel resistivity meter and collection of a 3-dimensional resistivity grid could greatly improve the resolution of the resistivity method. Because of their ability to characterize large areas rapidly at close grid spacings, terrain conductivity (e.g., the Geonics EM-38 or EM-31) should also be considered to help guide more detailed geophysical exploration prior to archaeological excavations, and as a complementary method to resistivity imaging.

References

1. Campbell, D. L., Beanland, S., Lucius, J. E. and Powers, M. H., 2001, "Magnetic and GPR Surveys of a Former Munitions Foundry Site at the Denver Federal Center, in Proceedings, *SAGEEP 2000, Symposium on the Application of Geophysics to Engineering and Environmental Problems*, Arlington, Virginia, February 20-24, 2001, pp. 453 - 458.
2. Conyers, L. B. and Goodman, D., 1997, Ground-penetrating Radar, Altamira Press, pp. 149-194.
3. Conyers, L. B., 2001, "Ground-penetrating Radar Amplitude Analysis for Archaeological Applications," in Proceedings, *SAGEEP 2001, Symposium on the Application of Geophysics to Engineering and Environmental Problems*, Denver, Colorado, March 4-7, BCF-3.
4. Dove, D. E., Wheeler-Smith, R. L., and Dove, D. M., 1997, *The Mitchell Springs Ruin Group, Archaeological Investigations, 1990 - 1994, A Descriptive Summary of a Five-Year Testing Program*, Archaeological Report No. 1, Glendale Community College, Glendale, Arizona, 135 pp.
5. Goodman, D., Nishimura, Y., and Rogers, J. D., 1995, "Time Slices in Archaeological Prospection," *Archaeological Prospection*, Vol. 2, pp. 85-89.

6. Kutrubes, D. L., Soter, S., Katsonopoulou, D., 1997, "The Search for Ancient Helike: a GPR Case Study," in Proceedings, *SAGEEP'97, Symposium on the Application of Geophysics to Engineering and Environmental Problems*, Reno, Nevada, March 23-26, pp. 973-981.
7. Luke, B. A., Begley, C. T., Chase, D. S., Ross, A. J. and Brady, J. E., 1997, "Rapid-Response Geophysical Site Investigations at a Pre-Columbian Settlement in Honduras, in Proceedings, *SAGEEP'97, Symposium on the Application of Geophysics to Engineering and Environmental Problems*, Reno, Nevada, March 23-26, pp. 983-992.
8. Skokan, C., Edwards, Edwards, Holt., J., and Vaughan, A., 1996, "An Integrated Geophysical Study of the Yarmony Archeological Site, Colorado, in Proceedings, *SAGEEP'96, Symposium on the Application of Geophysics to Engineering and Environmental Problems,* Keystone, Colorado, April 28-May 2, pp. 1269-1278.
9. Versteeg, R., Rothschild, N., Wall, D., Copeland, C., Seignoret, H. and Ergun, K., 2001, "Integrated Use of Geophysics, GIS and Archaeological Records to Locate Seneca Village," in Proceedings, *SAGEEP 2001, Symposium on the Application of Geophysics to Engineering and Environmental Problems*, Denver, Colorado, March 4-7, BCF-4.