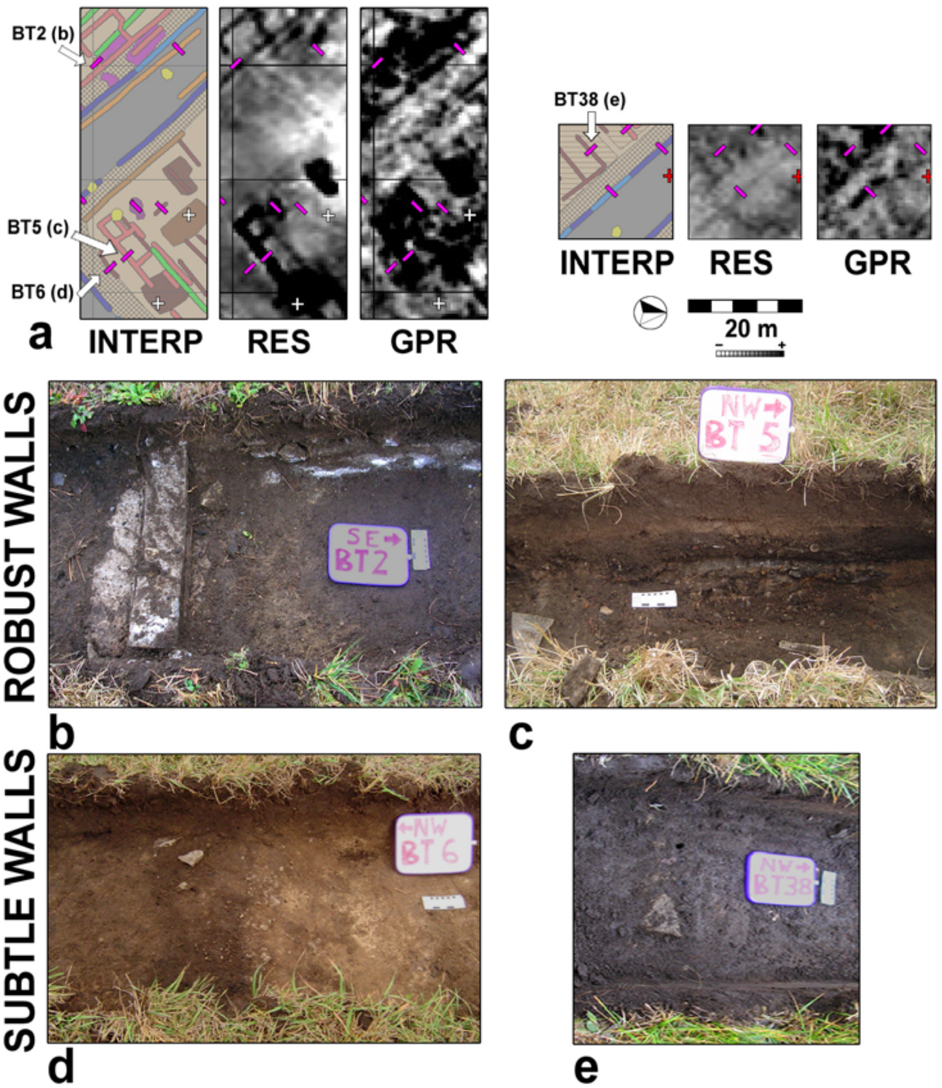
RESULTS AND FUTURE APPLICATIONS

The process of archaeological remote sensing as carried out in this project is a multi-step undertaking. The first stage, designed to meet the primary data integration goal, includes remote sensing data collection, processing to clarify anomalies in individual sensors established within GIS databases, data fusion to integrate information from all sensors, definition of potentially “significant” cultural anomalies, and classification of the anomalies into likely types of cultural features. This is normally the final product of most remote sensing projects, and the point at which archaeological fieldwork takes over. This project endeavored to go several steps farther with a *second* principal goal.

The second goal of this research project was very different and designed to meet an important criterion in the SERDP Statement of Need. Specifically, “ground-truth” testing was called for to demonstrate the feasibility of the data integration technologies and associated procedures. Three additional project tasks were therefore designed. They include development of a sampling design that allowed archaeological excavation of representative anomalies of each defined type to provide validation of remote sensing predictions about the subsurface. This validation phase often turned into a learning process, however, because the soils, geology and the archaeology in each site are unique, idiosyncratic, and confound predictability. In other words, remote sensing predictions cannot be perfect and a look into the ground through excavation offers additional insights that allow modifications to original predictions. Consequently, a final stage was defined that includes modification of original remote sensing predictions, based on excavation findings. Numerous scholarly presentations and publications were produced during the project. Preparation of a final report was, of course, the ultimate task.

These operations were undertaken at each of four prehistoric and historic archaeological sites distributed across time and space in a wide diversity of environmental settings from South Carolina to New Mexico. This provided a variety of contexts in which to assess the value of the methods investigated at very different archaeological sites with very different remains in very different environments. In so doing a better understanding of which methods consistently worked and offered useful results could be achieved, but this knowledge was also augmented by the considerable experience of project team members.



Samples of archaeological sources for anomalies classified as "walls." a) Vector interpretations, resistivity, and GPR imagery showing loci of anomalies and excavations. b) BT2 showing concrete walls of the Hippodrome. c) BT5 showing a massively burned wall of the Orpheum Theater. d) Subtle wall in BT6 revealed as a soil stain. e) Subtle wall in BT38 defined by a line of concrete and masonry rubble. KEY: INTERP= interpretations; RES=resistivity; GPR=ground-penetrating radar; BT=backhoe trench (purple).

Integrating multiple geophysical data sets offers large potential for improved understanding of the subsurface. A single survey, for example, might reveal only part of a buried building. Integrated information from several surveys may illustrate the entire structure as well as interior components. Moreover, integrated data may *simultaneously* show relationships between conductive, resistant, magnetic, thermal, and metallic anomalies, potentially improving knowledge of features within a site, inter-sensor relationships, enhancing overall interpretations.

Graphical solutions for data integration are easy to implement and effectively combine information from disparate sources into interpretable displays. They allow complex visualizations of the subsurface, but their weakness rests in relatively low dimensionality—only 2-3 data sources may effectively be represented. Moreover, these methods are purely descriptive, yielding only images, not new data that may subsequently be analyzed. Discrete integrating methods, on the other hand, allow application of readily available Boolean operations to any number of geophysical data sets. A shortcoming is that the binary maps upon which these methods are based rely on arbitrary thresholds to define significant anomalies, while more subtle ones must be ignored. Continuous data integrations can yield insights beyond the capabilities of other methods. Robust *and* subtle anomalies may be simultaneously expressed, producing composite imagery with high information content. Interpretive data are also generated in the form of principal component scores, factor loadings, or regression weights that add to understanding of interrelationships and underlying dimensionality. Supervised and unsupervised classification methods are noteworthy because they introduce a predictive aspect to the integrating process. Patterns in these data fusions may point to anomalous conditions much less visible in any single data set that might otherwise be overlooked. They therefore offer a possible means to augment prospecting capabilities. Although the approaches to geophysical data integration examined here span a wide range of commonly available techniques, they are by no means exhaustive. A host of other supervised and unsupervised classification algorithms exists, as well as new context-based image segmentation, and intelligent knowledge-based methods.

If the foregoing results can be generalized, it is that robust anomalies exist in the data and tend to dominate any form of fusion, regardless of the method employed. The consequence is amazingly parallel results between widely different forms of integration. Consequently, they really should be considered as offering new information about subsurface variation.

The determination of which integrating methods are best may depend on purpose. Some yield visually pleasing results that appear to well-combine available information while others may seem less revealing but may offer interpretive or predictive potential. If a goal is to define discrete classes of anomalies that may be subsequently interpreted through comparison with primary data then categorical methods may be best. If a goal is merely a continuous-tone image that represents most of what is known about the subsurface then a composite color graphic or mathematical-statistical integration may be most suitable. Of course, continuous methods yield quantitative data that may subsequently be analyzed, plus regression weights, PCA scores, or factor loadings that give additional insights beyond graphical representations, important for improved understanding of the subsurface and its interaction with geophysical methods. In practice, a variety of different integrating methods may work best in practice, because each variation may give new insights about a different aspect of the subsurface.

The results of the integrated data sets clearly illustrate the very substantive subsurface site characteristics that are discoverable from the integrative methods used. Based on these results a dramatically clearer picture of the subsurface is realized, compared to traditional site evaluative methods. By more clearly imaging the totality of information about the subsurface from all sources, a better understanding of site content, structure, and organization may also be achieved. The amount of information provided from these methods dramatically improves the ability to assess the site properties consistent with eligibility evaluations. The extensive amount of information yielded by the approach also will serve as important guidance should site mitigation be needed.

Compared to the typical site evaluation results these methods provide orders of magnitude more information on the nature of the internal sites structures and its characteristics. This is particularly evident at sites such as Army City and Pueblo Escondido but to a lesser degree at all the sites.

It should be noted that while these methods are very effective in the horizontal delineation of site characteristics, such as the mapping of a house foundation, they are somewhat more limited in their capabilities in delineation of the site’s vertical characteristics. However, as this project demonstrates, GPR does give good depth estimates and potentially allow 3D modeling and portrayal. Multiple depth slices showing structural changes with depth at Escondido and the other report examples of 3D models incorporating the vertical dimension illustrate these potentials..

The methods developed in this investigation will increasingly serve as critical steps in the evaluation of archeological properties as required by the National Historic Preservation Act. Use of these methods can increase the effectiveness and (often reduce the cost) of the evaluation efforts. Since excavation of entire sites or settlements, or even large areas of them, is impossible owing to funding limitations and ethical concerns, it may be only through integrated remote sensing that real understandings of the content, structure, and extent of archaeological sites may be achieved. It is anticipated that the methods pioneered here provide an important step in the direction of that goal.