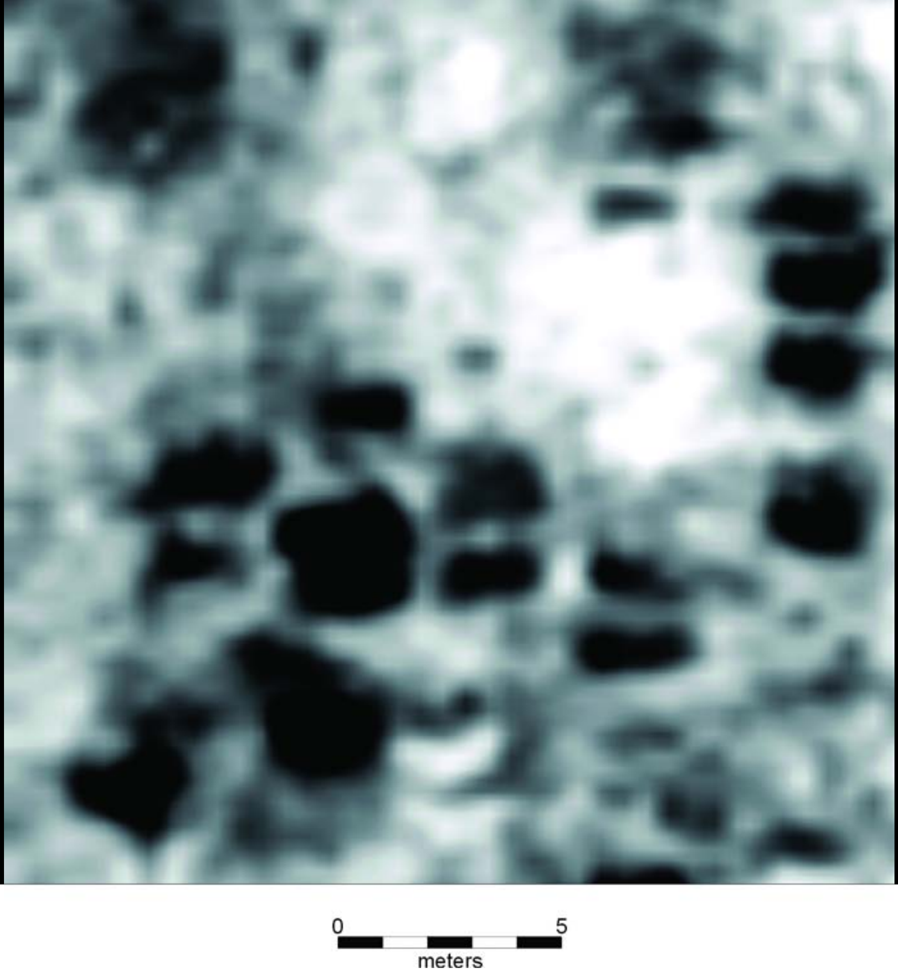


A ground penetrating radar map of an historic cemetery. A number of graves are clearly visible. While there may be graves that have not been detected within this area, the overall patterning is obvious. This survey was performed prior to construction of a new parking lot for visitors to the cemetery, to help avoid disturbance to burials. Missing or misplaced grave markers are very common on older cemeteries, and often even the limits of the cemetery are unknown. This map shows an area known to contain graves, and was used for comparison with the proposed parking lot, which was surveyed to verify that it did not contain unmarked graves.

Imaging the Buried Past

The 20th century saw an explosion of ever-more intensive land use and development. Even as our nation enjoyed unprecedented economic prosperity, many began to fear the destruction of our natural and cultural heritage in the face of unbridled development. The tension between these conflicting public interests spurred the creation of federal and state laws that attempt to balance growth and preservation. Compliance with environmental and cultural resources laws has become part of our reality, and these fields have become industries in their own right.

There are literally millions of recorded archaeological sites in the United States, and it is safe to say that there is a far greater number of sites that have yet to be discovered. From prehistoric cities that were home to tens of thousands of people to historic homesteads, these sites can tell us much about the past that we could not know by any other means. Both historic and prehistoric cemeteries are protected by law, and the discovery of unrecorded burials has put the brakes on many a project.

Subsurface Mapping

Competition in the cultural resource management industry (or CRM for short) has spurred archaeologists to become more effective and cost-efficient. One of the most effective of the new technologies adopted by archaeology is geophysical imaging of archaeological sites. A number of geophysical sensing technologies can be used to map what lies beneath the ground on archaeological sites. A subsurface map of a site can allow archaeologists to be more strategic in their use of time-consuming and costly excavation, and understand the “big picture” of a site outside of exca-

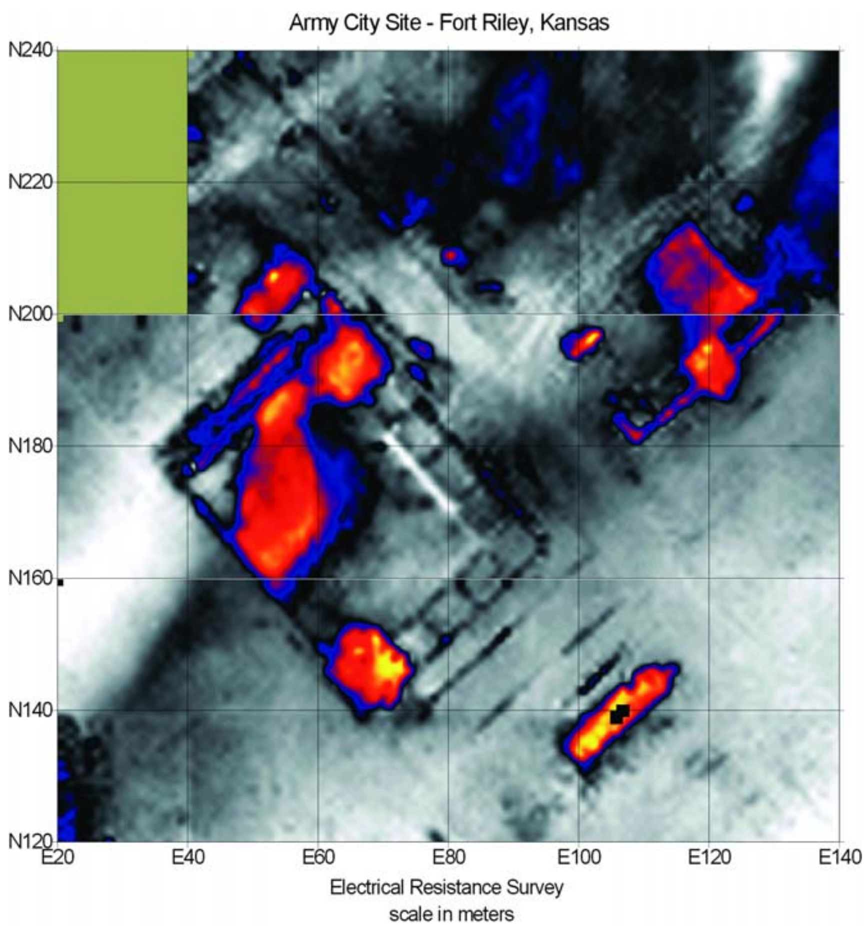
>> By Geoffrey Jones

vated areas. In other cases (notably cemeteries) it can be used to avoid disturbing a site.

It is a common misconception that archaeologists are concerned only with artifacts–portable relics like stone tools and gold monkey statues. Actually, they are usually more concerned with "features," structures or traces of human activities left in the soil, whether they are the remains of buildings, campfires, or graves. Many types of features can be detected from the surface by measuring the electrical or magnetic properties of the soil, or by reflected radar signals. Readings taken in a systematic pattern become a dataset that can be rendered as maps.

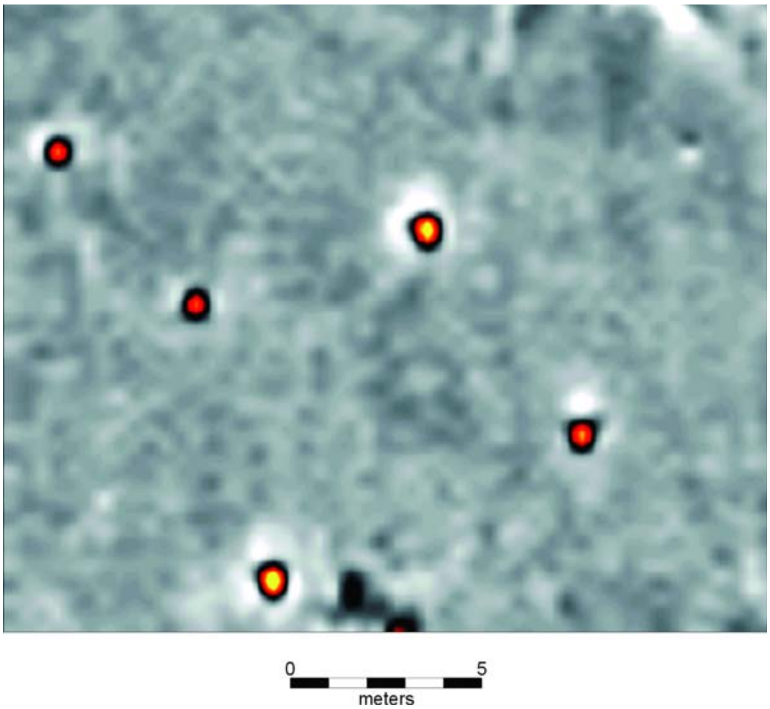
Geophysical methods used in archaeology are largely adapted from those used in mineral exploration, engineering, and geology. Archaeological mapping presents unique challenges, however, which have spurred a separate development of methods and equipment. In general, geological applications are concerned with detecting relatively large structures, often as deeply as possible. In contrast, most archaeological sites (at least the known ones) are within a few feet of the surface, and often instruments are configured to limit the depth of response to better resolve the near-surface phenomena that are likely to be of interest. Another challenge is to detect subtle and often very small features–which may be as ephemeral as the stained soil from decayed wooden posts–and distinguish them from rocks, roots, and other natural "clutter." To accomplish this requires not only sensitivity, but also high density of data points, usually at least one and sometimes dozens of readings per meter. The major developments that have made archaeological geophysics a practical tool have been high-speed automated data logging and computer technolo-

David Maki of Archaeo-Physics conducts a ground penetrating radar survey. The instrument is a pulseEKKO 1000, manufactured by Sensors and Software. Transmitter and receiver antennas are being pulled across the ground. The trailing wheel is an odometer that records the position of each reading as the instrument is pulled with ropes marking successive traverses.



Results of an electrical resistance survey of an historic fort. Electrical resistance meters are similar to the ohm meters used to test electrical circuits. Archaeological features are detectable when they have higher or lower electrical resistance than surrounding soils. Color is used to show extreme values, which allows subtle detail to be displayed in the gray range, which displays values close to the geologic "background" value. In this map, buried building foundations, streets, and even the compacted soils of wagon-wheel tracks are visible.

Geoffrey Jones uses a Geoscan Instruments fluxgate gradiometer to map a prehistoric archaeological site. This instrument is basically a sensitive magnetometer. It is compact and speedy, and is capable of mapping many types of archaeological features. Under favorable conditions, it can detect a wide variety of materials ranging from decayed wood and food refuse to stone and metal. It can even detect places where soils and rock have been heated by fires.



A gradiometer survey of a prehistoric archaeological site in Wyoming. Circular colored areas show magnetic highs caused by ancient campfires. This is a small detail of a much larger site, and most of the survey area showed no evidence of human activity. Clusters of features like this one left by prehistoric hunters were scattered across the site, but would have been difficult to locate without geophysical mapping. Archaeologists were able to concentrate their efforts on areas like this, maximizing the information gained (the site was subsequently destroyed by mining), while saving time and money.

gies to handle, analyze, and plot large amounts of data.

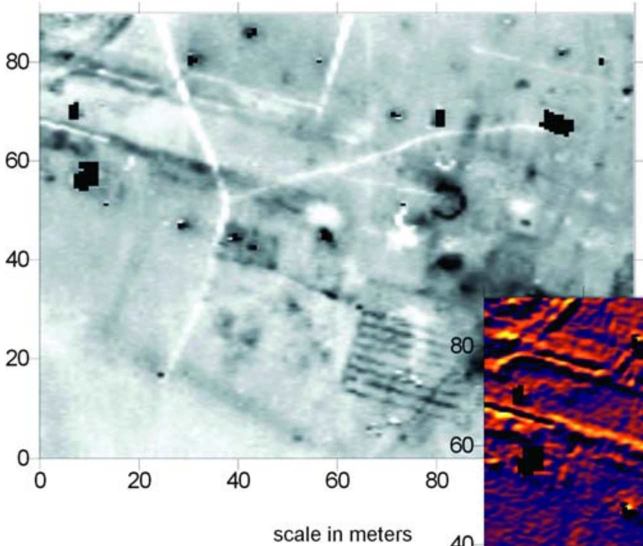
Ground penetrating radar (GPR) is the best known of these methods (although it is not the most widely applied in archaeology). The concept of radar is familiar to most people. In this instance, the radar signal–an electromagnetic pulse–is directed into the ground. Subsurface objects and stratigraphy (layering) will cause reflections that are picked up by a receiver. The travel time of the reflected signal indicates the depth. Data may be plotted as profiles (which resemble the readout of a sonar "fish finder"), or as planview maps isolating specific depths.

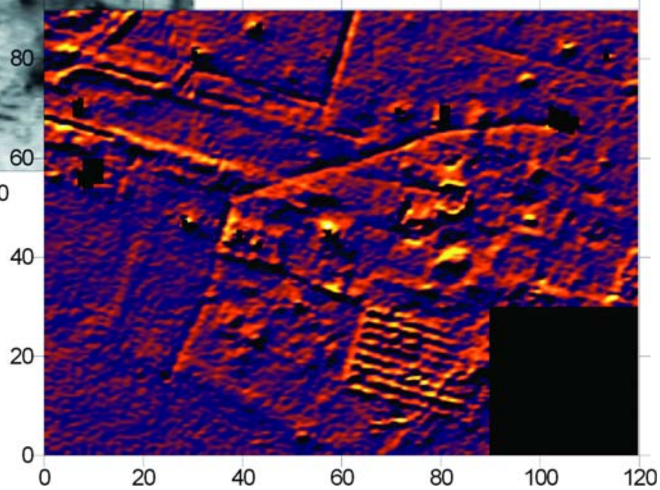
While GPR can be a powerful tool in favorable conditions (uniform sandy soils are ideal), it can be very finicky and perform poorly under many conditions. Another disadvantage is that data collection is relatively slow. While a number of alternative technologies may be used, electrical resistance meters and magnetometers are the real workhorses of archaeological geophysics. They are relatively rapid, are able to detect many types of features under a wide range of conditions. Because they measure different physical properties, they can be complementary and are often used together.

Electrical resistance meters can be thought of as similar to Ohm meters used to test electrical circuits. Metal probes are inserted into the ground to obtain a reading of the local electrical resistance. Archaeological features can be mapped when they are of higher or lower resistance than their surroundings. A stone foundation might impede the flow of electricity, for example, while the organic deposits within an outhouse pit might conduct electricity more easily than surrounding soils.

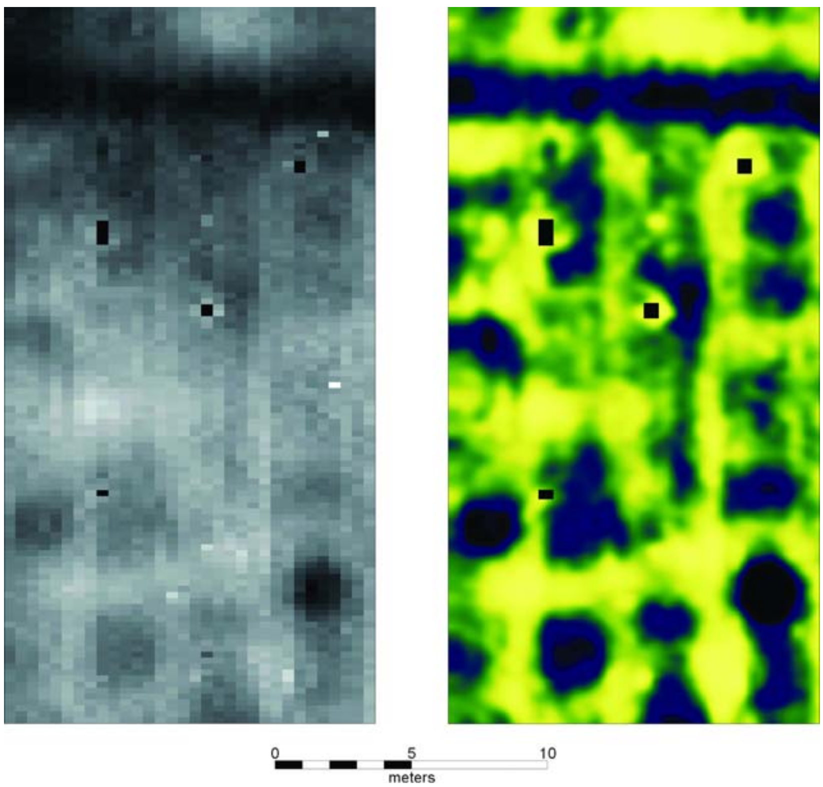
Every kind of material has unique magnetic properties, even those that we do not think of as being "magnetic." Different materials below the ground can cause local disturbances in the earth's magnetic field that are detectable with sensitive magnetometers. Magnetometers react very strongly to iron of course, and brick, burned soil, and many types of rock are also magnetic, and archaeological features composed of these materials are very detectable. Where these highly magnetic materials do not occur, it is often possible to detect very subtle anomalies caused by disturbed soils or decayed organic materials.

Regardless of the particular sensing instrument, geophysical survey usually involves walking with the instrument along closely spaced parallel traverses, taking readings at regular intervals. In most cases, the area to be surveyed is staked into a series of squares (often 20x20 meters).





Resistance survey results from a mid-19th century brewery. The site is now a city park, and no sign of archaeological features is visible on the surface, but the geophysical map shows a multitude of buried building foundations, and even a city street and associated utility lines. Survey results are presented as a greyscale map of data values, and in shaded relief for more intuitive interpretation. This survey was used to assess archaeological impacts of a proposed flood control project.



Data processing and display can greatly enhance interpretation. The image on the left is a plot of raw resistance data from a 19th century cemetery. Although the data are of very good quality, the patterning of the graves can be seen only faintly. In the processed image on the right, rows of graves can be seen very clearly, generally appearing in the green-blue range of the color scale. The dark east-west band near the top of the image is thought to be a utility line, possibly intruding into burials. Existing grave markers are indicated in white. Although individual graves may not be clearly defined, it is obvious that there are many unmarked graves. It also appears that grave markers do not correspond well with detected graves, suggesting that the stones may not be in their original places.

With the corners of the squares as known reference points, the instrument operator uses tapes or marked ropes as a guide when collecting data. In this way, positioning error can be kept to within a few centimeters for high-resolution mapping. Instruments using differential GPS to record position have been used for low-resolution reconnaissance, but under field conditions, these lack sufficient precision for most applications.

The Big Picture

In addition to ground-based geophysical mapping, archaeologists are becoming more effective by integrating remote sensing, GIS, and other spatial technologies as analytical tools. Patterning and relationships can be studied within sites and between sites, across regions, and through time. Accurate and well-integrated spatial data is also important to interface with developers, government agencies, and other researchers. Land surveyors, geographers, and other geospatial professionals are working more often and more closely with archaeologists. While archaeology has become an integral part of land use and development, spatial technologies have become indispensable to archaeologists.

Geoffrey Jones is an archaeological geophysicist and a partner with the consulting firm Archaeo-Physics, LLC, in Minneapolis, MN. The company performs geophysical surveys of archaeological sites, cemeteries, and environmental mitigation sites across North America and worldwide. More information on geophysical imaging with numerous case studies can be found on their website at www.archaeo-physics.com.