GROUND PENETRATING RADAR APPLICATIONS TO CONNECTICUT ARCHAEOLOGY: EXCAVATION IN THE DIGITAL AGE

By David E. Leslie

Archaeologists, in both public and research settings, have long searched Connecticut landscapes for evidence of peoples' lifeways and histories in a generally successful effort to uncover compelling stories about the past. Traditional methods of archaeological investigation have proven fruitful, particularly in our state, where the archaeological community has documented a rich history. Past pages of *Connecticut Explored* are filled with incredible archaeological discoveries (see, for instance, "Exploring and Uncovering the Pequot War," Fall 2013; "Connecticut's Contested 17th Century Landscape," Summer 2019; and "12,500-Year-Old Paleo-Indian Site Discovered," Spring 2020) and important stories of people commonly forgotten by historians of their time that have been critically informed by archaeological investigations (see the Spring 2023 profiles, "Archaeology at the Freeman Houses in 19th-Century Bridgeport's Little Liberia Community" and "Eastern Pequot Archaeological Field School"). Given all these successes, we may wonder how we can improve the general process of archaeology. Put another way, is it possible for archaeologists to identify archaeological sites and the features within them more quickly or, even better, to identify sites without physically disturbing them? Geophysical applications to archaeology, which are increasingly common and include techniques such as ground penetrating radar, metal detection, and magnetometry, provide an important element in the archaeological "toolkit" when assessing a site's potential.

When people think of an archaeologist, they may conjure ideas of an adventurer with a fedora and bullwhip or a professor pontificating about past societies. The fedora and bullwhip notwithstanding, these pursuits represent only a small fraction of archaeological practice in the United States. Recent estimations by Lynne Sebastian and William D. Lippe in *Archaeology and Cultural Resource Management* (School for Advanced Research Press, 2010) indicate that over 90 percent of archaeology is conducted within the framework of cultural resource management (CRM), an umbrella term to describe archaeology done to comply with federal, state, and local regulations, generally before a development project. Already tasked with undertaking most archaeological investigations within the United States, CRM archaeologists are now inundated with work that must precede infrastructure projects like improving roadways, replacing bridges, and installing electrical transmission lines and solar arrays.

At the same time, archaeologists who work in museums or curation facilities are grappling with limited space from over 50

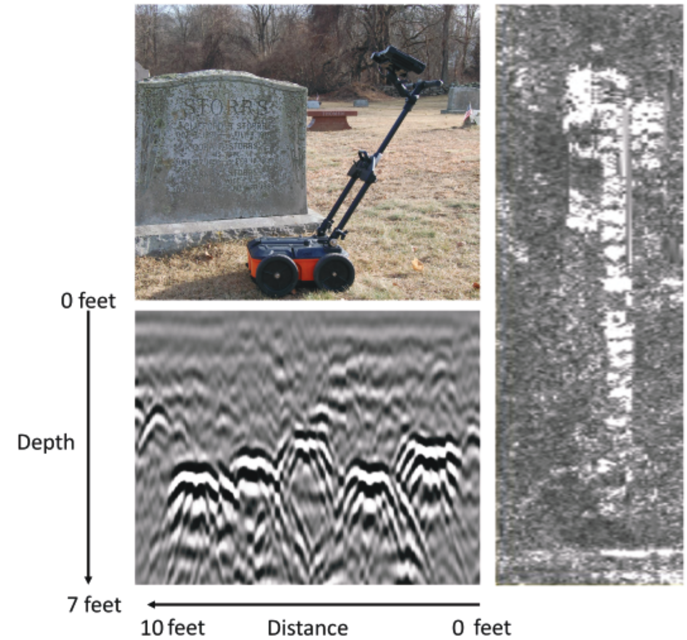

Figure A. A GPR machine in a historic cemetery (upper left). A radargram, or below-ground profile, of five intact coffin interments, indicated in the radargram at approximately 3.5 feet below the ground surface (lower left). A plan view, or amplitude map, of 31 intact coffins, visible as highly reflective rectangular shapes in orderly rows, at about 3 feet below the ground surface (right). Only 13 of these graves were marked by headstones! photo and images: TerraSearch Geophysical LLC and Heritage Consultants LLC

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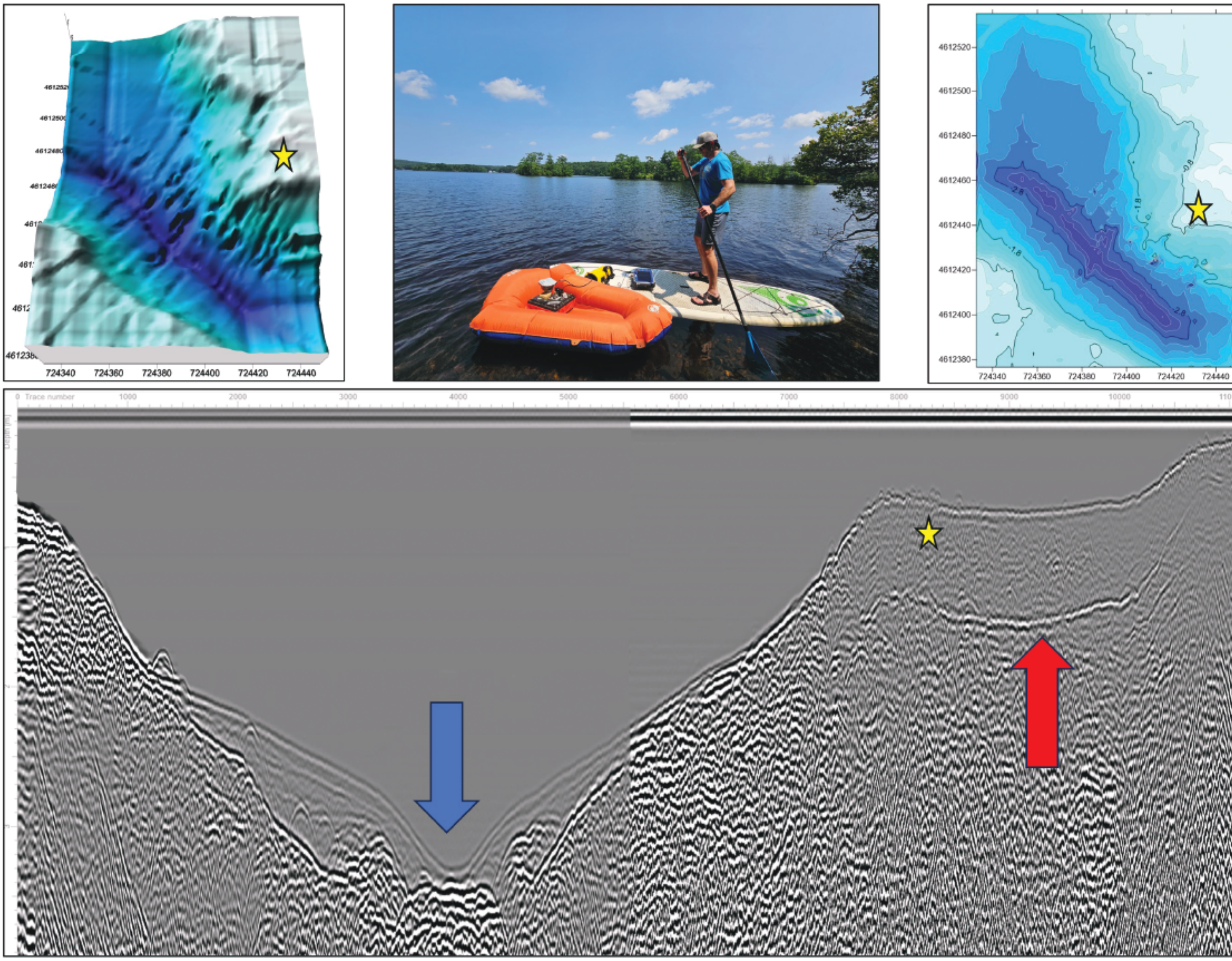


Figure B. Waterborne GPR data collection at Williams Pond (top center). GPR-derived bathymetric contours (upper right) and three-dimensional model of the inundated landscape (upper left). Select GPR transect (lower) displays the highly reflective pond floor and underlying stratigraphy, including the inundated river channel morphology (blue arrow) and a buried floodplain (red arrow) associated with the Liebman Site (yellow star).
photo and images: TerraSearch Geophysical LLC

years of compliance- and research-based archaeological projects. Furthermore, there is less and less space available for archaeological collections, necessitating a shift in either how we conduct archaeology or how we sample sites. Archaeologists also must contend with a complicated past, during which archaeologists often raided the graves of Native Americans or excavated archaeological sites without any collaboration with or permission from descendant communities. Any of these issues cause concern regarding the normal archaeological process; taken together, they represent a need to reevaluate the means and methods of archaeological practice.

Geophysical applications to archaeology present an opportunity to update these archaeological investigation techniques in several ways. They can target archaeological features without employing costly excavation techniques, such as large shovel test pit and excavation unit surveys, which require multiple trained professionals. They can also reduce the number of artifacts recovered and requiring curation and thus the overall effort associated with archaeological investigations. These applications can identify archaeological sites, including precolonial or post–European contact burials, and ensure these areas are properly protected. They can remotely identify archaeological sites with minimal investigations, resulting in far less impact on significant sites or places of cultural importance to descendant communities.

While many geophysical techniques are available to archaeologists, ground penetrating radar (GPR) represents the most

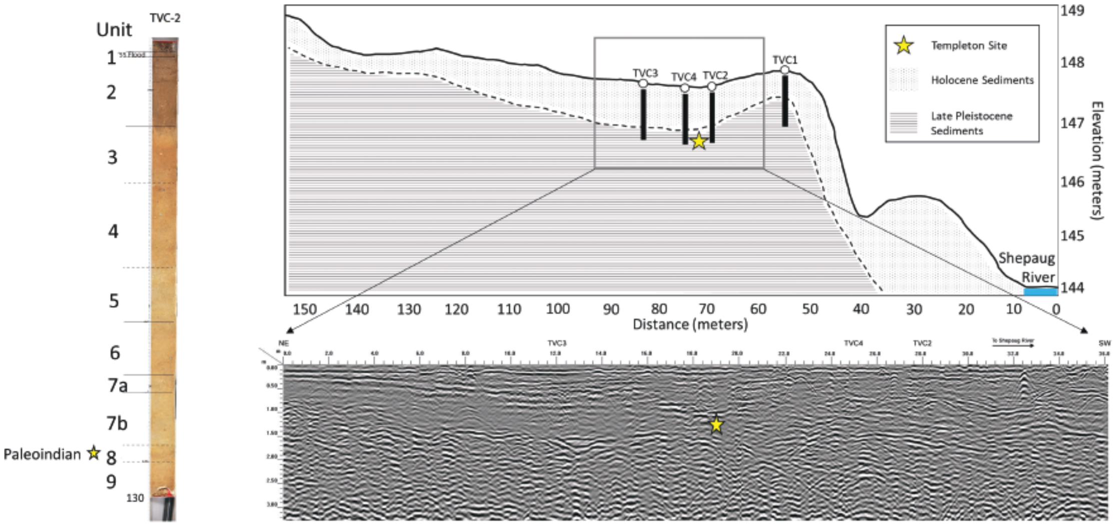


Figure C. High-resolution image of sediment vibracore collected from the Templeton Site (left), with preliminary sedimentary unit designations and uncalibrated Accelerator Mass Spectrometry radiocarbon dates from sediments. Elevation profile (upper right) indicates the position of the site and vibracore locations. GPR transect radargram (lower right) displays the alluvial sedimentation and stratigraphy of the site with Paleo-Indian occupation indicated by a yellow star. images: TerraSearch Geophysical LLC, Peter Leach, and Archaeological Society of Connecticut

widely used application, with some of the most significant results. GPR machines emit a pulse of electromagnetic energy into the ground via an antenna. The energy is either reflected, amplified, or absorbed by the material it is transmitted through. A computer integrated into the antenna records the strength of the signal emitted and reflected, as well as the time (in nanoseconds) required for the reflection and return of the signal. Variations in subsurface materials, such as stratigraphic layers of soils, archaeological features, or geologic layers (think bedrock), are examples of reflective layers or boundaries generally identified via GPR surveys. GPR is often considered the most accurate and highest-resolution type of geophysical technology. It works best in dry, sandy soils but is less effective in soils or water with high salt or clay content. The latter materials readily absorb the electromagnetic energy, resulting in a scattering effect where no or very little signal returns to the antenna.

As with all archaeological techniques, GPR works best in tandem with other remote sensing techniques, such as magnetometry, the use of uncrewed aerial vehicles (UAVs or drones), metal detecting, and Light Detection and Ranging (LiDAR) surveys, as well as "ground truthing" via normal archaeological excavations. LiDAR represents a way to measure the surfaces of objects or the earth via a laser transmitted and received from an antenna, with distances measuring the time it takes the laser to leave and return to the antenna. Recent innovations in GPR processing and analytical techniques, as well as individual investigations in Connecticut, are expanding the ways archaeologists can better understand the past.

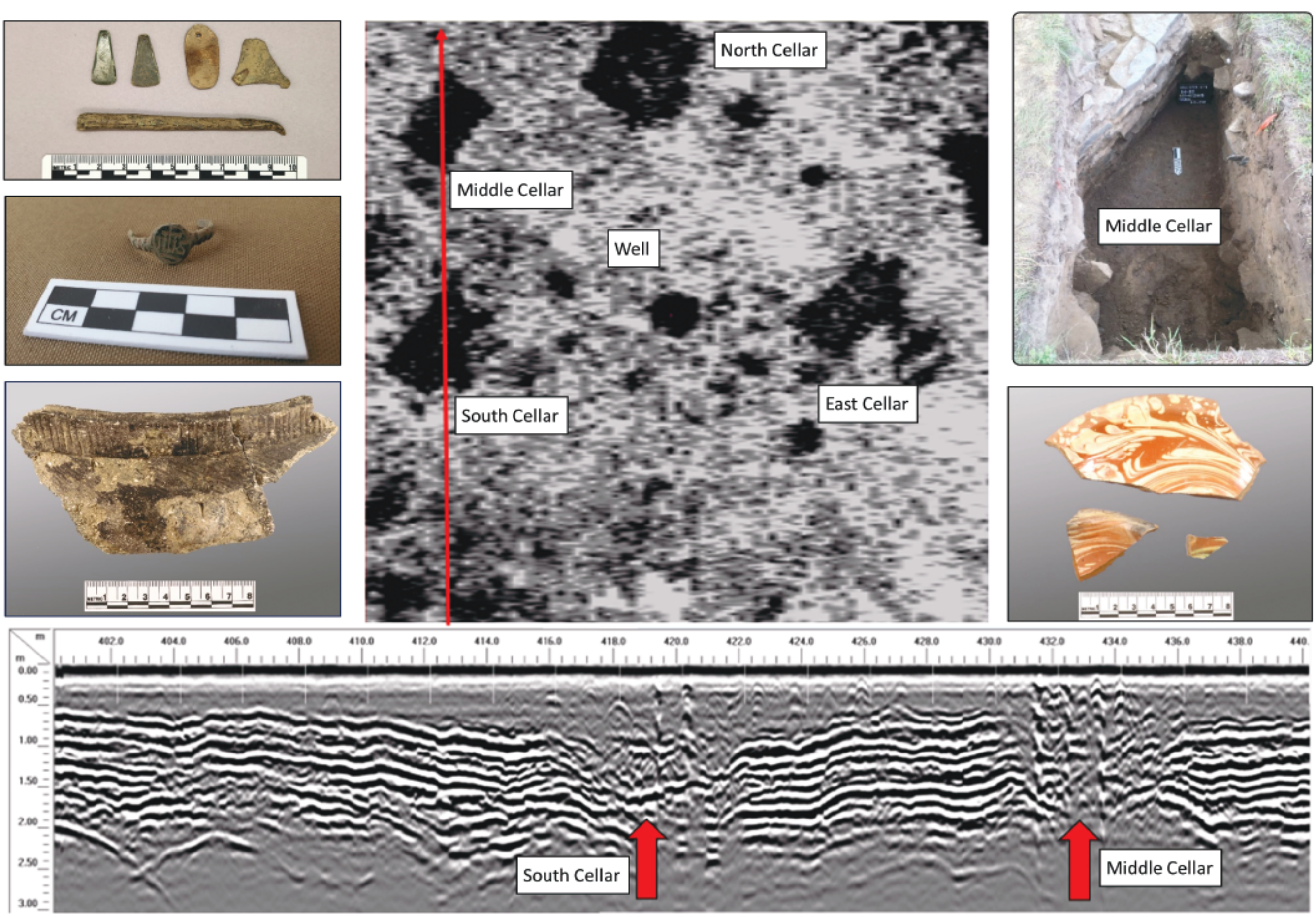
Historical cemeteries are perhaps the most common and effective location for GPR studies; the contrast between intact soils and grave shaft deposits or fill soils that generally include mixed soil strata provide ideal conditions for effective geophysical surveys. When present, wooden and metal coffins provide important transformations of the radar signals emanating from and returning to the antenna. Encountering wood generally causes a significant polarity change in the return signal received by the antenna, while metal is highly reflective, restricting the penetration of the radar waves.

Unfortunately, historical graveyards were often dramatically altered during the late 19th and early 20th centuries. In some cases, old cemeteries, like Hartford's Ancient Burying Ground, were originally much larger than they are today. As communities expanded, many of these lots became prime real estate, and gravestones (and sometimes burials) were relocated to make way for new infrastructure. In other cases, headstones were rearranged into neat lines in service of cemetery beautification projects and modern landscaping techniques. These processes resulted in "lost" cemeteries or burials and the separation of markers from their associated burials. While incredible work is now underway throughout our state to preserve these burying grounds (see, for example, "Preserving Connecticut's Historic Burying Places," *Connecticut Explored*, Winter 2022–2023), GPR studies provide a way to link these preservation efforts with active maps of historical burials (see fig. A). GPR studies are also useful for cemetery boards or sextons, as these surveys can provide maps of existing burials and identify areas where no burials are present and can therefore be used for future burials. Indeed, the Connecticut State Historic Preservation Office actively recognizes the importance of GPR work in cemeteries and offers a nonmatching grant opportunity to support geophysical surveys of historical burying grounds within our state.

GPR has been instrumental in investigating several archaeological sites throughout Connecticut, from the earliest periods of human occupation (Paleo-Indian period) to the more recent industrial age (mid-to-late 19th century). GPR investigations at the Liebman Site, a Middle Paleo-Indian site excavated by Dr. John Pfeiffer in the 1990s and preserved beneath Williams Pond in Lebanon, have helped to locate the now inundated terrace originally inhabited by Paleo-Indians, adjacent to a stable river system (see fig. B). GPR surveys were conducted by paddleboard and raft and documented the stratigraphy of the site, as well as future areas for investigation via sediment coring. Similar investigations at the Templeton Site, a site excavated by Dr. Roger Moeller in the 1970s and '80s and Dr. Zachary Singer over the last decade, have also helped situate the formation processes of the site or the ways in which artifacts are preserved at a site. In this case, the Templeton Site is preserved, like the Liebman Site, on a terrace adjacent to a river and was gently buried by successive flooding over 11,000 years. At Templeton, GPR investigations were paired with terrestrial "vibracoring," a process where a concrete vibrator is attached to an aluminum barrel core and driven into the ground using the vibration of the core, reducing the frictional resistance of the coring method. This technique was particularly effective in understanding site-formation processes. It produced a radiocarbon-dated sequence of the site documenting over 5,000 years of Paleo-Indian and Early, Middle, and Late Archaic activity (see fig. C). GPR, when paired with vibracoring, has been an effective tool to help archaeologists reevaluate the environmental settings of the earliest archaeological sites preserved within our state and to aid in the identification of future sites.

Perhaps no site in Connecticut has benefited more from integrating geophysical techniques than the Hollister Site, a 17th-century farm complex preserved in South Glastonbury. The layout of the site was originally discovered through a

Figure D. Amplitude map of the Hollister Site (upper center) at approximately 3 feet beneath the ground surface. The red arrow in the amplitude map indicates the position of the radargram transect (below) shown from left to right. 17th-century Native American and European artifacts recovered from the site are shown. Profile of the stone-lined middle cellar (upper right). photos and images: Connecticut Office of State Archaeology and Peter Leach



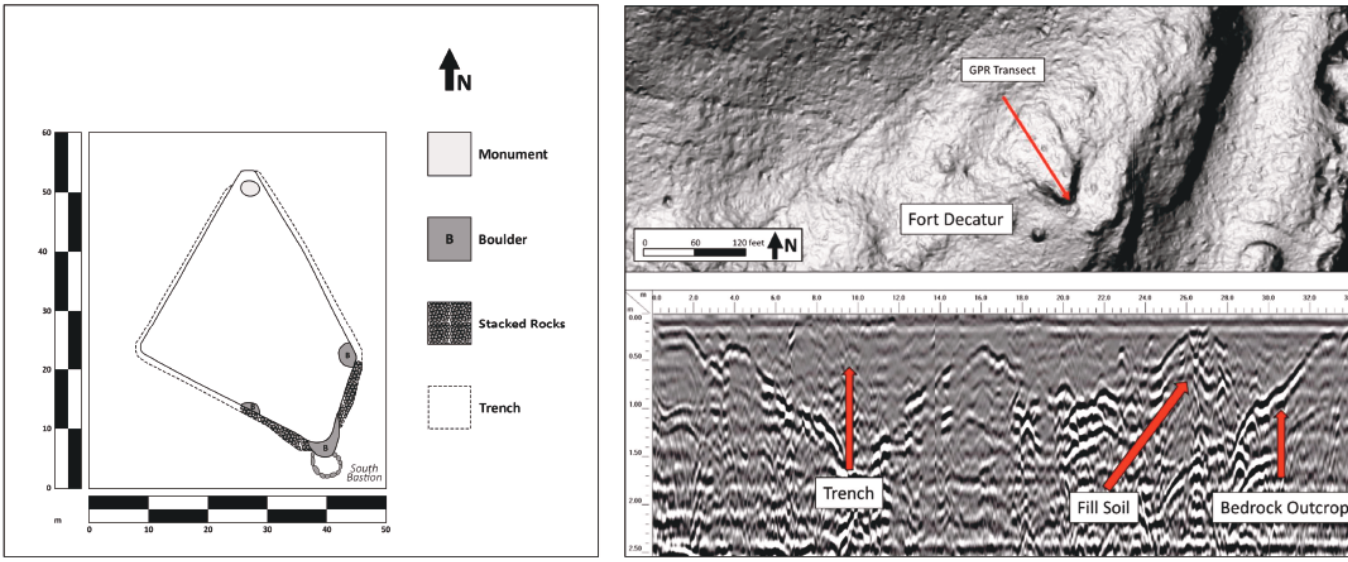


Figure E. Diamond-pointed sconce fort schematic from traditional archaeological investigations of Fort Decatur (left). LiDAR map of hilltop and fort (upper right). Radargram (lower right) shows the construction of the trench, fill soil that was brought in from a nearby borrow pit to raise and level the south-facing portion of the fort above the south bastion, and an existing bedrock outcrop. images: Heritage Consultants LLC

collaboration between Peter Leach of Geophysical Survey Systems Inc. and Dr. Brian Jones, then the Connecticut state archaeologist.

Together, they provided compelling evidence for multiple 17th-century features, including six large cellar holes and two wells. Later geophysical investigations by Maeve Herrick, Jasmine Saxon, and Cyndal Groskopf, graduate students at the University of Denver, and continued excavations by Jones and current state archaeologist Dr. Sarah Sportman have uncovered a wealth of information about the Gilbert and Hollister families and their complicated interactions with their Wangunk neighbors (see fig. D). It is difficult to overstate the importance of GPR in the investigation of this site: while traditional excavation methods might have taken years to identify the layout of structural features at the site, the GPR survey identified the features in a single afternoon!

Geophysical techniques were also very effective in relocating Fort Decatur, a War of 1812 fort preserved in Gales Ferry. The fort, named after Commodore Stephen Decatur, was erected to protect Decatur's ships and men from a possible British attack after his fleet was blockaded in the Thames River in 1813. While the fort's location was previously established through 19th-century maps, and there has been renewed interest in the fort's history (see "War of 1812: The Mysterious Bluelights" and "Site Lines: Fort Decatur," *Connecticut Explored*, Summer 2012), the site had not been professionally investigated. Fortunately, a recent study using traditional and geophysical methods uncovered evidence that suggests the fort is eligible for listing in the National Register of Historic Places under multiple criteria. While traditional archaeological investigations helped map the fort, they uncovered very few military artifacts. The application of geophysical techniques, however, was a game changer. A systematic metal detector survey yielded over 70 period artifacts, including musket balls, military uniform fragments, and fort-related construction implements. A statewide airborne LiDAR survey was also useful in identifying the fort. The LiDAR and GPR surveys, conducted in conjunction with the metal detector investigation, provided excellent evidence of fort construction techniques and aided in identifying Fort Decatur as a highly defensible diamond-pointed sconce fort (see fig. E).

Geophysical survey techniques have also successfully located and documented industrial archaeological sites. Along the Hop River in Columbia, a series of 19th-century mills were constructed, primarily to serve the garment industry of the day. While some remnants of these mill structures are visible at the surface and historical documentation of the buildings exists, the physical locations of the structures were unknown until a combined GPR and magnetometry survey was conducted. Magnetometers are machines that are attuned to the earth's magnetic field and can measure large and small variations of materials buried in the ground. Magnetic materials in historical-period sites are most likely to be ferrous artifacts, the remains of structures lined with magnetic fieldstones or bricks, or the midden or fill deposits buried within these structures. At the Hop River Warp Mill Site, the combined strengths of these survey techniques proved particularly effective at identifying the structural elements of the 19th-century mill complex (see fig. F). Similar geophysical efforts also positively identified a remnant

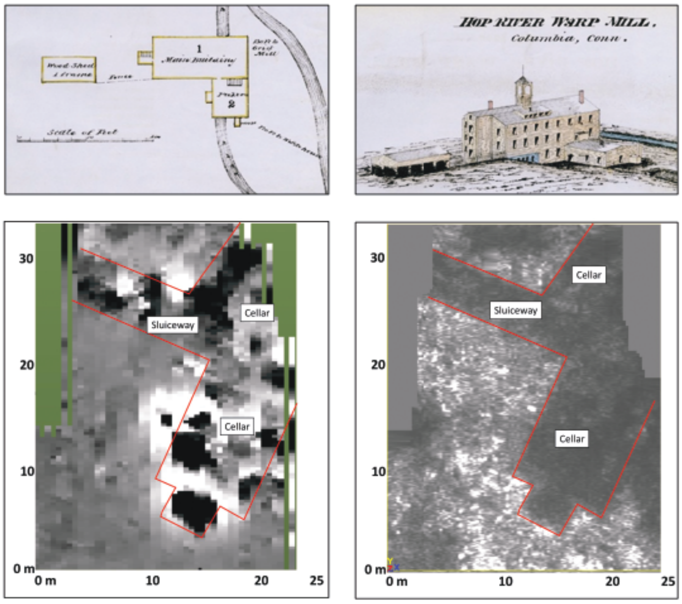
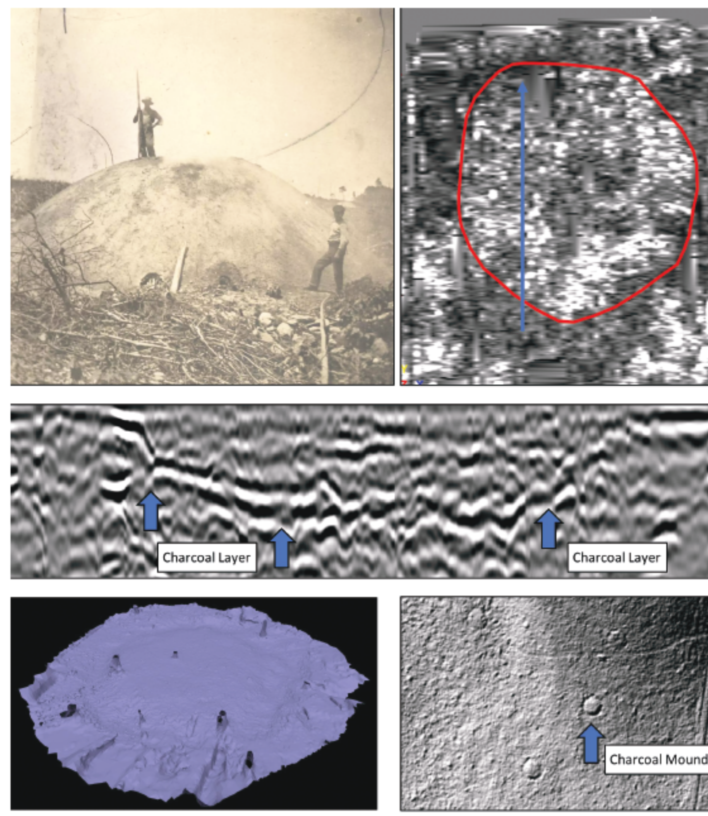


Figure F. Insurance maps of the Hop River Warp Mill from 1874 (upper left and right). The GPR amplitude map (lower right) indicates large cellar foundations for the mill and sluiceway, also clearly visible in the magnetic anomaly map (lower left). Outlines for the cellars and sluiceway are indicated in red. images: Columbia Historical Society and TerraSearch Geophysical LLC

charcoal mound in the Natchaug State Forest in Eastford. Charcoal mounds are relics of the collier industry, which focused on producing wood charcoal through controlled timber burning. In the early 19th century, charcoal was the primary fuel source for the iron and steel industries. Charcoal mounds were created by slowly burning wood and smothering the fires in large earthen mounds. After several days, the mounds were excavated to retrieve large quantities of lump charcoal that were then sold to fuel local industries. The Natchaug State Forest Site was identified through a combination of LiDAR mapping, digital photogrammetry through UAV flights, and GPR, showcasing the archaeological results that are possible when multiple remote sensing techniques are employed (see fig. G).

These case studies illustrate the range and depth of the uses of GPR and other geophysical and remote sensing techniques in archaeological investigations. While no technique can provide a panacea for understanding the past, GPR studies represent a powerful way to identify and interpret archaeological sites, often with minimal ground truthing or disturbance. This technology, when paired with other geophysical applications, provides an essential digital toolkit that can be used to better identify, image, and understand our state's archaeological resources, particularly for those archaeologists who work within the framework of CRM. Using this technology within development-focused or academic archaeology will also aid in the reduction of overall archaeological efforts by helping to focus investigations, thereby reducing the number of artifacts requiring curation. Expanded use of GPR is also essential so that archaeologists can work closely with communities to identify and avoid impacting archaeological resources, interments, and culturally sensitive landscapes and sites. ☛

Figure G. A 19th-century photograph of a large charcoal mound produced by a collier (upper left). GPR amplitude map of a remnant charcoal mound (upper right) in the Natchaug State Forest. The charcoal mound is highly reflective and indicated by a red outline, as is the transect position (blue arrow) of the radargram (center). The charcoal mound is also visible in LiDAR imagery (lower right) and a three-dimensional model of the charcoal mound (lower left) created from UAV photography.
photo and images: Cornwall Historical Society and TerraSearch Geophysical LLC



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