In late September 2013, Nick Bellantoni, the Connecticut state archeologist, was asked to assist police in Manchester, CT on a cold case from the early 1950s. An alleged child molester living in Manchester at the time was suspected of murdering a girl and burying her body somewhere on his property. After a witness came forward, police dug the floor of the suspect’s former garage but found nothing. However, the witness also remembered seeing a suspicious burn pit in the backyard, where she’d played sometimes as a child. This is where Bellantoni came in. Authorities wanted him to search for the decades-old pit with ground-penetrating radar (GPR).

Unlike police radar that sends radar waves through the air, GPR works by sending this energy into the ground. Some of it then bounces back to a receiving antenna when it hits what are termed “anomalies”—or unusual features—in the soil. In the Manchester case, Bellantoni’s survey detected four such spots in the backyard. One of them also corresponded to a location where the suspect was seen digging. But when the investigators dug down, they unearthed only aspirin bottles and other debris from the 1940s and 1950s. “It turns out what he was digging were garbage pits,” Bellantoni says.

No television producer would ever choose to end a TV crime drama with such a mundane finding, nor would it necessarily make the news. But in the real world, not only is this kind of outcome entirely typical of GPR work, it also illustrates the instrument’s power. Radar surveys have definitely helped locate hidden graves and bodies, says Jim Doolittle, a USDA-NRCS soil scientist and GPR expert who collaborates frequently with Bellantoni. “But in a lot of other cases, we go out and we just don’t find anything. Well, that’s information in itself.” The first time Doolittle helped in a forensic investigation, he was disappointed not to detect any additional remains after a human bone was discovered at an Idaho highway rest stop. The authorities, on the other hand, were extremely pleased.

“Other than tearing up the whole site, which was financially out of the question, the sheriff could report that we had done everything to assess if the body was at the site,” says Doolittle, an SSSA member. “He was satisfied that he had gone the extra mile to do a survey with GPR, and he had peace of mind.”

Besides ruling certain locations out, GPR also helps investigators pinpoint the most promising ones, as it did in Manchester. “To have a glimpse of what’s underneath the ground before you start is a tremendous benefit,” Bellantoni says. Still, like any technology, the instrument has limitations, he adds. And only by working carefully through them have archeologists, forensic investigators, and soil scientists made GPR the valued search tool it is today.

“The positive stories seem to be pushed to the forefront. But we learn—and I’ve learned mostly—from times when the radar didn’t work,” Doolittle says. “You ask: What am I up against? And it’s usually something in the soil.”

Pioneering GPR Use in Soils and Discovering its Limitations

Doolittle knows this better than nearly anyone. After reading about GPR’s potential to map soils in a 1980 newsletter published by NRCS (then, the Soil Conservation Service), he applied for a Soil Conservation Service job in a Florida and became USDA’s first-ever GPR operator. Not long afterward, he connected with Mary Collins, herself a new soil science professor at...
the University of Florida. Together, they pioneered the use of GPR in soils.

They worked hard, of course, but they were also lucky, admits Collins, who is now retired and lives in Iowa. “One of the reasons we were pioneers down there,” says the ASA and SSSA Fellow, “is that the soil conditions were ideal for using the radar.” Doolittle learned just how ideal they were in 1983, the first time he took his radar unit on a demonstration trip outside of Florida. At his first stop near the town of Hondo, TX, he tried to chart the depth to bedrock with GPR as a large crowd of spectators looked on—and failed utterly. “I’ll never forget that day,” he says. “The radar had no penetration.”

What soil scientists now know is that radar energy quickly attenuates when the electrical conductivity of the soil is high, such as when soils are saline or contain a lot of clay, as in Hondo. “The signal energy gets absorbed by the chemical properties of the soil so that we don’t get a reflection back,” Collins explains. But in Florida, she adds, where many soils are composed of electrically resistive sand, “Oh, it would work beautifully.” Doolittle would spend much of the next two decades refining this understanding of the conditions under which GPR worked well and those where it didn’t. Eventually, he linked this information to the U.S. soil classification system to create a GPR “soil suitability map” of the entire continental United States.

Another limitation is that GPR can detect things, but it doesn’t identify them. That is, rather than producing a full-blown image of, say, a skull, GPR usually only indicates the presence of something unusual—or a “generalized anomaly,” says John Schultz, a University of Central Florida forensic anthropologist, who earned his doctorate with Collins. This means the larger context is critical when hunting for a clandestine grave.

“We need to think about where the anomaly is, how deep it is, its size,” Schultz says. “For example, if we’re getting anomalies near a tree, well, there’s a pretty good chance we’re hitting tree roots.” Or if a septic tank or electrical line is present underground, investigators need to know, so they can rule those areas out.

This also means that GPR work is never complete without some ground-truthing of the results; in other words, a dig to discover what the anomaly truly is. “We’ve been fooled before, thinking [we’ve spotted] what we were looking for,” says Debbie Surabian, who as state soil scientist for Connecticut and Rhode Island works frequently with Bellantoni and Doolittle. “Then we dig and we say, ‘Oh, that’s what it is,’” she adds with a laugh.

On the positive side, fewer holes are usually required to complete an inquiry because “you can home in on something unusual—or a generalized anomaly,” says John Schultz, a University of Central Florida forensic anthropologist, who earned his doctorate with Collins. This means the larger context is critical when hunting for a clandestine grave.

“We need to think about where the anomaly is, how deep it is, its size,” Schultz says. “For example, if we’re getting anomalies near a tree, well, there’s a pretty good chance we’re hitting tree roots.” Or if a septic tank or electrical line is present underground, investigators need to know, so they can rule those areas out.

This also means that GPR work is never complete without some ground-truthing of the results; in other words, a dig to discover what the anomaly truly is. “We’ve been fooled before, thinking [we’ve spotted] what we were looking for,” says Debbie Surabian, who as state soil scientist for Connecticut and Rhode Island works frequently with Bellantoni and Doolittle. “Then we dig and we say, ‘Oh, that’s what it is,’” she adds with a laugh.

On the positive side, fewer holes are usually required to complete an inquiry because “you can home in on something the radar sees,” Doolittle says. “So there’s a greater likelihood you’ll have a productive pit or excavation.”

Using GPR in Criminal Investigations

Increased efficiency is of course vital in criminal investigations, so
it wasn’t long before forensic specialists began homing in on GPR. In 1983, Gregg Schellentrager became the first USDA soil scientist to work on a forensic case. Near Vero Beach, FL, he searched unsuccessfully with GPR for the buried body of a missing six-year-old boy. The boy’s father, John Walsh, would later host the television program *America’s Most Wanted*.

Collins, too, began helping Florida police locate buried remains. On a day in 1998 that she’ll never forget, she surveyed the ground for the body of a 12-year-old boy murdered years earlier, as an Orlando TV news crew filmed and the boy’s parents watched. Her radar search uncovered nothing, however, but buried rocks and roots. “It was a real shame,” she says, “because I really did want to find something.”

Disappointed as she was, Collins also wasn’t surprised. She knew decomposition happened quickly, making a body buried for years very tough to find with radar. But the police needed specifics. “They always wanted to know, ‘Well, does [decomposition] take six months, six weeks, a year?’” she recalls. “Or, if someone is 150 pounds, how long does it take?’” When she met Schultz, then a graduate student working at University of Florida’s C.A. Pound Human Identification Laboratory, the two decided to collaborate on those questions.

After concluding from reading the literature that GPR was the best tool for hunting for bodies and graves, the scientists carried out their experiment. They dug 24 graves of varying depths and in two soil types common to Florida: ultisols and entisols. Into each hole, they placed individual pig carcasses of different sizes, filled the graves in, and then followed both the decomposition process and GPR’s ability to detect the buried remains over the next two years. Additionally, they monitored at least eight control graves that had nothing inside them but earth. That way, Schultz says, the researchers could see what kind of response they’d get with GPR from simply disturbing the soil.

It turned out to be a pivotal question. What he, Collins, and others have since learned is that while a decomposing body becomes mostly invisible to radar after just one or two years, the disturbed soil of a grave site can remain detectable for decades. “What the radar will pick up are changes in the soil,” Bellantoni explains. “You dig a hole, you put the body in it, and you refill the hole. So, you’ve mixed the soil, you’ve cut through the stratified soil that’s been there for thousands of years. You’ve homogenized the various soil layers.”

Soil that has been removed and then shoveled back into a hole also has more pore spaces—and thus holds more moisture—than the more compacted, undisturbed soil around it. It’s these types of long-lasting “burial features” that allowed Bellantoni to locate the 60-year-old evidence of digging in the Manchester investigation, and help him and his colleagues find Colonial era graves dug as far back as the 1700s.

But there are nuances, as well. In Florida entisols, for instance, which are poorly developed soils often composed mainly of sand, signs of digging can be much harder to spot, Schultz explains. That’s because sand taken from a hole and then put back in tends to blend seamlessly with the surrounding sand, leaving behind little disturbance to detect. He and Collins also found that when a pig carcass was placed directly atop a clay layer it also became difficult to see. “It just looked with GPR like a natural undulation of the clay horizon,” Schultz says.

Something else he’s observed—and that archeologists already knew, he says—is that graves can be easier to locate during the rainy season. The idea again is that disturbed sand has larger pore spaces between the grains. These in turn hold more water, creating more contrast between disturbed and undisturbed soil. But when soils lose this added moisture during the dry season, the effect is lost. “So this told us that seasonality might make a difference,” Schultz says, “even in the forensic realm.”
Searching for Unmarked Graves

Over this career, Schultz has aided law enforcement in dozens of criminal investigations, but what he much prefers these days is searching for unmarked graves in graveyards. The chance of locating a hidden grave is infinitely higher than in forensic work, for one, especially since anomalies in graveyards often occur in rows, Schultz explains. This allows him and his grad students to survey a known grave first to learn the depth, size, and orientation of the grave shafts. They then simply use this “key” to look for unmarked burials.

Besides being easier, graveyard work helps local towns and governments improve their documentation and better manage their cultural resources. In Florida, Schultz is often called in to do a GPR survey when counties are looking to expand roads near cemeteries. In Connecticut, meanwhile, Bellantoni and Surabian are sometimes asked to find unmarked graves in 200-year-old burying grounds. In some cases, old cemeteries are still active. In others, people have made special requests to be buried next to their great-grandfather or great-great-grandfather.

“One of the issues is they don’t want to put somebody in the ground and hit somebody else,” Bellantoni says. “So to know [where the older burials are] is a great management tool.” Plus with GPR, graves can be located without actually having to dig for and disturb them.

John Schultz collecting data over an unmarked grave.

Separating Tall Tales from Historical Events using GPR

Since she began working with ground-penetrating radar (GPR) in 2000, Debbie Surabian has used the instrument to search for all manner of things in the soil, including unmarked graves, buried time capsules, pipes, foundations, water raceways, and even the crash site of a fighter jet.

But finding the objects themselves isn’t what interests the Natural Resources Conservation Service (NRCS) soil scientist the most. It’s learning the truth behind the tales people tell about them. “When I go to these sites, I’m always hearing stories, and they’re part of our history,” Surabian says. “So, is it just a story or is it real?”

One of her favorite examples comes from work she did for a historic cemetery in the Stonington borough of Connecticut. According to the Stonington Historical Society, an English mariner named Captain Thomas Robinson bought 11 acres of land on Long Point in the borough in 1771. He then built a house, sold house lots to others, and began using one lot as a burial place for his family and a few friends. This cemetery was eventually expanded and became known as the Robinson Burying Ground.

The cemetery was thought to contain several unmarked graves, but when Surabian was called in to search for them, she was told about something else that might be under the ground. According to local legend, a British bombshell landed in the cemetery during the Battle of Stonington in 1814 (part of the War of 1812), creating a large crater. When a local woman named Elisabeth Hall died shortly afterward from an illness, Surabian was told, her daughter hastily buried her and her bed in the cavity.
But are there really that many unmarked graves to discover? Absolutely, Bellantoni says. “When people go into cemeteries and see tombstones, they have no idea there are probably double that number” of people buried there. In earlier centuries, he explains, only the wealthy could afford crypts, tombstones, or other permanent burial markers. Farmers, slaves, and other poor and disenfranchised people were given wooden markers or no marker at all. Many old cemeteries, in fact, had potter’s fields or pauper’s areas expressly for these types of burials. And the unbaptized? In some instances, they were placed outside the cemetery perimeter because of Church rules against laying them to rest in sacred ground.

A Growing Field

What this all means is that the need for radar surveys won’t be going away anytime soon. True, other types of geophysical technologies are beginning to see wider use; for example resistivity, electromagnetic induction, and magnetometry measurements are becoming important tools in soils where GPR doesn’t work as well. Still, Schultz says, “Nothing really gives you the real-time information you get with GPR. That’s what makes it such a great tool. You can run around and get results immediately because of the monitor and what it provides.”

Doolittle agrees, adding that the demand for GPR surveys and operators seems to be rising. Case in point: In 1981, he was USDA’s only radar operator; today, NRCS alone has 17. What he doesn’t see growing quite as fast is people’s appreciation of how critically GPR depends on the soil. Even a seemingly straightforward task, such as locating a solid object, can be hampered by soil conditions. As he and Bellantoni described in a 2010 paper, for example, metal coffins weren’t common before the 1860s, and untreated wooden coffins break down relatively quickly in Connecticut’s acid soils. Once this decay occurs, a coffin will collapse and fill with soil from above, making it nearly as impossible to detect with GPR as the bones themselves.

Besides high acidity, Connecticut soils present another difficulty for would-be grave-hunters: They are mostly glacial till, a mixture of unsorted sediments and rocks that vary widely in texture, size, and density. “So, if you’re looking for anomalies and you’re not used to viewing this type of material, it can be really confusing,” Surabian says. “It takes a lot of passes to get comfortable with identifying something out of the ordinary.”

But if people aren’t as aware of these complexities as they should be, this also suggests something else: So long as there are jobs for GPR to do, there will also be work for soil scientists. And that suits Surabian just fine. “It’s not only the variety of work I’ve done as a radar operator—from soil survey to archeological work to police investigations,” she says. “When you’re searching around, you see so much more than you would digging one hole. And it just becomes addicting.”

M. Fisher, Science Communications Manager