# Geophysical Survey Results on the Front Lawn of Red Cloud Indian School, Pine Ridge, South Dakota

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2022

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*On the cover*: Working on radar data collection. (Photo credit: Jarrod Burks)

**OVAI Contract Report #2022-29**

# Geophysical Survey Results on the Front Lawn of the Red Cloud Indian School, Pine Ridge, South Dakota

by

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# Executive Summary

In late May 2022, Ohio Valley Archaeology, Inc. conducted a two-instrument geophysical survey on the proposed site of a new building in the front lawn area of Red Cloud Indian School, Pine Ridge, South Dakota. The survey focused on locating possible signs of graves and other indications of site use, such as old building foundations, pit-type features, and refuse deposits. This work was performed on behalf of Red Cloud Indian School, with assistance from members of the school and the community.

The front lawn area today is a flat, triangular shaped area of mowed grass between the new Holy Rosary Church and U.S. Highway 18. Analysis of historic aerial and ground-based photographs identified a number of features once present in this area. The earliest photographs of the school, including Drexel Hall circa 1890, show a distinct gully or wash feature (at least 10 feet deep) along the west and south sides of the lawn area, out in front of Drexel Hall. Based on later photographs, this gully becomes filled in over the next 10-20 years. Other features in the lawn area visible on photographs include a baseball field and a windmill over what likely is a water well. These features disappear from the area by the 1960s.

The geophysical survey work in the project area included magnetometer and ground penetrating radar surveys covering about 2 acres. The magnetometer survey results show a large number of iron objects scattered across the lawn area. The data also appear to show the former location of the windmill/water well pipe and an iron pipe leading away from the well to the south. While the well dates to the late nineteenth century, the iron objects scattered across the project area likely represent various episodes of fill deposition and grading. The radar survey results include indications of the fill used to flatten out the gully, as well anomalies associated with trees and vehicle/walking paths. No indications of graves, building foundations, or other kinds of archaeological resources were detected.

While the front lawn area appears to have been heavily modified by filling and grading, graves and archaeological features may yet be present beneath these modified layers. Archaeological and tribal monitoring is recommended during ground disturbance activities related to the new construction work. Specifically, grading and bulldozer work for the new building foundation/footprint should begin with or be preceded by careful machine stripping using a flat-bladed excavation bucket with an archaeologist on hand to identify possible cultural features of interest.

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# Acknowledgements

Many very helpful individuals assisted with this project in a variety of important ways. We would like to thank Maka Black Elk, Executive Director of Truth and Healing for Red Cloud, who made this project possible in so many ways—we cannot thank he and his assistant Billy Critchley-Menor, SJ, enough. Likewise, we greatly appreciate the efforts of Executive Vice President Tashina Banks Rama and the rest of the school staff for welcoming us into the community and helping to make our work there go smoothly. In addition, we would like to thank President Raymond Nadolny for welcoming us to the school and making his staff and resources available to us for this project. We would like to recognize, former school staff member, Justin Pourier, who kindly shared his knowledge of events related to the basement of Drexel Hall, where the geophysical survey team also collected radar data (see Report II). In the field, we were assisted by community members, Mato White Plume of the International Indigenous Youth Council-Oglala Lakotah Chapter and Russell Zephier, B.S., both of whom were hired as archaeological technicians. They participated in setting up the survey grid and collecting radar data. We would also like to thank Basil Braveheart and Alex White Plume for their guidance as we all worked together on this survey, being mindful of tribal protocols. Most of all, we would like to thank the Ancestors for having the resilience to continue forward that we may all be here, in a good way. Last but certainly not the least, we appreciate Kevin Killer, President of the Oglala Sioux Tribe for his prescience in bringing Bryan Newland, Assistant Secretary of the Interior, to the survey. It is through networking such as this that we one day may be able to find remedy for the children in the Indian boarding school cemeteries and descendants.

# Introduction

From May 18-21, 2022, and at the request of school officials, Marsha Small and Ohio Valley Archaeology, Inc. conducted a multi-instrument geophysical survey in the front lawn of Red Cloud Indian School in Pine Ridge, South Dakota (Figure 1). This work was performed ahead of a proposed project to construct a new building between the existing church and the school's southeastern entrance. While no graves or other cultural resources are known to be present in this area, the geophysical surveys were conducted to look for unknown or undocumented (1) graves, (2) building foundations, (3) other possible features associated with the school, and (4) use of the area before the school was built in 1887/88.

The following report is organized in several sections. It begins with this brief introduction and a description of the site setting. Next, a methods section discusses graves and their detectability with geophysical survey instruments. The instruments used in the survey are then introduced. A presentation of the geophysical survey results then follows, with descriptions of the geophysical anomalies of interest that were detected. A final summary and recommendation section pulls together the findings and provides suggestions for next steps.

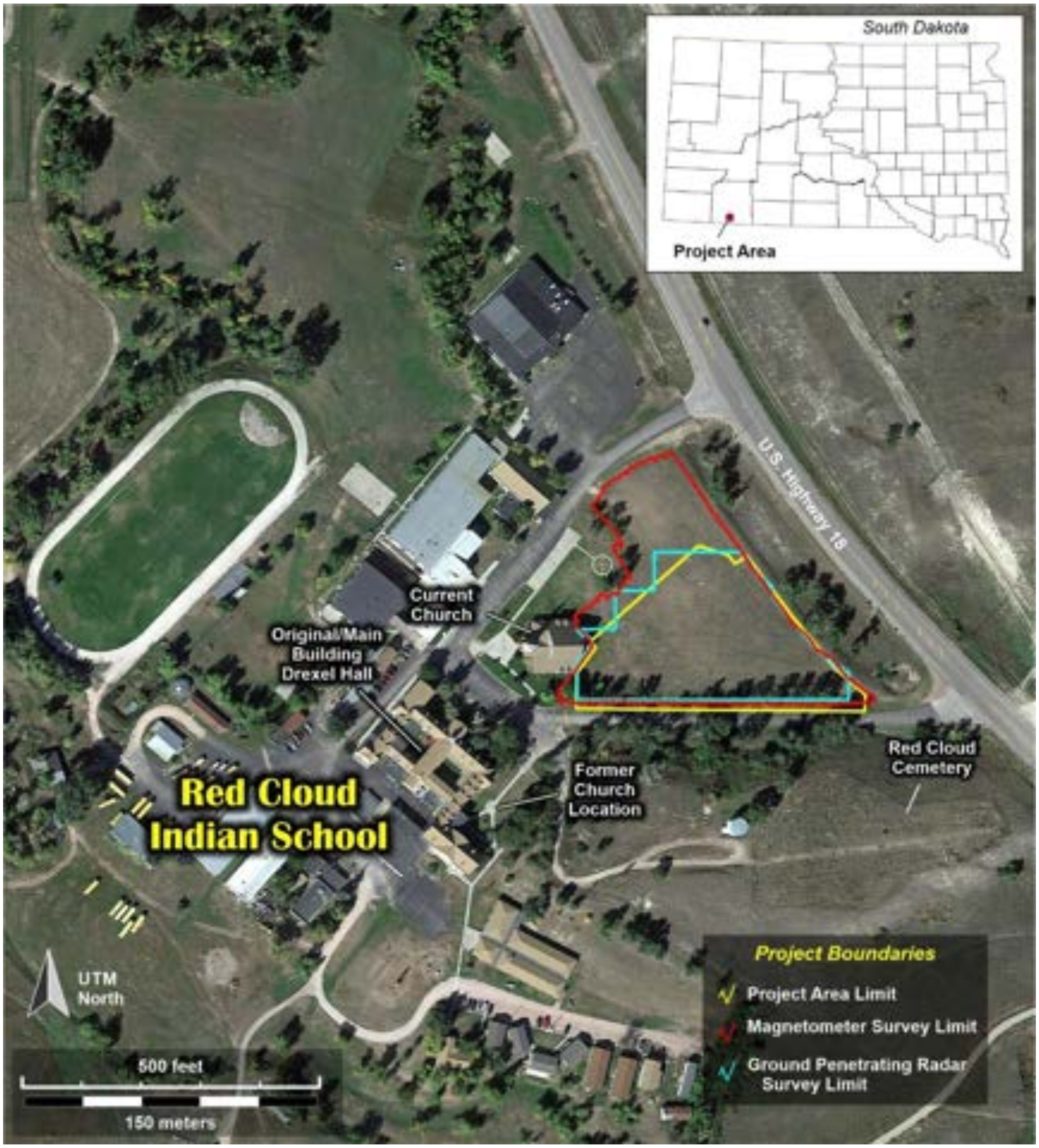


**Figure 1**. Survey area location on a 2016 Google aerial photograph.

## Site Setting

### *Location*

The proposed new building location, the "Project Area," is located on the grassy lawn between the new Holy Rosary Church and U.S. Highway 18 (latitude 43°4.713 north, longitude 102°35.074 west). This area is relatively flat today. The colorful map in Figure 2 is a shaded map of topography based on LiDAR (Light Detection and Ranging) data collected from an airplane and made available online. This image shows a gentle slope downward from the southeast to the west/northwest. An embankment of soil runs along the east/northeast side of the field—likely put in place to catch runoff from the steep road bank along that side of the property and a culvert that allows runoff to move into the area from the other side of U.S. Hwy 18. To the south, the survey extended up to wood barriers along the southern school entrance road, which is lined on the north with trees and small bushes. A ditch and buried utility lines (e.g., a water line) fill the space between the wood barriers and the road to the south. The church and a surrounding drainage ditch define much of the west edge of the project area, with the current medicine wheel to the northwest.

To our knowledge, this portion of the school property has remained open ground and has not been used for buildings. However, the flatness of the ground in this area suggests that it has at least been graded in the past. As we show from historic images, a considerable amount of fill has been added to portions of the project area.

### *Soils and Geology*

Soils play an important role in the outcome of geophysical surveys (Doolittle and Collins 1995; Jordanova 2017; Weston 2001). They are a major determinant in the penetration depth of radar waves and the degree of magnetic contrast between a grave or buried feature (e.g., a building foundation) and its surrounding matrix. They also contain objects, layers, and voids that can look remarkably like archaeological features or graves in geophysical data. Thus, it's worth knowing a bit about the soils and other sediments within a survey area before attempting to tackle the interpretation of geophysical survey results from that area.

According to the United States Department of Agriculture's Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm), the project area is covered by Lohmiller series silty clay loam soils developed into water-laid (alluvial) sediment (USDA 2005). Soils found in these settings typically have up to 8 inches of silty clay loam to clay loam topsoil (A horizon) over 8-60 inches of clay loam alluvial parent material (C horizon). Layers of loam, fine sandy loam, and silty clay loam can also be present in the C horizon. This is a challenging setting for radar surveys because the clay in the soil and underlying sediments tends to absorb the radar energy and limit the depth to which it can penetrate. Working in dry conditions can help improve radar penetration depth, but reduced soil moisture can also limit the detectability of features such as graves.

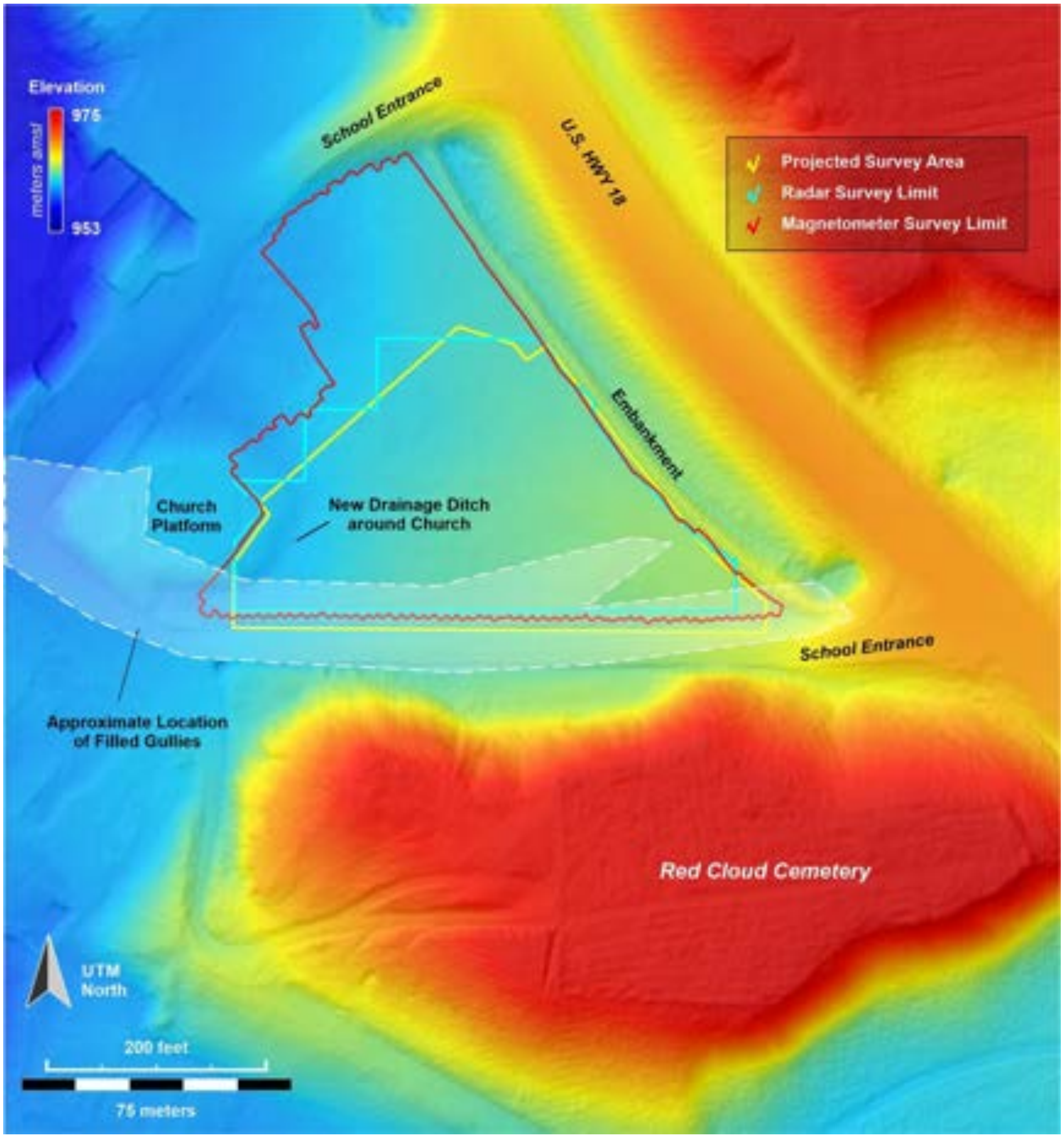


**Figure 2**. The project and survey area boundaries on a LiDAR-based topographic relief map.

### *Area and School History*

When established in 1887/1888, Red Cloud Indian School was originally named Holy Rosary Mission. Initial construction in the first year was made possible by a donation of $6,000 from Katherine Drexel, for whom the first notable building, Drexel Hall (Figure 3a), was named (Galler 1998:159). Construction of the building was carried out under the direction of Father Jutz and Brother Henry Billing, with labor provided by local Oglala people and hired Euro-American workmen. Using local resources, the main building was constructed with clay and lime extracted from the White Clay Creek valley. While little remains of the numerous support structures and outbuildings that once covered the campus in the early years (some of which are visible in Figure 3), Drexel Hall stands largely unaltered in its footprint.

In 1968, Holy Rosary Mission was renamed Red Cloud Indian School. Red Cloud is one of 407 Indian boarding schools manifested during the atrocious federal Indian policies. The school was a fully operating Indian boarding school during the years 1888-1980. Today, Red Cloud is an incorporated private school, still for Native American students, with most of the cost for student entry borne by donors. The school is the face of multiple economic engines, both currently and historically.

For the purposes of understanding the geophysical survey results, our interests in the history of the school focus on its physical development and change through time. Specifically, we need to know how today’s front lawn was used in the past, and what the land might have looked like before the school. Photographs and maps can provide a quick snapshot of a place’s history.

The earliest readily accessible photo of the project area (shown later in the report) depicts the newly built Drexel Hall, perhaps still under construction, without the original Holy Rosary Church, suggesting the photo was taken some time between 1888 and 1898. Other early photos (Figure 3b) show that the tower and steeple of the church remained unfinished for a time after the rest of the church was built, indicating these photos were taken prior to 1898 when the church was completed. It is, however, possible that the church was considered finished when the interior was first utilized for mass, which could have easily been done with an incomplete steeple. The original church remained for nearly a century before being destroyed by fire in 1998. The present Holy Rosary Church was erected in 1998 to the northeast of Drexel Hall, along the southwestern edge of the geophysical survey area. Red Cloud Hall, built in 1922, helps provide an early range for other photographs, such as the images in Figure 4 that show a baseball game in progress at the northwestern corner of the front lawn (Figure 4a) and a school procession heading northwest toward the lawn (Figure 4b). Red Cloud Hall stood for 57 years until it was demolished in 1979 to make way for new buildings (The Lakota Times [TLT] 7 July 1981:A5).

One of the most notable natural features in the project area and visible in early photographs of the school is a series of depressions just northeast of Drexel Hall. The wintery scene depicted in the Figure 3a image shows this gully or wash coming into the image from the left (east) and extending west all the way across the front of the building. This gully is an extension of a wash that comes southwest out of the hills opposite the school, on the northeast side of U.S. Highway 18. In the circa 1898 photo in Figure 3b, the gully appears to be 8-10 feet deep given how it dwarfs horses standing next to it. A small building is evident on the north side of the gully to the right of Drexel Hall in Figure 3a. Based on its size and shape, this may be a privy. It is the only building known to have occurred within the front lawn area. By the 1910s or early 1920s the gully had been filled in, a process that may have taken over a decade to complete. As a result, the local drainage pattern was dramatically altered. An earthen berm, or embankment, was installed along the base of the slope leading down from US HWY 18 in a clear effort to divert runoff to the northwest and away from the campus.

The only other feature known to have been constructed in the front lawn area is a well and windmill pump. It appears in a photograph from circa 1898 (shown later in the report), where it is located northeast of and in line with the east side of the original Holy Rosary Church. Though it is hard to gage its precise location from the photograph, it is located some distance out into the lawn area, with the gully between it and the church. In this same photo, the gully itself appears to have been somewhat filled in as its extent seems slightly reduced. A photo of a procession on the campus dated 1934 shows a column of adults and children marching along the southeast side of the church and heading northeast (Figure 4b). This image shows a substantial amount of cutting, and erosion, on the west slope of the Red Cloud Cemetery hill. It is possible that some of this excavated material was used to fill in the gully.

Sometime in the second quarter of the twentieth century, perhaps as early as the 1920s, students appear to have played baseball in the north corner of the survey area. A photo (Figure 4a), postdated 1934, depicts a number of players and spectators gathered around a diamond that included a wooden post backstop. An aerial photo from 1953 shows this same baseball diamond (Figure 5). Little change occurred within the survey area from the 1950s onward until a medicine wheel was installed at the present site of Holy Rosary Church (well before the church was built) sometime between 1966 and 1981, based on available aerial photographs of the site. The 1967 United States Geological Survey map of the area in Figure 6 shows the configuration of the campus during this period. The Medicine Wheel's original location is visible in the 1996 aerial photograph presented in Figure 5. After the original church's destruction in 1996, the school's current church was built in 1998 at the location of the original Medicine Wheel. This new building sits on an elevated platform of sediment on top of the fill used to level up the old gully. A shallow drainage ditch surrounds the church on its east side (see Figure 2).

Today, the project area is maintained as a mowed grass lawn (Figure 7). The grass was mowed short not long before the arrival of the geophysical survey team. The geophysical survey work extended south to the wood post barriers shown in Figure 7b. South of these is a ditch containing utility lines. As demonstrated by the historic photographs discussed previously, this area of the project area was once a gully that has since been filled in.

**Figure 3**. Early photographs of Red Cloud Indian School (the Holy Rosary Mission), (a) looking south from the road in the 1890s at Drexel Hall and the Church to the east. Red arrows indicate a gully or wash in front of the school that had yet to be filled with sediment. A closer look at Drexel Hall (b) looking southeast shows how deep the gully/wash once was. (Photographs from the Holy Rosary Mission-Red Cloud Indian School Records, used with permission from Marquette University)

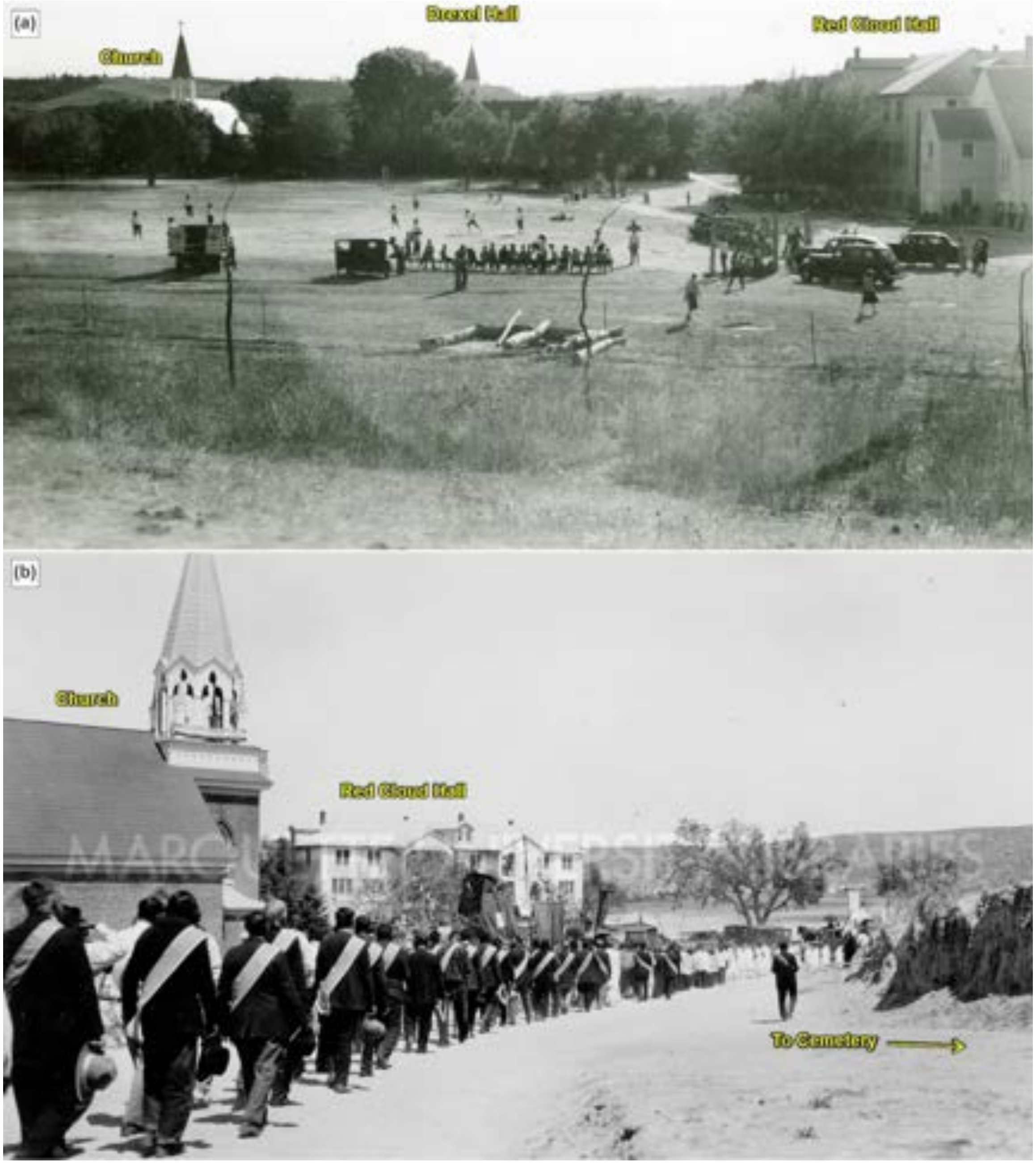


**Figure 4**. Early photographs of Red Cloud Indian School (Holy Rosary Mission) showing (a) a game underway c. 1930s in the baseball field once located in northwestern corner of the front lawn (just at the western edge of the project area), and (b) a rare view in 1934 looking northwest from the southeast side of the lawn, with the church to the left and the road up to the cemetery hill on the right. (Photographs from the Holy Rosary Mission-Red Cloud Indian School Records, used with permission from Marquette University)

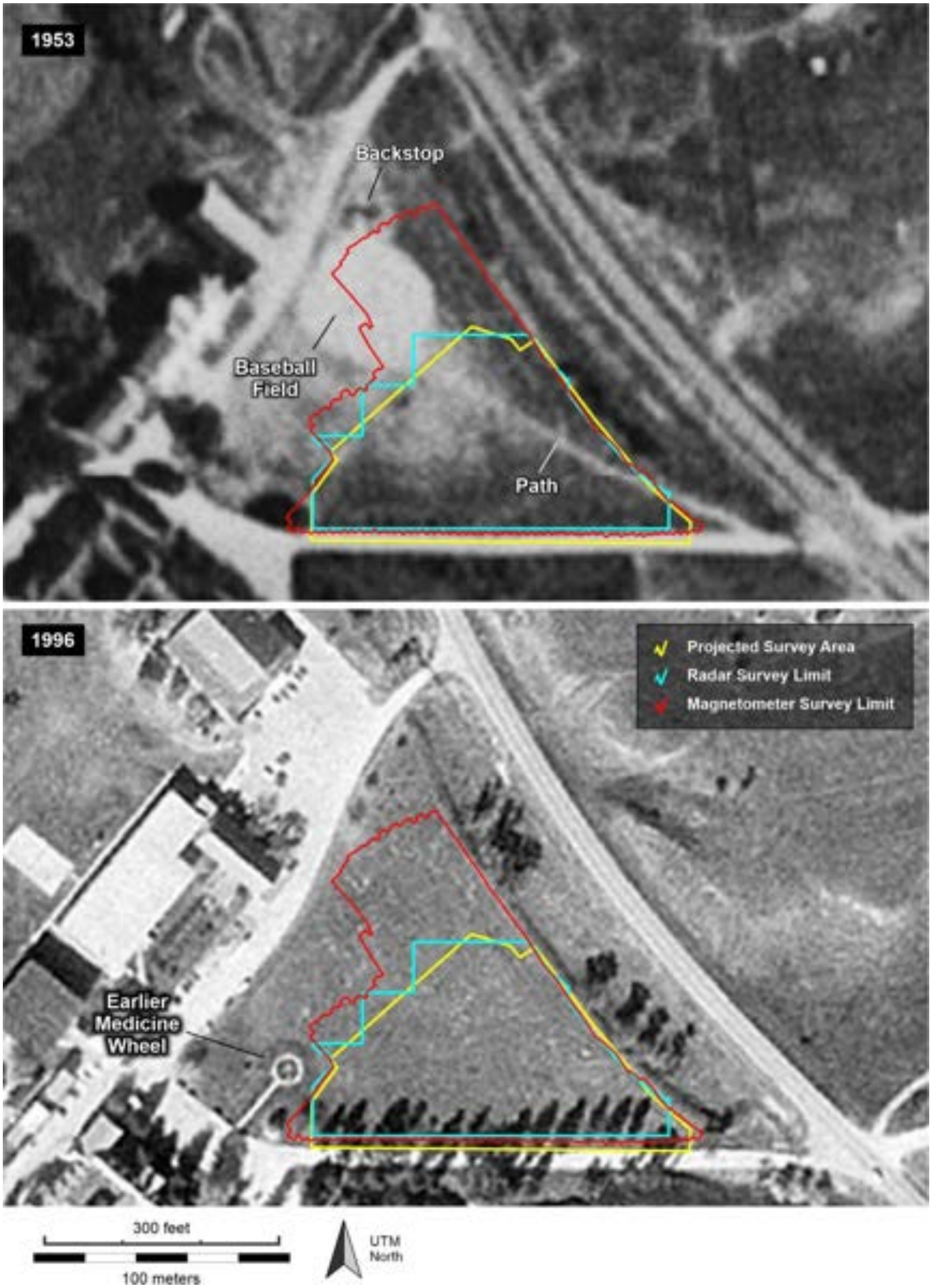


**Figure 5**. Historic USDA aerial photographs showing the project area in 1953 and 1996.

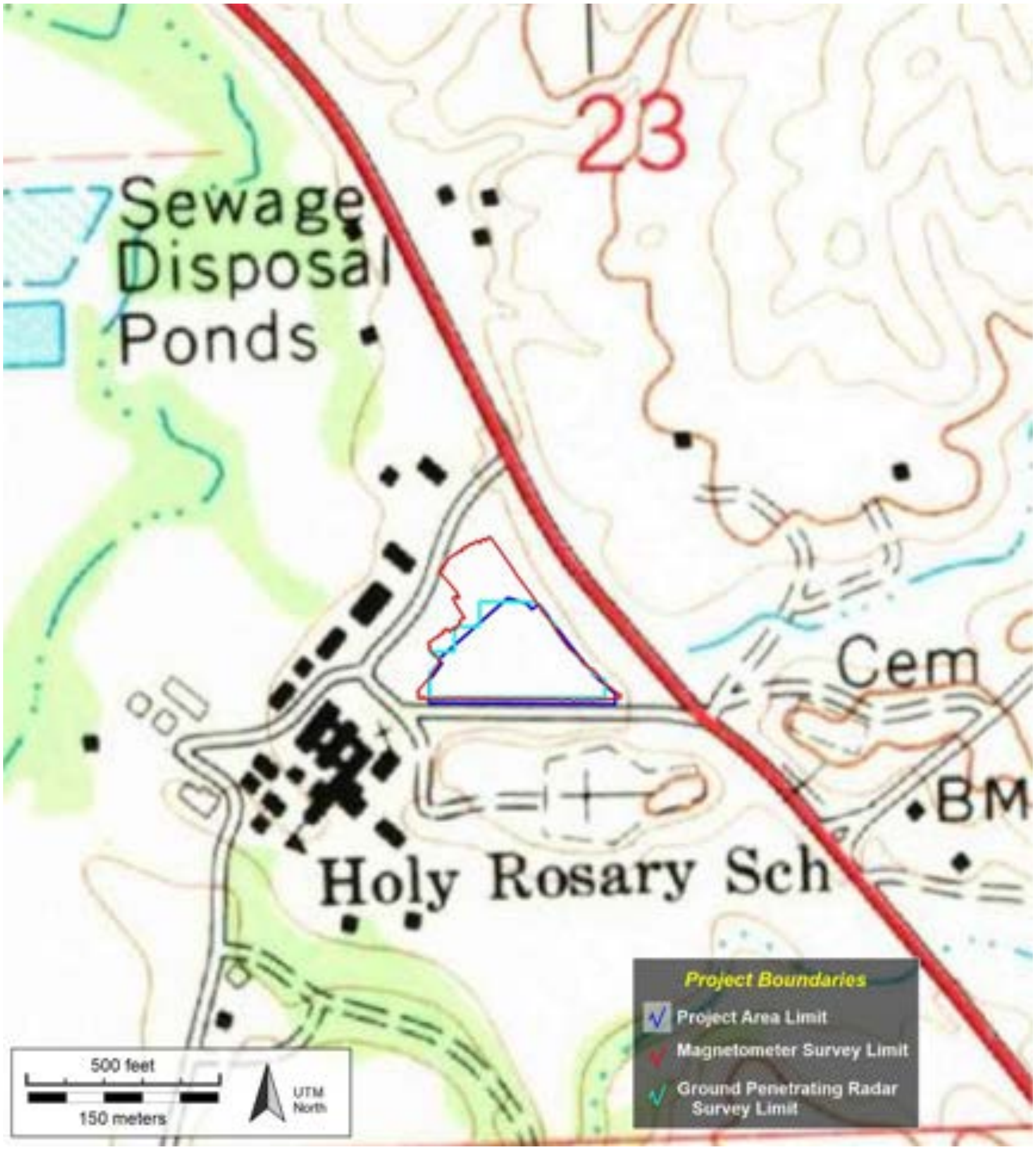


**Figure 6**. A portion of the 1967 "Pine Ridge" 7.5 minute USGS quadrangle map showing the project area.

**Figure 7**. Photographs of the project area at the time of the survey, (a) from the southwest looking northeast (with the back of the church to the left) and (b) from the southeast looking northwest.

## Methods

Geophysical survey instruments can be a great way to quickly and non-invasively look for things buried in the ground without needing to excavate. When surveys are successful, the results can be stunning and obvious, even to the untrained eye. However, more often than not it can be difficult to identify features of interest, even when they are present in the data. There are many steps involved in producing useful survey results, from setting up the survey area to properly assembling the instruments, collecting the data, and processing/presenting maps made form the data in way that highlights the kinds of features we are interested in finding. For the Red Cloud survey, we are interested in finding a range of target types, from things as small as graves to those as large as building foundations. This requires careful data collection at high data density, and we need to have a basic understanding of what these targets of interest might look like when they are detected—especially the graves.

The following sections briefly outline the use of geophysical survey instruments for detecting graves, because these are some of the most difficult feature types to detect. It also briefly outlines how each instrument works and the types of things that can be detected, with example results from other sites. This information helps set the stage for the presentation of results from the surveys at Red Cloud Indian School.

### *Background on Geophysics and Cemeteries*

Any forthright discussion about cemeteries and geophysical survey must begin with caution: graves are notoriously difficult to detect with geophysical survey instruments and often for unpredictable reasons (e.g., Jones 2008). In some cemeteries each individual grave might be detected, while in others the graves are totally invisible to the instruments. Most of this difference in detectability is related to variability in the types of soils found in the areas used for burial, such as sandy soils versus clayey soils. Some soil types facilitate grave detection more than others (Bevan 1991; King *et al*. 1993; Scott and Hunter 2004). Of course, what is in the grave is also a major contributor to detectability. For example, vaults and metallic coffins can be readily detected, while collapsed and disintegrated wood coffins are often quite difficult to detect.

Each of the instruments we have at our disposal for detecting graves, from magnetometers to earth resistance meters and ground penetrating radar systems, works by identifying contrasting geophysical properties in the ground. What is inside the grave shaft (the hole excavated to contain the individual being buried) must be geophysically different than the surrounding soil if the grave is to be detected. In particular, these instruments are good at detecting (1) differences in soil moisture levels, (2) varying amounts of different materials in the soil and sediment layers (especially the localized presence of sand, gravel, and clay), and (3) the presence of disturbed ground, especially if the sediment is loose and full of air pockets. In addition to being able to detect graves by the soil that was used to fill them in, we can also sometimes locate unmarked graves by finding things that were associated with them but are now invisible at the surface, such as the foundations of headstones and footstones, or the remains of objects placed at the graveside. In general, it is easier to detect rows of graves than a lone grave because the pattern created by a row of features is more recognizable against a background of many other things that are visible as grave-sized features in geophysical data.

Several properties of the graves themselves can make them stand out from the background soil in a geophysical survey, including most importantly: the grave shaft and its fill (Bevan 1991), the presence of a burial vault, and the coffin type and its condition at the time of survey (Conyers 2006) (Figure 8).

### *Grave Shaft and Fill*

The grave shaft and its fill are perhaps the most important aspects of older graves (i.e., 19th century and earlier) when thinking about their ability to be detected during geophysical surveys (Bevan 1991). Grave shafts are oval to rectangular holes excavated two to six feet into the ground. Their horizontal extent varies widely and is dependent on the size of the grave's occupant (e.g., adult versus child) and the use of a coffin and/or a burial vault. Larger grave shafts, such as those of adults, are more likely to be detected by geophysical instruments than graves containing children. In general, adult graves should be about 5-7 feet (1.5-2 m) long and 1-2.5 feet (0.3-0.75 m) wide, while infant graves can be just 3 feet long (under a meter) and rarely are more than 1.25 feet (40 cm) wide.

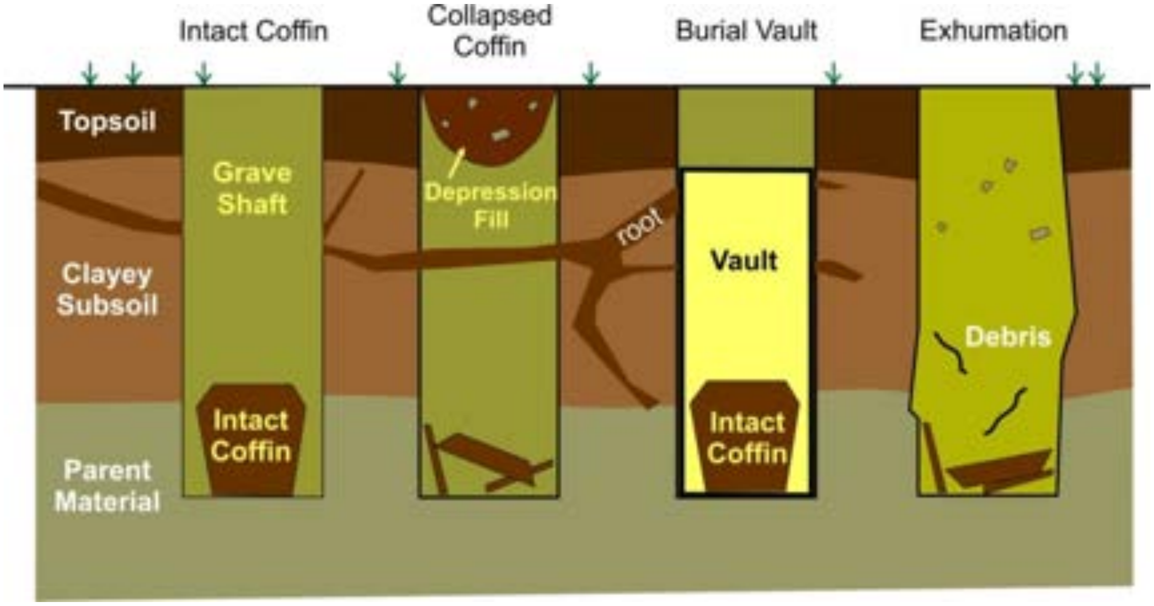


**Figure 8**. Idealized examples of graves and their components in profile.

Along with grave size, the type of soil within which the grave shaft is excavated is also important for detection with geophysical survey devices. The sediments in grave shafts are detectable because their properties are significantly different (e.g., they are disturbed) than the surrounding, intact soils. However, a grave shaft dug into soil without distinctive layers may be less detectable than one dug into a well-developed soil (one with numerous, distinctive layers).

Several other soil characteristics are also factors in grave shaft detectability. Because the soil properties (porosity, compactness, etc.) of grave shaft fill differ from the undisturbed soil that surrounds them, grave shafts tend to hold and drain moisture differently than their surroundings. Thus, differential soil moisture plays a key role in grave detectability. In particular, recent heavy rains can make the tops of grave shafts (i.e., at and just below the ground surface) easier to detect for some instruments, such as ground penetrating radar. Interruptions or disturbances of soil layers, which are common to all graves, also can sometimes be detected by geophysical instruments, especially ground penetrating radar (Conyers 2006). In these cases, the instruments detect the intact soil layers that surround graves, while the graves appear as gaps in these reflective layers. Finally, many graves, especially older ones lacking burial vaults, experience subsidence as the grave shaft fill settles and/or the coffin collapses. If soil is brought in to level off these depressions, it often is obtained from a different source than the original grave shaft fill. This different soil is sometimes detectable to magnetometers, especially if it is subsoil from other recently excavated graves or it is fill dirt from an external source that contains refuse such as building debris or other materials.

### *Presence of a Burial Vault*

Nearly all modern graves in formal cemeteries in the United States involve placing a coffin in a subsurface burial vault—this practice is also used in many other parts of the world. Vaults became very common in the early 1900s, a period when the number of patent filings for various configurations peaked (Habenstein and Lamers 2010). Today, these vaults are made from reinforced concrete or fiberglass, for example. Older graves sometimes contain vaults made with brick, slate, or even metal. Whatever the material, vaults will certainly impact the soil moisture levels present in the grave, making them detectable with most instrument types sensitive to moisture, such as earth resistance meters. Vaults made of reinforced concrete or brick are readily detected by magnetometers and electromagnetic induction meters, as well as radar.

### *Type of Coffin Used*

Coffin type may also affect a grave’s detectability during a geophysical survey. Most wooden coffins cannot be detected, and in older cemeteries many wooden coffins have collapsed and rotted away. However, it is possible that intact wooden coffins, if they still contain an air pocket, can be detected by ground penetrating radar—if the radar signal can penetrate deep enough into the ground. The deteriorating wood might also hold moisture, more so than the soil around it, which makes it more detectable in radar and electromagnetic induction surveys.

With only one exception, coffins and coffin hardware are generally not detectable during geophysical surveys because of the small size of the metallic components of the coffin (mostly the coffin hardware) and the depth of burial, which is usually beyond the range of detection. One type of coffin, on the other hand, is easily detected by magnetometers and induction meters—cast iron coffins/caskets. The first patent for a cast iron coffin in the U.S. was issued in 1848 for the Fisk metallic coffin (Habenstein and Lamers 2010), and not long thereafter (1850s) iron coffins were used in cemeteries across the country, though in small numbers and largely for affluent individuals (Crane, Breed, and Co. 1858). Large cast iron objects are highly magnetic and should be detectable with magnetometers even when buried at five to six feet below the surface. Ground penetrating radars and induction meters also can detect metallic coffins of any type and may even be able to detect coffin hardware if it is large enough (nails are not likely large enough to detect with radar)—assuming the instrument signals can penetrate deep enough into the ground to reach the coffin, which is not always the case.

In sum, three main aspects of graves determine their detectability in geophysical surveys: the grave shaft and the soils within and around it, the presence of burial vaults, and the type of coffin used and whether or not it is still intact. Except in cases of very recent or very shallow burial, it is unlikely that any of the instruments will detect the individual at the bottom of a grave, especially given that in most cases a skeleton is all that remains. In fact, the radar is the only instrument that can penetrate deep enough into the ground, and with sufficient resolution, to even reach the depth necessary for detecting the human occupants of most graves (certain resistance and induction meters can detect down many feet into the ground, but their resolution drops off with depth). But even when the radar can penetrate deep enough, bones and dirt have a similar radar signature. Furthermore, the detection of very subtle features or objects, such as bones in dirt, is complicated by the presence of other, more easily detected things in most cemeteries. For example, tree roots can be very distinctive in radar data, and they can obscure any subtle radar reflections next to and below them. Furthermore, they remain in the soil long after the tree has been cut down. It is important to remember that most graves are detectable because of the soils within the grave shaft. Therefore, graves without coffins can be detected, and the instruments do not have to penetrate all the way to the bottom of a grave to detect it—a grave may be detected within one or two feet of the surface.

In addition to graves, cemeteries also contain burial plot markers and fences, walls, paths, roads, small building foundations, perimeter fences, wells, irrigation and drainage systems, and other kinds of decorative/garden features. Finding the geophysical signatures of these kinds of features can be important to determining the structure of the cemetery, and by extension, the general locations of graves, as well as the locations of the cemetery boundary. Cemetery edges can also be distinguished by activities that have occurred outside the cemetery. For instance, plowing around the edges of burial areas or cemeteries often creates distinctive plow patterns in geophysical data that are notably absent within the cemetery.

### ***Notes on Geophysical Survey Instruments***

Geophysical survey instruments are commonly used around the world to find buried features, such as graves, building foundations, utility lines, and a wide range of other target types. Most things of interest to archaeologists and those looking to find graves are no more than 3-5 feet below the surface. At these depths, the instruments detect archaeological features and graves by measuring subtle changes caused by differences in the soil, including for example changes in its electrical conductivity, electrical resistance, and magnetism (e.g., Aspinall et al. 2008; Bevan 1998; Clark 2000; Conyers 2004, 2012; Gaffney and Gater 2003; Heimmer and DeVore 1995; Lowrie 2007; Weymouth 1986). Certain types of *objects* can also be detected with regularity.

Each instrument is designed to measure a different property of the ground, and some of these properties, like magnetism and electrical resistance, vary in ways almost totally independent of one another. This means that when looking for buried things that are subtle and difficult to detect, such as graves, it is worth using multiple instruments when possible. It can be difficult to anticipate which instrument will work the best, and often each instrument detects a different aspect of the target feature. Combining the results of multi-instrument surveys almost always yields a richer interpretive map than a single instrument survey.

**Figure 9**. Geophysical survey instruments used during the survey, (a) 5-probe magnetometer system (probes indicated by yellow arrows), (b) RTK-base station paired with magnetometer system, (c) ground penetrating radar (radar image from Red Cloud).

Two geophysical survey instrument types were used at Red Cloud to search for subsurface graves and other features of potential interest within the proposed new building site: a **ground penetrating radar** and a **magnetometer** (Figure 9). Geophysical surveys are typically conducted by using the instruments to collect a series of readings along parallel lines (a.k.a. transects) in a rectilinear block (a.k.a. grid square). Data points are recorded at timed intervals, or based on distance, as the instruments are moved along the transects in each block. When possible, it is better to survey an area that is considerably larger than the target feature to provide a context within which to see that feature. So, for example, if one is looking for a single grave, it is important to survey well beyond the edges of the grave to locate other possible nearby graves or the remains of a fence that might have surrounded the burial area. It also is important to collect high-density data when possible, especially when looking for graves or other small features. Higher density data provide a clearer image of what lies underground.

Generally, the data collected by geophysical survey instruments must be transferred to a computer where special software is used to process the data and make maps of the survey results. In these maps the data values are assigned a range of colors related to their strength. In areas with little change in the readings, the colors are all similar—think of these areas as the typical background signature of the site. Areas in the data with unusual values that differ from the background are referred to as *anomalies*, and the goal is for graves and other features of interest to appear as anomalies in the data. Of course, the real challenge is knowing which anomalies are important and which are caused by tree roots, animal burrows, and other things not significant to the goals of the project.

### *Ground Penetrating Radar*

Ground penetrating radar (GPR) is most often associated with surveys that look for graves. It works by moving a radar antenna along the ground as it transmits thousands of pulses of radar energy per second (Figure 10). As these waves of energy travel into the ground and encounter objects and layers, especially those with distinctly different electrical properties, some of the energy is reflected back to the surface and received by the antenna (Conyers 2004, 2012; Daniels 2007; Gaffney and Gater 2003; Utsi 2017; Witten 2006). The instrument records the strength of the reflections and how long it took the energy to travel away from and back to the antenna. This radar travel time can be used to calculate the depth of a detected object or feature.

Many things below ground can cause strong and weak radar reflections, including tree roots, pipes, larger rocks/bedrock, distinct soil layers, the water table, foundations, shaft-type features (e.g., graves, wells, cisterns, and privies), and disturbances to the natural soil layers. Radar energy can also penetrate asphalt, concrete, and gravel. Other materials, especially clayey, moist soils, tend to absorb radar energy and do not allow it to pass. At the extreme, radar energy cannot penetrate metals, so metal pipes and other large metal objects are readily detected, but they do obscure things below them. Ultimately, the depth of the radar signal penetration, and the depth to which objects can be detected, depends on the radio frequency of the radar antenna being used and the conductivity of the ground. Higher frequency antennas (e.g., 1000 MHz) can detect very small things but only at shallow depths, while lower frequency antennas (e.g., 50 MHz) can penetrate into the ground deeper but at the expense of only detecting larger things. The frequency of the antenna, however, can be irrelevant if the ground is so conductive that all the radar energy is absorbed (i.e., attenuated) before it can make its way back to the surface. This is a common problem for soils containing clay and other types of conductive materials.

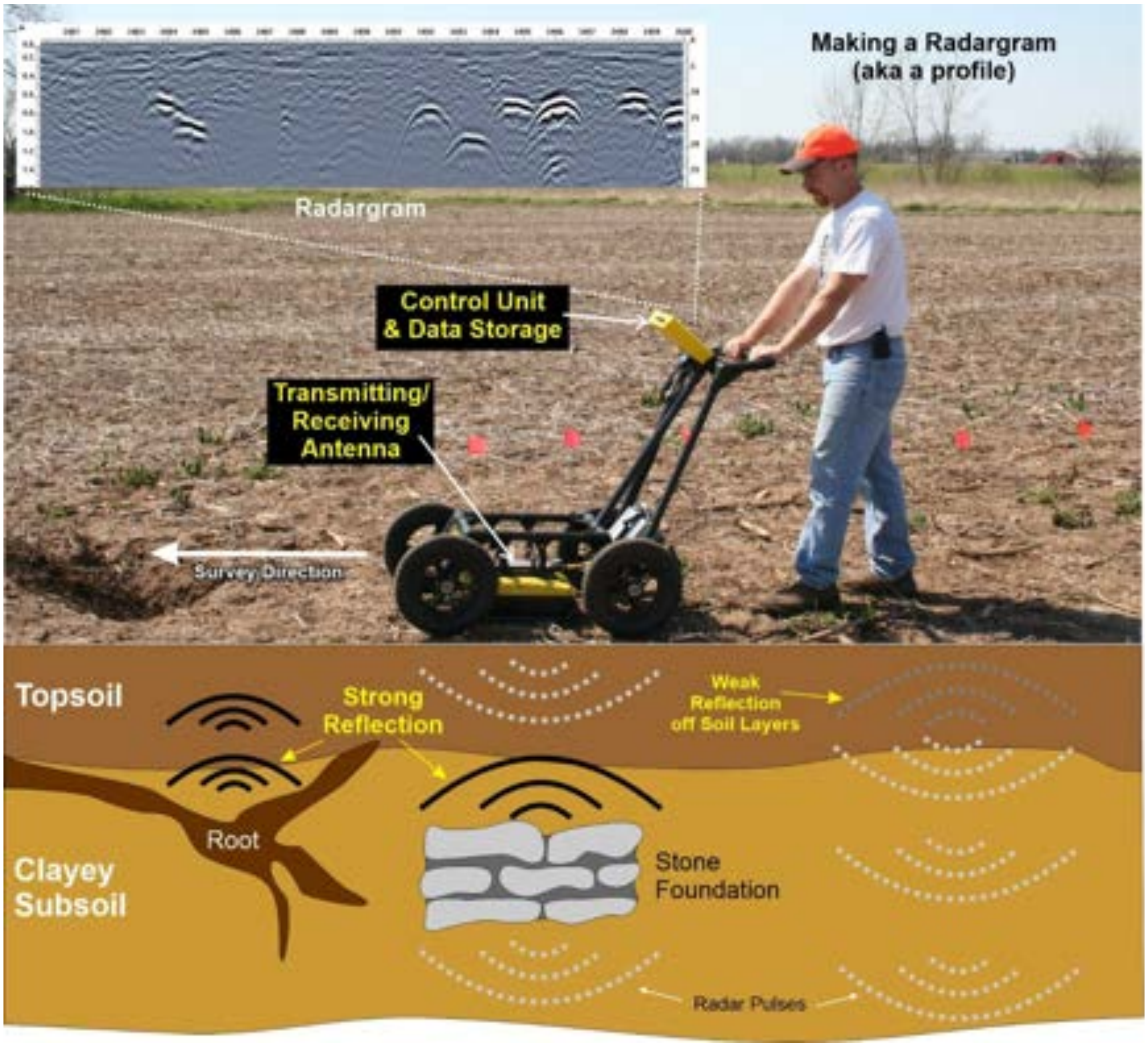


**Figure 10**. A demonstration graphic showing use of the ground penetrating radar instrument.

For the Red Cloud school survey, a Sensors and Software Noggin Plus 250 MHz system was used to collect the radar data (Figure 9c). It is a lower frequency system that works well for detecting graves and other larger targets in sediments with lots of background targets (e.g., animal burrows). Thirty-three traces, essentially "readings," per meter were collected in zig-zag mode along transects spaced at 25 cm intervals. Collecting data at this density with a single channel antenna system is a very time-consuming process but it increases the odds that subtle features such as graves can be detected and discerned in the data. A 54 nanosecond time window was used to "listen" for return reflections from the transmitted radar pulses, which produced an effective penetration depth of about 1.5-1.7 meters (ca. 5-5.5 ft).

Each radar trace is akin to a very narrow profile of the ground. Arranging the 33 traces per meter side by side along the data collection transect creates a radargram (Figure 10), or a profile of the ground as the radar "sees" it. These radargrams are the nuts and bolts of a radar survey; they show the locations, shapes, and strength of the radar reflections. One can also glean information about the target from the range of radio frequencies it is reflecting. However, it can be difficult to interpret what has been found based on the radargrams alone.

Radargrams can be turned into three-dimensional blocks of data by arranging them side by side and having the computer software fill in the gaps by estimating (i.e., interpolating) what should be in between the radargrams. The resulting 3D block of data can then be "sliced" horizontally and looked at from the top rather than the side—making it seem as if one is excavating down through the data, and the site, one layer at a time (Figure 11). These horizontal data slices are called "time slices" or "amplitude slices" and they show a horizontal map of the radar reflection strength at a desired depth (Goodman, Nishimura, and Rogers 1995). Graves should appear in the slice images as small anomalies, about 2x7 ft (for adult graves), and they often occur in rows. The graves can be positive anomalies, where the graves themselves are what is causing the reflections (Figure 12a), or graves can appear as gaps (i.e., negative anomalies) in an otherwise reflective layer (Figure12b). In some cases, the graves are obvious in the radar data, and in others they are more subtle. Sometimes, even when graves are detected, they do not show up well in the time slice maps; therefore, it can be important to closely inspect radargrams for the telltale signs of a grave.

The radar data presented here were processed using Sensors and Software's Ekko_Project 5 and Ekko_Mapper 4 software, including a combination of the following steps: dewow, migration, enveloping, background subtraction, gain, and interpolation. Even with good data processing and conscientious interpretation, graves can be difficult to detect in radar data. Therefore, a lack of graves in the radar data should not be used as the only indication that graves are absent from a survey area.

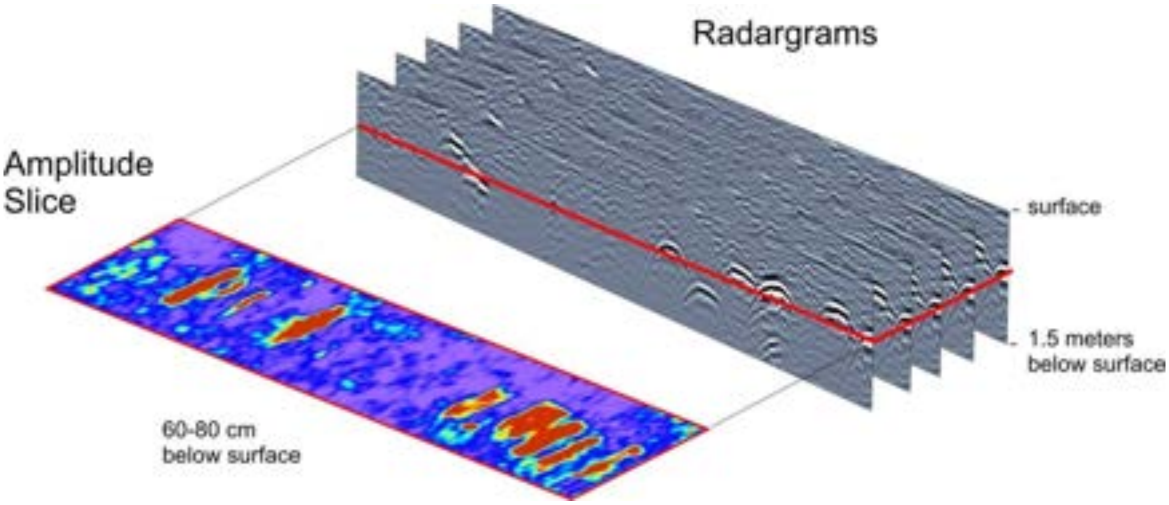


**Figure 11**. A demonstration graphic showing the creation of a radar amplitude slice from radargrams.

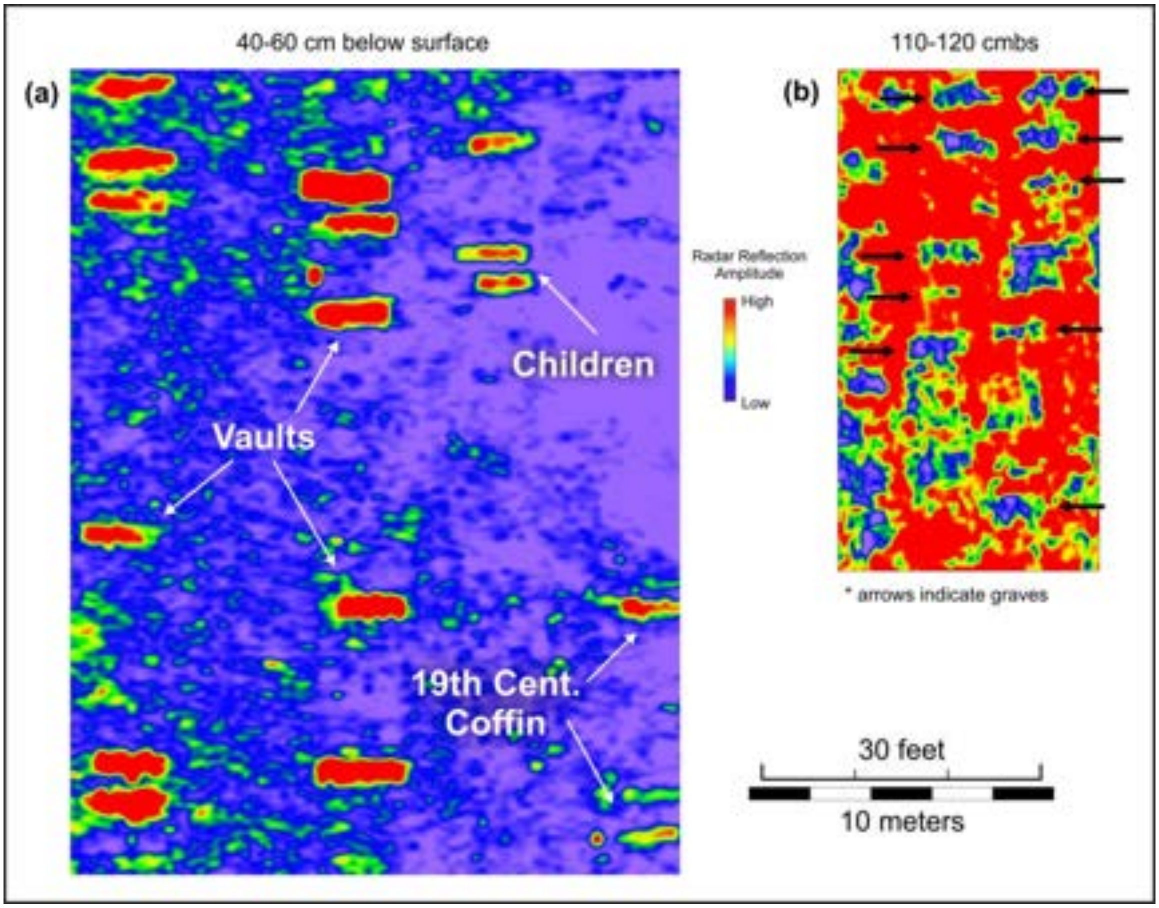


**Figure 12**. Examples of graves in amplitude slice maps detected at nineteenth and early twentieth century cemeteries in (a) Ohio and (b) Pennsylvania.

*Magnetometry*

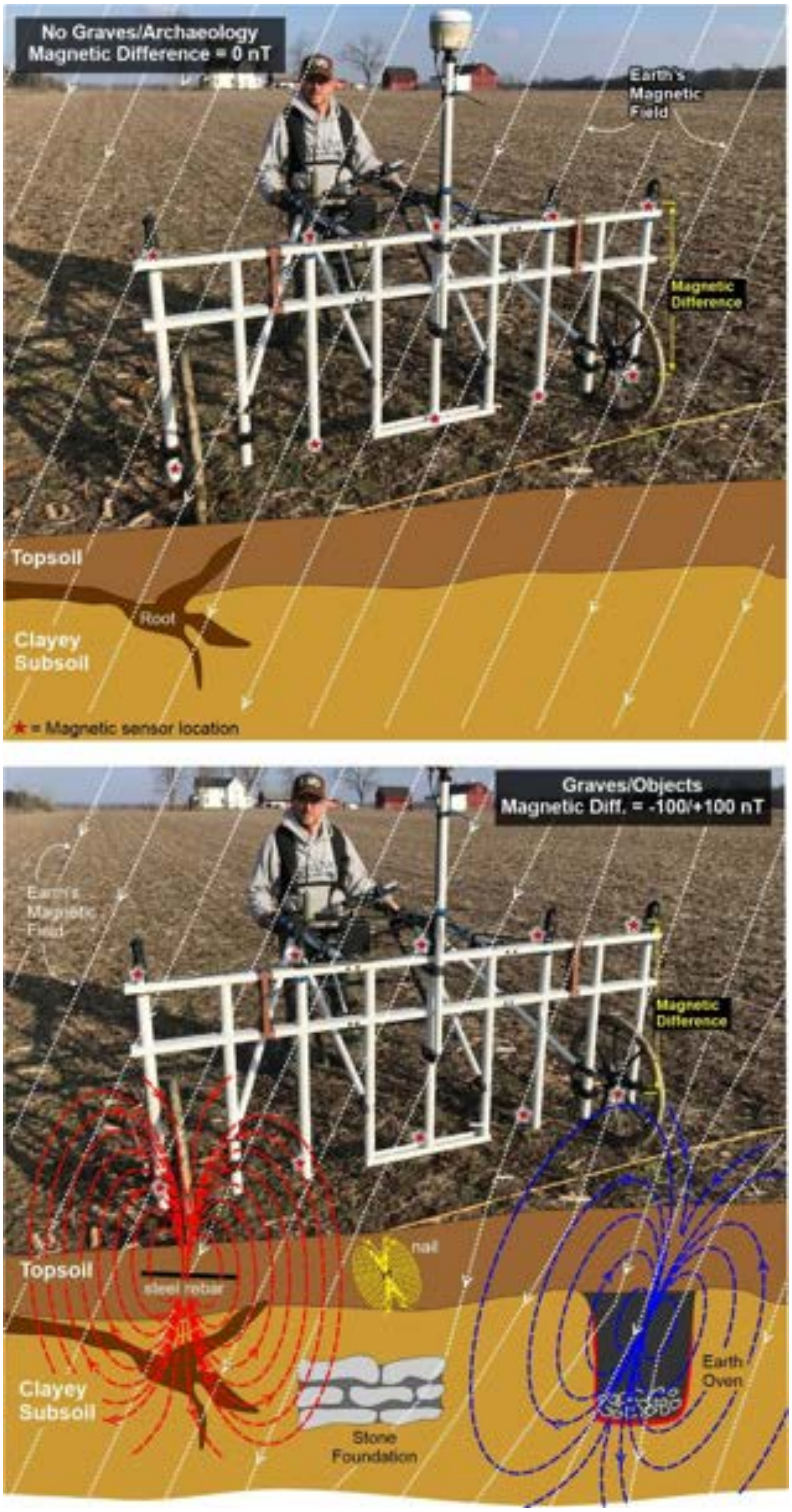
Magnetometers detect changes in the earth's magnetic field caused by the magnetic properties of things close to the instrument (Figure 13) (Aspinall et al. 2008; Gaffney and Gater 2003). They can detect the presence of magnetic objects (e.g., iron objects or igneous rocks) and subtle changes in the soil, especially if the soil changes involve the local accumulation or removal of topsoil or other magnetically distinct sediments. While objects in the ground such as smaller nails are quite magnetic, they are usually too far away from the instrument to be detected during a survey. However, larger iron objects can be detected if they are not buried too deeply.

Like most magnetometers, the magnetometer system used for this project—a Sensys MXPDA—is a passive instrument (i.e., it does not create a magnetic field), and it simultaneously detects both kinds of magnetism relevant to archaeological and cemetery surveys: remanent magnetism and magnetic susceptibility. This instrument cannot differentiate between the two. The Sensys magnetometers (there were five on the system used for the survey) consist of two fluxgate magnetic detectors spaced 65 cm apart, one atop the other. The uppermost detector senses the earth's background magnetic field, which in the South Dakota region measures approximately 55,000 nanotesla (nT) and can vary throughout a day as much as a few hundred nanotesla (Breiner 1973). The lower detector senses the earth's background magnetic field *and* changes in it caused by objects or soils on the surface or as much as about two to three feet beneath the surface. Many readings are simultaneously logged per second by each detector. Once a set of readings has been taken, the instrument's onboard electronics subtract the reading of the top detector (earth's varying background magnetism) from the reading of the bottom detector (earth's varying background magnetism plus local magnetic variability), leaving—in principle—the local magnetic gradient/difference caused by surface and buried phenomena. These numbers are then stored in the instrument until a data dump is performed.

Buried features such as wells, cisterns, privies, burned areas, and other kinds of pit-type features can be detected with a magnetometer. Graves can also appear in magnetic data, and usually it is the soil within the grave shaft that the magnetometer detects. Iron coffins and vaults also are readily detectable and can create quite large anomalies. If the area surveyed has numerous other magnetic objects on or near the surface, like iron or steel fences, this can make it difficult or impossible to detect subtle graves.

Though often complicated with many kinds and shapes of anomalies, magnetic data can be distilled down to a small selection of anomaly types that are useful for understanding what has been detected. Figure 14 presents the three primary types of magnetic anomalies, along with some variants, that are typically encountered during surveys on archaeological sites and in cemeteries. Monopolar anomalies are small areas where stronger or weaker readings have been detected. These anomalies are often associated with pits that have been dug into the ground. If topsoil or magnetically enhanced soil ends up inside the pit, then a

**Figure 13**. An illustration of magnetic fields during a magnetometer survey—red and blue lines are the magnetic fields of objects and features while white lines represent the earth's magnetic field.



monopolar positive anomaly will be created. If clayey subsoil or sand are used to fill up the pit and occur near the surface, then it is possible that a monopolar negative anomaly will be created, though these are relatively rare. Dipolar simple anomalies are the easiest to identify in magnetic data as they have side-by-side positive and negative peaks. They most often are associated with iron objects and magnetic rocks—the larger the object or rock, the larger and stronger the magnetic anomaly. Sometimes dipolar anomalies are found clustered together or as very irregular areas of negative and positive readings. These clusters of anomalies are referred to as dipolar complex anomalies and they often are associated with historic-era refuse dumps, building foundations, and burned areas. Utility lines can also produce linear arrangements of complex anomalies.

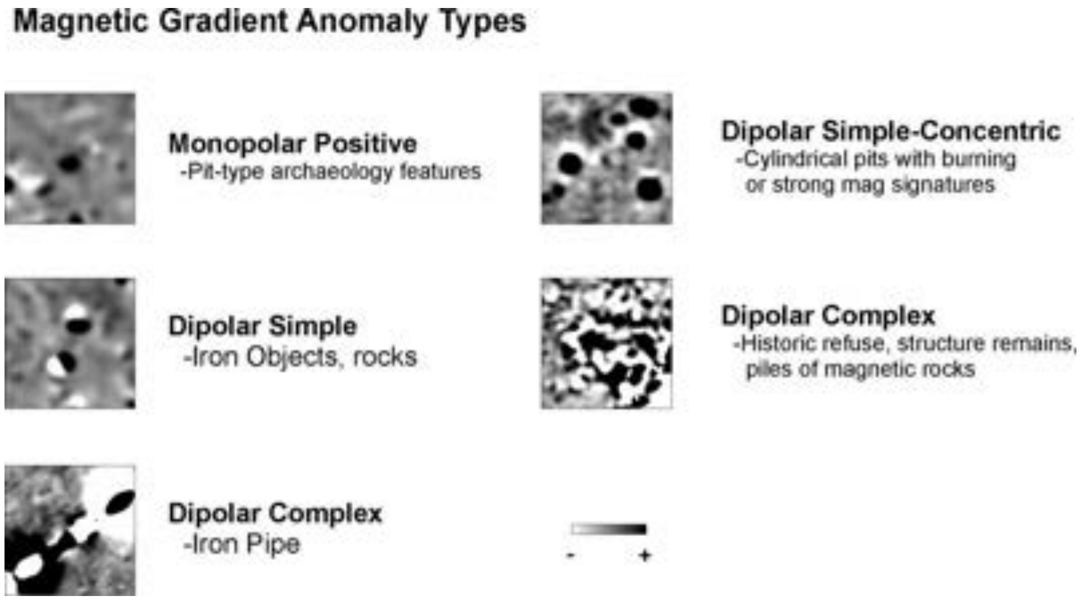
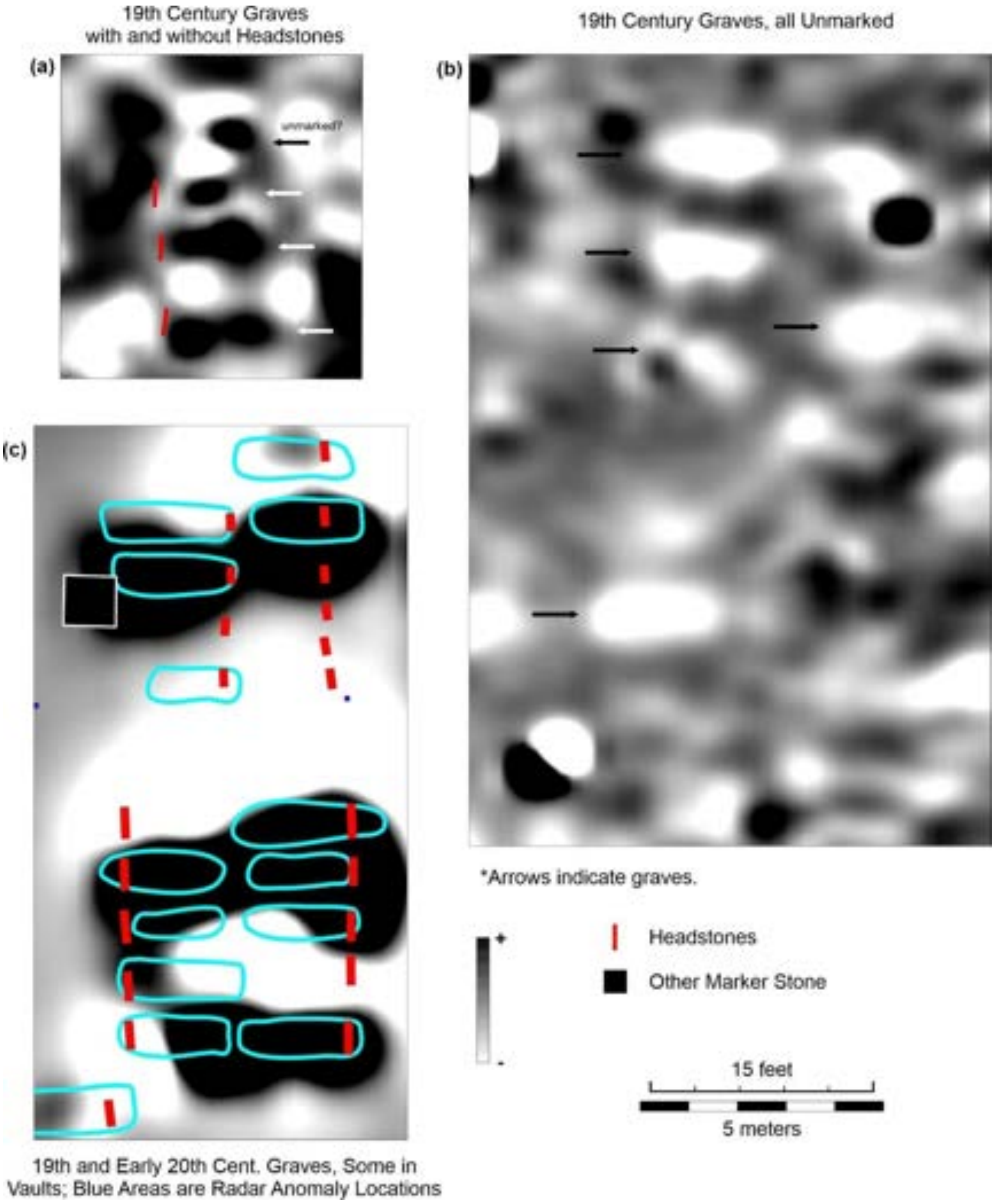


**Figure 14**. Common magnetic anomaly types.

Cemeteries, parks, school campuses, and other urban areas are challenging settings for magnetic surveys. They often are full of obstacles and a wide range of magnetic materials. When detected in magnetic data, graves appear in a variety of ways (Figure 15). They can be monopolar positive or negative anomalies approximating the size of a grave (Figure 15b). They can also occur as smaller (Figure 15a) or larger (Figure 15c) dipolar anomalies. Finding evenly-spaced anomalies lined up in rows makes grave identification much more straightforward, as in the example from Chemawa Indian Boarding School cemetery presented in Figure 16. However, sometimes it is only possible to identify the presence of rows—individual graves may be hard to pick out of the data. Many nineteenth century cemeteries also contain iron coffins and/or vaults. These will appear as large (i.e., larger than the grave itself) dipolar simple (side by side positive and negative) or dipolar simple-concentric anomalies.


19th Century Graves with and without Headstones

19th Century Graves, all Unmarked

19th and Early 20th Cent. Graves, Some in Vaults; Blue Areas are Radar Anomaly Locations

*Arrows indicate graves.

**Figure 15**. Examples of graves detected in magnetic survey data.

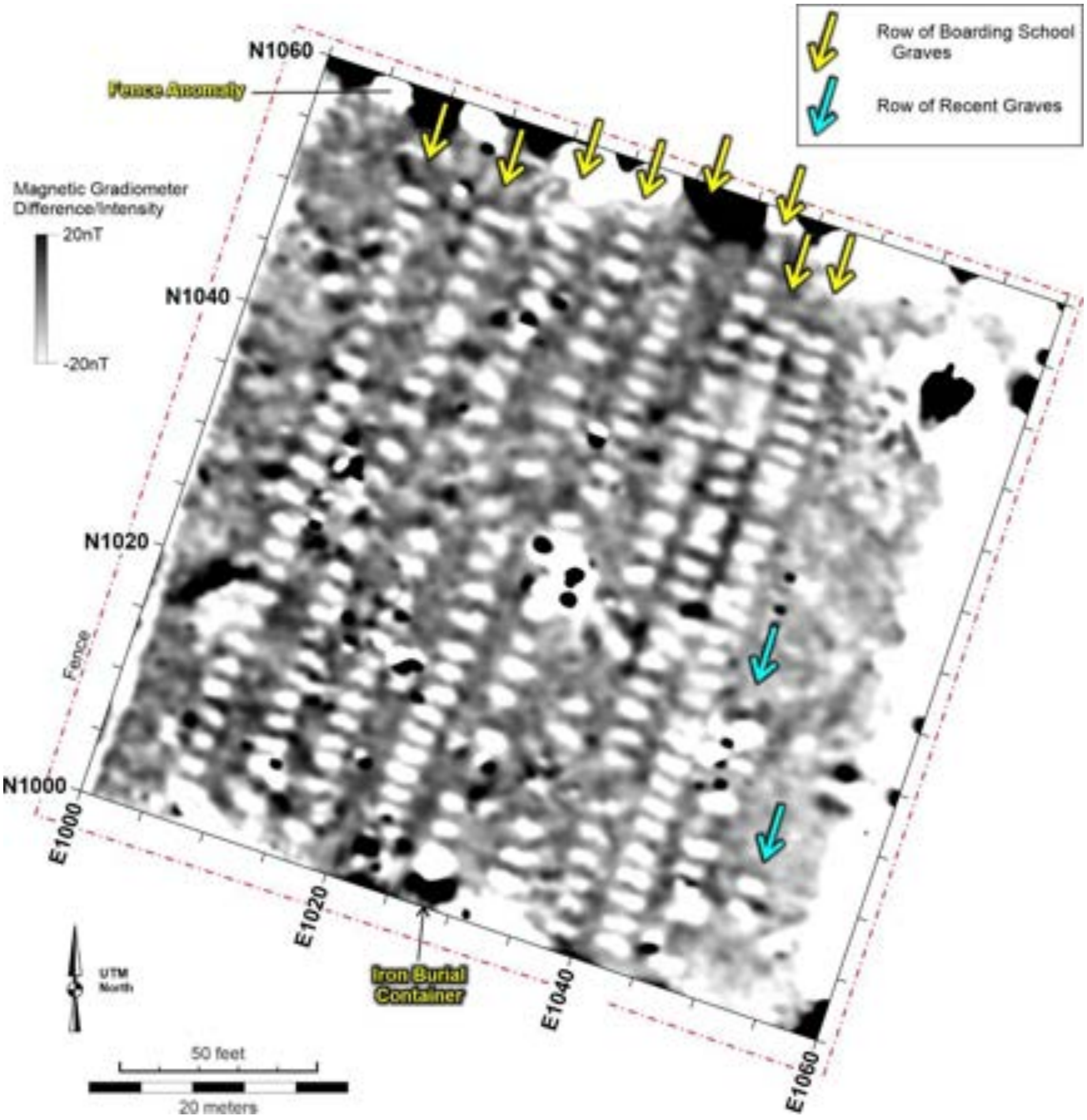


**Figure 16**. Example of magnetic gradiometer data from the Chemawa Indian Boarding School in Salem, Oregon (from Small and Burks 2022).

## Results of the Field Work

### *The Site Grid*

Geophysical survey data typically are collected within uniform grid squares of a set size, each of which consists of lines of readings recorded at fixed intervals. For this project, about three dozen wooden grid stakes were set out to begin the survey work (Figure 17). The survey grid was aligned to UTM north (Universal Transverse Mercator), producing a good fit with the southern edge of the survey area. This alignment also allowed the radar data to be collected in a north-south direction, which produces the best coverage over graves that tend to be aligned east-west (e.g., note the east-west alignment of the graves in the Red Cloud Cemetery to the south of the project area, in the lower right corner of Figure 17). The grid coordinates shown in Figure 17 are in meters, and corners for each grid square were first established in GIS software. From there they were exported for staking out the survey grid in the field using a real time kinematic global navigation satellite system (RTK GNSS).

In the field, a StoneX S10 base and rover RTK GNSS was used for setting up the grid. The base station position was established at the Datum 1 location in Figure 17 as an average of 200 DGNSS readings. Once the base had established its position, it was switched over into base mode, broadcasting a correction signal for the rover unit. All subsequent rover positions had an accuracy of +/- 1-2 cm relative to the base station's position. The base+rover combination also provided real-time GNSS positions for the magnetometer while it was collecting data. Coordinates for Datum 1 are provided in Table 1 as Universal Transverse Mercator (meters) coordinates and decimal degrees lat/long coordinates. The Datum 1 location was marked in the field by a 10-inch galvanized nail pounded down flush with the ground surface. This nail was left in place for future mapping efforts interested in relocating anomalies detected during this survey.

### *Geophysical Survey Results*

The magnetometer survey was the first of the instrument surveys to be completed, and the results are presented in Figure 18 (a gridded version of the data is provided in Appendix A). Because the magnetic data are so quick to collect, the survey was extended across the entire lawn area to help place the project area in a larger context. In the magnetic results map, dark colored areas are more magnetic while light colored areas are less magnetic. At first glance we can see that the magnetic data are full of hundreds of small black and white anomalies. These are the magnetic signatures of iron objects of various sizes. While there do appear to be general clusters of iron objects in several areas, these clusters are not arranged in distinctive rectilinear patterns like might be expected for a former building location or a fenced area that could have contained graves.

A number of other discrete features of note were also detected in the magnetic data. The most distinctive is the strong black and white linear anomaly associated with an iron pipe running north-south from the southern edge of the survey area. The pipe terminates at a large/strong negative anomaly that likely is a deeply buried iron pipe set vertically. Iron pipes typically connect to things such as buildings or drains, and an early photograph of the area shown in Figure 19 reveals the likely source for this iron pipe: a well and windmill pump. The iron pipe likely carried water away from the well to another pipe running along the road at the southern edge of the project area. In the image in Figure 19, we can see that the windmill is located in front of the original church (its steeple incomplete), beyond (northeast of) the old gullies once present to the northeast of Drexel Hall and the church. These gullies were filled sometime around 1910-1920. The magnetic data also contain dipolar simple-concentric anomalies possibly associated with the bases of iron fence posts/rods buried in the ground, as well as a very subtle set of buried vehicle tracks. They are not visible at the surface and therefore must be buried.

Not present in the magnetic data are any monopolar positive or negative anomalies commonly associated with graves. Nor are there any linear arrangements of grave-sized anomalies that might indicate the locations of rows of graves. The large dipolar complex anomalies typically associated with former building locations are also lacking in the magnetic data. This lack of grave-like anomalies or signs of buildings also carries over into the ground penetrating radar data.

Figure 20 shows one of the processed radar amplitude slice maps from the survey, in this case at 30-50 cm below surface. Red areas in the slice map are stronger reflections while blue areas are weaker. In this relatively shallow slice, we can see a number of small anomalies scattered across the survey area, but no distinctive patterns are evident. The buried vehicle track identified in the magnetic data is also visible in the radar data. Cart and other vehicle tracks are visible in many of the older photographs of the project area. For example, the image in Figure 21a is one of the oldest photographs of Drexel Hall, taken before construction of the church. A distinctive cart track is visible moving left to right across the image. However, this track is at the wrong angle to be the linear feature detected in the magnetic and radar data. An older, abandoned track may also be visible running down into the head of one of the gullies (see Figure 21a). But this too is not quite at the correct angle to be the detected track. A final, more likely candidate is visible in the 1929 photograph in Figure 21a. This track appears to be running northeast to southwest, heading toward Red Cloud Hall. This is the approximate path of the magnetic and radar anomalies. Importantly, the fact that this track is not visible at today's surface indicates that it has been leveled off and/or has become buried beneath a layer of fill. In the radar slice maps it does not become visible until about 25-30 cm (about 1 foot) below the surface.

In deeper slice maps, such as the one in Figure 22 from 110-130 cm below surface, the vehicle track has disappeared, along with most other anomalies of interest. Many of those that are distinctly visible in this slice map actually are related to shallow metal objects. Because the radar cannot penetrate metal, it continues to reflect off the top of metal objects for the entire length of the "listening" window for each radar pulse. This results in the software plotting multiple copies of this metal reflection all the way down the profile, thus the reason why the anomalies created by metal objects are referred to as "multiples." The Example 1 radar profile in Figure 23 shows a good example of multiples caused by a near surface metal object from Red Cloud. In this profile we can also see the effective penetration depth of the 250 MHz system at Red Cloud. While the radar system can listen for radio wave reflections for an extended time, eventually all the system hears coming back to the antenna is ambient radio noise—radio energy and instrument noise occurring in the background. The noise in Example 1 in Figure 23 begins to dominate the results at about 1.5 meters to 1.7 meters below surface. This then is the effective penetration limit of the radar survey. The deeper radar slice map in Figure 22 also shows some other stronger reflections at the southern edge of the survey area. These are associated with trees growing at these locations.

A closer examination of radar slice maps from a variety of depths, as in Figure 24, shows that the shallow radar results have numerous scattered anomalies, which quickly disappear with increasing depth. These shallow anomalies are associated with metal objects in the top 30 cm (1 ft) of sediment, which most likely is a fill or graded layer that contains a considerable about of metal debris. Some of these anomalies are also associated with (1) another possible path visible in the 1953 aerial photograph and (2) animal burrows, of which many were observed at the time of the survey. As we move deeper into the radar data, for example the 40-60 cm and 60-80 cm slices, stronger reflections appear to cluster along the southern edge of the survey area. These likely are associated with trees and bushes in this part of the survey area, as well as the sediment used to fill the old gully/wash. Below these slices, the deeper slice maps show very few radar reflections. This indicates that to a 250 MHz radar system, the sediments in the front lawn area all look quite similar to the radar with increasing depth. In part this is because the ground was fairly dry at the time of the survey. But it also suggests that there is little variability in the soil/sediment to be detected—it is a fairly homogenous mix of alluvial deposits, much as the USDA web soils data presented earlier in this report suggest.

Interestingly, the iron pipe running to the windmill was not detected in the radar survey. This may be because it is buried deeper than the radar could reach, or less likely it could have been missed by the radar by occurring just between two survey lines.

Based on the radar results, there are no indications of grave-like anomalies, building foundations, or other major buried features within the project area. Enlarged, gridded versions of the radar slice maps are presented in Appendix B.

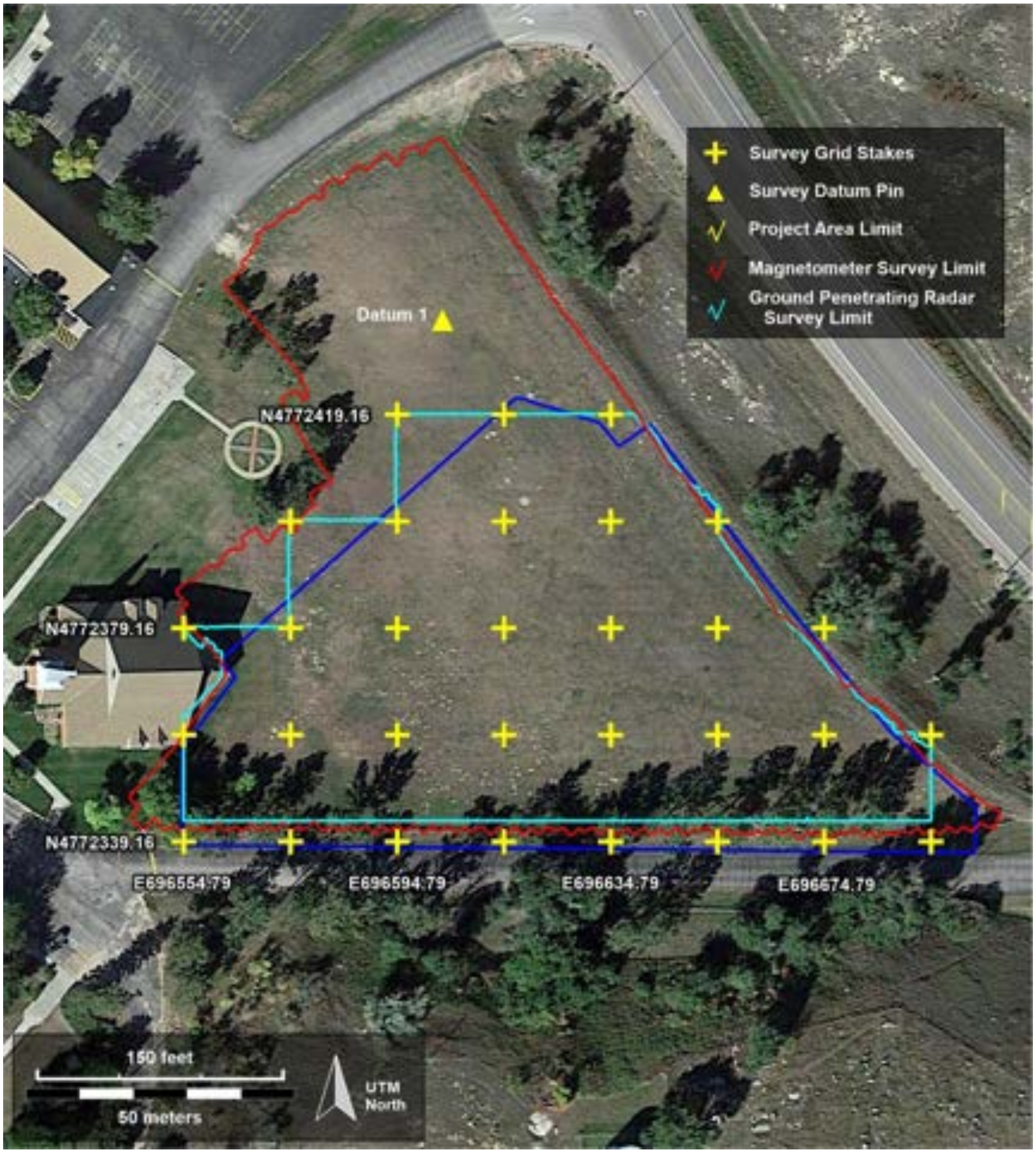


**Figure 17**. Map of the site survey grid and limits of the geophysical surveys relative to the project area.

**Table 1**. Survey datum coordinates.

| Datum | UTM Zone 13 north, WGS84 | | Latitude | Longitude | Comment |
|---|---|---|---|---|---|
| | **Northing** | **Easting** | | | |
| Datum 1 | 4772436.88 | 696603.27 | 43º04’44.991258” | -102º35’5.579550” | 10-inch galvanized nail wrapped in flagging tape, pounded flush with ground surface |

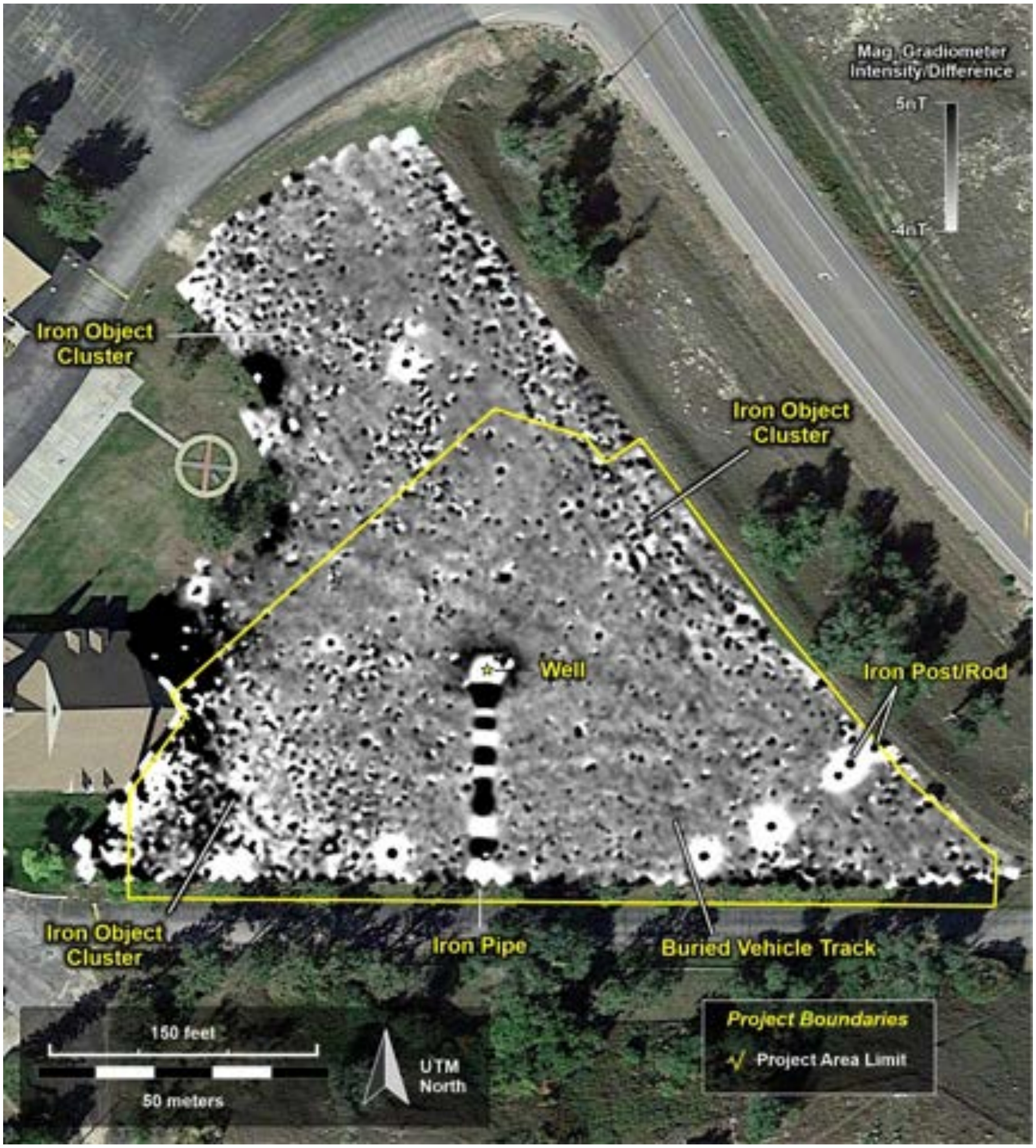


**Figure 18**. Magnetic survey results.

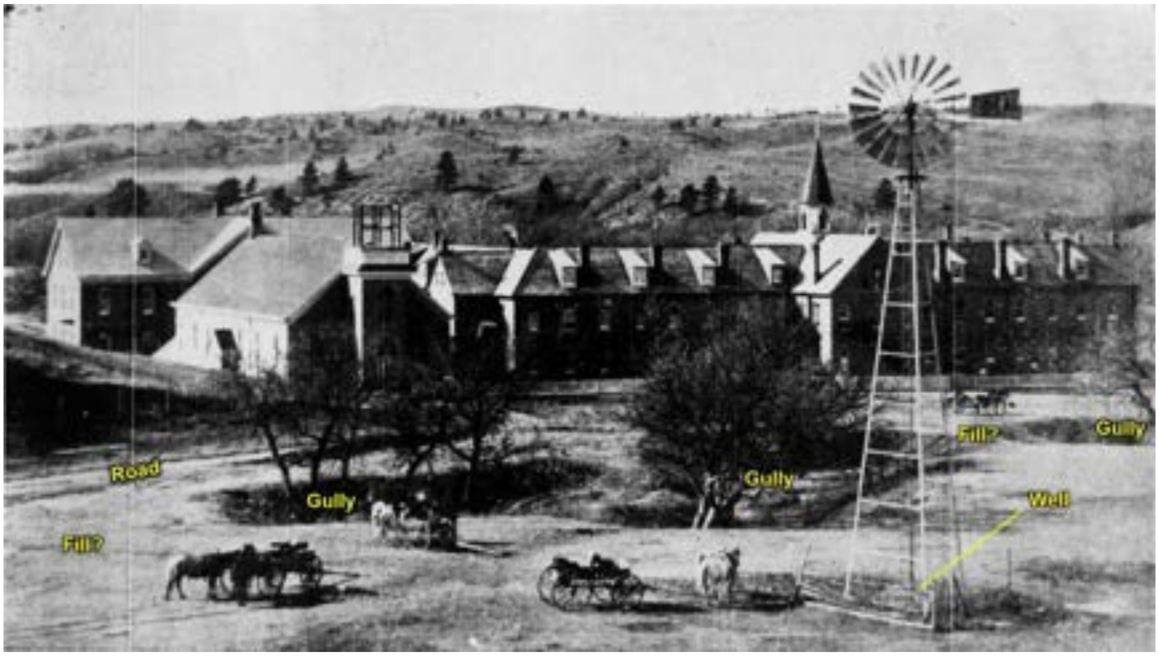


**Figure 19**. Photographic of Drexel Hall (with steeple) and the nearly completed church (left) circa 1890. Note the open gullies and the windmill over a well. (from *The Oglala Light* [TOL] 1 May 1910:34)

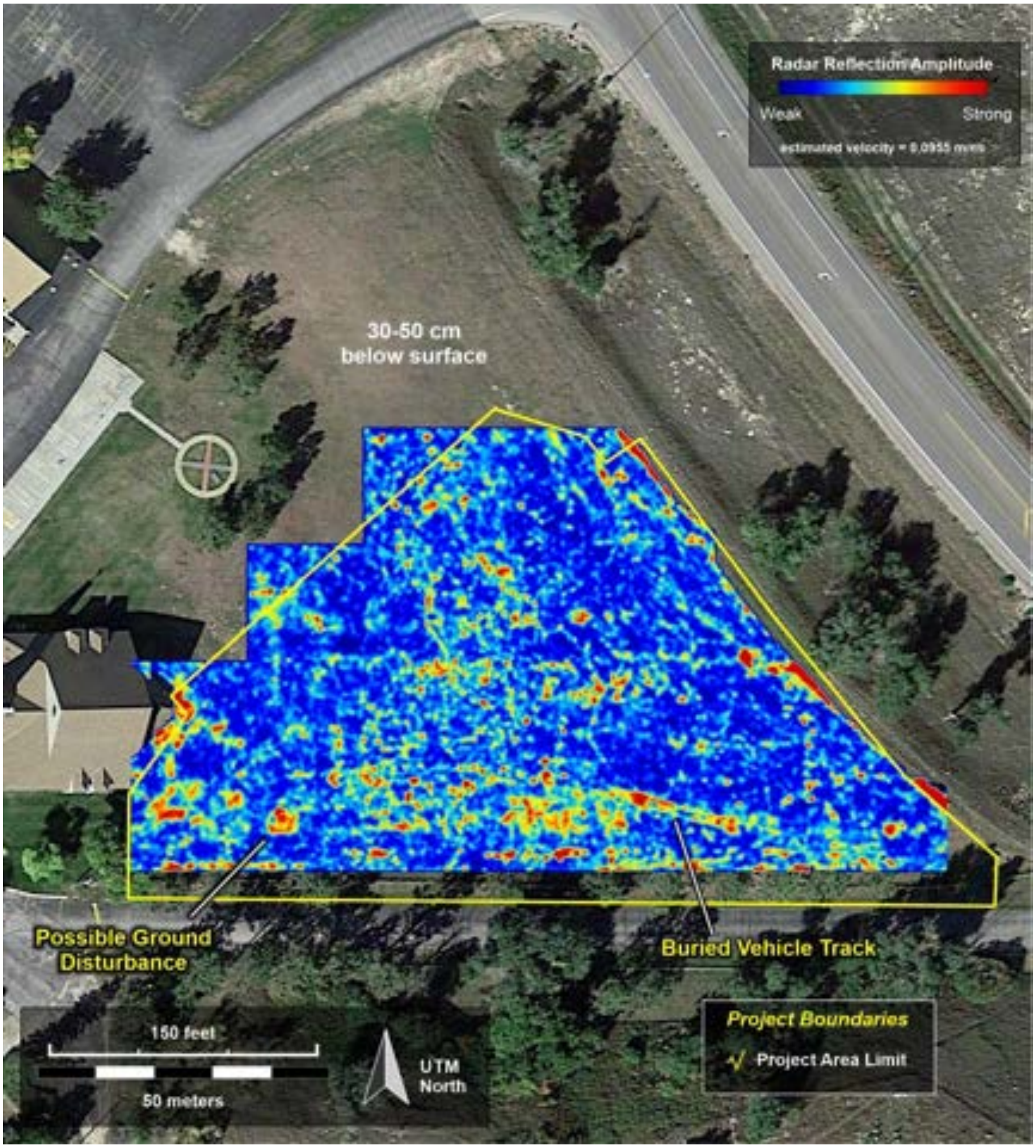


**Figure 20**. Detail view of a shallow radar amplitude slice map.

**Figure 21**. Early photographs of the front lawn area showing (a) looking south from the road at Drexel Hall under construction (c. 1888), before the church was built, and (b) in 1929 looking west (from somewhere on the cemetery hill) across the lawn toward Red Cloud Hall. Note the cart/vehicle tracks in both images. (top image from https://drexel.redcloudschool.org/; bottom image from the Holy Rosary Mission-Red Cloud Indian School Records, Marquette University).

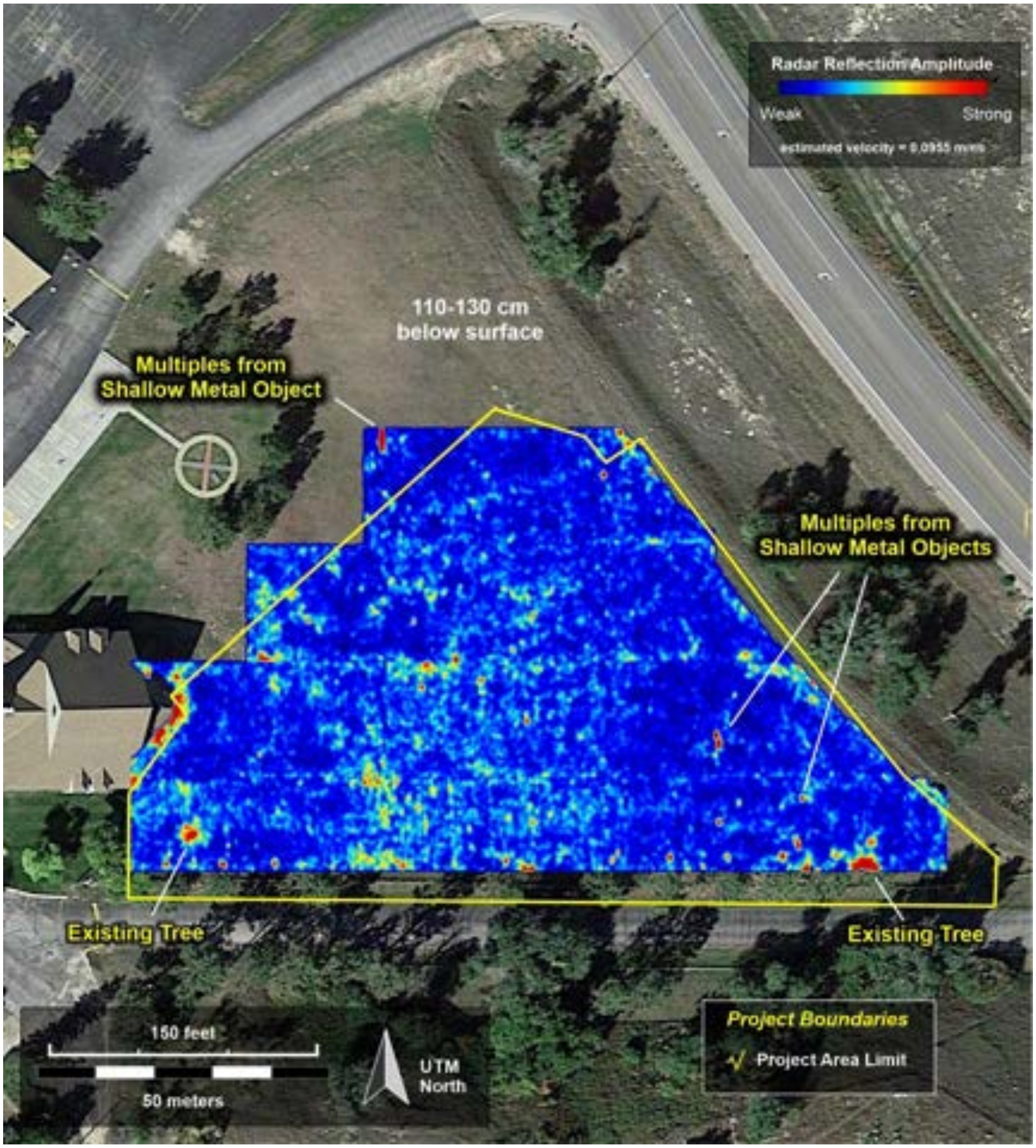


**Figure 22**. Detail view of a deeper radar amplitude slice map.

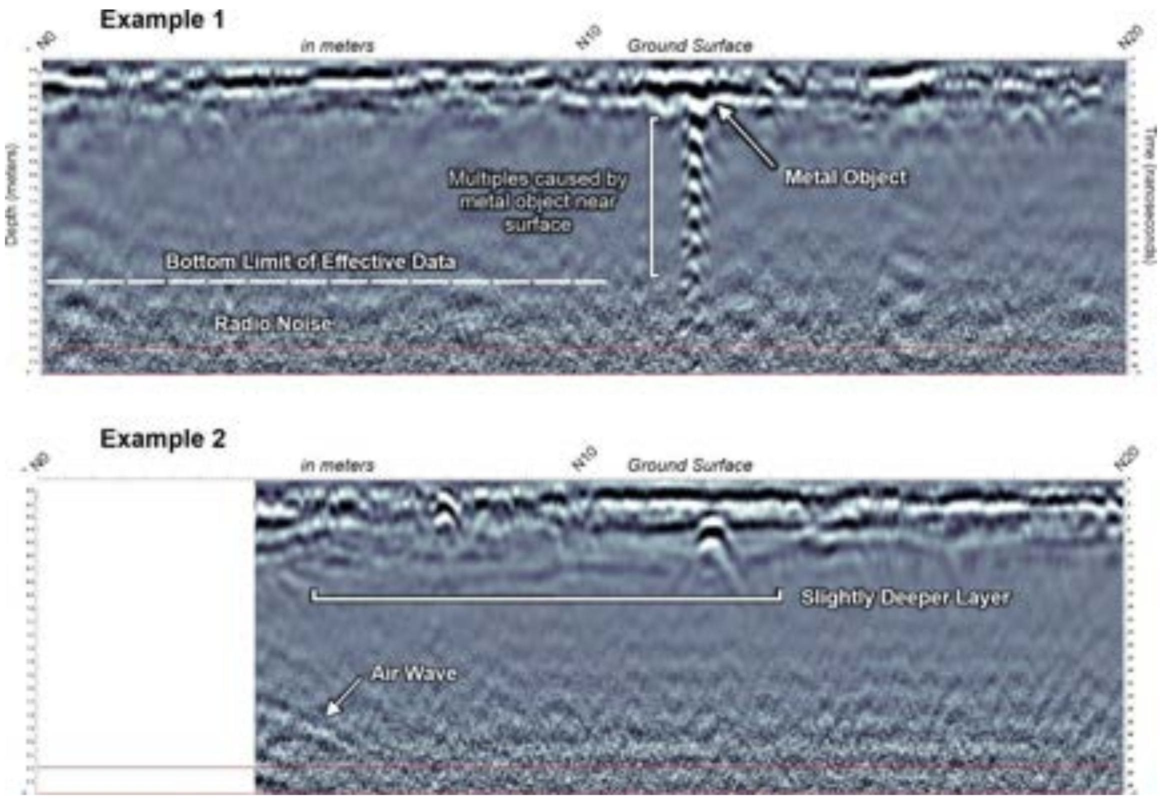


**Figure 23**. Examples of radar profiles showing a selection of reflection types, including (Example 1) a metal object near surface and (Example 2) a slightly deeper fill layer.

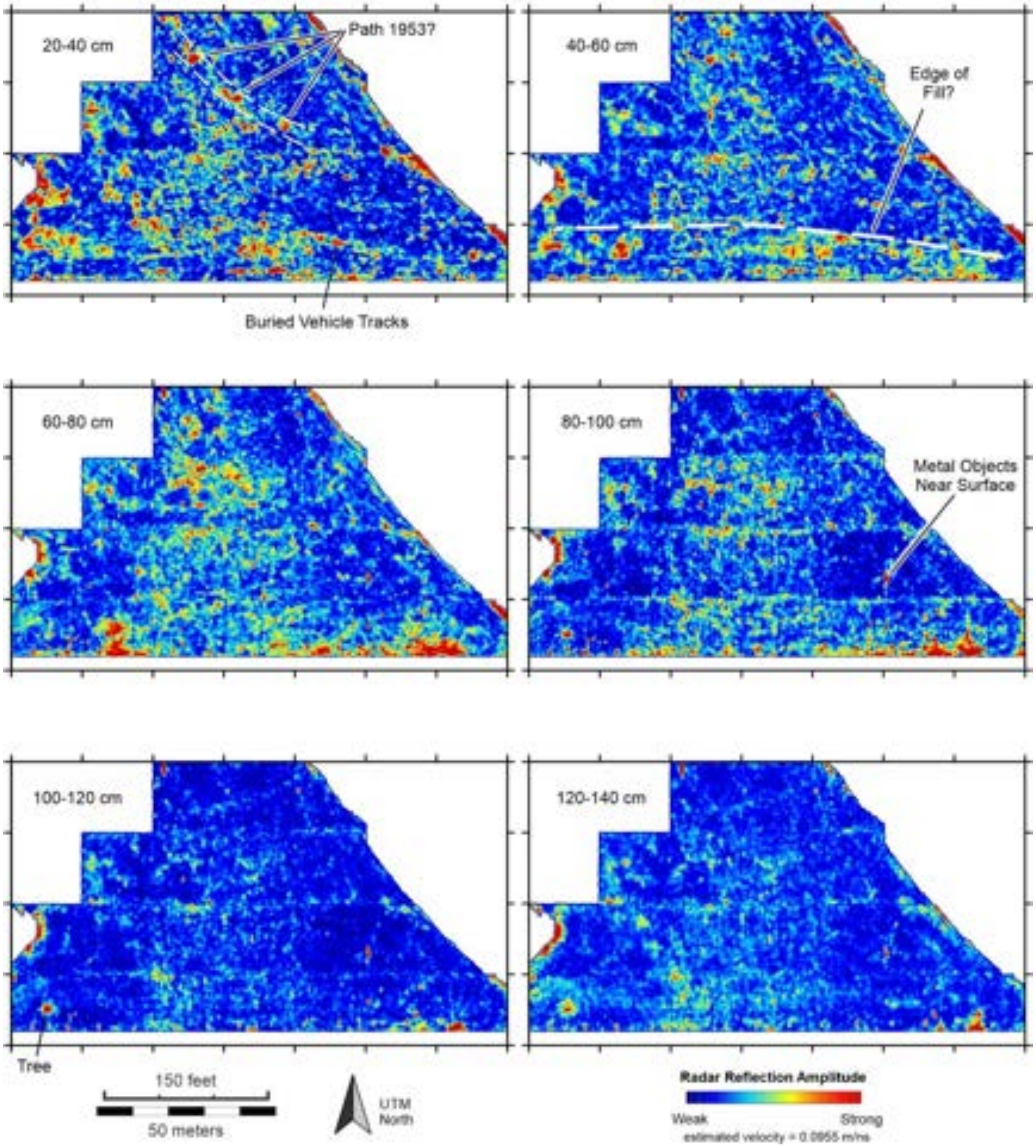


**Figure 24**. A series of radar amplitude slice maps at increasing depths.

## Summary and Recommendations

In late May 2022, geophysical surveys were conducted on the front lawn of Red Cloud Indian School in Pine Ridge, South Dakota ahead of a planned new building project that is to impact about 2 acres of the lawn. These surveys aimed to identify possible graves and other buried cultural features that would be impacted by the proposed construction. Examination of historic aerial and ground-based images indicates that this portion of the campus has experienced considerable change early in the school’s history. A large gully/wash that once ran along the southern school entrance road was completely filled by about 1910-1920, while evidence of a nineteenth century windmill and a former baseball field have been erased from the surface.

The results of the geophysical survey work support the likelihood that the ground containing the front lawn has experienced considerable filling and probable grading since the late 1800s. Figure 25 presents a map of the anomalies of potential interest detected during the geophysical survey work, with a summary of the anomalies outlined in Table 2. The magnetometer survey detected hundreds of iron objects scattered across the area in what is likely near-surface fill. The detection of buried vehicle tracks visible in early twentieth century photographs supports the idea that at least 25-30 cm of fill is present. That said, we know that the area has not been completely modified and disturbed since the magnetometer data also contained evidence of the windmill visible in at least one early photograph. The ground penetrating radar data also contained the buried indications of paths and vehicle tracks, as well as hints of the fill used to level off the gullies along the south side of the survey area.

**Table 2**. Notable geophysical anomalies detected during the survey.

| Anomaly # | Instrument | Description | Age |
|---|---|---|---|
| 1 | Mag | Well, vertical iron pipe | Late 1800s |
| 2 | Mag | Well distribution pipe, horizontal | Late 1800s |
| 3 | Mag/GPR | Vehicle track | 1920s |
| 4 | GPR | Fill in gully; west end may extend farther north, but not any closer than about 15 meters from well | 1890s-1910s |
| 5 | GPR | Layer of distinct fill material | 1910s |
| 6 | GPR | Footpath | Early 20th Cent. |
| 7-13 | Mag | Bases of iron/steel fence posts or poles; could have been related to plantings | unknown |

While no graves or other major cultural features were detected in the geophysical surveys, the fill and probable grading that have occurred in the project area may be covering culturally sensitive features or deposits. Therefore, we recommend archaeological and tribal monitoring for the initial excavations for the new project. These initial excavations, such as for the footprint of the building foundation, should begin with machine stripping of the top 30-50 cm of sediment with a flat-bladed excavation bucket. When performed carefully, such excavations can reveal the tops of pit-type and other features without extensive disturbance. If features of concern are found, they then can be documented and excavated or avoided during further ground disturbance activities.

**Figure 25**. Geophysical survey interpretation map with anomalies of potential interest.

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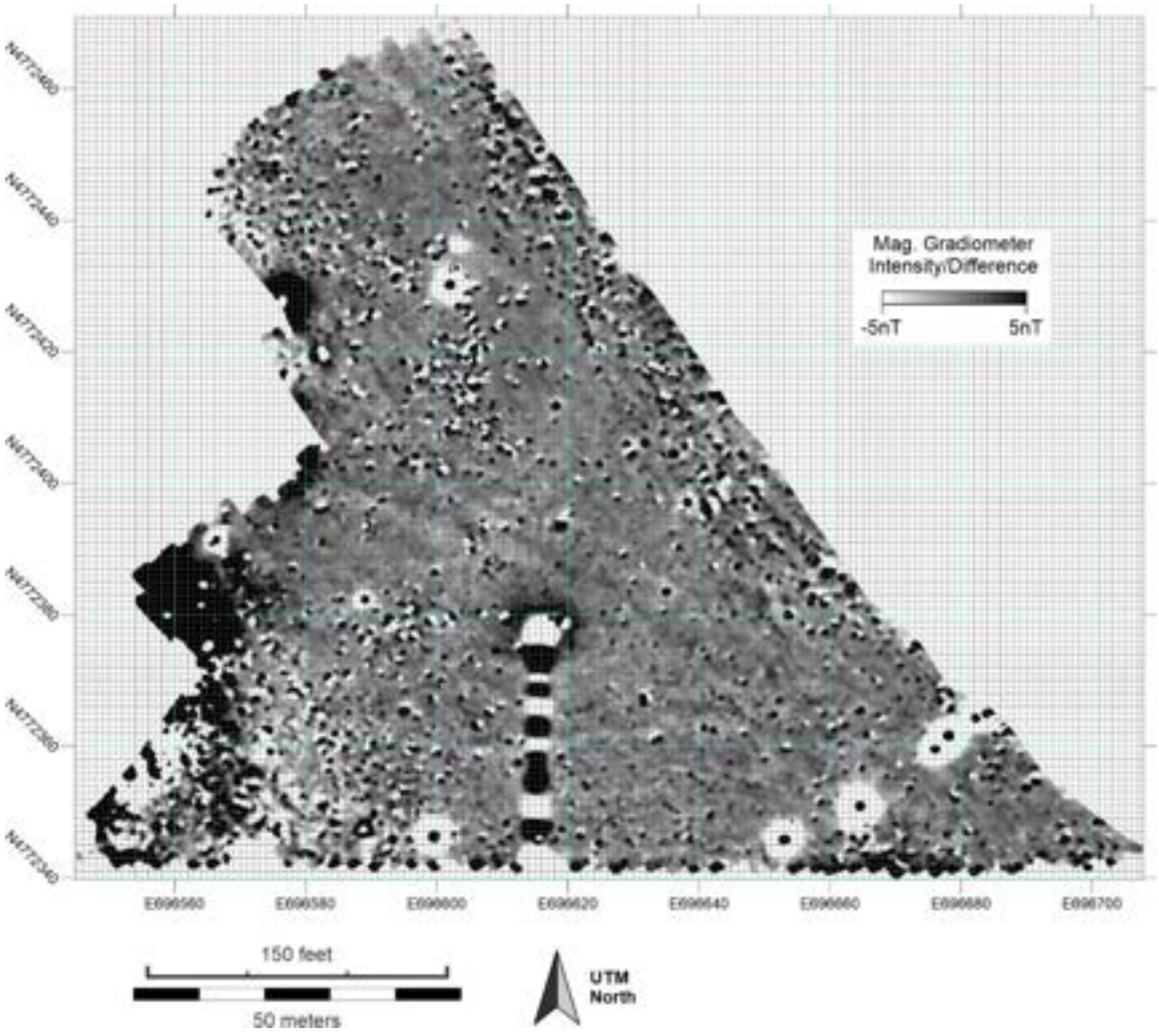
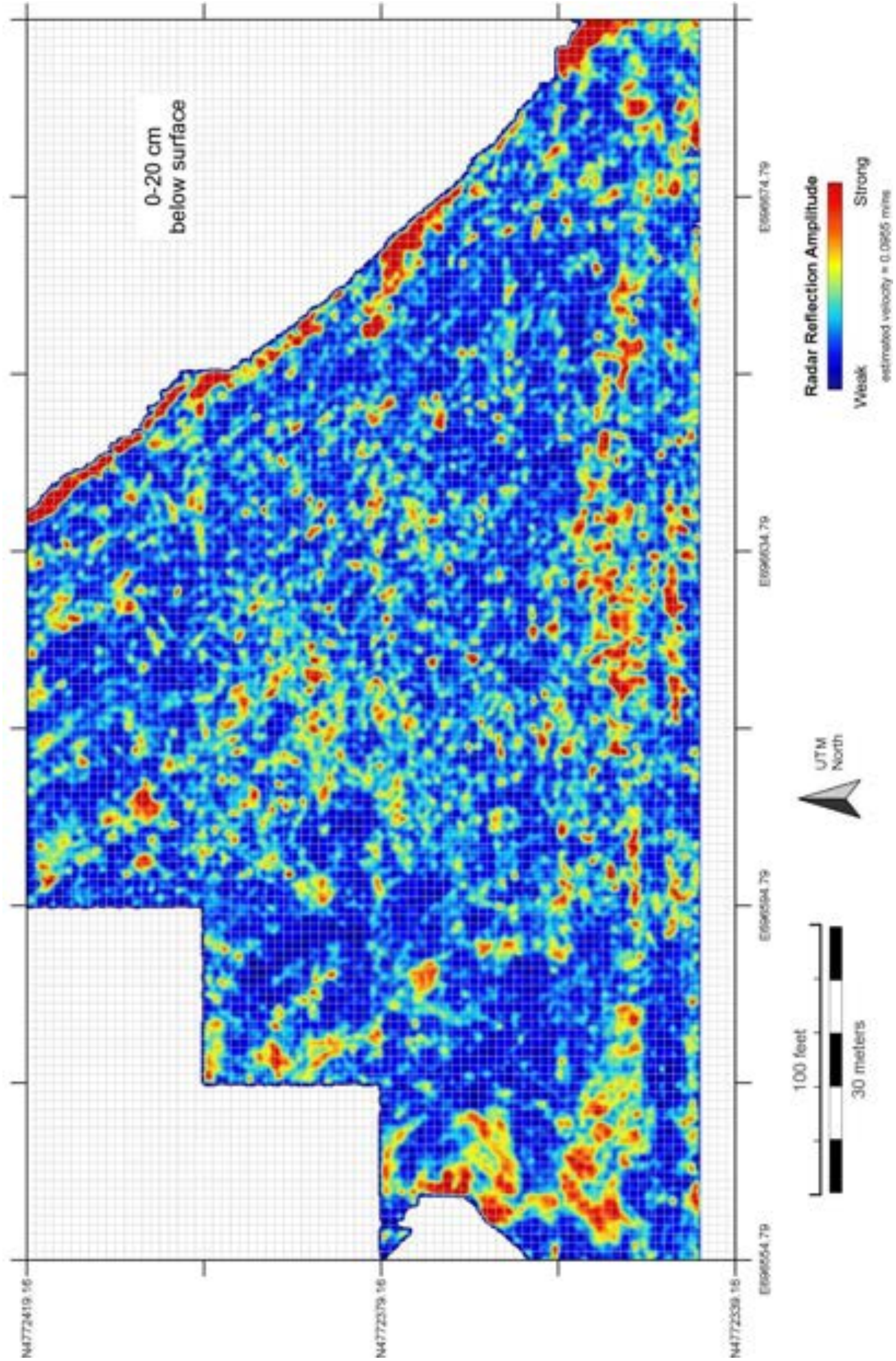
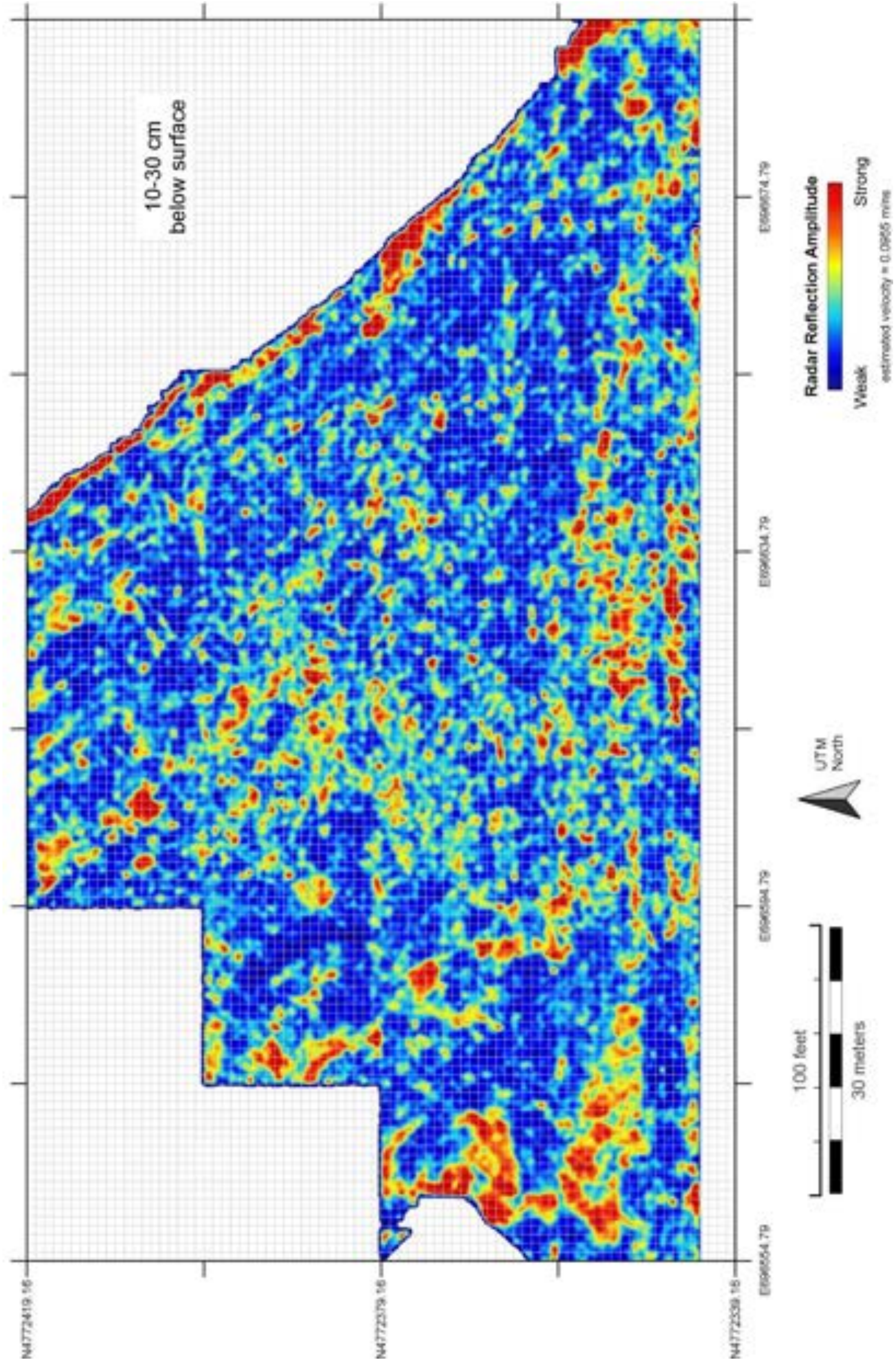
**Appendix A**. Magnetic gradiometer data with 1-meter grid overlay.



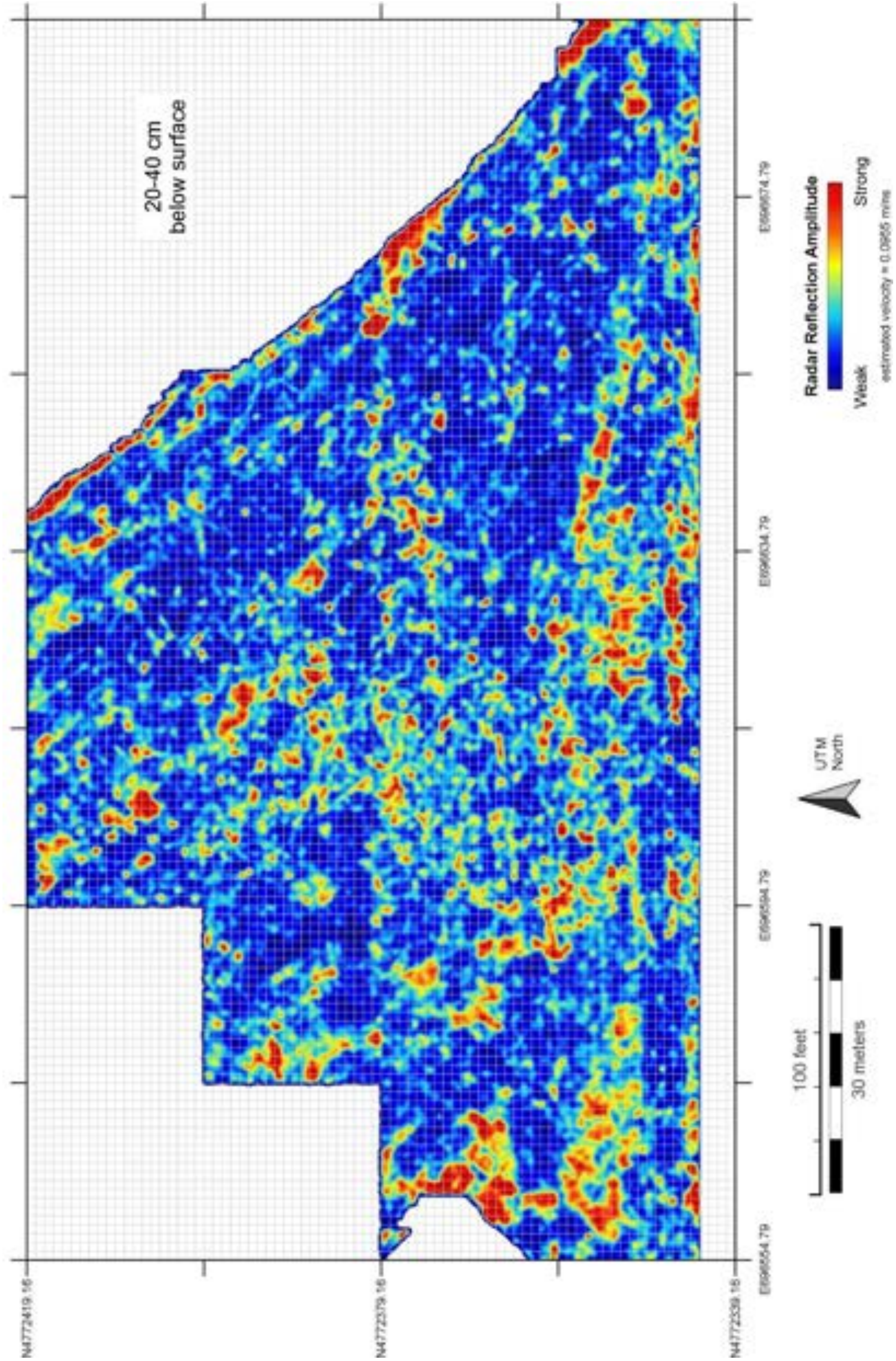
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay.



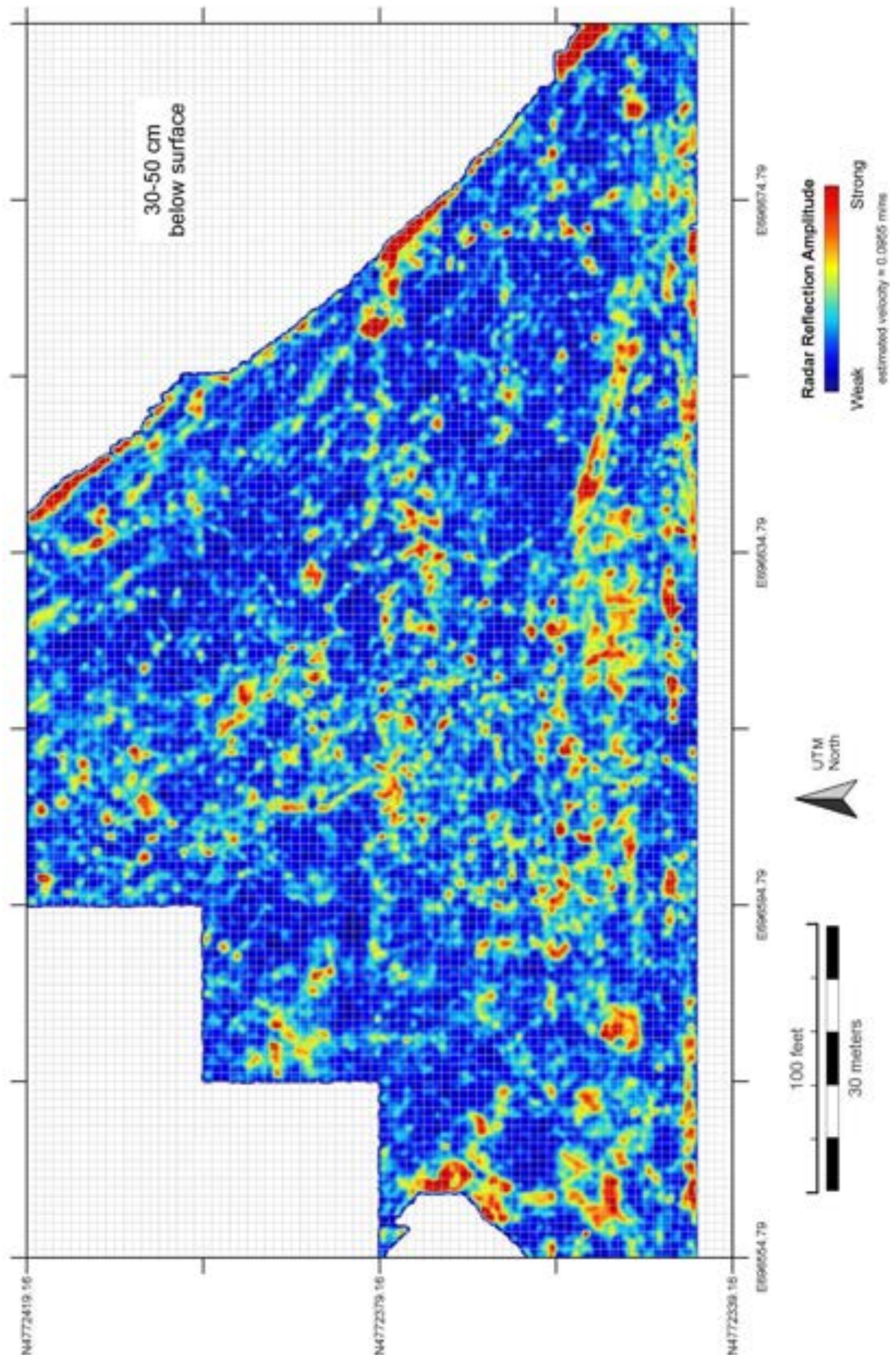
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



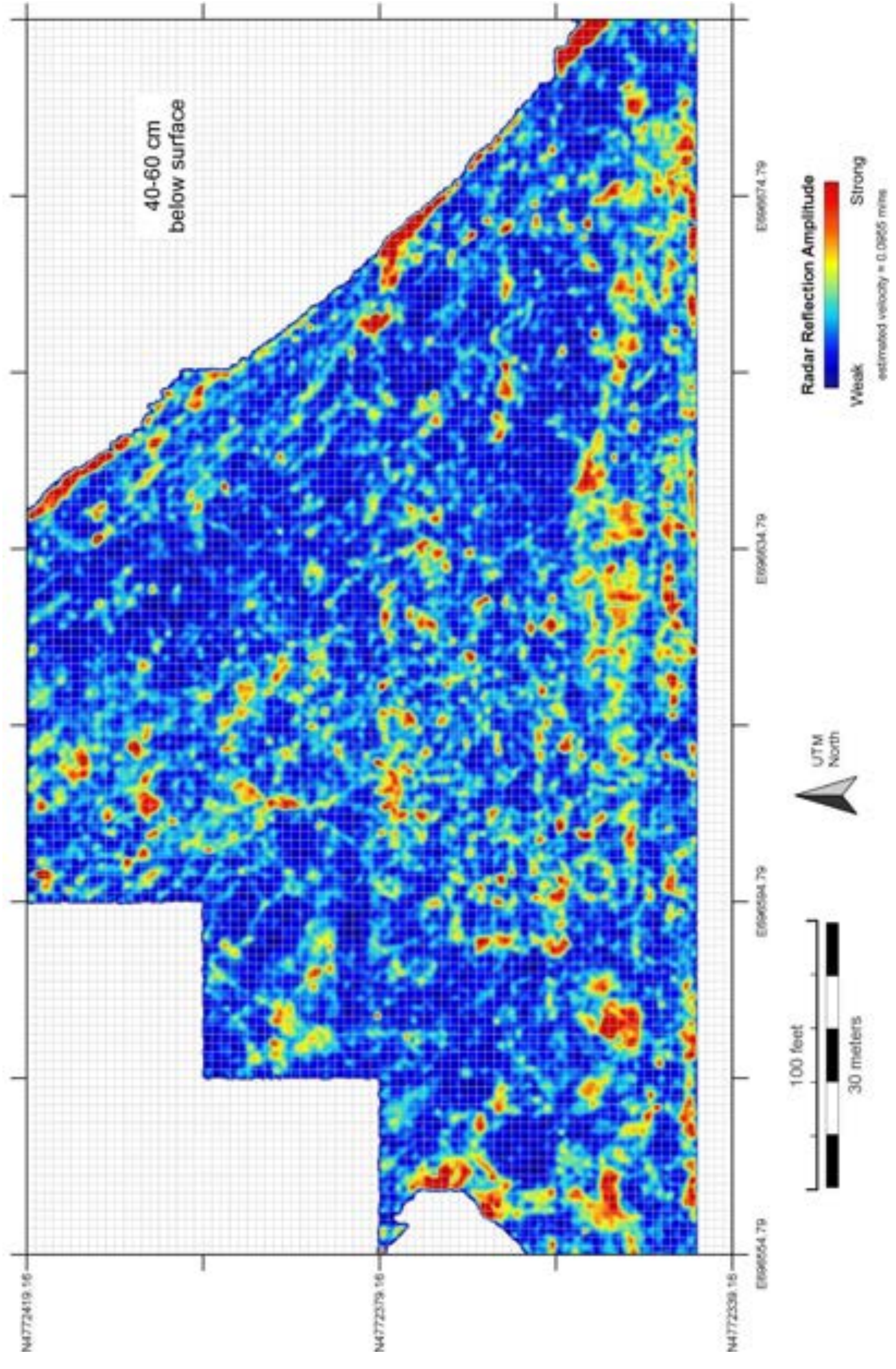
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



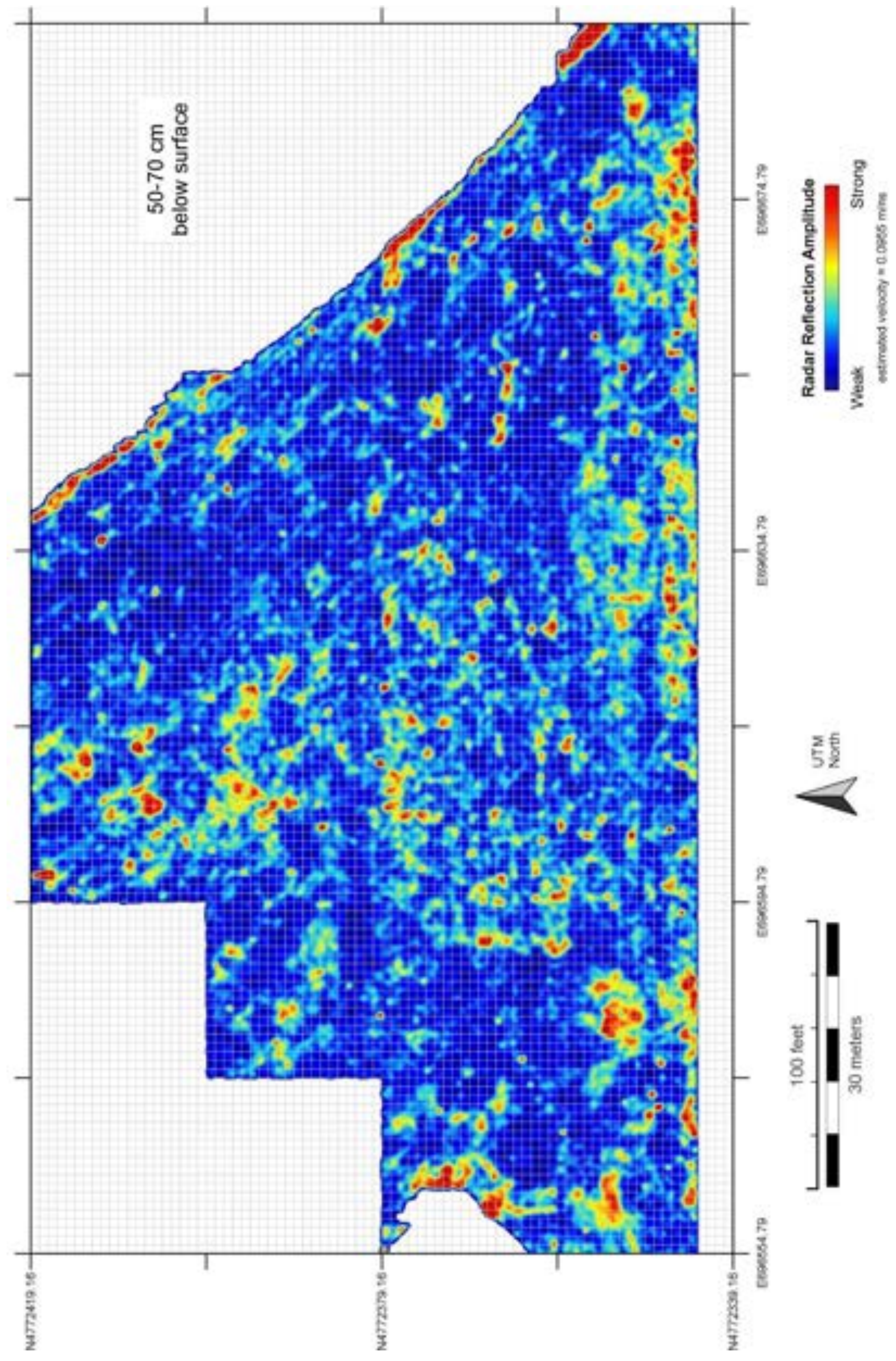
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



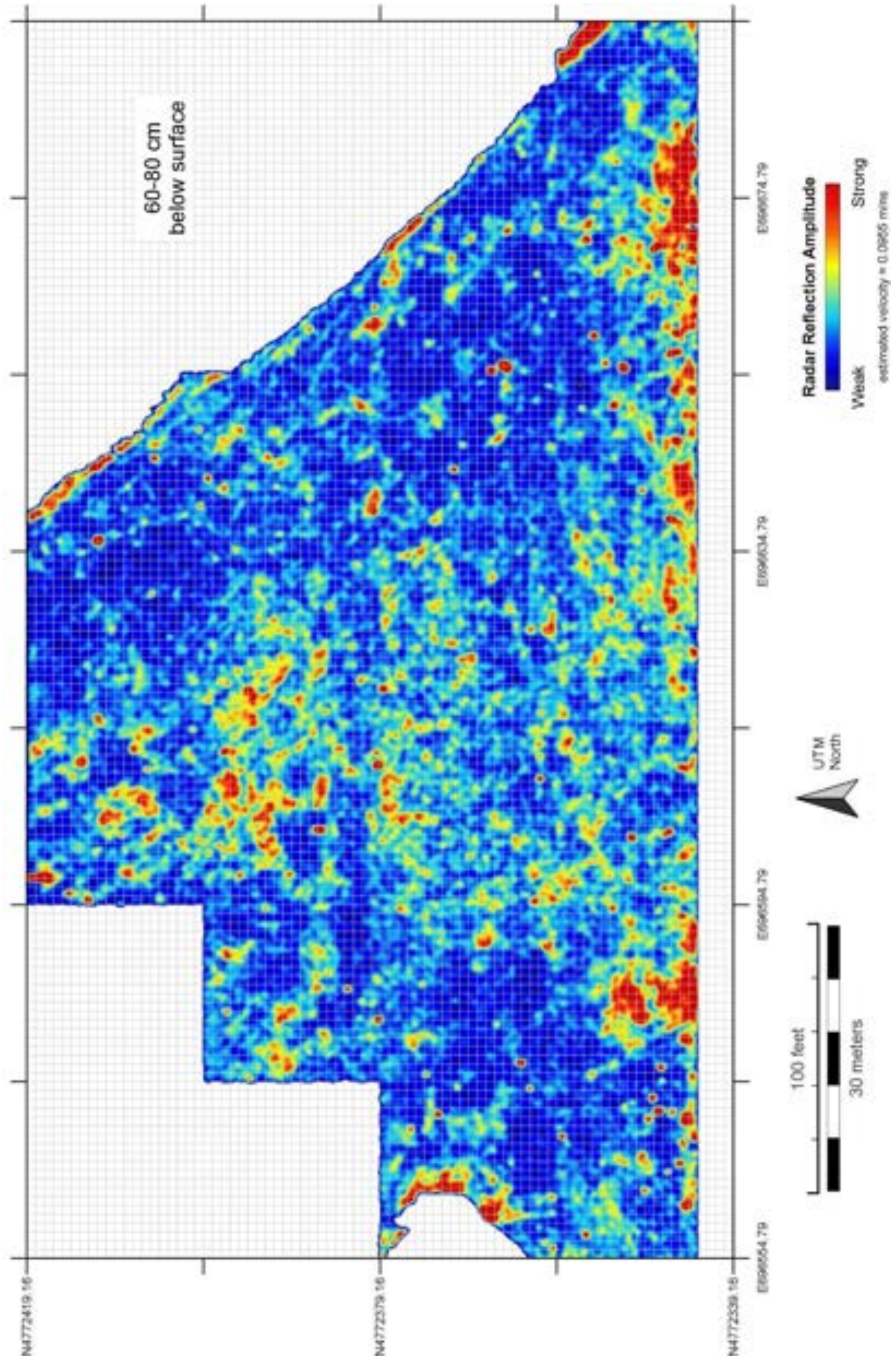
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



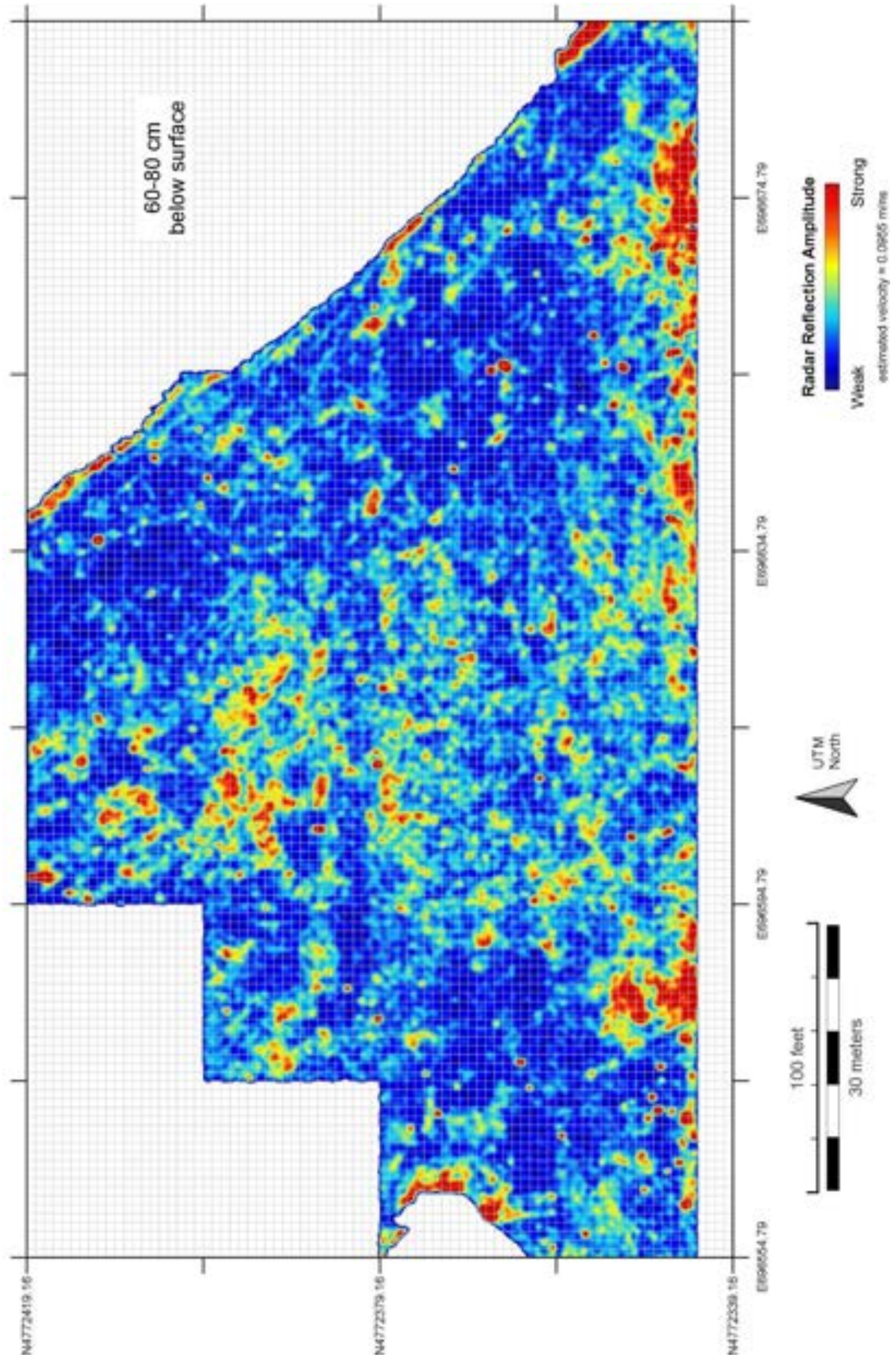
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



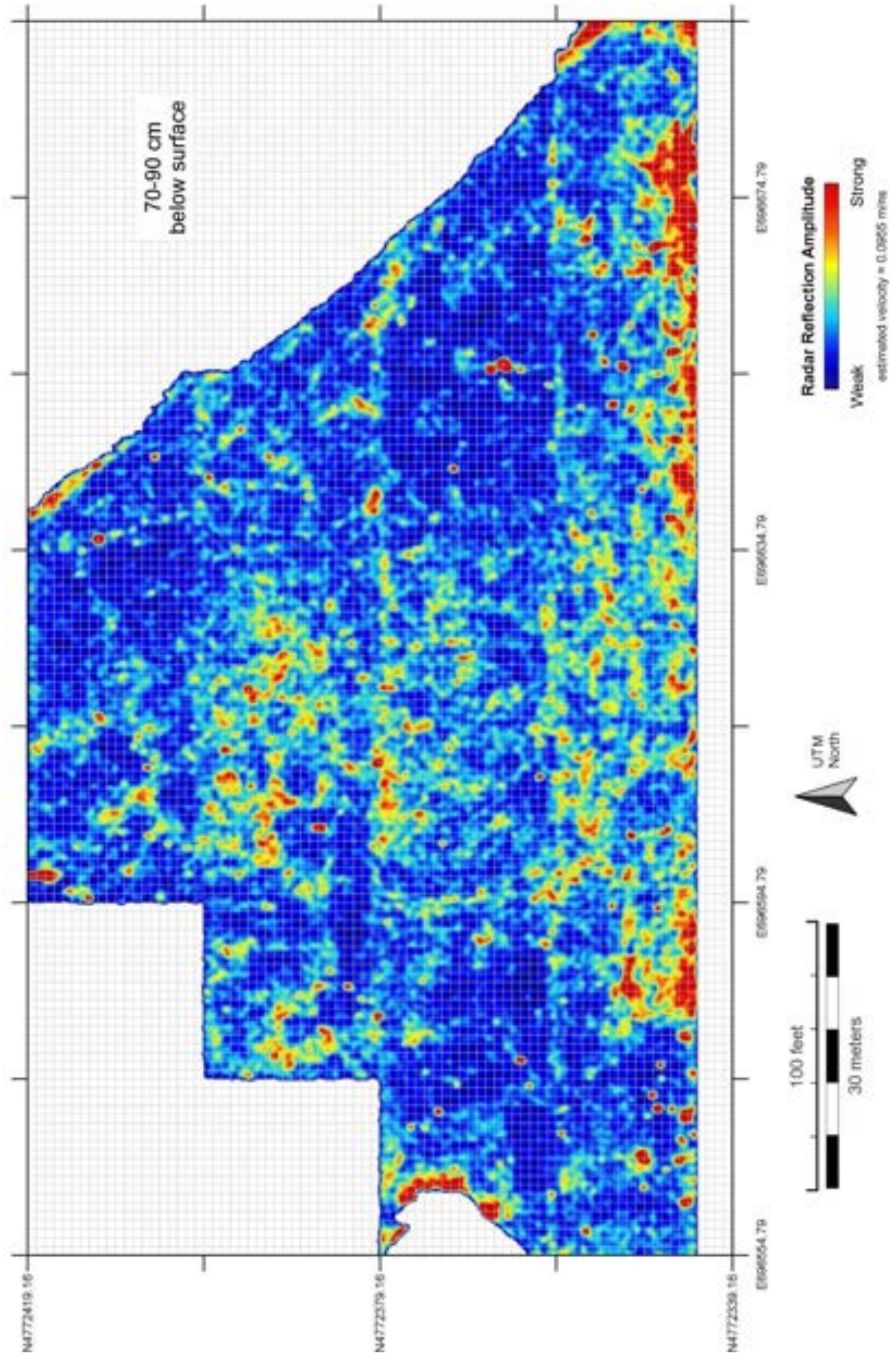
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



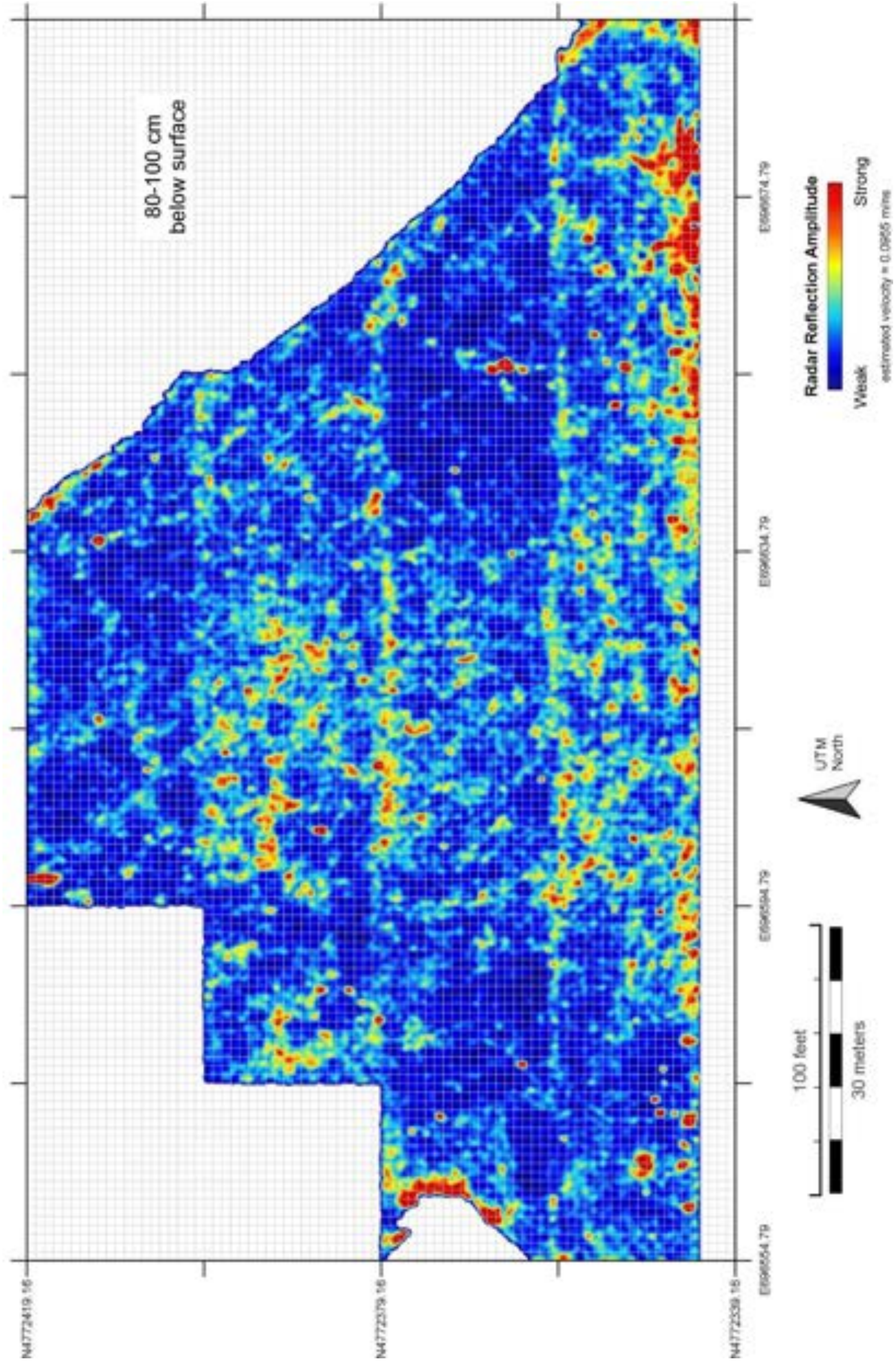
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



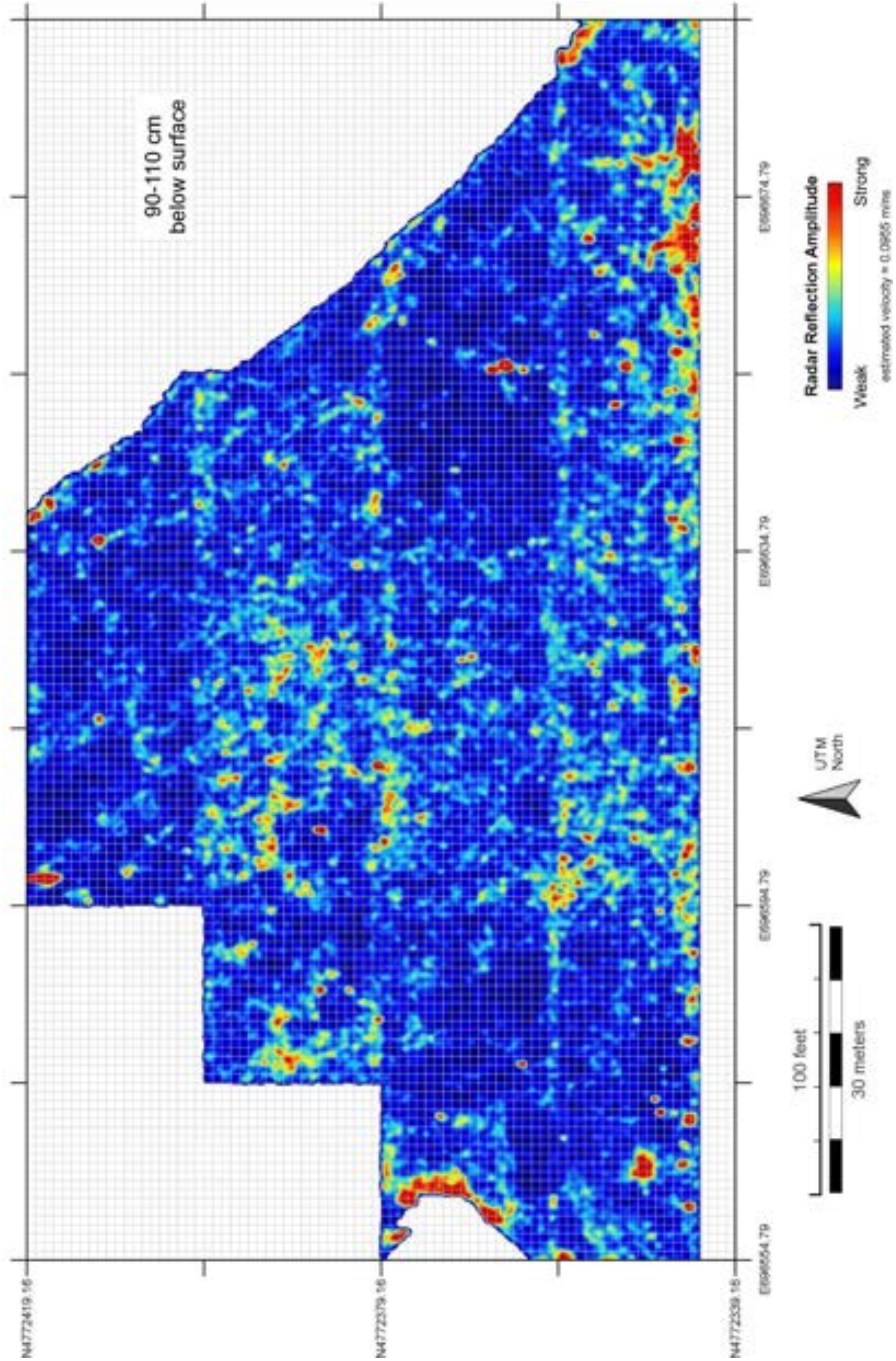
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



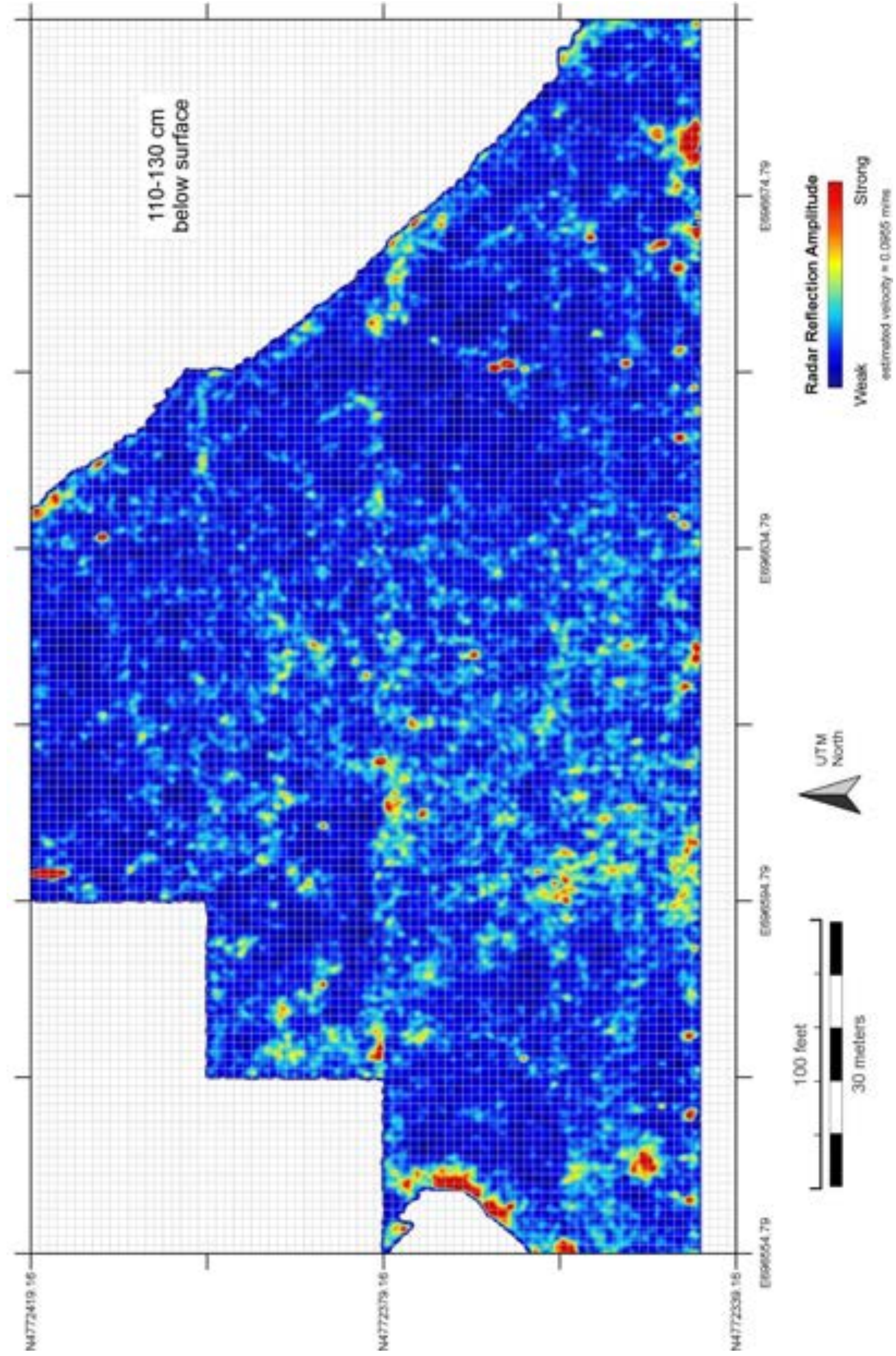
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



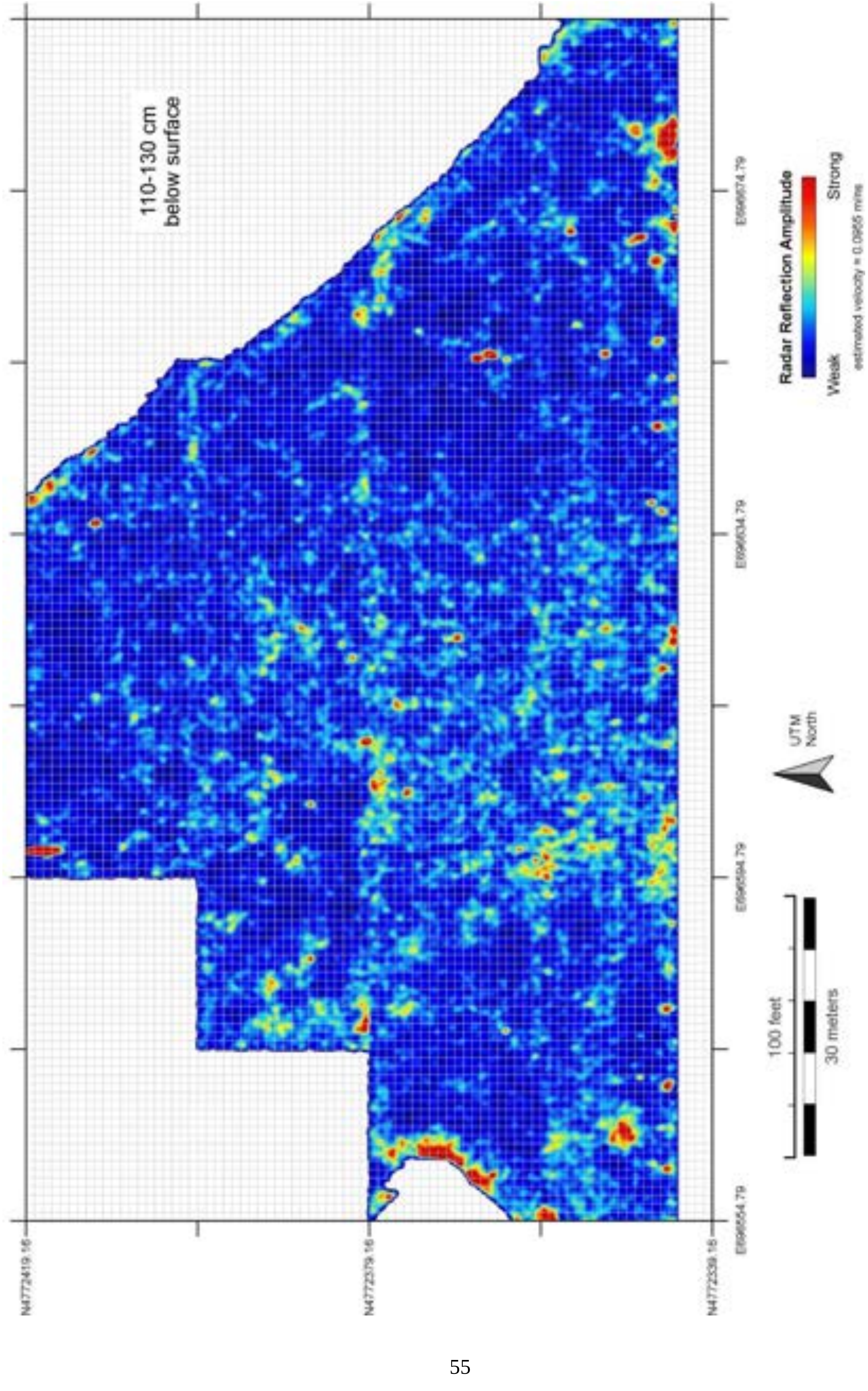
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



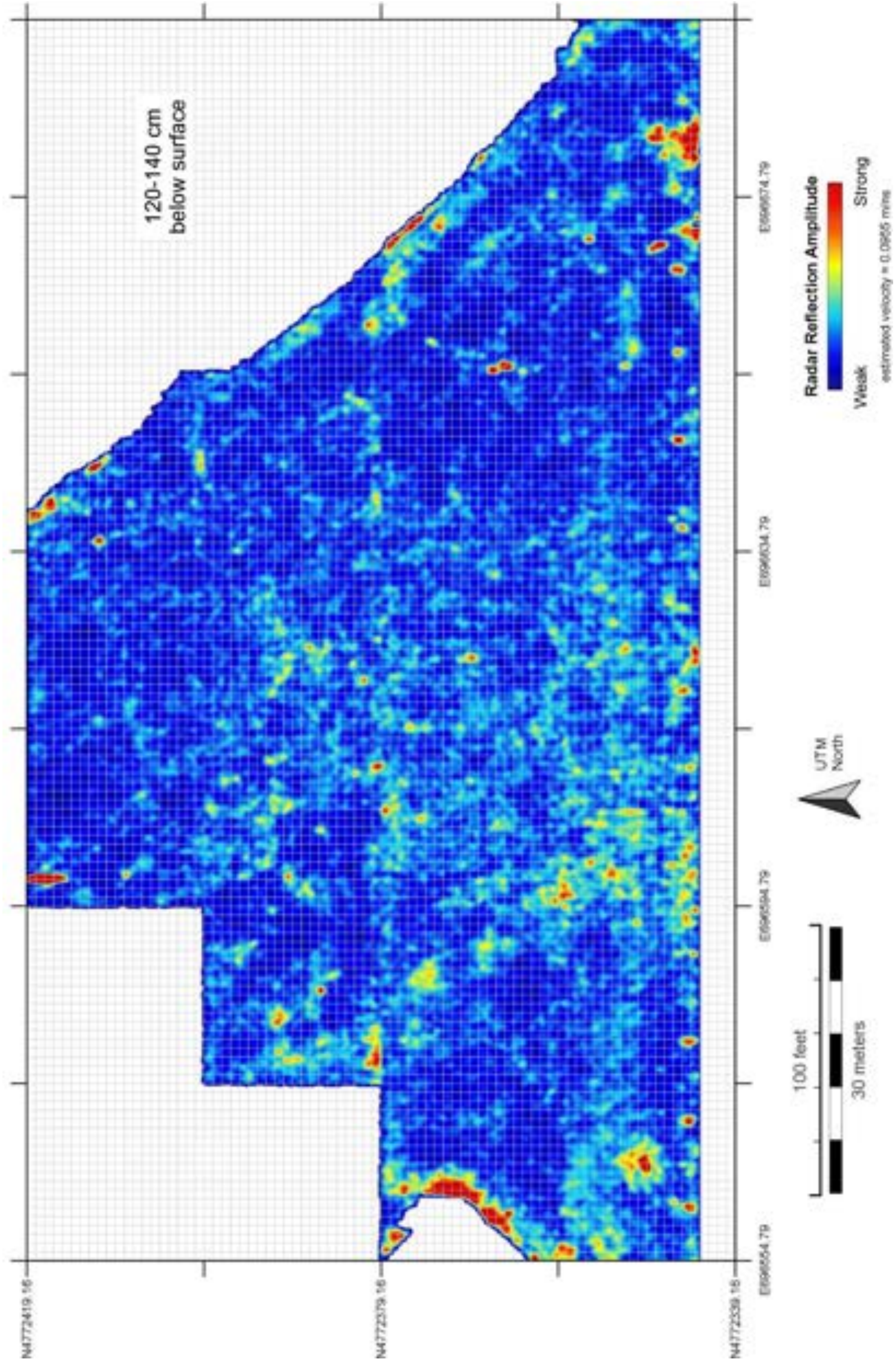
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



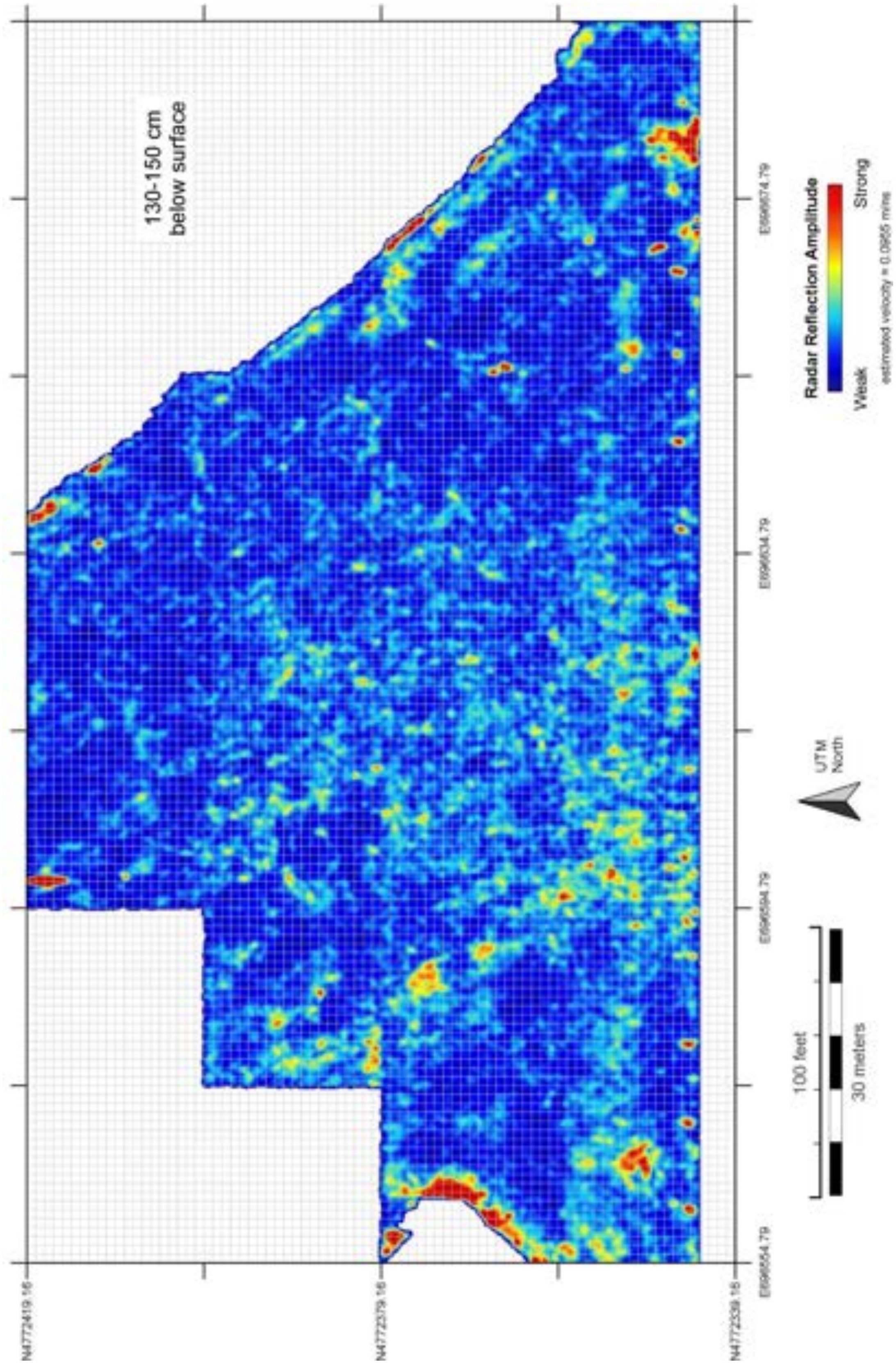
**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



**Appendix B**. Ground penetrating radar amplitude slice map with 1-meter grid overlay, *continued*.



# DREXEL HALL BASEMENT

## Ground Penetrating Radar Survey Results

## Red Cloud Indian School

## Pine Ridge, South Dakota

### Report II

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On May 21, 2022, Marsha Small and Jarrod Burks of Ohio Valley Archaeology, Inc. used a ground penetrating radar system to scan an area of new concrete on the floor of the basement of Drexel Hall, at Red Cloud Indian School in Pine Ridge, South Dakota. According to a former school staff member, in the 1990s when the basement floor was dirt rather than concrete, he observed two low piles of sediment in one of the small southeast corner rooms of the building's basement. (Figure 1**).** This area was subsequently covered by concrete, which appears to have been recently replaced. Thus, the goal of the radar survey was to determine if signs of the observed grave-like mounds, and possible graves beneath them, are still present below the concrete. This radar survey was performed at the request of Red Cloud Indian School, with support and concern from the local community. The work was conducted as part of a multi-instrument geophysical survey project that examined a portion of the school's front lawn area ahead of a proposed new building project (see Small, Burks, and Snider 2022).

## Methods

A Mala Easy Locator Core HDR radar system was used to collect the radar data (Figure 2). This 450 MHz system works well for penetrating concrete to identify targets below. As the radar system is pushed along the floor, it emits thousands of pulses of radar energy per second—the radar waves travel out and back at nearly the speed of light. With each pulse, the radar "listens" for reflections that might come back from things buried beneath the floor—such as utility pipes, wires, large rocks, the water table, and sometimes graves when they are present and detectable. The radar data were collected at a rate of one reading (a "trace") every inch (~ 2.5 cm) as the radar was pushed along survey lines spaced at 3-inch (10 cm) intervals. The area of the new concrete was covered twice with this method, with the data collection lines for the second survey running perpendicular to the data collection lines in the first. The resulting data collected from the two surveys was processed into two different sets of radar amplitude slice maps, which provide horizontal plan views of the radar results at any desired depth within the 60-nanosecond time window used for the survey.

## Results

The survey area in the basement of Drexel Hall is a small space located a couple meters from a set of stairs leading up to the ground floor (Figure 3). Once surrounded by stone and wood walls, the area is now more open—likely to allow space for new duct work related to a nearby HVAC system that looks to have been recently upgraded. The map in Figure 4 shows the extent of the radar survey, which aimed to cover as much of the new concrete as the radar system would allow. The red and blue lines indicate the extents of the radar data collected going in each of the survey directions. Note the narrow swath of new concrete at the lower right of the area. These narrow, linear patches of new concrete run along the floor in several places in this part of the basement. They likely indicate areas where drainage pipes or other utilities were buried in trenches in the floor, and one of these buried drainage pipes/utility lines appears to run into the area with the new concrete that was covered by the radar survey.

The map in Figure 5 shows some of the results from the first radar survey. Red areas indicate stronger radar reflections while blue areas are weaker. Note the linear red area near the middle of the survey area marked as Anomaly 1—it is about 4 feet long and 1 foot wide and occurs at about 1.75-2.75 feet beneath the basement floor. Figure 6 is a panel of maps showing the radar results at different depths beneath the floor. A strong area of radar reflections, indicated as Anomaly 2, is visible in the slice maps closer to the surface, near the door leading to the stairs. As we go deeper into the radar data, Anomaly 1 becomes evident at 1.75-2.75 feet below the surface as shown in Figure 5. Elements of this linear anomaly persist into the 2.5-3.5 feet slice map, but they begin to disappear below this.

Anomaly 1 is also visible in the second batch of radar data (see Figure 7) collected while running the instrument along lines perpendicular to the first batch of data. In the sequence of slice maps from the second survey shown in Figure 8, we can see that Anomaly 2 is present in the shallow slices, and Anomaly 1 is less distinct in the deeper slices (e.g., 1.75-2.75 ft). However, this anomaly does not appear to continue into the slices below this, as it does in the first dataset.

These results show that there are small areas of stronger radar reflections present below the basement floor. Anomalies 1 and 2 are the most distinct of these. Anomaly 1 has the size and shape of a possible grave, but Anomaly 2 produced the strongest reflections. Of course, graves are not the only things that can produce distinctive anomalies in radar data reflecting off things from beneath concrete floors. Accumulated water from leaks or poor drainage also will create distinct anomalies, as will air pockets, concentrations of sand and gravel, or construction debris that has been covered over by the concrete.

## Recommendations

Though definitive indications of graves are not present in the radar data, areas of small, distinct differences are visible in the slice maps from beneath the concrete. Removal of the concrete and careful excavation of the sediment below is recommended to test this area for indications of graves. This may be the only way to confidently identify the presence of graves because other materials beneath the concrete can create radar anomalies that are similar to those expected for graves. The sediment should be excavated in layers (e.g., 5-10 cm thick) and clean, flat excavation floors examined for the outlines of possible graves. All sediments should be screened through ¼ inch mesh. This work should be performed by a small team of archaeologists and tribal representatives, with support and permission from the school administration, the community, the Tribal Historic Preservation Officer (THPO), and the State Historic Preservation Officer (SHPO). We recommend that these and other interested parties participate in creating a project plan document and a memorandum of agreement for any proposed excavations so that the project upholds transparent objectives, methods, and results.

## Acknowledgements

The authors wish to thank the staff at Red Cloud Indian School for their assistance with the project, especially Maka Black Elk, Executive Director for Truth and Healing and his assistant Billy Critchley-Menor, SJ. We are also indebted to Justin Pourier, a former Red Cloud school staff member, for sharing his knowledge about grave-like features he observed on the floor of the basement during his normal work duties. We also acknowledge Basil Brave Heart for his opening blessing and guidance.

## References Cited

Small, Marsha, Jarrod Burks, and Joseph E. B. Snider
2022 Geophysical Survey Results on the Front Lawn of Red Cloud Indian School, Pine Ridge, South Dakota. OVAI Contract Report 2022-29. Ohio Valley Archaeology, Inc., Columbus, Ohio.

**Figure 1**. Location of the ground penetrating radar survey in Drexel Hall at Red Cloud Indian School, Pine Ridge, South Dakota.

**Figure 2**. Authors with the Mala ground penetrating radar system used to scan the new concrete on the basement floor.

**Figure 3**. The area examined during the radar survey, with radar system sitting on the new concrete.

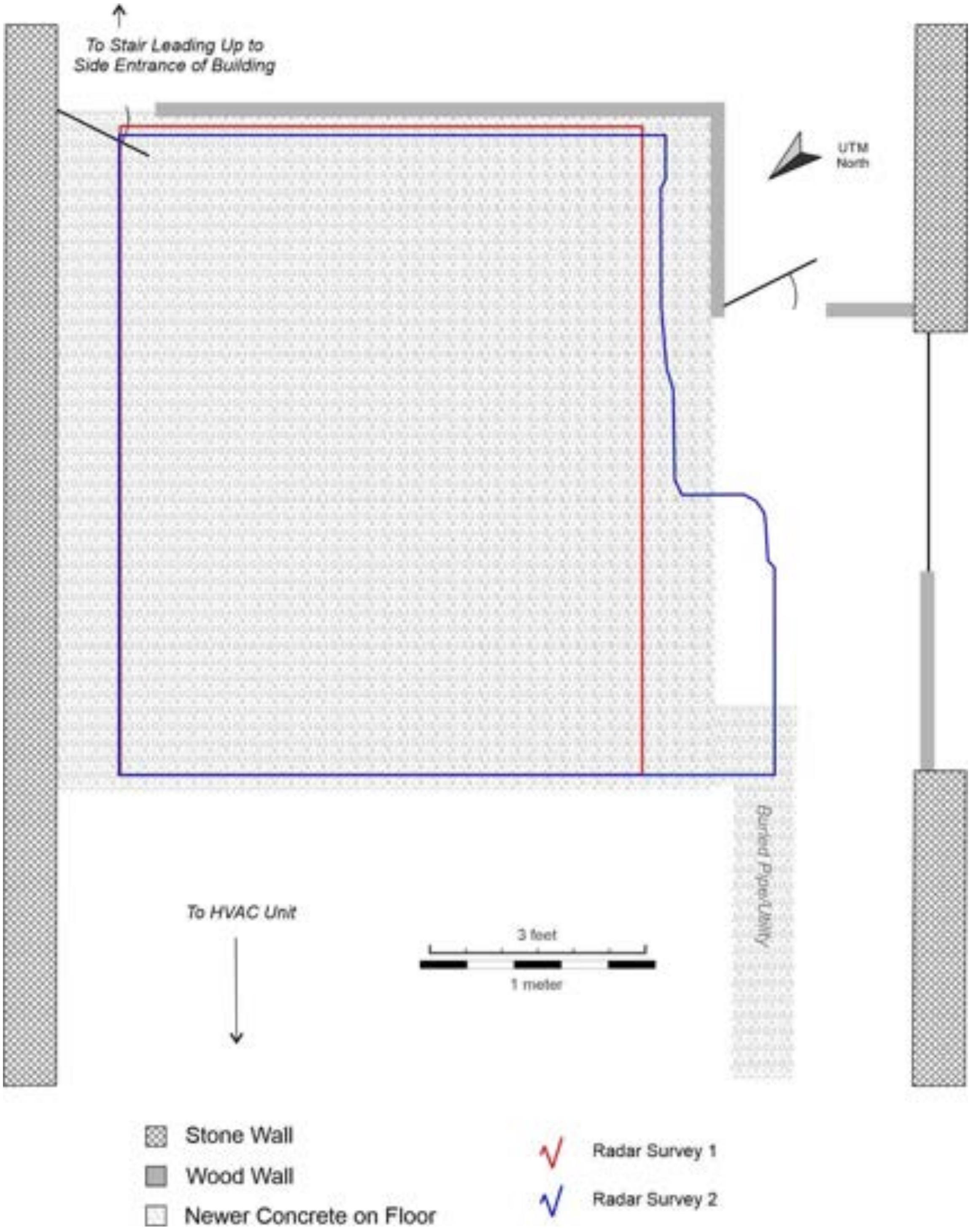

**Figure 4**. Map of the survey area on the basement floor, showing the approximate limits of the radar surveys relative to the new concrete on the floor.

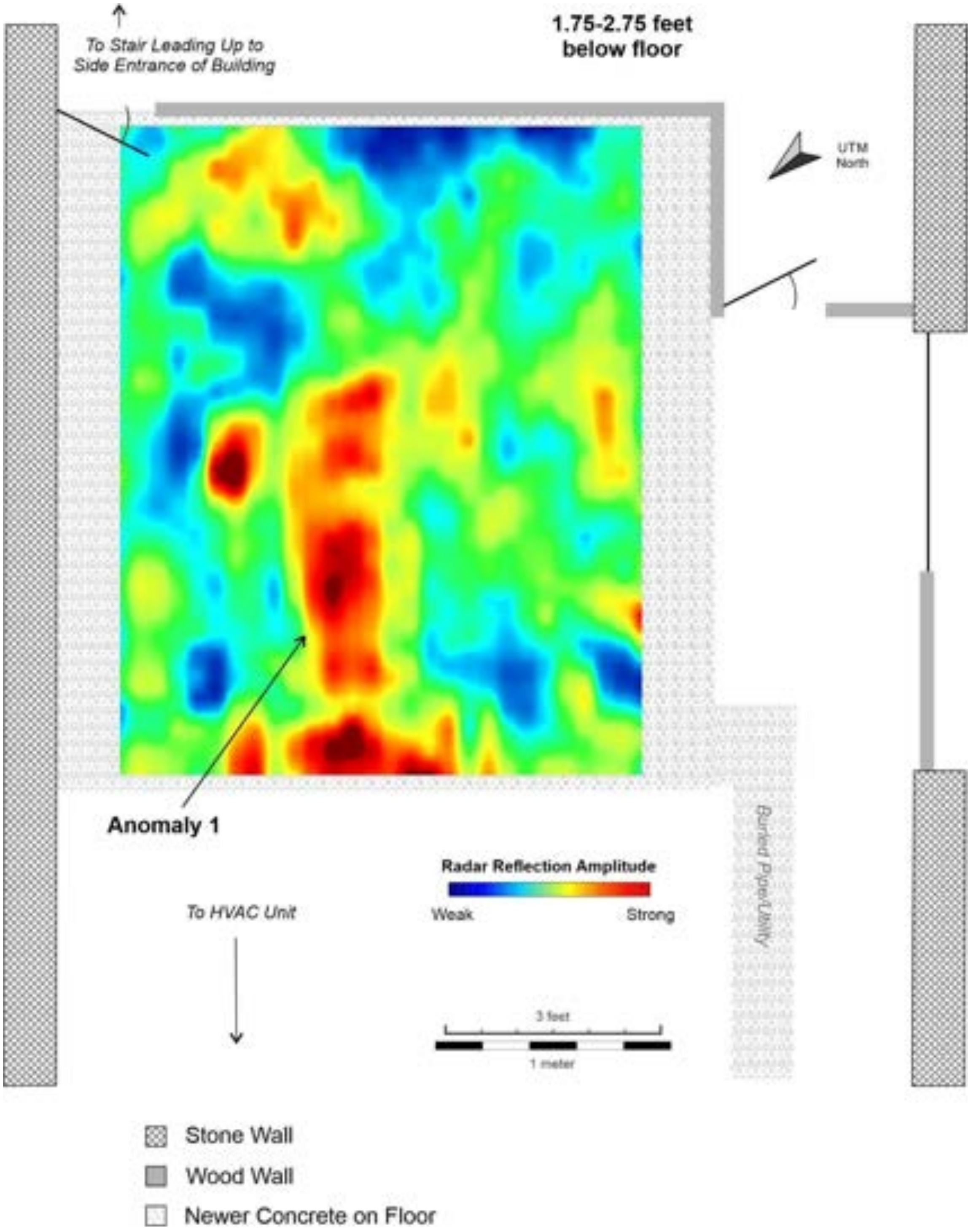

**Figure 5**. Example radar slice map from 1.75 ft to 2.75 ft below the basement floor, from the first radar survey.

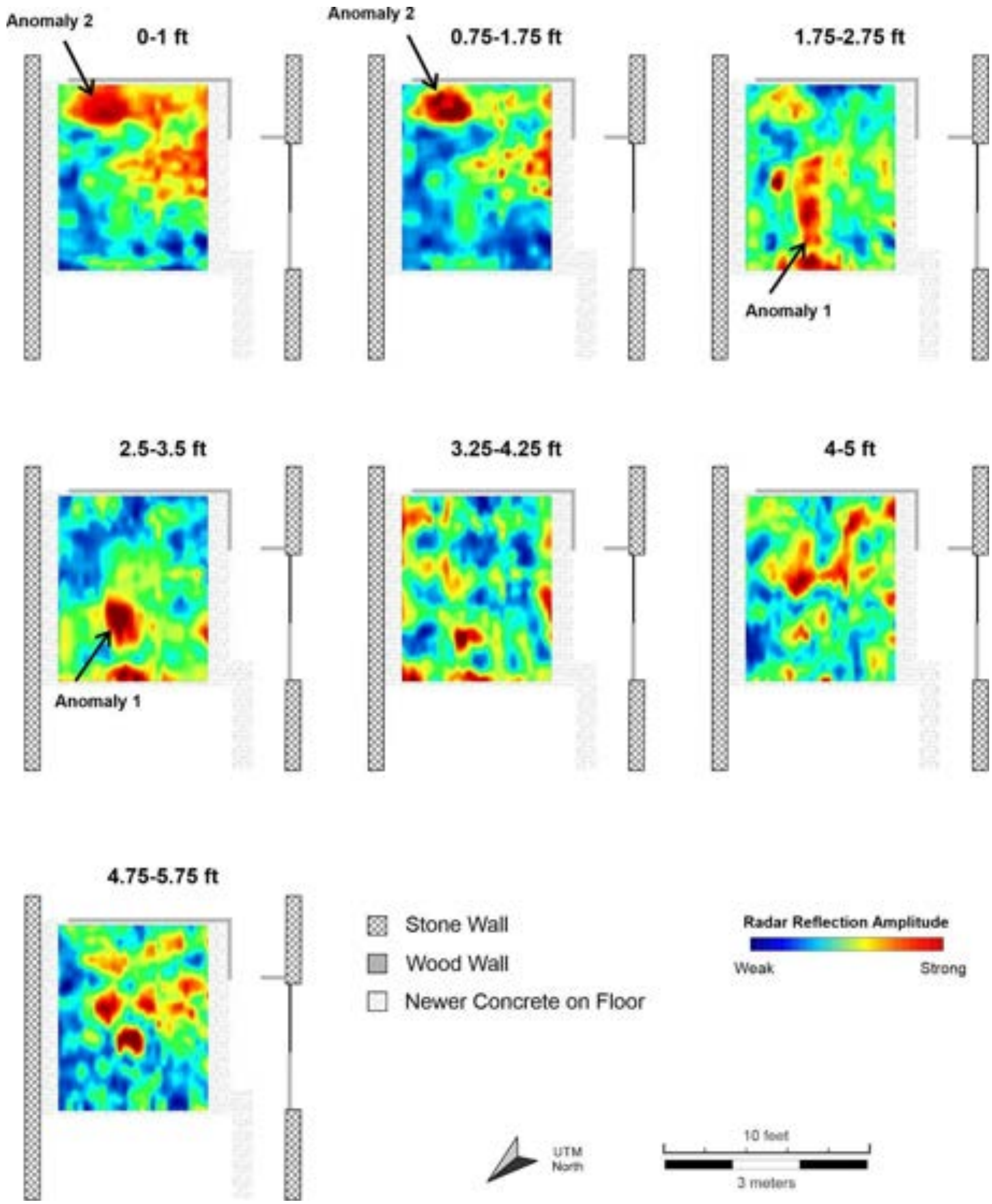

**Figure 6**. Sequence of radar slice maps at increasing depth below the basement floor from the first radar survey.

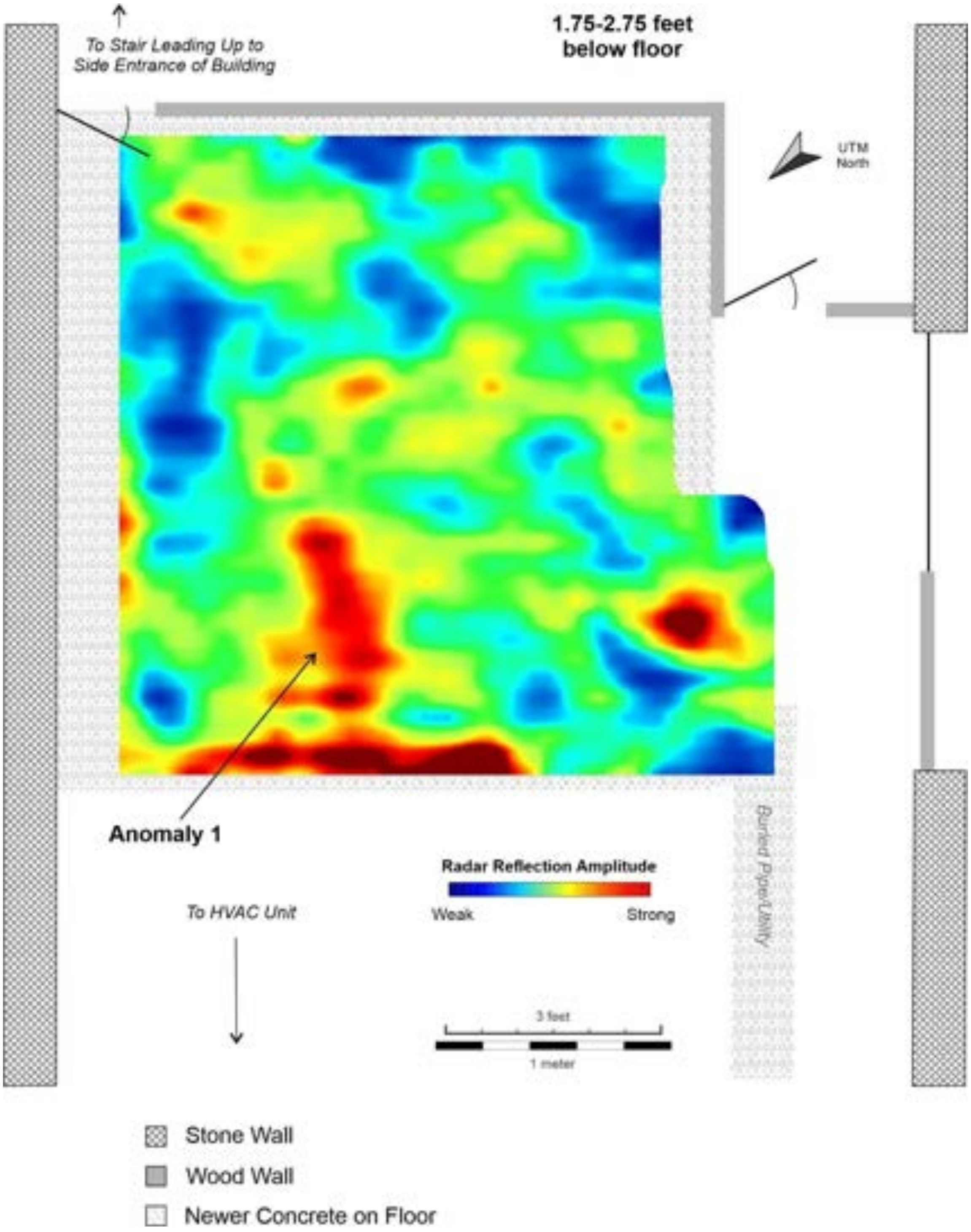

**Figure 7**. Example radar slice map from 1.75 ft to 2.75 ft below the basement floor, from the second radar survey.

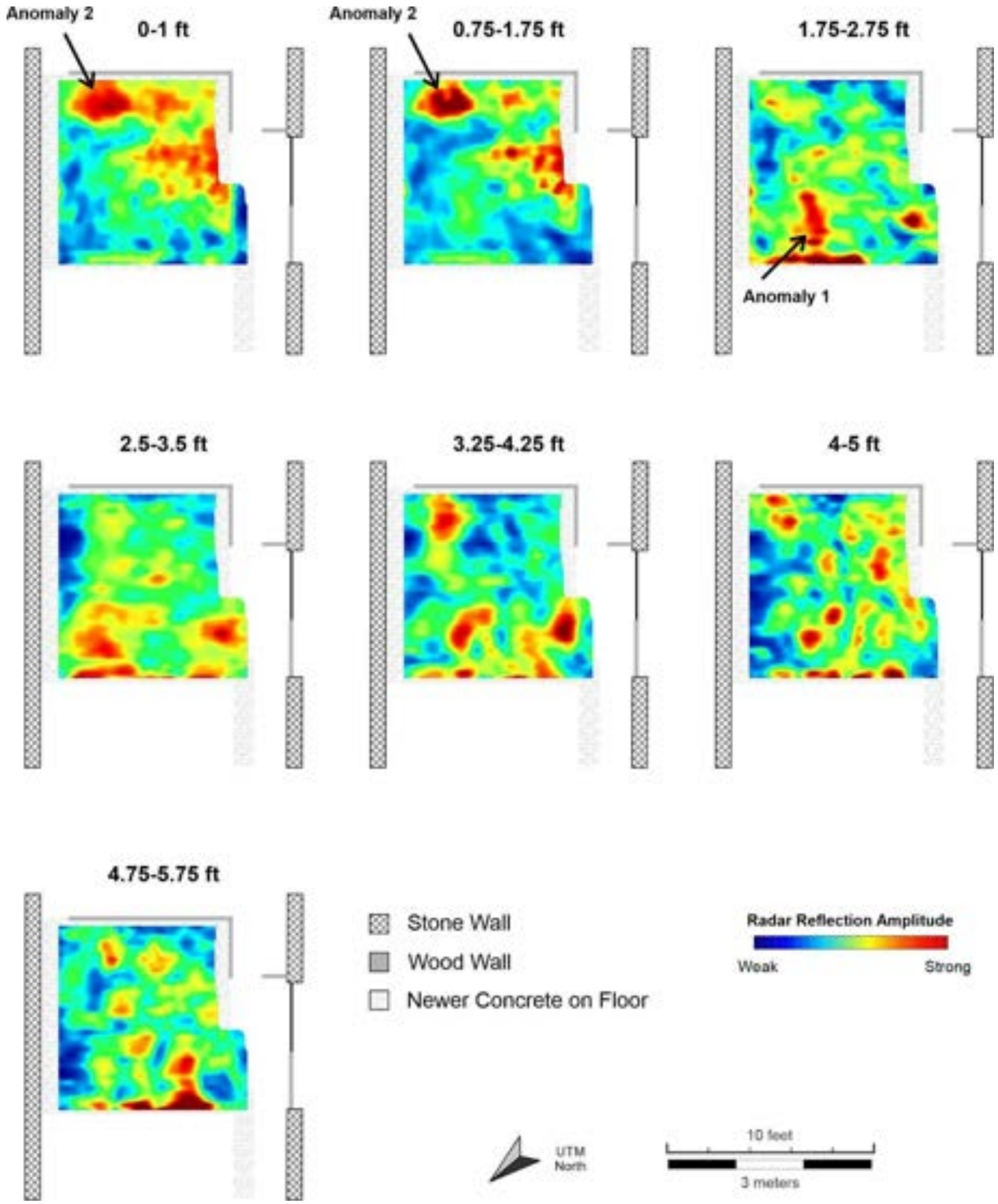

**Figure 8**. Sequence of radar slice maps at increasing depth below the basement floor from the second radar survey.