Geophysical Investigations of a Historic Iowa Family Cemetery (14BN111), Brown County, Kansas

by
Steven L. De Vore

Midwest Archeological Center
Technical Report No. 99

NATIONAL PARK SERVICE
Midwest Archeological Center

Cover. Campbell Family (Iowa Tribe) Cemetery in Brown County, Kansas (view to the south)

This report has been reviewed against the criteria contained in 43CFR Part 7, Subpart A, Section 7.18 (a) (1) and, upon recommendation of the Midwest Regional Office and the Midwest Archeological Center, has been classified as

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Making the report available meets the criteria of 43CFR Part 7, Subpart A, Section 7.18 (a) (1).

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United States Department of the Interior
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HISTORIC IOWA FAMILY CEMETERY

ABSTRACT

The geophysical investigations of a family cemetery (14BN111) in Brown County, Kansas, were initiated by the National Park Service in response to a request from the Iowa Tribe of Kansas and Nebraska executive committee. A meeting and site tour were held with the tribal chairman and executive committee staff members, tenant farmer, and Midwest Archeological Center (MWAC) Archeological Assistance and Partnership Program archeologist on January 15, 2004. This visit was to assess the feasibility of the application of geophysical techniques to the identification and evaluation of the Campbell cemetery. During the week of March 22, 2004 and on April 1, 2004, the author, a MWAC archeologist, conducted geophysical investigations at the Campbell family cemetery (14BN111). Geophysical investigations, including magnetic gradient, resistance, conductivity, and ground-penetrating radar surveys, were conducted at the cemetery location identified by the Iowa Tribe executive committee chairman and vice-chairman.

During the investigations, 400 square meters were surveyed with a Geoscan Research FM36 fluxgate gradiometer, a Geoscan Research RM15 resistance meter and PA5 multi-probe array, a Geonics EM38 ground conductivity meter, and a Geophysical Survey Systems Inc. (GSSI) TerraSIRch SIR System-3000 ground-penetrating radar system with a 400 mHz (GSSI Model 5103) antenna on the GSSI Model 623 survey cart. A vertical resistivity sounding was also conducted with a Gossen Geohm 40D resistivity meter. The project area was mapped with a Nikon DTM-730 field station. The survey resulted in the identification of subsurface magnetic gradient anomalies, resistance anomalies, conductivity anomalies, and ground-penetrating radar anomalies. Several geophysical anomalies were identified in the four complementary data sets. The disturbed area within the western half of the geophysical grid and the presence of several gravestones suggested the location of graves associated with the cemetery. All four data sets identified the location of the pre-1970s cemetery fence on the south and east side of the cemetery. During the geophysical survey, additional archeological investigations of the area indicated the presence of a prehistoric site. A small triangular projectile point, several pieces of lithic debitage, and two ceramic sherds were observed.

This report provides an analysis of the geophysical data collected during four days at the site. Since 14BN111 represents a known historic Iowa tribal cemetery associated with the Campbell and Dupuis families. The site is a multi-component site with the late 1800s family cemetery and a prehistoric occupation. Additional archeological investigations in the form of excavations are not recommended at the present time. Should there be any development on or near the cemetery, then a research design needs to be developed for the implementation of archeological excavations to determine the nature and extent of this cemetery and the prehistoric component.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Geophysical investigations of a historic Iowa family cemetery (14BN111) were initiated by the National Park Service (NPS) in response to a request from the Iowa Tribe of Kansas and Nebraska in November 2003. A formal request was submitted to the Midwest Archeological Center (MWAC) by the Iowa Tribe of Kansas and Nebraska in December 2003 (DeRoin 2003).The Iowa Tribal Executive Committee chairman requested that the Center provide technical assistance to help identify the boundaries of the Campbell cemetery in northern Brown County, Kansas. The tribal members were interested in identifying the extent of the cemetery. They were also hoping that the geophysical techniques would provide conclusive evidence of grave locations and provide an accurate count of individuals buried in the cemetery. Funding was provided by the Iowa Tribe of Kansas and Nebraska through an Intergovernmental Personnel Act assignment agreement with the Midwest Archeological Center for the geophysical investigations of the cemetery.

Robert Nickel, a private consultant, and the author initially visited the cemetery on January 15, 2004 (De Vore 2004). It was pointed out to tribal representatives during the preliminary site visit that the geophysical techniques may possibly provide the information that they were seeking but the conditions had to be ideal. The author has been involved in several geophysical surveys across the country and in specific cemetery projects similar to the present one in the Midwest and Western United States. Between March 23 and 24, 2004, MWAC archeologist Steven L. De Vore conducted magnetic, resistance/resistivity, ground conductivity, and ground-penetrating radar surveys at the Campbell cemetery location identified by Iowa tribal members. On April 1, 2004, the author returned to the cemetery to redo the ground-penetrating radar survey in both the north and east directions.

The project area containing the Campbell cemetery is in the NW ¼ of the NE ¼ of the SE ¼ of Section 4, Township 1 South, Range 18 East in Brown County, Kansas (Figures 1a and 1b). The Campbell family cemetery contains graves of members of the Campbell and Dupuis families. Headstones indicate that the cemetery was in use between 1875 and 1901. This small family burial plot is located in a tree grove on the right or south side of an upland drainageway above the left bank of Roys Creek in northeastern Kansas (Figure 2). The tree grove contains three or four large trees including a red maple of substantial size measuring over a meter in diameter. One cedar is present west of the line of headstones, footstones, and monument bases. Several smaller trees are also present including a few east of the line of graves. At the initial assessment of the cemetery, the tree grove containing the cemetery was overgrown with tall grasses, green briar, and saplings. Members of the tribal maintenance facility cleared the smaller vegetation and leaf litter from the site prior to the geophysical investigations.

While non-invasive instruments certainly cannot be expected to identify individuals interred at specific locations, these geophysical instruments can detect physical contrasts resulting from excavation and subsequent refilling of the grave. For the graves to be identified by the geophysical techniques employed during the present project (i.e., magnetic gradient, resistivity, conductivity, and ground-penetrating radar), there needs to be sufficient contrasts in the measured physical property of the earth (Bevan 1991). Several factors contribute to the success or lack of success of the geophysical search for graves. Without significant contrasts in soil moisture, compaction, texture, or structure, it would be impossible to identify specific grave locations. The lack of coffins, grave goods, and associated permanent stone or metal markers would also make the search more difficult. The size and depth of the grave shaft are also important to the overall success of the geophysical investigations. If the graves were hurriedly excavated and shallow, there may not be enough mixing of the excavated soil matrix as it was returned to the grave excavation. The lack of coffins would mean that there would be minimal collapse of the grave fill for the formation of a depression over the buried body. Any combination of these factors could spell disaster for positive grave identification in the geophysical investigations. It is impossible to detect unmarked historic graves with geophysical instruments in many cases due to the lack of sufficient contrasts in the physical properties being measured. The goal of this project was to try to delimit the extent of the family cemetery and if possible, identify individual graves.

Although the soils may have high clay content that would make a ground-penetrating radar (GPR) survey impractical, none of the techniques has been applied to this type of cultural resource investigation in the project area. It is possible that the ground-penetrating radar could still identify the sides and bottom of the grave shaft. It is doubtful that the radar would detect coffin remains if those were present, and it will not identify individual human bones. The magnetometer can identify the presence on magnetic materials such as iron or steel artifacts (e.g., coffin hardware, nails, buckles, and other artifacts), as well as disturbances to the natural soil matrix resulting from the mixing of topsoil and subsoil in the excavation and refilling of the grave. The resistivity meter and conductivity meter can detect changes in the soil resulting from disturbances caused by excavation of a grave shaft. Conductivity data can also indicate the presence of conductive metals buried in the ground.

2. ENVIRONMENTAL SETTING

The present project is located in the glaciated region of northeastern Kansas (Socolofsky and Self 1972:3). The region is part of the dissected till plains section of the Central Lowlands Province of the Interior Plains (Fenneman 1938:588-605; Mandel 1987: III-3; Schoewe 1949:289-291). During the Kansas glacial episode, the region was covered by a continental ice sheet (Fenneman 1938:594-595). As the ice sheet advanced into this region, the existing stream valleys were scoured and the uplands were leveled throughout the drift plain (Frye and Leonard 1952). One of the more common glacial erratics in northeastern Kansas was pink Sioux quartzite from southeastern South Dakota and northwestern Iowa (Frye and Leonard 1952:11). Granites, diorites, diabases, gabbros, and greenstones were also left by the glaciers. These materials provided the prehistoric inhabitants with a source for stone tools, including axes, hammers, and other heavy implements (Wedel 1959:14-15). Sands, gravels, and clays from the till and outwash from the retreating glaciers provided the Euroamerican settlers of the region with construction materials (Bayne and Schoewe 1967). In the Pennsylvanian and Permian formations, limestone, sandstone, shale, gypsum, coal, and chert beds provided the aboriginal inhabitants and Euroamerican settlers with materials for stone tools and building construction materials (Bayne and Schoewe 1967; Cutler 1883; Tolsted and Swineford 1984; Wedel 1959).

The thick deposits of till, outwash, and loess conceals the cuesta-type topography of the underlying Pennsylvanian and Permian formations (Bayne and Schoewe 1967; Fenneman 1938:595-596; Frye and Walters 1950; Schoewe 1949:289; Tolsted and Swineford 1984; Wilson 1984). Erosion of the glacial deposits has left the region with smooth, broad, gently rolling hills on the interstream divides. The land becomes more dissected as it approaches the major stream valleys. Flat, wide floodplains with steep walls characterize the major stream valleys. Exposures of bedrock may be found along the valley walls.

Roys Creek and its tributaries form the main drainage network in the northeastern quarter of Brown County. Roys Creek flows to the northeast from its headwaters in the central part of Brown County. The creek enters the Big Nemaha River in the southeastern corner of Richardson County, Nebraska.

Soils in northeastern Kansas are dominated by Typic Udolls of the Mollisol order (Foth and Schafer 1980:116-125), although the young alluvial soils of the floodplains are primarily Entisols and Inceptisols (Forth and Schafer 1980:37,63; Mandel 1987:III-30). Alfisols are found under forest vegetation (Forth and Schafer 1980:143; Mandel 1987:III-30). The soils are more or less freely drained with udic soil moisture and mesic soil temperature regimes. Parent materials are primarily glacial till with some thick or moderately thick deposits of loess. Loess is present on the ridgetops, slopes, and valley floors. Soils are generally deep to shallow, black or very dark brown silt loams, clay loams, and silty clay loams (Foth and Schafer 1980:118; Mandel 1987:III-30). The Nebraska and Kansas Loess-Drift Hills land resource area contains soils that formed under prairie grass vegetation (Palmer et al. 1998a:11). Depth to bedrock ranges from shallow to very deep. Soils in the

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Iowa and Missouri Deep Loess Hills lie along the Missouri River in extreme northeastern Brown County (Palmer et al. 1988a:11). These soils formed under mixed prairie grass and forest vegetation. Depth to bedrock is very deep. The project area lies within the Marshall-Morrill soil association of "very deep, gently sloping to strongly sloping, well drained soils that have a silty or loamy subsoil; on uplands (Palmer et al. 1998a:20-21). The soil within the project area is identified as the Reading silt loam, moderately wet, rarely flooded (Re). Reading soils are very deep, moderately well drained soils on the high flood plains in the valleys (Palmer et al. 1998a:54,1998b:35-36). Formed in alluvium, the soil has a moderately slow permeability, slow surface runoff, and a high available water capacity (Palmer et al. 1998b:36). The soil also has a moderate organic matter content. The soil pH ranges from moderately acid to slightly acid in the upper portion of the pedon. The C horizon has a slightly alkaline pH level (Palmer et al. 1998a:54). The loessial soils on the uplands and the alluvial sediments in the valleys provide rich soils for the growth of cultivated crops and other edible and usable plant species (Kindscher 1987, 1992). These resources provide the basis of the aboriginal subsistence of prehistoric times and the historic and modern Euroamerican farming economy.

The project area also lies within the Illinoian biotic province (Dice 1943:21-23). The alternating forest and prairie in the western part of the province is highly dependent on local soil conditions and slope exposures. Grasses dominate the landscape. The tall grass communities are part of the temperate plains grasslands (Brown et al. 1998:29; Reichenbacher et al. 1998; Shelford 1963:334). The bluestem prairie extends across uplands throughout eastern Kansas (Küchler 1974:595-597; Socolofsky and Self 1972:5). Prairie vegetation occurs in dense stands of tall and medium grasses. Dominant grasses include big bluestem, little bluestem, switchgrass, and Indian grass (Brown 1985:45; Gates 1937:17-18; Küchler 1974:595-597; Ohlenbusch et al. 1983). Forbs vary in height from short to very tall and affect the physiognomy of the prairie. Forbs are dominated by the legumes and composites, which add color to the vast sea of grasses (Bare 1979; Barkley 1983; Brown 1985:36; Owensby 1980). Trees are most commonly found along streams and on north-facing slopes (Shelford 1963:309-313). The upland forest communities contain many of the plant species common to the northeastern oak-hickory deciduous forest (Brown et al, 1998:29; Gates 1928; Küchler 1974:599: Reichenbacher et al. 1998; Shelford 1963:17-55; Stephens 1969). These forests consist of medium tall multilayered broadleaf deciduous species. Dominate species include the bitternut hickory, shagbark hickory, white oak, red oak, black oak, and walnut. Along the floodplains, the deciduous forests are dominated by hackberry, cottonwood, peachwood willow, black willow, and American elm (Cutler 1883; Gates 1928; Küchler 1974:600-601, 1990; Shelford 1963:309-313; Stephens 1969). Other minor forest species included buckeye, honey locust, crab apple, sycamore, hazel, linden, box elder, mulberry, cedar, dogwood, and prickly ash (Barker 1969:553; Cutler 1883; Solecki 1953:3). Persimmon, elderberry, serviceberry, chokeberry, wild plum, wild grapes, and mushrooms were some of the resources used by prehistoric inhabitants of the region, as well as, the historic Euroamerican settlers (Cutler 1883; Horn et al. 1993; Robinson 1990; Wedel 1959:14). These forests can have well developed undergrowth vegetation communities of small trees, shrubs, and fords, including redbuds, hornbeam, pawpaw, hawthorn, gooseberry, sumac, sweet haw, blackberry, raspberry, jack-in-the-pulpit, bloodroot, mayapple, wild asters, goldenrods, chenopods, ragweeds, and smartweed (Brown 1985:43-44,52-53; Cutler 1883; Gates 1940; Mandel 1987:III-19—III-27; Robinson 1990; Shelford 1963:23-35,94-99,118-119,334-344; Stephens 1969). They are often interrupted by freshwater marshes and prairie communities. A common marsh plant species is the prairie cordgrass (Küchler 1974:601-603; Ohlenbusch et al. 1983; Shelford 1963:89-119).

In the tall grass region, bison and pronghorn antelope roamed the open plains until the mid to late 1800s (Shelford 1963:334-335). During the prehistoric and historic periods, deer were present in the timbered areas along streams and slopes, along with bear, squirrel, and cottontail rabbits. Jackrabbits were common along with coyotes, badgers, mink, bobcats, and foxes. Wolves were also important predators until exterminated from the region in the late 1800s.

Numerous other mammals and rodents also inhabit the region (Bee et al. 1981; Hall 1955). Numerous species of birds inhabit the grasslands, the shrublands, and wooded areas of the region (Brown 1985:26-28; Shelford 1963:26-35,336). Wild turkey, quail, ruffed grouse, and prairie chicken represented some of the regional game birds, as well as migratory waterfowl, in both prehistoric and historic times (Wedel 1959:14). Numerous grassland and forest species of songbirds are present (Thompson and Ely 1989,1992; Zimmerman 1993). Reptiles include several species of lizards, turtles, and snakes (Caldwell and Collins 1981; Collins 1993). Amphibians are found in the prairies, forests, and wetlands (Collins 1993). Fish, including catfish, carp, and bass, and fresh water mussels are found in the streams throughout the region (Cross and Collins 1975). Insects and other invertebrates abound throughout the region with the grasshopper being one of the most abundant insect groups (Kansas Biological Survey 1985; Shelford 1963:337-339; White and Salsbury 2000).

The region has a typical continental climate characterized by large daily and annual variations in temperature (Robb 1941:873-883). The project area lies within the moist subhumid climatic zone (Thornthwaite 1948). Winters are cold and the summers are warm. Extremes in the temperature occur in January and July (Flora 1948:195). Annual January temperatures average -2.72° C (Robb 1941:873). The average daily minimum winter temperature is -7.78°C. The lowest recorded winter temperature is -34.44° C (Palmer et al. 1998a:12,14). Annual July temperatures average 25.5° C (Robb 1941:873). The average daily maximum temperature in the summer is 31.67° C. The highest recorded summer temperature is 44.44° C (Palmer et al. 1998a:12,14; Robb 1941:873). Annual precipitation averages 91.44 centimeters (Palmer et al. 1998a:12,14) with the majority falling from April through September. The average seasonal snowfall is 44.20 centimeters per year (Palmer et al. 1998a:12,14). The growing season averages 179 days with killing frosts occurring as late as April 20th in the spring and as early as October16th in the fall. Tornadoes and severe thunderstorms occur occasionally. Although these are generally local in extend and of short duration, the resulting damage can be severe. Hail may occur with these in the warmer months. Snow cover seldom lasts more than seven days. Droughts may occur anytime throughout the year, but are most damaging in July and August (Robb 1941:883).

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The sun shines approximately 75% of the time in summer and 60% of the time in winter. The prevailing winds are from the south except in the winter months when more northerly winds prevail.

3. CULTURE HISTORY

Kansas archeology may be divided between the prehistoric and historic periods. The prehistoric periods defined for Kansas archeology include the Paleo-Indian, the Archaic, and the Ceramic periods (Brown 1987a:VIII-1-VIII-6; Brown 1987b:XIV-1-XIV-57; Brown and Brown 1987; O'Brien 1984:27-78). The historic period in Kansas is divided into two broad categories including the Reservation and the American periods (Brown 1987a:VIII-6; Brown 1987b:XIV-58-XIV-59; O'Brien 1984:79-86).

The Paleo-Indian period is placed between 12,000 and 8,000 years before the present (B.P.). The period is typically divided into three complexes although there continues to be recognition of a pre-Clovis complex (prior to 12,000 B.P.): 1) the Llano, 12,000 to 11,000 B.P.; 2) the Folsom, 11,000 to 10,000 B.P; and 3) the Plano, 10,000 to 8,000 B.P. (Brown 1987a:VIII-1; O'Brien 1984:27-37). The presence of a pre-Clovis complex in Kansas has not yet been substantiated (Brown and Brown 1987:IX-2-IX-6). Traditionally, the Llano complex is characterized by the presence of Clovis projectile points (see Brown and Brown 1987:IX-6-IX-9, O'Brien 1984:28-31, and Wedel 1959:536-542 for more information on the Llano complex in Kansas). Viewed as efficient large game hunters, the people of the Llano complex hunted mammoth, mastodon, extinct forms of bison, and other Pleistocene animals. Llano sites in Kansas are limited to isolated surface finds of Clovis projectile points (O'Brien 1984:30; Wedel 1959:175-176). The Folsom complex is also recognized by the presence of fluted projectile points (Folsom points) and the hunting of extinct forms of bison (see Brown and Brown 1987:IX-9-IX-12'O'Brien 1984:28-31 for more information on the Folsom complex in Kansas). One of the earliest associations of human artifacts and the large extinct Pleistocene bison comes from the 1895 excavation of the Twelve Mile Creek site in western Kansas (O'Brien 1984:28). The Late Paleo-Indian complex is actually a series of different complexes referred collectively as Plano (Brown and Brown 1987:IX-12). The Plano complexes represent the last cultural systems associated with the Pleistocene megafauna (see Brown and Brown 1987:IX-9-IX-16; O'Brien 1984:31-36 for more information on the Plano complexes in Kansas). These terminal complexes of the Paleo-Indian period are represented by a number of different projectile point types, including Agate Basin, Alberta, Eden, Hell Gap, Milnesand, Plainview, and Scottsbluff. Plano sites throughout the region consist of kill sites, butchering sites, long term camp sites, and short term camp sites (Brown and Brown 1987:IX-16). A Hell Gap quarry site is located in Norton County. A couple of other Plano sites have been identified in Burton and Riley Counties (O'Brien 1984:32).

Beginning around 9,000 to 8,500 B.P., the climate started to become warmer and drier. The end of the Pleistocene saw the decline and extinction of the megafauna. Hunting in the Archaic period shifted from large megafauna to smaller game (see Brown 1987b: XIV-2-XIV-6, O'Brien 1984:39-44, and Wedel 1959:536-542 for more information on the Archaic period). People were becoming less nomadic. There was also an increase in the local exploitation of plant foods. Grinding slabs for processing plant materials into food was a common feature in the Archaic toolkit. Stone tools increased in the diversity of shapes, sizes, and functions. The Archaic period is often further split into three subdivisions: 1) Early Archaic, ca. 9,000 – 7,000 B.P.; 2) Middle Archaic, 7,000-4,500 B.P.; and 3) Late Archaic, 4,500-2,000 B.P. A number of defined Archaic complexes occur across Kansas including Nebo Hill, Munkers Creek, Black Vermillion, El Dorado, and Walnut phases (Brown 1987b:XIV-3-XIV-6; O'Brien 1984:39-40).

The introduction of pottery, appearance of burial mounds, domestication of plants, long-distance trade networks, increased complexity of the social systems and the development of chiefdoms occurred during the Ceramic period (see Brown 1987b:XIV-8-XIV-57, O'Brien 1984:78, and Wedel 1959:98-210,542-637 for more information on the Ceramic period in Kansas). Typically the period is divided into three subdivisions: 1) Early Ceramic or Woodland period, 2,000 to 1,000 B.P.; 2) Middle Ceramic or Village Gardener period, 1,000 to 500 B.P.; and 3) Late Ceramic or Protohistoric period, 500 to 300 B.P. Subsistence continued to depend on hunting and gathering with the addition of domesticated plants like squash, marshelder, and maize. The bow and arrow made their appearance. During the Early Ceramic period, the eastern part of the state was dominated by the influence of Hopewellian traits from further east in the Ohio region (Brown 1987a: XIV-7-XIV-17; O'Brien 1984:46-49; Wedel 1959:542-557). The rest of the state contained several complexes associated with the Plains Woodland including Butler phase, Greenwood phase, Grasshopper Falls phase, Keith focus, unnamed Kansas City Late Woodland phase, and Schultz focus. The Plains Woodland sites tended to be smaller villages or camps than village sites associated with the Hopewell manifestation in eastern Kansas (Brown 1987a: XIV-18-XIV-32; O'Brien 1984:50-55; Wedel 1959:542-557). The Middle Ceramic period is often referred to as the Mississippian period in the Eastern United States (Brown 1987a: XIV-33-XIV-; O'Brien 1984:51-66; Wedel 1959:557-571). During this period, the creation of the temple mound towns came into existence along with the development of an agricultural subsistence system. The dual economy was based on bison hunting and cultivation of maize, beans, squash and domestic sunflower. Ceramic technology continued to advance with the production of better pottery due to changes in clay and vessel form. Settlements became larger and more permanent. In the eastern part of the state around the Kansas City vicinity, the Steed-Kisker variant sites were related to the Middle Mississippian cultures to the east (Brown 1987a:XIV-33-XIV-40; O'Brien 1984:57-59). The most numerous and widespread sites during the Middle Ceramic period were part of the Central Plains Village tradition (Brown 1987a:XIV41-XIV-49; O'Brien 1984:59-65). Complexes included the Upper Republican, Nebraska, and Smoky Hill variants, as well as minor complexes including Pratt, Bluff Creek, and Pomona. Settlement pattern consisted of isolated earth lodges or small cluster of earth lodges. The subsistence strategy was based on small scale farming. Hunting also played a role in the subsistence strategy. During the Late Ceramic or Protohistoric period, the European explorers entered Kansas beginning with the Spanish in 1541 and the French in 1724 (Brown 1987a:XIV50-XIV-57; Wedel 1959:571-615). The archeological remains of historic tribes were first identified during this period, which included the Kansa from the Oneota aspect, the Pawnee from the Lower Loup aspect, the Wichita from the Great Bend aspect, and the Plains Apache from the Dismal River aspect (Lees 1989:69-71; O'Brien 1984:67-78). The Kansa Indians (Unrau 1971;Wedel 1959:50-54) controlled the northeast corner of the state from the Missouri River to the Big Blue River and from the Nebraska border to the Kansas River (Lees 1989:69).

The first treaty between the United States and the Kansa was a treaty of peace and friendship signed in 1815 at St Louis (Kappler 1972:123-124). In 1825, the Kansa signed a treaty with the United States to cede all claim to lands in Missouri and to a large portion of northeastern Kansas (Kappler 1972:222-225). These lands were to be used by the American government for the removal of tribes from the East and Midwest to Kansas (O'Brien 1984:79-82). The Sac and Fox Nation of Missouri and the Iowa Tribe were included in this group of Midwestern and Eastern tribes.

4. HISTORIC IOWA TRIBAL BACKGROUND

The first treaty concluded between the Iowa Tribe and the United States occurred on September 15, 1815 (Kappler 1972:122-123). The treaty called for peace and friendship between the Iowa Tribe and the United States. In 1824, the Iowa signed a treaty which ceded all of their lands in the State of Missouri for an initial payment of $500.00 in cash or merchandise and for ten annual payments of $500.00 (Dorsey 1905:613; Kappler 1972:208-209). In 1825, the Congress of the United States passed an act for the relocation of Eastern tribes in the western territories (Kansas Preservation Department 1987:29). In 1830, the Congress passed the Indian emigration bill (Indian Removal Act of 1830) that authorized the President to establish districts in the western territory for the Eastern emigrant tribes and other native tribes (Cutler 1883). The President was also authorized to exchange these districts for existing tribal lands within the States or Territories. In 1830, the Iowa along with the Sac and Fox, the Dakota Sioux, the Oto and the Missouri tribes relinquished all title to lands in the western part of the present day State of Iowa. The lands ceded by the treaty were to be assigned and allotted to the tribes signing the treaty and to other tribes that may be relocated there by the President. The Iowa were to be paid $2,500.00 annually for ten years (Kappler 1972:305-310). Future allowances could be made after the expiration of the ten years. Additional annuities were also to be set aside for the education of the youth. The treaty also called for the creation of half-breed reservations or tracts. For the Iowa, Omaha, Otoes, and the Yankton and Santee Sioux, the half-breed tract was established between the Little and Big Nemaha Rivers in the present day State of Nebraska. In 1836, the Iowa Tribe along with the Missouri band of Sac and Fox were assigned a “small strip of land on the south side of the Missouri River, lying between the Kickapoo northern boundary line and the Grand Nemahar (sic) river, and extending from the Missouri back and westwardly with the said Kickapoo line and the Grand Nemahar (sic), making four hundred sections; to be divided between the Ioways (sic) and Missouri band of the Sacks (sic) and Foxes, the lower half to the Sacks (sic) and Foxes, and the upper half to the Ioways (sic)” (Kappler 1972:468-469). The land was divided equally between the Iowa and the Sac and Fox (Figure 3). The government was to erect five houses; to fence and plow 200 acres of ground; to provide a blacksmith, schoolmaster, farmer, and interpreter; to furnish agricultural implements for five years; to furnish rations for one year; to provide livestock including cattle and hogs; and to construct a mill (Kappler 1972:468-470). The Territory of Kansas was created by Congress in 1854 along with the Territory of Nebraska. The Iowa along with the Sac and Fox of Missouri were forced to cede a large portion of their reservations in the treaties of 1854 and 1861 (Connelley 1918; Kappler 1972:628-631,811-814). The two treaties call for the sale of the ceded lands at public auction or private entry on the unsold lands (Figure 4). The treaties also called for the division of reservation land among the families with the remaining reservation land held in trust by the tribe. The Iowa Indian Trust lands encompassed several thousand acres in Brown County (Morrill 1876). Between 1854 and the early 1860s, individual farms began to replace the village community (Wedel 2001:441). With the arrival of statehood in 1861, more pressure was placed on the reservation tribes to relocate to Indian Territory. By 1878, most of the Iowa were acculturated and somewhat assimilated into the surrounding Anglo-American community; however, a group of more traditional Iowas opposed the more progressive stance of the tribe and also opposed allotment in severally. They split from the main group and began to move to Indian Territory (Oklahoma) between 1878 and 1881. In 1883, a reservation was established for this group in central Oklahoma. Additional information on the Iowa Tribe may be found in Martha Blaine's study (Blaine 1979).

In 1887, Congress passed the General Allotment Act commonly referred to as the Dawes Act (Indian Lands Working Group 2003). The act called for the division and allotment of tribal reservation land to individual owners. The purpose was to accelerate the civilization and assimilation of Native Americans into the larger Anglo-American society by making them private landholders and farmers. Individual tribal members were allotted 40, 80, and 160-acre parcels. The remaining reservation lands were declared surplus and sold to the Anglo-Americans. In 1887, the Iowa lands in northeastern Kansas and southeastern Nebraska (the Great Nemaha Reserve) were allotted in severalty or individual land holdings (Figure 5). The area of the cemetery was still held by the tribe or tribal members. In 1890, additional lands were allotted and the excess sold to the neighboring Anglo-Americans. During the early 20th Century, the Iowa lost a substantial portion of the reservation lands due to exploitation by neighboring Anglo-Americans. Allotted lands were leased to the surrounding Anglo-American farmers at extremely low values causing additional economic hardships. Land was also released from trust and sold. By the 1930s, the Iowa Tribe of Kansas and Nebraska owned less then 10 percent of the reservation lands allotted to them in 1894 (Wedel 2001:443). The General Allotment period finally ended in 1934 (Indian Lands Working Group 2003). The Iowa Tribe of Kansas and Nebraska was organized and chartered under the Indian Reorganization Act of 1934 (Foster 1995). In 1995, the Iowa Tribe of Kansas and Nebraska owned 947.63 acres in Kansas with 181.01 acres in tribal member allotments (Foster 1995). In Nebraska, the Iowa Tribe owned 280 acres with 210.06 acres in tribal member allotments. The reservation formed a checkerboard pattern of Iowa and Anglo-American owned land across Brown and Doniphan Counties in Kansas and Richardson County in Nebraska (Foster 1994:276-277). One thousand six hundred eighteen and seven-tenths tribal lands acres remain held in trust status. In 1995, tribal enrollment was 2,147 (Foster 1995).

The land containing the cemetery once belonged to the Campbell family but was sold to non-tribal members during the allotment period in the late 19th or early 20th Century. The land including the cemetery is presently owned by Mary Blocker of Birmingham, Michigan. Bill Fee, the present tenant farmer, starting farming the land in 1979. Mr. Fee indicated the possibility of more headstones but he believed some had been removed to Rulo, Nebraska (De Vore 2004).

5. FILE SEARCH AND ARCHEOLOGICAL DOCUMENTATION

A file search of archeological resources for the Iowa Family Cemetery project was requested from the Archaeology Office and the State Historic Preservation Office of the Kansas State Historical Society. The search was conducted in order to identify previously recorded archeological resources in the vicinity of the present geophysical investigations of the Campbell family cemetery. The file search (Frank 2004) revealed the lack of documental archeological sites in Sections 4 and 5, Township 1 South, Range 18 East of Brown County; however, recorded sites were identified in Sections 3, 6, and 10 surrounding the project area.

During the geophysical investigations of the Campbell cemetery, several pieces of lithic debitage were noted on the high flood plain overlooking Roys Creek. A small triangular projectile point was located in the area south of the geophysical grid along with two ceramic body sherds (one with 2 parallel cord impressions). Unifacial flake tools (i.e., side scrapers) were also noted. The unidentified prehistoric occupation probably represents a small camp site from the Middle Ceramic period. The project area also contained more recent historic or modern trash, including a bottle base, can fragments, a brick fragment, pop tops from beverage cans, and woven and barbed wire directly associated with the cemetery. The site form was completed and submitted to the Kansas State Historical Society. The prehistoric site containing the historic Campbell cemetery was recorded as 14BN111 by the Archeology Records Manager in the Archeological Division at the Kansas State Historical Society (Anita Frank, personal communications, 2004).

The Campbell family cemetery contains a minimum of eight individuals based on the inscriptions on the headstones and the additional number of bases (Figure 6). In addition to the headstones and monument bases, there are three footstones. The monument stones form a rough north-south line through the center portion of the tree grove in the center of the agricultural field. Beginning at the northern edge, the first headstone lies on its side near the monument base (Figure 7a). Floral designs are carved into the headstone above and below the inscription. Harvey Campbell's first name and initial are contained within a flowing banner. There is an urn with flowers above the inscription for George Campbell. The headstone contains the following inscription for Harvey W. Campbell:

HARVEY W.
CAMPBELL

DIED
MAY 19, 1875
AGED
32 YEARS

Farewell dear father
Take thy rest

God called thee home
He thought it best.

The stone bears a second inscription for George Campbell on the right adjacent side:

GEORGE

INFANT SON OF
MURRAY & IDA
CAMPBELL

A small stone protrudes out of the ground on the east side of the monument base and the headstone of Harvey and George Campbell. The headstone for Murray Campbell (Figure 7b) also lies to the west of its base south of the headstone for Harvey and George Campbell. On the top of the headstone is a carved relief of a Bible. On the front of the headstone is a carving of Heaven's pearly gates. Scroll work is carved around the base of the headstone. The stone bears the following inscription for Murray A. Campbell:

MURRAY A. CAMPBELL

BORN
SEPT. 20, 1867

DIED
JAN. 27, 1901.

Next in line, there are two monument bases. The larger monument base nearest the headstone of Murray Campbell is decorated with cross-hatched carved around the base. Three footstones are next in line. Two footstones in line with the headstones and monument bases bear the initials "J. D." (Figure 8a) and "F. D." (Figure 8b) The footstone with the initials "J. D." is north of the one with the initials "F. D." The third footstone lies to the east of the second monument base adjacent to the other two footstones. The footstone to the east of the monument base bears the inscription of the individual's initials: "H. W. C." (Figure 8c) The initial carvings on all three footstones face west. The next headstone in line contains the names of two Dupuis family members on the opposing sides of the stone (Figure 7c). This headstone is the only standing headstone in the cemetery. The front of the stone faces west. On the top of the stone are two carved Bibles. The carving on the front portion of the headstone below the two books represents Heaven's pearly gates. The carving on the north side of the headstone bears the following inscription:

JOHN DUPUIS

DIED
JAN. 27, 1897

Aged
54 Yrs. 2 Mos.
11 Days.

The inscription on the south side of the headstone is the following:

FRANCIS DUPUIS

DIED

NOV. 17, 1897

Aged
84 Years.

The final marker in the row located on the south side is a monument base.

It is interesting to note that the three footstones bear the same initials as the names of Harvey W. Campbell, John Dupuis, and Francis Dupuis. Do these footstone and headstones go together or do they belong to entirely different people? If the footstone and headstones represent the same people then there are at least eight individuals interred in the cemetery. If not, there may be a minimum of eleven individuals buried in the small Campbell family cemetery. Also important to the present study is the identification of a small fence that surrounded the cemetery. According to Harvey Frederick (personal communications, 2004), the cemetery fence was removed ca. 1974.

6. AERIAL PHOTOGRAPHS

During the Great Depression, several farm programs were instituted to help the farm community. Consequently, farmers needed a way to accurately measure their farmlands. Precise measurement continued to use surveyor's chains, which had to be carried around the fields. The resulting map continued to be drawn by hand. Due to the large number of acres numbering in the millions needing to be measured and mapped, the government sought a way to more quickly and cheaply map the agricultural acreage of the Nation. In 1935, the United States Department of Agriculture (USDA) instituted the rectified-to-scale aerial photography program. The program allowed a more efficient method to measure farm acreage. Vertical imagery was used for and continues to be used for rectified aerial photography. The camera was mounted on an airplane so it pointed straight down. Due to wind currents, changing elevation, and camera motion during flight, the resulting photographs were often at an angle rather than truly vertical. The resulting tilt of the photograph was corrected by a system of analytical triangulation which measured point on the photograph and mathematically computed the scale and tilt data to correct the accurate scale photographs. The primary format for the aerial photographs was the 9x9-inch film negative. Most of the conterminous United States has been covered.

During the first several decades, the aerial photographs taken by the USDA Agricultural Stabilization and Conservation Service (ASCS) were black-and-white panchromatic negative film at a scale of 1:20,000. In 1978, several Federal agencies combined their efforts to provide consistent and systematic aerial photographic coverage of the United States. The National High Altitude Program (NHAP) collected two different scales of photography simultaneously. Black-and white panchromatic film was used for the 1:80,000 scale while color infrared film was collected at a scale of 1:58,000. The NHAP was replaced in 1987 with the National Aerial Photography Program (NAPP), which was to acquire uniform coverage of the conterminous United States every 5 to 7 years. NAPP photography has a scale of 1:40,000. Color infrared or black-and-white film was used based on the project requirements. In 2001, the National Agriculture Imagery Program (NAIP) was implemented to replace the existing compliance imagery program. NAIP imagery may be delivered at 1 meter to 2-meter resolution in natural color or color infrared imagery. USDA aerial photography acquired since 1955 is available from the Field Service Agency's Aerial Photography Field Office in Salt Lake City, Utah. Aerial photographs acquired before 1955 have been transferred to the National Archives and Records Administration in the Nation's capitol. Other agencies, such as the USDA Forest Service, the U.S. Geological Survey, U.S. Army Corps of Engineers, and the National Aeronautics and Space Administration, also acquire aerial photographs and satellite imagery. Aerial photographs of the project area were obtained from the National Archives and Records Administration, United States Geological Survey, and the Aerial Photography Field Office (Johnson and Barber 1997:654-655).

Aerial photo interpretation involves the evaluation of several factors in the identification of features on vertical photographs (see Colwell 1997:3-47; Deuel 1969;

Palmer and Cox 1993; Riley 1987; Scollar et al. 1990:26-125; Teng 1997:49-113; and Wilson 1982 for additional information of the application of aerial photographic interpretation to archeological investigations). Major factors include the shape of the object, the size of the object, photographic tone, spatial pattern or arrangement of the objects, shadows cast by the object, the object's relative topographic location, association with other objects, site location, and the degree of coarseness or texture (Avery 1977:23-24; Avery and Berlin 1985:52-57). Although it may be feasible to use only one vertical photograph for the identification and classification of specific features, the method only allows for the perception of two dimensions (i.e., length and width). It leaves out depth perception used for stereoscopic vision (Avery 1977:26-28; Avery and Berlin 1985:58-59). Two photographs of the same object are taken at slightly different positions during the flight are required in order to obtain stereoscopic images. Aerial photographs are collected by overlapping consecutive photographs taken by the airplane flying horizontally over the project area. In addition to overlapping consecutive photographs along the single flight line, adjacent flights lines must also overlap along the sides of the area photographed. The aerial camera stations are spaced to provide a 60 percent forward overlap along each flight line and a 20 to 30 percent sidelap for adjacent lines (Avery and Berlin 1985:59-60).

The instrument used to view a stereo pair of aerial photographs is the stereoscope. The stereoscope is used to deflect converging lines of sight so each eye views a different image. It produces a sharply defined, although exaggerated or distorted, three-dimensional image. Three general types of stereoscopes exist: 1) lens or pocket stereoscopes, 2) mirror or reflecting stereoscopes, and 3) zoom stereoscopes (Avery 1977:29-31; Avery and Berlin 1985:60-62). The analysis of the stereo pairs of aerial photographs obtained for the present project was conducted with a Topcon MS-3 mirror stereoscope (Topcon 1994).

Stereo pairs of aerial photographs must be arranged in the position they were taken along the flight line (Avery 1977:33-35; Avery and Berlin 1985:63; Topcon 1994:3-6). The principal point or optical center is identified and marked on the two photographs (Note: Marking the point may be accomplished by placing a small pinhole at the location). This is the point at the intersection of the imaginary line connecting the top and bottom and the left and right fiducial marks at the edges of the photographs. The next step is to identify and mark the conjugate principal point. The conjugate principal point is the location of the principal point from the other photograph. The flight line is represented by a line connecting the principal and conjugate principal points of the two aerial photographs. The aerial photographs are mounted on a magnetic photo panel to keep them from moving while viewing them with the stereoscope. The stereoscope is placed over the photographs and aligned with the imaginary flight line. The separation between the two photographs is approximately 260 mm between the principal point on one photograph and its conjugate principal point on the second photograph. This provides approximately 14 cm of common viewing area. Viewing the set of aerial photographs should produce a tree dimensional (3D) of the area of interest. Normally, objects viewed in stereo have their vertical heights exaggerated with respect to the horizontal distances (Avery and Berlin 1985:64-66). The binocular eyepieces on the stereoscope provide the largest viewing area measuring 180mm- x 240 mm at 1x magnification. The stereoscope also has a set of built-in magnifiers for observing a wide area of 170 mm x 230 mm at a higher magnification of 1.8x. The stereoscope also comes with two detachable binocular viewers for precision measurements of height when used with the accessory stereometer. The 3x magnification viewer provides a 70 mm diameter field of vision while the 6x magnification viewer provides a 30 mm diameter field of vision. The detachable binocular eyepieces are also adjustable for the pupillary distance of an individual's eyesight.

Aerial photographs for the project area were obtained from the National Archives and the Aerial Photography Field Office (Table 1). The first set of available ASCS aerial photographs for the project area was flown in 1954 (Figure 9). The tree grove containing the immediate geophysical project area is located at the south end of a cultivated field. The adjacent southern field appears to have been recently harvested or mown due to its much lighter color that the field containing the tree grove. The fence line separating the two fields is immediately south of the tree grove. There appears to be one large tree with several smaller ones next to it. This tree may be the large maple, which is still present in the tree grove on the west side of the line of gravestones. The upland drainage lies on the west side of the tree grove. Several farm buildings including the house are located at the southeastern corner of the field south of the tree grove. The 1959 aerial photograph clearly shows the isolated tree grove (Figure 10a). The previous field boundaries have been changed. The upland drainage has been channelized and straightened. The line of trees in the drainageway below the tree grove and cemetery. The large maple trees are visible along with the smaller trees to the east of the line of maples. In the 1966 aerial photograph (Figure 10b), the trees on the east side of the cemetery have been removed. The large maples still form a line on the west side of the headstones. The removal of the smaller trees east of the maples provides a better view of the ground in the main part of the cemetery. There appears to be two square objects, which are probably headstones at the southern end of the cemetery. There also appears to be a difference in the vegetation along the east side of the cemetery and the surrounding cultivated fields. This suggests the presence of a fence separating the cemetery area from the agricultural fields. The adjacent fields continue to be farmed and the tree grove remains approximately the same size in the 1972 (Figure 10c) and the 1981 (Figure 10d) aerial photographs. The growth of smaller trees in the eastern part of the cemetery is noticed in these aerial photographs. By 1991 (Figure 10e), several buildings have been removed from the farm. The field south of the tree grove and cemetery has also been terraced. The 1998 and 1999 aerial photographs (Figures 10f and 10g, respectively) indicate that the tree grove and surrounding fields changed little during the 1990s following the terracing of the field and the removal of several farm buildings. The cemetery area encompassed by the tree grove changed little over the years between the last aerial photograph in 1999 and the present geophysical investigations. It should be noted that the farm house was demolished and removed during the spring of the year while the geophysical investigations were being conducted at the cemetery site. The analysis of the aerial photographic coverage of the project area between 1954 and 1999 suggests little change in the size of the tree grove associated with the cemetery in the middle of the agricultural fields. Landscaping activities associated with the channelization of the upland drainageway, the terracing of the field, and continuing agricultural practices did not severely impact the dimensions of the tree grove containing the cemetery.

7. GEOPHYSICAL PROSPECTION TECHNIQUES

Various geophysical instruments have been used by archeologists to locate evidence of past human activity. Magnetometers and soil resistance meters began to be employed on Roman sites in England during the late 1940s and early 1950s (Aitken 1961), and their use was the focus of considerable research in the 1960s and 1970s. During this period the archeological applications of additional instruments were explored (Aitken 1974, Clark 2000, Scollar et al. 1990, Tite 1972). While many of the early studies in England and Europe were very successful, it was some time before improvements in detector sensitivity and data processing techniques allowed a wide range of New World sites to be mapped. Virtually all the instruments used in non-invasive mapping of historic sites originated as prospecting devices for geological exploration. In general, cultural resource applications using geophysical instruments focus on weaker anomalies or smaller anomalies. It is important to emphasize that instruments employed in archeological geophysical surveys do not respond only to the desired cultural targets, and consequently feature detection depends greatly on the recognition of patterns that match the anticipated form of the cultural target. The challenge in archeological geophysics is to recognize the anomalies produced by the target features and sort them out from the "noise" produced by the responses from the surrounding matrix. The amount of data collected in any given area and the method of collection both affect one's ability to recognize the specific anomaly type or "signature" of the feature being sought.

Geophysical prospection techniques available for archeological investigations consist of a number of techniques that record various physical properties of earth, typically in the upper couple of meters; however, deeper prospection can be utilized if necessary. Geophysical techniques are divided between passive techniques and active techniques. Passive techniques are ones that measure inherently or naturally occurring local or planetary fields created by earth related processes under study (Heimmer and De Vore 1995:7,2000:55; Kvamme 2001:356). The primary passive method utilized in archeology is magnetic surveying. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground (Heimmer and De Vore 1995:9,2000:58-59; Kvamme 2001:355-356). The interaction of these signals and buried materials produces alternated return signals that are measured by the appropriate geophysical instruments. Changes in the transmitted signal of amplitude, frequency, wavelength, and time delay properties may be observable. Active methods applicable to archeological investigations include electrical resistivity, electromagnetic conductivity (including ground conductivity and metal detectors), magnetic susceptibility, and ground-penetrating radar. Active acoustic techniques, including seismic, sonar, and acoustic sounding, have very limited or specific archeological applications.

Passive Geophysical Prospection Techniques

The passive geophysical prospection technique used during the project is the magnetic survey. As indicated above, passive techniques measure existing physical properties of the earth. Other passive geophysical techniques include the measurement of earth's natural electrical fields, gravitational fields, radiometric measurement of radioactive elements, and thermal measurements of soil temperature changes. These passive methods with limited archeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis.

Magnetic Surveys

A magnetic survey is a passive geophysical prospection technique used to measure the earth's total magnetic field at a point location. Magnetometers depend upon sensing subtle variation in the strength of the earth's magnetic field in close proximity to the archeological features being sought. Variation in the magnetic properties of the soil or other buried material induces small variations in the strength of the earth's magnetic field. Its application to archeology results from the local effects of magnetic materials on the earth's magnetic field. These anomalous conditions result from magnetic materials and minerals buried in the soil matrix. Ferrous or iron based materials have very strong effects on the local earth's magnetic field. Historic iron artifacts, modern iron trash, and construction material like metal pipes and fencing can produce such strong magnetic anomalies that nearby archeological features are not detectable. Other cultural features, which affect the earth's local magnetic field, include fire hearths, and soil disturbances (e.g., pits, mounds, wells, pithouses, and dugouts), as well as, geological strata.

Magnetic field strength is measured in nanoteslas (nT; Sheriff 1973:148). In North America, the earth's magnetic field strength ranges from 40,000 to 60,000 nT with a inclination of approximately 60° to 70° (Burger 1992:400; Milsom 2003:55; Weymouth 1986:341). The project area has a magnetic field strength of approximately 55,900 nT with a inclination of approximately 69.9° (Peddie 1992; Peddie and Zunde 1988; Sharama 1997:72-73). Magnetic anomalies of archeological interest are often in the ±5 nT range, especially on prehistoric sites. Target depth in magnetic surveys depends on the magnetic susceptibility of the soil and the buried features and objects. For most archeological surveys, target depth is generally confined to the upper one to two meters below the ground surface with three meters representing the maximum limit (Clark 2000:78-80; Kvamme 2001:358). Magnetic surveying applications for archeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects (see Bevan 1991,1998:29-43; Breiner 1973; Burger 1992:389-452; Clark 2000:92-98,174-175; David 1995:17-20; Gaffney and Gater 2003:36-42,61-72; Gaffney et al. 1991:6,2002:7-9; Heimmer and DeVore 1995:13,2000:55-56; Kvamme 2001:357-358; Lowrie 1997:229-306; Milson 2003:51-70; Mussett and Khan 2000:139-180; Nishimura 2001:546-547; Scollar et al. 1990:375-519; and Weymouth 1986:343 for more details on magnetic surveying).

Two modes of operation for magnetic surveys exist: 1) the total field survey and 2) the magnetic gradient survey. The instrument used to measure the magnetic field strength is the magnetometer (Bevan 1998:20). Three different types of magnetic sensors have been used in the magnetometer: 1) proton free precession sensors, 2) alkali vapor (cesium or rubidium) sensors, and 3) fluxgate sensors (for a detailed description of the types of magnetometers constructed from these sensors see Aitken 1974; Clark 2000:66-71; Milsom 2003:58-62; Scollar et al. 1990:450-469; Weymouth 1986:343-344).

The total field magnetometer is designed to measure the absolute intensity of the local magnetic field. This type of magnetometer utilizes a single sensor. Due to diurnal variation of the earth's magnetic field, the data collected with a single sensor magnetometer must be corrected to reflect these diurnal changes. One method is to return to a known point and take a reading that can be used to correct the diurnal variation. A second method is to use two magnetometers with one operated at a fixed base station collecting the diurnal variation in the magnetic field. The second roving magnetometer is used to collect the field data in the area of archeological interest. Common magnetometers of this types used in archaeological investigations include the proton precession magnetometer, the Overhauser effect magnetometer (a variation of the proton precession magnetometer), and the cesium magnetometer.

The magnetic gradient survey is conducted with a gradiometer or a magnetometer with two magnetic sensors separated by a fixed vertical distance. The instrument measures the magnetic field at two separate heights. The top sensor reading is subtracted from the bottom sensor reading. The resulting difference is recorded. This provides the vertical gradient or change in the magnetic field. Diurnal variations are automatically canceled. This setup also minimizes long range trends. The gradiometer provides greater feature resolution and potentially provides better classification of the magnetic anomalies. Two commonly used gradiometers in archeological investigations are the cesium gradiometer and the fluxgate gradiometer. They are capable of yielding 5 to 10 measurements per second at an accuracy resolution of 0.1 nT (Kvamme 2001:358). Cesium gradiometers record the absolute total field values like the single sensor magnetometers. The fluxgate sensors are highly directional, measuring only the component of the field parallel to the sensor's axis (Clark 2000:69). They also require calibration (Milsom 2003:2003:61-62). Both cesium and fluxgate gradiometers are capable of high density sampling over substantial areas at a relatively rapid rate of acquisition (Clark 2000:69-71; Milsom 2003:60-62).

Active Geophysical Prospection Techniques

The active geophysical prospection techniques used during the project included conductivity, resistivity, and ground-penetrating radar. As indicated above, active techniques transmit electrical, electromagnetic, or acoustic signals into the ground. The interaction of these signals and buried materials produces an altered return signal, which is measured by the appropriate geophysical instrument. The ground-penetrating radar and ground conductivity meter utilize electromagnetic signals. The resistivity meter injects an electric current into the ground.

Soil Resistivity Surveys

The resistivity/soil resistance survey is an active geophysical technique, which injects a current into the ground (see Bevan 1991,1998:7-18; Burger 1992:241-318; Carr 1982; Clark 2000:27-63,171-174; David 1995:27-28; Gaffney and Gater 2003:26-36,56-61; Gaffney et al. 1991:2;2002:7; Heimmer and DeVore 1995:29-35,2000:59-60; Kvamme 2001:358-362; Lowrie 1997:206-219; Milson 2003:83-116; Mussett and Khan 2000:181-201; Nishimura 2001:544-546; and Scollar et al. 1990:307-374 for more details on resistivity surveys). It measures the resistance to the flow of an introduced electrical current in the soil. The voltage is measured, and by Ohm's Law, one may compute the resistance at any given point (**R=V/I** where **R** is resistance, **V** is voltage, and **I** is current). Soil resistance is dependent on several factors, including the soil structure, soil texture, soil water solution conductivity, capillary conductance, the depth of the archeological targets (i.e. features or objects), and the material comprising the archeological target. The differential electrical resistance is primarily dependent on the moisture content in the subsurface matrix (Carr 1982:47-105; Clark 2000:27; Heimmer and De Vore 1995:9,30). Since electricity is easily conducted through water and follows the path of least resistance, the resistivity anomalies are identified as contrasts between the resistance values of the buried features and objects and those of the surrounding soil matrix.

The two types of resistivity surveying techniques used in archeology are the lateral profiling (horizontal) and the vertical electrical sounding (VES). Lateral profiling is done with fixed electrode spacings. Resistance measurements in ohms (Sheriff 1973:156) are collected by moving the electrode array from point to point along fixed traverses. Due to the problem of contact resistance between two electrodes in the ground, a typical soil resistance survey makes use of four electrodes or probes. The current passes through two electrodes and the voltage is measured between the other two probes. The configuration of the electrodes also varies (see Gaffney and Gater 2003:29 and Milson 2003:99 for common configurations). The present survey utilizes the twin probe array (Geoscan Research 1996). On the twin probe array, a current and voltage probe are located on a mobile frame that is moved around the site. Two additional probes are located away from the survey area and also consist of a current probe and voltage probe. The probes on the frame are located at a fixed distance apart. A general rule of thumb for the depth investigation of soil resistance survey is the depth is equal to the distance between the probes. This value is not a unique number but an average for the hemispheric volume of soil with a radius equal to the probe separation distance. The probes are connected to the resistance meter, which is also on the frame. The measurement is taken when the mobile probes make contact with the ground and completes the electrical circuit. The measurements are stored in the resistance meter's memory until downloaded to a lap-top computer. The resulting data is integrated to provide areal coverage of the site under investigation.

The VES is done at a location by measuring several resistance values with increasing electrode separation (see Bevan 1998:17-18; Gaffney and Gater 2003:34-35; Lowrie 1997:215-217; Milsom 2003:108-112; and Mussett and Khan 2000:186-194 for additional information for conducting a vertical electrical sounding). As the separation between the electrodes increases, the same proportion of current is disturbed through an increasing depth of soil. This results in a proportionally larger effect of the deeper layers on the apparent resistivity. The Wenner array is most commonly used probe array for VES. In this configuration, the electrodes are evenly spaced with the current electrodes on the ends and the voltage electrodes in the middle (C1 P1 P2 C2). The near surface conditions differ at each electrode for each reading resulting in a relatively high noise level. To produce a smoother sounding curve, the VES is produced by using an offset array where the electrodes are expanded in opposite directions. The two readings for each offset separation are averaged together. This suppresses the local effects at each electrode. The difference between the two readings indicates the significance of these effects. The resistance values using the Wenner probe array obtained are converted to apparent resistivity by the formula $\boldsymbol{\rho_a = 2\pi ar}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **a** is the electrode spacing, and **r** is the measured resistance at each electrode separation. The resulting apparent resistivity values in ohm-meters (Sheriff 1973:156) are plotted by electrode spacing. Variation of the apparent resistivities with each increasing electrode spacing are compared to sounding curves (Orellana and Mooney 1972) or modeled in a computer program (Butler 1999; Interpex 2002). This produces an estimate of the electrical stratification of the soil. This information provides the investigator with basis data that can be used to determine the applicability of the various techniques to the project area (i.e., if the resistivity is high, then ground-penetrating radar should work well on the site, or if the resistivity is extremely high, then a ground conductivity survey may not be practical).

By combining the two methods, one can obtain both lateral profiles at different vertical depths. This requires the use of multiple sets of probes. For this to be achieved, data must be gathered along multiple traverses at a number of different spacings, which are multiples of a fundamental distance. The probes are moved along the traverse at regularly spaced intervals to obtain the horizontal changes. With the different distance spacings between the probes, the vertical changes are also identified during the survey. By combining the two resistivity methods, the resulting data may be displayed as layers at the various depths based on the probe separation or as vertical pseudo-sections (Milson 1996:91-93). The most common probe array used in archeology using this combination is the twin electrode probe array, although multiprobe switching resistivity systems are becoming more common (Geoscan Research 1993; Iris Instruments 1999; Milson 1996:71). Combining the resistance meter, probes, and a multiplexer unit, several probe configurations can be measured at a single location (Geoscan Research 1995). By combining the multiple configurations, pseudo sections or depth information can be collected relatively rapidly over a large area. The conversion of the soil resistance measurements to resistivity is more complicated than in the Wenner probe array (Bevan 2000:2). Like the Wenner probe array, four probes are used to take the resistance measurement; however, instead of having the linear arrangement of potential, current, current, and potential probes set at equal distances apart, in the twin electrode array, one current and one potential set of probes are on the mobile frame and moved about the site collecting readings. The second set of remote probes is set away from the grid. To convert the resistance readings from the multiple sets of probes to comparable apparent resistivity measurements the following formula is used (Geoscan Research 1995: B-1): $\boldsymbol{\rho_a = 2\pi r/G.F}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **r** is the measured resistance at each electrode separation, and **G.F.** is equal to the inverse of the distance between the remote probes plus the distance between the mobile probes minus inverse of the distance between the remote potential and mobile current probes minus the inverse of the remote current and mobile potential probes (**G.F. = 1/C2P2 + 1/C1P1 – 1/C2P1 – 1/C2P1** where **C2P2** equals the probe separation distance between C2 and P2, etc.). The resistance measured by the twin electrode probe array is determined by the resistivity below both sets of probes ($\boldsymbol{R = V/I = (1/2\pi)\ (\rho_1/a_m + \rho_2/a_r\ )}$ where $\boldsymbol{\rho_1}$ is the resistivity of the soil beneath the mobile probes, $\boldsymbol{a_m}$ is the mobile probe separation distance, $\boldsymbol{\rho_2}$ is the resistivity of the soil beneath the remote probes, and $\boldsymbol{a_r}$ is the remote probe separation distance). The apparent resistivity can be approximated by the formula $\boldsymbol{\rho_a = \pi a r}$, where the electrode spacing **a** of both the mobile and remote electrodes are equal, or to $\boldsymbol{\rho_a = 2\pi a r}$ (approximate), where the electrode spacing **a** is equal to the mobile probe separation when the remote probe spacing in much greater than the mobile probe spacing. A more accurate method (Bevan 2000) of determining the resistivity measurements from the soil resistance data is to determine the resistivity below the remote, fixed electrodes by taking measurements at two separate probe spacings where $\boldsymbol{\rho_2 = 2\pi\ ((R_1 - R_2)/(1/a_r - 1/a_{r2}))}$. The resistivity below the mobile probes can be computed as $\boldsymbol{\rho_1 = 2\pi a_m R - \rho_2(a_m/a_r)}$. By combining all the resistivity data, a three dimensional display can be generated of the soil resistivity.

Electromagnetic Conductivity Surveys

The capacity of soil to conduct electrical currents has led to the use of soil conductivity and soil resistivity meters in cultural resource management (Heimmer and De Vore 1995:29-41). Both resistivity and conductivity represent active geophysical techniques. Soil resistivity meters used in archeological surveys typically involve four metal probes placed in contact with the soil. A small alternating current is normally applied to two of the probes and the voltage difference between the other two probes is measured. Variations in soil moisture, chemistry, and structure affect the electrical resistance of the soil. Soil resistivity surveys are particularly well suited to locating high resistance material (e.g. stone or brick) in relatively conductive soil (e.g. clay). Soil conductivity meters provide another method of measuring the soil's ability to conduct electrical current. This survey technique measures the soil conductivity. Theoretically, conductivity represents the inverse of resistivity. High conductivity equates to low resistivity and vice versus. The electromagnetic ground conductivity meter induces an electromagnetic field into the ground through a transmitting coil (see Bevan 1983,1991,1998:29-43; Burger 1992:310; Clark 2000:34-37,171; Clay 2001:32-33; David 1995:20-23; Gaffney and Gater 2003:42-44; Gaffney et al. 1991:5,2002:10; Heimmer and DeVore 1995:35-41,2000:60-63; Kvamme 2001:362-363; Lowrie 1997:222-225; McNiel 1980a,1980b; Milson 2003:129-147; Mussett and Khan 2000:210-227; and Nishimura 2001:551-552; Scollar et al. 1990:520-575 for more details on conductivity surveys). The induced primary field causes an electromagnetic wave flow in the earth similar to the electrical current in a resistivity survey. The materials in the earth create secondary eddy current loops, which are picked up by the instrument's receiving coil. The interaction of the generated eddy loops or electromagnetic field with the earthen materials is directly proportional to terrain conductivity within the influence area of the instrument. The receiving coil detects the response alteration (secondary electromagnetic field) in the primary electromagnetic field. This secondary field is out of phase with the primary field (quadrature of conductivity phase). The in-phase component of the secondary signal is used to measure the magnetic susceptibility of the subsurface soil matrix. Only the quadrature or conductivity phase data were collected during the present project. Contrasts result from electrical and magnetic properties of the soil matrix. Contrasts are caused by materials buried in the soil, differences in soil formation processes, or soil disturbances from natural or cultural modifications to the soil. Electromagnetic conductivity instruments are also sensitive to surface and buried metals. Due to their high conductivity, metals show up as extreme values in the acquired data set. On occasion, these values may be expressed as negative values since the extremely high conductivity of the metals cause saturation of the secondary coil. The apparent conductivity data were recorded in units of millisiemens per meter (mS/m). The electrical conductivity unit or siemens represents the reciprocal of an ohm-meter or the unit for resistivity (Sheriff 1973:197). The relationship between conductivity and resistivity is represented by the following formula (Bevan 1983; McNeil 1980): mS/m = 1000/ohm/m.

Its application to archeology results from the ability of the instrument to detect lateral changes on a rapid data acquisition, high resolution basis, where observable contrasts exist. Lateral changes in anthropogenic features result from compaction, structural material changes, buried metallic objects, excavation, habitation sites, and other features affecting water saturation (Heimmer and De Vore 1995:37). Since the conductivity meter has no direct contact with the soil, this permits the conductivity meter to be moved more rapidly than a resistivity meter and a greater area can be surveyed in a shorter period of time. The instrument has been used to identify areas of impaction and excavation as well as buried metallic objects. It has the potential to identify cultural features that are affected by the water saturation in the soil (Clark 2000:36; Heimmer and De Vore 1995:36-37). In the present project, the investigations are looking for changes in the electromagnetic conductivity between the natural soil surrounding the grave and the disturbed soil within the grave. Conductivity meters are also susceptible to interference from metal including gas or water pipes and wires. Metallic trash in the topsoil can degrade conductivity signals.

Ground-penetrating Radar Survey

Ground-penetrating radar (gpr) is an active method that has recently achieved popularity in cultural resource management applications (see Bevan 1991,1998:43-57; Clark 2000:118-120,183-186; Conyers and Goodman 1997; David 1995:23-27; Gaffney and Gater 2003:47-51,74-76; Gaffney et al. 1991:5-6,2002:9-10; Heimmer and DeVore 1995:42-47,2000:63-64; Kvamme 2001:363-365; Lowrie 1997:221-222; Milson 2003:167-178; Mussett and Khan 2000:227-231; Nishimura 2001:547-551; and Scollar et al. 1990:575-584 for more details on ground-penetrating radar surveys). Although Bruce Bevan pioneered the archeological use of gpr a quarter-century ago (Bevan 1977; Bevan and Kenyon 1975), the cost of equipment and problems dealing with the massive amount of data produced by gpr surveys limited the number of archeological applications. Recently, Conyers and Goodman (1997) have published an introduction to gpr for archeologists, and Bevan (1998) has provided an excellent comparison of various radar antennae as applied to a consistent group of archeological features. Reductions in the cost of equipment and improvements in the software available for processing the voluminous data have helped to make gpr surveys more affordable and analysis more efficient.

Ground-penetrating radar uses pulses of radar energy (i.e., short electromagnetic waves) that are transmitted into the ground through the surface transmitting antenna. A short burst of radio energy is transmitted and then the strength of the signal received from reflectors a few nanoseconds after the pulse's transmission is recorded by the receiving antenna. The combination of time after transmission and strength of reflected signal provides the data used to create plan maps and profiles. The radar wave is reflected off buried objects, features, or interfaces between soil layers. These reflections result from contrasts in electrical and magnetic properties of the buried materials or reflectors. The contrasts are a function of the dielectric constant of the materials (Sheriff 1973:51). The depth of the object or soil interface is estimated by the time it takes the radar energy to travel from the transmitting antenna and for its reflected wave to return to the receiving antenna. The depth of penetration of the wave is determined by the frequency of the radar wave. The lower the frequency, the deeper the radar energy can penetrate the subsurface; however, the resulting resolution, or the ability to distinguish objects, features, and soil changes, decreases. These low frequency antennas generate long wavelength radar energy that can penetrate several tens of meters under certain conditions, but can only resolve larger targets or reflectors. The higher the radar wave frequency, the higher the resulting resolution but the depth penetration decreases. High frequency antennas generate much shorter wavelength energy, which may only penetrate a meter into the ground. The generated reflections from these high frequency antennas are capable of resolving objects or features with maximum dimensions of a few centimeters. A resulting tradeoff exists between subsurface resolution and depth penetration: the deeper the penetration then the resulting resolution is less or the higher the resolution then the resulting depth penetration is much shallower.

As the radar antenna system (transmitting and receiving antennas) is moved along the survey line, a large number of subsurface reflections are collected along the line. The various subsurface materials affect the velocity of the radar waves as they travel through the ground (Conyers and Goodman 1997:31-40). The rate at which these waves move through the ground is affected by the changes in the physical and chemical properties of the buried materials through which they travel. The greater the contrast in electrical and magnetic properties between two materials at the interface results in a stronger reflected signal. As each radar pulse travels through the ground, changes in material composition or water saturation, the velocity of the pulse changes and a portion of the energy is reflected back to the surface where it is detected by the receiving antenna and recorded by ground-penetrating radar unit. The remaining energy continues to pass into the subsurface materials where it can be reflected by deeper reflectors until the energy finally dissipates with depth. In a uniform soil, there would be little energy reflected (except at the air/soil interface), and the bulk of the energy would be absorbed within a short distance. Objects included in the soil or strata with contrasting electrical properties may result in reflection of enough energy to produce a signal that can be detected back at the antenna. The radar system measures the time it takes the radar pulse to travel to a buried reflector and return to the unit. If the velocity of the pulse is known, then the distance to the reflector or the depth of the reflector beneath the surface can be estimated (Conyers and Lucius 1996).

Actual maximum depth of detection also depends upon the electrical properties of the soil, the frequency of the antenna, and the contrast between the target and its matrix. Plan maps present the average signal strength across the grid during the selected time interval (e.g. 7.2 to 14.4 ns). Because these time intervals correspond with horizontal layers or slices of soil, they are called either time-slices or depth-slices. The analyst can set the span of the time-slice and consequently the thickness of the depth-slice. Ground-penetrating radar profiles illustrate a cross section through the soil with the ground's surface at the top of the image. The profile images are conceptually similar to what one would see when looking at the side of an excavated trench. The vertical scale used on the profiles can be marked in nanoseconds (ns) indicating the amount of time between the transmission of the radar pulse and the receipt of the reflected signal or in units indicating depth below the ground surface. The earlier reflections are received from targets nearer the surface and the later reflections are received from deeper levels or features. The velocity can be measured directly in the field in some cases, calculated from the form of strong hyperbolic reflections, or estimated by using values of similar soils.

The success of the survey is dependent on soil and sediment mineralogy, clay content, ground moisture, depth of burial, and surface topography and vegetation. The ground-penetrating radar signal can be lost or attenuated (i.e., quickly dissipated) in soils that have high moisture content, high electrical conductivity, highly magnetic materials, or high clay contents. Dry soils and sediments, especially those with low clay content, represent the best conditions for energy propagation. The soils at the project sites do contain a relatively high clay content but were relatively moist during the survey. A ground-penetrating radar survey, with its capability for estimating the depth and shape of buried objects, may be an extremely valuable tool in the search of grave shafts. At times, radar cannot profile deep enough or the strata may be so complex as to render the graves indistinguishable from the surrounding soil profile. Selection of the appropriate antenna frequency is also important in providing a good compromise between the depth penetration and resolution.

8. GEOPHYSICAL SURVEYS OF HISTORIC CEMETERIES

The location and identification of unmarked graves incorporated modern forensic and more traditional archeological methodologies. Unlike archeological issues concerned with unmarked graves, forensic investigations typically involve little passage of time between the burial episode and the attempted detection. Forensic investigations typically presume that the burial was not intended to be discovered. Generally, most historic graves were originally identified with some type of marker, such as a wooden cross or other type of wooden grave marker, headstone, footstone, metal marker, or other type of monument (Nickel 2001:1,2003:3). According to Robert K. Nickel (2003:3-4):

> *Most historic graves were intended to be recognized but many have become lost with the passage of considerable time. Some grave markers were never installed, some decayed through time, and some have been removed for one reason or another. Many attempts have been made to map historic cemeteries with the goal of detecting unmarked graves. In some cases, where sites are threatened with destruction or encroachment, excavation is used to evaluate the results. With the exception of graves that contain iron caskets or reinforced vaults, grave contents are rarely detected directly. Human skeletal elements are not expected to produce significant anomalies. More often, successful results can be attributed to the detection of soil changes that result from the excavation and refilling of the grave shaft.*

In some cases, where sites are threatened with destruction or encroachment, excavation is used to evaluate the results. More often, most results must be evaluated based on more circumstantial evidence.

Generally, the most distinctive feature of a grave is the disturbed soil in the refilled grave shaft (Bevan 1991:1). Geophysical instruments in common use do not have the capability to detect human remains. A geophysical survey of a historic cemetery normally includes known graves that should yield a “signature” or typical data measurements of a refilled grave, as well as, background readings of the undisturbed soils. With these two opposing data sets, one can then model the response from unmarked graves by predicting the nature of the anticipated anomalous readings based on the soil’s physical properties and expected differences between backfilled grave excavations and the unexcavated natural soil matrix. In other words, the ability to identify unmarked graves is greatly increased when one has comparative geophysical signatures from known graves in a cemetery survey. It is expected that in the more recent cemeteries, there will be a greater differentiation between disturbed grave fill and adjacent natural soil matrix. In small and abandoned burial plots, where documentation is poor and visible markers are missing or non-existent, it is more difficult to reliably detect graves with a given geophysical instrument and to determine typical background values for undisturbed soils.

Dr. Bruce W. Bevan (1991) reported on the results of several geophysical surveys in cemeteries ranging from Minnesota to New England. A variety of instruments were used at the sites, including ground-penetrating radar, magnetometers, resistivity, and ground conductivity meters. At the Burton Parish churchyard in Williamsburg, Virginia, the results of the radar were clear and unambiguous (Bevan 1991:1313-1314, Figure 5). Low values of conductivity (high resistivity) and high magnetic readings also occurred in the vicinity of a grave. At the other sites, the results were more ambiguous with some graves clearly detected while others showed no clear signature (Bevan 1991:1311, Figure 1). Dr. Bevan concluded that the ground-penetrating radar had the greatest success of locating unmarked graves in this study (Bevan 1991:1316). The best conditions for the radar survey occurred when the soils were highly resistive, contained few underground objects such as tree roots and rocks larger than cobble size, and had no apparent soil stratification beyond weak, planar strata (Bevan 1991:1316). Conductive, clayey soils provided the worst conditions for the ground-penetrating radar. Dr. Bevan (1991:1316) concluded that "*These surveys have found no guarantee of success. Geophysical evidence has suggested that there were graves where there were none; known graves have also been invisible on these surveys*."

Two years later, Dr. Bevan conducted another test of geophysical techniques at the historic Plains Cemetery in Mechanicsville, Maryland. The geophysical data collected during the investigations were confirmed by extensive test excavations (King et al. 1993). The magnetic data were disappointing with the poor results primarily attributed to historic and modern iron debris not associated with the graves. The ground-penetrating radar data successfully identified approximately half of the potential graves. The remainder of the radar reflections appeared to have resulted from other shallow near-surface sources. In these two studies, Dr. Bevan identified several attributes of graves that can result in successful detection. These included air pockets in intact coffins, a metal coffin or framework, loose fill in a collapsed coffin and disturbed stratigraphy in the grave shaft. He also noted that troublesome features included large rocks, animal dens, tree roots, naturally occurring lenses of contrasting soil and other complex natural stratigraphy. In some cases, the distribution of excess soil around the area of a grave made it difficult to precisely locate the actual grave shaft.

The geophysical survey of the Middlecoff and Perschbacher pioneer family cemeteries on Scott Air Force Base, St. Clair County, Illinois, produced mixed results on the location of the graves (De Vore and Bevan 1995). Magnetic, conductivity, resistivity, and ground-penetrating radar survey techniques were employed at the pioneer cemeteries. At the Middlecoff cemetery, four stones marked grave locations. It was expected that the burials would be on the east side of these stones. The geophysical survey found no clear indications of the burials in these locations. Data from five separate locations surrounding the known grave locations indicated the possibility of unmarked graves. At the Perschbacher cemetery, the ground-penetrating radar evidence was not as clear as that from the Middlecoff cemetery. The ground conductivity survey data at the Perschbacher cemetery were closely associated with the topographic contours of the cemetery area. Tree roots and naturally occurring lenses of contrasting soil also created spurious readings. The multi-instrument geophysical survey was not a reliable predictor of grave locations although portions of or complete gravestones were *in situ*.

GEOPHYSICAL SURVEYS OF HISTORIC CEMETERIES

A geophysical survey of the Kane Cemetery in Bighorn National Recreational Area, Wyoming was conducted in order to determine the location of unmarked graves and to determine if known graves were correctly marked (De Vore 2002b). Ground-penetrating radar and ground conductivity surveys were conducted over the enclosed cemetery. The gpr survey provided positive data concerning the known grave locations. The radar data did not indicate the presence of stacked graves or unmarked graves beyond the known marked graves or visible depressions associated with unmarked graves. The ground conductivity survey identified several anomalies associated with metal markers at known grave locations. A few high conductivity anomalies may suggest the location of broken metal markers at the location of unmarked graves. Overall, the radar survey proved to be best suited to meet the park's objectives for the project.

At the Nez Perce Mission Cemetery at Spalding, Idaho, the geophysical investigations utilized a multi-instrument survey to examine portions of the cemetery (Nickel 2000a). The magnetic, soil resistance, and ground-penetrating radar surveys were about equally successful at detecting subtle anomalies associated with existing stone grave markers. Similar anomalies were recorded at most of the shallow depressions and several comparable anomalies were detected in areas without surface evidence of graves. Weak near-surface gpr anomalies, as well as, deeper and stronger anomalies were detected and associated with the marked and unmarked graves in the single cemetery.

The geophysical survey of the Moses Carter family cemetery at George Washington Carver National Monument in Missouri utilized magnetic, soil resistance, and ground-penetrating radar survey techniques (Nickel 2000b). The magnetic and soil resistance surveys recorded considerable variation over relative small distances. This made it extremely difficult to detect a typical "grave signature" that could be used throughout the cemetery. The results did not predictably correspond to known grave locations. Of the three geophysical techniques, the gpr appeared to be partially successful in detecting known graves.

Investigations of known cemeteries and suspected grave locations along the Oregon and California trails in Kansas (De Vore and Nickel 2003) illustrated the difficulty of detecting historic graves. Ground-penetrating radar, magnetic, resistivity, and conductivity techniques were utilized during the investigations. Gravestones were present at 14MH323 and the Cholera cemetery, 14PO312. At the Cholera cemetery, detectable radar anomalies were observed on multiple traverses over the marked graves. It was hoped that such a pattern would be noticeable in the rest of the survey area; however, that was not to be the case. The geophysical data failed to indicate the presence of any more graves in an area where at least fifty people were known to have been buried in the area. The multiplexer resistance data did suggest the presence of a few graves. At Site 14MH323, the known grave did not produce an anomaly, which could be associated with the burial or any other graves at the cemetery. The investigations at the remaining two sites, 14MH322 and 14PO406, were even more problematic since it was not known whether the features were associated with pioneer graves. The geophysical techniques provided a non-invasive, non-destructive avenue of investigations at the cemetery sites. The investigations were successful as far as the operation of the instruments and the collection of data measuring the sites' physical properties; however, the techniques did not provide clear indications for the presence of graves. Two possible explanations exist: 1) there was a lack of sufficient change in the measured physical properties associated with the graves, or 2) there were no graves in the areas of investigation.

The investigations of a known historic family cemetery located on the Sac and Fox tribal lands in Richardson County, Nebraska, also illustrates the difficulty in detecting historic graves (De Vore and Nickel 2004). Ground-penetrating radar, magnetic, and conductivity techniques were utilized in the investigations of the late 19th/early 20th century family cemetery. A 40 meter by 40 meter area was examined on the low terrace on the right bank of the channelized Noharts Creek. The three different data sets provided complementary data concerning the cemetery location and more recent farming activities. A series of anomalies in the west central part of the geophysical survey area appeared to represent two or three rows of graves. A linear anomaly identified as a fence line may have divided the cemetery from the rest of the field. Overall, the authors (De Vore and Nickel 2004:47) felt that the geophysical techniques provided the best initial evaluative phase of cemetery investigations where eminent destruction of the cemetery was not at issue, and there needed to be follow up archeological excavations to verify the geophysical anomalies identified during the survey efforts.

In applying geophysical techniques to archeological problems, one is challenged with the detection and recognition of anomalous conditions caused by human alteration of natural soil properties. There is no unique interpretation of substantial geological or anthropogenic anomalies that can be used to identify similar features at different site settings (Breiner 1973:18-19). Many different geological or pedological configurations of buried material (e.g., soils, rocks, or other substances) can produce an individual anomaly. The challenge is to identify the most probable or realistic model. Similar problems occur in archeological interpretations of geophysical anomalies, but on a much smaller scale than those encountered in geological anomalies (Nickel 2000b:10).

For grave identification, there needs to be a contrast in the physical property being measured by the geophysical instrument between what is in the grave and the surrounding natural soil matrix. If the displaced soil from the excavation of the grave is piled to the side of the grave as the shaft is being dug and then replaced over the body in the reverse order with the deeper soil on the top of the pile shoveled back into the grave first, there may not be any differentiation between the displaced soil and the surrounding unexcavated soil. If the soil is not compacted during its replacement, there may be no change in compaction between the surrounding soil matrix and the displaced soil. These factors would affect the ability of the geophysical instruments to detect the contrast between the surrounding soil matrix and the disturbed excavated soil of the grave. If the soil moisture levels between the disturbed and undisturbed soil matrices are approximately the same, then the geophysical instruments may not be able to detect any contrasts as well.

Depending on how the individual was buried (e.g., in a coffin, blanket/shroud, or clothes), there may be metal objects on the body or in the coffin furniture that could be detected by a magnetic, conductivity, or ground-penetrating radar survey. The ability of the geophysical instruments to detect a grave is based on the presence of significant contrasts in the property being measured by the instrument. If there is no change or very little change in magnetic properties, conductivity, resistance, dielectric constant, the geophysical instruments will not register a contrast in the data and the grave will be indistinguishable from the surrounding natural/undisturbed soil matrix.

Several attributes of graves can result in successful detection (Bevan 1991; King et al. 1993). These include air pockets in intact coffins, a metal coffin or framework, loose fill in a collapsed coffin, and disturbed stratigraphy in the grave shaft. Troublesome features include large rocks, animal dens, tree roots, naturally occurring lenses of contrasting soil and other complex natural stratigraphy. In some cases, the distribution of excess soil around the area of a grave may make it difficult to precisely locate the actual grave shaft. One thing is clear: it is difficult to predict the success of any geophysical technique on the basis of work in other depositional contexts or with other cultural traditions. Certainly one should not be surprised if similar features (graves) produce quite different anomaly patterns in different areas or even within different soil groups in a local area.

9. FIELD SURVEY PROCEDURES

The survey scope-of-work for the Iowa cemetery (14BN111) project called for magnetic, resistivity/conductivity, and ground-penetrating radar surveys of the area associated with known cemetery in order to identify the extent and location of possible graves. The survey was to cover an area 20 meters by 20 meters in the general location of the cemetery as identified by tribal members and oral history. The geophysical grid was established at the project location with a portable Ushikata S-25 Tracon surveying compass (Ushikata n.d.) and 100 meter tape. The surveying compass was used to sight in the two perpendicular base lines and grid corners. Wooden hub stakes were placed at the 20-meter grid corners. A datum point was established at the southwest grid corner.

Once the geophysical grid was established, a Nikon DTM-730 electronic field station (Nikon 1993) was positioned over the site datum or mapping station. Arbitrary values were assigned to the Northing (N) or y coordinate, Easting (E) or x coordinate, and elevation (Z coordinate) of the mapping station (Note: these values were North 500 meters and East 500 meters with an elevation of 500 meters). The backsight reference point for the project was aligned on magnetic north. The site features, geophysical grid points, and topography were mapped with the field station, prism, and prism pole. The data were stored on the memory card of the DTM-730 and subsequently downloaded into a laptop computer. Initially the coordinate data (i.e., survey codes, northing coordinates, easting coordinates, and elevation) and raw field data (i.e., survey codes, horizontal angle, vertical angle, slope distance) files were transferred from the field station to the laptop computer with the Transit software package (Nikon 1996). These data files for each site were then transferred to the WordStar 5.5 software package (MicroPro 1989). The extraneous information in the coordinate data files were removed leaving the northing (Y) coordinates, easting (X) coordinates, elevations (Z coordinates), and point descriptions. This locational information was then converted to an XYZ data (dat) file for processing in the SURFER 8 mapping software (Golden Software 2002).

Once in SURFER 8, a grid file was created from the data file (Golden Software 2002:89-161). The data columns were identified. Column B contained the X values or the East coordinates. Column A contained the Y values or North coordinates. Column C contained the Z or elevation values. Column D contained the description of the individual points. The grid line geometry was set for minimum and maximum values in both the X and Y directions. These values formed the corner points for the generated contour maps. The data were gridded using the Kriging algorithm (Golden Software 2002:17-121). The generated grid file was then smoothed (Golden Software 2002:383-387). The spline smoothing routine was selected to eliminate the angular contours by rounding the edges using a cubic spline interpolation over the gridded data. The grid file defined the XY locations of each grid node over the extent of the map and the interpolated Z value at each node. Finally, a blanking file was created and the blanking routine was run over the topographic data set. (Golden Software 2002:403-405). The blanking routine removed grid mode data from the area of the grid that did not contain any original data in order to eliminate contour lines in that area.

A contour map was then created from the grid file (Golden Software 202:197-230). The contour map consisted of several components, which defined the appearance of the contour map (Figure 11). These included the contour level, which defined the interval between contour lines. The line component determined the appearance of the contour lines, including type, thickness, and color. The area between the contour lines could be filled with a gradually changing spectrum of colors. The labeling feature allowed for the placement of the contour value on the contour lines. This component controlled the text properties, numeric format, spacing, and interval of the labels. Hachures or small tick marks could also be placed along the contour lines to indicate the direction of slope. These were generally not used in the generation of the topographic or feature maps, but were used for indicating negative values in the geophysical data. The contour lines were drawn as a series of smoothed line segments between adjacent grid lines. A map posting the location of the individual feature points was also generated (Golden Software 2002:241-258) and overlain (Golden Software 2002:373-380) on the contour map. The points were used to draw natural and cultural features and objects including lines, polygons, and points; to label specific features; to change the appearance of the objects; and to assign unique symbols to classes of objects (Golden Software 2002:467-492). A scale bar and north arrow were added to the finished contour map. The project area's natural and cultural features were also labeled.

Before the start of the geophysical survey, yellow nylon ropes were laid out on the grids. These ropes served as guide ropes during the actual data acquisition phases of the project. Twenty-meter ropes were placed along the top and bottom base lines connecting the grid corners. The survey ropes formed the boundaries of each grid during the data collection phase of the survey. Additional traverse ropes were placed a one-meter intervals across the grid at a perpendicular orientation to the base lines beginning with the line connecting the two wooden hubs on the left side of the grid unit. The ropes serve as guides during the data acquisition. The 20-meter lengths of ropes are divided into 0.5 meter increments by different colored tape. One color (blue) is placed every meter along the rope with a different colored (red) tape placed at half-meter intervals. The use of different colored tape on the ropes provides a simple way to maintain one's position within the geophysical survey grid unit as data are being collected. The geophysical data were therefore recorded in a series of evenly spaced parallel lines with measurements taken at regular intervals along each line resulting in a matrix of recorded measurements (Kvamme 2001:356; Scollar et al. 1990:478-488). Beginning in the lower left-hand corner of the grid, data collection occurred in a parallel (unidirectional) or zigzag (bi-directional) mode across the grid(s) until the survey was completed for each technique.

Magnetic Survey Methodology

The magnetic survey was conducted with a Geoscan Research FM36 fluxgate gradiometer with a ST1 sample trigger (Geoscan Research 1987). MWAC archeologist Steven

L. De Vore operated the instrument (Figure 12). The instrument is a vector magnetometer, which measures the strength of the magnetic field in a particular direction. The gradiometer consists of a control unit that contains the electronics, menu keyboard pad, power source, operating program, on-off switch, connector for the charger/data output/external logger, analog output connector, LCD display screen, sounder outlet, balance control, and memory chips (Geoscan Research 1987:8-10). The tubular carrying handle connects the control unit to the vertical sensor housing tube that contains the two fluxgate sensors. N/S and E/W sensor alignment controls are located on the sensor tube. It has a resolution of 0.05 nT with a 0.1 nT absolute accuracy.

The sensors are set at 0.5 meters apart from one another. The instrument is carried so the two sensors are vertical to one another. Height of the bottom sensor above the ground is relative to the height of the surveyor. In the carrying mode at the side of the body, the bottom sensor is approximately 0.30 meters above the ground. Two readings are taken at each point along the survey traverse, one at the upper sensor and one at the lower sensor. The difference or gradient between the two sensors is calculated (bottom minus top) and recorded in the instrument's memory. Each sensor reads the magnetic field strength at its height above the ground. The gradient or change of the magnetic field strength between the two sensors is recorded in the instrument's memory. This gradient is not in absolute field values but rather voltage changes, which are calibrated in terms of the magnetic field. The fluxgate gradiometer does provide a continuous record of field strength. With a built-in data logger, the gradiometer provides fast and efficient survey data collection. Typically, data across a 20-m by 20-m grid unit with sampling parameters of eight samples per meter and one-meter traverses in the zigzag mode of operation can be collected in 15 minutes. This amounts to 3,200 readings per survey grid. With eight samples per meter and one-half meter traverses in the zigzag mode, it takes approximately 30 minutes to complete a 20-m by 20-m grid unit. This amounts to 6,400 readings per survey grid. In the parallel data collection mode, the time to complete the survey of a complete grid unit is approximately 50 minutes.

Prior to the start of the survey, the memory of the gradiometer is cleared and the menu settings are checked for the appropriately planned survey. The operator must be free of any magnetic metal. If any clothing or objects carried by the operator is slightly magnetic, there is a high probability that the survey results will be degraded due to presence of magnetic materials in close proximity to the sensors in the instrument. As one walks along the traverse, the presence of magnetic materials on the operator will resulting in a shift in the readings of 1 to 2 nT or greater. This will cause a stripe effect to the data. In the case of the present project at all four sites, the gradiometer is programmed for a resolution of 0.1nT, reading average off, log zero drift off, log interval at 0.25 m, baud rate of 2400, average period set to 16 readings, check offset off, and the encoder external trigger type. When the instrument is turned on, the initial LCD display indicates the current display resolution, the status of the log drift facility, and the battery status. The resolution display reading can be either positive or negative. Although some magnetic anomalies may be stronger in the positive and negative values, the instrument defaults to a program recognized value

(2047.5) when these extremely strong values are observed. Generally such strong fields result from the close proximity of highly magnetic iron artifacts to the instrument. On the sample trigger, the samples/m knob is set to 8 samples/m and the rate knob is located at the 1 o'clock position. The toggle switch is set to the stop position. The grid size interval in the instrument and the traverse m knob on the sample trigger must be set to the same value. The value is set to 20 for the 20 m grid unit size.

The sensors must be accurately balanced and aligned along the direction of the field component to be measured. The zero reference point was established at N500/E520 grid corner and the balancing and alignment procedures were oriented to magnetic north. This point was selected where there were no noticeable localized changes in the digital display or by raising the instrument above the ground with the use of a plastic step stool. The readings should vary less than 2 to 3 nT. The balance control on the instrument was adjusted first. The balancing the instrument was conducted in the 1 nT resolution range by first inverting the instrument and zeroing the instrument. The instrument was then rotated 180 degrees about the same horizontal plane of the axis of the handle. The trimming tool was inserted into the balance control slot on the side of the instrument and the reading in the digital display was reduced in half. The procedure was repeated until the reading in the upright and inverted positions was within a range of -1 to 1 nT. With the instrument held vertically at a height where the alignment controls were within easy reach, the two sensors were then aligned. At first, the bottom sensor was aligned. The instrument was pointed to magnetic north and the instrument was zeroed so that the display reading was zero. The instrument was then rotated around the sensor tube 180 degrees until it pointed south. The small aluminum wheel of the N-S alignment control at the bottom of the tube was used to adjust the sensor until the reading was half of the value first observed when it was rotated to the south. The instrument was rotated back 180 degrees until it pointed to magnetic north and rezeroed. The display reading was checked. If the north reading was within the range of -1 to 1 nT, the alignment was considered successful and the bottom sensor was aligned. If the north reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the bottom sensor was aligned, the top sensor was then aligned. The instrument was rotated 90 degrees until it faced east. The instrument was zeroed and then rotated 180 degrees until it faced west. The display reading was noted. The E-W alignment control wheel at the top of the sensor tube was adjusted until the reading was half of the observed reading. The instrument was then returned to its east facing position and rezeroed. If the east reading was within the range of -1 to 1 nT, the alignment was considered successful and the top sensor was aligned. If the east reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the top sensor was aligned, the top sensor was then aligned. As a final check, the instrument was rotated 360 degrees about the vertical tube axis. If the display reading stayed within the -1 and 1 nT range, the sensor alignment procedures were considered successful. If the observed display readings went over the acceptable range, the balancing and alignment procedures were repeated until successful. The instrument was returned to the 0.1 nT resolution operating range and then zeroed at arms length over the operator’s head. The operator’s manual (Geoscan Research 1987:29-31) illustrates the steps involved in preparing the instrument for actual field data collection.

The survey of each traverse was conducted in a zig-zag or bidirectional mode beginning in the southwest corner or lower left-hand corner of each grid unit. With the instrument on, the Enable Log button on the menu pad is pushed to initialize the logging display mode. The LCD screen displayed the starting Grid Number (G1), the Line Number (L1), and the Position Number (P1). The toggle switch on the sample trigger was moved to the start position and the operator began walking the traverse line. The instrument was carried along the traverse rope with control box facing magnetic north. The sample trigger on the instrument provided a series of clicks for every sample reading and the instrument signals a beep on every eighth sample reading. As each measurement was recorded, the logging display was advanced one position until reaching the end of the line and then the line number advanced. The grid number advanced when the end of the grid was reached. The geophysical investigator maintained a pace along the traverse in accordance with the audio beeps from the fluxgate gradiometer. This placed the eighth sample reading at the meter tape mark. At the end of the first traverse, the instrument stopped collecting and recording the data. The toggle switch was moved to the stop position. At the end of each line, the operator moved over to the next traverse, revered his direction of travel, and proceeded back down the next traverse line towards the starting edge of the grid unit. The zigzag mode of data acquisition was repeated over and over until the end of the grid was reached. At the end of the grid, the instrument was turned off. The operator maintained a constant vigilance of the tilt of the instrument throughout the survey. The gradiometer was maintained in a vertical position during data acquisition. Any rotation or tilt in the instrument could cause errors of shifts in the readings of 1 to 2 nT or more.

During the survey, data were collected at 8 samples per meter (0.125 m) along each traverse and at half-meter traverses across each individual grid unit resulting in 16 samples per square meter. A total of 160 magnetic measurements were recorded for each traverse in the memory of the Geoscan Research FM36 fluxgate gradiometer. A total of 6,400 measurements was recorded during the magnetic survey for the 20 m by 20m grid. With two samples per meter and one-half meter traverses in the zigzag mode, it took approximately 30 minutes to complete a 20m by 20 m grid. The instrument’s memory can hold data acquired from two grid units. At the end of the data acquisition of two grid units, the magnetic data from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research) on a laptop computer. It took approximately 13 minutes to download the data from the complete 20-m by 20-m grid unit. The grid file created in GEOPLOT was reviewed in the field prior to the clearing of the gradiometer’s memory.

Soil Resistance Survey Methodology

For the Iowa family cemetery project, the Geoscan Research RM15 advanced resistance meter (Figure 13) and PA5 multiprobe array (Geoscan Research 1996) is used in a twin probe array. The resistance meter has a resolution of 0.05 ohms with an absolute accuracy of 0.1 ohms. The resistance meter consists of a control unit that contains the electronics, menu pad, power source, operating program, and memory chips. It also contains the on/off switch, expansion ports for the potential and current mobile and remote probes, a LCD display screen, and charger connector. The mobile and remote probe cables are plugged into the back of the RM15 resistance meter. The control unit is attached to the multiprobe array frame by a mounting plate and short and long knoblet screws. The instrument is operated by MWAC archeologist Steven L. DeVore.

The soil resistance survey is designed with a twin electrode probe array. The stainless steel mobile probes on the frame consist of a set of current and potential probes. The remote probes also consist of a set of stainless steel current and potential probes. The mobile probes on the frame with the resistance meter are moved uniformly across the site. The mobile probes are at a set distance apart on the array frame, which for the present survey was 0.5 meters. The mobile probes are inserted into the ground so the center of the frame is over the center of the traverse point. For acceptable readings, the mobile probes need to be within ±7.5 cm of the center point of the 0.5 meter cell on the traverse line since the reading is of an average volume of a hemisphere with a radius equal to the mobile probe separation distance. This provides some freedom in the placement of the probes, which makes the system fast and easy to use. If an obstacle is in the way of the probes, the frame can simply be moved to one side or the other of the obstacle for the placement of the probes if the displacement will not greatly affect the location of the measurement. The insertion depth for the mobile probes is not critical. With reasonably moist soil, the downward momentum of the frame is enough force to push the probes into the ground to a depth of 3 to 5 cm. The remote probes are stationary, and are set at a distance that is 30 times the twin probe separation distance on the PA5 frame from the survey grid area. At this distance, the background resistance reading is essentially independent of the mobile probes' location. The remote probes were placed approximately 15 meters south of N500/E510. The separation distance between the remote probes is not critical since the probes are left in a fixed position throughout the survey. The remote probes were separated by a distance of approximately one-half meter. The remote probes are connected to the resistance meter by means of a 50-meter cable and drum. Although the insertion depth of the remote probes is not critical due to the high contact resistance tolerability of the RM15, it is best to insert the probes as far into the ground as possible to eliminate any offset in background resistance caused by remote probe contact resistance or capacitive coupling of the 50 m cable. This is not generally important in a twin electrode probe survey since one is only looking for changes in an arbitrary background level as the mobile probes are moved along the traverse lines in a grid survey; however, should the remote probe contact resistance change, as in the case of a rain shower, then the offset and background resistance could also change beyond acceptable survey levels.

Prior to the start of the survey, the memory of the resistance meter is cleared and the menu settings are checked for the appropriately planned survey. For the present project, the resistance is programmed for a Mapping grid size of 20 m, a grid sample interval of 0.5 m, a grid traverse interval of 0.5 m, and the zig-zag grid traverse mode. The Range parameters include a gain of 10, a current of 1 mA, and a frequency of 137 Hz. The Setup includes a medium auto-log speed, an output voltage of 40 v, an high pass filter value of 13 Hz, and a mains frequency equal to the United States standard of 60 Hz. In the Array, the PA5 is the selected hardware with the twin configuration. The probe separation was set to 0.5. The Communications parameters for downloading the data are set to 9600 baud rate and with a data separator of no space. In the Program menu, the meter can be programmed as a single twin array (the default setting), parallel arrays, and multiple arrays. As the word single implies, only one configuration is used during the survey. This is set by the placement of two probes on the array frame. The final menu category contains the battery voltage status.

In order to have an appropriate operating range for data acquisition, the soil resistance system is moved around the grid area to check the dynamic range of resistance values. The gain and current ranges are adjusted so that changes of approximately 1% in the background resistance are observed. Typically this means adjusting the current and/or gain ranges up or down to get a measurement display of three decimal places on the LCD screen. Once the gain and current ranges are set, they are not changed during the survey of the grid. If they require a change because of repeated over-range readings, the data must first be downloaded and the memory cleared. The grid may need to be re-surveyed at the new settings. Once the gain and current ranges are set (x10 for the gain and 1mA for the current) the operator is ready to begin the survey. The Enable Log button is pushed to enable the Logging Display. The LCD screen displays the ohm reading and the initial position location (G1, L1, P1). To take the first reading, the Start button is pushed. The averaged measurement is recorded into memory and the P, L, and G position values will increment one position. An “A” is also displayed on the LCD screen, which indicated the meter, is in the Auto-Log mode and ready for the next measurement. The array frame and meter are picked up, moved to the next location, and the probes are inserted into the ground. At this point in the survey, the readings are automatically recorded. The RM15 detects the placement of the mobile probes in the ground in the automatic method of logging. The instrument provides both an audible warble for the recordation of the averaged resistance value in the instrument’s memory, and advances the position counter to the next point value. When the mobile probes removed from the ground the LCD screen indicates an open circuit (HCR / Open cct.). The survey continues to the end of the grid. At the end of the line, the instrument will provide one beep and at the end of the grid, it makes two beeps. There are also times when the reading from one of the positions may be over the operating range of the RM15. In those cases, the Dummy Log button is depressed and a dummy value of 2047.5 in inserted into the data set.

During the survey, data were collected at 2 samples per meter (0.5 m) along each 0.5 meter traverse across the grid resulting in 4 samples per square meter. For each traverse, a total of 40 resistance measurements were recorded in the memory of the Geoscan Research RM15 resistance meter. A total of 1,600 measurements was recorded during the soil resistance survey. At the end of the data acquisition phase at the site, the resistance data (Appendix D) from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research 2003) on a laptop computer. It took approximately less than five minutes to download the data from the survey. One grid file was created in GEOPLOT. The file was reviewed in the field prior to the clearing of the resistance's memory.

Vertical Electrical Sounding Methodology

The vertical electrical sounding (VES) was conducted with the Gossen Geohm 40D earth tester (Figure 14) with a Wenner probe array (see Bevan 1998:7-18; Carr 1982; Gafeney and Gater 2003:34-36; Gossen-Metrawatt GMBH 1995; Lowie 1997:215-217; Milsom 1996:71-73; and Mussett and Khan 2000:186-194 for more details of vertical resistivity soundings). The resistivity meter has four measuring or operating ranges: 1) 0.01 Ω (ohms) to 19.99 Ω, 2) 0.1 Ω to 199.9 Ω 3) 1.0 to 1.999 kΩ, and 4) 10 Ω to 19.99 kΩ. It has an intrinsic error of ±2% of reading ±3 digits; service error ±5% of reading ±3 digits.

The VES at the Campbell cemetery was centered at N510/E520 with the offset line oriented north-south. The offset Wenner array of five electrodes was used to take resistance readings at the following increments: 0.1, 0.15, 0.2, 0.3, 0.4, 0.5, 0.70, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0 meters in both directions from the center probe to obtain data for the offset sounding. The distance between the probes also approximate the depth of investigation. The resistance measurements including the probe separations for both directions along the Wenner array offset were hand recorded in the field notebook for both directions of the offset. A total 26 measurements were recorded. It took approximately 1.5 hours to set up the array and conduct the vertical electrical sounding.

Ground Conductivity Survey Methodology

The present survey utilizes a Geonics EM38 ground conductivity meter (Geonics Limited 1992). The instrument is operated by MWAC archeologist Steven L. DeVore. The instrument is lightweight and approximately one meter in length (Figure 15). The apparent conductivity of the ground is in millisiemens per meter (mS/m) with a measurement precision of ±0.1% of full scale deflection. Conductivity is measured in the quadrature phase operating mode (Note: the in-phase operating mode measures magnetic susceptibility in parts per thousand or ppt). The meter consists of the transmitting and receiving coils embedded in the case of the instrument, a 9 volt battery, horizontal and vertical digital displays, recorder connector, and control panel. The control panel contains the conductivity range switch with two settings (1000 millisiemens/meter and 100 millisiemens/meter), on/off/battery test switch, a fine and course inphase (I.P) zero controls, a phase adjustment knob, the quadrature phase (Q/P) zero control, and a toggle switch for Q/P and I/P modes. The transmitting and receiving coils are located at opposite ends of the meter with an intercoil spacing of 1 meter. It has an operating frequency of 14.6 kHz in the 100 mS/m range and 40.4 kHz in the 1000 mS/m range. The conductivity meter can collect conductivity data in the quadrature phase operating mode or magnetic susceptibility data in the in-phase operating mode. The present ground conductivity survey is operated in the quadrature phase. The EM38 ground conductivity meter has a depth of investigation of approximately

1.5 meters in the vertical dipole mode with optimum resolution at 0.6 meters. An adjustable tubular handle is attached to the meter for carrying during survey. The handle also contains the manual trigger button.

Prior to the start of data acquisition, the meter must be nulled and the battery checked for nominal operating voltage. The battery test is conducted at the beginning of the survey and start of each day or when the voltage is thought to be low. With the range switch in the 1000 mS/m position and the battery test switch to BATT, a good battery should have a display of over -720 units. The battery is replaced if the display is below -720. After the battery check, the instrument is nulled in the inphase mode and then zeroed in the quadrature phase mode. Nulling in conducted at the beginning of the survey at a single reference point. For the present project, the reference point used to null the EM38 is located at N500/E520. Since the EM38 measures ground conductivity by inducing very small electrical eddy currents into the ground and measuring the magnetic field that these currents generate, it is important to null the larger primary signal produced by the transmitting coil so that the electronic circuitry is not overloaded by the primary signal. All metal objects must be removed from the operator prior to beginning the initial inphase nulling operation. The range switch is set to the 1000 mS/m position. The instrument is positioned at a height of 1.5 meters above the reference point in the vertical dipole position (upright). The mode toggle switch is set to the I/P position. The meter is nulled by first adjusting the I/P course knob and then the fine I/P knob until the display reads zero. The range switch is then set to the 100 mS/m position and the procedures are repeated. The meter is successfully nulled when the meter reads approximately zero (±10 mS/m) on the 100 mS/m setting at 1.5 meters above the ground. The instrument is then zeroed. The instrument zeroing is conducted at the beginning of the survey and checked three to four times throughout the day. Using the same reference point and with the instrument at a height of 1.5 meters above the ground, the mode toggle switch is set to the normal Q/P position. With instrument in the horizontal dipole position (flat) and the range switch set to 100 mS/m, adjust the Q/P Zero Control until the meter reads 50 mS/m. This value is referred to as **H**. Without changing the instrument height rotate the EM38 about its long axis to the vertical dipole position. The value in this position is referred to as **V**. Regardless of any layering in the earth at a height of 1.5 meters, **V** should equal twice **H** (**V=2H**). If it doesn't, then the Q/P Zero is not set correctly. To adjust the Q/P Zero, one needs to calculate the correlation **C** value that affects **V** and **H** equally (**C=V-2H**). With the meter in either the horizontal or vertical dipole position, the Q/P Zero Control is adjusted by the correlation value. Adjustment of the displayed value is made by turning the control in the direction of higher conductivity if the value is positive and lower conductivity if the value is negative. The vertical and horizontal dipole measurements are rechecked to insure that the instrument zero is set correctly. If not, the procedures are repeated until the instrument is correctly set. After the Q/P Zero is set, the instrument needs final inphase nulling before commencing the survey. The final inphase nulling is carried out as previously mentioned for the initial inphase nulling procedure, except the EM38 is placed on the ground in the vertical dipole position.

HISTORIC IOWA FAMILY CEMETERY

The meter was connected to the Omnidata DL720 Polycorder (Geonics 1998) for digital data acquisition after the nulling and zeroing procedures have been completed. Data were collected in the continuous mode and stored in the Polycorder's memory. The data stored in the Polycorder were downloaded into the laptop computer at the end of the day for processing in the Geonics DAT38 software (Geonics 1997). The polycorder contains the EM38 operating program along with BATTERY, CREATEDIR, FILE DIR, and DEMO programs. The EM38 program acquires and records the data from the EM38 ground conductivity meter. It also record field survey information (i.e., survey line number, starting station, survey increment, recorded phase component, survey comments, etc.). It is important to note that data files can not be appended. So if a mistake is made in the file setup or during the survey, or if the polycorder is turned off, one can not use the same file. A new one, including file name, must be created. The BATTERY program is used to check the voltage status of the polycorder's rechargeable battery pack. FILEDIR has to be present for the EM38 program to run. The CREATEDIR program creates a directory file FILEDIR if it is deleted by mistake or if the data files are erased manually. The DEMO program is used to examine the voltage output of any analog channel in the Polycorder. With the polycorder connected to the EM38 and the EM38 on and in the Q/P mode, the polycorder is turned on. At the mode prompt, 0 (zero) is selected to initiate the polycorder program setup. The EM38 program is then selected and executed. The polycorder prompt requires confirmation of the Polycorder clock setting. The digital instrument type is selected. The operator is then requested to provide a file name. The file name can be up to 8 alphanumeric characters in length. The Polycorder creates two files with this name, a header file and a data file. The operator is then prompted for the GPS option (global positioning system), which is answered with no. The operator then selects the survey phase type (Q for quadrature or conductivity; I for inphase or susceptibility; or B for both), the mode (V for vertical dipole; H for horizontal dipole; or B for both), and the number of orientations (1 or 2; can be in 0 and 90 degree rotation about the common axis or at two different heights about the ground). For the present survey, Q was selected for the survey phase type. V was selected for the vertical dipole position, and 1 was selected of the number of orientations. The operator can provide his or her name and additional comments in the operator and comment fields. The polycorder can be set to the automatic data collection mode or to the manual mode. The automatic collection mode was selected. The polycorder then prompts for the time interval in seconds between data readings which was set at 0.5 seconds. The polycorder then prompts the operator for the line number, line direction, start station, and increment in the positive or negative direction. After all the information requested for the file setup has been completed, EM38 program provides the ready prompt after which the operator presses the enter key to start the logging. From that point on, the data is automatically logged until the end of the line is reached. The enter key is pressed at the end of the line to stop further data collection. The line "L" key is pressed to end the collection of data along the traverse line. The EM38 program then prompts for the new survey line number, direction, start station, and increment. All prompts must be answered before the operator starts the next line. Upon completion of the grid, the file is closed with the end option, and the polycorder is returned to file setup routine.

The ground conductivity survey was designed to collect 4 samples per meter along 0.5-meter traverses or 8 data values per square meter. The data were collected in a parallel fashion with the surveyor returning to the starting side of the grid and maintaining the same direction of travel for each traverse across the grid. A total of 3,321 data values were collected over the grid. With four samples per meter and one-half meter traverses in the parallel mode, it took approximately 20 minutes to complete a 20-m by 20-m grid. The data were downloaded to a laptop computer for processing in Geonics DAT38RT software. It took approximately 10 minutes to download the data from the complete 20-m by 20-m grid unit. DAT38RT created a header and data file for the data collected. These files were converted to a *.g38 file and then converted to SUFER file format for further processing on the laptop computer. The data may then be viewed in the field for any operational errors before the data is deleted from the polycorder.

Ground-penetrating Radar Survey Methodology

The Geophysical Survey Systems, Inc. (GSSI), TerraSIRch SIR System-3000 ground-penetrating radar (gpr) system (Figure 16) is used for the Iowa Campbell family cemetery project. The instrument is operated by MWAC archeologist Steven L. DeVore. The gpr system consists of the digital control unit (DC-3000), a 400 mHz ground coupled antenna (Model 5103), and the GSSI Model 623 survey cart with survey wheel for mounting the antenna and control unit (GSSI 2003a). System hardware contains a 512 mb compact flash memory card as its internal memory. The digital control unit accepts industry standard compact flash memory card up to 2 gb. The processor is a 32-bit Intel StrongArm PISC 206 mHz processor with enhanced 8.4" TFT display, 800 x 600 resolution, and 64k colors. The processor also produces linescan and O-scope displays. The gpr system uses one channel. The Model 5103 antenna operates at a nominal frequency of 400 mHz. The 400 mHz antenna has a depth of view of approximately 4 m assuming a ground dielectric constant of 5 with a range of 50 ns, 512 samples per scan, 16 bit resolution; 5 gain points, 100 mHz vertical high pass filter, 800 mHz vertical low pass filter, 64 scans per second, and 100 kHz transmit rate.

The SIR 3000 control unit was placed on the survey cart and connected to the antenna. The odometer survey wheel attached to the frame of the cart was also connected to the antenna by a small cable. As the cart was moved along on the ground the cart's right rear wheel turned the odometer wheel and the revolutions were translated into distance along the traverse line.

The LCD display on the SIR 3000 control unit provides immediate visual display of the gpr profile data as it is collected. Once the battery is installed into the SIR 3000, the unit boots up (GSSI 2003a:6). The initial screen displays the words TerraSIRch SIR-3000 in the middle of the screen. At the bottom of the screen, there is a set of six buttons positioned over the function keys. The mark button on the right side of the unit allows one to change between English and Metric units of measurement. This is set to metric. Selection of the function key below the TerraSIRch button display initiates the gpr data collection program.

A set of three screens is displayed with the left window containing the parameter selection tree, the middle window displaying the profile data in linescan format, and the right window showing a single scan in an oscilloscope trace depiction. The command bar at the bottom of the screen allows one to toggle between functions.

Initially, the System menu is opened on the parameter tree. The System menu contains the choices for the system setup. Under the System menu is the submenus for Units, Setup, Path, Backlight, Date/Time, Battery, and Version (GSSI 2003a:9-10). Metric units are selected for depth and distance. Time is selected for Vscale (vertical scale) display. Setup contains factory setups for the various antenna configurations, which can not be overwritten, and 16 user setups. The factory default for the 400 mHz antenna (400met) is selected and saved in one of the user setups. The Path submenu allows for the creation of separate folders for the gpr profile files. The Backlight submenu controls the LCD screen brightness. The Date/Time submenu allows one to set the system's internal clock to the correct date and time. The Battery selection provides a check on the remaining charge on the battery in percent of total charge. The Version informs one of the current version of TerraSIRch operating software.

The next step is to configure the SIR-3000 for data collection. The Collect menu is opened (GSSI 2003a:11-16). There are five submenus that need to be configured. The Radar submenu contains the information concerning the antenna frequency selection (400 mHz), the antenna transmit rate (100 kHz), the mode of data collection (distance for survey wheel with value of -1583 for survey cart system), and activation of gps capability (off). The Scan submenu allows for the selection of the number of individual data points or samples collected per scan (512 samples/scan), the data format (16-bit), the time window range (100 ns which is two-way travel time), the Diel or dielectric constant value of the material (generally left at the factory default of 8). The dielectric constant is a measure of the capability of a material to store and pass a charge when an electromagnetic field is applied to the material (Sheriff 1973:51). It reflects the velocity of the radar wave that can pass through a given material. The scan Rate is the number of scans that the SIR-3000 records in its RAM memory per second (100 with a T-RATE of 100 kHz and use of a survey wheel). The scans per unit of horizontal distance is set to 50 scans per meter. This equals 1 scan every 2 cm. The Gain submenu allows for the artificial enhancement of the radar signal in order to offset the natural effects of signal attenuation. During the survey, the Gain is set to the manual mode. The auto mode is used to re-initialize and adjust the antenna's gain values during the initial reconnaissance of the survey area in order to keep from clipping the data. Five separate values are available for the evenly spaced gain points ranging from 1 to 5 (3 is the factory default). The individual gain values can be manipulated are left at the factory default values. The Position submenu controls the position of the time zero setting. Time zero is defined as the location of the beginning of the transmit pulse. During a survey, the Position is set to the manual mode. The offset represents the time lag from the initiation of the radar pulse in the SIR-300 control unit to the transmission of the pulse from the antenna dipole. This is generally represented by the time value where the direct coupling of the signal between the transmitting and receiving antennas. The Surface submenu allows for the display option of setting time zero at the first reflected target or the ground surface. The gpr system was moved around the grid prior to the start of the survey to adjust the gain. If a location caused the trace wave to go off the screen, the gain was set to auto and then back to manual. The position was set to the manual mode with the offset value at the factory default and the surface display option set to zero. The final submenu allows for the manipulation of data collection filters to remove interference and smooth noise. These include low and high pass filters, stacking, and background noise removal filters. These are left at their factor defaults for the specific antenna in use.

The final step prior to the start of the data collection is to return to the System menu and select the path for the profile data. In the Path submenu, a new folder can be named. The folder will contain the radar profile collected in the grid. Once the new path is selected, it is saved in one of the user defined setups. With the setup completed, the run/stop button at the bottom of the display screen is selected and the collect mode is initiated. The gpr unit is moved across the grid and at the end of the traverse, the collect button is selected and data acquisition is halted. The gpr unit is placed at the start of the next line before saving the profile. Once the profile line is saved, the gpr unit is ready to collect the next profile line. The gpr data are recorded on a 512 mb compact flash card and transferred to a lap-top computer at the end of the survey.

The gpr profiles were collected along 0.5 meter traverses beginning in the southwest corner of the grid. The data were collected in the parallel or unidirectional mode with the operator returning to the same side of the grid to start the next traverse line. The gpr profiles were collected first in the North or y direction and then in the East or x direction. A total of 82 radar profiles were collected across the cemetery survey area with 41 profiles oriented along the North or y traverses and 41 profiles along the East or x traverse lines. With one-half meter traverses in the parallel mode, it took approximately 25 minutes to complete a 20m by 20 m grid in one direction. The tow data folders containing the profile line data were transferred to the laptop computer via the 512 mb compact flash card used to record the data in the TeraSIRch SIR-3000.

Ground-penetrating surveys generally represent a trade-off between depth of detection and detail. Lower frequency antennae permit detection of features at greater depths but they cannot resolve objects or strata that are as small as those detectable by higher frequency antennas. Actual maximum depth of detection also depends upon the electrical properties of the soil. If one has an open excavation, one can place a steel rod in the excavation wall at a known depth and use the observed radar reflection to calibrate the radar charts. When it is not possible to place a target at a known depth, one can use values from comparable soils. Reasonable estimates of the velocity of the radar signal in the site's soil can be achieved by this method. Using one of the hyperbolas on a radargram profile (Goodman 2004:76), the velocity was calculated to be approximately 6.3 cm per ns. For a time slice between 5 and 15 ns with the center at 10 ns (two way travel time), the approximate depth to the center of the gpr slice would be 31.5 cm. With a 100 ns window open, the total depth displayed was approximately 3.15 meters; however, due to noise and signal attenuation, the ability of the radar to detect buried cultural and natural features extended to less than 1.5 meters.

10. DATA PROCESSING AND INTERPRETATION

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme 2001:365; Music 1995; Neubauer et al. 1996). Drs. Roger Walker and Lewis Somers (Geoscan Research 2003) provide strategies, alternatives, and case studies on the use of several processing routines commonly used with the Geoscan Research instruments in the GEOPLOT software manual. Dr. Kenneth Kvamme (2001:365) provides a series of common steps used in computer processing of geophysical data:

> ***Concatenation*** *of the data from individual survey grids into a single composite matrix;*
>
> ***Clipping and despiking*** *of extreme values (that may result, for example, from introduced pieces of iron in magnetic data);*
>
> ***Edge matching*** *of data values in adjacent grids through balancing of brightness and contrast (i.e., means and standard deviations);*
>
> ***Filterin****g to emphasize high-frequency changes and smooth statistical noise in the data;*
>
> ***Contrast enhancement*** *through saturation of high and low values or histogram modification; and*
>
> ***Interpolation*** *to improve image continuity and interpretation.*

It is also important to understand the reasons for data processing and display (Gaffney et al. 1991:11). They enhance the analyst's ability to interpret the relatively huge data sets collected during the geophysical survey. The type of display can help the geophysical investigator present his interpretation of the data to the archeologist who will ultimately use the information to plan excavations or determine the archeological significance of the site from the geophysical data.

Processing Magnetic Data

Due to the limited memory capacity and changes in the instrument setup of the FM36 fluxgate gradiometer, the data were downloaded into a laptop computer after the completion of two grid units at the site. On the laptop computer, the GEOPLOT software was initialized and the download data routine was selected from the file menu (Geoscan Research 2003:4/1-29). The default input template was then selected. The selection of the gradiometer and FM36 were then made. The grid input template was displayed. For the gradiometer survey, the survey information was entered under the general category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 2). The next step required entering the grid name for downloading data from the FM36. In the grid name for downloading screen, the file name for the grid unit was entered into the laptop computer. The grid file contained the magnetic raw data obtained during the survey. The file name for the grid unit included the grid name, the letter “g” for the gradiometer survey type, and the grid number (i.e., iag1). The download instructions screen was displayed after the file names were checked for duplicate names in the laptop computer and entered into the laptop computer. The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The DUMP key on the FM36 keyboard was depressed and the download process was initiated. Downloading the magnetic data from a typical 20-m by 20-m grid unit at 8 samples/m and 0.5 m traverses required approximately 13 minutes to complete the download process. The FM36 was then switched off and disconnected from the laptop computer. The grid files were reviewed in the shade plot display under the graphics menu in the Geoscan Research GEOPLOT processing software (Geoscan Research 2003) for data transfer or survey errors. If no data transfer errors were observed, a composite of the data file(s) was created for further data processing. Generally, while in the field, the composite file was processed with the zero mean traverse routine and viewed on the laptop computer before the memory in the gradiometer was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. Grids actually consist of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the magnetic data, the grid files from the survey must be combined into a composite file. To construct a composite file containing all of the grid files collected at a site, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2003:3/15-21). The master grid file names screen is displayed and the grid files are entered into the mesh template by the grid position in the overall survey of the site. The mesh template defines how the grids fit adjacent to one another within the surveyed area. The grid files are entered into the mesh cells according to their position beginning in the upper left hand corner of the surveyed area. For grids that are in the line of travel or traverse direction (X direction on the template), the grid names are placed from left to right in the mesh cells on the screen display. Grids that are perpendicular to the traverse direction (Y direction on the template) are placed from the top cell to the bottom cell of the mesh template. The GEOPLOT survey directions have the display the line of travel along the traverse on the X axis and the movement across the grid along the Y axis. This format is also followed for the creation of the composite file. Once the grid files have been placed in the correct position in the mesh template, the composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file name included the field acronym for the site (ia) and the letter “g” for the gradiometer survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite file for the magnetic data collected at the site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2003:5/2-3). In order to continue to analyze the data, the grid or composite files must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window with clip between a minimum value of -3, maximum value of 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Inspection of the background should show the data as bipolar and centered on zero. There should be a broad range in the archeological anomalies with weak anomalies less than 1 nT, typical 1 nT to 20 nT anomalies, strong anomalies greater than 20 nT. If the anomalies are weak then reset the clip plotting parameter to a minimum of -2, a maximum of 2, and units to absolute. Then one should identify weak and strong ferrous anomalies, which often represent modern intrusions into the site such as localized surface iron trash, wire fences, iron dumps, pipelines, and utility lines. Geological trends in the data set should also be identified. Since gradiometers provide inherent high pass filtering, broad scale geological trends are already removed from the data set. If such trends appear to exist, there may be changes in the topsoil thickness, natural depressions, igneous dikes or other geomorphological changes in the landscape. Final step prior to processing the data is to identify any defects in the data. These can range from periodic errors appearing as linear bands perpendicular to the traverse direction, slope errors appearing as shifts in the background between the first and last traverses, grid edge mismatches where discontinuities exist between grids, traverse striping consisting of alternating stripes in the traverse direction which most commonly occurs during zigzag or bi-directional surveys, and stager errors resulting in the displacement of a feature on alternate traverses (Geoscan Research 2003:Reference Card 3).

Initially, the spectrum function (Geoscan Research 2003:6/87-95) was applied to the data. The spectrum function provided analysis of the frequency spectrum of the data, splitting it into amplitude, phase, real, or imaginary components. The amplitude component was selected for the analysis to identify any periodic defects. These defects may have been the effects of cultivation (e.g., plow marks, ridge and furrow) or operator induced defects during data acquisition). It operated over the entire site data set. The spike tolerance was left in the default on position. This had the effect of reducing any broad spectral energy from noise spikes in the data set. No periodic defects were noted in the data set.

The magnetic data were “cleaned up” using the zero mean traverse algorithm (Geoscan Research 2003:6/107-115). This algorithm was used to set the background mean of each traverse within a grid to zero, which removed any stripping effects resulting from “scan to scan instrument and operator bias defects” (Jones and Maki 2002:16). It also was useful in removing grid edge discontinuities between multiple grids. The algorithm utilized the least mean square straight line fit and removal default setting on over the entire composite data set. The letter “z” was added to file name when the composite file was saved to indicate that the zero mean traverse routine had been applied to the data.

The statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire magnetic data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The magnetic data ranged from -203.86 to 206.15 nT with a mean of -1.821 and a standard deviation of 27.842. The relatively low mean represents the affect of the large amount of historic iron material present at the project location. Generally, the mean should approximate zero, which represents the background magnetic.

The data set is interpolated to produce a uniform and evenly spaced data matrix (Geoscan Research 2003:6/53-56). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is an 8 x 2 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinx/x or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements is expanded using the sinx/x method. This yields a 8 x 4 data matrix. In the X direction, the number of data measurements are shrunk using the sinx/x method. This yields a 4 x 4 matrix. The letter “i” was added to file name when the composite file was saved to indicate that the interpolation routine had been applied to the data.

The low pass filter was then used to remove high-frequency, small scale spatial details over the entire data set (Geoscan Research 2003:6/57-60). It was also used to smooth the data and to enhance larger weak anomalies. The function scanned the data set with a gaussian weighted, rectangular window set to the default values for the X radius of 1 unit and the Y radius of 1 unit. The letter “l” was added to file name when the composite file was saved to indicate that the low pass filter routine had been applied to the data.

The composite data files were then exported to separate xyz files for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2003:5/4-7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension “dat” was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file names remained the same for all the files. The files were the exported to “expdata” folder in GEOPLOT. The files are then transferred to an appropriately named site folder in the SURFER 8 contouring and 3d surface mapping program’s project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The open file command is selected to open the zero mean traverse, interpolate, and low pass filter processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/4** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/4** to provide the correct traverse interval position for the data. The value 500 was added to both the North and East coordinate values in order to express the results into the mapped site coordinate system. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. Due to the large ranges of values, the data are also clipped to 20 for data values greater than 20 nT and to -20 for data values less than -20 nT. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 2002). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C.

The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of lines field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For the present project, the data columns consist of 500 to 520 in the North or Y direction, 500 to 520 in the East or X direction with the X-spacing of 0.25 and the Y-spacing of 0.25. The Kriging gridding method was selected for processing the data. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name. Due to the presence of a small unsurveyed area in the northwest corner of the grid (10 x 9 m), a blanking file was constructed and applied to the grid file. The blanking file contains the X and Y coordinates used to outline the blanked portion of the grid, as well as, the number of parameter points and whether the blanking operation is located on the interior of the parameter points or on the exterior of these points. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated (Figure 17). The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. The image map is created by selecting the image map operation from the map menu and opening the grid file. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a gradulated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another way to represent geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. Contour maps are useful in determining the strength of the magnetic anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the magnetic data.

Processing Soil Resistivity Data

The soil resistance data were downloaded into a laptop computer after the completion of survey at each site. On the laptop computer, the GEOPLOT software was initialized and the download data routine was selected from the file menu (Geoscan Research 2003:4/1-4/27). The default input template was then selected. The selection of the resistance (instrument type) and RM15 (instrument) was made. The grid input template was displayed. For the resistance survey, the survey information was entered under the general category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 6). The next step required entering the grid name(s) for downloading data from the RM15. In the grid names for downloading screen, the file name for the grid unit was entered into the laptop computer. The grid file contained the resistance raw data obtained during the survey. The file name for the grid unit included the site name identifier (i.e., ia), followed by the letter "r" for the survey type (resistance), and ended with the number "1." The download instructions screen was displayed after the file name was checked for duplicate names in the laptop computer and entered into the laptop computer. The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The dump key on the RM15 keyboard was depressed and the download process was implemented. Downloading the resistance data from a typical 20-m by 20-m grid unit at 2 samples/m and 0.5 m traverses required approximately 5 minutes to complete the download process. The RM15 was then switched off and disconnected from the laptop computer. The grid file was reviewed in the shade plot under the graphics menu in the Geoscan Research GEOPLOT processing software (Geoscan Research 2003) for data transfer or survey errors. If no data transfer errors were observed, the memory in the resistance meter was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. The grid data set actually consists of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

HISTORIC IOWA FAMILY CEMETERY

In order to process the resistance data, the grid file from the site must be combined into a composite file. To construct a composite file, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2003:3/15-18). The master grid file names screen is displayed and the grid file name is entered into the mesh template. The grid data needs to be converted into a composite file. The composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file names included the field name for the site (i.e., ia), the letter "r" for the resistance survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite file for the resistance data collected at the site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2003:3/18-21). In order to continue to analyze the data, the grid or composite files must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window to clip with minimum value of -3, maximum value or 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to Standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data are displayed in a shade plot or trace plot. The clip parameters are set to a minimum of -3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing resistance data from a single twin probe separation distance begins with the inspection of the data changes on the background signal. These data changes are superimposed on the local geology.

There should be a broad range in the archeological anomalies with weak anomalies or archeological features having less than 5 % change, typical anomalies with 5% to 20% change, and strong anomalies with greater than 20% change in resistance values. The data are checked for noise spikes including low level spikes which create a noisy appearance in the data displays, and extremely high anomalous readings which may be as large as ±1000% about the mean. The large background, which underlies the archeology, may have a regional gradient that is dependent on the local geology, drainage, or topography. The regional gradient may change from virtually none to over 300% across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2003:Reference Card 2).

The statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire resistance data set. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The resistance data ranged from 17.65 to 78.25 ohms with a mean of 25.582 ohms and a standard deviation of 4.040 ohms.

The noise spikes are removed with the despike function (Geoscan Research 2003:6/35-39). The function locates and removes random, spurious measurements present in the resistance data. The despike parameters are left in the default settings with both the x radius and y radius set to 1, the threshold set to 3.0 standard deviations, and the spike replacement set to the mean. The mean indicates that the noise spike value will be replaced by the window mean value obtained from the surrounding values. The letter “d” was added to file name when the composite file was saved to indicate that the dispiking routine had been applied to the data.

A high pass filter (Geoscan Research 2003:6/4952) was used to remove the low frequency, large scale spatial detail (i.e., the slowly changing geological “background” response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the x radius and y radius. The weighting uses the default Gaussian setting. The resulting data is bipolar with the mean centered on zero. The original mean may be restored by using the add function (Geoscan Research 2003:6/11-13). The letter “h” was added to file name when the composite file was saved to indicate that the high pass filter routine had been applied to the data.

The composite data file was then exported to separate disk file in a different file format for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2003:5/4-5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file name remained the same for the data file. The file was the exported to "EXPDATA" folder in GEOPLOT. The file was then transferred to an appropriately named site folder in the SURFER 8 contouring and 3d surface mapping program's project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The Open File command is selected to open the low pass filter and zero mean traverse processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/2** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/2** to provide the correct traverse interval position for the data. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 2002). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of lines field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For Site 14BN111, the data columns consist of 0 to 20 in the North or Y direction, 0 to 20 in the East or X direction with the X-spacing of 0.5 and the Y-spacing of 0.5. The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The spline smoothing operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated. The image map is a rastor representation of the grid data (Figure 18). Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. Selecting the image map operation from the map menu and opening the grid file creates the image map. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration.

Processing Vertical Electrical Sounding Data

The field measurements were then averaged for each probe spacing along the two offset directions. The resulting average resistance value was used to calculate the resulting apparent resistivity using the formula: $\boldsymbol{\rho_a = 2\pi a r}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **a** is the electrode spacing, and **r** is the measured resistance at each electrode separation. The probe spacing and apparent resistivity values were entered into the spreadsheet in the IX1D modeling software package (Interplex 2002). The first step in the IX1D program was to create a new sounding file by selecting the DC Resistivity Sounding popup under Sounding under New under File menu. The Wenner Array was selected under the Array Type in the New Sounding parameters window with Apparent Resistivity Data selected under the Type of Data. Clicking on the OK button at the bottom of the window opened the Apparent Resistivity Entry/Edit menu window. Entry window contained header information fields for the Data Set Name (Iowa), the Easting coordinate (E520), the Northing coordinate (N510), the elevation (499.6 m) and Azimuth (0.0) in degrees where zero is North. The spreadsheet beneath the header information fields contains the identification number for the probe spacing, the probe spacing value, and the apparent resistivity value. These values were entered form the processed data in the field notebook (Table). The OK button at the bottom of the screen was selected. The resulting apparent resistivity values in ohm-meters (Sheriff 1973:156) are plotted by electrode spacing. Under the Calculate menu, the Estimated Layered Model routine was selected. The forward model of the data was carried out using a 283 point adaptive linear filter (Anderson 1979; Davis et al. 1980). The model uses the probe spacings data and the apparent resistivity to generate a synthetic response. A four layer model was created for the approximate subsurface electrical layering (Figure 19). The graphic file and the data were saved as a IX1D binary file under the file name "iowa.IXR." The calculated model values were then hand-transferred to the GRAPHER 5 worksheet for the display of the electrical stratification plot (Golden Software 2003).

In GRAPHER 5, the model data is entered into a new worksheet under the File menu (Golden Software 2003:35-71). The worksheet is saved as a dat file. The next step is to create a 2D line graph under the Graph menu in GRAPHER 5 (Golden Software 2003:73-90). The Line Plot type is selected in the Select Plot Type window under the Graph Wizard button. The data columns used for the X and Y axis are identified. The depth below the surface is on the Y-axis and the resistivity value is located on the X-axis. Using this ling graph, an electrical stratigraphic block diagram is created by inserting rectangles in the data ranges. The rectangles are subsequently filled and labeled for the final presentation (Golden Software 2003:127-224).

Processing Ground Conductivity Data

The ground conductivity data were downloaded into a laptop computer after the completion of survey at each site. The Polycorder 720 was connected to the laptop computer via the serial port by means of a 25 pin to 9 pin converter cable (Geonics 1997:19). On the laptop computer, the DAT38RT software was initialized and the copy files from Polycorder 720 routine was selected from the menu (Geonics 1997:19-25). The default fast mode was selected for copying or downloading the data from the Polycorder to the laptop computer. The fast mode permits the rapid transfer of all data files in the Polycorder's dirfile directory. The header and data files for each site are also sequentially copied and then simultaneously converted to the DAT38RT file format. The dump program is selected on the Polycorder. The Ploycorder parameters for communications with the laptop are set to a baud rate of 9600 with 8 data bits, No parity and the Mating call equal to <CR>. At the ready prompt on the Polycorder, the Polycorder is driven by the laptop computer. Selecting the entry key on the laptop computer, the fast file copy from Polycorder 720 screen is displayed. The first prompt on the laptop computer asks for the Polycorder's file names. All is entered or the enter key is selected. The second prompt asks for the disk files in the Polycorder format. Two files are created for each site data file (i.e., the header file with H prefix plus file name and the data file with the D prefix plus file name). The third prompt identified the created file in DAT38 format. The Polycorder header and data files (i.e., the DL files) are converted into the DAT38 format with the file name and “G38” extension identifier). The serial port is set to com1. The copy files routine is selected from the menu on the laptop computer. The header file is transferred first followed by the data from each site file from the Polycorder to the laptop computer. Once the files have been transferred to the laptop computer, the next step is to create the data files. The enter data files routine is opened in the DAT38RT program (Geonics 1997:35-37). A list of entered survey files is displayed in the window. The DAT38 (*.g38) file is selected. The screen then displays the profile lines within the file (with Component/Mode/ Orientation). Information including the measured component (i.e., conductivity phase), mode (i.e., vertical), and orientation (i.e., 1) are listed next to the line numbers. All of the lines in the file are selected by pressing <ENTER>. The final stage in the preparation of the data files for processing is the creation of the surfer XYZ (*.dat) files in ASCII format. The write file for contour package subroutine is selected from the main DAT38RT menu (Geonics 1997:62-65). The surfer format is selected for the format of the created file. A file name is given to the finished file. The dipoles mode, instrument orientation, component, and survey geometry fields are left in the default values of vertical, 1, conductivity, and arbitrary respectively. The create file command is selected from the submenu. Messages and prompts are provided to enter the beginning and ending X and Y coordinates for each line in the survey grid file. All of the X and Y coordinates with the corresponding conductivity measurements are written to the *.dat file, a window displays the created data file. It can be examined without leaving the program. The file is saved in the DAT38RT folder in the laptop computer. The *.dat files from the survey are then transferred to SURFER 8.

In SURFER 8 (Golden Software 2002), the data file created in DAT38RT is opened through the open routine in the file menu. The data are presented in the worksheet display. The worksheet contains the East (X) coordinate in the A column, the North (Y) coordinate in the B column, and the data value (Z) in C column. In order to process the data in GEOPLOT (Geoscan Research 2003), the data values must be arranged in ascending order by sorting the X and Y values. All three columns are selected. The sort routine in the data menu is selected and the sort parameters are set with the Column B set for sorting first in ascending order and Column A set for sorting second in ascending order. The data are checked for the correct number of entries based on the number of traverses covered in the survey and by the number of sample intervals per traverses. The conductivity data collected from project contain 12,360 measurements taken over the 20 m by 20 m survey area (sample interval of 0.25 meters or 80 readings along the North axis and traverse interval of 0.5 meter or 41lines along the East axis of the grid). In order to import the data into GEOPLOT, one must make certain that the total number of data values equals the number of measurements taken in the grid unit. For the present survey, a total of 3,200 readings is needed (Note: The dummy value of 2047.5 is added at the correct spacing interval to complete the data matrix if needed.). The file is sorted in ascending order in with the X values sorted first and then the Y values sorted next to arrange the data in its correct orientation within the columns of the file’s worksheet. The X and Y values are deleted from the file leaving the Z or data values. The data file is saved in SURFER 8 and then copied to GEOPLOT’s impdata folder.

To process the data in GEOPLOT, the data is imported into GEOPLOT using the import data routine under the file menu. The default grid template is selected in the import data screen. The electromagnetic survey type is selected and the user defined category is selected as the instrument. The grid input template screen is displayed on the laptop computer. The ground conductivity survey information is entered under the general category, which contains the settings for the acquisition of the data and the instrumentation used to acquire the data (Table 3). The next step required entering the grid name(s) for importing. The import data screen is displayed after the grid input template parameters are entered. In the import data screen, the import file format is set to Z. The import file parameters are set to top-left reference corner for the start of the grid data acquisition point and the import dummy value equals 2047.5. Unlike the X or East and Y or North directions in the original conductivity data, the X and Y directions in GEOPLOT are reversed with X representing the North direction and Y representing the East direction. Under the import file names, the drive is set to the d drive, the extension is set to the “dat” file extension type, and directory path is set to d:\geoplot\impdata. The correct data file is selected from the list of import file names. The imported grid file is saved to the correct sitename directory. The data file name for the grid unit included the name identifier (i.e., cond). A notification window indicates the successful completion of the import routine. The grid data set actually consists of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the conductivity data, the grid file from the site must be combined into a composite file. To construct a composite file, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2003:5/2). The master grid file names screen is displayed and the grid file names are entered into the mesh template in the correct location and orientation. The grid file is converted into a single composite. The composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modification if necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file names included the site location acronym (i.e., ia for Iowa cemetery) and the letter “q” for the quadrature phase conductivity survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite file for the ground conductivity data collected at the site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2003:5/2-3). In order to continue to analyze the data, the grid or composite file must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window to clip with minimum value of -3, maximum value or 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data is displayed in a shade plot or trace plot. The clip parameters are set to a minimum of -3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing conductivity data begins with the inspection of the data changes on the background signal. These data changes are superimposed on the local geology. There should be a broad range in the archeological anomalies with weak anomalies or archeological features having less than 5 % change, typical anomalies with 5% to 20% change, and strong anomalies with greater than 20% change in conductivity values. The data are checked for noise spikes including low level spikes which create a noisy appearance in the data displays, and extremely high anomalous readings which may be as large as ±1000% about the mean. The large background, which underlies the archeology, may have a regional gradient that is dependent on the local geology, drainage, or topography. The regional gradient may change from virtually none to over 300% across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2003:Reference Card 2).

The statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire magnetic data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The original data ranged from -53.53 to 43.58 mS/m with a mean of 19.889 mS/m and a standard deviation of 8.815 mS/m.

The data set is interpolated to produce a uniform and evenly spaced data matrix (Geoscan Research 2003:6/53-56). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is a 4 x 2 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinX/X or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements is expanded using the sinX/X method. This yields a 4 x 4 data matrix. The letter “i” was added to file name when the composite file was saved to indicate that the interpolation routine had been applied to the data.

A high pass filter (Geoscan Research 2003:6/49-52) was used to remove the low frequency, large scale spatial detail (i.e., the slowly changing geological “background” response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the X radius and Y radius. The weighting uses the default gaussian setting. The resulting data is bipolar with the mean centered on zero. The original mean may be restored by using the add function (Geoscan Research 2003:6/11-13). The letter “h” was added to file name when the composite file was saved to indicate that the high pass filter routine had been applied to the data.

The composite data were then exported to separate disk file in a data file format for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2003:5/4-7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension “dat” was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file names remained the same for all the files. The files were the exported to “expdata” folder in GEOPLOT. The files are then transferred to an appropriately named site folder (i.e., iowa) in the SURFER 8 contouring and 3d surface mapping program’s project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The Open File command is selected to open the zero mean traverse, edge match, interpolate, high pass filter processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/4** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/4 t**o provide the correct traverse interval position for the high pass filtered data. A value of 500 was added to both the North and East coordinate values. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 2002). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of line field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. The data columns consist of 500 to 520 in the North or Y direction, 500 to 520 in the East or X direction with the X-spacing of 0.25 and the Y-spacing of 0.25. The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The spline smoothing operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name. Due to the presence of a small unsurveyed area in the northwest corner of the grid (10 x 9 m), a blanking file was constructed and applied to the grid file. The blanking file contains the X and Y coordinates used to outline the blanked portion of the grid, as well as, the number of parameter points and whether the blanking operation is located on the interior of the parameter points or on the exterior of these points. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated (Figure 20). The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. Selecting the image map operation from the map menu and opening the grid file creates the image map. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. Contour maps are useful in determining the equal strength of the resistance anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the magnetic data.

Processing Ground-penetrating Radar Data

The gpr radargram profile line data (Figure 21) is imported into GPR-SLICE (Goodman 2004) for processing. The first step in GPR-SLICE is to create a new survey name in the files menu. The 16-bit GSSI radargrams are converted to 8-bit data for further processing under the filter menu. During the conversion process, the signal may be enhanced by applying gain to the radargrams. Once the conversion process is completed, the next step is to create the info file for the project. The number of profiles are entered (41 profiles collected at 0.5 meter traverses), along with the file identifier name, .dzt for GSSI radargrams, the profile naming increment of 1, the first radargram name (generally this is 1), the number of scans per meter (these profiles were collected at 50 scans per meter), the grid direction is set to the y-direction, unit per markers set to 1, a 100 ns time window, and 512 scans per sample. Selecting the create info file button completes the information file for the project. A separate info file is created for radar profiles collected in the x direction. The radargrams were collected in the parallel mode, there was no need to reverse every even line. The next step is to insert locational markers into the resample radargrams. The GSSI SIR 3000 and the artificial markers button are selected to apply markers based on the total number of scans in the radargram. The show markers button allows one to view an example of a radargram with the artificial markers in place. The next step is to create the time slices of the data (Conyers and Goodman 1997; Goodman et al. 1995). The program resamples the radargrams to a constant number of scans between the markers and collects the time slice information from the individual radargrams. The number of slices is set to 20 slices. The slice thickness is set to 50 to allow for adequate overlap between the slices. The offset value on the radargram where the first ground reflection occurs is viewed in the search 0 ns subroutine. This value is used to identify the first radargram sample at the ground surface. The end sample is 512. The offset value in entered in the samples to 0 ns box. The cut parameter is set to square amplitude with the cuts per mark set to 2. The slice/resample button is selected for processing the radargrams. The final step in the slice menu is to create the XYZ data file. The grid menu is entered next in the processing steps. The beginning and ending values for the x and y coordinates are entered. The grid cell size is set to 0.1 with an x search radius of 0.9 and a y search radius of 0.9. The blanking radius is set to 0.45, the data type is regular, the number of grids equal 20 for the number of slices, and the starting grid number is 1. The Kriging algorithm is utilized to estimate the interpolated data. The covariance and sill are set to 1.2 with the nugget set to 0.2 and a smoothing factor of 1.4. The start gridding button is selected and the gridded dataset is created. At this point in the grid menu, the y data set is combined with the x data set using the (grid#1)+a*(grid#2) routine. This overlays the two data sets. A low pass filter may be applied to the combined dataset to smooth noisy time slices in this menu. At this point, one may view the time sliced radar data in the pixel map menu (Figure 22). The gain may be readjusted for any time slice. This is done in the transforms submenu. The interpolations value is set to 5 and the interpolate grids routine is selected. The new interpolated grids are all normalized. The next step is to create the 3D dataset in the grid menu. The number of grids is now equal to 95 ((20-1)*5). The 3D database is created under the create 3D file routine. The 3D data may be displayed as a series of z slices in the creation of a 3D cube with a bitmap output for animating the 3D cube.

The data was also imported into the GSSI RADAN software (GSSI 2003b) for processing. The software allowed both radargram profile and plan-view (time slice) presentation of the data. Initially, a file containing the radargram profile line data was created in the source directory and an output directory was also selected. A few radargram profile line files were opened for evaluation of the data. The next step was to create a 3D project file in RADAN (GSSI 2003c:13). The grid dimensions from the survey were entered into the RADAN software, including the X/Y directions, the starting coordinates, the X and Y lengths, the number of profile lines, the line spacing, and the line order. Auto load files box was selected and the individual profile lines were combined into one continuous profile line file. The 3D cube button was then selected to run the project. The first step was to set the surface position to time zero at the top of the scan at the point where the ground coupling of the signal occurred. The selected 0-postion will give a more accurate depth calculation. Once the program runs through the entire file, the position setting in the header must also be changed to zero. The second processing step was to removal background noise from the profiles. The FIR filter routine was selected and run over the data. The final step in general processing was to run the migration procedure over the data set. This reduced or eliminated hyperbolic diffraction patterns by taking out the tails of the hyperbolas to more accurately represent the shape and location of the target. The final step was to image the 3D file. The 3D project can be viewed on multiple axes. The Z direction provides time/depth sliced of the profile data. X and Y direction slicing gives profile line views. Multiple axes can be set to display fence displays and cutout cubes. The views can be saved as screen views or as comma delimited files for display in SURFER 8.

In order to combine all of the separate grid block files into one composite site file and map, the individually processed 3D project files were combined into one super 3D file (GSSI 2003c:57-64). Using the add file button, the file parameter dialog is opened and the starting X and Y coordinated are entered into the file parameters. Upon selection of the first file, a block appears in the site grid map window showing the direction of the first radargram collected. The second file is entered in the survey area and added to the map. The final step was to image the Super 3D file. The Super 3D project can also be viewed on multiple axes. The views can be saved as screen views or as comma delimited files for display in SURFER 8 (Figure 23).

The slice option provides the means to specify the number and type of plots either in time slices or depth slices. Times slices are generally used since gpr systems record the time for the radar or radio waves to travel to a target and return to the gpr unit. Depth has to be calculated before it can be used. Depth depends on the velocity of the wave to the target and back. Depth is determined by the following equation: **D = V x T/2** where **D** is depth (meters), **V** is velocity (meters/nanosecond), and **T** is the two-way travel time (nanoseconds). Velocity of the radar wave is determined by the dielectric permittivity of the material (Conyers and Goodman 1997:31-35; Sheriff 1973:51). Other physical parameters that affect the transmission of the radar wave include the magnetic permeability and electrical conductivity of the material. Increases or decreases in these parameters may increase the velocity, slow it down, or attenuate it so there is no reflected signal. In most heterogeneous soils, the various soil layers have differing affects on the velocity of the radar wave. The velocity may be estimated using velocity charts of common materials (GSSI 2003a:49-50) or by identifying reflections in gpr profiles caused by buried objects, artifacts, or stratigraphic soil/sediment layers (Conyers and Goodman 1997:107-135). The depth used in this report was calculated using a value of ca. 0.063 m/ns.

Interpretation – Magnetic Data

Interpretation of the magnetic data (Bevan 1998:24) from the project requires a description of the buried archeological feature of object (e.g., its material, shape, depth, size, and orientation). The magnetic anomaly represents a local disturbance in the earth's magnetic field caused by a local change in the magnetic contract between buried archeological features, objects, and the surrounding soil matrix. Local increases or decreases over a very broad uniform magnetic surface would exhibit locally positive or negative anomalies (Breiner 1973:17). Magnetic anomalies tend to be highly variable in shape and amplitude. They are generally asymmetrical in nature due to the combined affects from several sources. To complicate matters further, a given anomaly may be produced from an infinite number of possible sources. Depth between the magnetometer and the magnetic source material also affect the shape of the apparent anomaly (Breiner 1973:18). As the distance between the magnetic sensor on the magnetometer and the source material increases, the expression of the anomaly becomes broader. Anomaly shape and amplitude are also affected by the relative amounts of permanent and induced magnetization, the direction of the magnetic field, and the amount of magnetic minerals (e.g., magnetite) present in the source compared to the adjacent soil matrix. The shape (e.g., narrow or broad) and orientation of the source material also affects the anomaly signature. Anomalies are often identified in terms of various arrays of dipoles or monopoles (Breiner 1973:18-19). A magnetic object in made of magnetic poles (North or positive and South or negative). A simple dipole anomaly contains the pair of opposite poles that relatively close together. A monopole anomaly is simply one end of a dipole anomaly and may be either positive or negative depending on the orientation of the object. The other end is too far away to have an affect on the magnetic field.

Magnetic anomalies of archeological objects tend to be approximately circular in contour outline. The circular contours are caused by small size of the objects. The shape of the object is seldom revealed in the contoured data. The depth of the archaeological object can be estimated by half-width rule procedure (Bevan 1998:23-24; Breiner 1973:31; Hinze 1990; Milsom 2003:67-70; Telford et al. 1990:87). The approximations are based on a model of a steel sphere with a mass of 1 kg buried at a depth of 1.0 m below the surface with the magnetic measurements made at an elevation of 0.3 m above the ground. The depth of a magnetic object is determined by the location of the contour value at half the distance between the peak positive value of the anomaly and the background value. With the fluxgate gradiometer, the contour value is half the peak value since the background value is approximately zero. The diameter of this contour (Bevan 1998:Fig. B26) is measured and used in the depth formula where **depth = diameter - 0.3 m** (Note: The constant of 0.3 m is the height of the bottom fluxgate sensor above the ground in the Geoscan Research FM36 were I carry the instrument during data acquisition. This value needs to be adjusted for each individual that carries the instrument.). The mass in kilograms of the object (Bevan 1998:24, Fig. B26) is estimated by the following formula**: mass = (peak value - background value) * (diameter)^3/60**. It is likely that the depth and mass estimates are too large rather than too small, since they are based on a compact spherical object made of iron. Archeological features are seldom compact but spread out in a line or lens. Both mass and depth estimates will be too large. The archaeological material may be composed of something other than iron such as fired earth or volcanic rock. Such materials are not usually distinguishable from the magnetic data collected during the survey (Bevan 1998:24). The depth and mass of features comprised of fired earth, like that found in kilns, fireplaces, or furnaces could be off by 100 times the mass of iron. If the archeological feature were comprised of bricks (e.g., brick wall, foundation, or chimney), estimates could be off by more than a 1000 times that of iron. The location of the center of the object can also be determined by drawing a line connecting the peak positive and peak negative values. The rule of thumb is that the center of the object is located approximately one third to one half of the way along the line from the peak positive value for the anomaly. One should also be cautious of geophysical anomalies that extend in the direction of the traverses since these may represent operator-induced errors.

The magnetic anomalies may be classified as three different types: linear, 2) dipole, and 3) monopole (Figure 24). The most noticeable in the data set are the three linear anomalies. A very strong linear anomaly occurs across the southwestern quadrant of the geophysical survey grid. It extends from N505/E500 to N506/E512. It then turns at a 90 degree angle and extends off of the geophysical grid at N520/E510. The northwest corner of the geophysical grid also contains a portion of a linear anomaly. These linear anomalies appear to represent the location of the ca. 1970s fence line. The southern portion of the linear anomaly is also represented a slight topographic high or berm. At the southwestern corner of the grid woven and barbed wire were noted in the ground and adhering to the large red maple tree, The wire extends at least fine more meters to the west of the grid. The most noticeable in the data set are the three linear anomalies. The second most common anomalies is the dipole anomaly with strong north poles and weak south poles. The third type is the monopole. Basically. a monopole anomaly is a dipole that lying on one of its ends. As a result, it can be either negative or positive depending on which pole is pointing upward. Several of the dipole and monopole anomalies are extremely strong. It is assumed that these strong magnetic anomalies represent historic and modern iron artifacts associated with agricultural equipment or debris left by relatives of the deceased. None of the dipole or monopole anomalies appear to be directly related to the cemetery markers.

Interpretation – Soil Resistance Data

Interpretation of the resistivity data results in the identification of lateral changes in the soil. Since the array parameters are kept constant through out the survey, the depth of penetration varies with changes in the subsurface layers. For each probe separation, the depth penetration is approximately the same as the distance between the current and potential probe for each separation distance. The resistance reading for each separation distance represents the average value for the hemispheric volume of soil with the same radius. If the soil below the survey area was uniform, the resistivity would be constant throughout the area. Resistances of the increasing volumes reflected by the increasing probe separation distances will change but is the resistivity which takes into account the changing depth remains approximately the same. Changes in soil characteristics (e.g., texture, structure, moisture, compactness, etc.) cause small and large areas to have different resistivities. Large general trends reflect changes in the site's geology whereas small changes may reflect archeological features.

There is a low value, linear resistance anomaly in the geophysical survey grid's southwestern quadrant (Figure 25). The anomaly is surrounded on both sides by relatively high resistance anomalies. The anomalies are located in the area of the berm associated with the ca. 1970s cemetery fence line. The low resistance anomaly also corresponds with the magnetic anomaly in the same location. The eastern side of the fence line is less apparent in the resistance data, although, there is a rather high value anomalous area near the three trees in the southeastern portion of the uncultivated tree grove. There is a relative high value, resistance anomaly in the northwest corner of the geophysical survey area. These may be associated with the two Campbell stone markers. A third relatively high value, resistance anomaly is adjacent to the marker base at the south end of the line of gravestones. It may represent a grave associated with the headstone base. There is a another anomalous area to the east of the marker. It is possible that this area is also associated with an unmarked grave. One other relatively high resistance anomalies is located between N508 and N510 and E508 and E509. Other relatively high resistance anomalous areas appear to be directly associated with the location of the trees in the survey area. It is possible that these anomalies, as well as the other resistance anomalies are directly associated with the trees rather that any marked or unmarked graves.

Interpretation - Vertical Electrical Sounding

The results of the modeling of the vertical electrical sounding data suggest a four-layer curve for the electrical stratification (Figure 26). The model indicates that the upper 0.06 meters have an apparent resistivity of 6.56 ohm-meters, the second 0.21 m thick layer measures 21.59 ohm-meters, the third 1.99 meter thick layer measures 11.43 ohm-meters and the bottom layer measures 6.91 ohm-meters. This model suggests a highly conductive clayey soil throughout the profile (Bevan 1998:8; McNiel 1980a:16; Telford et al. 1990:289-291). This may be due in part to recent rainstorms during the survey. The very resistive values in the clayey layer suggest that ground-penetrating radar may have problems with wave attenuation in this area due to the relatively high clay content of the soil. Using this as a basis for antenna selection, a 400 mHz antenna may provide adequate depth penetration from 1.5 to 2.0 meters and better resolution than antennas with low frequencies.

Interpretation – Ground Conductivity Data

Ground conductivity surveys are much faster to complete than the resistivity surveys but are also more complicated (Bevan 1998:29). Like the resistivity surveys, ground conductivity surveys detect changes in soil contracts. These soil contracts can result from natural conditions or from cultural activities (Bevan 1988:31-33). The conductivity anomalies represent the location and approximate shape of the features; however, different kinds of features can produce similar conductivity anomalies. They also detect metal objects. The resulting conductivity anomalies from buried metal (e.g., utility lines, pipes, and objects) may hide other features in immediate vicinity.

The conductivity data revealed portions of the fence lines noted in the magnetic and resistance survey data (Figure 27). The southern section of the ca. 1970s fence line is highly visible in the data set. The linear anomaly consist of a negative value conductivity low surrounded by conductivity highs. The negative values are the results of the over saturation of the receiving coil on the conductivity meter. The magnitude of the signal did not allow for the receiving coil to obtain reset itself before taking the next measurement. This is a common occurrence in a setting where conductive metals are present such as the buried woven fence wire. Along the eastern side of the probable fence line is a series of negative conductivity anomalies, which appear to be associated with remnants of the fence line. Three negative dipole conductivity anomalies in other portions of the survey grid appear to represent historic or modern iron/steel artifacts or materials. The conductivity of the interior portion of the tree grove is slightly lower than the conductivity values associated with the agricultural field.

Interpretation – Ground-penetrating Radar Data

Analysis and interpretation of the gpr data may be conducted in several different ways. The individual radargrams for each profile line may be analyzed for hyperbolic reflections. The radargrams may be combined and processed to provide planar time slices of the data. The time slices may also be combined to form 3D cubes of the gpr data. The majority of the gpr radargrams show numerous small reflections along any given profile. There does appear to be a correlationship between the some of the hyperbolic anomalies and fence line and associated berm in the southwestern quadrant of the survey grid. Some of the reflections also appear to be associated with roots from the trees in the grid area. However, due to the number and complexity of the hyperbolic reflections, there does not seem to be any direct correlation with the suspected grave locations next to the grave markers. Constructing the time slices for the geophysical survey area provides another way of looking at the gpr profile data. In the 20 slices constructed in GPR-SLICE (Goodman 2004; Goodman et al. 1995), the slices provide a planar view of the data at 9.8 ns intervals with an overlap of 4.7 ns. The tree grove is visible in the majority of time slices. It is especially noticeable in the upper four slices between 0 and 23.8 ns. The area of the tree grove is represented by higher amplitude reflection values. The fence line noted in the magnetic, resistance, and conductivity data sets is represented by a high value, linear amplitude reflection in the upper 19.1 ns. The time slice from 0 to 10 ns clearly illustrates the fence line, as well as a series of small dimension, high value amplitude reflections within the tree grove (Figure 28). A few of these are closely associated with the grave markers in the northern part of the cemetery area; however, others appear to be associated with tree roots based on their proximity to the trees within the survey area. Others may be associated is historic artifacts, prehistoric features, or unmarked graves. One final way of analyzing the data is to view different time slices from the 3D cube (Figure 29). The slices of the 3D cube associated with the 0 and 11.5 ns clearly show the fence line and the separation between the tree grove and the cultivated field. The view of the 27.9 ns slice of the 3D cube illustrated the disturbed condition of the tree grove. This disturbance appears and disappears in subsequent slices at 44.3, 60.7, and 91.9 ns. There also appears to be a very strong reflector in the southeast corner of the grid. This reflector is apparently associated with the strong magnetic anomaly and conductivity anomaly in this part of the geophysical survey area. It probably represents a large iron artifact associated with a piece of agricultural equipment.

11. CONCLUSIONS AND RECOMMENDATIONS

During March and April of 2004, the Midwest Archeological Center staff conducted geophysical investigations at the location of a historic Iowa (Campbell) family cemetery (Site 14BN111) in Brown County, Kansas. The project was conducted for the Iowa Tribe of Kansas and Nebraska. During the investigations, 400 square meters were surveyed with a Geoscan Research FM36 fluxgate gradiometer, a Geoscan RM15 resistance meter and PA5 twin probe array, a Geophysical Survey System Inc's TerraSIRch SIR-3000 ground-penetrating radar and 400 mHz antenna, and the Geonics EM38 ground conductivity meter.

The magnetic, resistance, and ground conductivity data collected at the cemetery site provided information of the physical properties (magnetic, resistance, and conductance, and ground-penetrating radar reflections) of the subsurface materials. Several small scale magnetic, conductivity, resistance, and ground-penetrating radar anomalies were identified. A series of linear magnetic, resistance, conductivity and ground-penetrating radar anomalies appear to represent the remnants of ca. 1970s cemetery fence. There area several high magnetic dipoles as well as a number of weak magnetic dipoles. The strong magnetic dipoles represent large concentrations of magnetic iron, probably of recent or modern agricultural origin. Weaker magnetic dipole and monopole anomalies may be associated with the prehistoric occupation at the site. Three negative conductivity anomalies correspond to strong magnetic anomalies indicating that they are composed of iron or steel. Other magnetic anomalies, not identified in the conductivity data, suggest the presence of fired materials, such as, burned earth, bricks, or prehistoric hearths.

Some geophysical anomalies identified during the investigations suggest the presence of a number of grave locations in the area encompassed by the tree grove within the surveyed area. Additional geophysical investigations utilizing downhole magnetic susceptibility equipment should be used at the cemetery due to the lack of definitive grave identifications. While these techniques represent extremely valuable methodologies for the initial investigation of cemeteries and grave locations, it may necessary to verify the identified anomalies as graves through some means of excavation. The question could be raised that the use of traditional excavation methods would have been more productive. It is true that the excavations would have allowed a better view of the subsurface materials; however, the amount of time and costs in labor and analysis to conduct such excavations would have been substantially higher to cover the same area investigated with the geophysical techniques. With an estimated cost of $3,000.00 per cubic meter of excavation, approximately three excavation units could have been placed on the site. The chances of placing one excavation over the top of unmarked graves in the cemetery would be astronomical. It would still not provide information on the location of multiple graves in the cemetery. Nor would it be feasible or even ethical to conduct such excavations in a known cemetery location without an impending treat of destruction to the cemetery. Preliminary shovel testing of the cemetery would also not provide substantial information on the location of the graves due to the lack of depth necessary to verify the presence of the graves. The use of an auger or posthole digger does not open up enough area to visually inspect the soil matrix for the boundaries of the grave. There is also high probability of damaging buried skeletal remains during the auguring operations. Overall, geophysical techniques provide the best initial evaluative phase of cemetery investigations where eminent destruction of the cemetery is not at issue. There may be a need for follow up archeological excavations to verify the geophysical anomalies identified during the survey efforts. These excavations can be more efficiently planned with the geophysical background data than through the use of traditional archeological excavation strategies in extremely cultural sensitive areas such as cemeteries.

This report has provided an analysis of the geophysical data collected during four days at the cemetery site (14BN111). Based on the evaluation of the geophysical anomalies, placement of a protective fence should be along the route of the 1970s fence line surrounding the tree grove. The remnants of the fence line are clearly visible in the geophysical data sets. Although the location is associated with a known cemetery with marked graves and unmarked, it is not recommended that any additional archeological investigations in the form of excavations be conducted at this site at the present time. Should there be any development on or near this site, then a research design needs to be developed for the implementation of archeological excavations to determine the nature and extent of the Campbell family cemetery.

Finally, refinement of the archeological and geophysical interpretation of the survey data is dependent on the feedback of the archeological investigations following geophysical survey (David 1995:30). Should additional archeological investigations occur at the site investigated during this project, the project archeologist is encouraged to share additional survey and excavation data with the geophysical investigators for incorporation into the investigators' accumulated experiences with archeological problems. Throughout the entire geophysical and archeological investigations, communication between the geophysicist and the archeologist is essential for successful completion of the archeological investigations. It is also important for the investigators to disseminate the results of the geophysical survey and archeological investigations to the general public, which in this case are the Iowa descendants of the Campbell and Dupuis families. It is through their support in funds and labor that we continue to make contributions to the application of geophysical techniques to the field of archeology.

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TABLES

Table 1. Aerial photographs of the Iowa Tribe of Kansas and Nebraska cemetery project area.

Date		Can	Frames	Scale	Film
National Archives and Records Administration					
7-17-54	RG 145	ON Can # 41010	YY-4N-129 & 130	1:20,000	240mm black and white panchromatic
Aerial Photography Field Office					
06-13-1959			YY-1W-61 & 62	1:20,000	240mm black and white panchromatic
09-8-1966			YY-2GG-79 & 80	1:20,000	240mm black and white panchromatic
10-18-1972	A40		20013-172-62 & 63	1:40,000	240mm black and white panchromatic
09-09-1981	USDA 40		20013-181-126 & 127	1:40,000	240mm black and white panchromatic
10-12-1991	NAPP		4232-165 & 166	1:40,000	240mm black and white panchromatic
04-10-1998	NAPP10		42-8910-19 & 20	1:40,000	240mm black and white panchromatic
03-30-1999	NAPP		11331-22 & 23	1:40,000	240mm black and white panchromatic

Table 2. Acquisition and instrumentation information for the gradiometer survey used in the grid input template.

GENERAL			
Acquisition	value	Instrumentation	value
Sitename	iowa	Survey Type	Gradiometer
Map Reference		Instrument	FM36
Dir. 1st Traverse	N	Units	nT
Grid Length (x)	20 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	20 m	Baud Rate	2400
Traverse Interval (y)	0.5 m	Averaging	Off
Traverse Mode	Parallel	Averaging Period	16

Table 3. Acquisition and instrumentation information for the resistance survey used in the grid input template.

GENERAL			
Acquisition	value	Instrumentation	value
Sitename	iowa	Survey Type	Resistance
Map Reference		Instrument	RM15
Dir. 1st Traverse	N	Units	Ohm
Grid Length (x)	20 m	Current Range	AUTO
Sample Interval (x)	0.5 m	Gain Range	AUTO
Grid Width (y)	20 m	Baud Rate	9600
Traverse Interval (y)	0.5 m	Frequency	137 Hz
Traverse Mode	Zig-zag	High Pass Filter	13 Hz
ACCESSORIES			
	Accessories	value	
	Array Hardware	PA5	
	Interface	AD1	
	Log Mode	Single	
	Configuration	Twin	
	Probe Spacing	0.5	

Table 4. Acquisition and instrumentation information for the ground conductivity survey used in the grid input template.

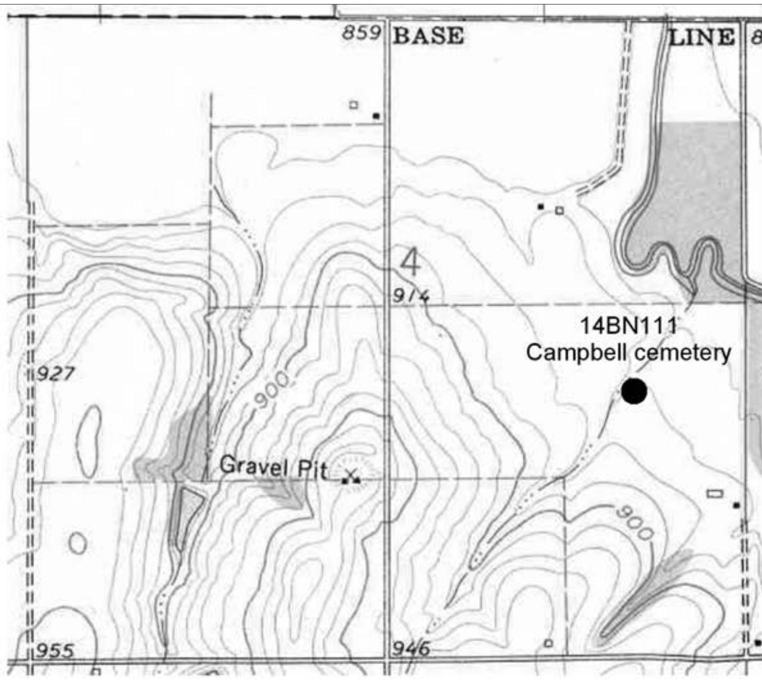
GENERAL			
Acquisition	Value	Instrumentation	Value
Sitename	iowa	Survey Type	EM
Map Reference		Instrument	EM38
Dir. 1st Traverse	N	Units	mS/m
Grid Length (x)	20 m		
Sample Interval (x)	0.25 m		
Grid Width (y)	20 m		
Traverse Interval (y)	0.5 m		
Traverse Mode	Parallel		

Table 5. Acquisition and instrumentation information for the ground-penetrating radar survey.

GENERAL			
Acquisition	value	Instrumentation	Value
File Nam	iowac	Survey Type	GPR
Number of Profile Lines	41	Instrument	GSSI TerraSIRch SIR 3000
Dir. 1st Traverse	N	Samples/scan	512
Grid Length (x)	20 m	Bits/sample	16
Scans/meter	50	Scans/second	100
Grid Width (y)	20 m	Meters/mark	2
Traverse Interval (y)	0.5 m	Diel Constant	8
Traverse Mode	Parallel	Antenna	400 mHz
ACCESSORIES			
	Channel(s)	1	
	Range Gain (dB)	-20.0 26.0 31.0 43.0	
	Position Correction	0 ns	
	Vertical IIR LP N = 1F	800 mHz	
	Vertical IIR HP N = 1F	100 mHz	
	Position (ns)	0	
	Range (ns)	100	

a) profiles collected in North or Y direction.

FIGURES



a) USGS topographic map of Campbell cemetery (14BN111) and vicinity, Brown County, Kansas (adapted from HIGHLAND, NW Quadrangle, Kansas, 7.5 minute series, 1961).

b) USGS aerial photograph of the Campbell cemetery and vicinity, Brown County, Kansas (122 km NE of Kansas City, Missouri, 12 October 1991).

Figure 1. Location of the geophysical project area within Section 4, Township 1 South, Range 18 East, Brown County, Kansas.

Figure 2. Tree grove containing Campbell cemetery in agricultural field (view to the northwest).

Figure 3. Location of the Iowa and Sac and Fox reservation lands in Kansas and Nebraska in 1854 (adapted from the Colton 1854 map of Kansas and Nebraska).

Figure 4. Location of the Iowa and the Sac and Fox reservations in Kansas and Nebraska and the present geophysical project area (adapted from the 1866 U.S. General Land Office map).

HISTORIC IOWA FAMILY CEMETERY

Figure 5. Brown County, Kansas, in 1880s showing Iowa Tribe Reservation in northeastern portion of the county and approximate location of the Campbell cemetery (adapted from Cutler 1883).

Figure 6. Campbell cemetery in tree grove with line of gravestones (view to the south).

Figure 7. Engraved headstones at the Campbell cemetery. a) Side views of the headstone of Harvey W. and George Campbell

Figure 7 (continued). b) View of the headstone of Murray A Campbell

Figure 7 (concluded). c) Side views of headstone of John and Francis Dupuis

Figure 8. Engraved footstones at the Campbell cemetery. a) J.D.

Figure 8 (continued). b) F.D.

Figure 8. (concluded). c) H.W.C.

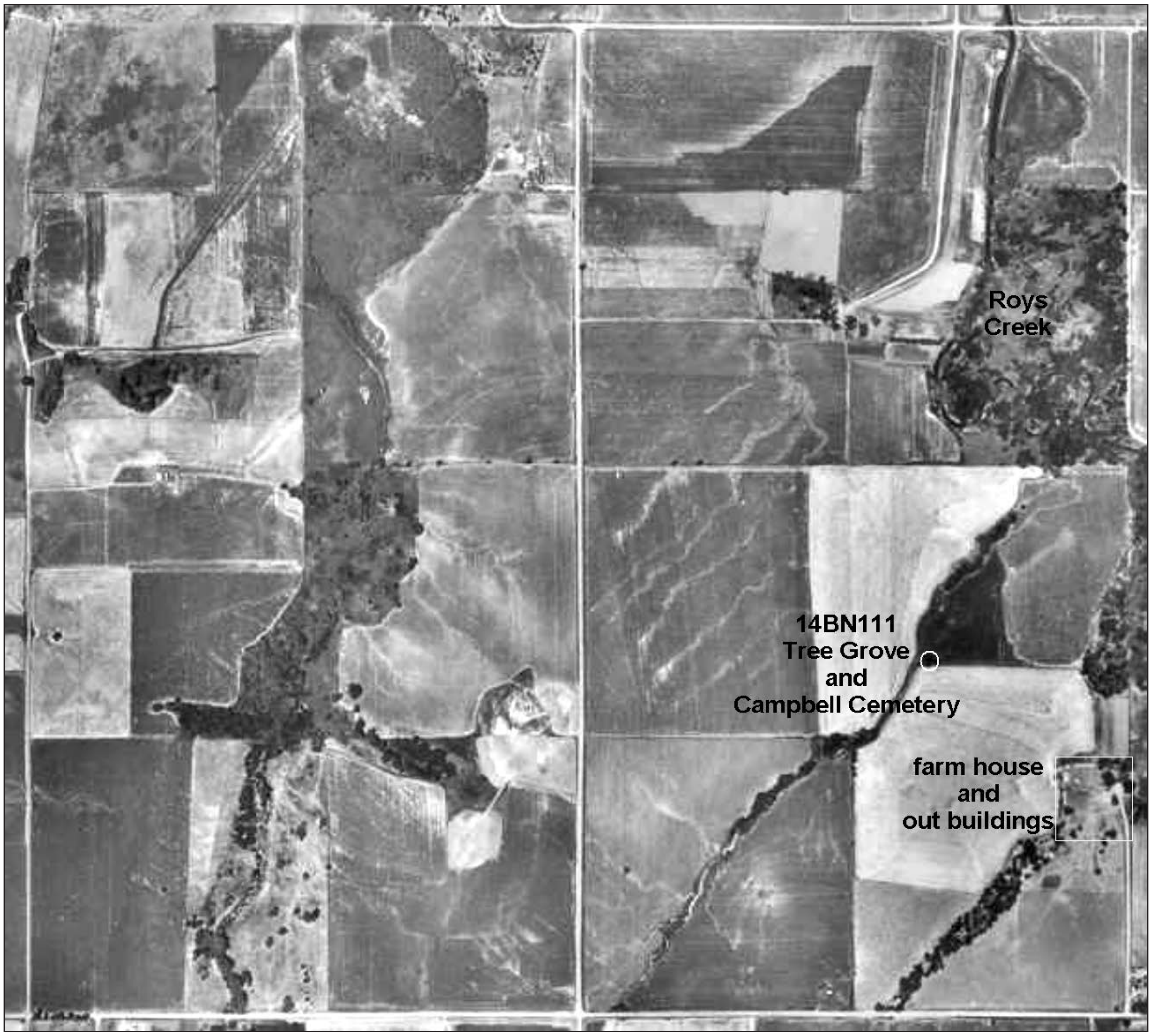


Figure 9. US Department of Agriculture Agricultural Stabilization and Conservation Service's 1954 aerial photograph of Section 4 showing the location of the Campbell cemetery and the farm buildings.

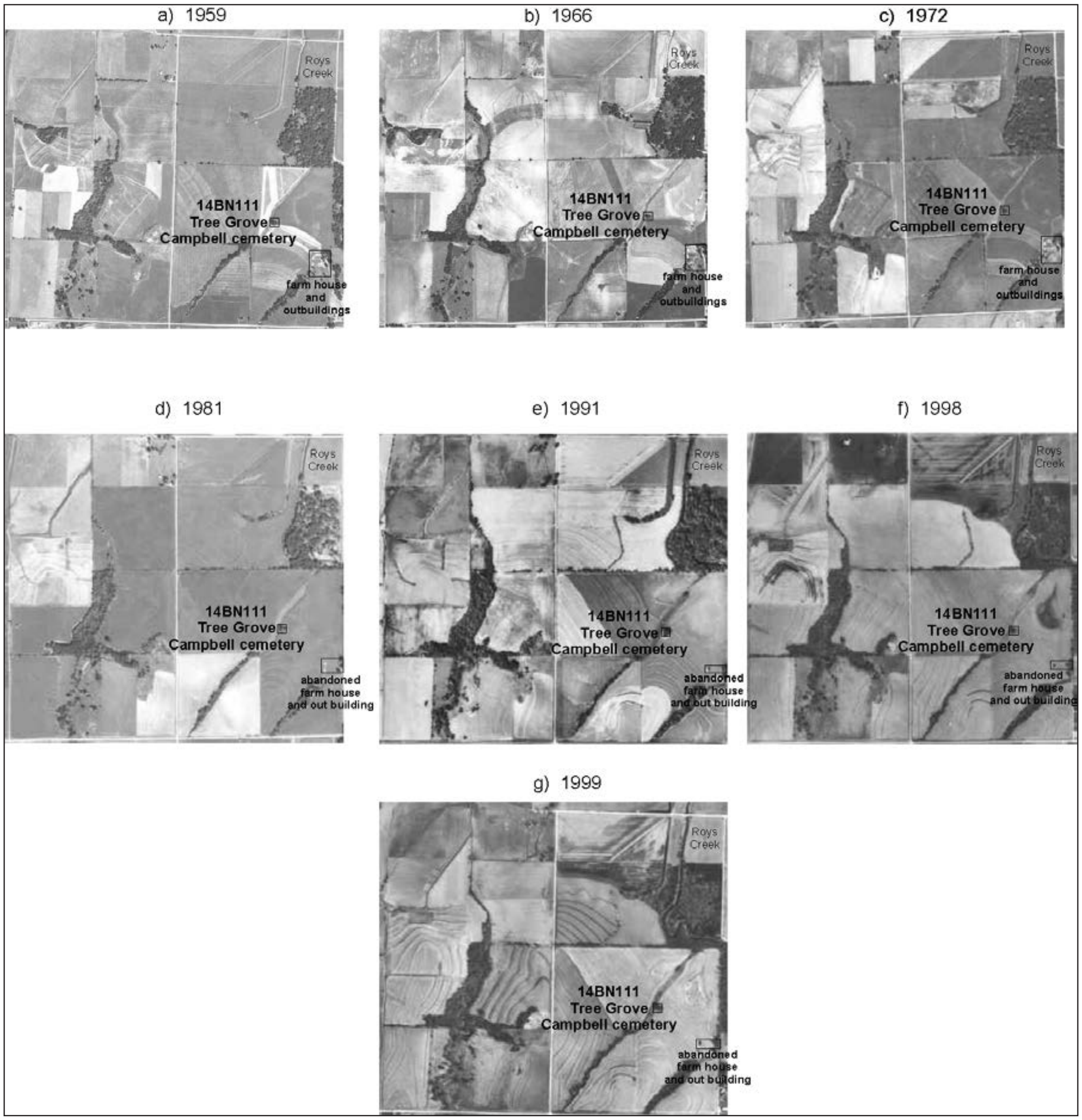


Figure 10. USDA's ASCS aerial photographs from 1959 to 1999.

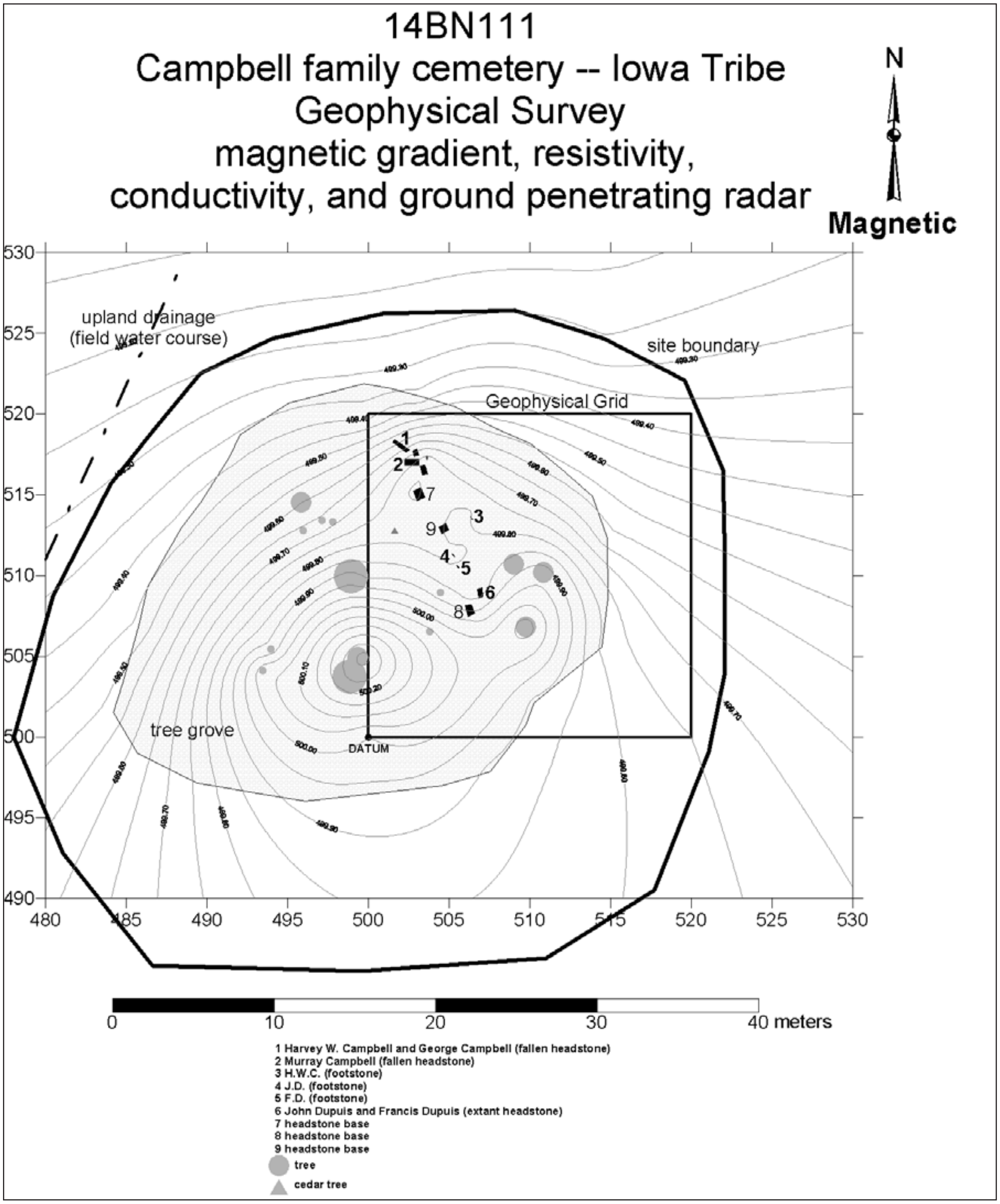


Figure 11. Location of geophysical grid at the Campbell cemetery.

Figure 12. The Geoscan Research FM36 fluxgate gradiometer survey demonstration (view to the west southwest).

Figure 13. The Geoscan Research RM15 resistance meter and PA5 twin probe array demonstration (view to the west).

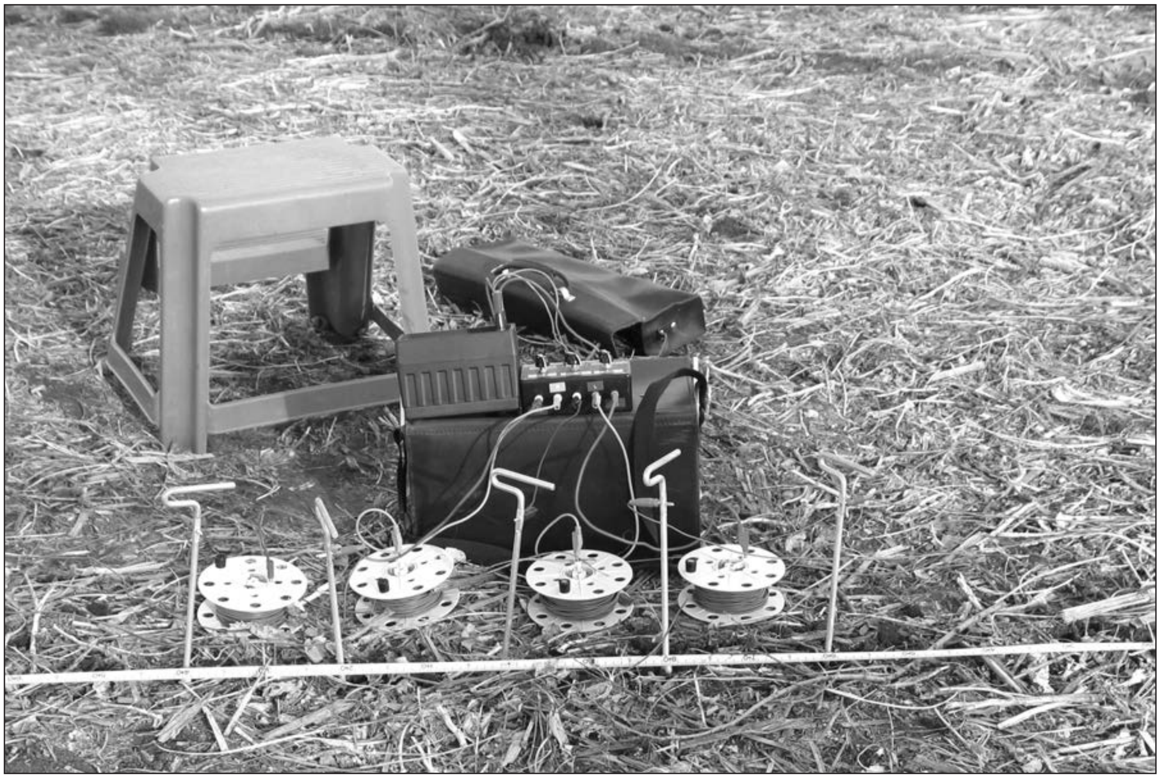


Figure 14. The Gossen Geohm 40D resistivity system using the offset Wenner array (view to the east).

Figure 15. The Geonics EM38 ground conductivity meter survey demonstration (view to the west).

Figure 16. The Geophysical Survey Systems, Inc. TerraSIRch SIR-3000 ground-penetrating radar system with a 400 mHz antenna mounted on a survey cart (view to the west).

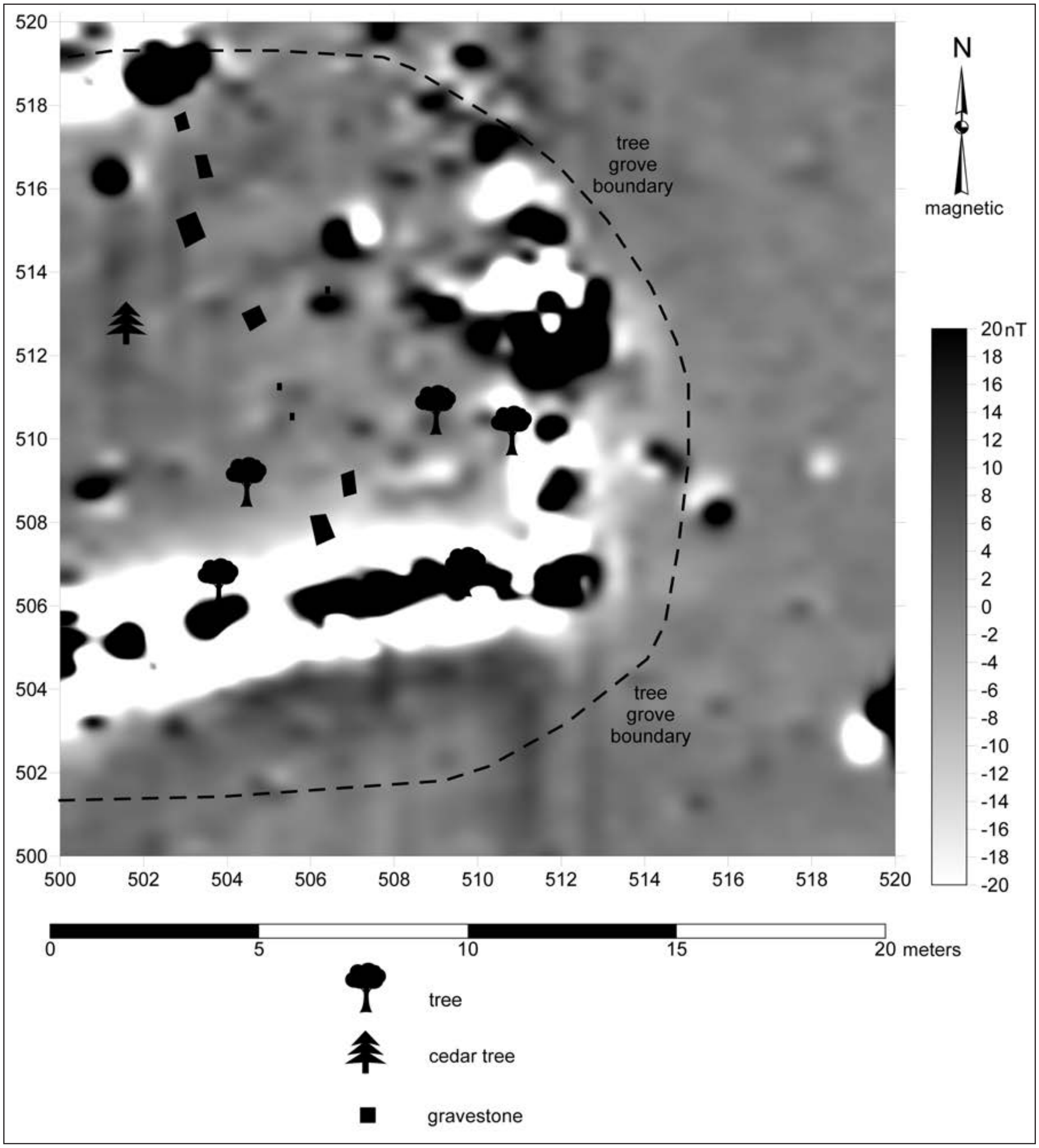


Figure 17. Magnetic image data plot.

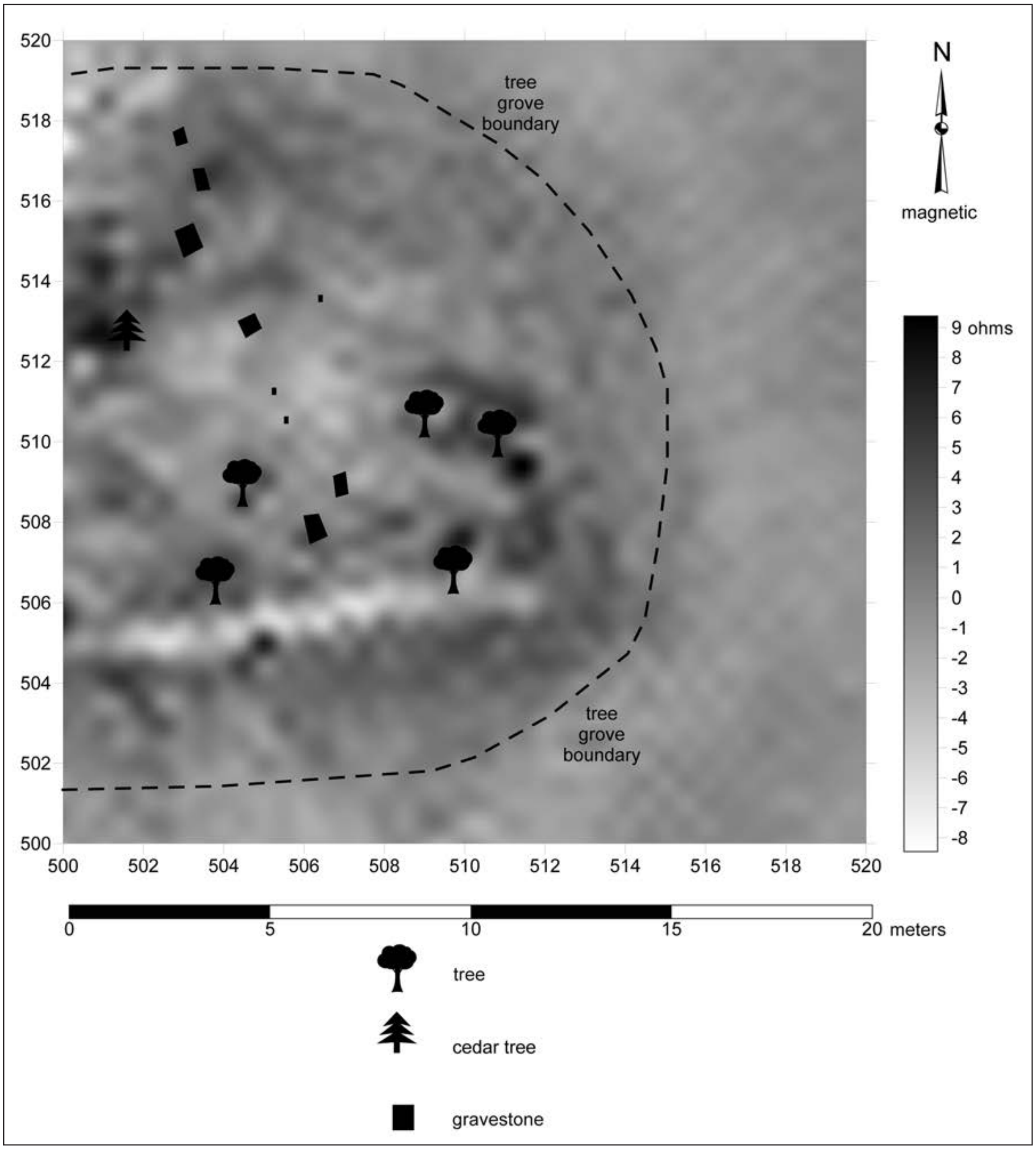


Figure 18. Resistance image data plot.

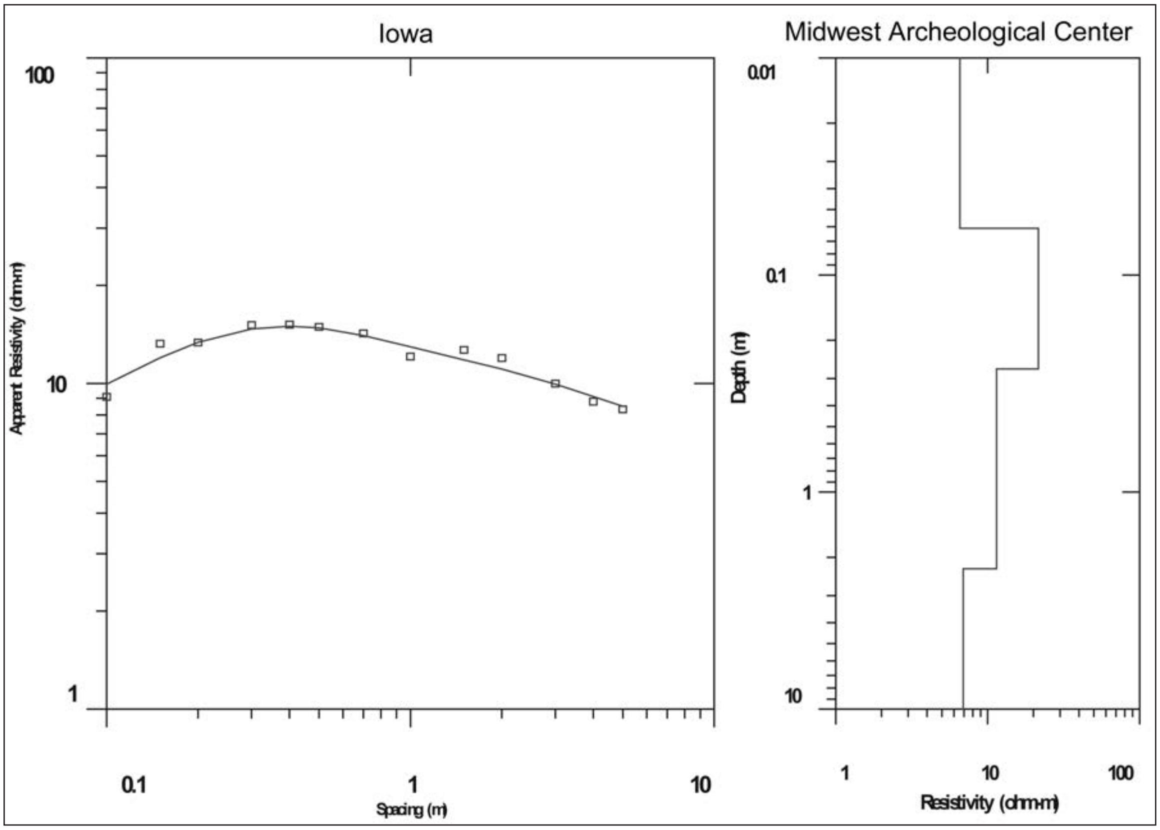


Figure 19. VES resistivity plot and computer generated model.

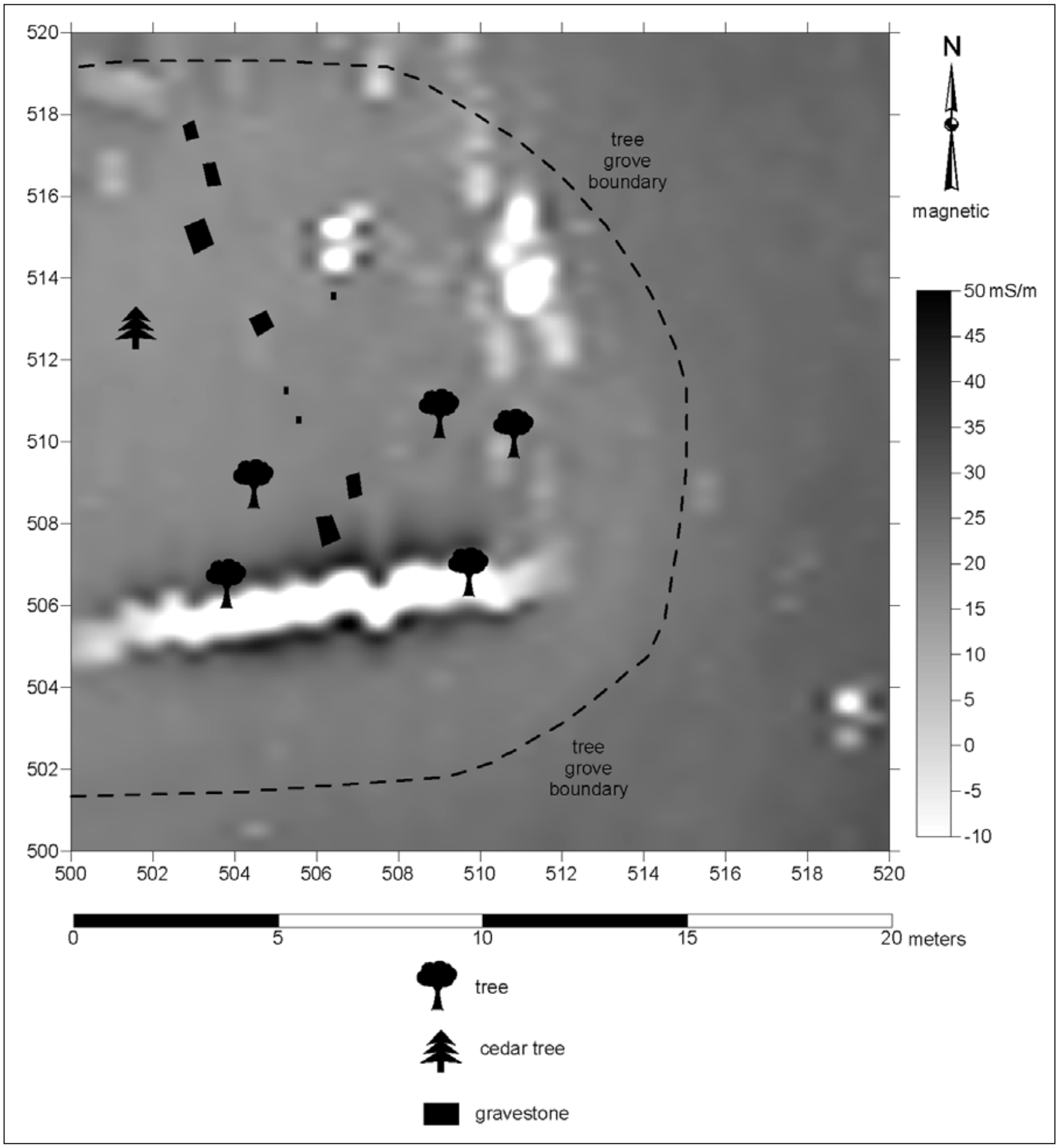


Figure 20. Conductivity image data plot.

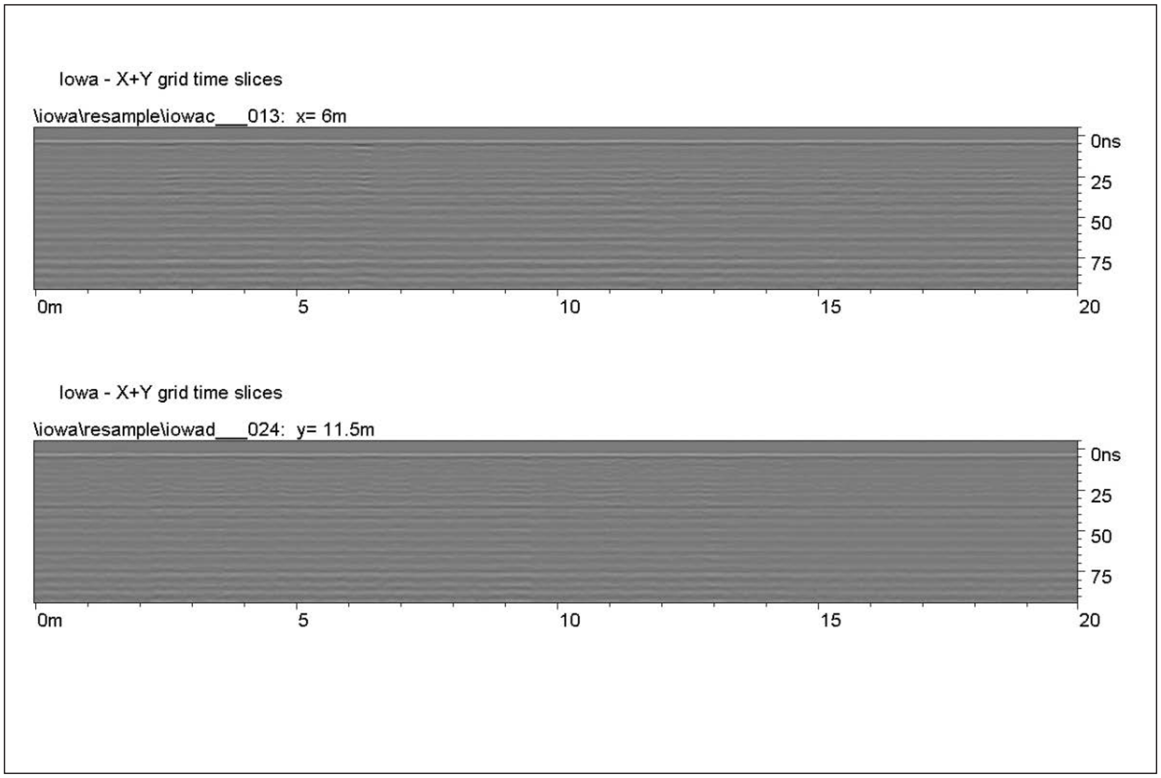


Figure 21. Selection of gpr radargram profile line data displays.

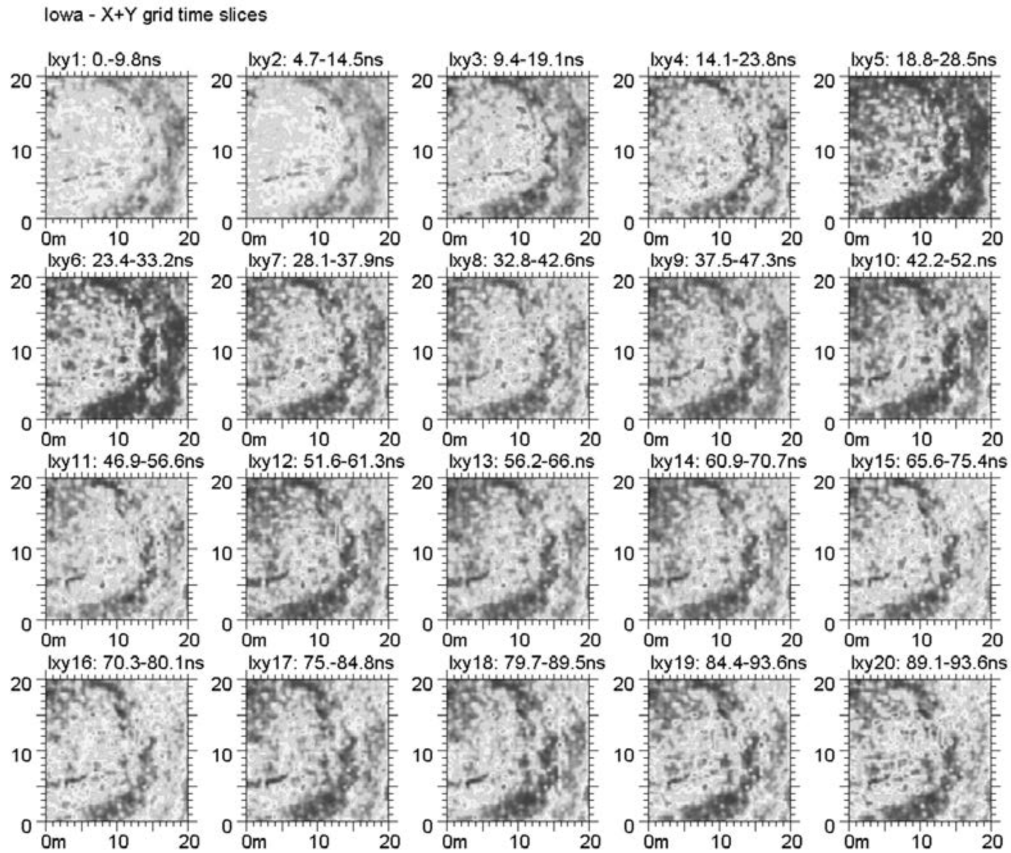


Figure 22. Time slices of the ground-penetrating radar profile data.

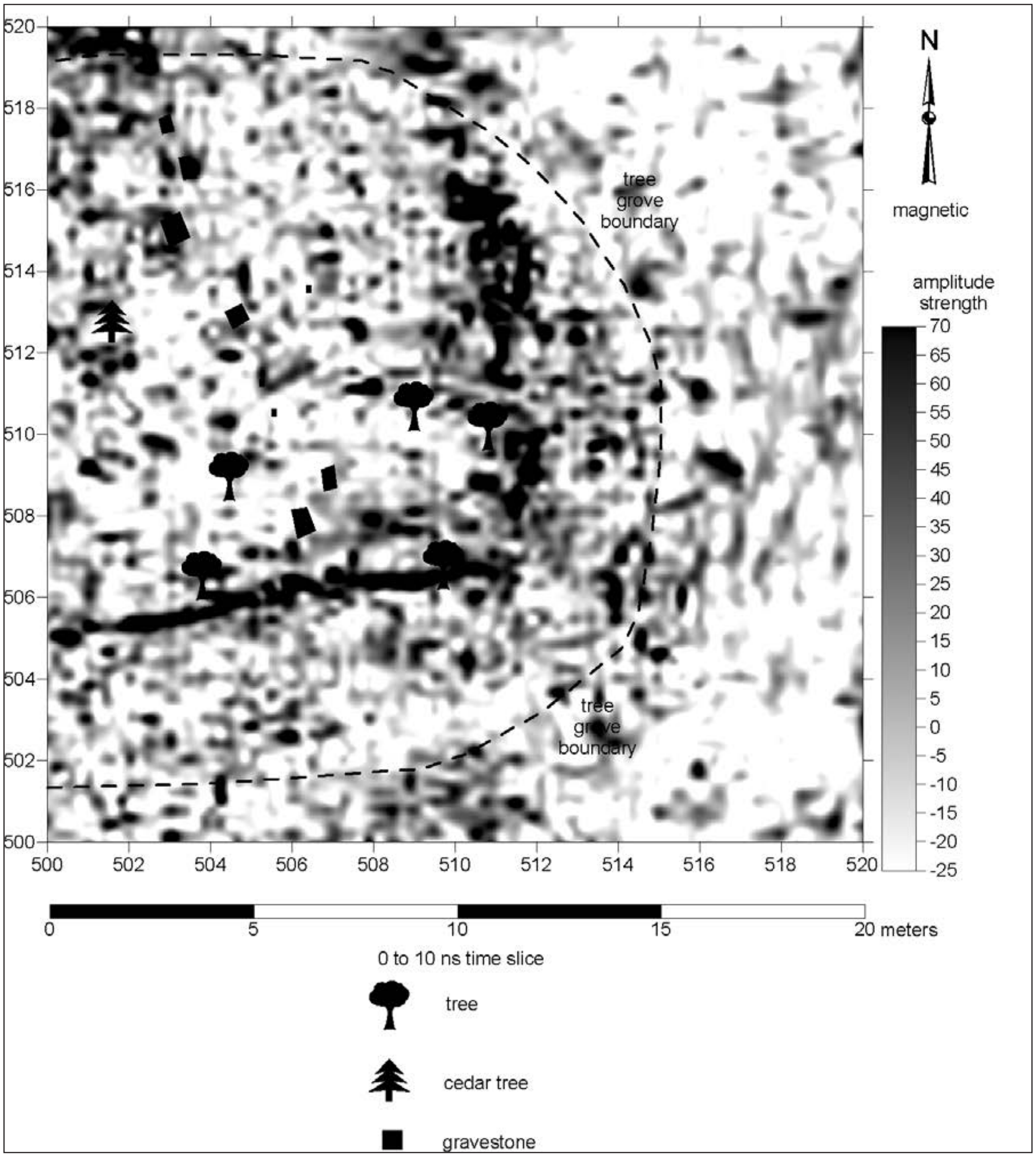


Figure 23. Time slice window from 0 to 10 ns.

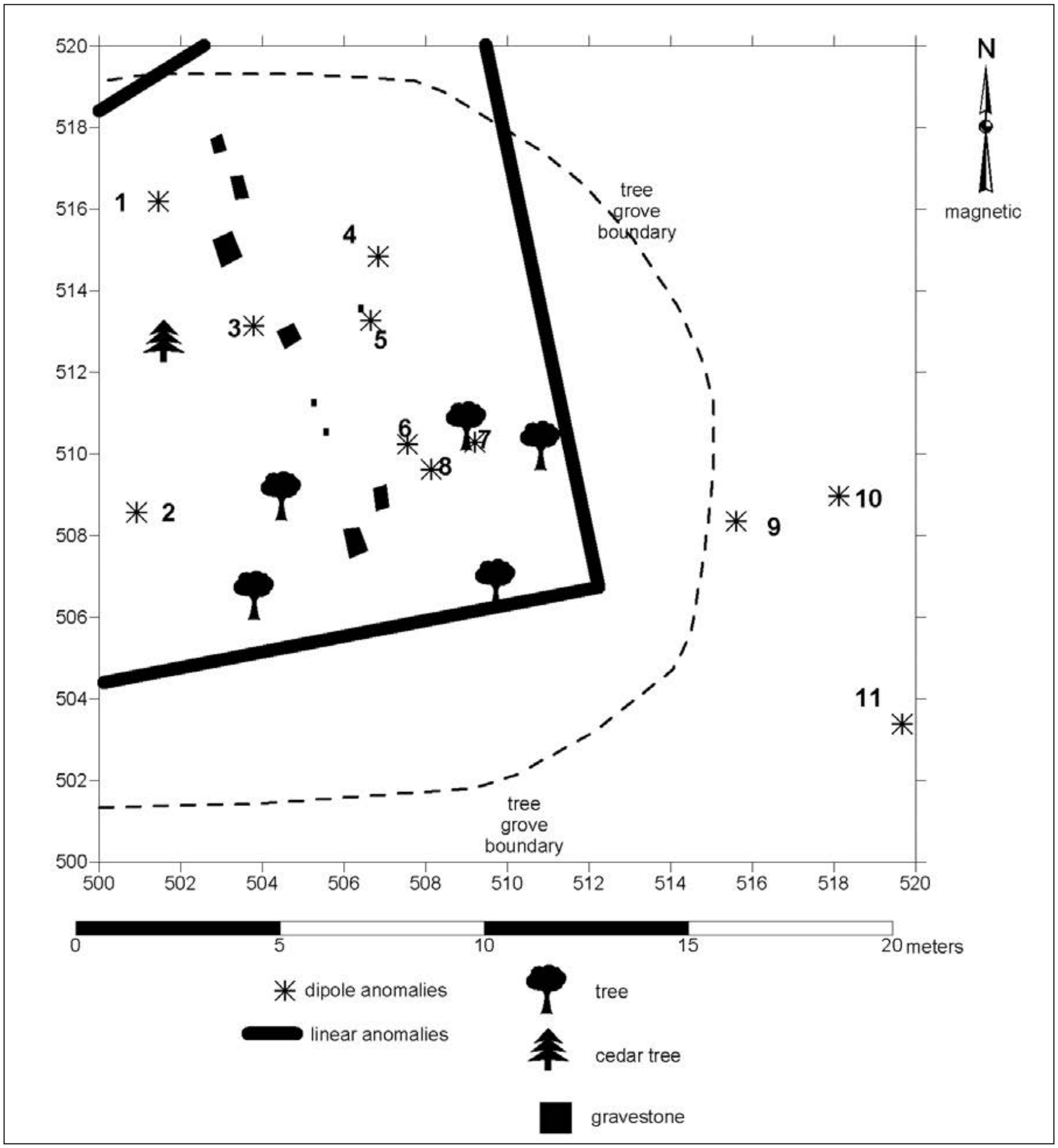


Figure 24. anomalies located within the geophysical project area.

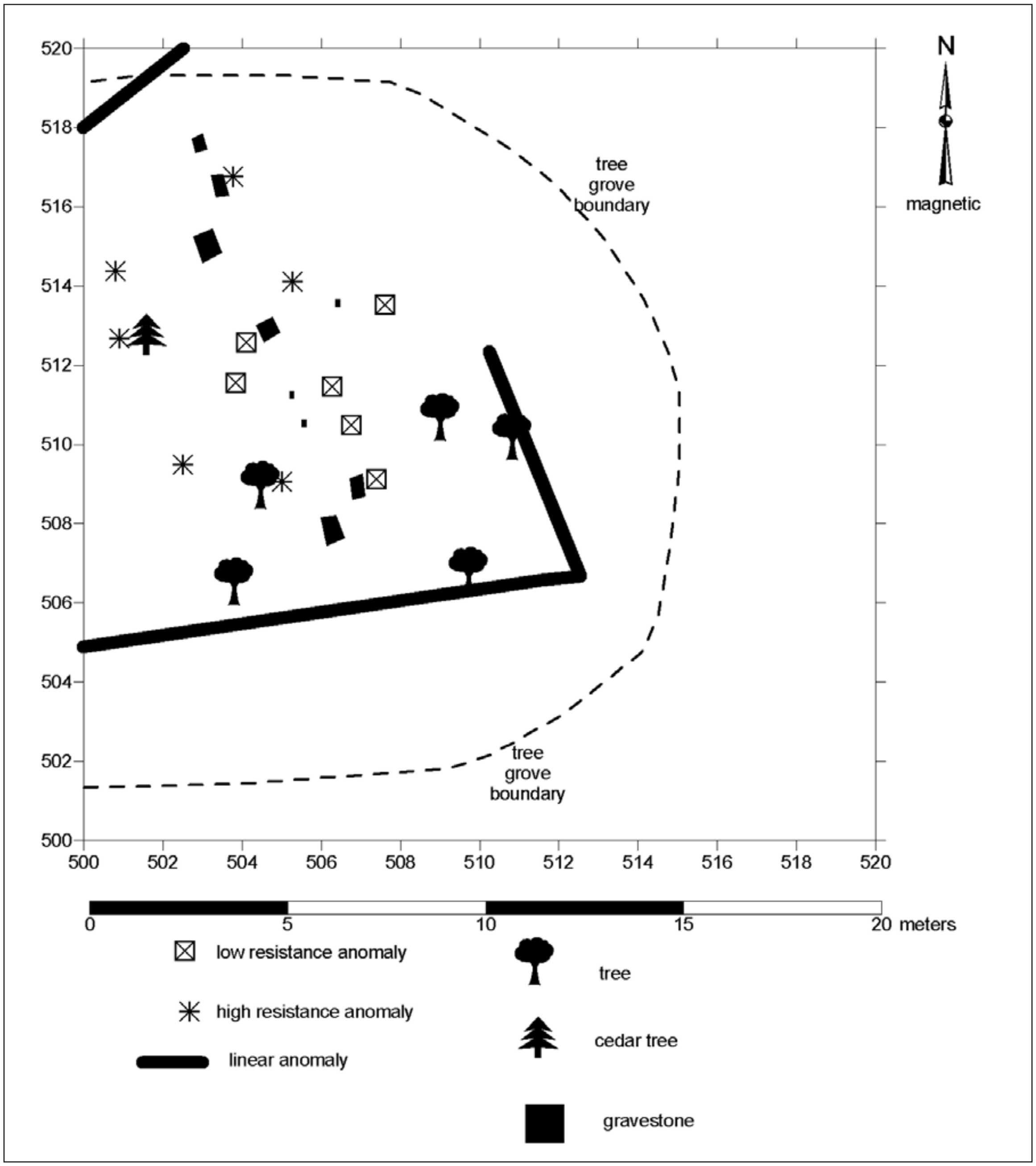


Figure 25. Resistance anomalies located within the geophysical project area.

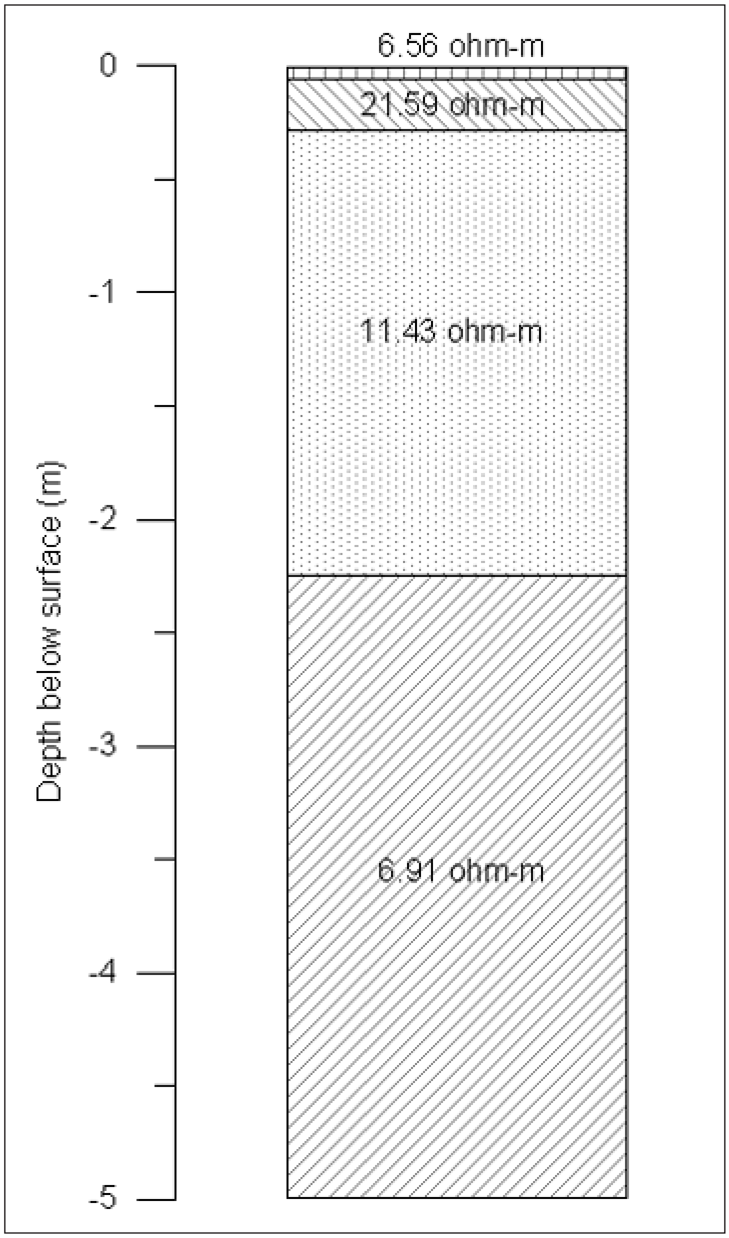


Figure 26. Electrical stratification of VES data.

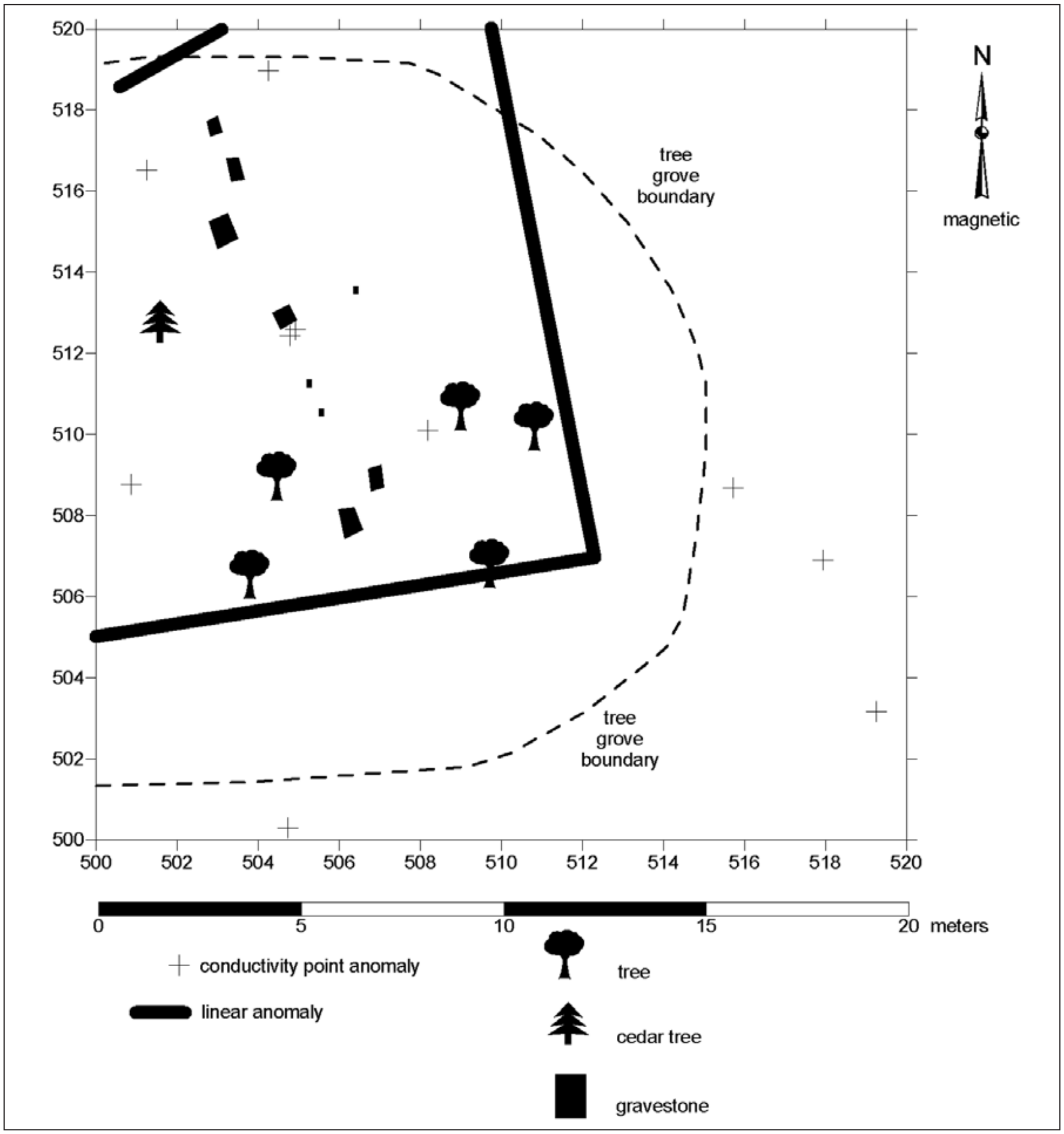


Figure 27. Conductivity anomalies located within the geophysical project area.

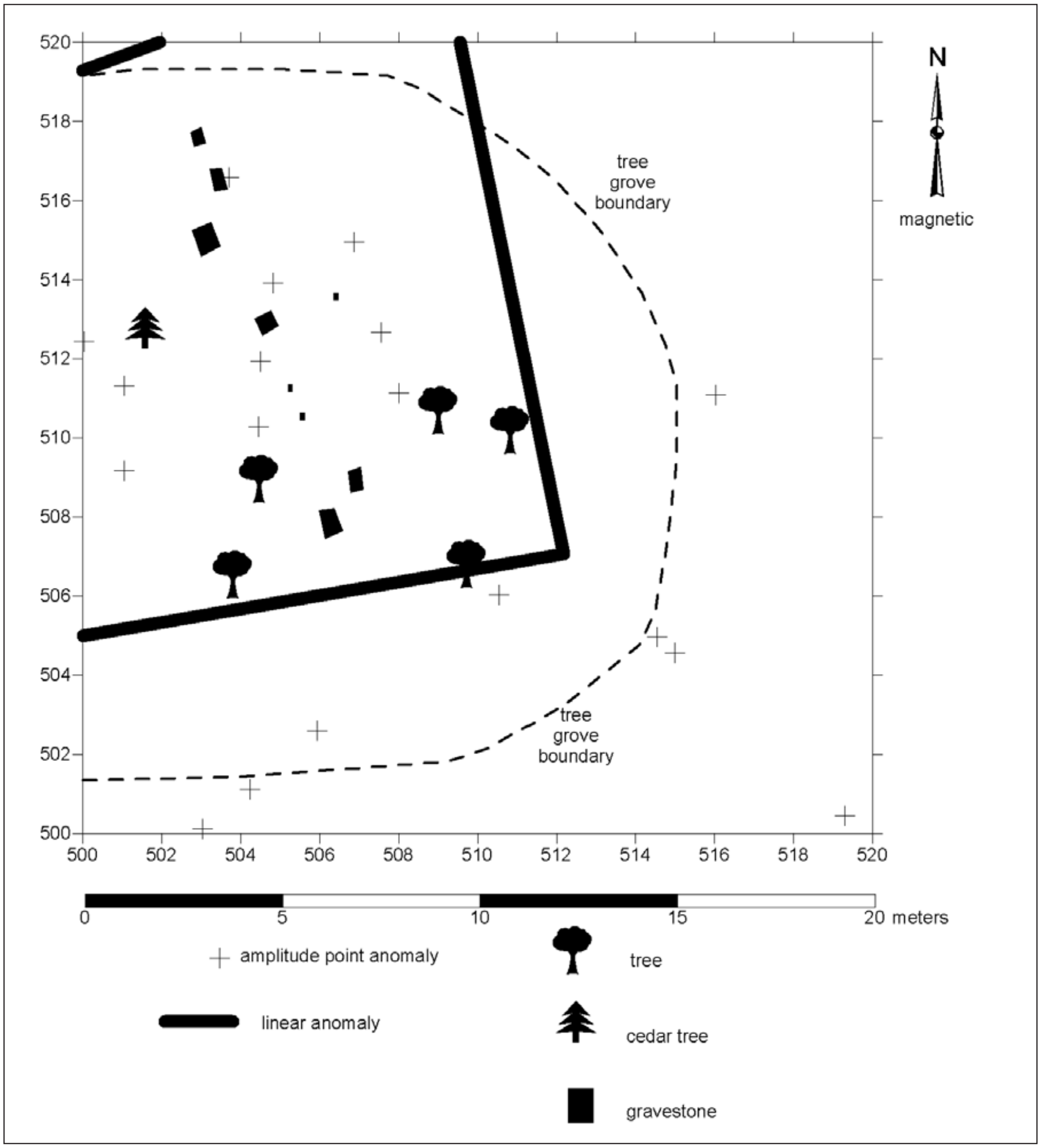


Figure 28. Ground-penetrating radar amplitude anomalies located within the geophysical project area.

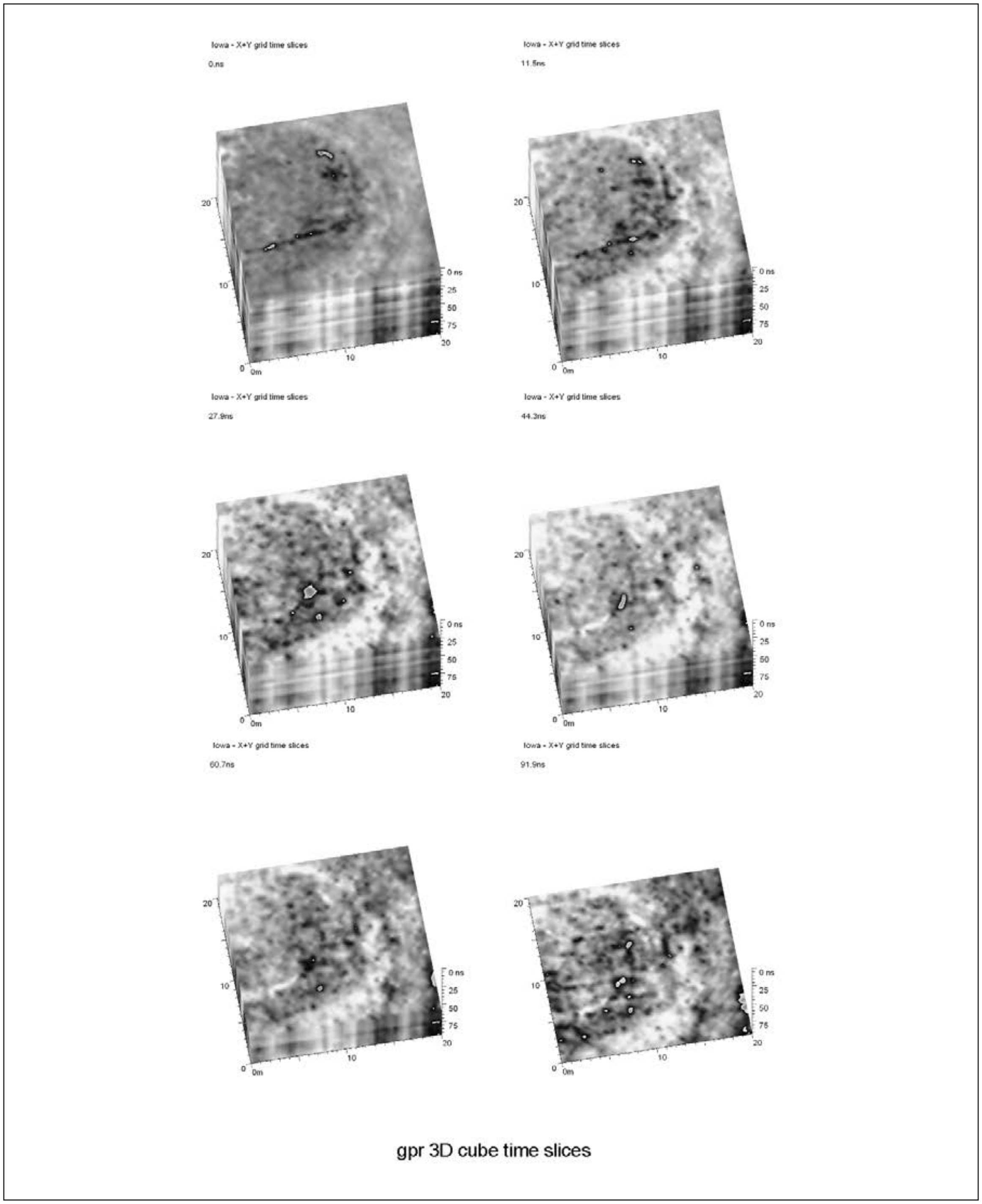


Figure 29. Ground-penetrating radar 3D slices of gpr sliced profile data within the geophysical project area.