

GEOPHYSICAL INVESTIGATIONS OF PROPOSED INTERPRETATIVE GARDEN AT THE SECOND FORT SMITH SITE, FORT SMITH NATIONAL HISTORIC SITE (3SB79), SEBASTIAN COUNTY, ARKANSAS

By
Steven L. De Vore

Midwest Archeological Center
Technical Report No. 114



NATIONAL PARK SERVICE
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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

Available

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



ABSTRACT

During July 16 to 19, 2007, the Midwest Archeological Center and Fort Smith National Historic Site staffs conducted geophysical investigations at the second Fort Smith site within the Fort Smith National Historic Site (3SB79) in the City of Fort Smith in Sebastian County, Arkansas. The project was conducted in response to the park's request for the non-destructive and non-invasive investigations of a triangular area between the Officers Quarters location and the modern railroad tracks in response to a proposed plan to construct interpretative heirloom garden plots and place some fruit trees behind the concrete slabs marking the locations of the two Officers Quarters. The project location coincided with the backyards of the Officers Quarters on the west side of the second Fort Smith enclosure. During the investigations, 1,140 square meters or 0.28 acres were surveyed with a fluxgate gradiometer, a resistance meter and twin probe array, a ground-penetrating radar cart system and 400 mHz antenna, and an electromagnetic induction meter in the conductivity mode. The magnetic gradient, resistance, and ground conductivity data collected at the cemetery site provided information of the physical properties (magnetic, resistance, conductance, and ground-penetrating radar reflections) of the subsurface materials. Several small scale magnetic gradient, 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 the Coca-Cola security fence, the garage, rubble from the second Fort Smith, and buried utility lines. Based on the evaluation of the geophysical anomalies, the majority of the anomalies appear to be associated with the 20th century Coca-Cola bottling plant, especially the garage. Due to the high impact of the construction and demolition of the Coca-Cola bottling works, this portion of the Fort Smith National Historic Site (3SB79) apparently lacks intact historic features associated with the second Fort Smith site. It is still possible that historic features associated with the prehistoric or fort period may exist at a depth beyond the range of the ability of the geophysical instruments to detect. Since the plans for the interpretative heirloom gardens call for the use of raised garden plots, there is no further need for archeological investigations of the project area in the proposed garden plot locations.

ACKNOWLEDGEMENTS

This project was completed with the support and assistance from the Fort Smith National Historic Site staff. Sincere appreciation is extended to FOSM Superintendent William Black and FOSM Facility Manager Gary Smith for their support and insight into the park history and previous cultural resource investigations. FOSM Museum Technician Emily Lovick and FOSM Park Guide Jeremy Lynch assisted in the geophysical project by helping set up the geophysical grid units and laying out, moving, and packing the geophysical survey ropes, as well as helping with the mapping of the project area and participating in the resistance and ground penetrating radar survey efforts. All of the FOSM park staff went out of their way to make me feel welcome and provided assistance in getting the work done efficiently, safely, and as comfortably as possible during the geophysical investigations of the proposed interpretative heirloom garden construction during mid-summer in northwestern Arkansas.

At the Midwest Archeological Center, I would like to thank Archeological Assistance and Partnership Program Manager Dr. Ralph Hartley and Park Archeology Program Manager Jeff Richner for their direction and leadership throughout the course of this project. I am also grateful for the support that Manager Dr. Mark Lynott, Administrative Officers Bonnie Farkas and Jill Lewis, and the rest of the MWAC staff provided, for without their help this project would not have been completed as smoothly or efficiently as it was. Linda Clarke, Darin Schlake, and Sara Vestecka provided logistical, computer, transportation, and personnel support during the project, which was much appreciated. Finally, I'd like to thank Allan Weber and Anna Loach for their editing and report preparation in the publishing of this document.

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1. INTRODUCTION

The National Park Service's (NPS) Midwest Archeological Center (MWAC) and Fort Smith National Historic Site (FOSM) staffs conducted geophysical investigations at the second Fort Smith site at the Fort Smith National Historic Site (3SM79) within the City of Fort Smith in Sebastian County, Arkansas (Figure 1). The geophysical survey of the site was conducted between July 16 and 19, 2007 (De Vore 2007a). The geophysical investigations were requested by the park staff for the non-destructive and non-invasive investigations of a triangular area between the Officers Quarters location and the modern railroad tracks in response to a proposed plan to construct interpretative heirloom garden plots and place some fruit trees behind the concrete slabs marking the locations of the two Officers Quarters (Figure 2). The project location coincides with the backyards of the Officers Quarters on the west side of the second Fort Smith enclosure. The project area was located within one of the high priority areas identified for the park (Figure 3).

Fort Smith National Historic Site was established by the Congress of the United States of America on September 13, 1961, to commemorate and preserve the two military forts and the Federal Courtroom and the Jail of the United States District Court of the Western District of Arkansas (Public Law 87-215). Fort Smith also played an important role in the implementation of Federal Indian policy during the 79 years as a military post and federal court between 1817 and 1896 when the lands inside the garrison were granted to the City of Fort Smith. By 1900, several large multi-story buildings were built or under construction within the Old Fort Reserve. The area became a light industrial and warehouse district in 20th century Fort Smith. Public interest in the old fort resulted in the establishment of the National Park Service unit. The Fort Smith National Historic Site was designated 3SB79 by the Arkansas Archeological Survey on December 10, 1984 (AAS 1984; and Coleman and Scott 2003:1-1).

The purpose of the present geophysical survey of the site was to provide an evaluation of the buried archeological resources in the triangular area behind the Officers Quarters location for compliance with Section 106 of the National Historic Act of 1966, as amended through 1992, that would be in the primary area of potential effect (APE) of the proposed interpretative heirloom garden plots (Figure 4-7). The geophysical survey techniques included a magnetic survey with a fluxgate gradiometer, a resistance survey with a resistance meter and twin probe array, a vertical electrical sounding with a resistivity meter and Wenner probe array, a conductivity survey with an electromagnetic induction meter in the conductivity or quadrature phase, and a ground penetrating radar (gpr) survey with a gpr cart system and a 400 mHz antenna. These techniques offered inexpensive, rapid, and relatively non-destructive and non-invasive methods of identifying buried archeological resources and site patterns that were detectable and that also provided a means for sampling relatively large areas in an efficient manner (Roosevelt 2007:444-445; and Von Der Osten-Woldenburg 2005:621-626). During the course of the geophysical survey, two FOSM employees, Emily Lovick and Jeremy Lynch, assisted in the MWAC geophysical project.

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2. ENVIRONMENTAL SETTING

Fort Smith National Historic Site (3SB79) is located in the Arkansas Valley section of the Ouachita province of the Interior Highlands division (Fenneman 1938:663-668). The project area is also located within the eastern part of the Arkansas Valley and Ridges major land resource area of the East and Central Farming and Forest Land Resource Region (USDA 2006:381-384). The region consists of a peneplain with residual ridges resulting from gently folded strong and weak strata. The sandstone capped high, flat-topped mountains and the long, narrow ridges trend to the northeast (USDA 2006:381). The intervening valleys are broad and smooth. The Arkansas River and its tributary, the Poteau River, meet on the west side of the City of Fort Smith near the park. The valley fill and alluvial sediments in the area are level to gently rolling with the young flood plains and old stream terraces (Cox et al. 1975:1).

The project area also lies within the transition zone between the Carolinian and the Austroriparian biotic province (Dice 1943:16-21). The Carolinian province consists of the great temperate deciduous forest, which dominated by a mixture of hardwoods and pines (Dice 1943:16-18; Shelford 1963:56-88,89-119; and USDA 2006:383-384). The Oak-Hickory overstory of the Eastern Deciduous Forest consists of red oak, white oak, and hickory with shortleaf pine and eastern redcedar (Cox et al. 1975:58-59; Kricher 1998:81-85; Shelford 1963:57-59; and Sutton and Sutton 1985:71-80). Understory vegetation in open areas and under medium forest canopy includes big bluestem, switchgrass, Indiangrass, and little bluestem, while broadleaf uniola, longleaf uniola, wildrye, and low panicums occur under heavy canopy (USDA 2006:383-384). Several different types of canes, vines, and briars may be found along draws and valleys. Strips of deciduous trees, including eastern cottonwood, hackberry, maples, ashes, elms, sycamore, black walnut, oak, hickory, and willows, are commonly found on the bottomlands along stream channels (Cox et al. 1975:59; Kricher 1998:85-90; and Shelford 1963:89-119). The Austroriparian province is also dominated by forests of pine and hardwoods (Dice 1943:18-21). The most of the upland forests are covered by a subclimax pine forest with grasses and sedges blanketing the understory (Dice 1943:20). Oaks, magnolias, and hickories are the most important hardwood trees in the upland hardwood forests (Dice 1943:20). Cypressess and gums dominated swampy areas through out the region (Dice 1943:20). In the Arkansas Valley, the Post Oak-Blackjack Oak-Winged Elm- Black Hickory Forest represents the climax vegetation community (Foti 1974:25). The modern ground cover within the park consists of several grass species, including Bermuda, Johnson, crab, nut, rye, sandbur, wild oat, and wild wheat grasses (Gaines 1986:19). Numerous varieties of trees, including several introduced species, exist in the park and form border plantings along former streets in the second fort area, in the open woodlands at Belle Point, and along the narrow strip between the railroad tracks (Gaines 1986:22)

During the prehistoric and historic periods, white-tailed deer were present in the timbered areas along streams and slopes. Cottontail rabbits were common along with coyotes, red and gray foxes, black bear, bobcats, beavers, raccoons, opossums, skunks,

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muskrats, and fox and gray squirrels (Brady 1988:76; Shelford 1963:59-60; Sutton and Sutton 1985:77; and USDA 2006:384). Numerous other mammals and rodents also inhabited the region (Kricher 1998:81,84; Shelford 1963:60; and Sutton and Sutton 1985:77-80). Numerous species of birds inhabited the grasslands, the shrublands, and wooded areas of the region (Kricher 1998:81,85; Shelford 1963:59; and Sutton and Sutton 1985:78-80). Turkey and bobwhite quail represented some of the regional game birds, as well as migratory waterfowl, in both prehistoric and historic times. A variety of raptors and numerous grassland and forest species of songbirds were also present (Brady 1988:77; Kricher 1998:81,85; and Sutton and Sutton 1985:78-80). Reptiles included several species of lizards, turtles, and snakes (Shelford 1963:59-60; and Sutton and Sutton 1985:78-80). Amphibians were found in the prairies, forests, and wetlands (Sutton and Sutton 1985:80). Fish, including smallmouth bass, Kentucky bass, rock bass, longear and green sunfish, white suckers, and sculpins along with a variety of minnows, shiners, and darters were found in the cool-water streams throughout the region (Brady 1988:76). Insects and other invertebrates were common throughout the region with grasshoppers being some of the most abundant insect groups (Shelford 1963:60-61).

The region has a semitropical humid climate characterized by hot summers and relatively mild winters (Cox et al. 1975:58; and Trewartha and Horn 1980:273-282). The annual average temperature ranges between 15 and 17° C (Jetton 1975:2-4; and USDA 2006:383). Annual January temperatures average 9.8° C (Hickmon 1941:775; and Jetton 1975:3). The lowest recorded winter temperature is -26° C (Jetton 1975:3). Annual July temperatures average 34.2° C (Hickmon 1941:775; and Jetton 1975:3). The highest recorded summer temperature is 45° C (Jetton 1975:3). Annual precipitation averages between 99.0 centimeters (cm) and 117.0 centimeters (Hickmon 1941:775; Jetton 1975:3; and USDA 2006:383) with the majority falling from April through September. Snowfall averages 12.7 cm per year but the snow cover seldom lasts more than a couple of days (Hickmon 1941:781; and Jetton 1975:3). The growing season averages 223 days with killing frosts occurring as late as April 4th in the spring and as early as October 19th in the fall (Hickmon 1941:775; Jetton 1975:3; and USDA 2006:383). The prevailing winds are from the south and southwest in the summer and from the north and northwest in the winter (Hickmon 1941:782). Severe droughts occur on an average of every 10 to 15 years (Jetton 1975:3).

The bedrock geology (Figure 8) in the region consists of Pennsylvanian aged hard and soft sandstones, shale, siltstone, limestone and some conglomerates of the Cabaniss, Krebs, and Marmation groups (Cox et al. 59; and USDA 2006:383). Lying on top of the bedrock in the valleys are deposits of unknown thickness of Quaternary alluvium consisting of unconsolidated clay, silt, sand, and gravel (USDA 2006:383). In the immediate area of Fort Smith, the lithology of the Arkansas Valley consists of intervening layers of sandstone and shale. The McAlester Formation of shale and weathered shale forms the uppermost bedrock layer. It varies in thickness from 0.9 to 1.5 meters (m). A hard, gray, micaceous sandstone of the Hartshorne Formation lies beneath the McAlester Formation shale. Outcrops of Hartshorne sandstone occurs between 125 m and 123 m

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above mean seal level (amsl) near the first Fort Smith site on Belle Point (Coleman and Scott 2003:2-2). The Atokan Formation of red sandstone lies beneath the McAlester and Hartshorne Formations and outcrops north of the Arkansas River and Fort Smith National Historic Site (Arkansas Laboratories, n.d.:1; Cox et al. 1975:59; and Haley and Hendricks 1972:A24-A25).

Soils within the eastern part of the Arkansas Valley and Ridges are dominated by Udalfs and Udepts (Foth and Schafer 1980:149-160; and USDA 2006:383). The shallow to very deep, well drained, loamy soils have udic soil moisture and thermic soil temperature regimes with mixed or siliceous mineralogy (USDA 2006:383). Parent materials in Sebastian County consist of materials weathered from consolidated bedrock of the Pennsylvanian Periods of the Paleozoic Era (Cox et al. 1975:59; Croneis 1930; and Haley et al. 1993). The soils formed under hardwood forests or mixed hardwood and pine forests (Cox et al. 1975:58-59). Depth to bedrock ranges from shallow to very deep. The project area lies within the Leadvale-Taft soil association of *moderately well drained and somewhat poorly drained, level to gently sloping, deep, loamy soils that have a fragipan; in valleys* (Cox et al. 1975:5-6). The soil within the project area consists of the Muskogee silt loam with three to eight percent slopes (MuC) soil mapping unit (Cox et al. 1975:19-20). The Muskogee silt loam soil in the project area consists of a deep, moderately well drained, gently sloping soil located on the high terrace along the Arkansas River (Cox et al. 1975:19-20). Formed in stratified loamy and clayey sediments brought by the Arkansas River from the western mountains and prairies (Cox et al. 1975:19), the soil has a slow permeability, medium surface runoff, high available water capacity, and moderate natural fertility (Cox et al. 1975:19-20). The erosional hazard is severe (Cox et al. 1975:20). The soil pH ranges from medium acid in the upper portion of the pedon to strong acid at its base (Cox et al. 1975:20). The native vegetation in the project area consisted of mixed hardwoods and some pine (Cox et al. 1975:19). These resources provided the basis of the aboriginal subsistence of prehistoric times and the historic and modern Euroamerican farming economy.

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3. CULTURAL HISTORY OF THE ARKANSAS VALLEY REGION

The cultural sequence for the Arkansas Valley region spans the entire range of North American prehistory and history from the earliest Native American occupation to the Euro-American settlement and development in the Eastern Woodlands Archeological Culture Area (Coleman 1990a; Coleman and Scott 2003; Davis 1982,1994; Sabo et al. 1990; Schambach and Newell 1990; and Willey 1966). The sequence is divided into two periods based on the availability of written records: 1) the Prehistoric Period and 2) the Historic Period. The Prehistoric Period is further subdivided into the Paleoindian, Dalton, Archaic, Woodland, and Mississippian. The Historic Period in Arkansas began very early with the A.D. 1541-1543 expedition of Hernando de Soto. The subsequent four hundred-sixty years of human experience in the Arkansas Valley region includes a complex set of historic records with intertwined cultural groups and historical perspectives. The Historic Period is further subdivided into the Protohistoric/Contact, European Encounters, Early American Migration and Settlement, Civil War, Homesteading and Industry, and Modern Development. Current knowledge regarding the cultural history of the region comes from research conducted along the Arkansas River Valley in Arkansas and Oklahoma (Coleman and Scott 2003:3-1; and Early and Sabo 1990:15-33). Initially, the archeological research concentrated on sites south of Little Rock (Moore 1908; Palmer 1917; and Thomas 1894). In the early 20th century, investigations focused on the Spiro Mound site west of Fort Smith, as well as other Oklahoma sites along the Arkansas River Valley (Rogers et al. 1980). The archeological survey along the entire length of the Arkansas River in the early 1930s demonstrated the richness and variation of the archeological record along the river (Moorehead 1931). Commercial excavation of mounds and cemetery sites during this period also helped stimulate the professional archeologists in Arkansas and Oklahoma to conduct research projects on these important sites before they were completely destroyed by the commercial ventures. These projects served the basis for the development of the regional cultural history along the Arkansas River Valley (Brown and Bell 1964; Dickinson and Dellinger 1942; Hoffman et al. 1977; Hoffman 1977a, 1977b; and Orr 1946). Archeological research following World War II was concentrated on salvage archeological investigations connected with the construction of large reservoirs by the U.S. Army Corps of Engineers (Caldwell 1958; Greengo 1957; Hoffman 1977a; and Myer 1969). More recently, the archeological investigations in the Arkansas Valley have been in response to the federal environmental and preservation legislation requiring cultural resource investigations of the federal undertakings (e.g., Harcourt 1987; Hinkle 1988; Williams 1986, 1987; Taylor 1987; and Zahn 1985,1986). Summaries of current knowledge regarding the prehistoric cultural history of the Arkansas Valley region include Davis (1991), Sabo et al. (1990), and Schambach and Newell (1990). For more detailed discussions of the Historic Period in the Ozarks region, one is referred to Arnold (1991) Chapman (1959), Goodspeed (1889-1894), Sabo (1992), Sabo et al (1990a), Steel and Cottrell (1993), and Whyne et al. (2002).

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Paleoindian (12,000 B.C to 8500 B.C.)

The Paleoindian Period is the earliest confirmed period of human occupation in the Arkansas River Valley. The Paleo-Indian period is placed between 14,000 and 10,500 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: 1) the Llano; 2) the Folsom; and 3) the Plano (Sabo and Early 1990:34-41). The presence of a pre-Clovis complex in Arkansas has not yet been substantiated (Sabo and Early 1990:34-36). Distinctive artifacts included fluted and unfluted lanceolate points and a diverse toolkit of drills, graters, burins, knives, and scrapers, most of which continue with little modification into subsequent cultural periods. Most Paleoindian finds reported in Arkansas have been isolated surface discoveries with no intact features. No sites dating to this period have been excavated. The diagnostic artifacts have been found in bluff shelters and open sites, especially along river terraces and older upland surfaces. Traditionally, the Llano complex is characterized by the presence of Clovis projectile points (Sabo and Early 1990:37-41; and Schambach and Newell 1990:1-5). Viewed as efficient large game hunters, the people of the Llano complex hunted mammoth, mastodon, extinct forms of bison, and other Pleistocene animals. The Folsom complex is also recognized by the presence of fluted projectile points (Folsom points) and the hunting of extinct forms of bison. The Late Paleo-Indian complex is actually a series of different complexes referred collectively as Plano. The Plano complexes represent the last cultural systems associated with the Pleistocene megafauna. 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.

Dalton (8500 B.C to 7500 B.C.)

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. The transitional Dalton Period is, in comparison with the Paleoindian Period, well known throughout the region (Sabo and Early 1990:41-47; and Schambach and Newell 1990:5). The distinctive Dalton point is the primary diagnostic artifact of this archeological culture, but other tool types are known. Dalton sites have been found in a wide variety of topographic settings from terraces along major rivers to uplands. There is continuity that places Dalton comfortably between the Paleoindian and Early Archaic Periods, and its tool kit is sufficiently diagnostic to consider warranting it as a discrete archeological culture, irrespective of period. Although the hunting and gathering strategies of the Paleoindian Period continue into the Dalton Period, there is an increased dependence on deer following the extinction of the Pleistocene megafauna. Nuts (e.g., walnuts and hickory nuts) may have played an important role in the Dalton diet. Dalton Period sites occur on the hilly uplands and the terraces and natural levees of the alluvial bottomlands (Coleman and Scott 2003:3-2).

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Archaic (7500 B.C. to 500 B.C.)

The Archaic Period is defined by increasing diversity of material culture technology and a concomitant change in subsistence behaviors (Sabo and Early 1990:48-57; and Schambach and Newell 1990:6-18). The Archaic period is often further split into three subdivisions: 1) Early Archaic, 2) Middle Archaic, and 3) Late Archaic. Hunting in the Archaic period shifts from large megafauna to smaller game. People are becoming less nomadic. There is also an increase in the local exploitation of plant foods. A wide diversity in stone tools, both chipped and ground, is a hallmark of the Archaic Period. The mode of hafting of bifaces includes both stemmed and notched points. Grooved axes and celts appear for the first time in the archeological record of the region. There are increasing quantities of tools associated with plant processing, such as grinding stones and pitted cobbles. Bluff shelters have been found to contain preserved organics in the form of twined fiber bags and sandals. The first domesticates, squash and gourd, appear near the end of the Archaic as part of the increasing role of food production. Population increases may be inferred from the large number of sites with Archaic materials, and from the evidence of larger individual site size and duration of occupation. Archaic sites are more likely to occupy riverine environments, which may represent a regional adaptation to the climatic conditions of the Hypsithermal (Coleman and Scott 2003:3-2).

Woodland (500 B.C to A.D. 850)

The Woodland Period is defined by the appearance of pottery, the construction of mounds, an unequal distribution of exotic raw materials and finished goods, and horticultural activity in the archeological record, but otherwise is largely a continuation of trends already seen during the Archaic (Sabo and Early 1990:57-82; and Schambach and Newell 1990:19-27). Regional patterns of cultural activity develop during the period (Coleman and Scott 2003:3-2). The bow and arrow also made their appearance. The Woodland Period is divided into the Early, Middle, and Late Woodland. Very little information exists for the Woodland Period settlement in the Arkansas River Valley region.

Mississippian (A.D. 850 to A.D. 1541)

The Mississippian Period had an identifiable yet indeterminate presence in the Arkansas River Valley region (Sabo and Early 1990:82-120; and Schambach and Newell 1990:29-38). 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. Settlements became larger and more permanent. Along the Mississippi River, Mississippian people built large fortified villages, temple mounds, and cemeteries. In the area surrounding Fort Smith, the Arkansas Valley Caddoan tradition was identified by the presence of the Harlan, Spiro, and Fort Coffee phases (Coleman and Scott 2003:3-2; and Schambach 1999:169-224). Ceramic technology continued to advance with the production

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of better pottery due to changes in clay and vessel form. Mississippian people developed an elaborate material culture assemblage with distinctive shell-tempered and decorated ceramics and small arrow points. The evidence of Mississippian culture present in the Arkansas River Valley may also represent season visits for the acquisition of specific resources.

Protohistoric/Contact (A.D. 1500 to A.D. 1700)

The Protohistoric or Contact Period marks the transition from a strictly archeological record to one augmented by ethnographic, ethnohistoric, and historic records (Sabo 1990a:121-134,1990b:135-170,1992; and Schambach and Newell 1990:39-44). The archeology of this period is very poorly known in the Arkansas River Valley. Until the advent of Euro-American culture was felt here, there would be little to distinguish a protohistoric site from an earlier one. Typically, observations made by the first visitors are used to establish a baseline and to project back in time the locations and characteristics of native societies. At contact, which begins with the Spanish forays in the sixteenth and seventeenth centuries and continues with the early French and American records of the eighteenth and nineteenth centuries, the Osage appear to have been the dominant Native American group in northern Arkansas and southern Missouri, while the Quapaw controlled the confluence of the Mississippi and Arkansas Rivers. As the United States of American expands its settlement and territorial claims to the eastern part of North American, eastern tribes, including the Cherokee, Delaware, Kickapoo, and Shawnee were encouraged to settle west of the Mississippi River by the Spanish government to forestall British and American encroachment (Coleman and Scott 2003:3-3; and Sabo 1990a:121). Following the Louisiana Purchase, and the removal policies of the early and mid 1800s, other Native American tribes including the Chickasaw, Choctaw, Creek, and Seminole were relocated west of the Mississippi in Indian Territory. In terms of material culture, items associated with this period include metal objects, glass trade beads, and other items of Euro-American manufacture.

European Encounters (A.D. 1541 to A.D. 1803)

There is very little information regarding the interface between prehistory and history for the Arkansas River Valley region (Sabo 1990b:135-136; and Schambach and Newell 1990:41-42). The expedition led by the Spaniard Hernando de Soto between 1541 and 1543 passed through the region (Hudson 1985). Similarly, the French Jesuits and explorers followed the arteries of transportation and communication along the major rivers including the Mississippi and the Arkansas (Herndon 1922). The period consisted of European exploration and exploitation by traders and trappers (Coleman and Scott 2003:3-3). Although surrounding area had gradually become known during the prior century, it was not really until the early nineteenth century that the region entered the historic record to any significant extent (Coleman and Scott 2003:3-3).

Early American Migration and Settlement (1803 to 1860)

Included as part of the 1803 Louisiana Purchase, Arkansas became part of the territory controlled by the fledgling United States of America. A number of expeditions were conducted to explore this new land purchase: Meriwether Lewis and William Clark into the northern regions along the Missouri River (Moulton 1983-2004), Zebulon Pike into the Rocky Mountains (Hart and Hulbert 2007), Thomas Freeman and Peter Custis along the Red River (Flores 1986), and William Dunbar and George Hunter to the Washita River and “hot springs” in Arkansas and Louisiana (Berry 2003; and Berry et al. 2006). James Wilkinson led a small detachment of Pike’s men down the Arkansas River to Arkansas Post. He produced the first map of the Arkansas River and described the region in his journal (Coues 1895).

The early Euro-American settlers into the region consisted of hunter-herders (Sabo 1990b:138-139). They divided their attentions between hunting and minimal agricultural activities, including the tending of livestock. The Federal Government also started to promote the removal of the southeastern tribes to a permanent Indian frontier in the Louisiana Territory. The Osage Indians forfeited their traditional hunting grounds in 1809 for the resettlement of the southeastern tribes (Sabo 1992). The Federal Government established the first Fort Smith military post at Belle Point overlooking the Poteau and Arkansas Rivers in 1817 to control the increased hostilities between the Osage and the newly arrived southeastern tribes, especially the Cherokee (Coleman and Scott 2003:3-3). The fort consisted of a simple log stockade of four sides with two opposing blockhouses. Barracks, storehouses, shops, hospital and a magazine were located within the stockade walls. Steamboat traffic on the Arkansas River began in 1820. In 1822, the ROBERT THOMPSON was the first steamboat to ascend the Arkansas River to Fort Smith. It carried provisions for the fort’s garrison. Although the fort was located on the eastern border of the newly defined Indian Territory, it was too far from the area of hostilities. In 1824 the military troops at Fort Smith were moved to Fort Gibson (Bearss 1963; and Bearss and Gibson 1979:1-42). The 1825 treaty with the Choctaw reestablished a need for troops at Fort Smith, which was to serve as the agency for the western Choctaw (Coleman and Scott 2003:3-4). During 1827, the United States Government Land Office was in the process of conducting the public land survey in western Arkansas including the Fort Smith vicinity (Clarkson 1827; and Coleman and Dollar 1984:13,30). In 1831, troops arrived at Fort Smith and repairs to the existing fort were undertaken by the troops. The Choctaw started arriving in the area in August of the same year (Haskett 1966:213-228). In 1830, President Andrew Jackson instituted the removal and relocation of the eastern tribes with the Indian Removal Act of 1830, beginning with the Choctaw and eventually including the Cherokee, Creek, Chickasaw, and the Seminole (Sabo 1992). The exodus of more than a 100,000 Native Americans from the southeastern states undertook the arduous journey halfway across the country. In 1838, the Federal Government forcibly removed over 16,000 Cherokee from their homeland in the southeast and sent them to the Indian Territory. Several hundred died on the “Trail of Tears” journey, which passed through the

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Fort Smith locality (National Park Service 2008a). More than 10,000 individuals perished during the removal or shortly after their arrival in Indian Territory.

On land owned by John Rogers to the east of Fort Smith, a civilian community emerged to provide cheap whiskey to the emigrating Choctaws. The troops at Fort Smith tried to separate the two groups. Even with additional troops in 1833, the military was unable to control the contraband trade in whiskey to the Choctaws in what has been described as the “Arkansas whiskey war.” As a result, Fort Smith was again abandoned in 1834 and Fort Coffee was established at a more suitable location in Indian Territory (Bearss 1968:143-172; and Haskett 1966:213-228). Over the next few years, additional eastern tribes were relocated to the Indian Territory. Arkansas became the 25th state on July 15, 1836. The residents of the new State of Arkansas demanded a permanent military garrison on their western boundary. In 1838, Congress authorized the construction of the second military fort at Fort Smith and purchased 296 acres from John Rogers adjacent to the old fort at Belle Point (Coleman and Scott 2003:3-4). The plans for the second fort called for a pentagonal stone walled fort and bastions located at each corner. Within the seven acres stone walled enclosure, several buildings were to include an open parade ground surrounded by two barracks for the enlisted men, two officers quarters, the commandant’s quarters, a quartermaster store, a hospital, and other buildings. The plans were never fully realized, and by 1845, the unfinished fort was designated as a supply depot as war with Mexico loomed on the horizon. The fort perimeter wall was never raised to its intended height do to the change in its mission. The commandant’s quarters and one enlisted mens barracks were built while two bastions were transformed into the commissary and quartermaster storehouses. A third bastion was converted into the powder magazine. Other fort related structures, including maintenance buildings, stables, laundress quarters, the hospital, a storehouse, and a bakery were located outside the stone wall. In 1846, Fort Smith was formally garrisoned and continued to function as a supply depot for the next 25 years (Coleman and Scott 2003:3-4). Sebastian County was established on January 6, 1851. The civilian community started on John Rogers land eventually grew into the Fort Smith civilian community. The community of Greenwood was founded in 1851 and became the first county seat. The county seat was moved to Fort Smith in 1854.

Civil War (1860-1865)

The fort became the major supply depot for the Confederate Army of the Trans-Mississippi West when Arkansas State Troops occupied Fort Smith on April 23, 1861 within hours after the Federal troops evacuated the fort (Coleman and Scott 2003:3-4). It served as a Confederate staging area for the battles of Wilson’s Creek in Missouri and for Pea Ridge and Prairie Grove in Arkansas. It also served as a defensive bastion for Confederate interests in Arkansas and the Indian Territory (Wing 2006). On May 6, 1861, Arkansas voted to secede from the Union and to join the Confederacy. The state legislature divided Sebastian County into two judicial districts and recognized Greenwood as the county seat in 1861. Eventually, both Greenwood and Fort Smith shared the status as the county seat of Sebastian County. During the occupation of Fort Smith by Confederate troops, raids

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were dispatched to disrupt communications and ambush supply trains, as well as general small unit actions meant to weaken the Federal hold on Missouri, Northwestern Arkansas, and the Indian Territory. Fort Smith was retaken by Federal troops on September 1, 1863. A fortification line was constructed on the outskirts of the Fort Smith community to protect the area from any Confederate attack. In July of 1864, Confederate forces under the leadership of Stand Watie attacked the Federal garrison at Fort Smith. After six days of fighting, the Confederates withdrew. For the remainder of the Civil War, Fort Smith served as a refugee camp of thousands of former slaves and folks displaced by the fighting.

Homesteading and Industry (1865-1930)

After the Civil War, community centers began to establish themselves across the region. Agricultural production diversified and along the Arkansas River, subsistence farming gave way to more specialized agricultural pursuits (Sabo 1990b:153-170). Returning settlers after the Civil War brought about a rapid recovery as they rebuilt their farms and cultivated the land. The introduction of the railroads and, later, a road network provided means for farmers to sell their produce and livestock to national markets. Truck farms developed at the turn of the 20th century as an alternative form of specialized farming, and along with them, local canneries became important sources of seasonal employment (Sabo 1990b:180). Cotton was also an important cash crop to the Arkansas Valley until cotton prices fell and soil depletion forced a return to general farming activities in this area in the early 1900s. Fort Smith continued to develop as a major community center in the early part of the twentieth century.

The army also focused efforts on western expansion and the line of forts moved to the west. Fort Smith continued to serve as a supply depot but its days were numbered. Fires destroyed the Officers Quarters in 1865 and 1870 (Coleman and Scott 2003:3-4/3-5). On July 19, 1871, the military garrison left Fort Smith; however, in 1872, the United States District Court of the Western District of Arkansas was established at the old fort. The enlisted mens barracks became the Federal Courthouse and jail and a permanent gallows was built on the interior side of Bastion 3 or the old Magazine. The remaining buildings were relegated for civilian use (Coleman and Scott 2003:3-5). The court had jurisdiction over western Arkansas and the entire Indian Territory. Since the tribal courts had no jurisdiction of non-Indian settlers in the territory, it was up to a hand full of United States Marshals and deputies to bring outlaws hiding in Indian Territory to justice at the federal court in Fort Smith. In 1875, Federal Judge Isaac C. Parker was appointed to the bench by President Ulysses S Grant. Parker proved a tireless defender of Native American rights and helped bring law and order to the Indian Territory. As the non-Indian population in the Indian Territory increased in the late 1800s, new courts emerged limiting the authority of Parker's court in Fort Smith. In 1896, Congressional legislation reduced Judge Parker's jurisdiction of several counties in western Arkansas ending the Federal Court presence at Fort Smith (Coleman and Scott 2003:3-5).

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In 1883, Congress granted the right-of-way through the former military reservation to the St. Louis and San Francisco Railroad. Tracks through the old fort wall separated the Quartermaster building from the rest of the fort (Sanborn 1886,1889,1892). The Missouri Pacific Railroad also cut through the old military reservation. The 1886 Sanborn insurance maps of the old fort area indicated some development on Belle Point including the McLoud and Sparks Furniture Company at the north end and Ketcham's Foundry at the south end (Sanborn 1886). The St. Louis and San Francisco Railroad right of way was also identified on the insurance map of the City of Fort Smith in 1886. By 1889, the Sanborn insurance maps (Sanborn 1889) illustrated the relative positions of the parallel tracks of the St. Louis & San Francisco and the Missouri Pacific Railroad through the old fort area. The two businesses were still present, although the Ketcham Iron Company had expanded to both sides of the parallel railroad tracks. By 1892, several dwellings were shown on the insurance map of the Belle Point area along with the McLoud and Sparks Furniture Company complex (Sanborn 1892). A railroad bridge also crossed the Arkansas River below the confluence with the Poteau River. In 1896, Congress also called for the remaining lands inside the old garrison to be granted to the City of Fort Smith. In 1897, Congress granted the City the right to extend Parker and Rogers Avenues, and Second and Third Streets through the garrison property. The 1897 insurance map (Sanborn 1897) indicated the McLoud and Sparks Furniture Company facilities were now owned by the Fort Smith Bedding Company. The Little Rock and Fort Smith Railroad Company had taken over the St. Louis and San Francisco railroad line and a depot for the Little Rock and Fort Smith Railroad line and the Missouri Pacific Railroad line was present on the northwest side of the parallel tracks. Until 1897, the second Fort Smith had been represented on the insurance maps by an outline of the walled fort perimeter. The 1897 insurance map indicated the location of the old jail near the northern wall between South 2nd and 3rd Streets. Warehouses and a lumber yard were also present in the lots to the north of the old fort. Other small buildings were also identified on the outside of the fort wall along its eastern side. Wheeler and Pattens Sam Mill and the Ketcham Iron Company were located at the south end of Belle Point. From 1886 to 1901, the insurance maps (Sanborn 1886,1889,1892,1901) identified the boundary line separating Arkansas and Indian Territory at Belle Point. By 1900, the area was emerging as a light industrial and warehouse district for the City of Fort Smith. The Federal Courthouse and jail became a civic center. Belle Point was densely populated by a squatter community. The 1901 insurance map of the area (Sanborn 1901) indicated that South 2nd and South 3rd Streets, as well as Rogers and Parker Avenues had been extended through the old fort property. The old commissary had been converted to a hardware warehouse. The District Court building/fort enlisted mens barracks was the county jail and hospital building. The J. W. & Robert Meek Candy factory was located in the area of the fort's Officers Quarters. Wholesale grocery, wholesale drug, wholesale hardware, and implement storage warehouses were present between Rogers and Garrison Streets. Other buildings were also present inside the second fort's perimeter. The 1908 insurance map of Fort Smith (Sanborn 1908) identified numerous dwellings (Coke Hill) on Belle Point, which was identified as West Fort Smith, Oklahoma. A change in the state boundary line to the center of the Poteau River added the entire Belle Point area to the State of Arkansas (Coleman1990a:19). The J. W. & Robert Meek Candy factory had

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expanded and included a bottling works for Coca-Cola (Dollar 1982:2) to the west of South 2nd Street. The northern part of the District Court building was identified as the U.S. Jail. Of interest on the 1908 insurance map was the identification of the old Fort Smith's Officers Quarters on the state line between the railroad tracks. Although the identification of the structure was in error, it represented the location of one of the second Fort Smith's bastions. This bastion served as the second fort's Quartermaster store. The Ketcham Iron Company had also expanded its facilities. In 1927, the J. W. & Robert Meek Candy factory and bottling works converted entirely to the production of Coca-Cola (Dollar 1982:2; and Sanborn 1936). The old fort was not forgotten during the early twentieth century. The Old Fort Museum Association converted the Commissary building into a museum in 1910 (Coleman and Scott 2003:3-5).

Modern Development and Recreation (1930 to present)

By 1939/1940, the Meek bottling plant had expanded to the area of the two officers quarters and the communal cistern (Dollar 1982:2; and Sanborn 1950). The Meek bottling plant renamed the Coca-Cola Bottling Company, located between Rogers and Parker Avenues, and South 2nd Street and the Missouri Pacific railroad tracks, contained the bottling plant and vehicle garages (Sanborn 1950). The District courthouse and jail building was occupied by the Ct. Smith Federated Welfare Association during the middle of the 20th century (Sanborn 1936,1950). In 1957, the Public Historical Restoration, Inc., company restored the old federal courthouse and jail to its historic condition. The warehouse district on the north side of Rogers Avenue continued to prosper and expand during the mid 20th century (Sanborn 1936,1950). The 1950 insurance map (Sanborn 1950) was annotated with the comment that all of the buildings in the Coke Hill settlement were condemned. Additional warehouse and manufacturing companies were located on the eastern side of South 3rd Street between Rogers, Parker, and Garland Avenues (Sanborn 1936,1950).

Local Fort Smith businessmen donated funds to purchase the Coke Hill private properties, and in 1958, sponsored the first archeological investigations of the original Fort Smith site. In 1961, President John F. Kennedy designated the Fort Smith National Historic Site to commemorate the two western frontier military forts and the Federal Court for the Western District of Arkansas, which illustrated over *80 years of activity by the United States of America to administer justice for Native Americans and to control the nature of western expansion and settlement through both the U.S. Army and the Federal Court system, crime and punishment in the 19th century West, the U.S. Marshal's history on the frontier, as well as the settlement of Indian Territory and how the nature of Federal Indian Policy throughout the entire 19th century affected that process. It specifically addresses the forced removal of Indians from East to West through its designation as a unit of the Trail of Tears National Historic Trail* (National Park Service 2008b). In 1964, Lady Bird Johnson officially dedicated the Fort Smith National Historic Site. Since its creation as a unit in the national park system, the Fort Smith National Historic Site had increased from the 11 acres donated by the City of Fort Smith in 1961 to the present day total of approximately 75 acres. Several intrusive streets, including South 2nd and 3rd Streets and

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Rogers and Parker Avenues, and post-historic buildings, including the dwellings on Coke Hill, the Coca-Cola Bottling Plant, and a number of other warehouse buildings have been removed from the park (Coleman 1984a,1990:14; Coleman and Dollar 1984; Coleman and Scott 2003:3-6; Dollar 1982; and Paige 1981:46-66).

4. PREVIOUS ARCHEOLOGICAL INVESTIGATIONS AT FORT SMITH NATIONAL HISTORIC SITE

Fort Smith National Historic Site (3SB79) lies within the boundary of the Middle Arkansas River Valley (Davis 1982,1994). Prehistoric resources in the region are little understood. As a matter of fact, so little is known about the prehistoric resources in the study unit that the State Plan and its revised edition (Davis 1982,1994) did not contain any attempt to formulate research questions and only provided a bibliography of references. The investigation of historical archeological sites in the State Plan did provide research questions and a historical framework that could be applied to the Fort Smith National Historic Site (Stewart-Abernathy and Watkins 1982:HA1-HA97).

Archeological research at Fort Smith National Historic Site was initiated in 1958-1959 with the investigations of the first Fort Smith site on Belle Point in order to locate the stockade walls (Dollar 1960; and MWAC 2004). Excavations continued at the first Fort Smith site in 1962-1963 to identify the fort walls and interior structures (Dollar 1966; Moore 1963; and MWAC 2004). Since the initial archeological investigations at the first Fort Smith site, other archeological investigations over the years have been less intensive and more sporadic (Coleman 1990a:17; Coleman and Scott 2003:5-1; and MWAC 2004). Projects have included small scale monitoring activities, test excavations, and mitigation projects in order to provide archeological compliance with numerous park undertakings ranging from the demolition of post-historic period structures, providing archeological data for historic structure reports, cultural landscape studies, and rehabilitation of the second Fort Smith and District Courthouse buildings, reconstruction of fort period structures including the flagpole at the second Fort Smith site, construction of new visitor support facilities (e.g., parking lots, utility lines, and walkways), assessing storm related damage, and monitoring excavation activities by the Missouri Pacific Railroad Company within the boundary of the park (Anderson 1979,1981; Barnes 1993; Black et al. 1998; Coleman 1983,1984a,1984b,1986, 1987a,1987b,1989a,1989b, 1990a:17-40,1990b; Coleman and Dollar 1984; Coleman and Scott 2003:5-2/5-5-75; Dollar 1960,1966,1976,1982,1983; Frazier et al. 1987:153-176; Galonska 1995; Hampton and Vawser 2000; Hayes 1996; Hunt 1997a, 1997b,1998,1999a,1999b,1999c, 2000; Paige 1981; Parrish 1990; Scott and Hunt 2000; and Traylor 1981). Besides the archeological investigations, geophysical investigations have also been conducted at the park, including portions of the second Fort Smith's perimeter wall and bastions (Hunt 1999c; and Nickel and Hunt 2002) and selected areas of the two Fort Smith sites during the 2004 National Park Service's annual archeological prospection workshop (Haley 2004). A low altitude aerial reconnaissance flight with a powered parachute was also conducted at Fort Smith National Historic Site during the 2004 NPS workshop (Hailey 2004).

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5. 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 also 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 geophysical 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

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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; and Weymouth 1986:341). The project area has a magnetic field strength of approximately 53,400 nT with an inclination of approximately 65° (Peddie 1992; Peddie and Zunde 1988; and 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; and 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 1973,1992:313-381; Burger 1992:389-452; Clark 2000:92-98,174-175; David 1995:17-20; Dorin and Savit 1988:633-749; 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 2001:357-358,2003:441,205, 434-436,2006a:205-233,2006b:235-250; Lowrie 1997:229-306; Milsom 2003:51-70; Mussett and Khan 2000:139-180; Nishimura 2001:546-547; Robinson and Çoruh 1988:333-444; Scollar et al. 1990:375-519; Telford et al. 1990:62-135; Weymouth 1986:343; and Witten 2006:73-116 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

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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; and 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; and 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.

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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; Dobrin and Savit 1988:750-773; Gaffney and Gater 2003:26-36,56-61; Gaffney et al. 1991:2;2002:7; Hallof 1992:39-176; Heimmer and DeVore 1995:29-35,2000:59-60; Kvamme 2001:358-362,2003:441-442;2005:434-436; Lowrie 1997:206-219; Milson 2003:83-116; Mussett and Khan 2000:181-201; Nishimura 2001:544-546; Robinson and Çoruh 1988:445-478; Scollar et al. 1990:307-374; Sharma 1997:207-264; Somers 2006:109-129; Tagg 1964; Telford et al. 1990:522-577; Van Nostrand and Cook 1966; Weymouth 1986:318-341; Witten 2006:299-317; and Zonge et al. 2005:265-300 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; and 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 typical archeological horizontal 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.

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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 and Tagg 1964 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 or potential 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 $\rho_a = 2\pi ar$, where ρ_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; and 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 low to 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 multi-electrode probe array combined with a multiplexer unit, although multiprobe switching resistivity systems are becoming more common (Geoscan Research 1993; Iris Instruments 1999; and 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

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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): $\rho_a = 2\pi r / G.F.$, where ρ_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 ($R = V/I = (1/2\pi) (\rho_1/a_m + \rho_2/a_r)$ where ρ_1 is the resistivity of the soil beneath the mobile probes, a_m is the mobile probe separation distance, ρ_2 is the resistivity of the soil beneath the remote probes, and a_r is the remote probe separation distance). The apparent resistivity can be approximated by the formula $\rho_a = \pi a r$, where the electrode spacing a of both the mobile and remote electrodes are equal, or to $\rho_a = 2\pi a r$ (approximate), where the electrode spacing a is equal to the mobile probe separation when the remote probe spacing is 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 $\rho_2 = 2\pi ((R_1 - R_2)/(1/a_{r1} - 1/a_{r2}))$. The resistivity below the mobile probes can be computed as $\rho_1 = 2\pi a_m R - \rho_2(a_m/a_r)$. 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 versa. 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

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2001:362-363; Lowrie 1997:222-225; McNeil 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 formula $\text{mS/m} = 1000/\text{ohm/m}$ (Bevan 1983; and McNeil 1980a).

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; and 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;

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Clark 2000:118-120,183-186; Conyers 2004; 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; and 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 trade off 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

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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.

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The July 2007 project sought to determine the nature and extent of subsurface features and disturbance within the area of potential effect (APE) of the proposed interpretative heirloom garden plots. The condition of the project area at the time of the survey was stable. The project area was in mown domestic grasses. The work plan for the 2007 geophysical survey (De Vore 2007b) outlined a geophysical inventory and evaluation of historic features within the proposed interpretative garden area between the Officers Quarters on the river side of the second Fort Smith site and the fort wall/railroad right-of-way at the park in a high archeological potential area. The geophysical equipment used in the survey efforts, include the fluxgate gradiometer, a resistivity meter with twin probe array, a resistivity meter with a Wenner probe array for a vertical electrical sounding, ground penetrating radar cart system with a 400 MHz antenna, and an electromagnetic induction meter operated in the conductivity or quadrature phase (Heimmer and De Vore 1995). The geophysical inventory was to be used to identify undisturbed or minimally disturbed areas for the garden and fruit trees that will have the least impact on the cultural resources. It was expected that buried remnants of walkways, fence lines, latrines, and possibly foundations for sheds in the back yards might exist behind the Officers Quarters. While tree plantings were estimated to disturb the ground to a depth of at least 60 to 90 cm (2-3 feet), the park staff proposed to raise the garden deposit so it would have little or no impact on the buried archeological resources. It should be pointed out that MWAC Archeologist William Hunt (personal communications, 2007) argued that future garden tilling and excavation could penetrate into buried archeological deposits, therefore requiring the need for the geophysical inventory and evaluation of the buried archeological resources.

Initially, two reference points for the north-south baseline were set 30 cm on the railroad track side or back yard side of the interpretative brick porch piers for the Officers Quarters. The first reference stake for the north-south base line was placed in the southeast corner of the triangular geophysical survey area between the Officers Quarters interpretative concrete pads and the railroad tracks. The reference wooden hub stake was placed 30 cm from the center of the last interpretative brick porch pier on the southwest side of the Officers Quarters B interpretative concrete pad. A second stake was set approximately 10 m to the north of the first reference point at 30 cm from the interpretative brick porch pier. The wooden hub stakes were used to establish the geophysical survey grid for the project. A north-south base line was along these two reference points and the interpretative brick porch piers. The geophysical grid units were established at the project location with a portable Ushikata S-25 Tracon surveying compass (Ushikata 2005) and 100 meter tape. The surveying compass was used to sight in the two perpendicular base lines and grid corners. The base line was oriented 36 degrees east of magnetic north; however, for future reference in this report, all directions are based on Grid North with this base line oriented to Grid North (0°). The wooden hub stakes for the corners of the 20-m by 20-m grid units (gu) were sighted in with a surveying compass and 100-m tape. Four grid unit corner stakes extended 80 m north of the mapping station, which was designated

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N5020/E5040. Another hub stake was set 10 m south of the mapping station and the grid base line was extended to the edge of the cut bank above the railroad tracks. Beginning with N5030/E5040, the east-west grid unit corner stakes were set along the bank edge. The grid units consisted of two complete and five partial 20-m by 20-m grid units resulting in a triangular shaped geophysical survey area that measured 95 m north-south and 24 m east-west on the north end of the survey area. The geophysical project area consisted of 1,140 square meters or 0.28 acres.

Global positioning system (gps) coordinates were collected on the geophysical grid corners with a Trimble GeoExplorer 3 gps unit (Trimble Navigation 1999). The positional data was collected as Universal Transverse Mercator (UTM) coordinates in Zone 15 North using the North American Datum of 1983 (NAD-83) as the horizontal reference. Once the coordinates were collected, the rover files were downloaded to a field laptop computer for differentially correcting the data in the Trimble Patherfinder Office software (Trimble Navigation 2000). The National Geodetic Survey continuously operating reference station (CORS) 35 miles away at Sallisaw, Oklahoma, was selected as the provider for the base station gps data. The field gps data was differential corrected using the CORS Sallisaw base station data. The corrected data files were then exported to an EXCEL spreadsheet and a point and area map were generated (Figure 9). The corrected data was added to the park's geographic information system (gis) as a layer illustrating the location of the geophysical project grid.

A site map of the project area (Figure 10) was also made with a Nikon DTM-730 field station (Nikon 1993). The mapping station for the instrument was selected near the southeast corner of the survey grid. The arbitrary coordinates for the mapping station were North 5020 and East 5040 with an elevation of 100 meters were used for the mapping station location with the zero degree backsight reference point located at N5040/E5040. The grid unit corner hub stakes, the Officers Quarters interpretative slabs, the fort cistern, the fort perimeter interpretative wall, railroad track cut bank edge, the location of the resistance remote probes, the magnetic and conductivity reference point, the center point of the vertical electrical sounding, and trees within the project were mapped with the field station. The topographic data collected with the field station were downloaded to the field laptop computer with the Nikon TransIt download software (Nikon 1996). Both the coordinate data and the raw field measurement data files were downloaded into the TransIt folder. The data files were then transferred and processed in the WordStar (MicroPro 1989) software program package. Extraneous data fields were striped from the coordinate data file leaving the North coordinate, the East coordinate, and the elevation data field measurements. This processed data file was saved as a SURFER dat file and transferred to the project folder in the SURFER 8 folder for processing. The grid file was constructed from the topographic data. The contour map and data point plot map were constructed in SURFER 8 (Golden Software 2002). A project field map was constructed in SURFER 8 for the final presentation. During the magnetic survey while the survey ropes were in place in each grid unit, a sketch map was also made of relevant surface features. Elements from the completed project map and the sketch map were combined to form the site map of the project area (Figure 11).

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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 at 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 and in the development of the sketch map of the surface features. 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 (Figure 12). The instrument is a vector magnetometer, which measures the strength of the magnetic field in a particular direction (Geoscan Research 1987). The two fluxgate magnetic 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.

The gradiometer sensors must be accurately balanced and aligned along the direction of the field component to be measured. The zero reference point was established at in a quiet area where there were no noticeable localized magnetic variation located at a point approximately 33 meters east of the geophysical grid and Officers Quarters B. The readings should vary less than 2 to 3 nT. The balancing and alignment procedures were oriented to magnetic north. The balance control on the instrument was adjusted

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first. The balancing the instrument was conducted in the 1 nT resolution range to within a range of ± 1 nT. The magnetic sensors were then aligned to within a range of ± 1 nT. 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 zigzag or bidirectional mode beginning in the southwest corner or lower left-hand corner of each grid unit (Table 1). During the survey, data were collected at 8 samples per meter (0.125 m) along each traverse and at one-meter traverses across each individual grid unit resulting in 8 samples per square meter. A total of 3,200 measurements were recorded during the magnetic survey for each complete 20 m by 20m grid unit. With eight samples per meter and one-meter traverses in the zigzag mode, it took approximately 15 minutes to complete a 20m by 20 m grid unit. At the end of the data acquisition of four grid units, the instrument's memory was full and the magnetic data from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research) on a field laptop computer. It took approximately 26 minutes to download the data from memory of the gradiometer when it was full. The grid files identified as to their relative positions in the GEOPLOT mesh file. A composite data file created in GEOPLOT was reviewed in the field prior to the clearing of the gradiometer's memory.

Soil Resistance Survey Methodology

The Geoscan Research RM15 advanced resistance meter and PA5 multiprobe array in a twin probe configuration (Geoscan Research 1996) is used to collect the horizontal resistance data during the geophysical survey of the project area (Figure 13). 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 1.0 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

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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 separated by a distance of approximately one-half meter. The remote probes are connected to the resistance meter by means of a 100-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 100 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 be beyond acceptable survey levels.

During the resistance survey, data were collected at 2 samples per meter (0.5 m) along one-meter traverse across the survey area in a zigzag or bidirectional mode resulting in 2 samples per square meter (Table 2). For each traverse, a total of 40 resistance measurements were recorded in the memory of the Geoscan Research RM15 resistance meter. A total of 800 measurements were recorded for each complete 20-m by 20-m grid unit during the soil resistance survey. At the end of the day, the resistance data from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research 2003) on a laptop computer. It took approximately ten minutes to download the data from the survey. A mesh file of the grid unit relative locations was generated and a composite data file was constructed. The composite file was reviewed in the field prior to the clearing of the resistance's memory.

Vertical Electrical Sounding Methodology

The vertical electrical sounding (VES) is conducted with the Gossen Geohm 40D earth tester with a Wenner probe array (Gossen 1995). The VES was centered at N5100/E5035 with the offset line oriented east-west (Figure 14). 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, 0.7, 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 (Table 3). The distance between the probes also approximates 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 of 26 measurements were recorded along the VES offset line. It took approximately 1.5 hours to set up the array and conduct the vertical electrical sounding at the project area.

Ground Conductivity Survey Methodology

The present survey utilizes a Geonics EM38 ground conductivity meter (Geonics Limited 1992). The instrument is lightweight and approximately one meter in length

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(Figure 15). 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.

Prior to the start of data acquisition, the meter must be nulled and the battery checked for nominal operating voltage. Nulling is 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 the same point used to balance and align the sensors of the fluxgate gradiometer. 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 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 ground conductivity survey was designed to collect 4 samples per meter along one-meter traverses or 4 data values per square meter (Table 4). 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 1,600 data values were collected for each complete 20 m by 20 m grid unit. With four samples per meter (0.25 m) and one-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 DAT38W software. It took approximately 10 minutes to download the data from each complete 20-m by 20-m grid unit. DAT38W converted the header and data files to the Geonics proprietary format. These files were then converted to SUFER file format for further processing on the laptop computer. In SURFER8, the conductivity data for each grid unit was modified to the correct number of survey points corresponding to the sampling strategy (i.e., 800 data points per complete grid units). A image map was generated in SURFER 8. The data was then reviewed 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 Fort Smith geophysical project. 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

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mounting the antenna and control unit (GSSI 2003a). 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 gpr profiles were collected along 0.5 meter traverses beginning in the southwest corner of the grid (Table 5). The data were collected at 512 samples per scan and 50 scans per meter (0.02 m). The time travel interval window was set to a two way travel time of 100 ns. The data were collected in the zigzag or bidirectional mode with the operator returning to the same side of the grid to start the next traverse line. The gpr profiles were collected in the North or y direction. A total of 47 radar profiles were collected across the project survey area for a total linear distance of 3,027 meters. With one-half meter traverses in the parallel mode, it took approximately 15 minutes to complete a 20m by 20 m grid in the zigzag data collection mode. The data folder 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 8.0 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 40 cm. With a 100 ns window open, the total depth displayed was approximately 3.92 meters.

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7. DATA PROCESSING

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);

Filtering 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 data from the instrument was downloaded as grid data files on the laptop computer (Geoscan Research 2003:4/1-29). Each grid file contained the magnetic raw data obtained during the survey of the individual grids. The grid files were reviewed as a shade plot display (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

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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.

In order to process the magnetic data, the grid files from the survey must be combined into a composite file. The first step in creating a composite file is to create a mesh template with the grid files oriented in the correct position in the overall survey of the site (Geoscan Research 2003:3/15-21). Once the grid files have been placed in the correct position in the mesh template, the composite file is generated. The master grid or mesh template is saved as a file for later modification as necessary.

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). The shade plot represents the data in a raster format with the data values assigned 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. 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.

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 geomorphologic 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).

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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. 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 statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire magnetic data composite file for the southern portion of the site. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The magnetic data ranged from -260.0 to 311.4 nT with a mean of 0.37 and a standard deviation of 59.286 after the application of the zero mean traverse algorithm. 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 8×1 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. In the Easting direction, the number of data measurements are expanded to yield an 8×4 data matrix. In the Northing direction, the number of data measurements are shrunk yielding a 4×4 matrix. 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 resulting data is bipolar with a mean near zero representing the background value. The composite data files were then exported to xyz data files for use in the SURFER 8 contouring and 3d surface mapping program (Geoscan Research 2003:5/4-7; Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the xyz data file. Adjustments to the x and y coordinates were made to the data file. The x or Easting and the y or Northing coordinates was divided by four to yield the sample interval position at every 0.25 meters across the magnetic data set. The value 5000 was added to the Northing coordinate and the value 5000 was added to Easting 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. The data is saved as a new file containing the corrections.

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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 geometry is defined for the project area. 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 number of lines should correlate with the number of traverses and samples per traverse. 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 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. Due to the presence of unsurveyed areas along the edges of the rectangular survey area, 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.

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 raster 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 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 data are also clipped to a range between -20 and 20 nT for better visual presentation of the image. 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 a 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 magnetic value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. 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 (Figure 17).

Processing Soil Resistivity Data

In order to process the resistance data, the grid files from the geophysical project area must be combined into a composite file. On the laptop computer, the grid files were arranged in a mesh for the correct location of each grid data file collected during the survey. A composite file was generated for the resistance data for further processing of the resistance data (Geoscan Research 2003). The composite data file was reviewed for data transfer or survey errors. 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).

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. 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 $\pm 1000\%$ 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). Erroneous measurements are first removed from the composite data set through a search and replace routine (Geoscan Research 2003:6/85-86). The function looks for a specific band and replaces it with another specified number, which was the dummy default value of 2047.5. The software recognized this value and does not use it in other processing routines. The noise spikes are removed with the despiking function (Geoscan Research 2003:6/35-39). The function locates and removes random, spurious measurements present in the resistance data. The statistics function (Geoscan Research 2003:6/101-102) is then applied to the entire resistance data set. The mean, standard deviation, and variance are used to determine appropriate parameters for the subsequent processing steps. The resistance data ranges from 4.6 to 62.3 ohms with a mean of 19.22 ohms and a standard deviation of 4.555 ohms after the application of the search and replacement of erroneous reading and the despiking algorithm. 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 2 x 1 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. In the Easting direction, the number of data measurements are expanded to yield an 8 x 4 data matrix. In the Northing direction, the number of data measurements are expanded yielding a 4 x 4 matrix. A high pass filter (Geoscan Research 2003:6/4952) is then used to remove the low frequency, large

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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 resulting data is bipolar with a mean near zero representing the background value.

In SURFER 8 (Golden Software 2002), the initial step is to view the xyz data file. Adjustments to the x and y coordinates were made to the data file. The x or Easting and the y or Northing coordinates was divided by four to yield the sample interval position at every 0.25 meters across the magnetic data set. The value 5000 was added to the Northing coordinate and the value 5000 was added to Easting 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. The data is saved as a new file containing the corrections.

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predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create a 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 magnetic value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. 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 (Figure 18).

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: $\rho_a = 2\pi ar$, where ρ_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 RESIX modeling software package (Butler 1999). The probe spacing and apparent resistivity values were also entered into the spreadsheet in the IX1D modeling software package (Interplex 2002). The first step in the both the RESIX and the IX1D programs was to create a new sounding file for the offset Wenner array data from the site. The probe spacing value and the apparent resistivity value were entered from the processed data in the field notebook to the spreadsheet in the program software (Table 5). The resulting apparent resistivity values in ohm-meters (Sheriff 1973:156) were plotted by electrode spacing. The forward model of the data was carried out using a 283 point adaptive linear filter (Anderson 1979; Davis et al. 1980). The model used the probe spacings data and the apparent resistivity to generate a synthetic response. A three layer model was created for the approximate subsurface electrical layering (Table 6). The graphic file and the data were saved as a binary file (Figure 19). The calculated model values were then hand-transferred to the GRAPHER 7 worksheet for the display of the electrical stratification plot (Golden Software 2007). In GRAPHER 7, the model data was entered into a new worksheet (Golden Software 2007:23). A 2D line graph was illustrating the model was created in GRAPHER 7 (Golden Software 2007:23-24). Using this line 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).

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Processing Ground Conductivity Data

The ground conductivity data were downloaded to a laptop computer at the end of the survey of the geophysical project. The data were processed using the DAT38W software (Geonics 2002). After the transfer of the data and header files to the laptop computer, the files were automatically converted from the raw EM38 format to DAT38 format with the extension name of G38 (Geonics 2002:12-14). The data were then displayed as data profile lines (Geonics 2002:14-15). The individual EM38 data file was then converted to XYZ coordinate file in the Surfer data format. To create the XYZ file, the orientation or direction of the survey line was selected in the DAT38W program along with the data type and format (Geonics 2002:20-23). The resulting XYZ data file was transfer to the SURFER 8 mapping software (Golden Software 2002). The conductivity data were reviewed and an image plot was generated in SURFER 8. To further process the conductivity data, it was transferred to GEOPLOT. The conductivity data were stripped of the X and Y coordinates and then the Z values (measurements) were imported into GEOPLOT for further processing (Geoscan Research 2001). The resulting grid files were formatted to form a composite file in GEOPLOT. The search and replace function was applied to correct erroneous data values. The interpolation routine was applied to the data set to arrange the data from the 4 x 1 data matrix to an equally spaced 4 x 4 square matrix. A high pass filter was then applied over the composite data set. The high pass filter was used to remove low frequency, large scale spatial detail such as a slowly changing geological 'background' trend. The resulting data is bipolar with a mean near zero representing the background value. The data were then exported as an ASCII dat file and placed in the SURFER 8 mapping program. The data were then exported as an ASCII dat file and placed in the SURFER 8 mapping program. An image and contour plot of the resistance data was also generated for the survey area (Figure 20). The conductivity data from the site after the search and replace routine was applied ranged from -114.6 mS/m to 174.3 mS/m with a mean of 50.61 mS/m and a standard deviation of 36.729 mS/m.

Processing Ground-penetrating Radar Data

The gpr radargram profile line data is imported into GPR-SLICE (Goodman 2007) for processing. The first step in GPR-SLICE is to create a new survey name in the files menu. A new information file is created to identify the number of profiles, the name of the file, the data format, the direction of the survey or data collection, starting and ending points for the northing and Easting coordinates, the number of unit markers, the time window, samples per scan, number of scans per mark, and the type of data. Errors in the information can also be edited once the information file has been created. The next step is to transfer the profile data into the user folder where the original raw data is maintained through further processing steps. The profile data is then converted and regained. The conversion routine removes extraneous header information in the raw16-bit GSSI radargrams. During the conversion process, the signal may be enhanced by applying gain to the radargrams. Since the radargrams were collected in the zigzag or bidirectional mode, every other profile data set needs to be reversed. The next step is to

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insert navigational or locational markers into the resample radargrams. 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 35 to allow for adequate overlap between the slices. The first radargram sample value on the radargram where the first ground reflection occurs is set to 0 ns. This value is used to identify the first radargram sample at the ground surface. The cut parameter is set to square amplitude with the cuts per mark set to 4. The profile data is then sliced into 20 horizontal slices. Before crating the grid files of the sliced data, and XYZ data file is created for each slice layer. The next step is to create time slice pixel maps. The slice data is gridded which interpolates between the XYZ data. The grids can be very course as in the initial 20 gridded slices or additional interpolation between the data in each slice can be created to provide a smoother data set for the creation of a 3D data cube. A low pass filter may be applied to the combined dataset to smooth noisy time slices in the gridding process. At this point, one may view the time sliced radar data in the pixel map routine (Figure 21). Generally, one time slice from a survey is selected for further display and analysis. An image and contour plot of the gpr time slice 3 (10-15 ns) data was also generated (Figure 22). The gain may be readjusted for any time slice or the entire set of slices may be auto-gained automatically. The new interpolated grids are all normalized. The next step is to create the 3D dataset. The number of grids is now equal to 95 $((20-1)*5)$. The 3D database is created and 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. 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-position 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

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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). 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.

The slice option provides the means to specify the number and type of plots either in time slices or depth slices. Time 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: $D = V \times T/2$ 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 effects 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. 0.08 m/ns.

8. DATA INTERPRETATION

Andrew David (1995:30) defines interpretation as a “holistic process and its outcome should represent the combined influence of several factors, being arrived at through consultation with others where necessary.” Interpretation may be divided into two different types consisting of the geophysical interpretation of the data and the archaeological interpretation of the data. At a simplistic level, geophysical interpretation involves the identification of the factors causing changes in the geophysical data. Archeological interpretation takes the geophysical results and tries to apply cultural attributes or causes. In both cases, interpretation requires both experience with the operation of geophysical equipment, data processing, and archeological methodology; and knowledge of the geophysical techniques and properties, as well as known and expected archeology. Although there is variation between sites, several factors should be considered in the interpretation of the geophysical data. These may be divided between natural factors, such as geology, soil type, geomorphology, climate, surface conditions, topography, soil magnetic susceptibility, seasonality, and cultural factors including known and inferred archeology, landscape history, survey methodology, data treatment, modern interference, etc. (David 1995:30). It should also be pointed out that refinements in the geophysical interpretations are dependent on the feedback from subsequent archeological investigations. The use of multiple instrument surveys provides the archeologist with very different sources of data that may provide complementary information for comparison of the nature and cause (i.e., natural or cultural) of a geophysical anomaly (Clay 2001). Each instrument responds primarily to a single physical property: magnetometry to soil magnetism, electromagnetic induction to soil conductivity, resistivity to soil resistance, and ground penetrating radar to dielectric properties of the soil to (Weymouth 1986b:371).

Interpretation of 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 contrast 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 effects 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.,

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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 is made of magnetic poles (North or positive and South or negative). A simple dipole anomaly contains the pair of opposite poles that are 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 effect on the magnetic field.

Magnetic anomalies of archeological objects tend to be approximately circular in contour outline. The circular contours are caused by the small size of the objects. The shape of the object is seldom revealed in the contoured data. The depth of the archeological object can be estimated by half-width rule procedure (Bevan 1998:23-24; Breiner 1973:31; Milsom 2003:67-70). 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 archeological 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: 1) dipole, 2) monopole, and 3) linear.

There are numerous dipole and monopole magnetic anomalies in the data set from the magnetic survey of geophysical project area at the second Fort Smith site (Figure 23). The magnitude, orientation of the dipole, and shape and size of the anomalies suggest that

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the vast majority of the anomalies are caused by modern ferrous materials related to the Coca-Cola bottling plant and more recent park activities at the site (Figure 24). A linear anomaly running parallel to N5088 may represent an abandoned city storm drain (Mickle Daniel Associates 1964:Sheet 4). Several other linear anomalies along the eastern part of the survey grid appear to be related to the garage at the Coca-Cola bottling plant. The garage along the railroad tracks consisted of an automobile repair shop, a greasing bay, and parking bays for 7 cars (Sanborn 1950). The magnetic anomalies may represent remaining portions of the foundation to the garage, subsurface level service bays associated with the garage, or drainage lines from the garage and perhaps the bottling plant. Along the edge of the railroad cut bank, several magnetic anomalies are also present. It is possible that some of these may represent the location of the security fence for the Coca-Cola bottling plant. Others may be associated with rubble and debris from the demolition of the plant buildings along with other more recent NPS trash discarded next to the railroad tracks. A small triangular area between N5020 and N5050 contains relatively few magnetic anomalies away from the cut bank.

Interpretation of 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 are 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 resistivity values. Large general trends reflect changes in the site's geology whereas small changes may reflect archeological features.

There is a low value, linear resistance parallel to N5088, which may relate to the abandoned storm water line (Figure 25). A high value, linear resistance anomaly extending from the northern edge of the survey grid at N5100/E5025 to N5064/E5023 is associated with the interpretative stone line of the fort's perimeter wall. Several high value resistance anomalies correspond to the location of the Coca-Cola bottling plant's garage next to the railroad track cut bank. Based on the results of the archeological monitoring of the demolition of the Coca-Cola facility (Coleman 1984a), these are probably rubble piles or foundation remnants associated with the garage. A linear anomaly at the edge of the cut bank above the railroad tracks appears to be in the location of the security fence surrounding the bottling plant. This also an area where debris has collected at the edge of the cut bank. Three areas on the east side of the survey grid appear roughly rectangular. The one near the south end of the garage appears to coincide with stone rubble

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pile identified during the archeological monitoring of the plant's demolition. The one at the south end of the survey grid appears to be in the same location as a stone rubble and circular sand lens identified as features associated with the second fort. One small highly resistance anomaly in the northeastern portion of the survey area is directly associated with the modern tree planed by the park staff.

Interpretation of Vertical Electrical Sounding Data

The results of the modeling of the vertical electrical sounding data from the site suggest a three-layer curve for the electrical stratification of the soil. Using the 2D line graph as the background, an electrical stratigraphic block diagram is created by inserting rectangles in the data ranges (Figure 26). The rectangles are subsequently filled and labeled with the appropriate ohm-meter value from the model for the final presentation (Golden Software 2007:24-38). The model indicates that the upper 0.14 meters have an apparent resistivity of 14.41 ohm-meters, the second 1.93 m thick layer measures 10.88 ohm-meters, and the bottom layer measures 0.61 ohm-meters. This model suggests a very conductive silt loam soil grading into an extremely conductivity silty clay in the lower level of the vertical electrical sounding.(Bevan 1998:8; McNiel 1980:16; Telford et al. 1990:289-291). The upper levels may be indications of fill brought into the area to level the area behind the interpretative Officers Quarters concrete slabs. The very conductive 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 of 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 security fence line noted in the magnetic gradient and resistance survey data along the cut bank above the railroad tracks (Figure 27). A series of negative conductivity anomalies along the cut bank may indicate locations of the steel posts for the security fence or discarded metal objects along the cut bank edge. 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 chain link fence

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wire or steel fence posts. As number of linear low conductivity anomalies surrounded by high conductivity values appear to represent buried pipes. The one parallel to N5088 correspond to the location of the abandoned storm drain also identified in the magnetic and the resistance data sets. A second linear conductivity anomaly parallel to N5074 may be associated with a buried pipe from the bottling plant. Other linear conductivity anomalies appear to be inside the location of the plant's garage and may be drain lines associated with activities at the garage. It is also possible that these anomalies represent reinforced concrete foundations of the automobile bays in the garage. In addition to the linear anomalies, there are a few isolated negative conductivity anomalies in the survey area. It is probable that such anomalies represent buried metallic objects. As in the magnetic data, there is an area that contains little conductivity variation, which may be viewed as background values not associated with buried conductivity materials in the southern portion of the survey area.

Interpretation of 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 relationship 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 6 ns intervals with an overlap of 6.84 ns. The interpretative stone perimeter wall is identified as a linear reflection extending from the north side of the survey grid to the cut bank (Figure 28). The areas of highly reflective gpr anomalies area present. The northern most area is directly associated with the location of the Coca-Cola garage. Within this gpr anomalous area several linear anomalies appear to represent buried pipe also noted in the magnetic, resistance, and conductivity data sets including the abandoned storm drain. The oblong cluster of gpr high reflection anomalies centered near N5053/E5035 appears to be in the same location as the stone rubble pile affiliated with flagstone from the second fort site. The third area located along the edge of the cut bank south of the garage location may be rubble form the demolition of the bottling plant garage or more recent debris dumped along the edge of the cut bank by the park staff.

Combined Geophysical Data Set Interpretations

A different way of looking at the geophysical data collected during the investigations of the survey area at proposed interpretative heirloom garden location is to combine

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the complementary data sets into one display (Figure 29). A number of the different geophysical anomalies overlap suggesting a strong correlation between the geophysical data and the buried archeological features (Ambrose 2005). The locations of the interpretative stone perimeter wall, the Coca-Cola garage, buried utility lines including the abandoned storm drain, and the security fence surrounding the bottling plant are apparent in the complementary data sets. The locations of the garage's foundations or service bays are identified in three of the four data sets, while the concentration of geophysical anomalies associated with the historic fort and the more recent Coca-Cola bottling plant occupations are identified in all four complementary data sets. These areas of strong correlation suggest the presence of a buried archeological target that would be of interest to the archeological investigations. These areas of overlap would be considered areas of high probability areas for ground truthing and the investigations of buried archeological resources. While these correlations are important, individual isolated occurrences also need ground truthing in order to determine their unique nature as well. It also interesting to note that a small triangular area in the southern portion of the survey area is relatively devoid of conductivity, resistance, ground penetrating radar, and magnetic anomalies.

9. CONCLUSIONS AND RECOMMENDATIONS

During July 16 to 19, 2007, the Midwest Archeological Center and Fort Smith National Historic Site staffs conducted geophysical investigations at the second Fort Smith site within the City of Fort Smith in Sebastian County, Arkansas. The project was conducted in response to the park's request for the non-destructive and non-invasive investigations of a triangular area between the Officers Quarters location and the modern railroad tracks in response to a proposed plan to construct interpretative heirloom garden plots and place some fruit trees behind the concrete slabs marking the locations of the two Officers Quarters. The project location coincides with the backyards of the Officers Quarters on the west side of the second Fort Smith enclosure. During the investigations, 1,140 square meters or 0.28 acres were surveyed with a fluxgate gradiometer, a resistance meter and twin probe array, a ground-penetrating radar cart system and 400 mHz antenna, and an electromagnetic induction meter in the conductivity mode.

The magnetic gradient, resistance, and ground conductivity data collected at the cemetery site provided information of the physical properties (magnetic, resistance, conductance, and ground-penetrating radar reflections) of the subsurface materials. Several small scale magnetic gradient, 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 the Coca-Cola security fence, the garage, rubble from the second Fort Smith, and buried utility lines. There area several high magnetic gradient dipoles as well as a number of weak magnetic gradient dipoles. The strong magnetic gradient dipoles represent large concentrations of magnetic iron, probably of recent or modern origin. Weaker magnetic gradient dipole and monopole anomalies may be associated with the historic occupation at the site.

This report has provided an analysis of the geophysical data collected during four days at the area behind the interpretative Officers Quarters concrete slabs. Based on the evaluation of the geophysical anomalies, the majority of the anomalies appear to be associated with the 20th century Coca-Cola bottling plant, especially the garage. Due to the high impact of the construction and demolition of the Coca-Cola bottling works, this portion of the Fort Smith National Historic Site (3SB79) lacks intact historic features associated with the second Fort Smith site. It is still possible that historic features associated with the prehistoric or fort period may exist at a depth beyond the range of the ability of the geophysical instruments to detect. Since the plans for the interpretative heirloom gardens call for the use of raised garden plots, which will in effect bury the present ground surface, there is no further need for archeological investigations of the project area in the proposed garden plot locations. The proposed garden plot locations should, however, be covered with geo-textile fabric to separate the existing ground surface from the introduced garden plot fill. The fill also needs to be sterile of any prehistoric or historic cultural material. If fruit trees are to be planted, the excavation of the holes for the tree root ball needs to be monitored by a professional archeologist.

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

GENERAL			
Acquisition	value	Instrumentation	value
Sitename	FOSM	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)	1.0 m	Averaging	Off
Traverse Mode	ZigZag	Averaging Period	16

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

GENERAL			
Acquisition	Value	Instrumentation	value
Sitename	FOSM	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)	1.0 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	

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Table 3. Offset Wenner array resistivity data centered at N5040/E5070.

N5100/E5035				$\rho_a = 2 \pi R d$
Probe spacing (m)	East (left) offset resistance reading (ohms)	West (right) offset resistance reading (ohms)	Average resistance reading (ohms)	Apparent resistivity (ohm-meters)
0.1	23.80	23.6	23.70	14.891
0.15	15.12	15.05	15.085	14.217
0.2	12.77	12.70	12.735	16.003
0.3	6.49	6.50	6.495	12.243
0.4	5.04	4.68	4.86	12.215
0.5	4.01	3.92	3.965	12.456
0.7	2.77	2.67	2.72	11.963
1.0	1.74	1.75	1.745	10.964
1.5	1.03	0.96	0.995	9.378
2.0	0.65	0.64	0.645	8.105
3.0	0.28	0.28	0.28	5.278
4.0	0.22	0.18	0.20	5.027
5.0	0.03	0.12	0.075	2.356

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

Acquisition	value	Instrumentation	Value
Sitename	FOSM	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)	1.0 m		
Traverse Mode	Parallel		

TABLES

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

GENERAL			
Acquisition	value	Instrumentation	Value
File Nam	FOSM	Survey Type	GPR
Number of Profile Lines	47	Instrument	GSSI TerraSIRch SIR 3000
Dir. 1 st Traverse	N	Samples/scan	512
Grid Length (x)	20 m	Bits/sample	16
Scans/meter	50	Scans/second	50
Grid Width (y)	20 m	Meters/mark	1
Traverse Interval (y)	0.5 m	Diel Constant	8
Traverse Mode	Zigzag	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	

Table 6. Vertical electrical sounding model centered at N5100/E5035.

Number of layer	Apparent resistivity (ohm-meters)	Thickness of layer (m)
1	14.41	0.141
2	10.88	1.929
3	0.61	

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FIGURES

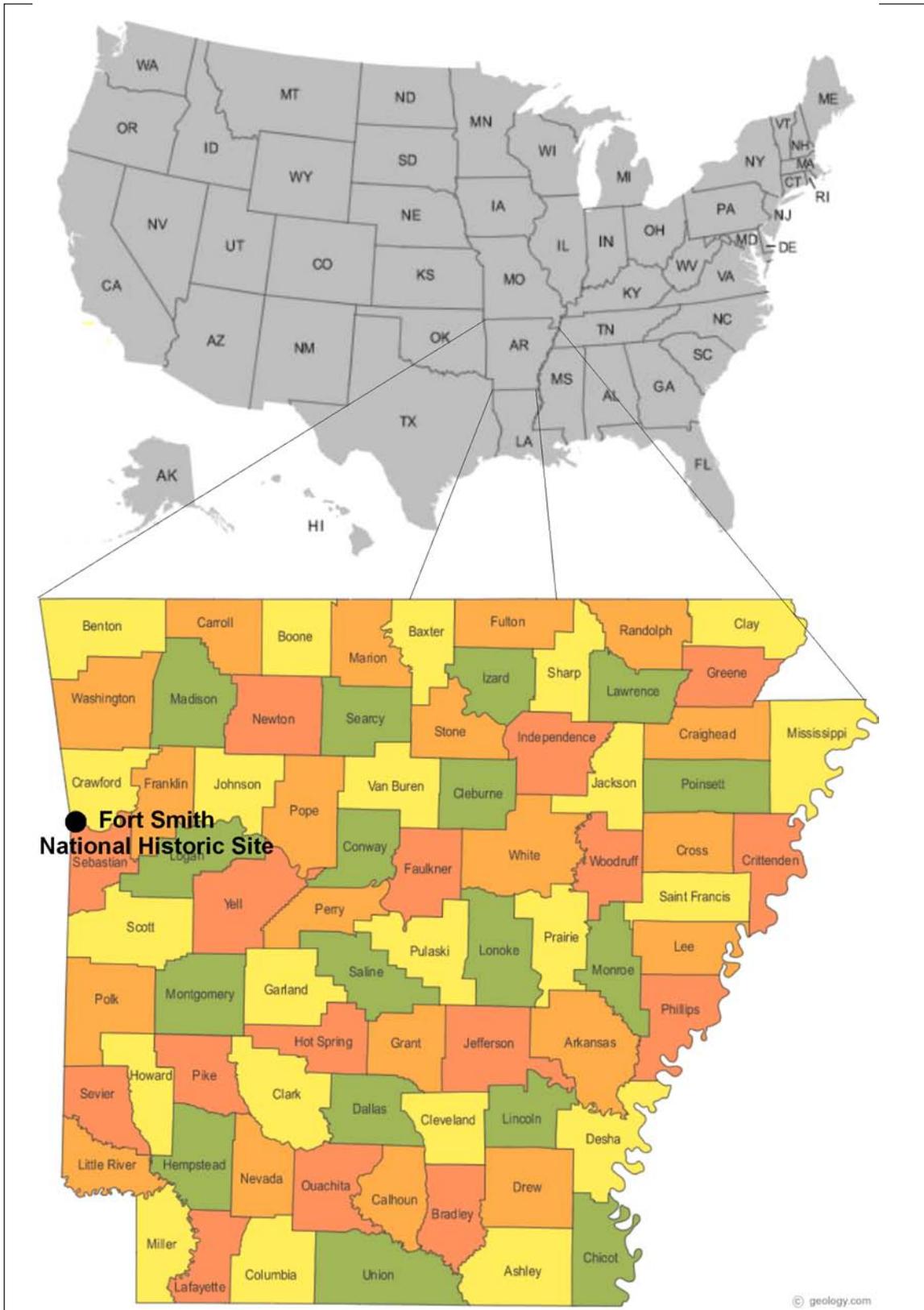
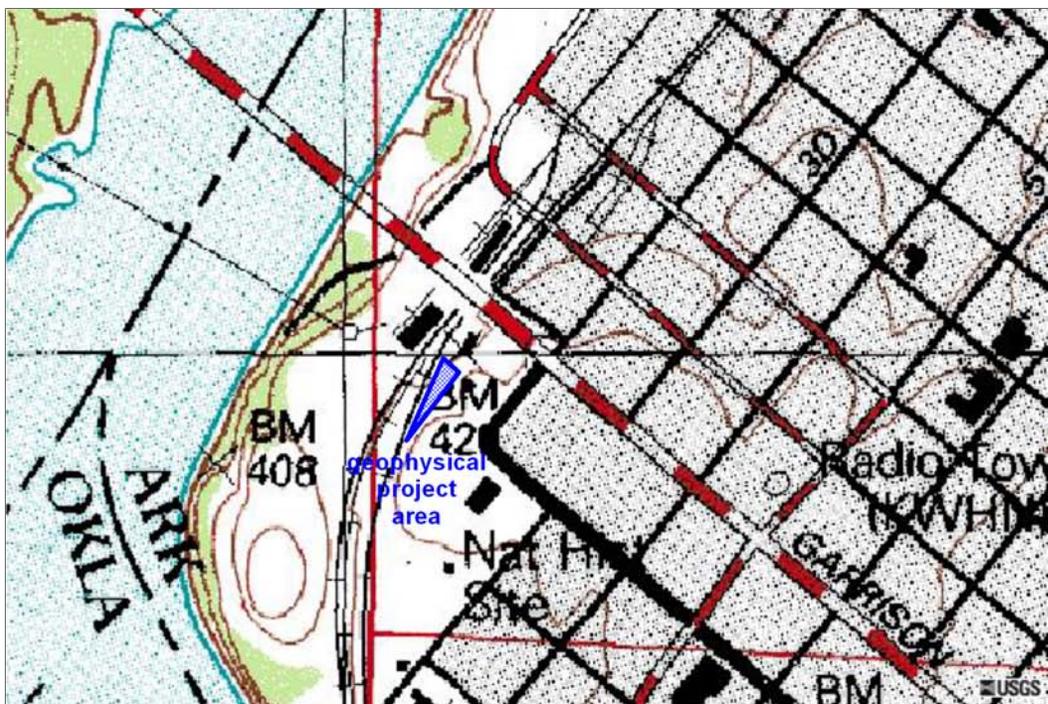
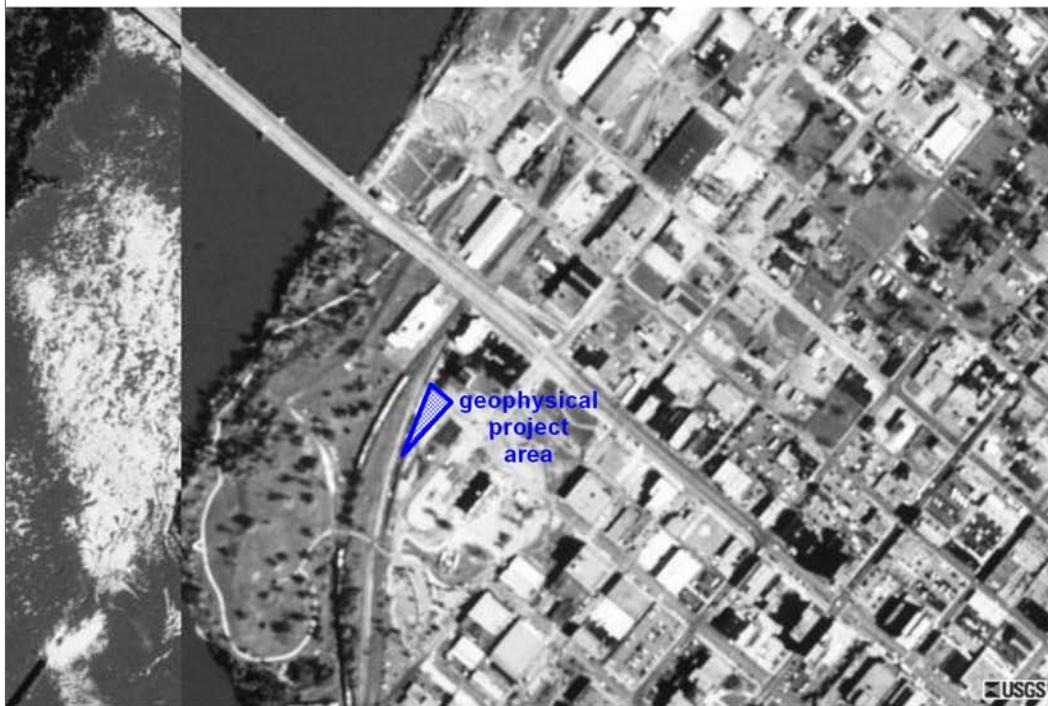


Figure 1. Location of the Fort Smith National Historic Site, Sebastian County, Arkansas.

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a) USGS topographic map of Fort Smith, Arkansas (dated 7/1/1995)



b) USGS aerial photograph of Fort Smith, Arkansas (dated 4/4/2000)

Figure 2. Geophysical project area at the Fort Smith National Historic Site, Fort Smith, Arkansas.

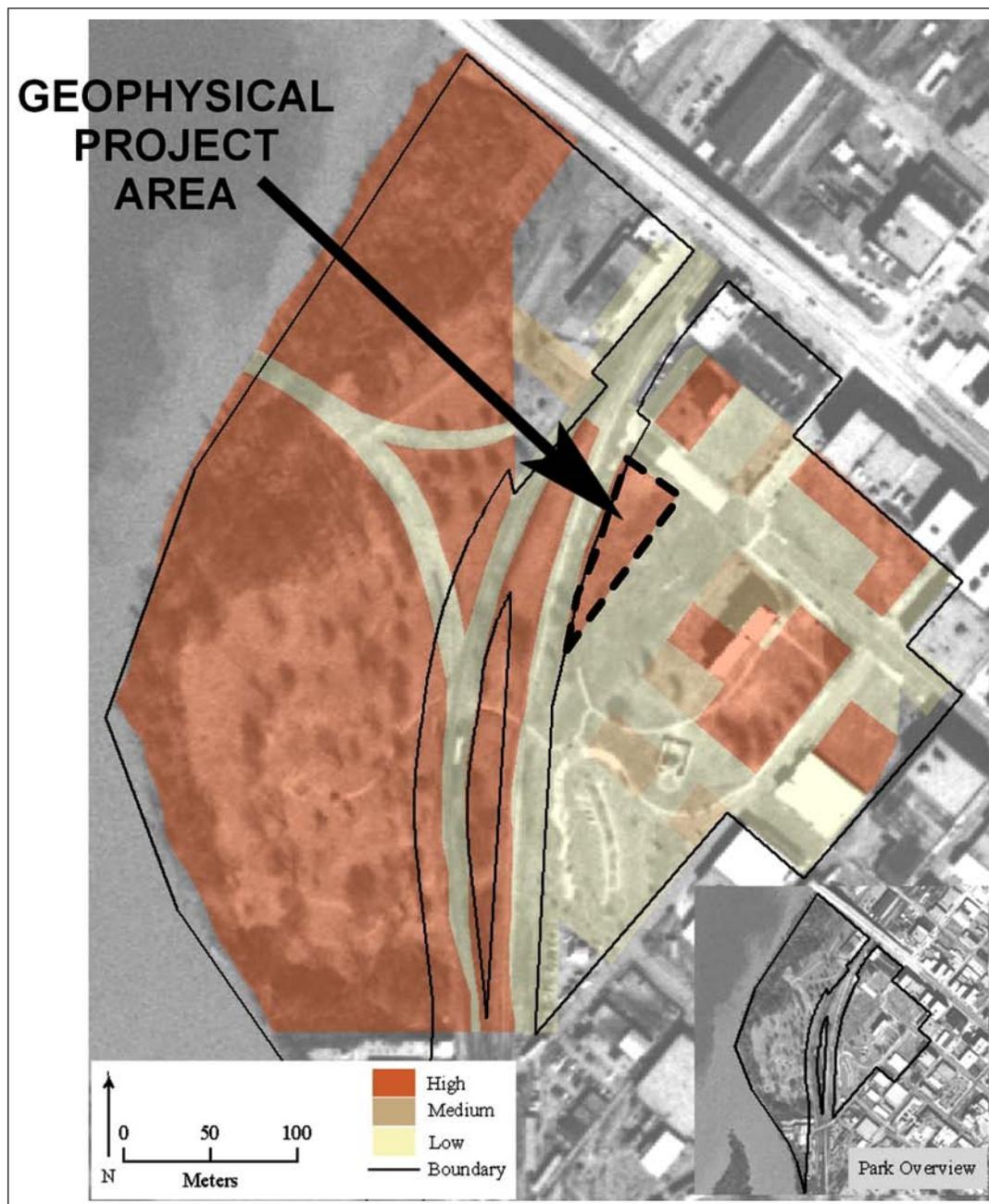


Figure 3. Geophysical project area within high potential archeological resource zone.

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Figure 4. Aerial view of the geophysical project area.



Figure 5. General view of the geophysical project area.



Figure 6. General view of the geophysical project area.



Figure 7. Geophysical project area from the north side with the interpretative stone perimeter wall in center of view.

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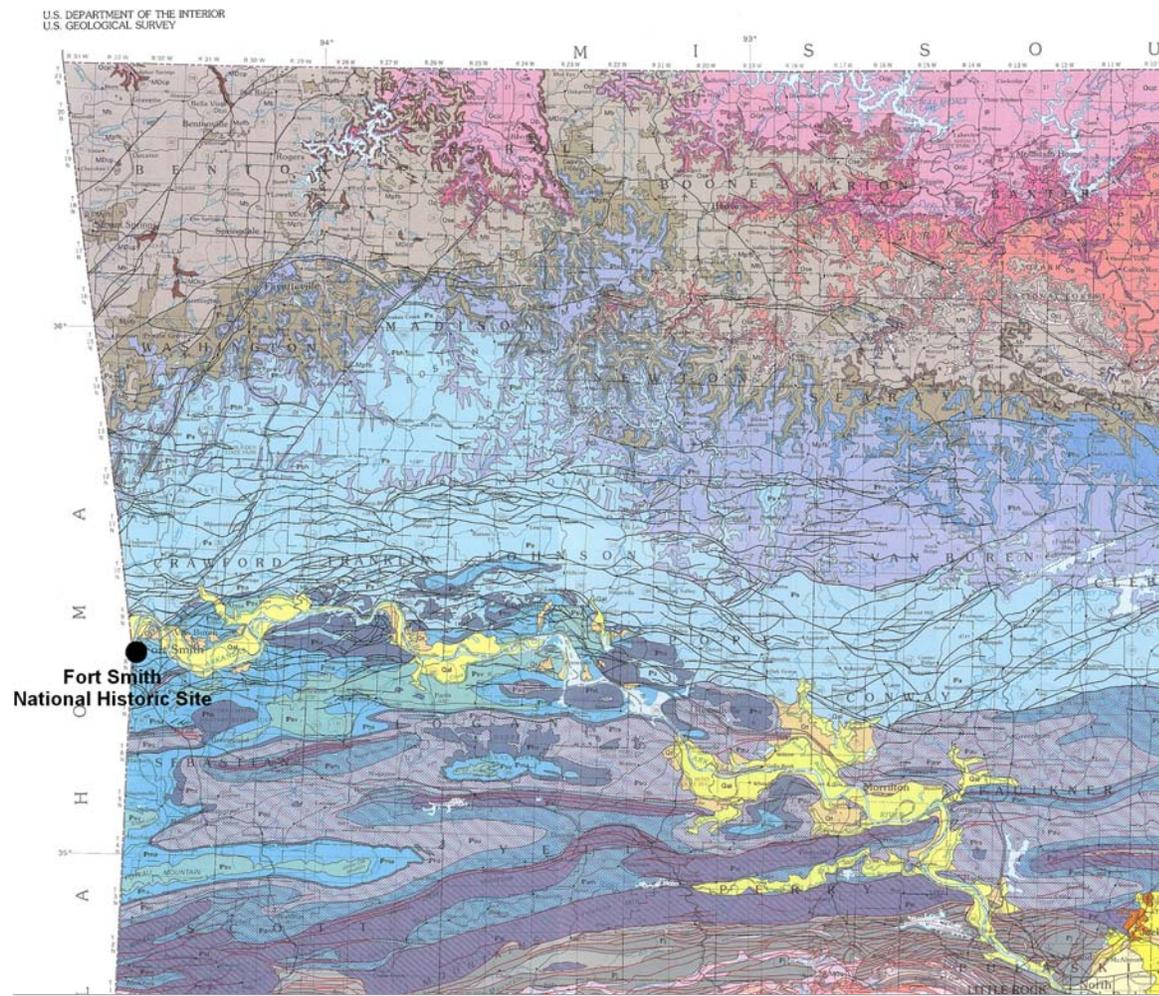


Figure 8. Geological map of northwestern Arkansas.

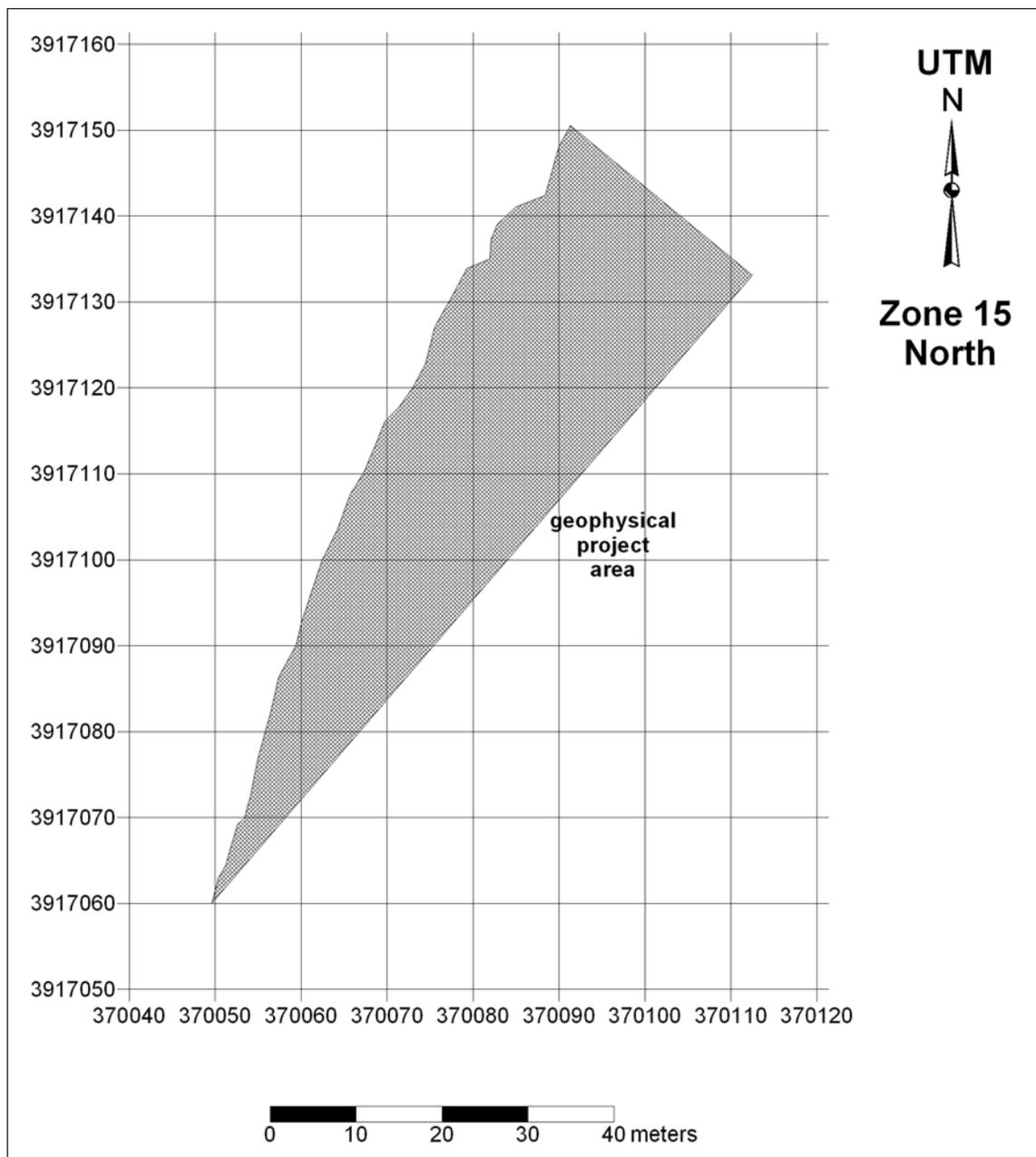


Figure 9. Global positioning system location of geophysical project area at Fort Smith National Historic Site.

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Figure 10. Mapping the project area with a Nikon DTM-730 field station.

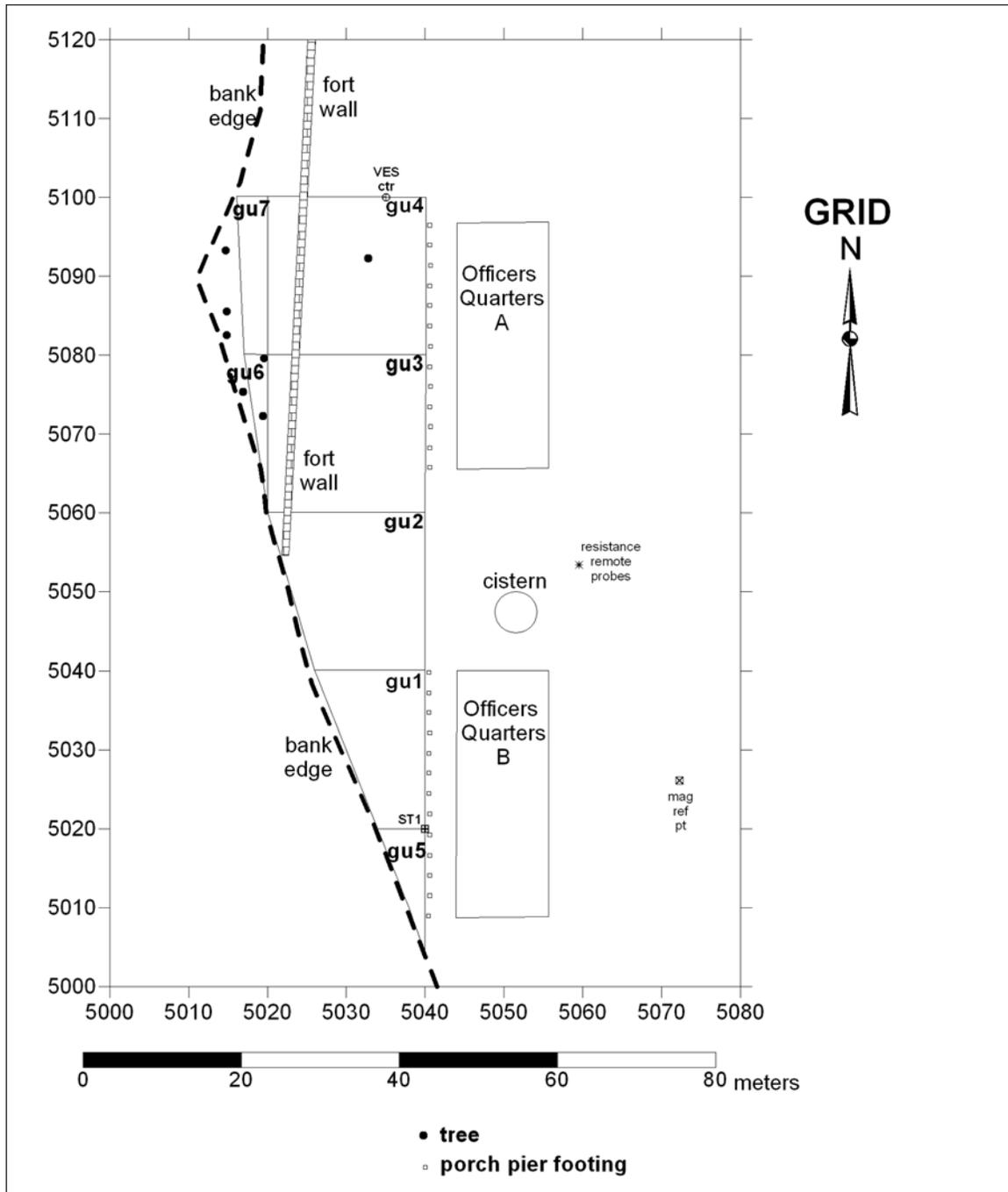


Figure 11. Project map of the archeological prospection project area at Fort Smith National Historic Site.

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Figure 12. Conducting the magnetic survey with a Geoscan Research FM36 fluxgate gradiometer.



Figure 13. Conducting the resistance survey with a Geoscan Research RM15 resistance meter and PA-5 multi-probe array in the twin probe array configuration.



Figure 14. Conducting a vertical electrical sounding with a Gossen Geohm 40D earth tester or resistivity meter and offset Wenner probe array.



Figure 15. Conducting the conductivity survey with a Geonics EM38 ground conductivity meter.

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Figure 16. Conducting ground penetrating radar survey with GSSI TerraSIRch SIR System-3000 and 400 mHz antenna.

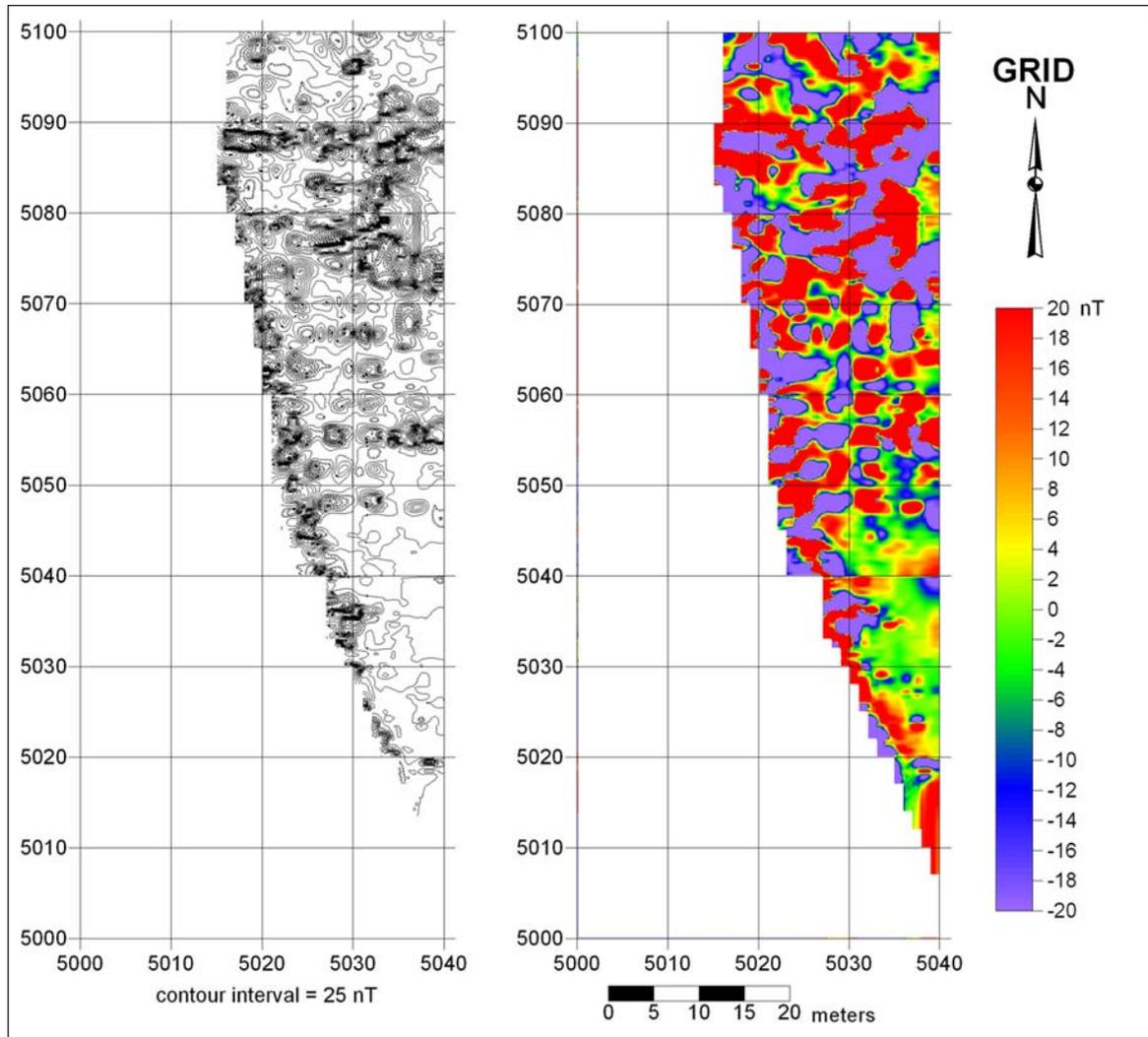


Figure 17. Magnetic image and contour data plots.

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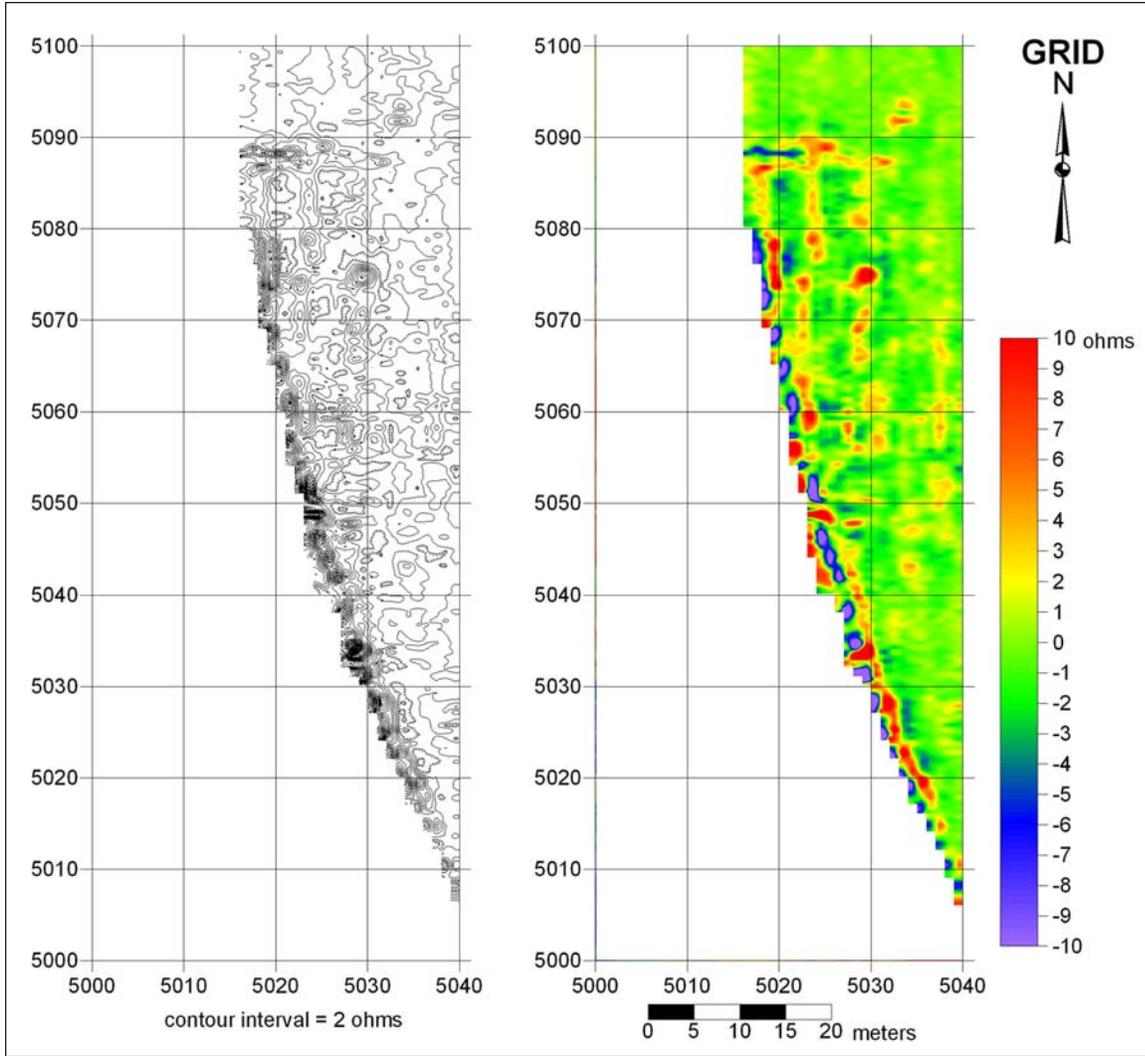


Figure 18. Resistance image and contour data.

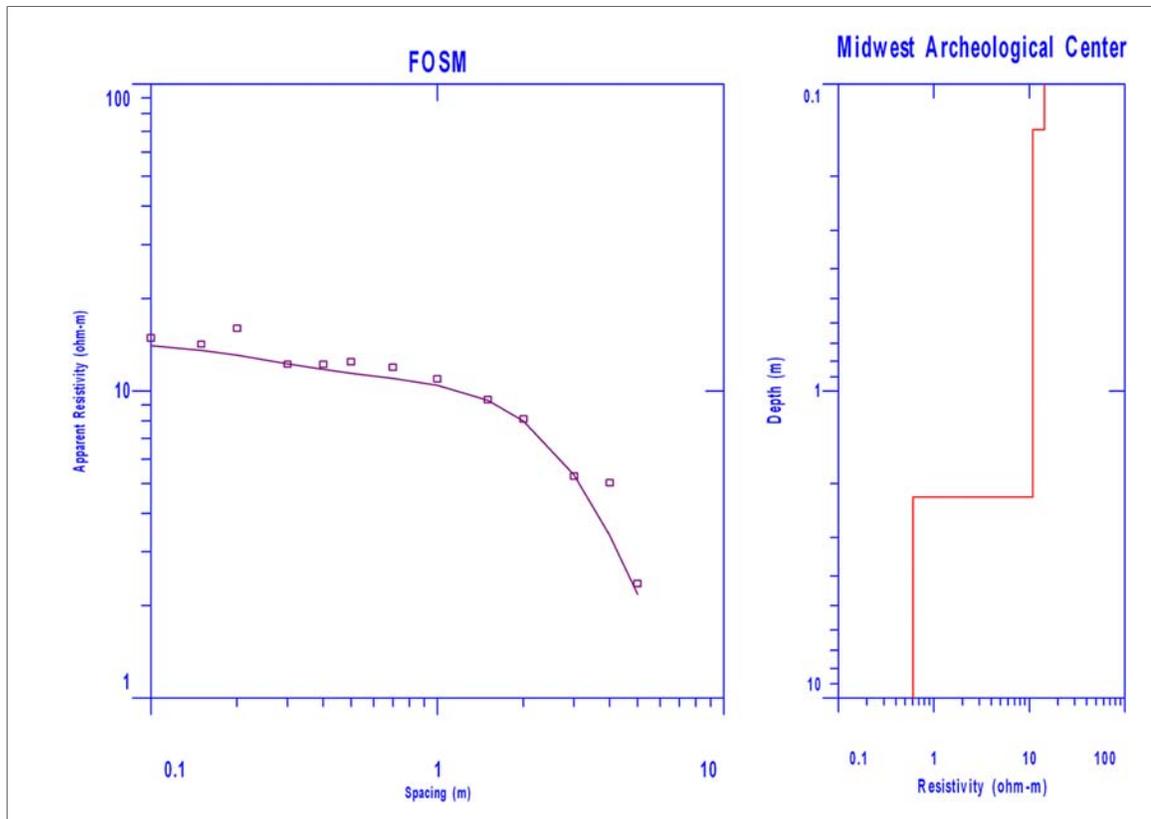


Figure 19. Resistivity data and model for vertical electrical sounding centered at N5100/E5035.

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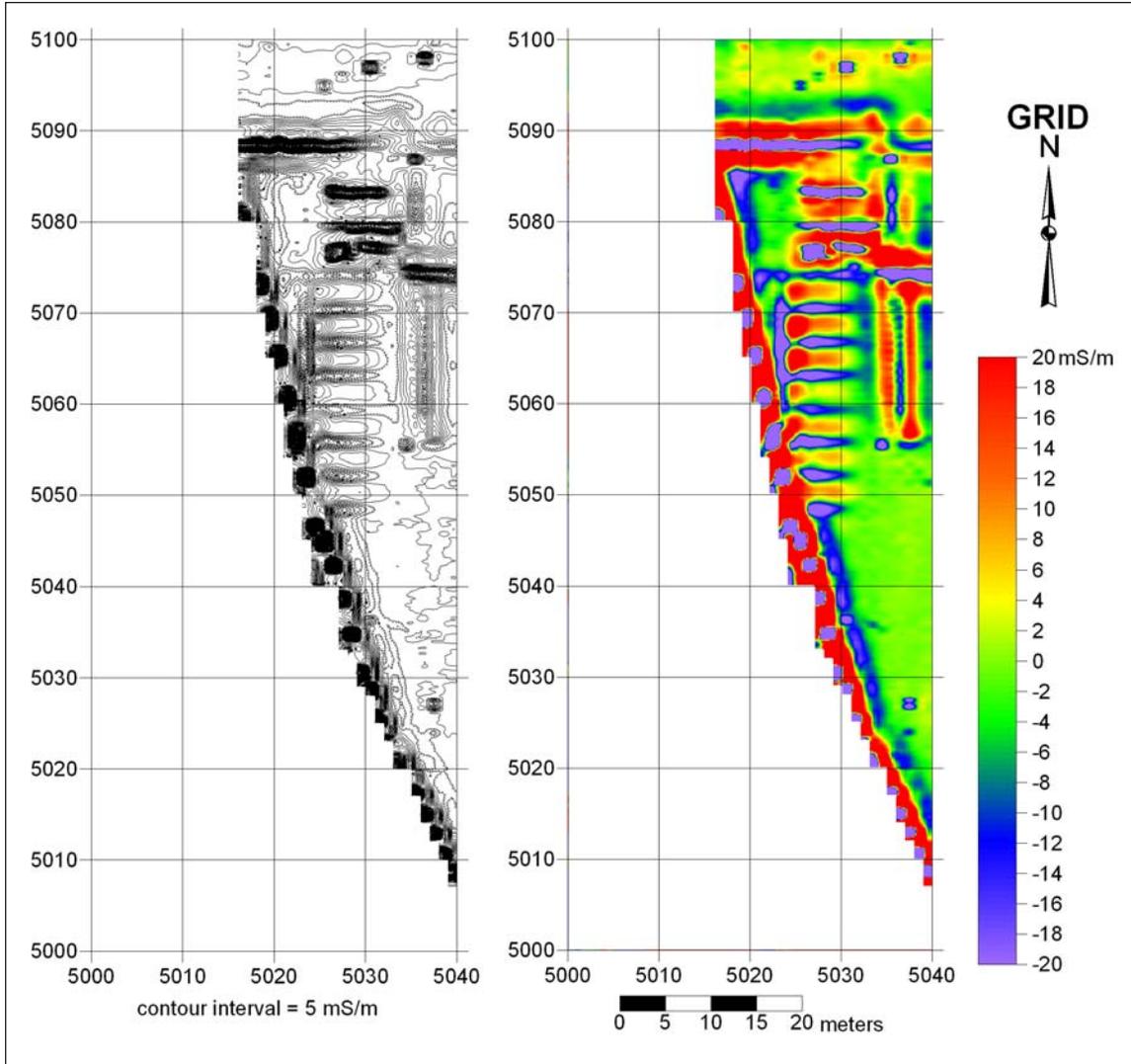


Figure 20. Conductivity image and contour data.

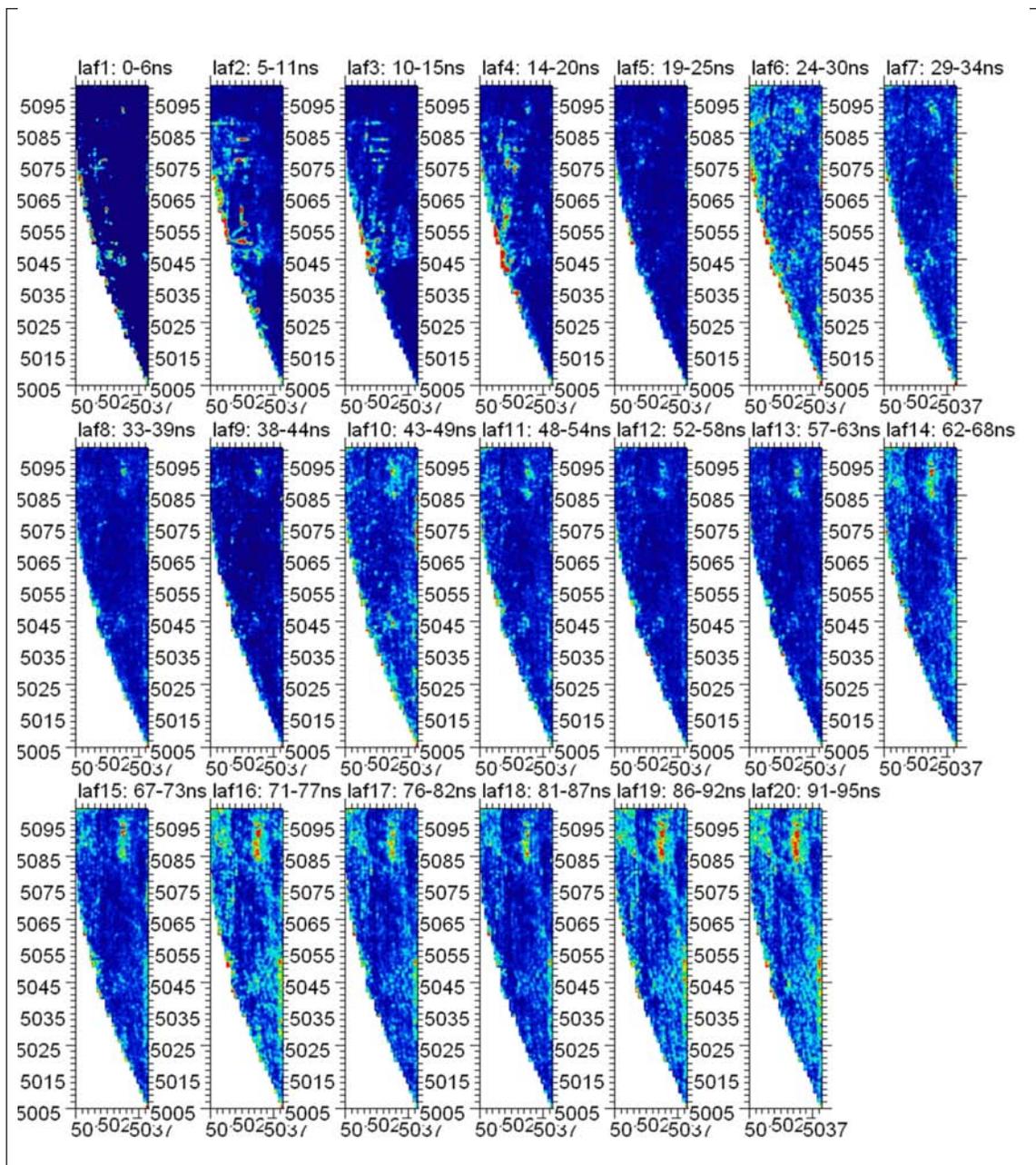


Figure 21. Ground penetrating radar time slices.

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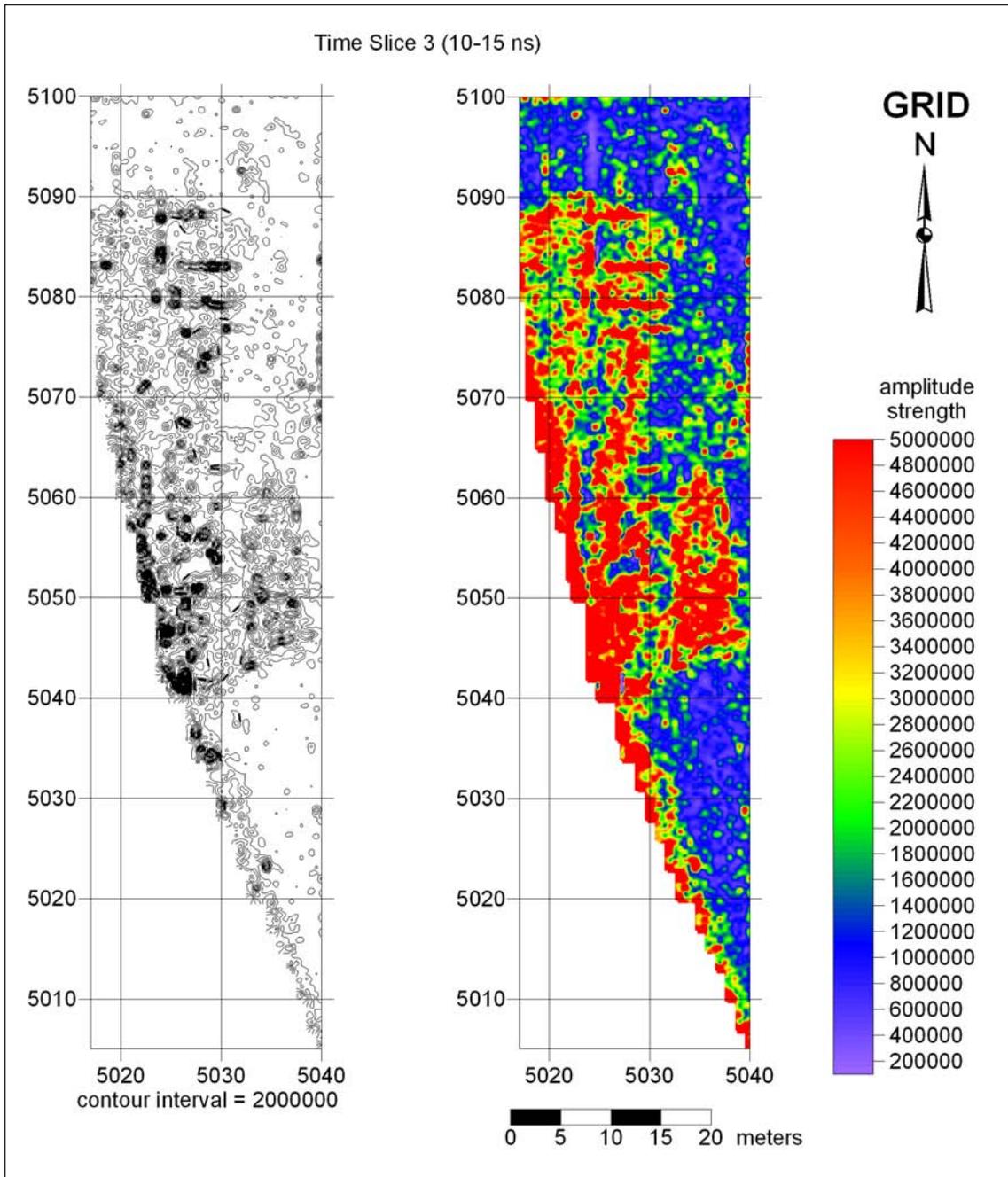


Figure 22. Ground-penetrating radar time slice 3 contour and image data.

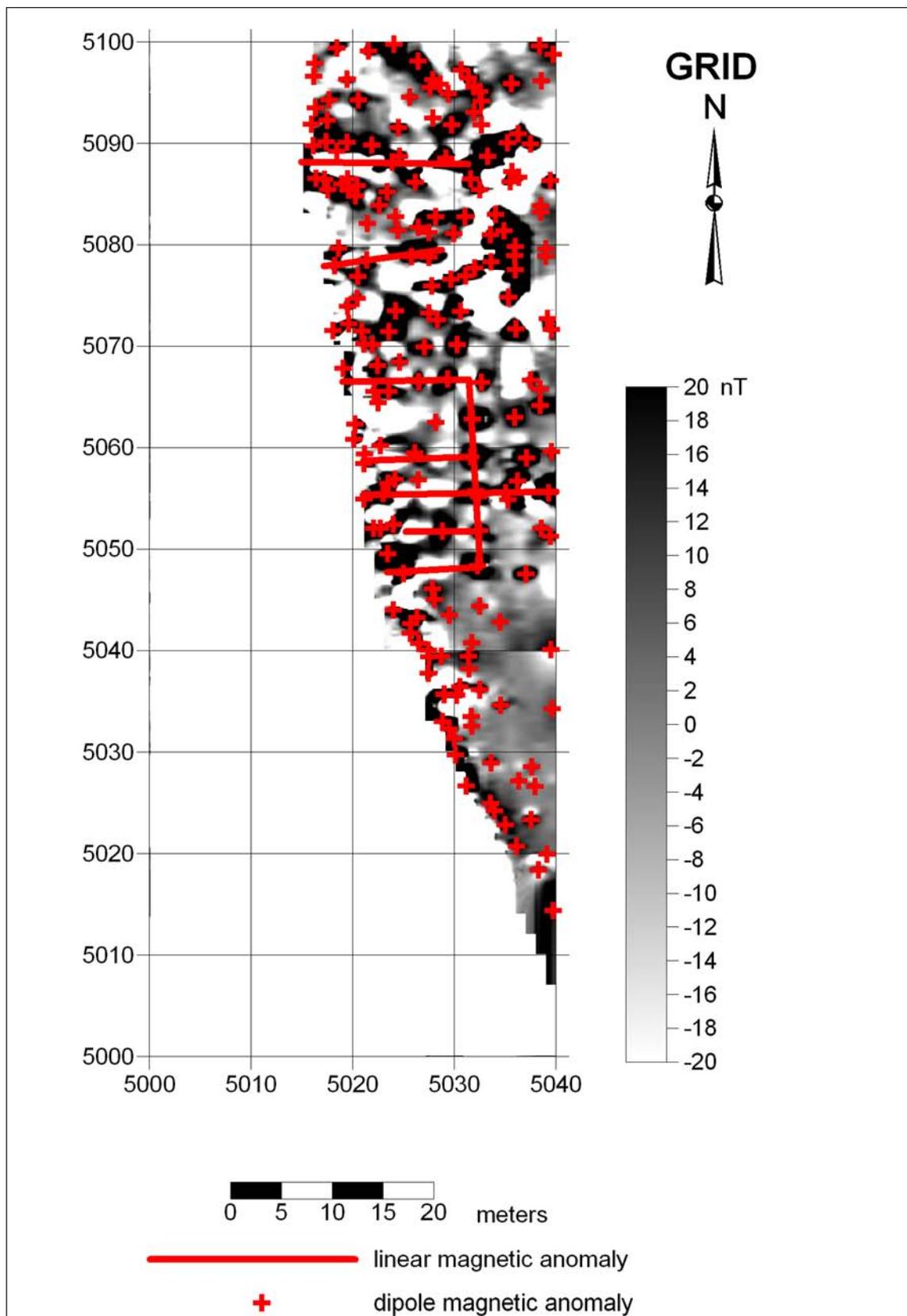


Figure 23. Interpretation of the magnetic data from the geophysical project area.

FORT SMITH

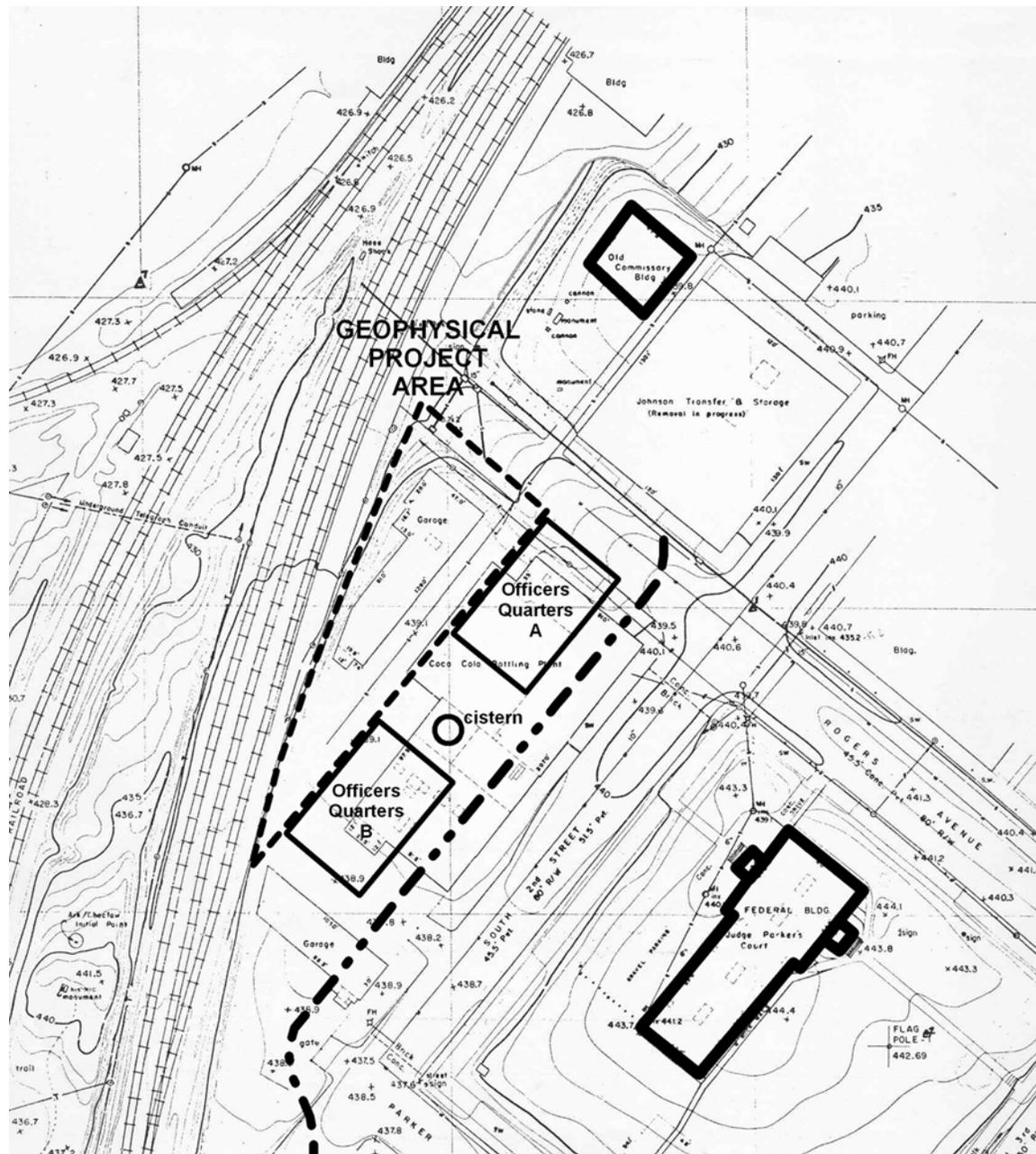


Figure 24. Geophysical project area overlain on park topographic map with location of the Coca-Cola bottling plant facilities and location of the second Fort Smith building and interpretive features.

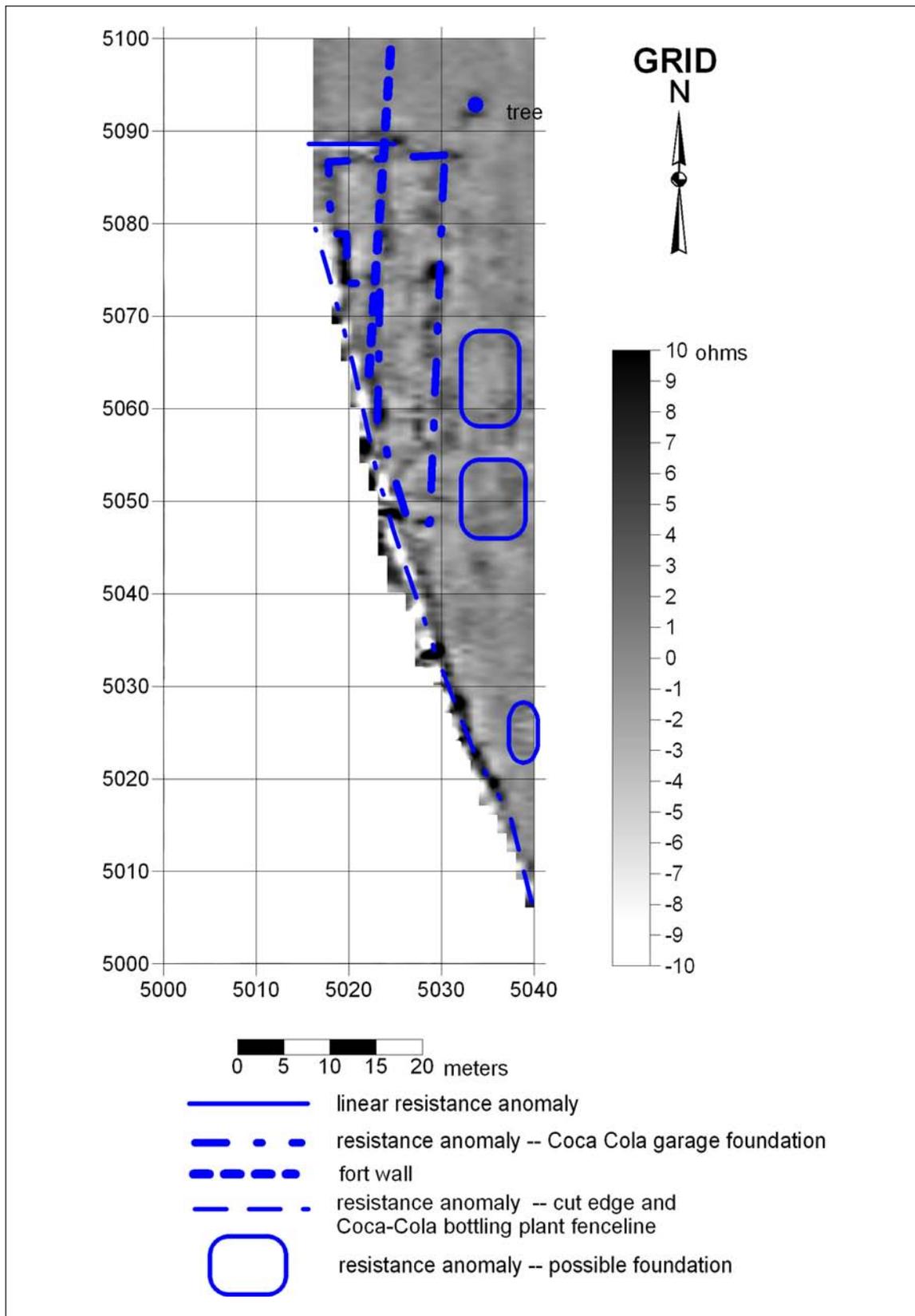


Figure 25. Interpretation of the resistance data from the geophysical project area.

FORT SMITH

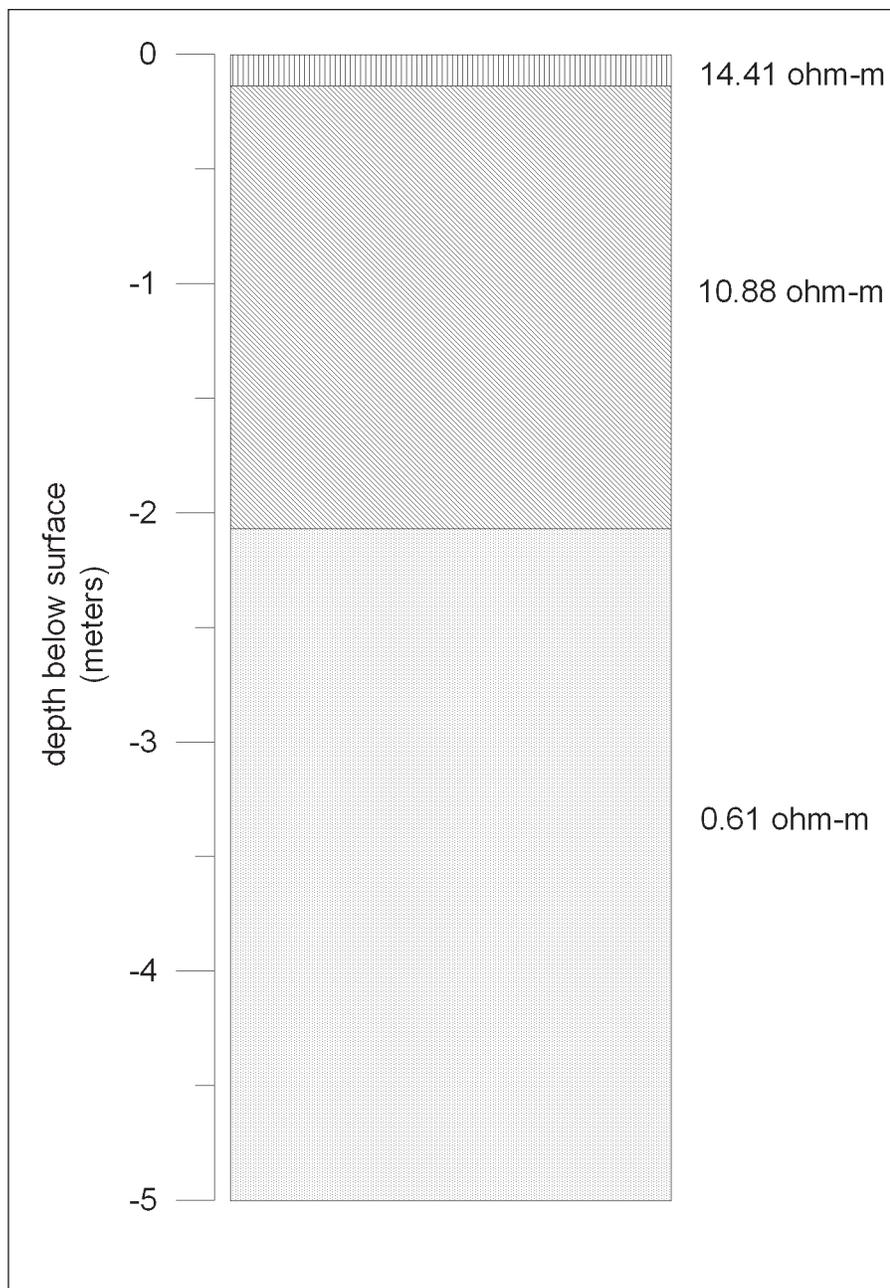


Figure 26. Electrical stratification of vertical electrical sounding data.

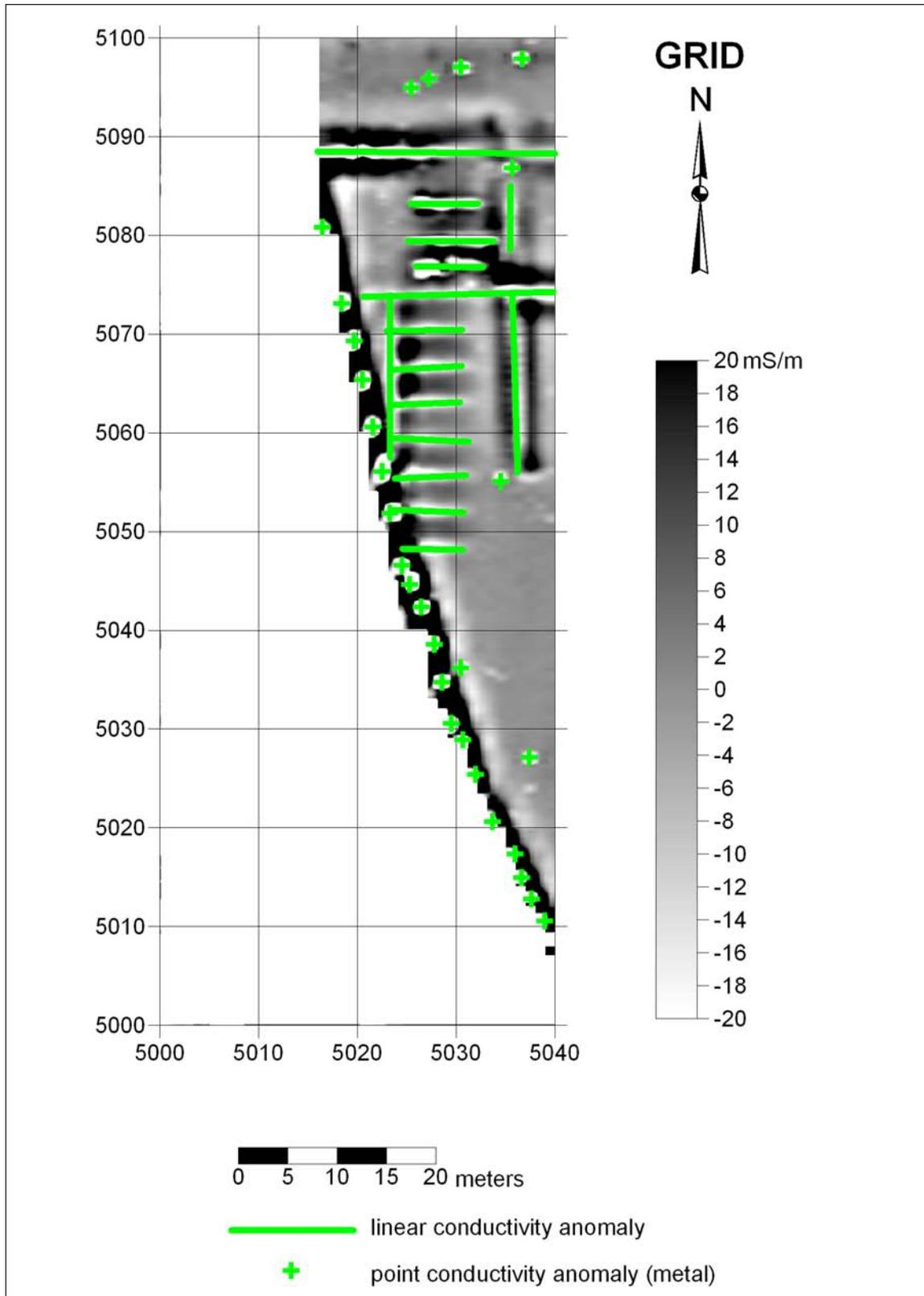


Figure 27. Interpretation of the conductivity data from the geophysical project area.

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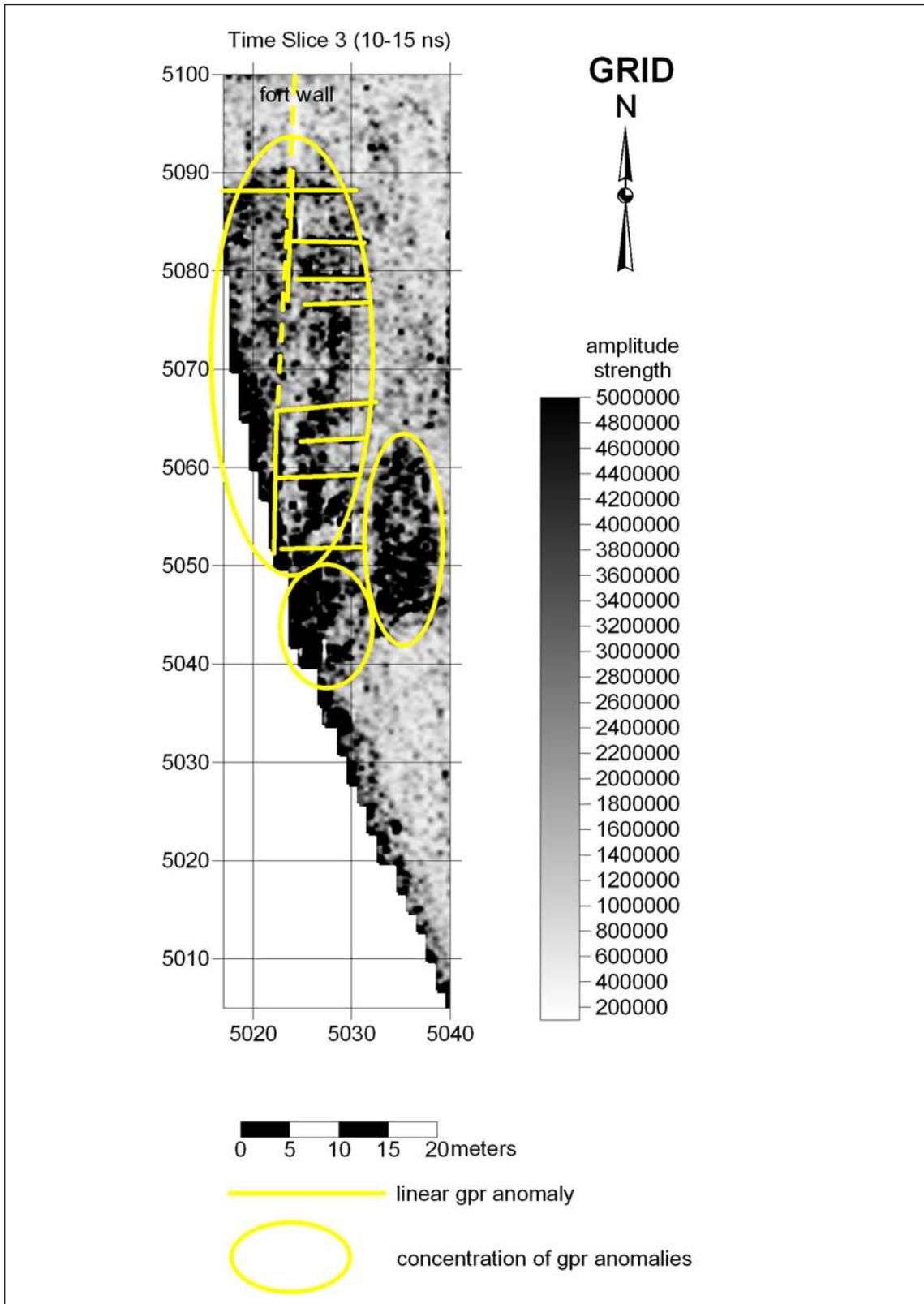


Figure 28. Interpretation of the ground-penetrating radar data from time slice 3 at the geophysical project area.

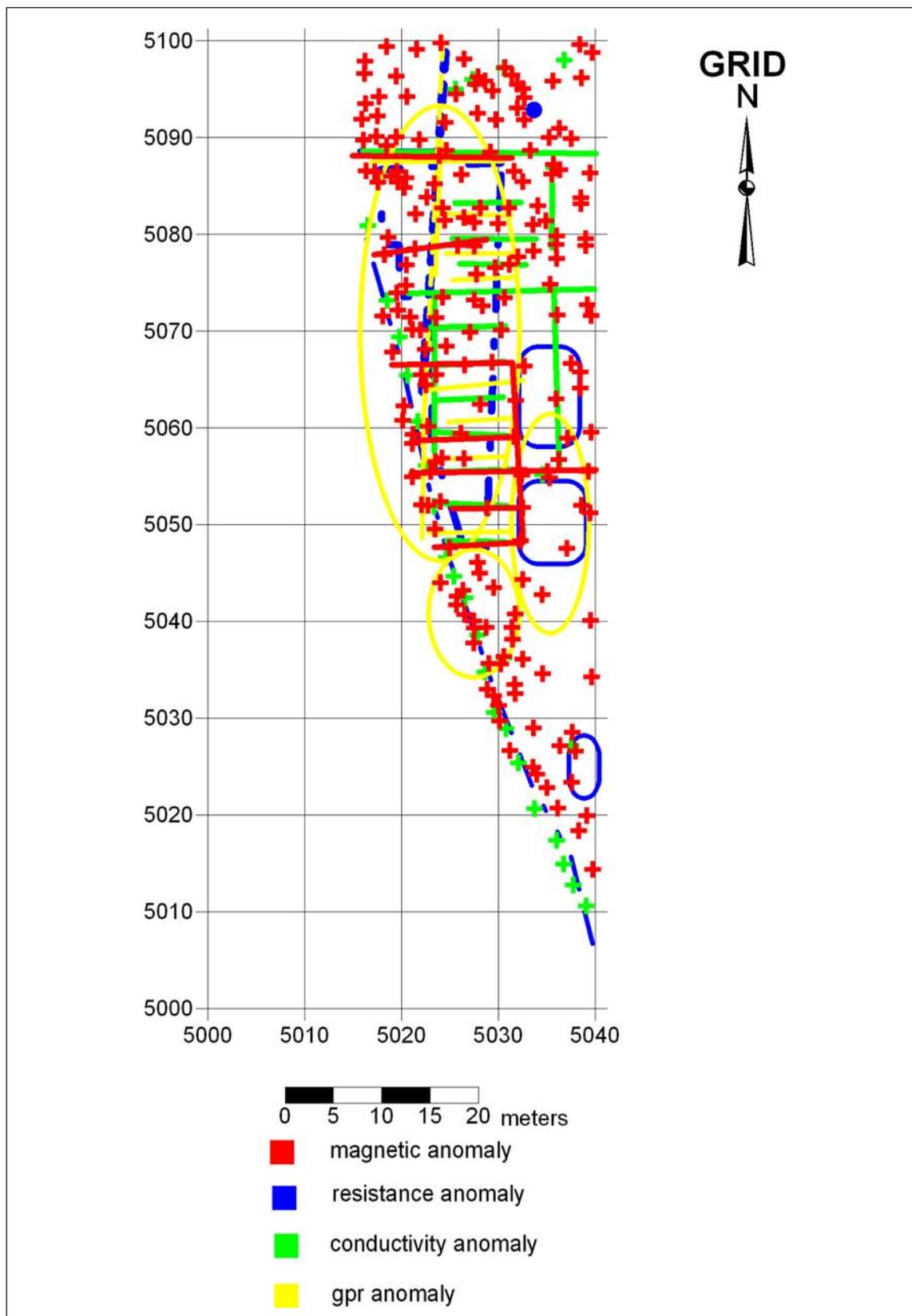


Figure 29. Combined geophysical anomalies from the geophysical project area.

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