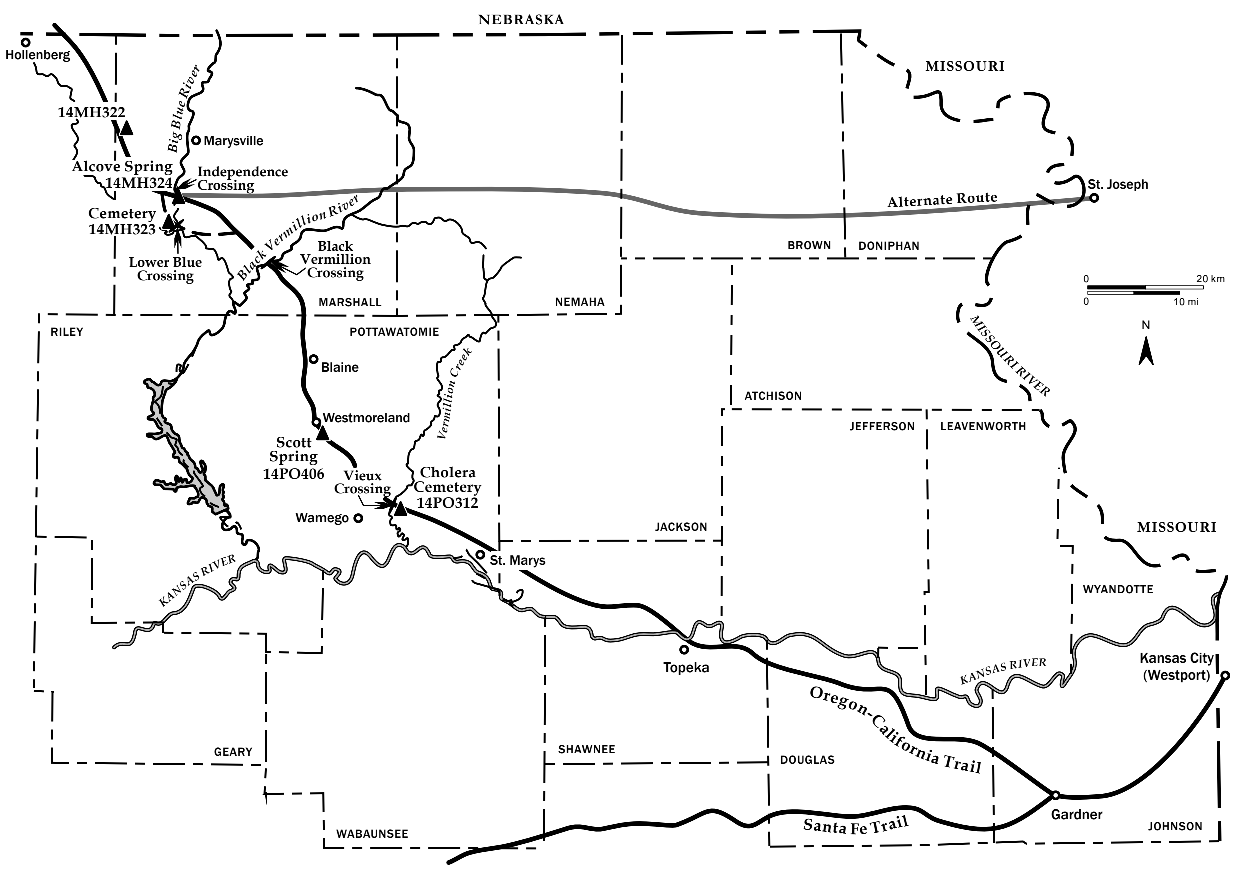
Geophysical Investigations of Four Suspected Pioneer Grave Locations Along the Oregon and California National Historic Trails, Marshall and Pottawatomie Counties, Kansas



National Park Service - Midwest Archeological Center

Geophysical Investigations of Four Suspected Pioneer Grave Locations Along the Oregon and California National Historic Trails, Marshall and Pottawatomie Counties, Kansas

By

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Abstract

The November 2000 and August 2001 archeological and geophysical investigations of grave sites along the Oregon and California National Historic Trails in northeastern Kansas was initiated by the National Park Service in response to a request from the KANZA Chapter of the Oregon and California Trails Association. A meeting and site tour were held with the members of KANZA Chapter and the Midwest Archeological Center Archeological Assistance and Partnership Program archeologist between May 8 and May 10, 2000. This visit was to assess the feasibility of the application of geophysical techniques to the search for historic graves along the trails in northeastern Kansas. Five possible grave locations were visited: three in Marshall County (14MH322, 14MH323, and 14MH324—the Alcove Spring site) and two in Pottawatomie County (14PO312—the Cholera Cemetery site, and 14PO406). The KANZA Chapter members felt that these locations contained graves associated with travel along the Oregon and California Trails. Geophysical investigations, including magnetic gradient, resistance, conductivity, and ground-penetrating radar surveys, were conducted at four of the five sites identified by the KANZA Chapter members.

During the investigations, 1,100 m² were surveyed with a Geoscan Research FM36 fluxgate gradiometer and with a Sensors and Software Noggin 250 Smart Cart ground-penetrating radar system (Nickel 2001). Eight hundred square meters were covered with a Geoscan Research RM15 resistance meter and PA5 multiprobe array, and 300 m² were covered with a Geonics EM38 ground conductivity meter. The surveys resulted in the identification of subsurface magnetic gradient anomalies at Sites 14MH322, 14MH323, 14PO312, and 14PO406. Some of the anomalies at Sites 14MH323 and 14PO312 might be associated with unmarked graves. None of the ground-penetrating radar grid surveys yielded patterns that compare with the model that was constructed from data that associate with the Prather headstone at Site 14PO312. The multiplexer resistance surveys at Sites 14MH323 and 14PO312 appear to offer some information about grave locations. Conductivity surveys at Sites 14MH322 and 14PO406 yielded inconclusive results concerning the nature of the cairns at Site 14MH322 and the upright stone at Site 14PO406.

This report provides an analysis of the geophysical data collected during four days at the sites. Since Sites 14MH323 and 14PO312 are associated with known and marked graves, it is not recommended that any additional archeological investigations in the form of excavations be conducted at these sites at the present time. Should there be any development on or near these sites, then a research design needs to be developed for the implementation of archeological excavations to determine the nature and extent of these two cemeteries along the Oregon Trail. At Sites 14MH322 and 14PO406, limited excavations around the rock features should be conducted to determine the nature of these features. A research design for the testing of the two sites needs to be developed in coordination with the Kansas State Historic Preservation Office and State Archaeologist Office staff.

Acknowledgments

The authors would like to thank the members of the KANZA Chapter of the Oregon and California Trails Association for their support and hard work completing the geophysical investigation phase of the project. Kenneth Martin (Oketo, Kansas), Glenn Larson (Waterville, Kansas), and Ernest White (Westmoreland, Kansas) provided unlimited enthusiasm for the project and knowledge about the Oregon Trail through northeastern Kansas. We would also like to extend our gratitude to the wives and families of these dedicated Oregon Trail enthusiasts. Without their support, this project would not have been possible. We appreciate the expertise of Duane Iles during the tour of the Alcove Spring site. We would also like to acknowledge the landowners, Art Pacha, Marc Vering, Jim Tessendorf, Gilbert Kemnitz, and the Alcove Spring Historic Trust for permitting access to the sites. The landowners, their families, and friends of the KANZA Chapter provided insight, labor, and the willingness to allow us the opportunity to conduct the geophysical investigations of the historic past on their homelands in northeastern Kansas. We would also like to thank Jere Krakow, superintendent of the National Park Service's Long Distance Trails Office in Salt Lake City, Utah, for his support and funding of the project. We would also like to thank Randy Thies, archeologist for the Kansas State Historical Society, for his support and response to questions and concerns from us during the project. Kenneth L. Kvamme provided input on the processing of the resistance data, which greatly appreciated by the authors.

At the Midwest Archeological Center, a number of people deserve credit for helping us complete this project. These include Dr. Mark Lynott, Dr. Ralph Hartley, and Thomas Thiessen. Production of this manuscript is attributed to Carrol Moxham. Bonnie Farkas and Linda Zumpfe should also be commended for all of their hard work addressing the various fiscal and personnel issues related to the project.

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Introduction

Archeological and geophysical investigations of grave sites along the Oregon and California National Historic Trails (Figure 1) in northeastern Kansas were initiated by the National Park Service (NPS) in response to a request from the KANZA Chapter of the Oregon and California Trails Association (OCTA) in August 1999. The KANZA Chapter members requested NPS Long Distance Trails Office (LODI) Superintendent Jere Krakow (personal communications 1999) to investigate suspected grave sites along the Oregon and California trail routes in Marshall and Pottawatomie Counties of northeastern Kansas. The KANZA members were interested in identifying and evaluating the presence of grave sites at five locations along the trails. They were hoping that geophysical techniques would provide conclusive evidence of grave locations and provide an accurate count of individuals buried in the cemeteries. They hoped that the geophysical information could be used to verify traveler's letters, dairies, and journal entries concerning the number and locations of graves. The authors pointed out to them that the geophysical techniques might provide the information that they were seeking but that the conditions had to be ideal. Both authors have been involved in several geophysical surveys across the country and in specific cemetery projects similar to the present one in the Midwest and the western part of the United States.

Superintendent Krakow proposed the possibility of the KANZA Chapter members participating in the geophysical investigations at the Mormon Pioneer National Historic Trail site at Garden Grove in south central Iowa. Three KANZA Chapter members (Kenneth Martin, Oketo, Kansas; Glenn Larson, Waterville, Kansas; and Ernest White, Westmoreland, Kansas) volunteered to assist the Garden Grove geophysical investigations during November 1999 (De Vore 1999). The KANZA Chapter members presented the LODI Superintendent and NPS Archeologist Steven L. De Vore with an invitation to conduct geophysical investigations at grave sites along the Oregon and California trails in northeastern Kansas.

Following the NPS workshop *Recent Advances in Archeological Prospection Techniques for Non-Destructive Investigations* (De Vore 2000a) in Tucson, Arizona, and a geophysical investigation of the Kane Cemetery at Bighorn National Recreation Area, Wyoming, in April and May 2000 (De Vore 2002a), Steven L. De Vore, an Archeological Assistance and Partnership Program Archeologist, Midwest Archeological Center (MWAC), made a site visit to northeastern Kansas before returning to the Lincoln office. A meeting and site tour were held with the members of KANZA Chapter between May 8 and May 10, 2000 (De Vore 2000b). This visit was to assess the feasibility of the application of geophysical techniques to the search for historic graves along the trails in northeastern Kansas. Five possible grave locations (Figure 2) were visited: three in Marshall County (14MH322, 14MH323, and 14MH324—the Alcove Spring site) and two in Pottawatomie County (14PO312—the Cholera or 49ers Cemetery site, and 14PO406). The KANZA Chapter members felt that these locations contained graves associated with travel along the Oregon and California Trails.

Site 14MH322 is located on the uplands on the Art Pacha farm in western Marshall County. Site 14MH323 is located on the Marc Vering property along the bank of the Big Blue River south of Alcove Spring in the western central portion of Marshall County. Site 14MH324 is located on Alcove Spring Historic Trust property along the grassy uplands, and the timbered bottomland adjacent to Alcove Spring, a freshwater spring and noted campsite, near the Independence Crossing of the Big Blue River in Marshall County. Site 14PO312 is located on the Jim Tessendorf farm along the left bank of Vermillion Creek in southeastern Pottawatomie County. Site 14PO406 is located on the Gilbert Kemnitz property south of Scott Spring in central Pottawatomie County. Of the five sites, two sites in Marshall County (14MH322 and 14MH323) and two sites in Pottawatomie County (14PO312 and 14PO406) are the focus of the present geophysical investigations. Site 14MH324, which includes the burial site of Sarah Keyes, is eliminated from further consideration of geophysical investigations due the large survey area required to detect grave locations within the site boundaries. Two sites, 14MH323 and 14PO312, contain headstones with the names of the persons buried in the cemeteries. All four of the sites also contain irregular stones without inscriptions that might be grave markers. Historic journal accounts written by travelers along the trails suggest the potential for multiple interments in the vicinity of some of the areas investigated.

The site assessments resulted in further discussions between MWAC and LODI staff personnel concerning the research design for the project, which included a budget and projected field schedule. The LODI Superintendent made a formal request to the Midwest Archeological Center Manager Dr. Mark Lynott for geophysical investigations of the potential grave locations along the Oregon and California trails in August 2000 (Krakow 2000a). The request was for technical assistance to the local KANZA Chapter members of the Oregon and California Trails Association (OCTA) in their ongoing investigations of the trail segments and grave locations in northeastern Kansas. Funding was provided by the LODI office, located in Salt Lake City, Utah. A purchase order for the ground-penetrating radar survey was awarded to Robert K. Nickel, a private consultant from Lincoln, Nebraska. Prior to the start of the fieldwork, the KSHS archeological staff was notified of the proposed geophysical investigations (Krakow 2000b).

For graves to be identified by the geophysical techniques employed during the present project (i.e., magnetic gradient, resistivity, conductivity, and ground-penetrating radar), there needs to be sufficient changes in the measured physical property of the earth. Several factors contribute to the success or failure of a geophysical search for graves. Without significant changes in soil moisture, compaction, texture, and/or structure, it would be impossible to identify specific graves. The lack of coffins, grave goods, and associated permanent stone or metal markers also makes a search more difficult. The size and depth of the grave shaft are also important to the overall success of the geophysical investigations. If the graves were hurriedly excavated and shallow, there might not be enough mixing of the excavated soil matrix as it was replaced in the grave shaft. The lack of coffins would mean that there would be minimal collapse of the grave fill for the formation of a depression over the buried body. Any combination of these factors could spell disaster for positive grave identification during geophysical investigations. Prior to the start of the survey, it was hoped that the geophysical results would identify the geophysical disturbances or anomalies associated with known graves. This information could then be used to identify unmarked interments.

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

Between November 14 and 16, 2000, Archeologist Steven L. De Vore and Site Sensors consultant Robert K. Nickel conducted magnetic gradient, soil resistance, and ground-penetrating radar surveys at the four sites identified in the Oregon–California Trails project field assessment (De Vore 2000b). Due to inclement weather at Site 14MH322, magnetic gradient and soil resistance surveys could not be completed; however, the ground-penetrating radar survey was completed along with topographic mapping of the project area. In addition, it was discovered through the course of the geophysical investigations that the soil resistance data recovered from 14PO312 and 14PO406 and the magnetic gradient data recovered from 14MH323 contained errors resulting from improper instrument setup and equipment malfunctions. De Vore conducted subsequent geophysical investigations of the four sites on August 1, 2001. The magnetic gradient surveys were completed on Sites 14MH322 and 14MH323. The soil resistance survey was completed on 14PO312. Due to the dry conditions at 14MH322 and 14PO406, it was not possible to insert the probes of the soil resistance system into the ground without damage to the instrument. In order to complete the project, a field decision (De Vore 2002b) was made to use a ground conductivity meter since it did not require the insertion of probes to obtain the data and the fact that conductivity represents the inverse of resistivity.

Historical Background

The Oregon Trail represented the primary emigrants' highway from the western edge of the populated United States across the Louisiana Territory to the fertile lands of the Oregon Country (Connelley 1918:145–188; Culter 1883; Historic Preservation Department 1987:11–13). Since Lewis and Clark's return from their exploration of the Louisiana Territory in 1806, the American people began to develop a keen interest in the Oregon Country where profits could be made in the lucrative fur trade industry and through agricultural endeavors (Franzwa 1988:1–2). Riches abounded in that place far to the west for those willing to chance the crossing of the Great Plains and the Rocky Mountains. In the beginning, there was no great rush to reach the west, but only a small trickle.

One of the first businessmen to see the potential profit in the Oregon territory was John Jacob Astor (Billington 1967:511). After establishing the Pacific Fur Company in 1810 with other fur traders, Astor sent two expeditions to set up a post on the Oregon coast. One proceeded by sea around Cape Horn. The ship *Tonquin* reached the mouth of the Columbia River on March 22, 1811. The crew soon selected a post on the north side of the river and named it Astoria. The second expedition went overland under the command of Wilson Price Hunt (Phillips 1961:270–278). With sixty-five people in the party, Hunt proceeded up the Missouri River along Lewis and Clark's route. The expedition left the Missouri River near the mouth of the Grand River in present day South Dakota and headed west. Numerous hardships were encountered along the way in the Rocky Mountains and on the lava plains of the Snake River. Although a few of the party made it to Astoria in January 1811, the last contingent did not arrive until five months later (Phillips 1961:276). Although the company had some success trading in the region, it was short lived. The War of 1812 and the arrival of North West Company in Oregon ended the Pacific Fur Company's venture at Astoria. In addition to these events, both Lewis and Clark's and Hunt's routes lacked the directness needed to establish viable commerce.

In June 1812, Robert Stuart and a few Astorian companions left Astoria for a return trip overland (Rollins 1995:3). After traveling upstream on the Columbia River, the small party of 61 men left the Columbia River at the mouth of the Walla Walla River and crossed overland on horseback to the Snake River near the confluence of the Snake and Burnt Rivers (Rollins 1995:3–74). The party then followed the Snake River until they reached American Falls. There they crossed overland to the Grays River. They lost their horses at McCoy Creek to an Indian raiding party (Rollins 1995:134). By raft and foot the party continued over Teton Pass, down the Green River, and then overland to South Pass. The group reached the Sweetwater River on October 28, 1812 (Rollins 1995:167). Crossing the Sweetwater River near the confluence with the North Platte River, the party began its long journey down the North Platte River on November 1, 1812 (Rollins 1995:189). The group paused just west of present day Casper and established their first winter quarters (Rollins 1995:190). After spending six days hunting and repairing clothing, the party headed down the North Platte on the 13th of November (Rollins 1995:193). On December 31, 1812, the party erected their second winter quarters a couple of miles below present day Torrington, Wyoming, along the left bank of the North Platte River (Rollins 1995:198, 206). They stayed at that location until March 8, 1813 (Rollins 1995:209). After leaving the second winter quarters, the group traveled on foot along the left bank of the North Platte River. On April 2nd, Stuart's party reached Grand Island in present day Nebraska (Rollins 1995:215). On the 4th of April, they crossed over to the right bank of the Platte River (Rollins 1995:216). On April 13th, the party arrived at an Oto village where they obtained a canoe for the remainder of their trip to St Louis (Rollins 1995:233–237). By the 18th of April, Stuart's band of travelers was camping near the Missouri River (Rollins 1995:237, 242). The party arrived in St. Louis on the evening of April 30, 1813, after traveling 6,380 km from the Pacific Ocean (Rollins 1995:298–251). During their journey, they faced numerous hardships from weather extremes, starvation, and hostile Indians. However, they were to leave the American people with an unending legacy by forging a route, which would become the Oregon Trail.

Although Stuart's Astorians had shown the way, if only in reverse, four more major events were to occur before the Oregon Trail became the emigrants' highway. In 1822, William Henry Ashley formed a fur trapping and trading expedition up the Missouri River under the command of Major Andrew Henry (Franzwa 1988:3–4). The following year, the outfit included James Clyman, Thomas Fitzpatrick, Jedediah S. Smith, and William M. Sublette. Other noted people in the fur trade and exploration of the west joined the expedition, included David E. Jackson, Milton Sublette, Robert Campbell, Étienne Provost, and James Bridger. Ashley and Henry established the beginnings of permanent trade with the Indians of the upper Missouri and Yellowstone region. More importantly, their efforts led to detailed exploration of the country (Dale 1941). Thomas Fitzpatrick, Jedediah S. Smith, and James Clyman with a small party of trappers made their way over South Pass in January 1824 (Hafen 1973:33). Ashley also initiated the rendezvous system where the trappers would bring their peltry to a selected location and trade for supplies, equipment, and whiskey (Franzwa 1988:4–5; Phillips 1961:396–397). In 1830, William Sublette, Jedediah Smith, and David Jackson led a caravan of 81 men to the rendezvous in the Wind River Mountains (Sunder 1959:84–89). This was the first rendezvous caravan to utilize wheeled vehicles. Ten wagons and two dearborns made the trip pulled by mules (Franzwa 1988:5). Although they did not go to Oregon, they illustrated the feasibility of wagon travel over the Great Plains and into the Rocky Mountains. Wagons would be needed to carry family possessions, supplies, equipment, and provisions for the emigrants until they could sustain themselves in the new territory.

In 1832, Captain Benjamin E. Bonneville, while on leave from the U.S. Army, led an expedition of 110 men from Missouri to Oregon Country (Chittenden 1986:395–434; Franzwa 1988:5–6; Goetzman 1991:52–55; Irving 1986). The wagons of his expedition crossed the Great Plains, crossed the Rocky Mountains through South Pass, and went to Fort Walla Walla in the Oregon Country. With the expedition's return to Independence, Missouri, in 1835, the entire country soon realized that it was possible to take wagons all the way to the Oregon Country. In addition, one of the trappers with the expedition, Joseph Walker, lead a small band of forty men to California (Irving 1986:281–296). Their trek from the Great Salt Lake, across Great Basin, and through the Sierras formed the emigrant route to California, which was to become important during the Californian Gold Rush of 1849. Captain Bonneville's adventures, along with his two maps of the western country, were published shortly after his return (Chittenden 1986:423–425; Irving 1986).

The American Board of Commissioners for Foreign Missions, consisting of the several denominations of Protestant groups, organized a missionary venture to the Oregon Country in 1836 (Jeffrey 1997:11). The missionary party consisted of Dr. Marcus Whitman and the Reverend Henry Spalding along with their wives, Narcissa Whitman and Eliza Spalding, William Henry Gray, three Nez Perces, and two hired men (Drury 1997:48–49). The Reverend Spalding, the Nez Perces, and the hired men left Liberty, Missouri, on April 27, 1836, with wagons, camping equipment, and supplies. Dr. Whitman and the two women were to catch the American Fur Company boat, travel up the Missouri, and join the caravan at Bellevue. The boat did not stop at Bellevue for them, and the Whitman party was forced to follow the caravan overland on May 3, 1836. The two parties had met by May 14th, the same day the American Fur Company's caravan, under Thomas Fitzpatrick, left Bellevue for the Rocky Mountain summer Rendezvous (Drury 1997:48–50,189). The missionary party joined the fur company's caravan on May 24th at the Loop Fork of the Platte River. The entourage arrived at the Rendezvous on July 6th.

The two women created a sensation at the 1836 Rendezvous at Fort Bonneville. They were the first two Euroamerican women seen by the natives (Drury 1997:63–70,189–194). On July 18th, the missionaries left the Rendezvous with a small group of Hudson's Bay traders on their way back to Fort Walla Walla (Drury 1997:70–86,194–195). The missionaries arrived at the post on August 19th. Leaving their wagons at Fort Walla Walla, the party continued on to Fort Vancouver on August 22, 1836. They arrived at the Hudson's Bay trading post on September 12, 1836 (Drury 1997:87,196). Narcissa Whitman and Eliza Spalding were the first Euroamerican women to make the trip along the overland route to Oregon. Their diaries and letters provided the first of many female accounts of travel along the Oregon Trail and details of the early settlement of the Oregon territory. Others soon followed them. In 1838, two more missionary couples, the Walkers and Eellses followed the Whitmans and Spaldings to Oregon to setup their mission. Like Narcissa Whitman and Eliza Spalding, Mary Walker and Myra Eells wrote in their diaries of their adventures along the Oregon Trail (Drury 1998). With wagons and women making the overland trip to

Oregon from the western extent of the settled portion of the United States, the emigration trickle was about to become a cascade.

In the 1841, the Bidwell-Bartleson party of sixty-nine people, including women and children, left for California (Billington 1967:565). Half of the group left the Oregon Trail at Soda Springs for California while the other half continued on to the Columbia River and the Willamette Valley in Oregon (Franzwa 1988:23, 1990:2, 1999:2). In the spring of 1842, a party of 112 persons, including Lansford W. Hastings and Dr. Elijah White, left Independence, Missouri, for Oregon with 18 wagons, horses, mules, and cattle (Franzwa 1988:23; Fremont 2002:8). In addition to the Hastings and White party, the U.S. Army sent an expedition to explore and map the country between the Missouri River and the Rocky Mountains and on to the Oregon Country and Northern California (Fremont 2002). The party gathered astronomical, topographical, and geological information about the western terrain. With the publication of the report in 1845, the emigrants now had detailed information on the region between the Missouri River and the Pacific Ocean.

The Great Migration along the Oregon and California Trails began in 1843 with 1,000 people immigrating to the far west (Coffman 1993; Franzwa 1988:23, 1990:2; Lavender 1980:44–60; 1987:22–51). By 1845, the emigrants to Oregon and California numbered over 5,000. (Franzwa 1988:23). The first of several guidebooks (Hastings 1994) made its way into the hands of the American public in 1845. Emigration was down in 1846 with less than 2,500 people on the trail to Oregon and California (Franzwa 1988:23). This was partially due to the international troubles with Mexico and Great Britain. Among these travelers were the ill-fated Donner and Reed families (Murphy 1995). By the end of 1847, travel had doubled. A large number of the emigrants were Mormons headed for the Great Salt Lake Valley in Utah (Lavender 1980:65–72; Stegner 1992). The Mormon Trail left Winter Quarters in eastern Nebraska and stayed on the north side of the Platte River (note that the Oregon and California Trails were on the south side of the Platte River) until it merged with the Oregon and California Trails at Fort Laramie. More than 12,000 people were in Oregon by the end of 1848 (Franzwa 1988:23–24).

Initially, the Oregon and California Trails had their beginning in Independence, Missouri (Franzwa 1990:18–19). The first part of the western overland trail to the Pacific followed the Santa Fe Trail (Connelley 1918:145; Franzwa 1989a,1989b). Near present day Gardner, Kansas, the trails split with the Santa Fe Trail proceeding on to the southwest and the Oregon and California Trails heading north to the Platte River Valley (Mattes 1987). The Oregon and California Trails overlapped through Kansas, Nebraska, and Wyoming (Figures 1 and 2). In Idaho, the two trails split at Soda Springs. The Oregon Trail continued along the Snake River through Idaho and into Oregon. Once the Oregon Trail reached Oregon, it headed for the Columbia River. From there, the emigrants traveled onward to the end of the trail in the Willamette Valley. The California Trail entered the northwestern corner of Utah and then crossed the Great Basin in Nevada. It crossed the Sierra Mountains of California and into the Sacramento Valley. Over the years, other points of departure came into existence as the migration increased in size. Numerous wagon trails departed from Independence and St. Joseph, Missouri, and from Nebraska City, Nebraska, and Council Bluffs, Iowa (Stewart 1983). Numerous cutoffs also developed to shorten the route and time required reach the Oregon and California destinations (Franzwa 1990, 1999). By the end of the nineteenth century, over 300,000 people had moved west along the trail (Franzwa 1988:24; Mattes 1987:23). According to Franzwa (1988:24), approximately 90 percent of the travelers made it. The remaining ten percent included those who turned back and those who died along the way.

Travelers along the trail endured numerous hardships during their journey. Weather was a primary consideration in planning the departure from the Missouri River (Mattes 1987:52–56). From the various starting points along the Missouri River, groups of emigrants would leave in the springtime when there would be sufficient new grass on the plains for the animals. Although a few emigrants were unable to overcome the hardships along the trail and turned back, the majority continued on their trek west. Severe weather, whether late snows or intense thunderstorms, made the trail impassible for days. Lightning from thunderstorms caused prairie fires. Droughts delayed departures. In the summer, droughts reduced the availability of water for the people as well as for their animals. Droughts also reduced the amount of grasses available for feeding the livestock. Summer heat also took a toll on travelers and livestock. Besides the weather, diseases, accidents, exhaustion, lack of provisions, and Indians took their toll on the emigrants (Mattes 1987; Unruh 1979). Most were buried in lone graves, although some were buried in small cemeteries with their fellow travelers. Cholera caused numerous deaths and reached its height in 1849 during the first year of the California gold rush (Franzwa 1988:42–45). Other diseases included diarrhea, tuberculosis, smallpox, mumps, mountain fever, and scurvy (Unruh 1979:345–346). Until the 1860s, there was little danger from the tribes along the trail; however, the accumulating Indian frustrations over loss of game and lack of respect for their rights, customs, and beliefs lead to increasing hostility towards the emigrant wagon trains (Unruh 1979:145–148). Many travelers left journals, diaries, and letters, describing their ordeals along the trail (Mattes 1987:24–29).

Oregon and California Trails in Kansas

The combined Oregon and California Trails originally entered Kansas on the Santa Fe Trail near New Santa Fe, Missouri (Blackmar 1912:393–395; Franzwa 1988:128, 1990:30–31). Near Gardner, Kansas, the Oregon and Santa Fe Trails separated (Franzwa 1988:132–137, 1990:40–41). The Oregon Trail crossed the Kansas River in present day Topeka (Blackmar 1912:393–395; Franzwa 1988:143–147, 1990:46–47).

Keeping to the left bank of the Kansas River, the trail (Figures 1 and 2) enters Pottawatomie County east of St. Marys (Franzwa 1988:148–149,1990:50–51; Smith 1928:440). The route crosses Vermillion Creek at the Vieux Crossing approximately three miles northeast of Wamego (Franzwa 1988:150–152, 1990:52–53; Howell and Howell 2001a; Smith 1928:440–441). The Cholera Cemetery (also called the 49ers or Emigrants Cemetery, designated Site 14PO312) is located near the crossing.

In late May 1849, a huge outfit bound for California camped near the ford on the right side of Vermillion Creek (Franzwa 1988:151), also called the Red Vermillion in historic accounts (Smith 1928:442). Asiatic cholera struck the group and within a week many had died. David Dewolf, in his May 31st, 1849, diary entry (Dewolf 1925) and the June 17th, 1849, Platte River letter to his wife (Cox 1998:11), mentioned that the cemetery contained six graves of cholera victims:

> We pass a great number of graves of Californians that have died on the road with the Colery. We passed six graves in one place there was a Company from North Carolina with seven in it & six died & but one was spared to tell the tale of woe.

The cemetery, 14PO312, is believed to hold the remains of some 50 cholera victims (Franzwa 1990:52; Howell and Howell 2001b; Smith 1928:442–443). Today, three headstones are present in a fenced in area adjacent to the creek. One head stone bears the name "T. S. Prather" and date of his death (May 27, 1849).

The trail angles towards the northwest to Scott Spring, which is located just south of the present day community of Westmoreland (Smith 1928:443–447). On the uplands before reaching Scott Spring, a single stone marker (Site 14PO406) sits along the trail route (Figure 2). The area surrounding the springs served as a major campground location due to the presence of fresh spring water (Franzwa 1988:153, 1990:52–53; Howell and Howell 1999a; Smith 1928:446). Leaving Scott Spring, the trail takes a more northerly direction until reaching the crossing on Black Vermillion River (Blackmar 1912:393–395; Franzwa 1988:153, 1990:54–57; Smith 1928:447–449). It also crosses the political boundary between Pottawatomie and Marshall Counties approximately five miles north of Blaine. The trail then angles to the northwest to Alcove Spring (Figure 2) and the Independence Crossing on the Big Blue River (Franzwa 1988:159–165, 1990:56–57).

At Alcove Spring (14MH324), the initials of James F. Reed (Figure 3) of the 1846 Donner-Reed party along with a date (26 May 1846) were carved into the rock by the spring (Murphy 1995:15). The spring received its name from one of the members, Edwin Bryant, of the large emigrant train (which included the Donner-Reed party) under the captainship of Col. Russell while they were waiting for the waters in the Big Blue River to lower at the Independence Crossing. Mr. Bryant and others in the party went exploring on the afternoon of May 27th. According to Bryant (2001:50):

> I strolled up the small branch, which I previously mentioned as emptying into the river just above the ford. About three-fourths of a mile from our camp we found a large spring of water, as cold and pure as if it had been melted from ice. It gushed from a ledge of rocks, which composes the bank of the stream, and falling some ten feet, its waters are received into a basin fifteen feet in length, ten in breadth, and three or four in depth. A shelving rock projects over this basin, from which falls a beautiful cascade of water, some ten or twelve feet. The whole is buried in a variety of shrubbery of the richest verdure, and surrounded by small mound-shaped inequalities of prairie. Altogether it is one of the most romantic spots I ever saw. So charmed were we with its beauties, that several hours unconsciously glided away in the enjoyment of its refreshing waters and seductive attractions. We named this the "*Alcove Spring*;" and future travellers will find the name graven on the rocks, and on the trunks of the trees surrounding it.

Sarah Keyes, James Reed's mother-in-law, passed away on the 29th of May and was buried near the spring (Howell and Howell 1999b; Murphy 1995:16; Smith 1936:211). The following inscription (Bryant 2001:53) was carved on the gravestone and tree above the grave:

MRS. SARAH KEYES
DIED May 29, 1846:
AGED 70.

Below Alcove Spring and the Independence Crossing, the Lower Blue Crossing is located approximately two and a half miles south of the spring (Figure 2). A small cemetery (Site 14MH323) is located near the crossing. One headstone bears the name "T. J. Lewis" and year of death (1866). The trail continues to angle to the northwest and leaves Kansas approximately five miles east of Hollenberg (Franzwa 1988:168, 1990:58–59). Before leaving Marshall County, another trail site (Site 14MH322) contains swales associated with the trail (Figure 2) and two cairns (for definitions of trail related features see Buck et al. 1996:17). From there, the trail headed for the Platte River in Nebraska and on to Fort Laramie, the Rocky Mountains, Oregon, and California.

The combined Oregon and California Trails covered approximately 310 km across northeastern Kansas (Socolofsky and Self 1972:17). The trail was never a single route but a series of feeders and alternative routes (Historic Preservation Department 1987:11–13). One of the earliest alternate routes, the Independence-Westport Road, started in Independence and headed to Westport, Missouri (Franzwa 1990:18–25). It crossed into Kansas and joined the Oregon Trail at the junction of the Oregon and Santa Fe Trails west of Gardner, Kansas (Franzwa 1990:24–25). An alternate route from St. Joseph, Missouri, joined the trail west of Marysville, Kansas (Blackmar 1912:393–395; Franzwa 1988:165, 1990:56–59, 1999:175–182). The first use of this alternate route by emigrants from the St. Joseph area occurred in 1845 (Werner 1995a). St. Joseph became the primary departure point along the Oregon and California Trails by the early 1850s.

Environmental Setting

The present project is located in the glaciated region of northeastern Kansas (Socolofsky and Self 1972:3). The region is part of the dissected till plains section of the Central Lowlands Province of the Interior Plains (Fenneman 1938:588–605; Mandel 1987:III-3). During the Kansas glacial episode, the region was covered by a continental ice sheet (Fenneman 1938:594–595). As the ice sheet advanced into this region, the existing stream valleys were scoured and the uplands were leveled throughout the drift plain (Frye and Leonard 1952). One of the more common glacial erratics in northeastern Kansas is the pink Sioux quartzite from southeastern South Dakota and northwestern Iowa (Frye and Leonard 1952:11). Granites, diorites, diabases, gabbros, and greenstones were also left by the glaciers. These materials provided the prehistoric inhabitants with a source for stone tools, including axes, hammers, and other heavy implements (Wedel 1959:14–15). Sands, gravels, and clays from the till and outwash from the retreating glaciers provided the Euroamerican settlers of the region with construction materials (Scott et al. 1959; Walters 1954). In the Pennsylvanian and Permian formations, limestone, sandstone, shale, gypsum, coal, and chert beds provided the aboriginal inhabitants and Euroamerican settlers with materials for stone tools and building construction materials (Culter 1883; Scott et al. 1959; Walters 1954; Wedel 1959).

The thick deposits of till, outwash, and loess conceals the cuesta-type topography of the underlying Pennsylvanian and Permian formations (Fenneman 1938:595–596; Frye and Walters 1950; Schoewe 1949:289; Scott et al. 1959; Walters 1954; Wilson 1984). Erosion of the glacial deposits has left the region with smooth, broad, gently rolling hills on the interstream divides. The land becomes more dissected as it approaches the major stream valleys. Flat, wide floodplains with steep walls characterize the major stream valleys. Along the Big Blue River and Vermillion Creek, the floodplains lie approximately 45 to 50 m below the surrounding bluff tops. Exposures of bedrock may be found along the valley walls.

Within Marshall and Pottawatomie Counties, the Big Blue River and its tributaries flow into the Kansas River at the southern edge of Pottawatomie County (Culter 1883; Socolofsky and Self 1972:6). The Big Blue River flows southward from its headwaters in south-central Nebraska to the Kansas River. The river valley is deep, narrow, and with a flat floor (Ziegler 1976:3). The valley bottomland averages approximately 1.6 km in width (Culter 1883). Numerous breaks along the river result from smaller spring fed tributary drainages originating in the nearby uplands. Originating approximately 25 miles northeast of its mouth. The smaller drainage system of Vermillion Creek also flows into the Kansas River. Numerous smaller tributary drainages flow into Vermillion Creek with most of them originating on the west side of the valley (Reynolds 1970:4). It is along these two drainage networks that the Oregon Trail passes through Pottawatomie and Marshall Counties.

Soils in northeastern Kansas are dominated by Typic Udolls of the Mollisol order (Foth and Schafer 1980:116–125), although the young alluvial soils of the floodplains are primarily Entisols and Inceptisols (Forth and Schafer 1980:37,63; Mandel 1987:III-30), and Alfisols are found under forest vegetation (Forth and Schafer 1980:143; Mandel 1987:III-30). The soils are more or less freely drained with udic soil moisture and mesic soil temperature regimes. Parent materials are primarily glacial till with some thick or moderately thick deposits of loess. Soils are generally deep to shallow, black or very dark brown silt loams, clay loams, and silty clay loams (Foth and Schafer 1980:118; Mandel 1987:III-30). The loessial soils on the uplands and the alluvial sediments in the valleys provide rich soils for the growth of cultivated crops and other edible and usable plant species (Kindscher 1987, 1992). These resources provide the basis of the aboriginal subsistence of prehistoric times and the historic and modern Euroamerican economy.

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

In the tallgrass region, bison and pronghorn antelope roamed the open plains until the mid to late 1800s (Shelford 1963:334–335). Deer were present in the timbered areas along streams and slopes, along with bear, squirrel, and cottontail rabbits (Ziegler 1976:4). Jackrabbits were common along with coyotes, badgers, mink, bobcats, and foxes. Wolves were also important predators until exterminated from the region in the late 1800s. Numerous other mammals and rodents also inhabited the region (Bee et al. 1981; Hall 1955). Numerous species of birds inhabited the grasslands, the shrublands, and wooded areas of the region (Brown 1985:26–28; Shelford 1963:26–35,336). Wild turkey, quail, ruffed grouse, and prairie chicken represented some of the regional game birds, as well as, migratory waterfowl, in both prehistoric and historic times (Wedel 1959:14). Numerous grassland and forest species of songbirds were present (Thompson and Ely 1989, 1992; Zimmerman 1993). Reptiles included several species of lizards, turtles, and snakes (Caldwell and Collins 1981; Collins 1993). Amphibians were found in the prairies, forests, and wetlands (Collins 1993). Fish, including catfish, carp, and bass, and freshwater mussels were found in the streams throughout the region (Cross and Collins 1975). Insects and other invertebrates abound throughout the region with the grasshopper being one of the most abundant insect groups (Kansas Biological Survey 1985; Shelford 1963:337–339; White and Salsbury 2000).

The region has a typical continental climate characterized by large daily and annual variations in temperature (Bark 1980:1–2, 1987:1–2; Robb 1941:873–883). The project area lies within the moist subhumid climatic zone (Thornthwaite 1948). Winters are cold and the summers are warm. Extremes in the temperature occur in January and July (Flora 1948:195). Annual winter temperatures average between –2.2 and 0.1°C with an average daily minimum temperature of between –8.5 and –5.8°C (Bark 1980:1–2, 1987:1–2; Horsch et al. 1987:90–91; Kutnink et al. 1980:50–51). The lowest recorded (1905) winter temperature is –37.22°C. Annual summer temperatures average between 24.6 and 25.3°C with an average daily maximum temperature between 31.4 and 31.9°C (Bark 1980:1–2, 1987:1–2: Horsch et al. 1987:90–91; Kutnink et al. 1980:50–51). The highest recorded (1954) summer temperature is 45.6°C. Annual precipitation ranges from 79.48 and 84.02 cm over most of the area (Bark 1980:1–2, 1987:1–2; Flora 1948:61; Horsch et al. 1987:90–91; Kutnink et al. 1980:50–51). The majority of the precipitation falls between April and September. Tornadoes and severe thunderstorms occur occasionally. Although these are generally local in extent and of short duration, the resulting damage can be severe. Hail might occur with these in the warmer months. Snowfall averages between 49.78 and 54.61 cm per year; however, snow cover seldom lasts more than seven days (Bark 1980:1–2, 1987:1–2). Droughts may occur anytime throughout the year, but are most damaging in July and August (Robb 1941:383). The average frost-free period in the two counties is approximately 171 to 183 days from north to south (Flora 1948:223–229; Horsch et al. 1987:90–91; Kutnink et al. 1980:50–51; Robb 1941:874–875). The sun shines approximately 75 percent of the time in summer and 60 percent of the time in winter. The prevailing winds are from the south except in the winter months when more northerly winds prevail.

File Search and Previous Archeological Investigations

A file search of archeological resources for the Oregon–California Trails project was requested from the Archaeology Office and the State Historic Preservation Office of the Kansas State Historical Society (De Vore 2000c). The search was conducted in order to identify previously recorded archeological resources in the vicinity of the present geophysical investigations at the sites identified during the May 2000 site visit (De Vore 2000b). The file search (Frank 2000) revealed the presence of archeological sites in two of the five localities requested by the National Park Service staff.

Within the project area in Marshall County near the location of Site 14MH323, nine archeological sites (Table 1) were previously recorded during the Inter-Agency Archeological and Paleontological Program investigations of the proposed Tuttle Creek Reservoir in Marshall, Pottawatomie, and Riley Counties (Solecki 1953). The project archeologists, Ralph S. Solecki and J. M. Shippe, conducted the archeological reconnaissance of the proposed reservoir area between July 23 and September 8, 1952. The reconnaissance was to locate archeological resources likely to be damaged or destroyed by the construction of the Tuttle Creek Reservoir (Solecki 1953:1). During their investigations, the archeologists identified 119 archeological sites (Solecki 1953:6). The majority of these sites represented prehistoric camp or village sites related to Upper Republican (Central Plains Tradition) and Plains Woodland cultures (Johnson et al. 1980; O'Brien 1984:50–55,59–66; Solecki 1953:6; Ziegler 1976). Other cultural affiliations represented include Paleoindian and Archaic (Johnson et al. 1980; Solecki 1953:20; Ziegler 1976). In the same section as Site 14MH323, the archeologists located a prehistoric campsite (14MH20). They also noted the location of a prehistoric fish trap in the Big Blue River that was dredged out by Robert McHugh (Solecki 1953:5). Of particular note to the present project, the archeologists identified two Oregon Trail crossings. One crossed the Black Vermillion River near Bigelow (Solecki 1953:4). The second was the Independence Crossing of the Big Blue River near Alcove Spring (Driggs 1942:43; Paden 1943; Solecki 1953:4). Ralph Solecki (1953:4) provided the following commentary on his observations at Alcove Spring:

> Alcove Spring, a spot made famous by the ill-fated Donner Party of pioneers and others before and after them, is situated on the Oregon Trail on the left bank of the Big Blue River downstream from Schroyer. The ruts worn by the wagons of the travelers are plainly visible in the pasture field close to the spring. A grave monument erected by the Daughters of the American Revolution to a pioneer mother, who died on the trail there in 1846, is situated nearby just off Route 13.

The grave monument that Solecki referred to was that of Sarah Keyes of the Donner Party. Although not recorded as an archeological site at the time of the investigations, Ralph Solecki (1953:4–5) also mentioned the cemetery on the right bank of the Big Blue River (Site 14MH323) and provided the following description of the cemetery:

> Of additional historical interest is a mid-19th century cemetery on the Vering farm, near the confluence of a small, unnamed creek and the Big Blue River in the eastern central part of the NE¼, Section 12, T4S, R6E. This burying place reportedly contained about 30 graves.

Within the project area in Pottawatomie County near the Cholera or 49ers Cemetery (14PO312), seven archeological sites (Table 2), including the cemetery, were identified in the file search (Frank 2000). Six sites were previously recorded during the Inter-Agency Archeological and Paleontological Program investigations of the proposed Onaga Reservoir on Vermillion Creek (Reynolds 1970). The seventh site, the Poem Village site (14PO405), was recorded by John R. Carrel (1999). Two archeological surveys were conducted in the proposed reservoir area to determine the extent of the archeological resources that would be endangered or lost by the proposed construction (Reynolds 1970:1). The first was conducted in the spring of 1965 by the Smithsonian Institution's Missouri River Basin Survey (SI MRBS) crew under the direction of Wilfred Husted. Forty-seven sites were documented. Due to changes in the proposed reservoir location, the Kansas State Historical Society (KSHS) under took a second archeological survey under a cooperative agreement with the National Park Service as part of the National Inter-Agency Salvage Program (Reynolds 1970:1). Initially, Thomas P. Barr conducted the KSHS survey efforts during the Fall of 1969. John D. Reynolds completed the survey efforts between March and May of

1970. A total of 49 previously unrecorded sites were identified and documented. The KSHS crew also relocated 31 of the SI MRBS's 47 sites. In reference to Site 14PO312, the Cholera or 49ers Cemetery, John D. Reynolds (1970:129) described the site as:

> Site Description: Three graves are located just east of a small drive leading into Robert Kersey's land just before the drive crosses a small creek. One has marking on it which may be the original markings although it has obviously been retouched fairly recently. Mr. Kersey reports that there used to be about 17 other grave markers in this area although the writer could find no evidence of them. This is very low land just above Vermillion Creek. The area around these markers is not cultivated and is in wooded pasture at the present time. It is likely (in fact Smith 1928 reports that it occurred) that the drive that leads through this graveyard disturbed some of the graves.
>
> …
>
> Analysis: This site appears to be a historic pioneer graveyard site. It probably dates to around 1849. The one gravestone still marked has "T. S. Prather, May, 1849" incised on it.

Reynolds (1970:129–130) provided further comment on the condition of the graves after his initial visit. He indicated that the graves were disturbed by vandals who dug into all three marked graves. The Prather grave was severely damaged with the vandals digging deep enough to disturb any skeletal material that may have been present. However, he recommended that no further archeological investigations be undertaken unless the site was threatened by borrow activities associated with construction of the Onaga Dam.

In mid-July 1996, the superintendent of the National Park Service's Long Distance Trails Office requested the KANZA chapter members to assist the National Park Service's National Historic Trails digital mapping program (Philbrick 1997). The KANZA members were asked to map and measure visible swales in northeastern Kansas. Contacting Donald Buck of OCTA's Trail Mapping Committee and Randy Brown of OCTA's Site and Grave Committee, the KANZA chapter members received guidance and information (Buck et al. 1996) for the National Park Service project. Since the end of July 1996, the KANZA chapter members, armed with a copy of Gregory Franzwa's (1990) *Maps of the Oregon Trail* and the OCTA mapping guidelines (Buck et al. 1996), have been conducting trail investigations searching for physical evidence of swales or ruts, graves, and scarred rocks left by the emigrants over 150 years ago (Philbrick 1997). They located and measured visible swales, documented unmarked emigrant graves, and mapped scarred rocks (striations left by the wagons) in Marshall, Pottawatomie, and Washington Counties. By October 1997, the KANZA chapter members measured 23,204 m of visible swales in the three-county area (Philbrick 1997). The KANZA chapter members (Ken Martin, Oketo, Kansas; Glenn Larson, Waterville, Kansas; and Ernest White, Westmoreland, Kansas) were instrumental in documenting the five grave and cemetery sites initially selected for the present project (De Vore 2000b).

Site 14MH322

This site is located in the NE¼ of Section 20, Township 2 South, Range 6 East (identified as OCTA Site 1 during field visit in May 2000: De Vore 2000b). It is situated on the broad ridgetop and side slope above Hop Creek (Martin 2000a). The present landowner is Art Pacha of Bremen, Kansas. The site is located in pastureland (Figure 4), which according to the present landowner (Art Pacha, personal communications 2000) has never been cultivated. The site contains two well-defined sets of wagon swales with two cairns located between the swales. Approximately six individual swales are contained in each set. One set of swales is located above the small stock pond near the head of Hop Creek. The second set crosses the creek below the pond dam. The two small rock piles or cairns are located between the two sets of swales. According to Art Pacha (personal communications 2000), the nearest rock outcrop is over 2.4 km away from the site. The cairns are believed by members of the KANZA chapter of OCTA (Kenneth Martin and Glenn Larson, personal communications 2000) to represent emigrant graves along the Oregon and California Trails. The trail is identified on the 1857 government township and section survey map of the county (Martin 2000a).

The site area consists of approximately 5.6 hectares. Soils are represented by the Wymore-Pawnee soil association. These soils are deep, moderately well drained upland soils that are gently to moderately sloping (Kutnink et al. 1980:3–4). Soil mapping units (Kutnink et al. 1980:20–21,42) within the site boundaries consist of Wymore silty clay loam (Wb) with 1 to 4 percent slopes, and eroded Wymore silty clay loam (Wc) with 3 to 6 percent slopes. Wymore soils have formed in loess on ridgetops and side slopes of upland areas dissected by drainageways and creeks. No artifacts have been collected from the site.

During the site visit in May 2000, the area surrounding the cairns was selected for further geophysical investigations due to the open area surrounding the cairns (De Vore 2000b). It was recommended that a small grid be placed over the area containing the cairns and that magnetic gradient, resistivity or conductivity, and ground-penetrating radar surveys be conducted at the site. A metal detector survey was also recommended in the area of the swales. The site also needed to be documented and the Kansas State Historical Society Archeological Site Form completed for the site. The site form was completed on August 20, 2000 (Martin 2000a).

Site 14MH323

Site 14MH323 is located in the NE¼ of Section 12, Township 4 South, Range 6 East (identified as OCTA Site 2 during field visit in May 2000: De Vore 2000b). It is situated within a mixed timber and grass setting (Figure 5) on the floodplain above the Big Blue River near the confluence of an unnamed upland drainage and the river (Martin 2000b). The present landowner is Marc Vering of Blue Rapids, Kansas. Located near the Lower Blue Crossing (Kenneth Martin, personal communications 2000), the site consists of the river crossing, wagon swales, and a small emigrant cemetery with multiple graves. The site contains several broken gravestones with one upright stone bearing the inscription "T. J. Lewis" and date of death "1866" (Martin 2000b). Marcus Whitman mentioned the crossing and campsite in his journal of his 1843 trip back to Oregon (Kenneth Martin, personal communications 2000). Approximately 30 graves might be present in the cemetery (Solecki 1953:4–5), which contains both emigrants and early settlers of Marshall County.

The site area consists of approximately 0.5 hectares. The soil (Kutnink et al. 1980:13–14,38) within the site boundaries consists of Nodaway silt loam (Na) which is part of the Muir-Eudora-Nodaway soil association (Kutnink et al. 1980:2–3) of deep, nearly level soils on the floodplains and terraces. These soils range from moderately well drained to well drained soils. The Nodaway soils have formed in the silty alluvium on bottomlands that are frequently subjected to flooding. No artifacts have been collected from the site.

During the site visit in May 2000, the cemetery portion of the site was selected for further geophysical investigations (De Vore 2000b). It was recommended that the area of geophysical survey be limited to approximately 20 m by 40 m. Magnetic gradient, resistivity or conductivity, and ground-penetrating radar surveys were recommended for the cemetery area. The site also needed to be documented and the Kansas State Historical Society Archeological Site Form completed for the site. The site form was completed on August 20, 2000 (Martin 2000b).

Site 14MH324, Alcove Spring

The Alcove Spring site (Figure 6) is located in NE¼ of Section 31 and the NW¼ of Section 32, Township 7 East, Range 4 South (identified as OCTA Site 3 during field visit in May 2000: De Vore 2000b). It is situated on the grassy upland and side slopes and the timbered toe slope on the left bank of the Big Blue River (Martin 2000c). The site also extends up the drainage to Alcove Spring (Figure 7), a noted campsite near the Independence Crossing (Howell and Howell 1999b; Trinklein and Boettcher 2002). The site is owned by the Alcove Spring Historical Trust of Blue Rapids, Kansas (Duane Iles, personal communications 2000). Wagon swales descend the uplands and side slope on the west side of East River Road off of U.S. Highway 77. The trail is marked with posts.

During the initial site visit in May 2000 (De Vore 2000b), a berm and associated depression (possible weigh scale) were identified on the west side of the county road. This was in the area believed to be the location of Sarah Keyes grave (Duane Iles, personal communications 2000). These features appeared to be related to the nearby gravel quarry. In addition to these more recent historic features, there was also a set of limestone steps (Figure 8) along the old parking area that was near the Sara Keyes gravesite.

The Daughters of the American Revolution marker (Figure 9) that once sat on the stone steps is now located in the new parking area on the east side of the road. In addition to the plaque dedicated to the memory of Sarah Handley Keyes, the following inscription is carved on the stone:

GOD IN HIS LOVE
AND CHARITY HAS
CALLED IN THIS
BEAUTIFUL VALLEY
A PIONEER MOTHER
MAY 29, 1846.

At the spring, the engravings / Alcove Spring / and / JFR / 26 MAY / 1846 / are still visible. The initials "JFR" belong to J. F. Reed of the Donner Party (Murphy 1995:15).

The site contains approximately 8 hectares. The site covers portions of Muir-Eudora-Nodaway soil association (Kutnink et al. 1980:2–3) and the Kipson-Tully soil association (Kutnink et al. 1980:5). The Kipson-Tully soils consist of shallow and deep, moderately sloping to moderately steep, uplands soils that range from well drained to excessively drained soils. Soil mapping units within the Wabash-Nodaway-Muir association at the site consist of the Eudora silt loam (Ea: Kutnink et al. 1980:7,34–35) the Nodaway silt loam (Na: Kutnink et al. 1980:13–14,38). The Eudora soils have formed in silty alluvium on bottomlands that are rarely or occasionally flooded. The silty alluvial Nodaway soils have formed in frequently flooded bottomlands. Within the Kipson-Tully association, soil mapping units consist of the Kipson-Sogn silty clay loams with 5 to 25 percent slopes (Kc: Kutnink et al. 1980:9,36,40), the Morrill loam with 1 to 4 percent slopes (Ma: Kutnink et al. 1980:11,37), and the Tully silty clay loam with 3 to 7 percent slopes (Ta: Kutnink et al. 1980:19,41). The Kipson soils are formed in parent material weathered from silty, calcareous shales on the upland ridges and side slopes. Sogn soils are formed in residuum comprised of weathered limestone on the uplands. Morrill soils are formed in the glacial till on the uplands. The Tully soils are formed in colluvium on foot slopes along the upland drainageways. No artifacts have been collected from the site.

Four people were known to have been buried at Alcove Spring (Werner 1995b). Sarah Keyes of the Donner party died on May 29, 1846. She was buried the hillside northwest of the spring "under the shade of an oak tree" in a cottonwood coffin (Barry 1972:846; Hixton 1849; Morgan 1993:208–209; Murphy 1995:16). A stone was place on her grave that contained her name, place of birth, age, and date of death. The headstone was still in place in the 1930s. John Fuller, a member of the G. W. Paul's party died of an accidental gunshot wound on April 28, 1849 (Barry 1972:845; Hixton 1849; Werner 1995b). The graves of the two unidentified emigrants were discovered in the 1960s at the south end Alcove Spring campsite (Werner 1995b).

During the site visit in May 2000, it was determined that the site would not be selected for further geophysical investigations due to the uncertain location of the Sarah Keyes gravesite. (De Vore 2000b). It was recommended that without more information on the general location of the grave, it would be impractical to conduct a geophysical survey for the gravesite. A metal detector survey was recommended for the area surrounding the trail swales. Such a survey would also be appropriate for searching for the associated Oregon Trail campgrounds at the Alcove Spring site. The site also needed to be documented and the Kansas State Historical Society Archeological Site Form completed for the site. The site form was completed on August 20, 2000 (Martin 2000c).

Site 14PO312, Cholera Cemetery

This site is located in the NE¼ of Section 24, Township 9 South, Range 10 East (identified as OCTA Site 4 during field visit in May 2000: De Vore 2000b). In addition to being called the Cholera Cemetery, the cemetery is also called the 49ers or Emigrants Cemetery (Kenneth Martin, personal communications 2000). It is situated within a mixed timber, shrub, and grass setting on the floodplain and toe slope (Figure 10) above Vermillion Creek and an unnamed upland drainage (Martin 2000d). The present landowner is Jim Tessendorf of Wamego, Kansas. Located near the Red Vermillion or Vieux Crossing (Howell and Howell 2001a), site consists of a small emigrant cemetery with multiple graves. The site contains three gravestones enclosed by a chain link fence (Figure 11). One upright stone bears the inscription "T. S. Prather" and date of death "1849" (Martin 2000b). In 1849, cholera struck the emigrants camped near the crossing. Several emigrants who died from this disease are buried in the cemetery along with others who died from other causes along the trail (Howell and Howell 2001a, 2001b). Morris W. Werner (1995b, 1995c) lists 10 individuals known to have died at the site. These include a person by the name of Hagin who died in 1849 (Gordon 1983); Captain Ashley of Chariton County, Missouri, died in 1849 (Gordon 1983); H. A. Wood of Buncombe, North Carolina, died May 26, 1849 (Brown 1987:11); T. S. Prather who died May 27, 1849; and six unidentified emigrants from a party of seven from Tennessee that died around May 26, 1849 of cholera (Dewolf 1925). In a letter to his wife, David Dewolf (Cox 1998:11) also identified the party as being from North Carolina. As many as 50 individuals might be buried in the cemetery.

The site area consists of approximately 0.5 hectares. The soil (Horsch et al. 1987:30–31,71–72) within the site boundaries consists of Tully silty clay loam (Tu) with 3 to 7 percent slopes, which is part of the Kennebec-Chase-Wabash soil association (Horsch et al. 1987:8) of deep, nearly level soils on the floodplains and stream terraces. These soils range from moderately well drained to somewhat poorly drained to very poorly drained soils that have silty or clayey subsoil. The Tully soils have formed in colluvium or local alluvium on the concave portion of the toe slope (Horsch et al. 1987:30–31,71–72). No artifacts have been collected from the site.

During the site visit in May 2000, the cemetery portion of the site was selected for further geophysical investigations (De Vore 2000b). It was recommended that the pasture to the east of the fence along the access road be investigated with resistivity, magnetic gradient, and ground-penetrating radar methods; however, the strong magnetic fields associated with the wire and chain link fences might interfere with the operation of the magnetometer. A resistivity sounding was also recommended as potentially useful in determining the practicability of a ground-penetrating radar survey The revised site form was completed on August 20, 2000 (Martin 2000d).

Site 14PO406

This site is located in the NE¼ of Section 10, Township 8 South, Range 9 East (identified as OCTA Site 5 during field visit in May 2000: De Vore 2000b). It is situated on the uplands above an unnamed drainage that flows into Rock Creek approximately 6.5 km southwest of the site. Rock Creek curves around the site from the northeast and also lies less than 2.5 km to the west of the site. The site is also located approximately 4 km southeast of Scott Spring The site lies within a triangular pastured area on the east side of the K-99 state route highway (Martin 2000e). The present landowner is Gilbert Kemnitz of St. George, Kansas. The site contains a single rectangular sandstone marker (Figure 12). The site is believed to contain a single grave (Kenneth Martin, personal communications 2000).

The site area consists of less than 0.5 hectares. The soil (Horsch et al. 1987:26,67–68) within the site boundaries consists of Pawnee clay loam (Pe) with 1 to 3 percent slopes, which is part of the Pawnee-Wymore soil association (Horsch et al. 1987:5–7) of deep, nearly level to moderately sloping soils on the uplands. These soils are moderately well drained with dominantly silty or clayey subsoils. The Pawnee soils have formed in glacial till on side slopes and narrow ridgetops (Horsch et al. 1987:26,67). No artifacts have been collected from the site.

During the site visit in May 2000, the site was selected for further geophysical investigations (De Vore 2000b). It was recommended that the area of investigation by geophysical methods be limited to the immediate area surrounding the upright stone. Magnetic gradient, resistivity or conductivity, and ground-penetrating radar surveys were recommended for the site vicinity. The site also needed to be documented and the Kansas State Historical Society Archeological Site Form completed for the site. The site form was completed on August 20, 2000 (Martin 2000b).

Geophysical Prospection Techniques

Geophysical prospection techniques available for archeological investigations consist of a number of techniques that record the 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 primarily ones that measure inherently or naturally occurring local or planetary fields created by earth related processes under study (Heimmer and De Vore 1995:7; Heimmer and De Vore 2000:55; Kvamme 2001:356). The primary passive method utilized in archeology is magnetic surveying. Other passive methods with limited archeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground (Heimmer and De Vore 1995:9; Heimmer and De Vore 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

A magnetic survey is a passive geophysical prospection technique used to measure the earth's total magnetic field at a point location. 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. Iron artifacts have very strong effects on the local earth's magnetic field. Other cultural features, which affect the local earth's 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° (Milsom 1996:43; Weymouth 1986:341). The project area has a magnetic field strength of approximately 55,000 nT with a inclination of approximately 65° (Sharma 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 1 to 2 m below the ground surface with 3 m representing the maximum limit (Clark 2000:78–80; Kvamme 2001:358). Magnetic surveying applications for archeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects (Bevan 1991; Clark 2000:92–98; Gaffney et al. 1991:6; Heimmer and De Vore 1995:13; Heimmer and De Vore 2000:55–56; Weymouth 1986:343).

Two modes of operation for magnetic surveys exist: the total field survey and the gradient survey. The instrument used to measure the magnetic field strength is the magnetometer (Bevan 1998:20). Three different types of magnetic sensors have been used in the magnetometer: (1) proton free precession sensors, (2) alkali vapor (cesium or rubidium) sensors, and (3) fluxgate sensors; for a detailed description of the types of magnetometers constructed from these sensors, see Clark (2000:66–71), Milsom (1996:45–47), 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 gradient magnetic survey is conducted with a gradiometer or a magnetometer with two magnetic sensors at a fixed vertical distance apart. 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 1996:46–47). Both cesium and fluxgate gradiometers are capable of high density sampling over substantial areas at a relatively rapid rate of acquisition (Clark 2000:69–71; Milsom 1996:46–47).

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.

Ground-Penetrating Radar Survey

Ground-penetrating radar (GPR) is an active method that has recently achieved popularity in cultural resource management applications; for more details on GPR surveys, see Bevan (1998:43–57), Clark (2000:118–120), Conyers and Goodman (1997), and Heimmer and De Vore (1995:41–47). Although Bruce Bevan pioneered the archeological use of GPR a quarter-century ago (Bevan 1977; Bevan and Kenyon 1975), the cost of equipment and problems dealing with the massive amount of data produced by GPR surveys limited the number of archeological applications. Recently, Conyers and Goodman (1997) have published an introduction to GPR for archeologists, and Bevan (1998) has provided an excellent comparison of various radar antennas 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. These radar waves are 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. Low-frequency antennas generate long wavelength radar energy that can penetrate several tens of meters under certain conditions, but can only resolve large 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 might penetrate only a meter into the ground. The generated reflections from these high-frequency antennas are capable of resolving objects or features with maximum dimensions of a few centimeters. A resulting tradeoff exists between subsurface resolution and depth penetration: the deeper the penetration then the resulting resolution is less, or the higher the resolution then the resulting depth penetration is much shallower.

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

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.

Soil Resistivity Surveys

The resistivity (soil resistance) survey is an active geophysical technique, which injects a current into the ground; see Bevan (1998:7–18), Carr (1982), Clark (2000:27–63), and Heimmer and De Vore (1995:29–35) for more details of resistivity surveys. It measures the resistance to the flow of an introduced electrical current in the soil. The voltage is measured, and by Ohm's Law, one may compute the resistance at any given point (**R = V/I** where **R** is resistance, **V** is voltage, and **I** is current). Soil resistance is dependent on several factors, including the soil structure, soil texture, soil water solution conductivity, capillary conductance, the depth of the archeological targets (i.e., features or objects), and the material comprising the archeological target. The differential electrical resistance is primarily dependent on the moisture content in the subsurface matrix (Carr 1982:47–105; Clark 2000:27; Heimmer and De Vore 1995:9,30). Since electricity is easily conducted through water and follows the path of least resistance, the resistivity anomalies are identified as contrasts between the resistance values of the buried features and objects and those of the surrounding soil matrix.

The two types of resistivity surveying techniques used in archeology are the lateral profiling (horizontal) and the vertical electrical sounding (VES). Lateral profiling is done with fixed electrode spacings. Resistance measurements in ohms (Sheriff 1973:156) are collected by moving the electrode array from point to point along fixed traverses. Due to the problem of contact resistance between two electrodes in the ground, a typical soil resistance survey makes use of four electrodes or probes. The current passes through two electrodes and the voltage is measured between the other two probes. The configuration of the electrodes also varies; see Milsom (1996:73) for common configurations. The present survey utilizes the twin probe array (Geoscan Research 1996). On the twin probe array, a current and voltage probe are located on a mobile frame that is moved around the site. Two additional probes are located away from the survey area and also consist of a current probe and voltage probe. The probes on the frame are located at a fixed distance apart. A general rule of thumb for the depth investigation of soil resistance survey is the depth is equal to the distance of probe separation. This value is not an unique number but an average for the hemispheric volume of soil with a radius equal to the probe separation distance. The probes are connected to the resistance meter, which is also on the frame. The measurement is taken when the mobile probes make contact with the ground and completes the electrical circuit. The measurements are stored in the resistance meter's memory until downloaded to a lap-top computer. The resulting data is integrated to provide areal coverage of the site under investigation.

The VES is done at a location by measuring several resistance values with increasing electrode separation. As the separation between the electrodes increases, the same proportion of current is disturbed through an increasing depth of soil. This results in a proportionally larger effect of the deeper layers on the apparent resistivity. The Wenner array is most commonly used probe array for VES. In this configuration, the electrodes are evenly spaced with the current electrodes on the ends and the voltage electrodes in the middle (C1 P1 P2 C2). The near surface conditions differ at each electrode for each reading resulting in a relatively high noise level. To produce a smoother sounding curve, the VES is produced by using an offset array where the electrodes are expanded in opposite directions. The two readings for each offset separation are averaged together. This suppresses the local effects at each electrode. The difference between the two readings indicate the significance of these effects. The resistance values using the Wenner probe array obtained are converted to apparent resistivity by the formula $\boldsymbol{\rho_a = 2\pi ar}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **a** is the electrode spacing, and **r** is the measured resistance at each electrode separation. The resulting apparent resistivity values in ohm-meters (Sheriff 1973:156) are plotted by electrode spacing. Variation of the apparent resistivities with each increasing electrode spacing are compared to sounding curves or modeled in a computer program. This produces an estimate of the electrical stratification of the soil. This information provides the investigator with basis data that can be used to determine the applicability of the various techniques to the project area (i.e., if the resistivity is high, then ground-penetrating radar should work well on the site, or if the resistivity is extremely high, then a ground conductivity survey might 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 (Milsom 1996:91–93). The most common probe array used in archeology using this combination is the twin electrode probe array, although multi-probe switching resistivity systems are becoming more common (Geoscan Research 1996; Iris Instruments 1999; Milsom 1996:71). Combining the resistance meter, probes, and a multiplexer unit, several probe configurations can be measured at a single location (Geoscan Research 1995). By combining the multiple configurations, pseudo sections or depth information can be collected relatively rapidly over a large area. The conversion of the soil resistance measurements to resistivity is more complicated than in the Wenner probe array (Bevan 2000:2). Like the Wenner probe array, four probes are used to take the resistance measurement; however, instead of having the linear arrangement of potential, current, current, and potential probes set at equal distances apart, in the twin electrode array, one current and one potential set of probes are on the mobile frame and moved about the site collecting readings. The second set of remote probes is set away from the grid.

To convert the resistance readings from the multiple sets of probes to comparable apparent resistivity measurements the following formula is used (Geoscan Research 1995:B-1): $\boldsymbol{\rho_a = 2\pi r/G.F.}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **r** is the measured resistance at each electrode separation, and **G.F.** is equal to the inverse of the distance between the remote probes plus the distance between the mobile probes minus the 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 ($\mathbf{R = V/I = (1/2\pi)\ (\rho_1/a_m + \rho_2/a_r\ )}$ where $\boldsymbol{\rho_1}$ is the resistivity of the soil beneath the mobile probes, $\mathbf{a_m}$ is the mobile probe separation distance, $\boldsymbol{\rho_2}$ is the resistivity of the soil beneath the remote probes, and $\mathbf{a_r}$ is the remote probe separation distance). The apparent resistivity can be approximated by the formula $\boldsymbol{\rho_a = \pi a r}$, where the electrode spacing **a** of both the mobile and remote electrodes are equal, or to $\boldsymbol{\rho_a = 2\pi a r}$ (approximate), where the electrode spacing **a** is equal to the mobile probe separation when the remote probe spacing in much greater than the mobile probe spacing. A more accurate method (Bevan 2000) of determining the resistivity measurements from the soil resistance data is to determine the resistivity below the remote, fixed electrodes by taking measurements at two separate probe spacings where $\boldsymbol{\rho_2 = 2\pi\ [(R_1 - R_2)/(1/a_{r1} - 1/a_{r2})]}$. The resistivity below the mobile probes can be computed as $\boldsymbol{\rho_1 = 2\pi a_m R - \rho_2(a_m/a_r)}$. By combining all the resistivity data, a three-dimensional display can be generated of the soil resistivity.

Electromagnetic Ground Conductivity Surveys

The electromagnetic ground conductivity survey is an active geophysical technique, which induces an electromagnetic field into the ground through a transmitting coil; for more details of conductivity surveys, see Bevan (1998:29–43), Clark (2000:34–37), and Heimmer and De Vore (1995:35–41). This survey technique measures the soil conductivity. Theoretically, conductivity represents the inverse of resistivity. High conductivity equates to low resistivity and vice versus. 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. 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).

An electromagnetic field is induced into the ground through the transmitting coil. 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. Changes result from electrical and magnetic properties of the soil matrix. Changes 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. Thus the instrument has the ability to detect lateral changes on a rapid data acquisition, high-resolution basis. In archeology, the instrument has been used to identify areas of compaction and excavation as well as buried metallic objects. It has the potential to identify cultural features that are affected by the water saturation in the soil (Clark 2000:36; Heimmer and De Vore 1995:36–37). In the present project, the investigations are looking for changes in the electromagnetic conductivity between the natural soil surrounding the grave and the disturbed soil within the grave; however, metallic trash in the topsoil can degrade conductivity signals.

The apparent conductivity data were recorded in units of millisiemens per meter (mS/m). The electrical conductivity unit or siemens represents the reciprocal of an ohm-meter or the unit for resistivity (Sheriff 1973:197). The relationship between conductivity and resistivity is represented by the following formula (Bevan 1983; McNeil 1980): mS/m = 1000/ohm/m.

Geophysical Surveys of Historic Cemeteries

Many attempts have been made to map historic cemeteries with the goal of detecting unmarked graves. In some cases, where sites are threatened with destruction or encroachment, excavation is used to evaluate the results. More often, the results must be evaluated based on more circumstantial evidence. The main question in geophysical studies of historic cemeteries is whether the geophysical devices will yield readings over known graves that differ from readings in areas devoid of graves. Do the geophysical anomalies detected correspond with burial monuments or depressions? Are the anomalies of appropriate size? Can the anomalies be reasonably attributed to soil changes that one would expect to result from the excavation of a grave or to grave inclusions?

With the exception of graves that contain iron caskets or reinforced vaults, grave contents are rarely detected directly. Geophysical instruments in common use have not been demonstrated to detect human remains. Successful results can more often be attributed to the detection of soil changes that result from the excavation and refilling of the grave shaft. A geophysical survey of a historic cemetery normally includes known graves that should yield a "signature" or typical data measurements of a refilled grave, as well as, background readings of the undisturbed soils. With these two opposing data sets, one can then model the response from unmarked graves by predicting the nature of the anticipated anomalous readings based on the soil's physical properties and expected differences between backfilled grave excavations and the unexcavated natural soil matrix. In other words, the ability to identify unmarked graves is greatly increased when one has comparative geophysical signatures from known graves in a cemetery survey. It is expected that in the more recent cemeteries will have a greater differentiation between disturbed grave fill and adjacent natural soil matrix. In small and abandoned burial plots, where documentation is poor and visible markers are missing or non-existent, it is more difficult to reliably detect graves with a given geophysical instrument and to determine typical background values for undisturbed soils.

Dr. Bruce W. Bevan (1991) reported on the results of several geophysical surveys in cemeteries. His study sites ranged from Minnesota to New England. At various sites he used ground-penetrating radar, magnetometers, and a ground conductivity meter. At the Burton Parish church in Williamsburg, Virginia, the results of the radar were clear and unambiguous (Bevan 1991:1313–1314, Figure 5). The same site resulted in low values of conductivity (high resistance) and high magnetic readings in the vicinity of a grave. At the other sites the results were much less clear with some graves clearly detected and others only a few meters away showing no clear signature (Bevan 1991:1311, Figure 1).

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

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

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

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

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

In applying geophysical techniques to archeological problems, one is challenged with the detection and recognition of anomalous conditions caused by human alteration of natural soil properties. There is no unique interpretation of substantial geological or anthropogenic anomalies that can be used to identify similar features at different site settings (Breiner 1973:18–19). Many different geological or pedological configurations of buried material (e.g., soils, rocks, other substances) can produce an individual anomaly. The challenge is to identify the most probable or realistic model. Similar problems occur in archeological interpretations of geophysical anomalies, but on a much smaller scale than those encountered in geological anomalies (Nickel 2000b:10). For grave identification, there needs to be a change in the physical property being measured by the geophysical instrument between what is in the grave and the surrounding natural soil matrix. If the displaced soil from the excavation of the grave is piled to the side of the grave as the shaft is being dug and then replaced over the body in the reverse order with the deeper soil on the top of the pile shoveled back into the grave first, there may not be any differentiation between the displaced soil and the surrounding unexcavated soil.

If the soil is not compacted during its replacement, there may be no change in compaction between the surrounding soil matrix and the displaced soil. These factors would affect the ability of the geophysical instruments to detect the change between the surrounding soil matrix and the disturbed excavated soil of the grave. If the soil moisture levels between the disturbed and undisturbed soil matrices are approximately the same, then the geophysical instruments may not be able to detect and changes as well. Depending on how the individual was buried (e.g., in a coffin, in a blanket or shroud, in clothes), there may be metal objects on the body or in the coffin furniture that could be detected by a magnetic gradient, conductivity, or ground-penetrating radar survey. The ability of the geophysical instruments to detect a grave is based on the presence of significant changes in the property being measured by the instrument. If there is no change or very little change in magnetic gradient properties, conductivity, resistance, dielectric constant, the geophysical instruments will not register a contrast in the data and the grave will be indistinguishable from the surrounding natural/undisturbed soil matrix.

Field Survey Procedures

The survey scope-of-work for the Oregon–California Trails project called for a magnetic gradient, resistivity/conductivity, and ground penetrating radar surveys of the areas associated with known cemeteries (Sites 14MH323 and 14PO312) or believed to contain graves (Sites 14MH322 and 14PO406) in order to identify the extent and location of possible graves. The geophysical grids were laid out at each site with a portable Ushikata S-25 Tracon surveying compass (Ushikata n.d.) and 100-m tape. The surveying compass was used to sight in the two perpendicular baselines and grid corners (Figure 13). Wooden hub stakes were placed at the 20-m grid corners or at 10-m midpoints. Placement of the geophysical grids within each site was determined by the presence of gravestones, possible gravestones, and cairns. A datum point was established at each site.

Once the geophysical grid was established, a Nikon DTM-730 electronic field station (Nikon 1993) was positioned over the site datum or mapping station (Figure 14). Arbitrary values were assigned to the Northing (Y) coordinate, Easting (X) coordinate, and elevation (Z coordinate) of the mapping station (Note: for all sites these values were North 1000 m, East 1000 m, and elevation of 1000 m). The backsight reference points for the four sites were aligned on magnetic north. The site features, geophysical grid points, and topography were mapped with the field station, prism, and prism pole. The data were stored on the memory card of the DTM-730 and subsequently downloaded into a laptop computer. Initially the coordinate data (i.e., survey codes, northing coordinates, easting coordinates, and elevation) and raw field data (i.e., survey codes, horizontal angle, vertical angle, slope distance) files were transferred from the field station to the laptop computer with the Transit software package (Nikon 1996). These data files for each site were then transferred to the WordStar 5.5 software package (MicroPro 1989). The extraneous information in the coordinate data files were removed leaving the northing (Y) coordinates, easting (X) coordinates, elevations (Z coordinates), and point descriptions (Appendix A). This locational information was then converted to an XYZ data (*.dat) file for processing in the SURFER 7 mapping software (Golden Software 1999).

Once in SURFER 7, a grid file was created from the data file (Golden Software 1999:89–102). The data columns were identified. Column B contained the X values or the East coordinates. Column A contained the Y values or East coordinates. Column C contained the Z or elevation values. Column D contained the description of the individual points. The grid line geometry was set for minimum and maximum values in both the X and Y directions. These values formed the corner points for the generated contour maps. The data were gridded using the Kriging algorithm (Golden Software 1999:103–129). The generated grid file was then smoothed (Golden Software 1999:361–373). The spline-smoothing routine was selected to eliminate the angular contours by rounding the edges using a cubic spline interpolation over the gridded data. The grid file defines the XY locations of each grid node over the extent of the map and the interpolated Z value at each node.

A contour map was then created from the grid file (Golden Software 1999:183–219). The contour map consisted of several components, which defined the appearance of the contour map. These included the contour level, which defined the interval between contour lines. The line component determined the appearance of the contour lines, including type, thickness, and color. The area between the contour lines could be filled with a gradually changing spectrum of colors. The labeling feature allowed for the placement of the contour value on the contour lines. This component controlled the text properties, numeric format, spacing, and interval of the labels. Hachures or small tick marks could also be placed along the contour lines to indicate the direction of slope. These were generally not used in the generation of the topographic or feature maps, but were used for indicating negative values in the geophysical data. The contour lines were drawn as a series of smoothed line segments between adjacent grid lines. Feature maps were generated and labeled for each site. A map posting the location of the individual feature points was also generated (Golden Software 1999:273–295) and overlain (Golden Software 1999:321–330) on the contour map. The points were used to draw objects including lines, polygons, and points; to label specific features; to change the appearance of the objects; and to assign unique symbols to classes of objects

(Golden Software 1999:463–489). A scale bar and north arrow were added to the finished contour map. The site's natural and cultural features were also labeled. At Site 4MH322, a 10-m by 20-m grid (Figure 15) was established. A 20-m by 20-m grid was established at Site 14MH323 (Figure 16). At Site 14PO321, a 20-m by 20-m grid (Figure 17) was established. A 10-m by 10-m grid was established at Site 14PO406 (Figure 18).

Prior to the geophysical survey of each site, 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 baselines connecting the grid corners. These ropes formed the boundaries of each grid during the data collection phase of the survey. Additional traverse ropes were placed at 1-m intervals across the grid at a perpendicular orientation to the baselines beginning with the line connecting the two wooden hubs on the left side of the grid unit. These ropes serve as guides during the data acquisition. These 20-m lengths of ropes are divided into 0.5-m increments by different colored tape. One color (blue) is placed every meter along the rope with red tape placed at 0.5-m 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 zig-zag (bi-directional) mode across the grid(s) until the survey was completed for each technique.

Once the ropes are in place and before the survey is completed for the grid, a sketch map should be made of the grid. The map should include the location of all cultural and natural features with the grid area. For the present project, cultural features include gravestones, depressions, rock pile or cairns, wagon swales, fences, and pin flags. Natural features include vegetation (e.g., trees and shrubs), drainages, and bank edges. The detailed sketch maps aid in the interpretation of the geophysical anomalies identified during the analysis of the data. The topographic mapping of Sites 14MH322 and 14PO406 provides such information in lieu of detailed sketch maps. A sketch map of Site 14MH323 provides information on the locations of the one marked gravestone, rock concentrations, depressions, pin flags, and rebar; however, the trees and brush within the grid are not placed on the sketch map. No sketch map is produced for Site 14PO312. The lack of a sketch map or lack of the vegetation (e.g., trees and shrubs) on the sketch maps will make interpretation of some of the geophysical anomalies more difficult.

Magnetic Gradient Survey Methodology

The magnetic gradient survey was conducted with a Geoscan Research FM36 fluxgate gradiometer with a ST1 sample trigger (Geoscan Research 1987). MWAC Archeologist and co-author Steven L. De Vore operated the instrument. The instrument is a vector magnetometer, which measures the strength of the magnetic field in a particular direction. The gradiometer (Figure 19) consists of a control unit that contains the electronics, menu keyboard pad, power source, operating program, on-off switch, connector for the charger/data output/external logger, analog output connector, LCD display screen, sounder outlet, balance control, and memory chips (Geoscan Research 1987:8–10). The tubular carrying handle connects the control unit to the vertical sensor housing tube that contains the two fluxgate sensors. N-S and E-W sensor alignment controls are located on the sensor tube.

The sensors are set at 0.5 m 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 m 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. This gradient is not in absolute field values but rather voltage changes, which are calibrated in terms of the magnetic field. The fluxgate gradiometer does provide a continuous record of field strength. With a built-in data logger, the gradiometer provides fast and efficient survey data collection. Typically, data across a 20-m by 20-m grid unit with sampling parameters of 8 samples per meter and 1-m traverses can be collected in 15 minutes. This amounts to 3,200 readings per survey grid. With 0.5-m traverses, it takes approximately 30 minutes to complete a 20-m by 20-m grid. This amounts to 6,400 readings per survey grid.

Prior to the start of the survey, the memory of the gradiometer is cleared and the menu settings are checked for the appropriately planned survey. The operator must be free of any magnetic metal. If any clothing or objects carried by the operator is slightly magnetic, there is a high probability that the survey results will be degraded due to presence of magnetic materials in close proximity to the sensors in the instrument. As one walks along the traverse, the presence of magnetic materials on the operator will resulting in a shift in the readings of 1 to 2 nT or greater. This will cause a stripe effect to the data. In the case of the present project at all four sites, the gradiometer is programmed for a resolution of 0.1nT, reading average off, log zero drift off, log interval at 0.25 m, baud rate of 2400, average period set to 16 readings, check offset off, and the encoder external trigger type. When the instrument is turned on, the initial LCD display indicates the current display resolution, the status of the Log Drift facility, and the battery status. The resolution display reading can be either positive or negative and with the instrument set to the 0.1 nT resolution mode, the maximum value recorded is 204.7 nT. Although some magnetic anomalies may be stronger in the positive and negative values, the instrument defaults to the maximum value when these extremely strong values are observed. Generally such strong field result from the close proximity of highly magnetic iron artifacts to the instrument. On the sample trigger, the samples/m knob is set to 8 samples/m and the rate knob is located at the 1 o'clock position. The toggle switch is set to the stop position. The grid size interval in the instrument and the traverse m knob on the sample trigger must be set to the same value. For Sites 13MH323 and 14PO312, the value is set to 20 for the 20-m grid sizes at both sites. Sites 13MH322 and 14PO406, the value is 10 for the 10-m grid sizes at both sites.

The sensors must be accurately balanced and aligned along the direction of the field component to be measured (Figure 20). The zero reference point was established at each site and the balancing and alignment procedures were oriented to magnetic north. This point was selected where there was no noticeable localized changes in the digital display or by raising the instrument above the ground with the use of a plastic step stool. The readings should vary less than 2 to 3 nT. The balance control on the instrument was adjusted first. The balancing the instrument was conducted in the 1 nT resolution range by first inverting the instrument and zeroing the instrument. The instrument was then rotated 180 degrees about the same horizontal plane of the axis of the handle. The trimming tool was inserted into the balance control slot on the side of the instrument and the reading in the digital display was reduced in half. The procedure was repeated until the reading in the upright and inverted positions was within a range of −1 to 1 nT. With the instrument held vertically at a height where the alignment controls were within easy reach, the two sensors were then aligned. At first, the bottom sensor was aligned. The instrument was pointed to magnetic north and the instrument was zeroed so that the display reading was zero. The instrument was then rotated around the sensor tube 180 degrees until it pointed south. The small aluminum wheel of the N-S alignment control at the bottom of the tube was used to adjust the sensor until the reading was half of the value first observed when it was rotated to the south. The instrument was rotated back 180 degrees until it pointed to magnetic north and rezeroed. The display reading was checked. If the north reading was within the range of −1 to 1 nT, the alignment was considered successful and the bottom sensor was aligned. If the north reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the bottom sensor was aligned, the top sensor was then aligned. The instrument was rotated 90 degrees until it faced east. The instrument was zeroed and then rotated 180 degrees until it faced west. The display reading was noted. The E-W alignment control wheel at the top of the sensor tube was adjusted until the reading was half of the observed reading. The instrument was then returned to its east facing position and rezeroed. If the east reading was within the range of −1 to 1 nT, the alignment was considered successful and the top sensor was aligned. If the east reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the top sensor was aligned, the top sensor was then aligned. As a final check, the instrument was rotated 360 degrees about the vertical tube axis. If the display reading stayed within the −1 and 1 nT range, the sensor alignment procedures were considered successful. If the observed display readings went over the acceptable range, the balancing and alignment procedures were repeated until successful. The instrument was returned to the 0.1 nT resolution operating range and then zeroed at arms length over the operator's head. These procedures were repeated at each site prior to commencing the magnetic gradient survey. The operator's manual (Geoscan Research 1987:29–31) illustrates the steps involved in preparing the instrument for actual field data collection.

At Site 14MH322, the survey of each traverse was conducted in a parallel or unidirectional mode beginning in the southwest corner or lower left-hand corner of each grid unit. With the instrument on, the Enable Log button on the menu pad is pushed to initialize the logging display mode. The LCD screen displayed the starting Grid Number (G1), the Line Number (L1), and the Position Number (P1). The toggle switch on the sample trigger was moved to the start position and the operator began walking the traverse line. The instrument was carried along the traverse rope with control box facing magnetic north. The sample trigger on the instrument provided a series of clicks for every sample reading and the instrument signals a beep on every eighth sample reading. As each measurement was recorded, the logging display was advanced one position until reaching the end of the line and then the line number advanced. The grid number advanced when the end of the grid was reached. The geophysical investigator maintained a pace along the traverse in accordance with the audio beeps from the fluxgate gradiometer. This placed the eighth sample reading at the meter tape mark. At the end of the first traverse, the instrument stopped collecting and recording the data. The toggle switch was moved to the stop position. At the end of each line, the operator returned to the same side of the grid as the initial starting point, moved over to the next traverse, and proceeded back up the next traverse line towards the far edge of the grid unit. This procedure was to reduce an error that may be incorporated into the survey due to the non-alignment of the grid on magnetic north. The parallel mode of data acquisition was repeated over and over until the end of the grid was reached. At the end of the grid, the instrument was turned off. The operator maintained a constant vigilance of the tilt of the instrument throughout the survey. The gradiometer was maintained in a vertical position during data acquisition. Any rotation or tilt in the instrument could cause errors of shifts in the readings of 1 to 2 nT or more. At Sites 14MH323, 14PO312, and 14PO406, the survey of each traverse line was also conducted in the parallel of unidirectional mode beginning in the lower left hand corner of the grid as the operator faced the direction of travel along the traverse. At Site 14MH323, the direction of travel was north northwest. The grid as oriented parallel to the Big Blue River bank. At Site 14PO312, the direction of travel was to the northwest. At Site 14PO406, the direction of travel was to the east because of the presence of the deep drainage cut along the southeastern corner of the grid. In all cases, the instrument was balanced and aligned to magnetic north at the magnetic reference point established for the individual site.

During the survey, data were collected at 8 samples per meter (at 0.125-m intervals) along each traverse and at 0.5-m traverses across each individual grid unit resulting in 16 samples per square meter. A total of 160 magnetic gradient measurements was recorded for each traverse in the memory of the Geoscan Research FM36 fluxgate gradiometer. For each complete 20-m by 20-m grid unit, a total of 6,400 measurements was recorded during the magnetic gradient survey. At Site 14MH322, the survey covered two 10-m by 10-m grids with a total of 3,200 measurements recorded. At Site 14MH323, the survey covered one complete 20-m by 20-m grid and a partial 20-m by 20-m grid with a total of 6,560 measurements recorded at the site. At Site 14PO312, the survey covered a single 20-m by 20-m grid with a total of 6,400 measurements recorded at the site. At Site 14PO406, the survey covered one 10-m by 10-m grid with a total of 1,600 measurements recorded. At the end of the data acquisition at each site, the magnetic gradient data (Appendix B) from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research 2001) on a laptop computer. It took approximately 13 minutes to download the data from a complete 20-m by 20-m grid. The grid file created in GEOPLOT was reviewed in the field prior to the clearing of the gradiometer's memory. The magnetic gradient data for Sites 14PO312, and 14PO406 were collected on November 14, 2000. The magnetic gradient data for Site 14MH323 were originally collected on November 15, 2000, but an error in the grid size in the setup menu resulted in redoing the magnetic gradient survey on August 1, 2001. The magnetic gradient data for Site 14MH322 were collected on August 1, 2001. It should be noted that the instrument used regular heavy-duty AA batteries at Sites

14PO312 and 14PO406 due to failure to charge the instrument's rechargeable AA battery pack overnight prior to the start of the survey. When the instrument's charging unit was plugged into the AC outlet at the motel room, the operator did not notice that the outlet was directly connected to the room's overhead light. When the light was turned off, the outlet was also disconnected from the electric current.

Ground-Penetrating Radar Survey Methodology

The Noggin Plus 250 Smart Cart System GPR unit (Figure 21) produced by Sensors and Software (2001) is used for the Kansas trails surveys. The GPR unit is operated and owned by Site Sensors consultant and co-author Robert K. Nickel. The Smart Cart System consists of the cart, a Noggin antenna, an odometer wheel, a Digital Video Logger (DVL), and a battery. The Noggin antenna used in the present project operates at a nominal frequency of 250 MHz (megahertz) and is mounted in a cart that records the location of the radar unit along a grid line. The antenna separation or spacing is 0.034 m.

The DVL contains the operating Noggin^{Plus} software, and provides a visual display of the data, which allows the results to be viewed almost immediately as they are recorded. The DVL also stores the digital radar profile data. The DVL is connected to the battery and to the antenna by a Y-shaped sensor cable. Prior to the start of the GPR survey, the operating parameters are set in the DVL. For the present project, the depth unit is set to time in nanoseconds (ns) and the horizontal distance unit is in meters. A 50 ns time window is used for the present project at the four Oregon and California Trail sites. The Noggin 250 has a normal data trace of 5 cm. The trace is fixed distance interval (i.e., station interval) over which one vertical strip of data is recorded. Data are averaged at 16 stacks per trace. Collecting several traces at each survey position and then averaging them into a single averaged trace is one way of increasing data quality and reduces random radio frequency noise or interference. The Noggin 250 antenna has an antenna separation of 0.3048 m with a pulser voltage of 100 volts. The survey mode is reflection.

The odometer is set to active, which allows it to be used to collect data. As the cart moves, data is collected; however, if the cart stops, then the system stops collecting data. Without the odometer active, the system operates continuously. The cart is pushed along each traverse in a forward direction.

GPR surveys often involve a trade-off between depth of detection and detail. Lower-frequency antennas permit detection of features at greater depth 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 wall of the excavation 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 and achieve reasonable estimates of the velocity of the radar signal in the site's soil. At the four sites in the present project, the 250 MHz Noggin generally resulted in detection to a depth of about 1 m (3.3 ft) based on a velocity of 0.06 m/ns.

The first site investigated was the Cholera Cemetery (Site 14PO312) on November 14, 2000. A small area was enclosed by chain-link fence. The fenced enclosure contained three stones suspected of marking grave locations. Only one of stones was inscribed. The small and irregular shape of the enclosure coupled with trees and uneven topography made this enclosure an inappropriate target for a close interval grid survey (Figure 22). A small number of lines were surveyed with the GPR unit. These were designed to cross the likely locations of graves that might be marked by the stones. A radar profile (Figure 23) was collected along a line that passes near the two unmarked stones near the east side of the fenced enclosure and represented the reflections of the soil layers. The gravestones were located between 1 and 2 m and between 8 and 9 m along the horizontal scale. Weak and moderate radar anomalies occurred on the profile near the 1.25-m and 8.75-m points. Soils in the area of these surveys were relatively high in clay content, which resulted in rather rapid attenuation of the radar signal. The potential grave anomalies were detectable from near the surface to a depth of about 70 cm. The radar profile (Figure 24) of a line that crosses the slight depression lying immediately east of the stone inscribed with the name of T. S. Prather and dated 1849 contained and anomaly that corresponded with the location of the Prather headstone. The stone marker was centered at the 4-m point along the horizontal scale on the radar profile. As with the radar reflections near the two unmarked stones, the anomaly is most prominent in the near surface portion of the profile.

It is likely that all three of these radar anomalies reflect disturbed soil in the upper portion of grave excavations. It is, however, also possible that non-burial excavations would produce similar signatures. There is no clear indication of interments. If an interment from the mid-1800s were very simple (with only a wooden box or fabric wrap) it is possible that we would not detect grave contents even as shallow as one meter. It is also possible that the actual interments lie below the limits of detection of the radar used on this site and that the anomalies result from differences between the soil in the top part of a grave shaft and the surrounding unexcavated soil matrix.

Other areas to be investigated as part of the Oregon–California Trails project consisted of close-interval gridded surveys at 0.5-m traverses with the radar and other geophysical instruments. These gridded surveys were most easily interpreted when the data were presented in plan-view maps. A simple “model” of how the data from near the T. S. Prather grave would appear in a plan-view map was created by duplicating two of the actual lines of data from across the probable gravesite and placing those four lines in a matrix of adjacent lines (on which the Prather grave was not visible) from within the enclosure. This contrived grid (Figure 25) serves to illustrate how a soil feature with a length of 1.5–2 m and with the same contrast as the soil at the Prather gravesite would look when rendered in the plan-view maps used to present the data from this and other Trails cemetery sites. This plan-view also serves to illustrate that data comparable to those associated with the Prather grave would produce a clear and prominent anomaly in plan-view maps. In order to explore the possibility that many other graves exist in proximity to those inside the fenced enclosure, a 20-m square grid was established east of the enclosure. This is the same grid that was used for the magnetic gradient and soil resistance surveys at the site.

The data acquisition parameter for the GPR system is set to the grid mode. This allows the operator to set the grid dimensions, line spacing, grid type, and survey format. The Grid collection mode allowed for the collection of the radar profiles in an organized pattern over the project area. The grid parameter also allows for the production of a plan-view map of the grid. The grid type specifies the way data is collected along the traverses. For the present survey at Sites 14MH322, 14MH323, and 14PO312, the data lines or traverses run in the Y or north direction. At Site 14PO406, the lines run in the X or east direction. The survey format specifies how the data in the lines are collected. For all four sites, the data are collected in a ziz-zag or bi-directional mode starting with 0 with the even numbered lines in the forward direction and the odd number lines in the reverse direction. The grid dimensions for Sites 14MH323 and 14PO312 are 20 m in the east or X direction and 20 m in the north or Y direction. At Site 14MH322, the grid dimensions are 20 m in the east or X direction and 10 m in the north or Y direction. At Site 14PO406, the grid dimensions are 10 m in the north or Y direction and 10 m in the east or X direction. The line spacing at all four sites is 0.5 m between the traverses or survey lines. The digital GPR data (Appendix C) for each line in the grid is saved in the *.dt1 file format by line number and direction (Liney*.dt1). Information about the parameters of each line is also saved in a header file (Liney*.hd). The header file contains information on the program type (i.e., Noggin^{Plus}), the date, number of traces, number of points per trace, time zero at point, total window time, starting position, final position, step size used, position units, nominal frequency of antenna, antenna separation between transmitting and receiving antenna, pulser voltage, number of stacks, and survey mode. The data is transferred from the DVL to a laptop computer at the end of the day using the WinPXFER program designed by Sensors and Software (2001:87–90). Once the data are reviewed in the laptop computer, the data are then deleted on the DVL.

The 20-m by 20-m square grid at the Cholera Cemetery site was surveyed with the GPR unit operated along the north-south oriented lines. The survey lines were 0.5 m apart resulting in 40 bi-directional traverses across the east-west axis of the grid. The GPR survey was conducted on November 14, 2000. At Site 14PO406, 20 bi-directional traverse lines were surveyed across the 10-m by 10-m square grid on November 14, 2000. The GPR profiles were collected along east-west oriented traverse lines. At Site 14MH323, 40 bi-directional traverse lines were surveyed across the 20-m by 20-m square grid on November 15, 2000. The GPR profiles were collected along southeast-northwest oriented traverse lines. At

Site 14MH322, 40 bi-directional traverse lines were surveyed across the 10-m by 20-m rectangular grid on November 16, 2000. The GPR profiles were collected along north-south oriented traverse lines.

Soil Resistance Survey Methodology

For the Oregon–California Trails project, the Geoscan Research RM15 advanced resistance meter (Figure 26) and PA5 multiprobe array (Geoscan Research 1996) is used with a MPX15 multiplexer (Geoscan Research 1995). The multiplexer and resistance meter combination is used at Sites 14MH323 and 14PO312. The combination of resistance meter and multiplexer provides the survey with the capability of additional depth data from 0.25 m to 1.5 m. MWAC Archeologist and co-author Steven L. De Vore operate the instrument; however, KANZA Chapter members and the owners' family members also operated the instrument once they received instruction in its use. The resistance meter consists of a control unit that contains the electronics, menu pad, power source, operating program, and memory chips. It also contains the on/off switch, expansion ports for the potential and current mobile and remote probes, a LCD display screen, and charger connector. The multiplexer contains a microprocessor that acts in conjunction with the RM15. It is connected to the expansion ports on the resistance meter by three cables. The mobile and remote probe cables are plugged into the bottom of the multiplexer unit. The control unit and multiplexer are attached to the multiprobe array frame by a mounting plate and short and long knoblet screws.

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 and multiplexer are moved uniformly across the site. The mobile probes are at a set distance apart on the array frame. 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-m cell on the traverse line since the reading is of an average volume of a hemisphere with a radius equal to the mobile probe separation distance. This provides some freedom in the placement of the probes, which makes the system fast and easy to use. If an obstacle is in the way of the probes, the frame can simply be moved to one side or the other of the obstacle for the placement of the probes if the displacement will not greatly affect the location of the measurement. The insertion depth for the mobile probes is not critical. With reasonably moist soil, the downward momentum of the frame is enough force to push the probes into the ground to a depth of 3 to 5 cm. The remote probes are stationary, and are set at a distance that is 30 times the twin probe separation distance on the PA5 frame from the survey grid area. At this distance, the background resistance reading is essentially independent of the mobile probes' location. The separation distance between the remote probes is not critical since the probes are left in a fixed position throughout the survey. The distance is generally between 0.5 m and 2 m (note that at Site 14MH323, the remote probe separation was 1.05 m, and at Site 14PO312, the remote probe separation was 2.008 m). The remote probes are connected to the multiplexer by means of a 50-m cable and drum and additional 25-m electrical jumper leads. Although the insertion depth of the remote probes is not critical due to the high contact resistance tolerability of the RM15, it is best to insert the probes as far into the ground as possible to eliminate any offset in background resistance caused by remote probe contact resistance or capacitive coupling of the 50-m cable. This is not generally important in a twin electrode probe survey since one is only looking for changes in an arbitrary background level as the mobile probes are moved along the traverse lines in a grid survey; however, should the remote probe contact resistance change, as in the case of a rain shower, then the offset and background resistance could also change beyond acceptable survey levels.

The combination of the multiplexer with the resistance meter and multiprobe frame provided multiple expanding twin arrays for depth investigations. Wings were added to the frame of the PA5 multiprobe array to accommodate the additional probes for multiple depth readings. The short wing was attached to the left side of the frame and the long wing with double probe positions was attached to the right side of the frame. A strut was also attached to the long wing and handle bar of the PA5 frame for additional support. Six stainless steel probes were attached to the wings and connected to the multiplexer by an electric cable through a series of different length jumper leads. The probes were connected to the multiplexer unit and programmed through the resistance meter. Probes were set to take depth measurements at 0.25 m, 0.50 m, 0.75 m, 1.00 m, 1.25 m, and 1.50 m below the surface. For each probe separation, the instrument averages the response over an area that is shapes like a semi-hemisphere with the deepest part directly beneath the center of the spacing of the two probes. For 0.25-m probe separation, the instrument is averaging a volume of soil that is 0.25 m deep at this midpoint location, for the 0.50-m probe separation, the depth is 0.50 m, etc.

Prior to the start of the survey, the memory of the resistance meter is cleared and the menu settings are checked for the appropriately planned survey. In the case of the present project at Sites 14MH323 and 14PO312, the resistance is programmed for a Mapping grid size of 20 m for both sites, a grid sample interval of 0.5 m, a grid traverse interval of 0.5 m, and the zigzag grid traverse mode. The Range parameters include a gain of 10, a current of 1 mA, and a frequency of 137 Hz. The Setup includes a medium auto-log speed, an output voltage of 40 v, a high-pass filter value of 13 Hz, and the mains frequency equal to the United States standard of 60 Hz. In the Array, the PA5 is the selected hardware with the twin configuration. The probe separation was set to 0.5. The Communications parameters for downloading the data are set to 9600 baud rate and with a data separator of no space. In the Program menu, the meter can be programmed as a single twin array (the default setting), parallel arrays, and multiple arrays. As the word single implies, only one configuration is used during the survey. This is set by the placement of two probes on the array frame. A parallel twin array uses more than one configuration of the same type and probe separation, which are set adjacent to one another on the PA5 frame. The final type measurement mode or logging is the multiple log mode which is used in the present project. There is more than one configuration of different types or different probe configurations. This is used to produce pseudo-sections or gaining depth information at different probe separations. Alternating current and voltage assignments (Table 3) between the six probes, six separate soil resistance readings were obtained at each traverse point. The final menu category contains the battery voltage status.

In order to have an appropriate operating range for data acquisition, the soil resistance system is moved around the grid area to check the dynamic range of resistance values. The gain and current ranges are adjusted so that changes of approximately 1 percent in the background resistance is observed. Typically this means adjusting the current and/or gain ranges up or down to get a measurement display of three decimal places on the LCD screen. Once the gain and current ranges are set, they are not changed during the survey of the grid. If they require a change because of repeated over-range readings, the data must first be downloaded and the memory cleared. The grid may need to be re-surveyed at the new settings. Once the gain and current ranges are set (x10 for the gain and 1mA for the current) the operator is ready to begin the survey. The Enable Log button is pushed to enable the Logging Display. The LCD screen displays the ohm reading and the initial position location (G1, L1, P1, M1). The additional M column is added to the display for the Multiple log mode with the multiplexer sequence. To take the first reading, the Start button is pushed. The averaged measurement is recorded into memory and the M, P, L, and G position values will increment one position. An ‘A’ is also displayed on the LCD screen, which indicates that the meter is in the Auto-Log mode and ready for the next measurement. For the multiplexer sequence the M value advances through the six probe-depth separations before advancing to the next position. The entire array is picked up, moved to the next location, and the probes are inserted into the ground. At this point in the survey, the readings are automatically recorded. The RM15 detects the placement of the mobile probes in the ground in the automatic method of logging. The instrument provides both an audible click for each multiplexer sequence and an audible warble for the last multiplexer measurement in the sequence, and it advances the position counter when the last multiplexer sequence measurement is recorded. The M value is reset to 1. When the mobile probes are removed from the ground, the LCD screen indicates an open circuit (HCR / Open cct.). The survey continues to the end of the grid. At the end of the line the instrument will provide one beep, and at the end of the grid it makes two beeps. With the extended array for the six probes, there are occasions when all six probes do not make contact with the ground. In order to get a reading the frame might need to be rocked to get the correct two probes in the ground. The with six separate depth measurements, there are also times when the reading from one of the depths may be over the operating range of the RM15. In those cases, the Dummy Log button is depressed and a dummy value of 2047.5 in inserted into the data set.

During the survey, data were collected at 2 samples per meter (every 0.5 m) along each meter traverse across each individual grid unit resulting in 2 samples per square meter. For each traverse, a total of 40 resistance measurements were recorded in the memory of the Geoscan Research RM15 resistance meter for each probe separation unit or 240 measurements for each probe separation distance from 0.25 m to 1.5 m along the traverse line. For each complete 20-m by 20-m grid unit, a total of 4,800 measurements were recorded during the soil resistance survey with 800 measurements recorded for each probe separation distance value. At the end of the data acquisition at each site, the resistance data (Appendix D) from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research 2001) on a laptop computer. It took approximately 10 minutes to download the data from the six levels of the complete 20-m by 20-m grid. Six separate grid files created in GEOPLOT. Each depth file was reviewed in the field prior to the clearing of the gradiometer's memory. The resistance data for Sites 14PO312 and 14PO406 were originally collected on November 14, 2000; however, a mistake in the probe separation unit field in the resistance meters program negated the results. Site 14PO312 was resurveyed on August 1, 2001. The ground was too hard and dry at 14PO406 in August 2001 to conduct the soil resistance survey without harming the instrument. The probe separation unit field in the RM15 was corrected for the survey at Site 14MH323. The resistance data for Site 14MH323 were collected on November 15, 2000. Cold weather in November 2000 and hard, dry ground in August 2001 precluded any soil resistance survey at 14MH322.

Ground Conductivity Survey Methodology

The present survey utilizes a Geonics EM38 ground conductivity meter (Geonics Limited 1992). The instrument is operated by MWAC Archeologist Steven L. De Vore. The instrument is lightweight and approximately 1 m in length (Figure 27). The meter consists of the transmitting and receiving coils embedded in the case of the instrument, a 9-volt battery, horizontal and vertical digital displays, recorder connector, and control panel. The control panel contains the conductivity range switch with two settings (1000 mS/m and 100 mS/m), on/off/battery test switch, a fine and course inphase (I/P) zero controls, a phase adjustment knob, the quadrature phase (Q/P) zero control, and a toggle switch for Q/P and I/P modes. The transmitting and receiving coils are located at opposite ends of the meter with an intercoil spacing of 1 m. It has an operating frequency of 14.6 kHz in the 100 mS/m range and 40.4 kHz in the 1000 mS/m range. The conductivity meter can collect conductivity data in the quadrature phase operating mode or magnetic susceptibility data in the in-phase operating mode. The present ground conductivity survey is operated in the quadrature phase. The EM38 ground conductivity meter has a depth of investigation of approximately 1.5 m in the vertical dipole mode with optimum resolution at 0.6 m. An adjustable tubular handle is attached to the meter for carrying during survey. The handle also contains the manual trigger button.

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

The meter is connected to the Omnidata DL720 Polycorder (Geonics Limited 1998) for digital data acquisition after the nulling and zeroing procedures have been completed. Data were collected manually with the push of the trigger button located on the EM38 handle. 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 Limited 1997). The Polycorder contains the EM38 operating program along with BATTERY, CREATEDIR, FILE DIR, and DEMO programs. The EM38 program acquires and records the data from the EM38 ground conductivity meter. It also record field survey information (i.e., survey line number, starting station, survey increment, recorded phase component, survey comments, etc.). It is important to note that data files can not be appended. So if a mistake is made in the file setup or during the survey, or if the Polycorder is turned off, one can not use the same file. A new one, including filename, must be created. The BATTERY program is used to check the voltage status of the Polycorder's rechargeable battery pack. FILEDIR has to be present for the EM38 program to run. The CREATEDIR program creates a directory file FILEDIR if it is deleted by mistake or if the data files are erased manually. The DEMO program is used to examine the voltage output of any analog channel in the Polycorder. With the Polycorder connected to the EM38 and the EM38 on and in the Q/P mode, the Polycorder is turned on. At the MODE prompt select 0. The EM38 program is then selected and executed. The Polycorder then provides confirmation of the Polycorder clock setting with a yes or no prompt. The digital instrument type is selected.

The operator is then requested to provide a filename. The filename can be up to seven alphanumeric characters in length. The Polycorder creates two files with this name, a header file and a data file. The operator is then prompted for the GPS option (global positioning system), which is answered with 'no'. The operator then selects the survey phase type (Q = quadrature or conductivity; I = inphase or susceptibility; or B = both), the mode (V = vertical dipole; H = horizontal dipole; or B = both), and the number of orientations (1 or 2; can be in 0- and 90-degree rotation about the common axis or at two different heights above the ground). The operator can provide his or her name and additional comments in the OPERATOR and COMMENT fields. The Polycorder can be set to the automatic data collection mode or to the manual mode at the AUTO (Y/N) prompt.

The Polycorder asks for the time interval in seconds between data readings. The Polycorder then prompts the operator for the Line Number, Line Direction, Start Station, and Increment (manual mode). After all the information requested for the file setup has been completed, the Polycorder provides the READY prompt, and the operator presses the Enter key to start the logging. From that point on, the data is logged to the Polycorder through the manual trigger button on the EM38 handle. At the end of the line, the L key is pressed to end the collection of data along the traverse line. The EM38 program then prompts for the new survey line number, direction, start station, and increment. All prompts must be answered before the operator starts the next line. Upon completion of the grid, the file is closed with the END option, and the operator is returned to FILE prompt.

The ground conductivity survey was designed to collect 2 samples per meter along 1-m traverses or 2 data values per square meter on Site 14MH322 and to collect 2 samples along 0.5-m traverses or 4 data values per meter on Site 14PO406. The data were collected in a zigzag fashion with the surveyor alternating the direction of travel for each traverse across the grid. A total of 441 data values were collected at both 14MH322 and 14PO406 (Appendix E). The data were downloaded to a laptop computer for processing.

Data Processing and Interpretation

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme 2001:365; Music 1995; Neubauer et al. 1996). Walker and Somers (1994) 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. 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 Gradient 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 survey at each site. On the laptop computer, the GEOPLOT software was initialized and the DOWNLOAD DATA routine was selected from the FILE menu (Geoscan Research 2001:4/1–4/27). The default INPUT TEMPLATE was then selected. The selection of the gradiometer (INSTRUMENT TYPE) and FM36 (INSTRUMENT) was made. The GRID INPUT TEMPLATE was displayed. For the gradiometer survey, the survey information was entered under the GENERAL category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 4). The next step required entering the grid names for downloading data from the FM36. In the GRID NAMES FOR DOWNLOADING screen, the filenames for each grid unit were entered into the laptop computer. The grid files contained the magnetic gradient raw data obtained during the survey. The filenames for the grid units at each site included the site name (i.e., octa1, octa2, octa4, and octa5), followed by the letter 'g' for the survey type (gradiometer). If more than one grid unit was collected at a site, then a second letter was added to the filename (e.g., two grids at Site 14MH322 were named octa1ga and octa1gb and the complete and partial grids at Site 14MH323 were named octa2ga and octa2gb). The second letter designated the sequence in which the grid unit was surveyed. The DOWNLOAD INSTRUCTIONS screen was displayed after the filenames were checked for duplicate names in the laptop computer and entered into the laptop computer.

The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The DUMP key on the FM36 keyboard was depressed and the download process was implemented. Downloading the magnetic gradient data from a typical 20-m by 20-m grid unit at 8 samples/m and 0.5 m traverses required approximately 13 minutes to complete the download process. The FM36 was then switched off and disconnected from the laptop computer. The grid files were reviewed in the shade plot under the GRAPHICS menu in the Geoscan Research GEOPLOT processing software (Geoscan Research

2001) for data transfer or survey errors. If no data transfer errors were observed, a composite of the grid files was created for further data processing. Generally, while in the field, the composite file was processed with the zero mean traverse routine and viewed on the laptop computer before the memory in the gradiometer was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. Grids actually consist of three files or parts: (1) the grid data file (*.dat), (2) the grid information file (*.grd), and (3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the magnetic gradient data, the grid files from each site must be combined into a composite file. To construct a composite file containing all of the grid files collected at a site, the MASTER GRID routine is selected from the FILE menu in GEOPLOT (Geoscan Research 2001:5/2). The MASTER GRID FILE NAMES screen is displayed and the grid files are entered into the mesh template by the grid position in the overall survey of the site. For the present project, the existence of one or two grid per site makes the construction of the master grid or mesh template relatively easy. The mesh template defines how the grids fit adjacent to one another within the surveyed area. The grid files are entered into the mesh cells according to their position beginning in the bottom left hand corner of the surveyed area. If no grid data was collected in a given area, the cell was left blank for that position within the surveyed area. For grids that are in the line of travel or traverse direction (X direction on the template), the grid names are placed from left to right in the mesh cells on the screen display. Grids that are perpendicular to the traverse direction (Y direction on the template) are placed from the top cell to the bottom cell of the mesh template. The X and Y directions follow the English survey format, which is opposite of the common X and Y display used by American archeologists in the United States. Generally grids are laid out so that the line of travel or traverse direction is to the north or Y direction and movement across the grid is in the east or X direction for American archeologist. The English or GEOPLOT survey directions have the display the line of travel along the traverse on the X axis and the movement across the grid along the Y axis. This format is also followed for the creation of the composite file. Once the grid files have been placed in the correct position in the mesh template, the composite file is generated by selecting the CREATE COMPOSITE button on the display screen. The MASTER GRID or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the filenames included the field name for the site (i.e., octa1, octa2, octa4, and octa5) and the letter 'g' for the gradiometer survey type. Like the grids, composites also consist of three files or parts: (1) the composite data file (*.cmp), (2) the composite information file (*.cmd), and (3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite files for the magnetic gradient data collected at each site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2001:5/2–5/3). In order to continue to analyze the data, the grid or composite files must be opened. The OPEN GRID/COMPOSITE command is selected under the FILE menu. The appropriate grid or composite data file is selected from the correct Sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale, and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the PARAMETER MODE is set in the SHADE PLOT window to CLIP with minimum value of –3, maximum value of 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the PARAMETER MODE is set in the TRACE PLOT window to Standard with a resolution of 0.5, units to standard deviation, view to front, 0 percent displacement in the X direction, and 0 percent expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Inspection of the background should show the data as bipolar and centered around zero. There should be a broad range in the archeological anomalies with weak anomalies less than 1 nT, typical 1 nT to 20 nT anomalies, strong anomalies greater than 20 nT. If the anomalies are weak then reset the CLIP plotting parameter to a minimum of –2, a maximum of 2, and units to absolute. Then one should identify weak and strong ferrous anomalies, which often represent modern intrusions into the site such as localized surface iron trash, wire fences, iron dumps, pipelines, and utility lines. Geological trends in the data set should also be identified. Since gradiometers provide inherent high-pass filtering, broad-scale geological trends are already removed from the data set. If such trends appear to exist, there may be changes in the topsoil thickness, natural depressions, igneous dikes or other geomorphological changes in the landscape. Final step prior to processing the data is to identify any defects in the data. These can range from periodic errors appearing as linear bands perpendicular to the traverse direction, slope errors appearing as shifts in the background between the first and last traverses, grid edge mismatches where discontinuities exist between grids, traverse striping consisting of alternating stripes in the traverse direction which most commonly occurs during zigzag or bi-directional surveys, and stager errors resulting in the displacement of a feature on alternate traverses (Geoscan Research 2001:Reference Card 3).

Initially, the SPECTRUM function (Walker and Somers 1994:9/16,9/101–9/110) was applied to the data. The SPECTRUM function provided analysis of the frequency spectrum of the data, splitting it into AMPLITUDE, PHASE, REAL or IMAGINARY components. The AMPLITUDE component was selected for the analysis to identify any periodic defects. These defects may have been the effects of cultivation (e.g., plow marks, ridge and furrow) or operator induced defects during data acquisition). It operated over the entire site data set. The SPIKE TOLERANCE was left in the default ON position. This had the effect of reducing any broad spectral energy from noise spikes in the data set. At Sites 14MH322, 14MH323, and 14PO312, no periodic defects were noted in the data sets; however, a periodic defect was noted in the data set from Site 14PO406. The periodic defect was removed before the ZERO MEAN TRAVERSE algorithm and LOW PASS FILTER function were applied to the data set. A relatively strong spectral component was present at the 0.875 m harmonic of the sampling frequency. The PERIODIC DEFECT function (Walker and Somers 1994:9/16,9/77–9/85) was used to remove/reduce the amplitude of the cyclic defect noted during the operation of the SPECTRUM function. The removal of the weak periodic components from the spatial spectrum was accomplished by means of a data dependent non-linear filter process. The PERIODIC DEFECT function served to preserve the stronger anomalies such as those associated with archeologically significant iron artifacts. With the SPIKE TOLERANCE in the ON position, the FREQUENCY INDEX NUMBER (FIN) was entered and the function was applied to the entire data set. The FIN was obtained during the application of the SPECTRUM function and was used to identify the spectral component slated for removal from the data. The central FREQUENCY INDEX NUMBER (FIN = 17) was filtered first. A CUT AND COMBINE operation (Walker and Somers 1994:9/15,9/35–9/42) was preformed to examine the effect of the filter. The adjacent FINs were also filtered (FIN = 16 and FIN = 18) for the data from Site 14PO406. These processing steps resulted in the improved visibility of larger, weak archeological features.

The magnetic gradient data from the Oregon–California Trails project's four sites were "cleaned up" using the ZERO MEAN TRAVERSE algorithm (Walker and Somers 1994:9/17,9/125–9/129). 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 at Sites 14MH322 and 14MH323. The algorithm utilized the least mean square straight line fit and removal default setting On over the entire composite data set.

The STATISTICS function (Walker and Somers 1994:9/17,9/115–9/116) was then applied to the entire magnetic gradient data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps (Table 5).

The LOW PASS FILTER was then used to remove high-frequency, small scale spatial details over the entire data set (Walker and Somers 1994:9/16,9/71–9/74). It was also used to smooth the data and to enhance larger weak anomalies. The function scanned the data set with a gaussian weighted, rectangular window set to the default values for the X radius of 1 unit and the Y radius of 1 unit.

The composite data files were then exported to separate disk files in a different file format for use in the SURFER 7 contouring and 3-D surface mapping program (Golden Software 1999). The EXPORT BATCH DATA routine was selected under the FILE menu in GEOPLOT (Geoscan Research 2001:5/4–5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 7 readily recognizes as a data file. The filenames remained the same for all the files. The files were the exported to "expdata" folder in GEOPLOT. The files are then transferred to an appropriately named site folder (i.e., octa1, octa2, octa4, and octa5) in the SURFER 7 contouring and 3-D surface mapping program's project folder (Golden Software 1999).

In SURFER 7 (Golden Software 1999), the initial step is to view the *.dat file. The Open File command is selected to open the low-pass filter and zero mean traverse processed file found in the sitename folder under the SURFER 7 projects folder. The data is displayed in a worksheet format with the north (Y) coordinates listed in Column A, the east (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the north and east coordinate values are corrected to the correct sample interval and traverse interval through the DATA TRANSFORM routine. The north coordinate (Column A) is corrected by the formula **A = A/8** to provide the correct sample interval position for the data. The east coordinate (Column B) is corrected by the formula **B = B/2** to provide the correct traverse interval position for the data. The data are sorted, using the DATA SORT command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. Due to the large ranges of values, the data are also clipped to 20 for data values greater than 20 nT and to –20 for data values less than –20 nT. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, surfaces), a grid must be generated (Golden Software 1999). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The GRID DATA command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under SPACING. The # OF LINES field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For Site 14MH322, the data columns consist of 0 to 10 in the north or Y direction, 0 to 20 in the east or X direction, with the X-spacing of 0.5 and the Y-spacing of 0.125. For Site 14MH322, the data columns consist of 0 to 20 in the north or Y direction, 0 to 20 in the east or X direction, with the X-spacing of 0.5 and the Y-spacing of 0.125. For Site 14PO312, the data columns consist of 0 to 20 in the north or Y direction, 0 to 20 in the east or X direction, with the X-spacing of 0.5 and the Y-spacing of 0.125. For Site 14PO406, the data columns consist of 0 to 10 in the north or Y direction, 0 to 10 in the east or X direction, with the X-spacing of 0.125 and the Y-spacing of 0.5.

The Kriging gridding method was selected for processing the data for the four sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the SPLINE SMOOTHING operation to the grid file. The SPLINE SMOOTHING operation produces grids that contain more round shapes on the displays. The default settings for the NODE METHOD and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 1999). 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 created by selecting the IMAGE MAP operation from the MAP menu and opening the grid file. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 7 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. The magnetic gradient data image maps for Sites 14MH322, 14MH323, 14PO312, and 14PO406 are presented in Figures 28 through 31, respectively. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two-dimensional representations of three-dimensional data (XYZ). The north (Y) and east (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the NEW CONTOUR MAP operation is opened under the CONTOUR MAP routine in the MAP menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the Levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. The magnetic gradient data contour maps for Sites 14MH322, 14MH323, 14PO312, and 14PO406 are presented in Figures 32 through 35, respectively. 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.

Processing Ground-Penetrating Radar Data

Initially, the GPR data is transferred from the DVL to a laptop computer through the parallel XFER cable using the Sensors and Software's WinPXFER program (Sensors and Software 2001:87–90). The WinPXFER software is started. On the DVL, the data in the Grid Project's current projects screen are selected from the DVL main menu. The data are transferred and stored in a sub-folder from the current data directory on the laptop computer. The data transfer progress is displayed on both the DVL and computer screens. After the GPR data files have been reviewed and verified in the laptop computer, the Grid Project's current projects in the DVL may be cleared from memory.

The GPR data from the four grave and cemetery sites are processed by Sensors and Software's EKKO_Mapper software (Sensors and Software 2002) which provides both profile (cross-sections) and plan-view presentation of the amplitude data. Since the traces within the forward and reverse lines are automatically positioned in the Noggin Smart System in the processing software (Sensors and Software 2002:6), it is not necessary to manually reverse every second line. A new mapping project is opened under the NEW routine in the FILE menu or an existing project may be opened under the OPEN or RE-

CENT PROJECTS routines in the FILE menu. GPR lines to be included in the plan-view map are listed using the INPUT LINES menu (Sensors and Software 2002:10). The GPR data files (*.dt1) must be listed in the same folder. The direction of travel (y direction) is selected. The starting position and the traverse separation distance (0.5 m) are specified for the Grid GPR data. The Input Lines menu also contains the routine for reversing GPR data is needed. The next step is to process the data. The PROCESS DATA menu contains several routines used to specify the details of the finished plan-view display (Sensors and Software 2002:10–12). These operations include a high-pass filter to remove low-frequency "wow" transmitter noise in the data, a down-the-trace filter to reduce the high-frequency noise, a trace-to-trace averaging filter to emphasize horizontal reflectors, a background subtraction operation to remove horizontal reflectors, and a migration operation to collapse hyperbolas to point targets. Since all GPR maps are displays of the signal amplitude plotted is its X and Y positions, the software has four amplitude types (Sensors and Software 2002:21–24) available for mapping (i.e., raw, RMS, rectified, and enveloped). The raw amplitude when averaged over a time or depth range contains negative and positive values. The other three types convert the converts the trace data to positive values. Rectified, RMS, and enveloped amplitude values are recommended for the production of the display plots. The SLICES option provides the means to specify the number and type of plot either in time slices or depth slices. Times slices are generally used since GPR systems record the time for the radar or radio waves to travel to a target and return to the GPR unit. Depth has to be calculated before it can be used. Depth depends on the velocity of the wave to the target and back. Depth is determined by the following equation: **D = V x T/2** where **D** is depth (meters), **V** is velocity (meters/nanosecond), and **T** is the two-way travel time (nanoseconds). Velocity of the radar wave is determined by the dielectric permittivity of the material (Conyers and Goodman 1997:31–35; Sheriff 1973:51). Other physical parameters that affect the transmission of the radar wave include the magnetic permeability and electrical conductivity of the material. Increases or decreases in these parameters may increase the velocity, slow it down, or attenuate it so there is no reflected signal. In most heterogeneous soils, the various soil layers have differing effects on the velocity of the radar wave. The velocity may be estimated using velocity charts of common materials or (Sensors and Software 2002:29) or by identifying reflections in GPR profiles caused by buried objects, artifacts, or stratigraphic soil/sediment layers (Conyers and Goodman 1997:107–135). The estimated velocity is used to determine depth parameters if depth slice windows are used to display the GPR data. The PLOT MAPS menu provides three map or visual display outputs: (1) PROCESSED MAP, (2) PENETRATION MAP, and (3) NOISE MAP (Sensors and Software 2002:32–35). The GPR plan-view plots are created under the PROCESSED MAP operation as time slice maps. Individual GPR line profiles are displayed under the PLOT Section menu (Sensors and Software 2002:36–43).

All of the plan-view maps of Site 14PO312 are presented with north at the top of the map. The relative strength of reflected signals for two time intervals or time-slice windows are illustrated in Figures 36 and 37. Figure 36 covers the time interval from 0 to 20 nanoseconds, which represents the upper three-quarters of a meter of the deposit. Figure 37 covers the next 20 nanoseconds and a comparably deeper section of the site. It is apparent that no soil feature with properties equivalent to those recorded near the Prather headstone exists in the grid. The penetration map (Figure 38) indicates that responses from at least a meter in depth were fairly uniformly received. The dispersed scatter of more shallow values may be a reflection of the root systems of the numerous small trees spread across the grid. The noise map (Figure 39) indicates relatively little noise in the radar signal received across most of the grid. In addition to the 20-m grid, a small series of radar profiles were recorded in the area west of the fenced enclosure and between the farm lane and the adjacent creek. These lines revealed a few very shallow anomalies that do not appear in the same location on adjacent profiles. It is likely that these were produced the roots of the large cottonwood tree at the south end of the group of traverses.

The second locality examined was Site 14PO406 near Highway 99. At this site a single stone is embedded in the prairie sod. The stone is not inscribed and no clear surface depression can be seen. A 10-m square grid was established around the stone. The southeast portion of the grid was significantly eroded and radar data were not recorded across the gully. To ensure the best data possible from the vicinity of the stone, the radar was operated along west-east traverses spaced every 0.5 m apart from north to south. Figures for the 10-m grid are presented with east at the top and north at the left of the maps. The stone is located 6.5 m east along the traverse located 7.5 m north in the grid. A series of narrow time-slice maps were generated and none of them showed a significant radar anomaly in the vicinity of stone. A broad time-slice (0 to 33 ns) represents the relatively uniform response for this grid (Figure 40). Working down through the data in narrow time increments shows the predictable decrease in signal strength with increasing depth but no anomaly that would be appropriate for a human grave was observed. A number of small-scale anomalies of moderate amplitude probably reflect buried stones since limestone bedrock is exposed in the gully to the south of the grid and a few fragments exist on the surface of the site. This is consistent with the variation shown in the noise map (Figure 41). The penetration map (Figure 42) shows slightly less depth penetration at Site 14PO406 than was experienced at Site 14PO312. If a burial was too deep or too ephemeral to be directly detected, one might still expect to see some changes associated with the excavation and partial refilling of the grave shaft. This pattern of probable soil disturbance, which appears in the radar profiles from inside the fenced enclosure at the Cholera cemetery, does not exist at Site 14PO406.

Following work at Site 14PO406, the crew moved to Site 14MH323 near the Blue River. At Site 14MH323, a 20-m grid was created in a small hardwood grove on a point overlooking the Blue River. A single inscribed stone marker is located about 3 m west of the east edge of the grid and about 5 m south of the north edge of the grid. The radar was operated from south to north across 20-m traverses spaced every 0.5 m. As with the grid at Site 14PO312, the Site 14MH323 grid contained 40 lines of radar data from west to east and the maps are presented with north at the top of the image. Noise and penetration maps (Figures 43 and 44, respectively) for Site 14MH323 are similar to those from Site 14PO312, although the depth of penetration is a bit less and more closely resembles that at Site 14PO406.

The amplitude maps from Site 14MH323 illustrate the slices between the 0 to 16.5 ns and 16.5 to 33 ns time segments (Figures 45 and 46, respectively). Lines 14 and 14.5 m east were truncated 2.5 m short of the grid boundary because of large trees that effectively blocked the movement of the antenna. No area shows an anomaly of the proportions that one would expect for an adult human's grave. As noted above, it is possible that actual human remains lie below the depth at which the radar signal is totally attenuated. However, there is no indication that grave excavations with mixed-soils filling the upper portions of the grave shaft are present. This type of mixed-soil excavation fill is what is believed to be the source of the radar anomalies near the stone monuments in the fenced enclosure at the Cholera cemetery.

At Site 14MH322, which contains two small clusters of limestone fragments, a 10-m south-north by 20-m west-east grid was established. The grid was more or less centered on the rock clusters. The radar was operated from south to north on the 10-m-long traverses placed every 0.5 m along the west-east axis of the grid. As a consequence, there were 40 radar lines from west to east across the grid. Figure 47 consists of the noise map for Site 14MH322. The penetration map (Figure 48) shows two distinct localities where penetration was significantly lower than normal. One is located in the left center of the figure and the other along the far right margin. Both of these areas correspond with recent burrowing activity, presumably by a badger or animal of similar size. Neither is interpreted as a cultural feature. A large series of time-slices was generated for this site. Figure 49 presents the data from the near-surface segment (0–4.1 ns). Figure 50 shows a much later (24.8 to 28.9 ns) section that reflects responses from deeper within the site. In general, the time-sections are all very similar with respect to major anomalies (or their absence). The center of the grid (where the stone clusters are located) is probably the least anomalous portion of the Site 14MH322 grid.

Processing Soil Resistivity Data

The soil resistance data were downloaded into a laptop computer after the completion of survey at each site. On the laptop computer, the GEOPLOT software was initialized and the DOWNLOAD DATA routine was selected from the FILE menu (Geoscan Research 2001:4/1–4/27). The default INPUT TEMPLATE was then selected. The selection of the resistance (INSTRUMENT TYPE) and RM15+ MPX15 multiple (INSTRUMENT) was made. The GRID INPUT TEMPLATE was displayed. For the resistance survey, the survey information was entered under the GENERAL category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 6). The next step required entering the grid names for downloading data from the RM15. In the GRID NAMES FOR DOWNLOADING screen, the filenames for each grid unit and each probe configuration was entered into the laptop computer. The grid files contained the resistance raw data obtained during the survey. The filenames for the grid units at each site included the site name (i.e., octa2 and octa4), followed by the letter 'r' for the survey type (resistance), and ended with a letter from 'a' to 'f' for the probe separations from 0.25 m to 1.50 m. The DOWNLOAD INSTRUCTIONS screen was displayed after the filenames were checked for duplicate names in the laptop computer and entered into the laptop computer. The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The DUMP key on the RM15 keyboard was depressed and the download process was implemented. Downloading the resistance data from a typical 20-m by 20-m grid unit at 2 samples/m and 1.0-m traverses required approximately 2 minutes for each probe separation layer or a total of 12 minutes to complete the download process. The RM15 was then switched off and disconnected from the laptop computer. The six grid files were reviewed in the shade plot under the GRAPHICS menu in the Geoscan Research GEOPLOT processing software (Geoscan Research 2001) for data transfer or survey errors. If no data transfer errors were observed, the memory in the resistance meter was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. Each grid data set actually consist of three files or parts: (1) the grid data file (*.dat), (2) the grid information file (*.grd), and (3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the resistance data, the grid files from each site must be combined into composite files. To construct a composite file, the MASTER GRID routine is selected from the FILE menu in GEOPLOT (Geoscan Research 2001:5/2). The MASTER GRID FILE NAMES screen is displayed and the grid filename is entered into the mesh template. The grid file for each probe separation layer is converted into a composite file. The composite file is generated by selecting the CREATE COMPOSITE button on the display screen. The MASTER GRID or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. Like the grids, composites also consist of three files or parts: (1) the composite data file (*.cmp), (2) the composite information file (*.cmd), and (3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite files for the resistance data collected at each site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2001:5/2–5/3). In order to continue to analyze the data, the composite files must be opened. The OPEN GRID/COMPOSITE command is selected under the FILE menu. The appropriate composite data file is selected from the correct Sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale, and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the PARAMETER MODE is set in the SHADE PLOT window to CLIP with minimum value of –3, maximum value of 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the PARAMETER MODE is set in the TRACE PLOT window to Standard with a resolution of 0.5, units to standard deviation, view to front, 0 percent displacement in the X direction, and 0 percent expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data is displayed in a shade plot or trace plot. The CLIP parameters are set to a minimum of –3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing 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 percent change, typical anomalies with 5 to 20 percent change, and strong anomalies with greater than 20 percent 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 that may be as large as ±1000 percent 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 percent across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2001:Reference Card 2).

The noise spikes are removed with the DESPIKE function (Walker and Somers 1994:9/49–9/54). The function locates and removes random, spurious measurements present in the resistance data. The DESPIKE parameters are left in the default settings with both the X RADIUS and Y RADIUS set to 1, the THRESHOLD set to 3.0 standard deviations, and the SPIKE REPLACEMENT set to the MEAN. The MEAN indicates that the noise spike value will be replaced by the window mean value obtained from the surrounding values. A HIGH PASS FILTER (Walker and Somers 1994:9/63–9/66) was used to remove the low-frequency, large-scale spatial detail (i.e., the slowly changing geological "background" response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the X RADIUS and Y RADIUS. The WEIGHTING uses the default GAUSSIAN setting. The resulting data is bipolar with the mean centered around zero. The original mean may be restored by using the ADD function (Walker and Somers 1994:9/25–28).

The data sets were then standardized prior to comparison of the six different depth data plots. The statistical Z-score was calculated: **Z = (X − mean) ÷ standard deviation**. When the data are standardized, they all have the same mean and variation and so are comparable (Kenneth L. Kvamme, personal communications 2002). The STATISTICS mode (Walker and Somers 1994:9/115–9/116) was used to get the mean and standard deviation of the data sets from the six levels at the two sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps at Sites 14MH323 and 14PO312 (Tables 7 and 8, respectively). The ADD function (Walker and Somers 1994:9/25–9/28) was used to subtract the mean from the data set (i.e., add its [mean] negative value). The MULTIPLY function (Walker and Somers 1994:9/75–9/76) was used to divide the mean differenced data by the standard deviation (i.e., multiply the mean differenced data by the reciprocal of the standard deviation). This method reduced the large differences in the data sets between depths so that the data comparisons were more equivalent (Kenneth L. Kvamme, personal communications 2002).

The composite data files were then exported to separate disk files in a different file format for use in the SURFER 7 contouring and 3-D surface mapping program (Golden Software 1999). The EXPORT BATCH DATA routine was selected under the FILE menu in GEOPLOT (Geoscan Research 2001:5/4–5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 7 readily recognizes as a data file. The filenames remained the same for all the files.

The files were then exported to "EXPDATA" folder in GEOPLOT. The files are then transferred to an appropriately named site folder (i.e., octa1, octa2, octa4, and octa5) in the SURFER 7 contouring and 3-D surface mapping program's project folder (Golden Software 1999).

In SURFER 7 (Golden Software 1999), the initial step is to view the *.dat file. The Open File command is selected to open the low-pass filter and zero mean traverse processed file found in the SITENAME folder under the SURFER 7 projects folder. The data is displayed in a worksheet format with the north (Y) coordinates listed in Column A, the east (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the north and east coordinate values are corrected to the correct sample interval and traverse interval through the DATA TRANSFORM routine. The north coordinate (Column A) is corrected by the formula **A = A/2** to provide the correct sample interval position for the data. The east coordinate (Column B) is corrected by the formula **B = B/2** to provide the correct traverse interval position for the data. The data are sorted, using the DATA SORT command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, surfaces), a grid must be generated (Golden Software 1999). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The GRID DATA command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under SPACING. The # OF LINES field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For Site 14MH322, the data columns consist of 0 to 20 in the north or Y direction, 0 to 20 in the east or X direction with the X-spacing of 0.5 and the Y-spacing of 0.5. For Site 14PO312, the data columns consist of 0 to 20 in the north or Y direction, 0 to 20 in the east or X direction with the X-spacing of 0.5 and the Y-spacing of 0.5. The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the SPLINE SMOOTHING operation to the grid file. The SPLINE SMOOTHING operation produces grids that contain more round shapes on the displays. The default settings for the NODE METHOD and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 1999). 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. Selecting the IMAGE MAP operation from the MAP menu and opening the grid file creates the image map. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 7 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. The resistance data image maps for Sites 14MH323 and 14PO312 are presented in Figures 51 and 52, respectively. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two-dimensional representations of three-dimensional data (XYZ).

The north (Y) and east (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the NEW CONTOUR MAP operation is opened under the CONTOUR MAP routine in the MAP menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the LEVELS page of the CONTOUR MAP PROPERTIES dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. The resistance data contour maps for Sites 14MH323 and 14PO312 are presented in Figures 53 and 54, respectively. Contour maps are useful in determining the equal strength of the resistance anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration.

Besides processing each individual probe separation distance of level for the resistance data collected at Sites 14MH323 and 14PO312, pseudo-sections of the data sets can also be generated (Geoscan Research 2001:5/8–5/9). Stacked pseudo-sections can be generated in the X or north direction or in the Y or east direction from the sequence of expanding twin probe separations. Pseudo-sections provide a profile or depth view of the resistance data over each traverse line (X direction) or each sample interval (Y direction). These profiles are similar in view to the GPR profiles. In order to create the pseudo-sections, a blank composite file is first generated using the CREATE BLANK COMPOSITE routine under the FILE menu in GEOPLOT. In the CREAT BLANK COMPOSITE screen select the “Resistance” SURVEY TYPE and “RM15 + MPX15 (Multiple)” INSTRUMENT from the choices listed. In the next screen, enter the correct details for the Sitename, composite size, sample interval, traverse interval, etc. (Table 9). The dimension in the X direction needs to be large enough to accommodate the six probe separation data sets. In this project, the dimensions at both sites are 120 m (six 20-m square grids). The blank composite is named and saved. The composite name follows the naming practice developed for the sites of the Oregon–California Trails project. The letter ‘r’ signifying a resistance survey and the letters ‘ps’ for pseudo-section follows the field assigned site name (i.e., octa2 and octa4). Using the processed composites (despiked, high-pass filtered, and standardized Z-scores) for each probe separation depth layer, the composite data sets are added to the blank composite template with the CUT AND COMBINE function by increasing probe separation to paste the individual composites into the template. The smallest separation distance must be on the left-hand side and the largest separation distance on the right hand side of the template. Once the composite containing the six separate probe separation depth data files is assembled and saved, the pseudo-sections for the resistance data from the site is created. Using the CREATE PSEUDO SECTION routine in the FILE menu in GEOPLOT, the source composite file is identified and its entire path including the drive, directories, and name but not the file extension is entered into the SOURCE COMPOSITE line. The NUMBER OF LAYERS is equal to the number of data sets used to construct the composite, which is six for the two resistance surveys in this project. For the two resistance surveys in the present project, the value of 0.25 m is selected for the THICKNESS OF LAYERS entry. This selection controls the aspect ratio of the sections. Finally, the SECTION DIRECTION is identified for the orientation of pseudo-sections. It may be in the X direction or Y direction. The X direction provides the display of the data section along the traverse direction. The Y direction provides the display of the data section perpendicular to the traverse direction along the sample intervals. After the creation of the X and Y direction pseudo-sections, the pseudo-section files are exported using the EXPORT BATCH DATA or EXPORT CURRENT DATA routines in the FILE menu. The Surfer (ASCII) file format is selected for the EXPORT FILE FORMAT. This creates the SURFER data grid for use in the final map presentation. The EXPORT FILE PARAMETERS are set to the TOP-LEFT REFERNCE CORNER, 0 for the REFERNCE X COORDINATE, 0 for the REFERNCE Y COORDINATE, 0.5 m for the X INCREMENT, 0.25 m for the Y INCREMENT, and “grd” for the EXPORT EXTENSION. The COMPOSITE DATA FILE TYPE is selected. The pseudo-section data files are selected from the list of files for the batch export or individually opened for the current file export. The files are saved to the EXPDATA directory in GEOPLOT. The WRITE DUMMY VALUE box is checked and the EXPORT DUMMY VALUE of

2047.5 is identified. The created pseudo-section SURFER grid files are moved from the EXPDATA directory in GEOPLOT to the correct site directory in the SURFER Project Directory. The IMAGE MAP routine is selected under the MAP menu in SURFER. The pseudo-section grid file is selected and the data is displayed. The image map is processed and labeled. There are twenty data lines or profiles for both Site 14MH323 (Figure 55) and Site 14PO312 (Figure 56).

Processing Ground Conductivity Data

The ground conductivity data were downloaded into a laptop computer after the completion of survey at each site. The Polycorder 720 was connected to the laptop computer via the serial port by means of a 25 pin to 9 pin converter cable (Geonics Limited 1997:19). On the laptop computer, the DAT38RT software was initialized and the COPY FILES FROM POLYCORDER 720 routine was selected from the menu (Geonics Limited 1997:19–25). The default FAST MODE was selected for copying or downloading the data from the Polycorder to the laptop computer. The FAST MODE permits the rapid transfer of all data files in the Polycorder's DIRFILE directory. The header and data files for each site are also sequentially copied and then simultaneously converted to the DAT38 file format. The DUMP program is selected on the Polycorder. The Polycorder parameters for communications with the laptop are set to a baud rate of 9600 with 8 data bits, No parity and the Mating call equal to <CR>. At the READY prompt on the Polycorder, the Polycorder is driven by the laptop computer. Selecting the ENTRY key on the laptop computer, the FAST FILE COPY FROM POLYCORDER 720 screen is displayed. The first prompt on the laptop computer asks for the Polycorder's filenames. ALL is entered or the ENTER key is selected. The second prompt asks for the disk files in the Polycorder format. Two files are created for each site data file (i.e., the header file with H-prefix plus filename and the data file with the D-prefix plus filename). The third prompt identified the created file in DAT38 format. The Polycorder header and data files (i.e., the DL files) are converted into the DAT38 format with the filename and extension .G38). The serial port is set to COM1. The COPY FILES routine is selected from the menu on the laptop computer. The header file is transferred first followed by the data from each site file from the Polycorder to the laptop computer. Once the files have been transferred to the laptop computer, the next step is to create the data files. The ENTER DATA FILES routine is opened in the DAT38 program (Geonics Limited 1997:35–37). A list of entered survey files is displayed in the window. The DAT38 (*.G38) file is selected. The screen then displays the profile lines within the file (with Component/Mode/Orientation). Information including the measured component (i.e., conductivity phase), mode (i.e., vertical), and orientation (i.e., 1) are listed next to the line numbers. All of the lines in the file are selected by pressing <ENTER>. The final stage in the preparation of the data files for processing is the creation of the SURFER XYZ (*.dat) files in ASCII format. The WRITE FILE FOR CONTOUR PACKAGE is selected from the main DAT38 menu (Geonics Limited 1997:62–65). The SURFER format is selected for the format of the created file. A filename is given to the finished file. The DIPOLES MODE, INSTRUMENT ORIENTATION, COMPONENT, and SURVEY GEOMETRY fields are left in the default values of VERTICAL, 1, CONDUCTIVITY, and ARBITARY respectively. The CREATE FILE command is selected from the submenu. Messages and prompts are provided to enter the beginning and ending X and Y coordinates for each line in the survey grid file. All of the X and Y coordinates with the corresponding conductivity measurements are written to the *.dat file, a window displays the created data file. It can be examined without leaving the program. The file is saved in the DAT38 folder in the laptop computer. The *.dat files from the survey are then transferred to SURFER7.

In SURFER7 (Golden Software 1999), the data file created in DAT38 is opened through the OPEN routine in the FILE menu. The data are presented in the worksheet display. The worksheet contains the east (X) coordinate in the A column, the north (Y) coordinate in the B column, and the data value (Z) in C column. In order to process the data in GEOPLOT (Geoscan Research 2001), the data values must be arranged in ascending order by sorting the X and Y values. All three columns are selected. The SORT routine in the DATA menu is selected and the sort parameters are set with the Column B set for sorting first in ascending order and Column A set for sorting second in ascending order. The data are checked for the correct number of entries based on the number of traverses covered in the survey and by the number of sample intervals per traverses. The conductivity data collected from 14MH322 contains 400 measurements taken over the 10-m by 20-m survey area (sample interval of 0.5 m or 20 readings along the north axis and traverse interval of 1.0 m or 20 lines along the east axis of the grid). The conductivity data collected from 14PO406 also contains 400 measurements taken over the 10-m by 10-m survey area (sample interval of 0.5 m or 20 readings along the north axis and traverse interval of 0.5 m or 20 lines along the east axis of the grid). The X and Y values are deleted from the file leaving the Z or data values. The data file is saved in SURFER7 and then copied to GEOPLOT's IMPDATA folder.

To process the data in GEOPLOT, the data is imported into GEOPLOT using the IMPORZT DATA routine under the File menu. The default grid template is selected in the IMPORT DATA screen. The ELECTROMAGNETIC survey type is selected and the USER DEFINED category is selected as the instrument. The GRID INPUT TEMPLATE screen is displayed on the laptop computer. The ground conductivity survey information is entered under the GENERAL category, which contains the settings for the acquisition of the data and the instrumentation used to acquire the data (Table 10). The next step required entering the grid names for importing. The IMPORT DATA screen is displayed after the grid input template parameters are entered. In the IMPORT DATA screen, the IMPORT FILE FORMAT is set to XYZ – COMMASV. The IMPORT FILE PARAMETERS are set to TOP-LEFT REFERNCE CORNER for the start of the grid data acquisition point, 0 for the REFERNCE X COORDINATE, 0 for the REFERNCE Y COORDINATE, 0.5 for the X INCREMENT, 1 for the Y INCREMENT, and the IMPORT DUMMY VALUE equals 2047.5. Unlike the X or east and Y or north directions in the original conductivity data, the X and Y directions in GEOPLOT are reversed with X representing the north direction and Y representing the east direction. Under the IMPORT FILE NAMES, the DRIVE is set to the C drive, the EXTENSION is set to the "dat" file extension type, and directory path is set to D:\GEOPLOT\IMPDATA. The correct data file is selected from the list of IMPOT FILE NAMES. The imported grid files are saved to the correct Sitename directory. The data filenames for the grid unit at each site included the site name (i.e., octa1 and octa5), followed by the letter 'c' for the ground conductivity survey. A notification window indicates the successful completion of the import routine. Each grid data set actually consist of three files or parts: (1) the grid data file, (*.dat), (2) the grid information file (*.grd), and (3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the conductivity data, the grid files from each site must be combined into composite files. To construct a composite file, the MASTER GRID routine is selected from the FILE menu in GEOPLOT (Geoscan Research 2001:5/2). The MASTER GRID FILE NAMES screen is displayed and the grid filename is entered into the mesh template. The grid file for each site is converted into a composite file. The composite file is generated by selecting the CREATE COMPOSITE button on the display screen. The MASTER GRID or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the filenames included the field name for the site (i.e., octa1 and octa5), the letter 'c' for the conductivity survey type. Like the grids, composites also consist of three files or parts: (1) the composite data file (*.cmp), (2) the composite information file (*.cmd), and (3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite files for the ground conductivity data collected at each site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2001:5/2–5/3). In order to continue to analyze the data, the grid or composite files must be opened. The OPEN GRID/COMPOSITE command is selected under the FILE menu. The appropriate grid or composite data file is selected from the correct Sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale, and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the PARAMETER MODE is set in the SHADE PLOT window to CLIP with minimum value of –3, maximum value of 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the PARAMETER MODE is set in the TRACE PLOT window to Standard with a resolution of 0.5, units to standard deviation, view to front, 0 percent displacement in the X direction, and 0 percent expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data is displayed in a shade plot or trace plot. The CLIP parameters are set to a minimum of –3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing conductivity data begins with the inspection of the data changes on the background signal. These data changes are superimposed on the local geology. There should be a broad range in the archeological anomalies with weak anomalies or archeological features having less than 5 percent change, typical anomalies with 5 to 20 percent change, and strong anomalies with greater than 20 percent change in conductivity values. The data are checked for noise spikes including low-level spikes that create a noisy appearance in the data displays, and extremely high anomalous readings that might be as large as ±1000 percent 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 percent across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2001:Reference Card 2).

The STATISTICS function (Walker and Somers 1994:9/17, 9/115–9/116) was then applied to the entire magnetic gradient data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps (Table 11). A HIGH PASS FILTER (Walker and Somers 1994:9/63–9/66) was used to remove the low-frequency, large-scale spatial detail (i.e., the slowly changing geological "background" response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the X RADIUS and Y RADIUS. The WEIGHTING uses the default GAUSSIAN setting. The resulting data is bipolar with the mean centered around zero. The original mean may be restored by using the ADD function (Walker and Somers 1994:9/25–28).

The composite data files were then exported to separate disk files in a data file format for use in the SURFER 7 contouring and 3-D surface mapping program (Golden Software 1999). The EXPORT BATCH DATA routine was selected under the FILE menu in GEOPLOT (Geoscan Research 2001:5/4–5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 7 readily recognizes as a data file. The filenames remained the same for all the files. The files were the exported to "EXPDATA" folder in GEOPLOT. The files are then transferred to an appropriately named site folder (i.e., octa1 and octa5) in the SURFER 7 contouring and 3-D surface mapping program's project folder (Golden Software 1999).

In SURFER 7 (Golden Software 1999), the initial step is to view the *.dat file. The Open File command is selected to open the high-pass filter processed file found in the SITENAME folder under the SURFER 7 projects folder. The data is displayed in a worksheet format with the north (Y) coordinates listed in Column A, the east (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the north and east coordinate values are corrected to the correct sample interval and traverse interval through the

DATA TRANSFORM routine. The north coordinate (Column A) is corrected by the formula **A = A/2** to provide the correct sample interval position for the data for both sites. The east coordinate (Column B) is corrected by the formula **B = B/2** to provide the correct traverse interval position for the data for Site 14PO406. Site 14MH322 does not need the traverse interval correction since data collection is conducted along 1 m traverses. The data are sorted, using the DATA SORT command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, surfaces), a grid must be generated (Golden Software 1999). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The GRID DATA command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under SPACING. The # OF LINES field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For Site 14MH322, the data columns consist of 0 to 10 in the north or Y direction, 0 to 20 in the east or X direction with the X-spacing of 1.0 and the Y-spacing of 0.5. For Site 14PO406, the data columns consist of 0 to 10 in the north or Y direction, 0 to 10 in the east or X direction with the X-spacing of 0.5 and the Y-spacing of 0.5.

The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the SPLINE SMOOTHING operation to the grid file. The SPLINE SMOOTHING operation produces grids that contain more round shapes on the displays. The default settings for the NODE METHOD and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name.

At this point in the process, maps of the data may be generated (Golden Software 1999). 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. Selecting the IMAGE MAP operation from the MAP menu and opening the grid file creates the image map. The image map is generated and may be edited. The color scale is set with the minimum value assigned to white and the maximum value assigned to black. The scale is graduated, flowing from white through several shades of gray to black. SURFER 7 has 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. The conductivity data image maps for Sites 14MH322 and 14PO406 are presented in Figures 57 and 58, respectively. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two-dimensional representations of three-dimensional data (XYZ). The north (Y) and east (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the NEW CONTOUR MAP operation is opened under the CONTOUR MAP routine in the MAP menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the LEVELS page of the CONTOUR MAP PROPERTIES dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. The conductivity data contour maps for Sites 14MH322 and 14PO406 are presented in Figures 59 and 60, respectively. Contour maps are useful in determining the equal strength of the conductivity 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.

Interpretation of Magnetic Gradient Data

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

Magnetic anomalies of archeological objects tend to be approximately circular in contour outline. The circular contours are caused by small sizes of the objects. The shape of the object is seldom revealed in the contoured data. The depth of the archaeological object can be estimated by half-width rule procedure (Bevan 1998:23–24; Breiner 1973:31; Hinze 1990; Milsom 1996:53–54; Telford et al. 1990:87). The approximations are based on a model of a steel sphere with a mass of 1 kg buried at a depth of 1.0 m below the surface with the magnetic measurements made at an elevation of 0.3 m above the ground. The depth of a magnetic object is determined by the location of the contour value at half the distance between the peak positive value of the anomaly and the background value. With the fluxgate gradiometer, the contour value is half the peak value since the background value is approximately zero. The diameter of this contour (Bevan 1998:Fig. B26) is measured and used in the depth formula where **depth = diameter – 0.3 m** (Note: The constant of 0.3 m is the height of the bottom fluxgate sensor above the ground in the Geoscan Research FM36 where I carry the instrument during data acquisition. This value needs to be adjusted for each individual that carries the instrument.). The mass in kilograms of the object (Bevan 1998:24, Fig. B26) is estimated by the following formula: **mass = (peak value − background value) * (diameter)^3/60**. It is likely that the depth and mass estimates are too large rather than too small, since they are based on a compact spherical object made of iron. Archeological features are seldom compact but spread out in a line or lens. Both mass and depth estimates will be too large. The archaeological material may be composed of something other than iron such as fired earth or volcanic rock. Such materials are not usually distinguishable from the magnetic data collected during the survey (Bevan 1998:24). The depth and mass of features comprised of fired earth, like that found in kilns, fireplaces, or furnaces could be off by 100 times the mass of iron. If the archeological feature were comprised of bricks (e.g., brick wall, foundation, chimney), estimates could be off by more than a 1,000 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 fourth 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.

Site 14MH322

The area is relatively quiet as far as magnetic surveys are concerned. A faint magnetic dipole is located near the cairn in the western portion of the grid area near N4/E5.5. The magnetic anomaly is centered at N4.78/E5.14 (Figure 61). It has a mass of 20 g and is located 48 cm below the ground surface. A magnetic dipole is also located near N6/E14. It is approximately 1 m southeast of the second cairn in the eastern portion of the grid area with its center located at N4.97/E15.5. It is approximately 15 cm below the ground surface and has a mass of 3 g. There is also a magnetic high in the northwest corner of the grid area. The magnetic data at 14MH322 yield inconclusive information about the nature of the two cairns.

Site 14MH323

Numerous magnetic dipoles are recognizable in the data (Figure 62). Several dipole anomalies are strong indicating that they are iron artifacts (Table 12). Other dipole anomalies are more diffuse. The roughly rectangular anomalies may represent grave locations. A broad disturbance is noted surrounding the gravestone of T. J. Lewis. The concentration of magnetic gradient anomalies in the eastern portion of the grid unit seems to have a higher correlation with the rocks than in other portions of the grid unit.

Site 14PO312

Numerous magnetic dipoles are recognizable in the data (Figure 63). Several dipole anomalies are strong indicating that they are iron artifacts (Table 13). There is a linear line of anomalies along the E17 line. One of these anomalies was a piece of iron brace from an agricultural implement. The effect of the chain link fence to the west of the grid is noticeable in the data set along the western edge of the grid area. Although there is no rectangular pattern to some of the magnetic dipoles, it is possible that some of these less-intense magnetic dipoles might be associated with graves.

Site 14PO406

Like the magnetic surveyed area at Site 14MH322, the area at Site 14PO406 is relatively quiet as far as magnetic surveys are concerned. A single upright sandstone slab is located near N6/E6.5. No magnetic disturbances are noted around the stone, although a few magnetic dipoles are present in the data. A faint magnetic dipole (Figure 64) is located near the northern portion of the grid area at N7.67/E5.44. It is located at a depth of 30 cm below the surface and has a mass of 59 g. An area of disturbed soil is located in the eastern and southeastern portion of the grid area represented by a series of magnetic highs and lows. This area contains a cattle path from the upland drainage and the edge of the gully wall associated with the drainage. The magnetic data at 14PO406 yield inconclusive information about the nature of the sandstone slab.

Interpretation of Ground-Penetrating Radar Data

The radar test at the Cholera Cemetery (Site 14PO312) suggested that the three stones inside the fenced enclosure mark areas of excavation. No clear indications of interments in these excavated areas were detected, but the depth of penetration might not be sufficient to reach the actual burials, if they exist. The excavation near the Prather headstone provided the strongest radar response (Figure 24). No similar radar features were detected in the 20-m square grid placed east of the fenced enclosure or in the area between the farm lane and the creek. It is possible that other graves existed in the area surveyed and that they were not characterized by soil changes that result in contrasting radar reflections. There are no indications of grave locations in the radar data from the other three sites, even though a marked gravestone was present at 14MH323. The other data (magnetic, soil resistance, or ground conductivity) might identify such features.

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

Site 14MH323

A broad disturbance is noted surrounding the gravestone of T. J. Lewis. A linear low-resistance anomaly passes from the southeast corner of the grid to the northwest corner of the grid with a roughly square area in the northeastern quarter of the grid. Several high resistance anomalies are noted in the central and southern part of the grid. These may correspond to trees in the grid area. Roots generally have a higher resistance value than the surrounding soils; however, their placement, especially noticeable in the 1.00-m and 1.50-m probe separations might suggest the location of graves (Figure 65). Further examination of the area for the location of the trees is needed to confirm this hypothesis. It is also possible that the low-resistance anomalous areas represent grave locations; however, the linear nature of the low-resistance area that extends on a diagonal from the southeast corner of the grid to the northwest corner suggests a natural feature associated with the terrace development above the Big Blue River. At the 1.25-m probe separation, a number of concentric low-resistance areas appear to be located in areas where rock, rebar, and pin flags were noted before the beginning of the survey.

Site 14PO312

The high- and low-resistance anomalies at Site 14PO312 are more dispersed across the grid than those at Site 14MH323 (Figure 66). The rapid changes between high and low readings suggest that the area is highly disturbed, possibly from the activities associated with the burial of the cholera victims and others who died from trail related injuries and illnesses. No distinct patterning is noted in the location of either the high-resistance or low-resistance anomalies.

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 contrasts. These contrasts can result from natural conditions or from cultural activities (Bevan 1998:31–33). 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, objects) might hide other features in the immediate vicinity. Comparing the metal anomalies in the conductivity data to the magnetic gradient anomalies can provide information on the nature of the metal anomaly. If the two types of geophysical data are represented by an anomaly in the same location, it is highly probable that the metal object is iron or steel. The lack of a correlation between the two data sets suggests that the conductivity anomaly by itself might represent a conductive metal other than iron of steel (e.g., brass, copper, lead, zinc) or the magnetic anomaly might represent a fired-clay feature or object (e.g., fire hearth, pottery, bricks).

Site 14MH322

The ground conductivity data sloped from a high-conductivity area along the western side and north central part of the grid area to a low-conductivity area in the northeastern corner of the grid area (Figure 67). A second high-conductivity area was located in the southeastern corner of the grid. A low-conductivity area extended to the northeast of the cairn in the eastern portion of the surveyed grid; however, its length, width, and orientation did not seem to represent a grave. Other low-conductivity areas lie in the area south of the westernmost cairn. A low-conductivity area was also noted in the extreme northwestern corner of the grid. The conductivity data at Site 14MH322 yielded inconclusive information about the nature of the cairns.

Site 14PO406

The ground conductivity data had a high correlation with the topographic setting in the grid (Figure 68). Near the southeastern corner of the grid area, active erosion and gully cutting in the drainageway formed a steep bank south of the upright sandstone marker. The conductivity data set had the highest values along the lowest topographic elevations along the drainage. Two major areas of low-conductivity were located on the upland area near the upright sandstone marker. The conductivity variation appeared to represent changes in the moisture content of the soil, as well as textural and structural changes in the soil between the ridge slope and the drainage. The conductivity data at Site 14PO406 yielded inconclusive information about the origin and nature of the sandstone column.

Interpretation of Combined Geophysical Data Sets

Another approach to the interpretation of the geophysical data from the four sites surveyed as part of the Oregon–California Trails project is to combine the data sets. At Sites 14MH322 and 14PO406, the conductivity data was prepared in an image plot. The contoured magnetic data was overlain on top of it. At Sites 14MH323 and 14PO312, the resistance image plots formed the background with the magnetic gradient contour data superimposed on top of a selected probe dept configuration plot.

At Site 14MH322, there is little change in the conductivity data (Figure 69). As indicated in the conductivity discussion for the site, there is a general geological trend across the grid area from highs along the western portion of the surveyed area to lower conductivity values along the eastern portion of the grid. Although one magnetic anomaly is located in the same place as the western cairn at the site, the anomaly is extremely weak and would have gone unnoticed if it was not for the low magnetic values across the grid area. Like the individual magnetic gradient and conductivity data sets, the combined magnetic gradient and conductivity data at Site 14MH322 yielded inconclusive information about the nature of the sandstone slab.

At Site 14MH323 (Figure 70), the majority of the magnetic gradient anomalies are located in areas associated with the sandstone rock fragments. The close association between the rock and magnetic anomalies suggest a direct relationship between the two phenomena. It is possible that these anomalies are associated with graves; however, one must be somewhat suspicious of this association since several of the rock clusters also had wire pin flags and metal spikes or rebar associated with them. Prior to the magnetic survey, all of the visually recognizable metal objects were mapped and collected. It is possible that some pieces were missed, which may account for some of the magnetic anomalies present in the magnetic gradient data. There does not seem to be any correlation between the magnetic anomalies and the resistance highs or lows.

At Site 14PO312 (Figure 71), the majority of the magnetic anomalies are situated along the eastern side of the grid. The magnetic gradient anomalies along the west side of the grid were associated with the chain link fence surrounding the three known gravestones. A few magnetic gradient anomalies were located along a line from the southeastern corner of the grid to the midpoint on the west side of the grid. There did not seem to be any correlation between the magnetic anomalies and the resistance highs and lows that are scattered across the site. A least one magnetic anomaly in the eastern portion of the grid was associated with a steel bar from a piece of farm machinery or a wagon.

At Site 14PO406, there is little change in the conductivity data (Figure 72). As indicated in the conductivity discussion for the site, there is a high-conductivity area in the southeastern portion of the grid area associated with the gully. The magnetic anomalies in the same area also represent this erosional landscape feature. Although one magnetic anomaly is located slightly northwest of the upright sandstone column, the anomaly is close to the surface and probably represents a piece of farm equipment. Like the individual magnetic gradient and conductivity data sets, the combined magnetic gradient and conductivity data at Site 14PO406 yielded inconclusive information about the nature of the sandstone slab.

Conclusions and Recommendations

During November 2000 and August 2001, the Midwest Archeological Center staff conducted geophysical investigations at four sites along the Oregon National Historic Trail in Marshall and Pottawatomie Counties in northeastern Kansas. The project was conducted for the National Park Service's Long Distance Trails Office and the northeastern Kansas local chapter of the Oregon and California Trails Association. During the investigations, 1,100 m² were surveyed with a Geoscan Research FM36 fluxgate gradiometer and with a Sensors and Software Noggin 250 Smart Cart ground-penetrating radar system (Nickel 2001). Eight hundred square meters were covered with a Geoscan Research RM15 resistance meter and PA5 multiprobe array, and 300 m² were covered with a Geonics EM38 ground conductivity meter.

The magnetic gradient, soil resistance, and ground conductivity data collected at the four sites provided information of the physical properties (magnetic, resistance, and conductivity) of the subsurface materials. The surveys resulted in the identification of subsurface magnetic gradient anomalies at Sites 14MH322, 14MH323, 14PO312, and 14PO406; however, it is extremely difficult to interpret any of these anomalies as being associated with grave locations. Given the documented history at Sites 14MH323 and 14PO312 as cemeteries, it is probable that some of the magnetic anomalies are associated with graves. Other anomalies appear to represent parts from agricultural implements or barbed and woven wire fences. None of the ground-penetrating radar grid surveys yielded patterns that compare favorably with the model that was constructed from data that associate with the Prather headstone at Site 14PO312. None of the grid surveys show other radar anomalies that conform to the anticipated dimensions of adult human graves.

Where there were stones (inscribed or not) the profiles were also inspected without any grave anomalies being recognized. The best candidates for graves were associated with the three stones inside the fenced enclosure at Site 14PO312. A detectable radar anomaly was observed on one or more traverses near each of these stones. The anomaly associated with the Prather stone was the strongest and was observed on multiple traverses. It provided a graphic model of what similar excavations might look like in plan-view. None of the other sites contained features that remotely approach the pattern generated from the traverses recorded adjacent to the Prather stone. The multiplexer soil resistance surveys at Sites 14MH323 and 14PO312 appear to offer some information about grave locations. The results of the conductivity surveys at Sites 14MH322 and 14PO406 yielded inconclusive results concerning the nature of the cairns at Site 14MH322 and the upright stone at Site 14PO406. Overall, the sites were well suited for geophysical investigations; however, the encroachment of the trees and other woody vegetation on Sites 14MH323 and 14PO312 did have an impact on the geophysical data from the various survey techniques. Tree roots tended to provide additional noise in the soil resistance data sets. Care was taken when analyzing the geophysical data in areas where the trees have been cut because of the remaining subsurface root system.

The purpose of the present project was to determine the applicability of geophysical investigations to the identification and evaluation of graves associated with four sites along the Oregon and California trails in northeastern Kansas. One grave was positively identified with the ground-penetrating radar survey at 14PO312. Areas of resistance, conductivity, and magnetic gradient disturbances were noted at cemeteries at Sites 14MN323 and 14PO312. None of the techniques indicated the presence of individual graves at Sites 14MN322 and 14PO406. The geophysical investigations failed to provide positive identification of unmarked graves at the four sites. Due to the nature of the soil matrix and lack of significant changes in the measured physical properties, the geophysical data did not indicate clear differentiation of any graves present at the sites. Changes in the magnetic gradient and resistance data were noted at the two cemetery sites, 14MN323 and 14PO312, but the data did not provide clear, crisp distinctions between grave fill and surround natural soil matrix. The investigations at Sites 14MN32 and 14PO406 were even more problematic since it was not known whether the features were truly associated with pioneer graves. Since Sites 14MN323 and 14PO312 were identified as historic cemeteries, it would not have been appropriate to conduct traditional archeological excavation on these two sites. Geophysical techniques proved to be a possible non-invasive, non-destructive avenue of investigation for the two cemetery sites. The geophysical investigations were successful as far as the operation of the instruments and the collection of data concerning changes in the measured physical properties; however, the techniques did not provide clear indications for the presence of graves at the sites. Two possible reasons exist: (1) there was a lack of sufficient change in the measured physical properties associated with the graves or (2) there were no graves in the investigated areas.

Although the geophysical investigations failed to provide conclusive evidence of the grave locations in this project, these techniques are still an extremely viable methodology for the initial investigation of cemeteries and grave locations. The question could be raised that the use of traditional excavation methods would have been more productive. It is true that the excavations would have allowed a better view of the subsurface materials; however, the amount of time and costs in labor and analysis to conduct such excavations would have been substantially higher to cover the same area investigated with the geophysical techniques. With an estimated cost of $3,000.00 per cubic meter of excavation, approximately one excavation could have been placed on each site. The odds against placing one excavation over the top of unmarked graves in either cemetery (14MN323 or 14PO312) would be astronomical. Should the improbable occur, it would still not provide information on the location of multiple graves in the cemeteries. Nor would it be feasible or even ethical to conduct such excavations in a known cemetery location in the absence of an impending threat of destruction to the cemetery.

Preliminary shovel testing of the cemeteries would also not provide substantial information on the location of the graves due to the lack of depth necessary to verify the presence of the graves. The use of an auger or posthole digger does not open up enough area to visually inspect the soil matrix for the boundaries of the grave. There is also high probability of damaging any skeletal remains during the auguring operations. Overall, geophysical techniques provide the best initial evaluative phase of cemetery investigations where eminent destruction of the cemetery is not at issue. There may be a need for follow up archeological excavations to verify the geophysical anomalies identified during the survey efforts. These excavations can be more efficiently planned with the geophysical background data than through the use of traditional archeological excavation strategies in extremely cultural sensitive areas such as cemeteries.

This report has provided an analysis of the geophysical data collected during four days at the sites. Since Sites 14MH323 and 14PO312 are associated with known and marked graves, it is not recommended that any additional archeological investigations in the form of excavations be conducted at these sites at the present time. Should there be any development on or near these sites, then a research design needs to be developed for the implementation of archeological excavations to determine the nature and extent of these two cemeteries along the Oregon Trail. At Sites 14MH322 and 14PO406, limited excavations around the rock features should be conducted to determine the nature of these features. A research design for the testing of the two sites needs to be developed in coordination with the Kansas State Historic Preservation Office and State Archaeologist Office staff.

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 sites 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.

References Cited

Bare, Janet
1979 *Wildflowers and Weeds of Kansas*. University Press of Kansas, Lawrence.

Bark, L. Dean
1980 Climate. In *Soil Survey of Marshall County, Kansas*, by Paul R. Kutnink, Donald A. Gier, Roger L. Haberman, and Donald R. Jantz, pp. 1–2. Government Printing Office, Washington, D.C.

1987 Climate. In *Soil Survey of Pottawatomie County, Kansas*, by Marcellus L. Horsch, Robert Kutnink, Donald A. Gier, Bobby D. Tricks, and William A. Wehmueller, pp. 1–2. Government Printing Office, Washington, D.C.

Barker, William T.
1969 The Flora of the Kansas Flint Hills. *The University of Kansas Science Bulletin* 48(14):525–584.

Barkley, T. M.
1983 *Field Guide to the Common Weeds of Kansas*. University Press of Kansas, Lawrence.

Barry, Louise
1972 *The Beginning of the West: Annals of the Kansas Gateway to the American West, 1540–1854*. Kansas State Historical Society, Topeka.

Bee, James W., Gregory Glass, Robert S. Hoffmann, and Robert R. Patterson
1981 *Mammals in Kansas*. Museum of Natural History, University of Kansas, Lawrence.

Bevan, Bruce W.
1977 Ground-Penetrating Radar at Valley Forge. Manuscript, National Park Service, Midwest Archeological Center, Lincoln.

1983 Electromagnetics for Mapping Earth Features. *Journal of Field Archaeology* 10:47–54.

1991 The Search for Graves. *Geophysics* 56(9):1310–1319.

1998 *Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration.* Special Report No. 1. National Park Service, Midwest Archeological Center, Lincoln.

2000 *The Pole-Pole Resistivity Array Compared to the Twin Electrode Array*. Technical Report No. 6. Geosight, Weems, Virginia.

Bevan, Bruce W., and J. Kenyon
1975 Ground-Penetrating Radar for Historical Archaeology. *MASCA Newsletter* 11(2): 2–7.

Billington, Ray Allen
1967 *Westward Expansion: A History of the American Frontier*. Third Edition. Macmillian Company, New York.

Blackmar, Frank W. (editor)
1912 *Kansas: A Cyclopedia of State History, Embracing Events, Institutions, Industries, Counties, Cities, Towns, Prominent Persons, Etc*. Volume 2. Standard Publishing Company, Chicago.

Breiner, Sheldon
1973 *Applications Manual for Portable Magnetometers*. GeoMetrics, Sunny Dale, California.

Brown, John E.
1987 *Memoirs of an American Gold Seeker*. Reprint. Ye Galleon Press, Fairfield, Washington. Originally published in 1908 in *Journal of American History*, Volume 2, 1st Quarter.

Brown, Lauren
1985 *Grasslands*. Alfred A. Knopf, New York.

Brown, David E., Frank Reichenbacher, and Susan E. Franson
1998 *A Classification of North American Biotic Communities*. The University of Utah, Salt Lake City, Utah.

Bryant, Edwin
2001 *What I Saw in California Being the Journal of a Tour, by the Emigrant Route and South Pass of the Rocky Mountains, Across the Continent of North America, the Great Desert Basin, and through California, in the Years 1846, 1847*. Reprint. The Narrative Press, Santa Barbara, California. Originally published in 1849 in New York.

Buck, Donald, Andrew Hammond, Thomas Hunt, David Johnson, and John Maloney
1996 *Mapping Emigrant Trails MET Manual*. Third Edition. Office of National Historic Trails Preservation, Oregon–California Trails Association, Independence, Missouri.

Caldwell, Janalee, and Joseph Collins
1981 *Turtles in Kansas*. Museum of Natural History, University of Kansas, Lawrence.

Carr, Christopher
1982 *Handbook on Soil Resistivity Surveying: Interpretation of Data from Earthen Archeological Sites*. Research Series Volume 2. Center for American Archeology Press, Evanston, Illinois.

Carrel, John R.
1999 Kansas State Historical Society Archeological Site Form: Site Number 14PO405 Poem Village. Recorded 04/27/1999. On file, Kansas State Historical Society, Topeka.

Chittenden, Hiram M.
1986 *The American Fur Trade of the Far West*. Volume 1. Reprint. University of Nebraska Press, Lincoln. Originally published in 1935 by Press of the Pioneers in two parts.

Clark, Anthony
2000 *Seeing Beneath the Soil: Prospecting Methods in Archaeology*. Reprinted. Routledge, London. Originally published in 1990 by B. T. Batsford Ltd., London.

Coffman, Lloyd W.
1993 *Blazing a Wagon Trail to Oregon: A Weekly Chronicle of the Great Migration of 1843*. Echo Books, Springfield, Oregon.

Collins, Joseph T.
1993 *Amphibians and Reptiles in Kansas*. Third Edition. Museum of Natural History, University of Kansas, Lawrence.

Connelley, William E.
1918 *A Standard History of Kansas and Kansans*. Volume 1. Lewis Publishing Company, Chicago.

Conyers, Lawrence B., and Dean Goodman
1997 *Ground-Penetrating Radar: An Introduction for Archaeologists*. AltaMira Press, Walnut Creek, California.

Conyers, Lawrence B., and Jeffrey E. Lucius
1996 Velocity Analysis in Archaeological Ground-penetrating Radar Studies. *Archaeological Prospection* 3(1):25–38.

Cox, Edwin E.
1998 David Dewolf Letters 1849–1850. *Overland Journal* 16(3):10–16.

Cross, Frank, and Joseph Collins
1975 *Fishes of Kansas*. Museum of Natural History, University of Kansas, Lawrence.

Culter, William G.
1883 *History of the State of Kansas*. A. T. Andreas, Chicago.

Dale, Harrison C.
1941 *The Ashley-Smith Explorations and the Discovery of a Central Route to the Pacific, 1822–1829*. Revised Edition. Arthur H. Clark Company, Glendale, California.

David, Andrew
1995 *Geophysical Survey in Archaeological Field Evaluation*. Research & Professional Services Guidelines No. 1. Ancient Monuments Laboratory, English Heritage, London.

De Vore, Steven L.
1999 Magnetic Gradient and Resistance Surveys at 13DT110 (Gunzenhauser Site), Decatur County, Iowa. Manuscript, National Park Service, Long Distance Trails Office, Salt Lake City, Utah.

2000a FY 2000 Cultural Resource Training National Park Service Summary: Recent Advances in Archeological Prospection Techniques. Manuscript, National Park Service, Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

2000b Memorandum to Superintendent, Long Distance Trails Office, Intermountain Region, from Archeologist, Archeological Assistance and Partnership Program, May 31, 2000. Subject: Trip Report – California and Oregon National Historic Trails, Marshall and Pottawatomie Counties, Kansas. File Code H2415 (MWAC). National Park Service, Midwest Archeological Center, Lincoln.

2000c Letter to Acting State Archeologist, Archeologist Office, Kansas State Historical Society, from Archeologist, Archeological Assistance and Partnership Program, October 30, 2000. Subject: File Search for Five Localities in Marshall and Pottawatomie Counties, Kansas. File Code H2415 (MWAC). National Park Service, Midwest Archeological Center, Lincoln.

2002a *Geophysical Investigations at the Kane Cemetery (48BH3104), Bighorn Canyon National Recreation Area, Wyomin*g. Technical Report No. 76. National Park Service, Midwest Archeological Center, Lincoln.

2002b Interim Report of the Geophysical Investigations at Four Sites in Marshall and Pottawatomie Counties, Kansas. Manuscript, National Park Service, Long Distance Trails Office, Salt Lake City, Utah.

De Vore, Steven L., and Bruce W. Bevan
1995 *Pioneer Family Cemeteries at Scott Air Force Base, St. Clair County, Illinois*. National Park Service, Denver, Colorado.

Dewolf, David
1925 Diary of the Overland Trail 1849 and Letters 1849–50 of Captain David Dewolf. *Transactions of the Illinois State Historical Society* 32:183–222.

Dice, Lee R.
1943 *The Biotic Provinces of North America*. University of Michigan Press, Ann Arbor.

Driggs, Howard R.
1942 *Westward America*. J. B. Lippencott, New York.

Drury, Clifford M. (editor)
1997 *Where Wagons Could Go: Narcissa Whitman and Eliza Spalding*. Reprint. University of Nebraska Press, Lincoln. Originally published in 1963 by Arthur H. Clark Company, Glendale, California.

1998 *On to Oregon: The Diaries of Mary Walker & Myra Eells*. Reprint. University of Nebraska Press, Lincoln. Originally published in 1963 by Arthur H. Clark Company, Glendale, California.

Fenneman, Nevin M.
1938 *Physiography of Eastern United States*. McGraw-Hill Book Company, New York.

Flora, Snowdon D.
1948 Climate of Kansas. *Report of the Kansas State Board of Agriculture* 67(285):1–297.

Foth, Henry D., and John W. Schafer
1980 *Soil Geography and Land Use*. John Wiley & Sons, New York.

Frank, Anita L.
2000 Letter to Archeologist, Midwest Archeological Center, from Records Manager, Kansas State Historical Society, November 8, 2000. Subject: Results of File Search Request. On file, Kansas State Historical Society, Archeology Office, Topeka.

Franzwa, Gregory M.
1988 *The Oregon Trail Revisited*. Fourth Edition. The Patrice Press, Tucson, Arizona.

1989a *The Santa Fe Trail Revisited*. The Patrice Press, St. Louis, Missouri.

1989b *Maps of the Santa Fe Trail*. The Patrice Press, St. Louis, Missouri.

1990 *Maps of the Oregon Trail*. The Patrice Press, St. Louis, Missouri.

1999 *Maps of the California Trail*. The Patrice Press, Tucson, Arizona.

Fremont, John C.
2002 *Report of the Exploring Expedition to the Rocky Mountains, and to Oregon and North California in the Years 1843–44*. Reprint. The Narrative Press, Santa Barbara, California. Originally published in 1845 by H. Polkinhorn, Washington, D.C.

Frye, J. C., and A. B. Leonard
1952 Pleistocene Geology of Kansas. *Kansas Geological Survey Bulletin* 99:1–230.

Frye, J. C., and K. L. Walters
1950 Subsurface Reconnaissance of Glacial Deposits in Kansas. *Kansas Geological Survey Bulletin* 86(Part 6):141–158.

Gaffney, Chris, John Gater, and Sue Ovenden
1991 *The Use of Geophysical Techniques in Archaeological Evaluations.* Technical Paper Number 9. Institute of Field Archaeologists, University of Birmingham, Birmingham, England.

Gates, F. C.
1928 Handbook of Kansas Trees. *Report of the Kansas State Board of Agriculture* 47(186-A):148–367.

1937 Grasses of Kansas. *Report of the Kansas State Board of Agriculture* 55(220-A):1–349.

1940 *Flora of Kansas*. Contributions No. 391. Department of Biology, Kansas State College, Manhattan.

Geonics Limited
1992 *EM38 Ground Conductivity Meter Operating Manual for EM38 Models with Digital Readout*. Geonics Limited, Mississauga, Ontario, Canada.

1997 *Computer Program Manual (Survey Data Reduction Manual) DAT38, Version 3.40*. Geonics Limited, Mississauga, Ontario, Canada.

1998 *DL720/38 Data Logging System Operating Instructions for EM38 Ground Conductivity Meter with Polycorder Series 720, Version 3.40*. Geonics Limited, Mississauga, Ontario, Canada.

Geoscan Research
1987 *Fluxgate Gradiometer FM9 FM18 FM36 Instruction Manual, Version 1.0*. Geoscan Research, Bradford, England.

1995 *MPX15 Multiplexer Instruction Manual, Version 1.0*. Geoscan Research, Bradford, England.

Geoscan Research, continued
1996 *Resistance Meter RM15 Instruction Manual, Version 2.4*. Geoscan Research, Bradford, England.

2001 *Geoplot Version 3.00 for Windows Instruction Manual, Version 1.6*. Geoscan Research, Bradford, England.

Goetzman, William H.
1991 *Army Exploration in the American West, 1803–1863*. Texas State Historical Association, Austin.

Golden Software
1999 *Surfer 7 User's Guide: Contouring and 3D Surface Mapping for Scientists and Engineers*. Golden Software, Golden, Colorado.

Gordon, Mary McDougall (editor)
1983 *Overland to California with the Pioneer Line: The Gold Rush Diary of Bernard J. Reid.* University of Illinois Press, Urbana.

Hafen, LeRoy R.
1973 *The Life of Thomas Fitzpatrick: Mountain Man, Guide, and Indian Agent*. Reprint. University of Nebraska Press, Lincoln. Originally published in 1931 by The Old West Publishing Company, Denver.

Hall, E. Raymond
1955 *Handbook of Mammals of Kansas*. Museum of Natural History, University of Kansas, Lawrence.

Hastings, Lansford W.
1994 *The Emigrants' Guide to Oregon and California*. Reprint. Applewood Books, Bedford, Massachusetts. Originally published in 1835 by the author.

Heimmer, Don H., and Steven L. De Vore
1995 *Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archeological Investigations*. Revised Edition. Interagency Archeological Services, National Park Service, Denver, Colorado.

2000 Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations. In *Science and Technology in Historic Preservation*, edited by Ray A. Williamson and Paul R. Nickens, pp. 53–73. Advances in Archaeological and Museum Science Volume 4. Kluwer Academic/Plenum Publishers, New York.

Hinze, William J.
1990 The Role of Gravity and Magnetic Methods in Engineering and Environmental Studies. In *Geotechnical and Environmental Geophysics, Volume 1: Review and Tutorial*, edited by Stanley H. Ward, pp. 75–126. Society of Exploration Geophysicists, Tulsa, Oklahoma.

Historic Preservation Department
1987 *Kansas Preservation Plan Study Unit on the Period of Exploration and Settlement (1820s–1880s)*. Kansas State Historical Society, Topeka.

Hixton, L. M.
1849 Letter of May 28, 1849, from Camp 19. On file, Missouri Historical Society, St. Louis.

Horn, Bruce, Richard Kay, and Dean Abel
1993 *A Guide to Kansas Mushrooms*. University Press of Kansas, Lawrence.

Horsch, Marcellus L., Robert Kutnink, Donald A. Gier, Bobby D. Tricks, and William A. Wehmueller
1987 *Soil Survey of Pottawatomie County, Kansas*. Government Printing Office, Washington, D.C.

Howell, John, and Susan Howell

1999a “The California-Oregon Trail.” <http://skyways.lib.ks.us/history/westmore.html> Document posted February 2, 1999; accessed February 22, 2002. Author’s email address provided as <howell @kotn.org>.

1999b “Alcove Springs & The Oregon Trail.” <http://skyways.lib.ks.us/history/alcove.html> Document posted May 10, 1999; accessed February 22, 2002. Author’s email address provided as <howell @kotn.org>.

2001a “The Vieux Crossing.” <http://skyways.lib.ks.us/history/belvue.html> Document posted January 30, 2001; accessed February 22, 2002. Author’s email address provided as <howell@kotn.org>.

2001b “The ‘49’ers Cemetery National Historic Site.” <http://skyways.lib.ks.us/history/cem49ers .html> Document posted February 1, 2001; accessed February 22, 2002. Author’s email address provided as <howell@kotn.org>.

Iris Instruments

1999 *Syscal Kid – Switch 22 Compact Resistivity Meter Multi-Electrode Switching System Operating Manual*. Iris Instruments, Orleans, France.

Irving, Washington

1986 *The Adventures of Captain Bonneville, U.S.A. in the Rocky Mountains and the Far West*. Revised Edition. University of Oklahoma Press, Norman. Originally published in 1837, under the title of *The Rocky Mountains: or Scenes, Incidents, and Adventures in the Far West, Digested from the Journal of Captain B. L. E. Bonneville, U.S.A., and Illustrated from Various other Sources* published by Craey, Lea, and Blanchard, Philadelphia, 2 volumes.

Jeffrey, Julie R.

1997 Introduction to the Bison Books Edition. In *Where Wagons Could Go: Narcissa Whitman and Eliza Spalding*, edited by Clifford M. Drury, pp. 11–16. Reprint. University of Nebraska Press, Lincoln. Originally published in 1963 by Arthur H. Clark Company, Glendale, California.

Johnson, Alfred E., Charles A. Johnson III, Brad Logan, Nancy O’Malley, and Robert J. Ziegler

1980 *Prehistoric Cultural Resources of Tuttle Creek Lake, Kansas*. Museum of Anthropology, University of Kansas, Lawrence. Submitted to U.S. Department of the Interior, Heritage Conservation and Recreation Service, Interagency Archeological Services, Denver, Colorado. Contract No. C3541(70).

Jones, Geoffrey, and David L. Maki

2002 *A Geophysical Investigation at the Garden Coulee Site (32WI18)*. Archaeo-Physics LLC, Minneapolis, Minnesota.

Kansas Biological Survey

1985 *Guide to the Freshwater Invertebrates of the Midwest*. Second Edition. Technical Publication No. 11. University Press of Kansas, Lawrence.

Kindscher, Kelly

1987 *Edible Wild Plants on the Prairie: An Ethnobotanical Guide*. University Press of Kansas, Lawrence.

1992 *Medicinal Wild Plants on the Prairie: An Ethnobotanical Guide*. University Press of Kansas, Lawrence.

King, Julia A., Bruce W. Bevan, and Robert J. Hurry

1993 The Reliability of Geophysical Surveys at Historic-Period Cemeteries: An Example from the Plains Cemetery, Mechanicsville, Maryland. *Historical Archaeology* 27(3): 4–16.

Krakow, Jere L.
2000a Memorandum to the Director, Midwest Archeological Center, from Superintendent, Long Distance Trails Office, August 18, 2000. Subject: Request for Archeological Assistance. National Park Service, Long Distance Trails Office, Salt Lake City, Utah.

2000b Letter to Acting State Archeologist, Kansas State Historical Society, October 26, 2000. Subject: Notification of Proposed Archeological Investigations at Three Sites along the Oregon and California National Historic Trails. National Park Service, Long Distance Trails Office, Salt Lake City, Utah.

Küchler, A. W.
1974 A New Vegetation Map of Kansas. *Ecology* 55(3):586–604.

Kutnink, Paul R., Donald A. Gier, Roger L. Haberman, and Donald R. Jantz
1980 *Soil Survey of Marshall County, Kansas*. Government Printing Office, Washington, D.C.

Kvamme, Kenneth L.
2001 Current Practices in Archaeogeophysics: Magnetics, Resistivity, Conductivity, and Ground-Penetrating Radar. In *Earth Sciences and Archaeology*, edited by Paul Goldberg, Vance T. Holliday, and C. Reid Ferring, pp. 353–384. Kluwer Academic/Plenum Publishers, New York.

Lavender, David S.
1980 *The Overland Migrations: Settlers to Oregon, California, and Utah*. National Park Service, Washington, D. C.

Mandel, Rolfe D.
1987 The Environment of Kansas. In *Kansas Prehistoric Archaeological Preservation Plan*, edited by Kenneth L. Brown and Alan H. Simmons, pp. III-1–III-30. Museum of Anthropology and Center for Public Affairs, University of Kansas, Lawrence.

Martin, Arleta
2000a Kansas State Historical Society Archeological Site Form: Site Number 14MH322. Recorded August 20, 2000. On file, Kansas State Historical Society, Topeka.

2000b Kansas State Historical Society Archeological Site Form: Site Number 14MH323. Recorded August 20, 2000. On file, Kansas State Historical Society, Topeka.

2000c Kansas State Historical Society Archeological Site Form: Site Number 14MH324. Recorded August 20, 2000. On file, Kansas State Historical Society, Topeka.

2000d Kansas State Historical Society Archeological Site Form: Site Number 14PO312. Revisit recorded August 20, 2000. On file, Kansas State Historical Society, Topeka.

2000e Kansas State Historical Society Archeological Site Form: Site Number 14PO406. Recorded August 20, 2000. On file, Kansas State Historical Society, Topeka.

Mattes, Merrill J.
1987 *The Great Platte River Road: The Covered Wagon Mainline Via Fort Kearny to Fort Laramie*. Reprint. University of Nebraska, Lincoln. Originally published in 1969 by the Nebraska State Historical Society, Lincoln.

McNeil, J. Duncan
1980 *Electromagnetic Terrain Conductivity Measurements at Low Induction Numbers*. Technical Note TN-6. Geonics Limited, Mississauga, Canada.

MicroPro
1989 *WordStar 5.5*. MircoPro International Corporation, San Rafael, California.

Milsom, John
1996 *Field Geophysics*. Second Edition. John Wiley & Sons, Chichester, England.

Morgan, Dale

1993 *Overland in 1846: Diaries and Letters of the California-Oregon Trail*. Volume I. Reprint. University of Nebraska Press, Lincoln. Originally published in 1963 by the Talisman Press, Georgetown, California.

Murphy, Virginia Reed

1995 *Across the Plains in the Donner Party: A Personal Narrative of the Overland Trip to California 1846–47*. Reprint. Vistabooks, Silverthorne, California. Originally published in 1980 by Outbooks, Golden, Colorado.

Music, B.

1995 On-Site Prospection in Slovenia: The Case of Rodik. *Archaeological Computing Newsletter* 43:6–15.

Neubauer, W., P. Melichar, and A. Eder-Hinterleitner

1996 Collection, Visualization, and Simulation of Magnetic Prospection Data. In *Interfacing the Past: Computer Applications and Quantitative Methods in Archaeology*, CAA95, Volume 1, edited by H. Kamermans and K. Fennema, pp. 121–129. Analecta Praehistorica Leidensia No. 28. University of Leiden, Leiden, The Netherlands.

Nickel, Robert K.

2000a An Evaluation of Geophysical Survey Instruments for Detecting Unmarked Graves at the Mission Cemetery, Spalding, Idaho. Manuscript, National Park Service, Midwest Archeological Center, Lincoln.

2000b Geophysical Surveys in the Carver Family Cemetery, George Washington Carver National Monument, Missouri. Manuscript, National Park Service, Midwest Archeological Center, Lincoln.

2001 Ground-Penetrating Radar Test at Possible Grave Sites in Eastern Kansas. Manuscript, National Park Service, Midwest Archeological Center, Lincoln.

Nikon

1993 *Field Station DTM-700 Series DTM-750/DTM-730/DTM-720 Instruction Manual*. Nikon Corporation, Tokyo.

1996 *TransIt Version 2.1 User's Guide*. Nikon Inc. Instrument Software Department, Melville, New York.

O'Brien, Patricia J.

1984 *Archeology in Kansas*. Museum of Natural History Public Education Series No. 9. University of Kansas Publications, Lawrence.

Ohlenbusch, Paul D., Elizabeth P. Hodges, and Susan Pape

1983 *Range Grasses of Kansas*. Publication C-567. Cooperative Extension Service, Kansas State University, Manhattan.

Owensby, Clenton

1980 *Kansas Prairie Wildflowers*. Iowa State University Press, Ames.

Paden, Irene D.

1943 *The Wake of the Prairie Schooner*. MacMillian, New York.

Philbrick, Marcia

1997 "Rut Nuts." <hppt://www.ukans.edu/kansas/seneca/oregon/kanza/rutnut.html> Document posted October 1997; accessed December 16, 2002. Author's email address provided as <pioneer@nvcs.com>.

Phillips, Paul C.

1961 *The Fur Trade*. Volume II. University of Oklahoma Press, Norman.

Reichenbacher, Frank, Susan E. Franson, and David E. Brown
1998 *North American Biotic Communities*. The University of Utah, Salt Lake City, Utah.

Reynolds, John D.
1970 Appraisal of the Archeological Resources of the Onaga Reservoir, Pottawatomie County, Kansas. Manuscript, Smithsonian Institution, Missouri Basin Project, Washington, D.C.

Robb, Andrew D.
1941 Climate of Kansas. In *Climate and Man: 1941 Yearbook of Agriculture*, edited by Grove Hambridge, pp. 873–883. House Document No. 27, 77th Congress, 1st Session. Government Printing Office, Washington, D.C.

Robinson, Sara T. L.
1990 *Kansas; Its Interior and Exterior Life: Including a Full View of Its Settlement, Political History, Social Life, Climate, Soil, Productions, Scenery, Etc*. Reprint. Kansas Heritage Press, Lawrence, Kansas. Originally published in 1856 by Crosby, Nichols and Company, Boston, Massachusetts.

Rollins, Philip A. (editor)
1995 *The Discovery of the Oregon Trail: Robert Stuart's Narratives of His Overland Trip Eastward from Astoria in 1812–13*. Reprint. University of Nebraska Press, Lincoln. Originally published in 1935 by Charles Scribner's Sons, New York.

Schoewe, Walter H.
1949 The Geography of Kansas, Part II. *Kansas Academy of Science Transactions* 52(3):261–331.

Scollar, I., A. Tabbagh, A. Hesse, and I. Herzog
1990 *Archaeological Prospection and Remote Sensing*. Topics In Remote Sensing 2. Cambridge University Press, Cambridge, England.

Scott, G. R., F. W. Foster, and C. F. Crumption
1959 Geology and Construction-material Resources of Pottawatomie County, Kansas. *U.S. Geological Survey Bulletin* 1060-C:97–178.

Sensors and Software
2001 *Noggin Smart Cart Users Manual Version 1.1*. Sensors and Software, Inc., Mississauga, Ontario, Canada.

2002 *EKKO_Mapper User's Guide Version 2.0*. Sensors and Software, Inc., Mississauga, Ontario, Canada.

Sharma, Prem V.
1997 *Environmental and Engineering Geophysics*. Cambridge University Press, Cambridge, United Kingdom.

Shelford, Victor E.
1963 *The Ecology of North America*. University of Illinois Press, Urbana.

Sheriff, Robert E.
1973 *Encyclopedic Dictionary of Exploration Geophysics*. Society of Exploration Geophysicists, Tulsa, Oklahoma.

Smith, William E.
1928 The Oregon Trail through Pottawatomie County. *Collections of the Kansas State Historical Society 1926–1928* 17:435–464.

1936 The Grave of Sarah Keyes. *The Kansas Historical Quarterly* 5(2):208–224.

Socolofsky, Homer E., and Huber Self
1972 *Historical Atlas of Kansas*. University of Oklahoma Press, Norman.

Solecki, Ralph
1953 Appraisal of the Archeological and Paleontological Resources of the Tuttle Creek Reservoir, Marshall, Pottawatomie, and Riley Counties, Kansas. Manuscript, Smithsonian Institution, Missouri Basin Project, Washington, D.C.

Stegner, Wallace
1992 *The Gathering of Zion: The Story of the Mormon Trail*. Reprint. University of Nebraska Press, Lincoln. Originally published in 1964 by the author.

Stephens, H. A.
1969 *Trees, Shrubs, and Woody Vines in Kansas*. University Press of Kansas, Lawrence.

Stewart, George R.
1983 *The California Trail*. Reprint. University of Nebraska Press, Lincoln. Originally published in 1962 by McGraw-Hill, New York.

Sunder, John E.
1959 *Bill Sublette: Mountain Man*. University of Oklahoma Press, Norman.

Telford, W. M., L. P. Geldart, and Robert E. Sheriff
1990 *Applied Geophysics*. Second Edition. Cambridge University Press, Cambridge, United Kingdom.

Thompson, Max C., and Charles Ely
1989 *Birds in Kansas*. Volume 1. University Press of Kansas, Lawrence.

1992 *Birds in Kansas*. Volume 2. University Press of Kansas, Lawrence.

Thornthwaite, C. W.
1948 An Approach toward Rational Classification of Climate. *Geographical Review* 38:55–94.

Trinklein, Michael, and Steve Boettcher
2002 "Alcove Spring on the Oregon Trail." <http://www.isu.edu/%7Etrinmich/Alcovespring.html> Document copyrighted 2002; accessed December 13, 2002. Document includes <http://skyways.lib .ks.us/kansas/towns/BlueRapids/asalbum.htm> for photographs of Alcove Spring. Author's email address provided as <mtrinklein@yahoo.com>.

Unruh, John D., Jr.
1979 *The Plains Across: The Overland Emigrations and the Trans-Mississippi West, 1840–1860*. University of Illinois Press, Urbana.

Ushikata
n.d. *Tracon & Surveying Compasses*. Ushikata Manufacturing Company, Tokyo.

Walker, Roger, and Lewis Somers
1994 *GEOPLOT 2.01 Instruction Manual 1.01*. Geoscan Research, Bradford, England.

Walters, K. L.
1954 Geology and Ground-water Resources of Marshall County, Kansas. *Kansas Geological Survey Bulletin* 106:1–116.

Wedel, Waldo R.
1959 *An Introduction to Kansas Archeology*. Bureau of American Ethnology Bulletin 174. Smithsonian Institution, Washington, D.C.

Werner, Morris
1995a "Northeast Kansas Trails." <http://history.cc.ukans.edu/heritage/werner/northeast.html> Document revised October 28, 1995; accessed December 16, 2002. The internet site <hppt://history.cc .ukans.edu/heritage/werner/> is maintained by Stephen Chinn. His email address provided as <chinn @ctrvax.vanderbilt.edu>.

Werner, Morris, continued

1995b "Emigrant Graves on the Oregon and California Trails in Kansas." <http://history.cc.ukans.edu/heritage/werner/emigrave.html> Document revised October 28, 1995; accessed December 16, 2002. The internet site <hppt://history.cc.ukans.edu/heritage/werner/> is maintained by Stephen Chinn. His email address provided as <chinn@ctrvax.vanderbilt. edu>.

1995c "Emigrant Graves and Cemeteries." <http://history.cc.ukans.edu/heritage/werner/graveme.html> Document revised October 28, 1995; accessed December 16, 2002. The internet site <hppt://history .cc.ukans.edu/heritage/werner/> is maintained by Stephen Chinn. His email address provided as <chinn@ctrvax.vanderbilt.edu>.

Weymouth, John W.

1986 Geophysical Methods of Archaeological Site Surveying. In *Advances in Archaeological Method and Theory*, Volume 9, edited by Michael B. Schiffer, pp. 311–395. Academic Press, Orlando, Florida.

White, Stephan, and Glenn Salsbury

2000 *Insects of Kansas*. Kansas Department of Agriculture, Topeka.

Wilson, Frank

1984 Landscapes: A Geological Diary. In *Kansas Geology: An Introduction to Landscapes, Rocks, Minerals, and Fossils*, edited by Rex Buchanan, pp. 9–39. University of Kansas Press, Lawrence.

Ziegler, Robert J.

1976 *Cultural Resource Management Plan for Tuttle Creek Lake for the Years 1978–1983*. Museum of Anthropology, University of Kansas, Lawrence.

Zimmerman, John

1993 *The Birds of Kanza: The Avian Ecology of the Tallgrass Prairie*. University Press of Kansas, Lawrence.

Table 1. Archeological resources in the vicinity of Site 14MH323.

Site Number	Topographic Setting	Cultural Affiliation	Site Type	Condition During Survey	Nearest Stream	Site Description	Suggested Research
14MH5	N/A*	N/A	camp	N/A	Big Blue River	N/A	none
14MH6	N/A	N/A	large camp	N/A	Big Blue River	N/A	exploratory tests
14MH7	N/A	N/A	large camp	N/A	Big Blue River	N/A	none
14MH10	low terrace	Central Plains Tradition	village	cultivated field	Big Blue River	concentration of lithics, ceramics, fire-cracked rock, and mussel shell	excavation
14MH19	hillside slope	Prehistoric	camp	N/A	Big Blue River	scatter of lithic material including tools	none
14MH20	broad ridge top	N/A	camp	N/A	Big Blue River	N/A	none
14MH69	convex side slope	Archaic	camp	N/A	Big Blue River	scatter of lithic material including tools	none
14MH70	convex side slope and broad ridge top	Upper Republican and Plains Woodland	village	cultivated field	Big Blue River	concentration of lithics, ceramics, and daub	excavation
14MH71	N/A	N/A	camp	N/A	Big Blue River	N/A	none

* Information was not available in reports.

Table 2. Archeological resources in the vicinity of Site 14PO312, the Cholera Cemetery site.

Site Number	Topographic Setting	Cultural Affiliation	Site Type	Condition During Survey	Nearest Stream	Site Description	Suggested Research
14PO311	bluff	Prehistoric	habitation	grassy field	Vermillion Creek	scatter of lithics	small-scale testing
14PO312	floodplain and foot slope	Historic	mid-19th century cemetery	wooded pasture	Vermillion Creek	three gravestones, possibly 49 graves	none
14PO314	floodplain and foot slope	Prehistoric and Historic	artifact scatter of uncertain function	cultivated field	Vermillion Creek	scatter of lithics, glass, and ceramics	none
14PO315	terrace	Prehistoric	habitation	cultivated field	Vermillion Creek	scatter of lithics and bone	none
14PO316	terrace	Prehistoric and Historic	historic habitation or farmstead	cultivated field	Vermillion Creek	scatter of historic ceramics, brick, glass, and metal with one lithic chipped stone tool fragment	none
14PO346	bluff	Historic Pottawatomie	cemetery dating to post 1850s	grassy field	Vermillion Creek	numerous Pottawatomie graves including that of Louis Vieux, Sr.	none
14PO405	terrace	Prehistoric and Historic	village	cultivated field	Vermillion Creek	scatter of lithics, bone, and fire cracked rock along with 19th century ceramics, metal, and glass.	none

Table 3. Probe configuration for twin-array multiplexer soil resistance surveys at 14MH323 and 14PO312.

Probe Separation (m)	Offset from Center Line	Segment	A[1]	M[2]
0.25	0.0	1	green	yellow
0.50	12.5 cm right	2	red	yellow
0.75	0.0	3	red	white
1.00	12.5 cm right	4	red	black
1.25	25.0 cm right	5	blue	white
1.50	12.5 cm right	6	blue	black

[1] A represents the current probe jumper cable positions.
[2] M represents the potential probe jumper cable positions.

Table 4. Acquisition and instrumentation information for the gradiometer surveys used in the grid input template.

14MH322

Acquisition	Value	Instrumentation	Value
Sitename	octa1	Survey Type	Gradiometer
Map Reference	—	Instrument	FM36
Dir. 1st Traverse	N	Units	nT
Grid Length (x)	10 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	10 m	Baud Rate	2400
Traverse Interval (y)	0.5 m	Averaging	Off
Traverse Mode	Parallel	Averaging Period	16

14MH323

Acquisition	Value	Instrumentation	Value
Sitename	octa2	Survey Type	Gradiometer
Map Reference	—	Instrument	FM36
Dir. 1st Traverse	N	Units	nT
Grid Length (x)	20 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	20 m	Baud Rate	2400
Traverse Interval (y)	0.5 m	Averaging	Off
Traverse Mode	Parallel	Averaging Period	16

14PO312

Acquisition	Value	Instrumentation	Value
Sitename	octa4	Survey Type	Gradiometer
Map Reference	—	Instrument	FM36
Dir. 1st Traverse	NNW	Units	nT
Grid Length (x)	20 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	20 m	Baud Rate	2400
Traverse Interval (y)	0.5 m	Averaging	Off
Traverse Mode	Parallel	Averaging Period	16

14PO406

Acquisition	Value	Instrumentation	Value
Sitename	octa5	Survey Type	Gradiometer
Map Reference	—	Instrument	FM36
Dir. 1st Traverse	E	Units	nT
Grid Length (x)	10 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	10 m	Baud Rate	2400
Traverse Interval (y)	0.5 m	Averaging	Off
Traverse Mode	Parallel	Averaging Period	16

Table 5. Statistical analysis of the magnetic gradient data from the four sites.

Site Number	Mean (nT)	Std Deviation (nT)	Minimum Value (nT)	Maximum Value (nT)
14MH322	0.0269155	0.5810064	-3.6	8.85
14MH323	0.09161026	6.797348	-159.4	200.0
14PO312	0.3243466	7.236902	-82.10	175.7
14PO406	–0.02962556	2.259973	-13.7	16.35

Table 6. Acquisition and instrumentation information for the soil resistance surveys used in the grid input template.

14MH323, General

Acquisition	Value	Instrumentation	Value
Sitename	octa2	Survey Type	Resistance
Map Reference	—	Instrument	RM15
Dir. 1st Traverse	N	Units	ohms
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	Zigzag	High-Pass Filter	13Hz

ACCESSORIES:
Array Name: PA5
Interface: MPX15
Log Mode: Multiple
Readings per Station: 6

Configuration 1: user defined
Configuration 2: user defined
Configuration 3: user defined
Configuration 4: user defined
Configuration 5: user defined
Configuration 6: user defined

14PO312

Acquisition	Value	Instrumentation	Value
Sitename	octa4	Survey Type	Resistance
Map Reference	—	Instrument	RM15
Dir. 1st Traverse	NNW	Units	ohms
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	Zigzag	High-Pass Filter	13Hz

ACCESSORIES:
Array Name: PA5
Interface: MPX15
Log Mode: Multiple
Readings per Station: 6

Configuration 1: user defined
Configuration 2: user defined
Configuration 3: user defined
Configuration 4: user defined
Configuration 5: user defined
Configuration 6: user defined

Table 7. Statistics for soil resistance data at Site 14MH323.

Probe Spacing (m)	Max. Value (ohms)	Min. Value (ohms)	Mean (ohms)	Std. Deviation (ohms)
0.25	165.70	44.45	104.794	21.37136
0.50	204.70	20.75	48.76119	10.50232
0.75	189.35	27.75	114.5295	29.76966
1.00	28.80	13.75	19.60558	2.34488
1.25	204.70	13.40	101.3608	33.83585
1.50	142.00	10.20	12.35919	4.69638

Table 8. Statistics for soil resistance data at Site 14PO312.

Probe Spacing (m)	Max. Value (ohms)	Min. Value (ohms)	Mean (ohms)	Std. Deviation (ohms)
0.25	200.95	13.25	29.21971	19.5258
0.50	135.25	3.15	11.15556	6.379864
0.75	204.70	13.80	67.46313	37.00784
1.00	204.70	4.90	8.078438	47.14568
1.25	204.70	9.10	76.40668	43.19189
1.50	204.70	2.50	6.371902	12.1558

Table 9. Composite details and source grid information used to create blank composite templates.

14MH323

Composite Details:	Value
Sitename	octa2
Dir. 1st Traverse	North
Composite Length (x)[1]	120 m
Sample Interval (x)	0.5 m
Composite Width (y)[1]	20 m
Traverse Interval (y)	1 m
Survey Type	Resistance
Instrument	RM15
Units	ohms
Source Grid:	Value
Source Grid Length (x)	20 m
Source Grid Width (y)	20 m

[1] Enter dimensions in terms of meters, not readings.

14PO312

Composite Details:	Value
Sitename	octa4
Dir. 1st Traverse	North
Composite Length (x)[1]	120 m
Sample Interval (x)	0.5 m
Composite Width (y)[1]	20 m
Traverse Interval (y)	1 m
Survey Type	Resistance
Instrument	RM15
Units	ohms
Source Grid:	Value
Source Grid Length (x)	20 m
Source Grid Width (y)	20 m

[1] Enter dimensions in terms of meters, not readings.

Table 10. Acquisition and instrumentation information for the ground conductivity surveys used in the grid input template.

14MH322

Acquisition	Value	Instrumentation	Value
Sitename	octa1	Survey Type	EM
Map Reference	—	Instrument	
Dir. 1st Traverse	N	Units	mS/m
Grid Length (x)	10 m		
Sample Interval (x)	0.5 m		
Grid Width (y)	20 m		
Traverse Interval (y)	1.0 m		
Traverse Mode	Zigzag		

14PO406

Acquisition	Value	Instrumentation	Value
Sitename	octa5	Survey Type	EM
Map Reference	—	Instrument	
Dir. 1st Traverse	N	Units	mS/m
Grid Length (x)	10 m		
Sample Interval (x)	0.5 m		
Grid Width (y)	10 m		
Traverse Interval (y)	0.5 m		
Traverse Mode	Zigzag		

Table 11. Statistical analysis of the ground conductivity data from Sites14MH322 and 14PO406.

Site Number	Mean (mS/m)	Std. Dev. (mS/m)	Min. Value (mS/m)	Max. Value (mS/m)
14MH322	67.7806	5.06576	56.58	79.652
14PO406	60.45212	15.00264	38.94	116.212

Table 12. Magnetic gradient anomaly interpretations at Site 14MH323.

Mag. Grad. Anomaly Number	Anomaly Center Point Location	Peak Value (nT)	Contour Interval (nT) at Halfway Point Between Peak and Background	Diameter of Contour Interval (m)	Anomaly Depth (m)	Mass of Anomalous Object (kg)
1	N0.35/E5.00	8.6	4.345	0.40	0.10	0.009
2	N1.04/E6.73	3.3	1.695	0.48	0.18	0.006
3	N1.35/E5.44	22.9	11.495	0.50	0.20	0.048
4	N2.19/E2.20	8.2	4.145	0.48	0.18	0.015
5	N4.25/E2.50	10.3	5.195	0.40	0.10	0.011
6	N3.72/E7.72	5.8	2.945	0.36	0.06	0.004
7	N2.42/E11.00	33.0	16.545	0.62	0.32	0.131
8	N3.69/E9.28	5.8	2.945	0.68	0.38	0.030
9	N5.01/E9.89	80.6	40.345	0.38	0.08	0.074
10	N4.18/E17.88	2.9	1.495	0.32	0.02	0.0015
11	N0.58/E13.66	13.5	6.795	0.36	0.06	0.010
12	N1.325/E13.38	6.0	3.045	0.49	0.19	0.012
13	N3.60/E12.00	8.6	4.345	0.50	0.20	0.018
14	N2.69/E12.51	21.5	10.795	0.66	0.36	0.103
15	N3.30/E12.94	22.8	11.445	0.68	0.38	0.119
16	N3.66/E13.71	13.1	6.595	0.36	0.06	0.010
17	N1.90/E13.42	6.4	3.245	0.20	surface	0.0008
18	N2.31/E14.00	12.7	6.395	0.30	surface	0.006
19	N11.46/E3.68	20.4	10.245	0.36	0.06	0.016
20	N8.05/E6.54	5.3	2.695	0.72	0.42	0.032
21	N6.49/E10.36	4.8	2.445	0.72	0.42	0.029
22	N6.17/E13.00	7.2	3.645	0.32	0.02	0.004
23	N8.52/E12.50	6.8	3.445	0.36	0.06	0.005
24	N10.19/E17.26	4.3	2.195	0.67	0.37	0.021
25	N11.78/E15.34	10.9	5.495	0.52	0.22	0.025
26	N10.45/E14.59	3.6	1.845	0.58	0.28	0.011
27	N7.24/E17.64	156.8	78.445	0.50	0.22	0.326
28	N7.25/E17.97	156.8	78.445	0.30	surface	0.071
29	N7.22/E19.06	12.2	6.145	0.60	0.30	0.087
30	N8.36/E18.81	4.0	2.045	0.24	surface	0.0009
31	N10.91/E18.76	9.0	4.545	0.45	0.15	0.014
32	N12.05/E18.52	5.4	2.745	0.72	0.42	0.033
33	N12.75/E7.44	12.1	6.095	0.36	0.06	0.009
34	N12.52/E9.37	200.0	100.045	0.48	0.18	0.368
35	N12.35/E16.35	6.5	3.295	0.48	0.18	0.012
36	N13.08/E15.04	7.1	3.595	0.36	0.06	0.005
37	N13.05/E17.07	10.8	5.445	0.32	0.02	0.006
38	N14.39/E19.44	1.5	0.795	0.24	surface	0.0003
39	N14.72/E15.85	20.1	10.095	0.82	0.52	0.184
40	N17.27/E19.04	5.7	2.895	0.50	0.30	0.012
41	N12.90/E19.64	5.3	2.695	0.58	0.28	0.017
42	N17.41/E18.325	5.5	2.795	0.50	0.20	0.011
43	N18.405/E16.44	11.7	5.895	0.28	surface	0.004
44	N16.43/E9.03	7.8	3.945	0.40	0.10	0.008
45	N17.275/E9.53	5.7	2.895	0.32	0.02	0.003
46	N18.00/E9.72	29.6	14.845	0.40	0.10	0.031
47	N17.72/E7.95	8.6	4.345	0.38	0.08	0.0009
48	N19.21/E8.50	5.4	2.745	0.34	0.04	0.003

Note: the background value for all 48 entries is 0.09 nT.

Table 13. Magnetic gradient anomaly interpretations at Site 14PO312.

Mag. Grad. Anomaly Number	Anomaly Center Point Location	Peak Value (nT)	Contour Interval (nT) at Halfway Point Between Peak and Background	Diameter of Contour Interval (m)	Anomaly Depth (m)	Mass of Anomalous Object (kg)
1	N4.63/E3.55	4.6	2.46	0.38	0.08	0.004
2	N5.05/E4.64	2.1	1.12	0.46	0.16	0.003
3	N0.46/E5.54	4.0	2.16	0.50	0.20	0.008
4	N4.76/E6.81	6.9	3.61	0.38	0.08	0.006
5	N3.72/E7.53	6.8	3.56	0.42	0.12	0.008
6	N1.52/E6.375	4.3	2.31	0.48	0.18	0.007
7	N6.49/E6.23	17.6	8.96	0.46	0.16	0.028
8	N7.11/E9.19	33.5	16.91	0.56	0.26	0.097
9	N7.17/E8.145	1.3	0.81	1.22	0.92	0.013
10	N8.73/E7.18	2.0	1.16	0.42	0.12	0.002
11	N7.34/E6.00	8.9	4.61	0.40	0.10	0.009
12	N9.05/E4.50	3.8	2.06	0.80	0.50	0.030
13	N2.10/E12.11	16.8	8.56	0.78	0.48	0.0002
14	N1.54/E14.46	36.3	18.31	0.34	0.04	0.024
15	N2.28/E16.59	114.4	57.36	0.68	0.38	0.598
16	N1.71/E17.15	47.1	23.71	0.54	0.24	0.123
17	N2.55/E15.64	18.4	9.35	0.38	0.08	0.017
18	N2.63/E13.93	9.1	4.71	0.40	0.10	0.009
19	N3.06/E18.56	4.8	2.56	0.84	0.54	0.044
20	N5.65/E19.15	5.1	2.71	0.62	0.32	0.019
21	N7.50/E17.44	175.2	87.76	0.50	0.20	0.364
22	N7.94/E17.66	175.7	88.01	0.84	0.54	1.732
23	N7.69/E15.67	5.1	2.71	0.32	0.02	0.003
24	N9.49/E13.16	11.3	5.81	0.48	0.18	0.020
25	N10.84/E17.39	6.0	3.16	1.26	0.96	0.189
26	N13.94/E2.05	24.0	12.16	0.56	0.26	0.069
27	N15.68/E3.18	32.5	16.41	0.65	0.35	0.147
28	N15.945/E1.41	9.9	5.11	0.80	0.50	0.082
29	N13.68/E6.82	7.4	3.86	0.58	0.28	0.023
30	N10.41/E10.53	4.4	2.36	0.56	0.26	0.012
31	N13.72/E17.32	34.8	17.66	1.08	0.78	0.724
32	N12.86/E17825	18.2	9.26	0.66	0.36	0.096
33	N13.49/E19.45	3.5	1.91	1.24	0.94	0.101
34	N15.54/E17.76	19.1	9.71	0.52	0.22	0.044
35	N16.81/E18.16	8.7	4.51	0.64	0.34	0.037
36	N17.88/E19.45	18.7	9.51	1.62	1.32	1.302
37	N17.06/E16.13	37.8	19.06	0.68	0.38	0.196
38	N17.64/E1574	55.0	27.66	0.40	0.10	0.058

Note: The background value for all 38 entries is 0.32 nT.

Figure 1. Routes of pioneer trails in the western United States discussed in the text.

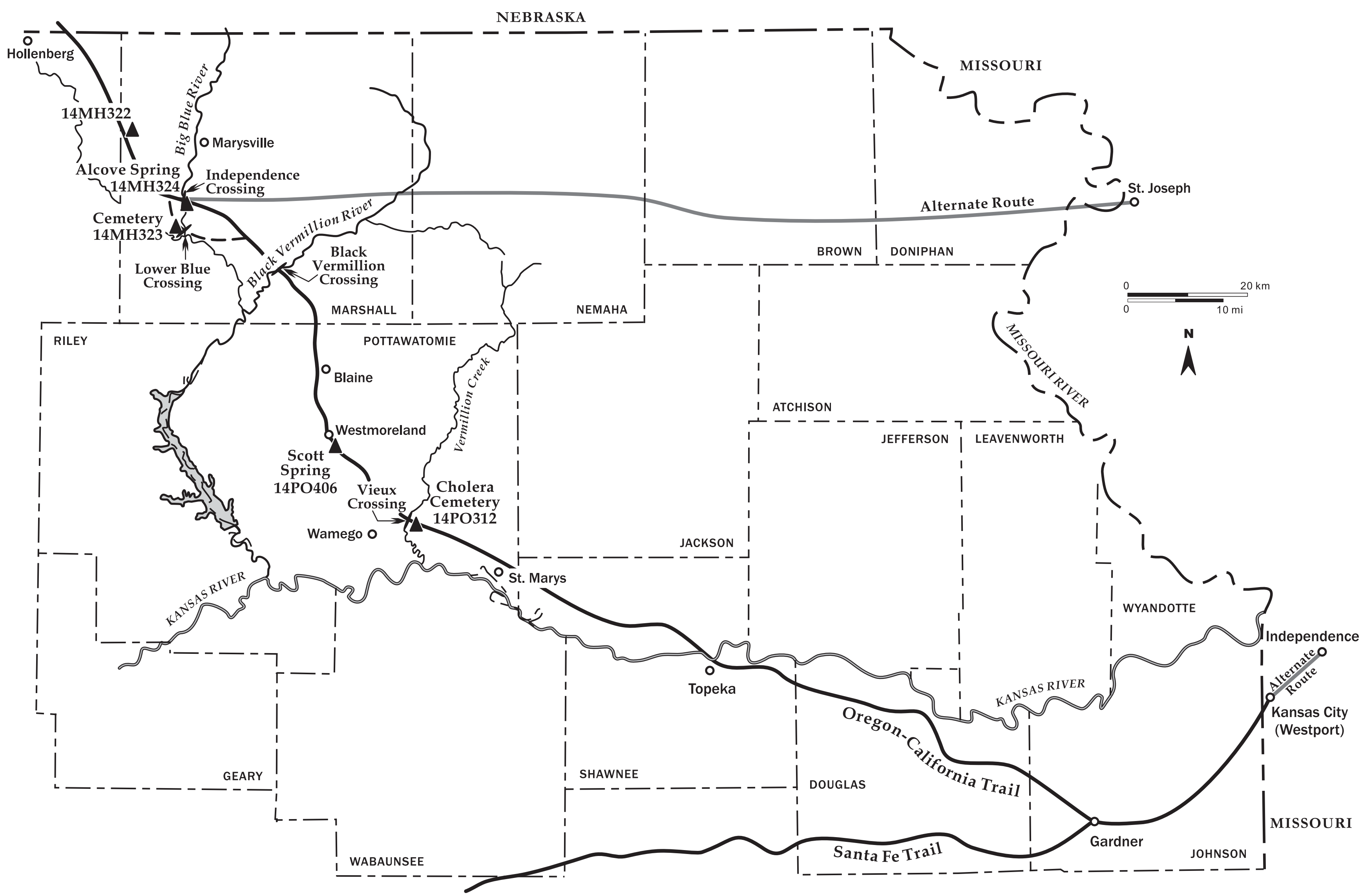

Figure 2. The Oregon–California Trail in northeastern Kansas and the locations of graves sites discussed in the text.


Figure 3. The initials of J. F. Reed carved in the bedrock at Alcove Spring.


Figure 4. Overview of the area of Site 14MH322 associated with the two cairns; view to the west.

Figure 5. Overview of Site 14MH323; view to southeast.

Figure 6. Overview of the Oregon Trail on side slope at Site 14MH324; view to the east.

Figure 7. Alcove Spring at Site 14MH324; view to east.

Figure 8. Stone stair steps leading to area of Site 14MH324 historically associated with the Sarah H. Keyes grave; view to northwest.

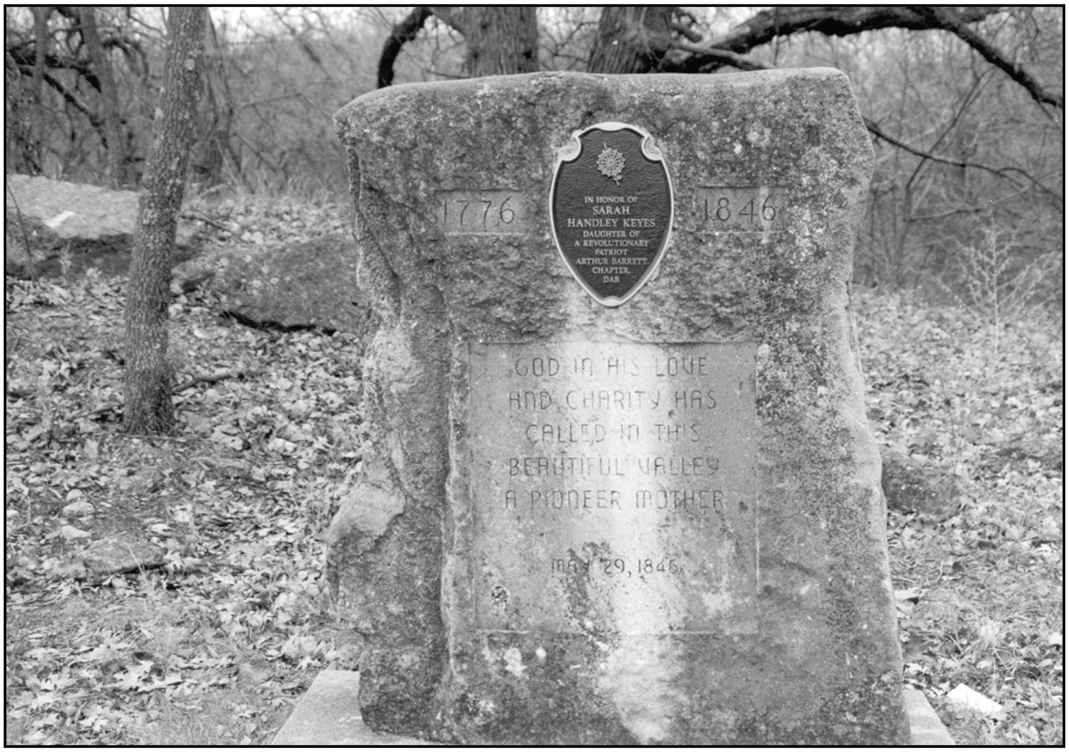

Figure 9. Daughters of the American Revolution marker dedicated to the memory of Sarah H. Keyes; view to the south.

Figure 10. Overview of geophysical grid area at Site 14PO312; view to northwest.

Figure 11. T. S. Prather gravestone inside chain link fence at Cholera Cemetery, Site 14PO312; view to southeast.

Figure 12. Overview of sandstone marker at Site 14PO406; view to northeast.

Figure 13. Setting up the geophysical grid at Site 14PO406; view to south southeast.

Figure 14. Mapping Site 14MH322 with Nikon field station with GPR in background; view to east northeast.

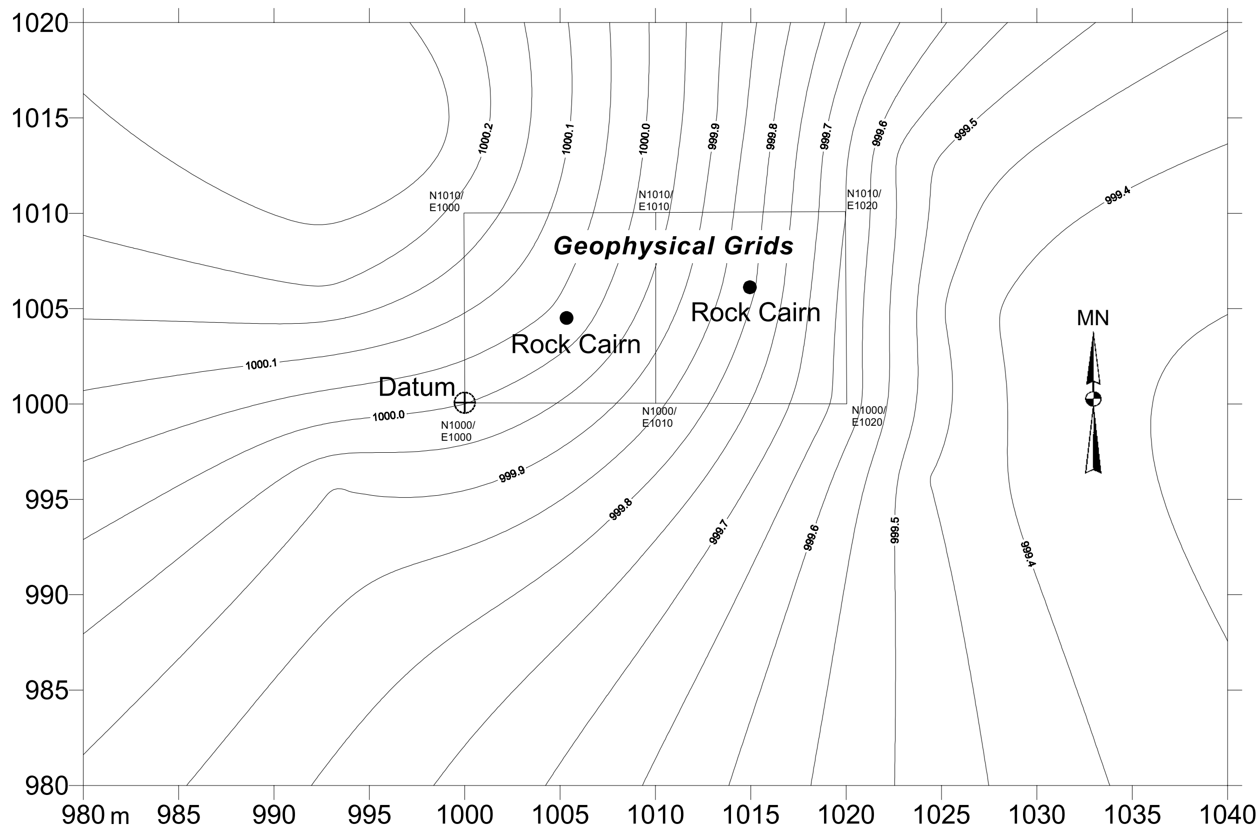

Figure 15. Geophysical grids at Site 14MH322, Art Pacha farm, November 16, 2000, and August 1, 2001. Axes are scaled in meters; the contour interval is 0.05 m.

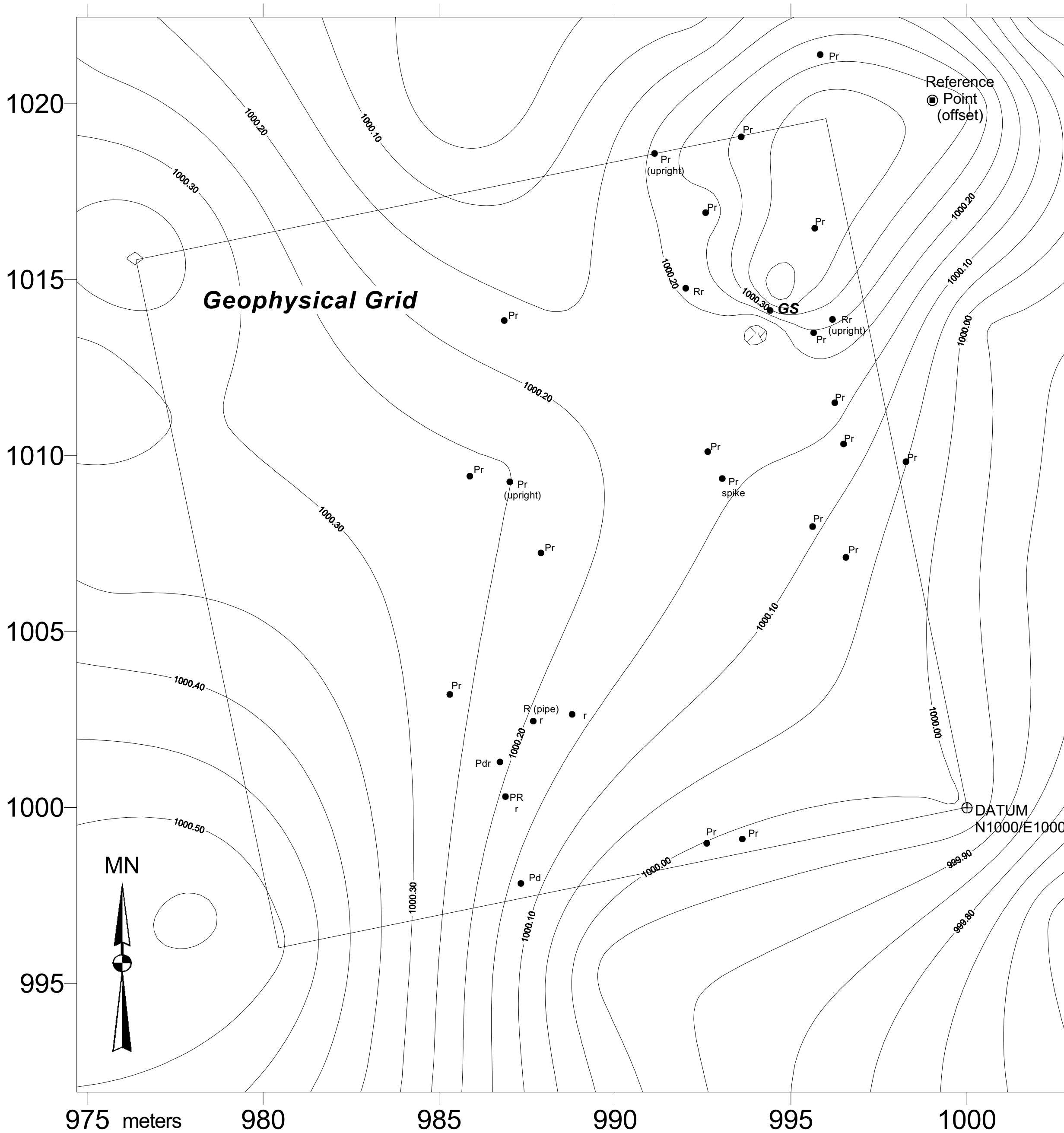

Figure 16. Geophysical grid at Site 14MH323, Marc Vering property, November 15, 2000, and August 1, 2001. Axes are scaled in meters; the contour interval is 0.05 m; GS = marked gravestone; P = pinflag; R = rebar; d = depression; r = rock(s).

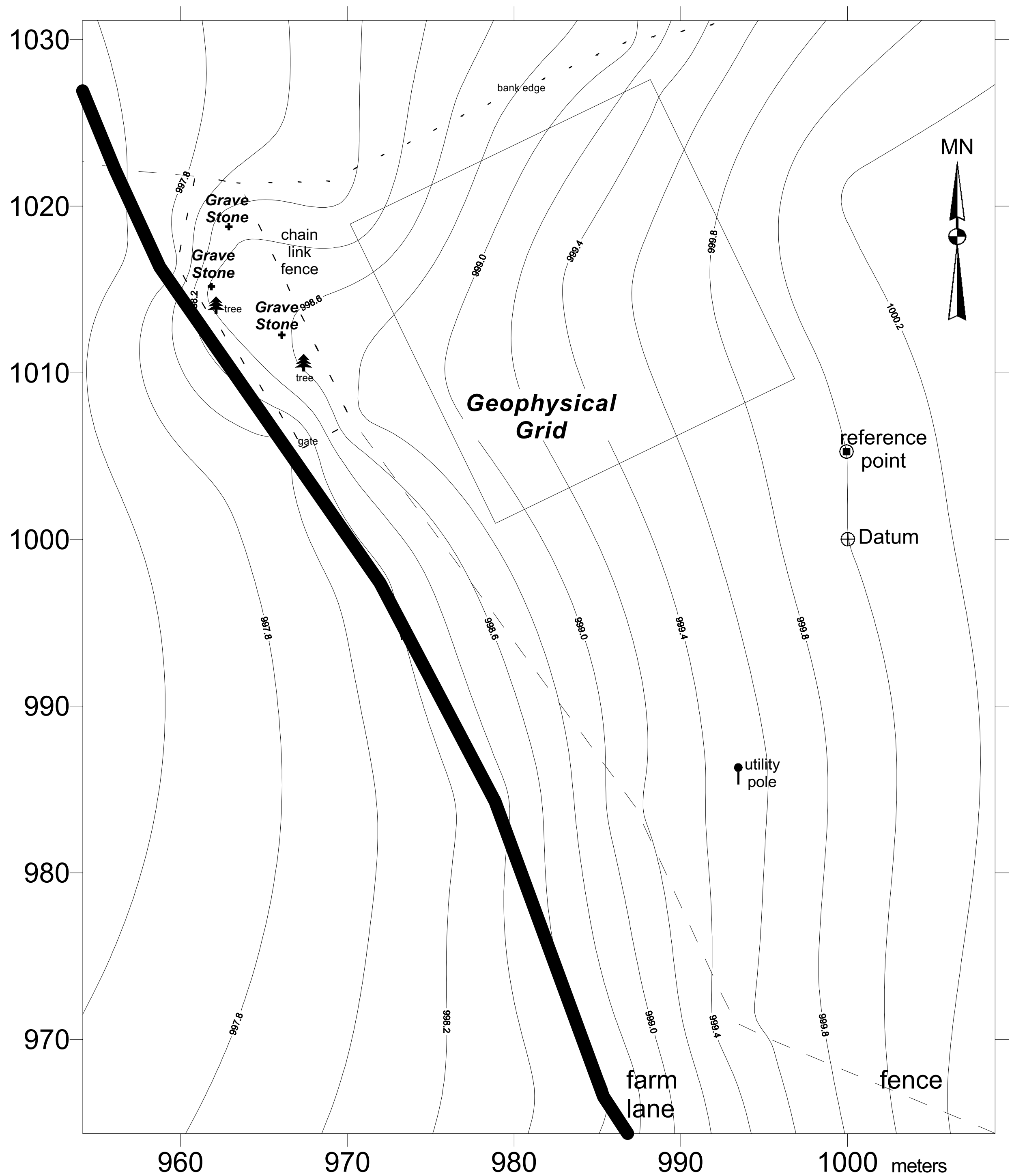

Figure 17. Geophysical grid at Site 14PO312, or the 49ers Cemetery, on the Jim Tessendorf farm, November 14, 2000, and August 1, 2001. Axes are scaled in meters; the contour interval is 0.2 m.

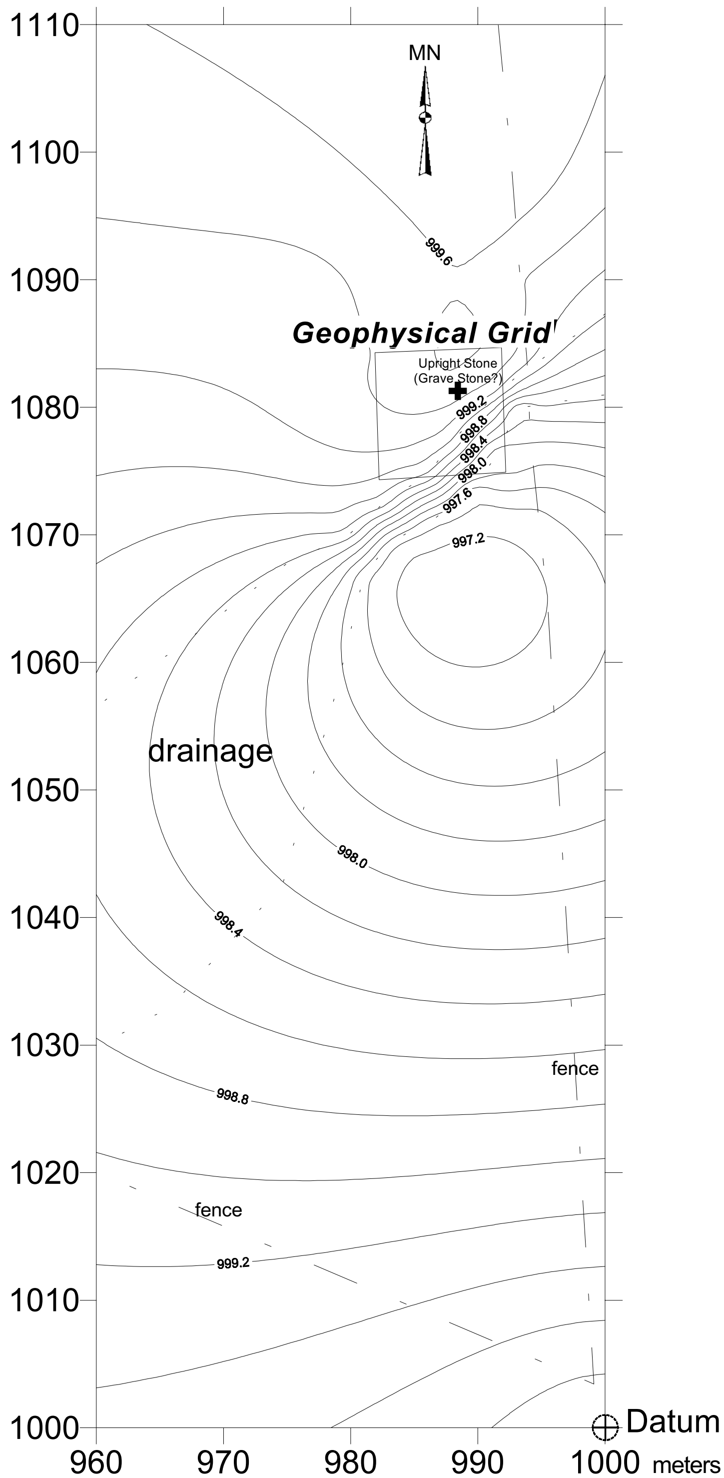

Figure 18. Geophysical grid at Site 14PO406, the Gilbert Chemnitz property, November 14, 2000, and August 1, 2002. Axes are scaled in meters; the contour interval is 0.2 m.

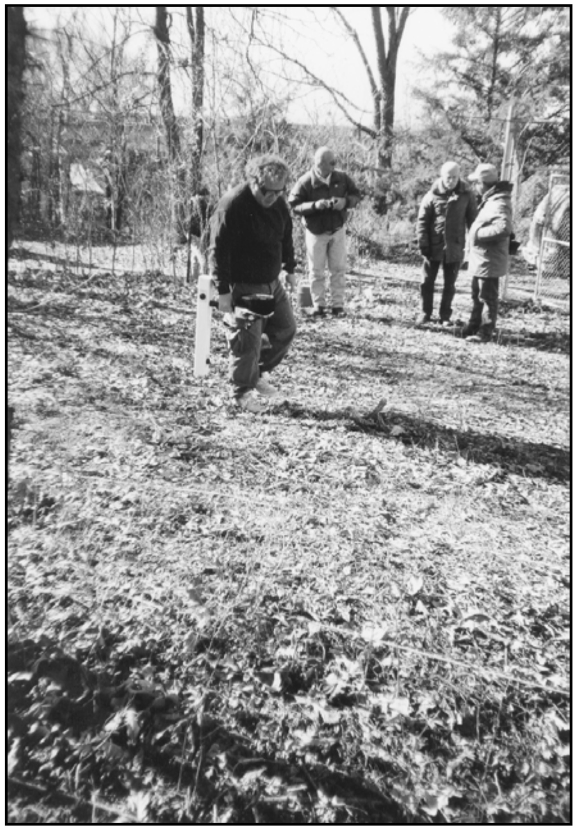

Figure 19. Conducting the magnetic gradient survey at Site 14PO312; view to the northwest.

Figure 20. Aligning the Geoscan Research FM36 fluxgate gradiometer at Site 14MH322.

Figure 21. Conducting the GPR survey at Site 14MH323 with the Sensors and Software's Noggin 250 Smart Cart system; view to the southwest.

Figure 22. GPR survey along graves inside chain link fence at Site 14PO312; view to the northeast.

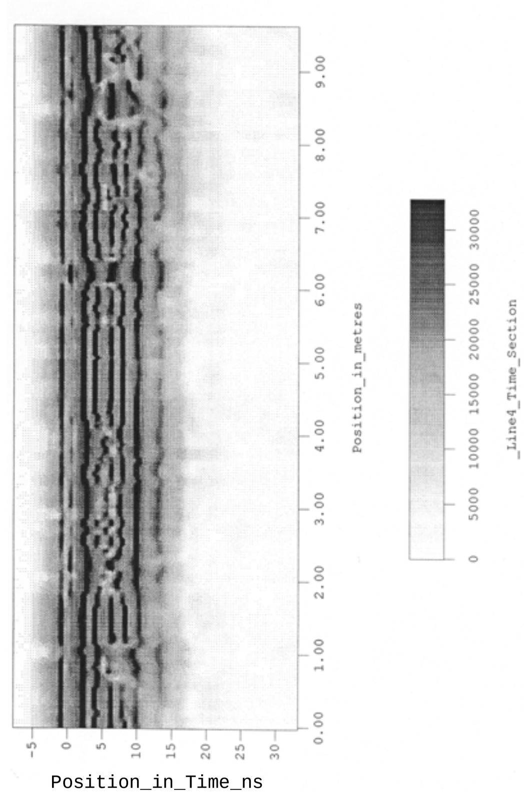

Figure 23. GPR profile across two possible graves along the east boundary of the fenced enclosure at Site 14PO312.

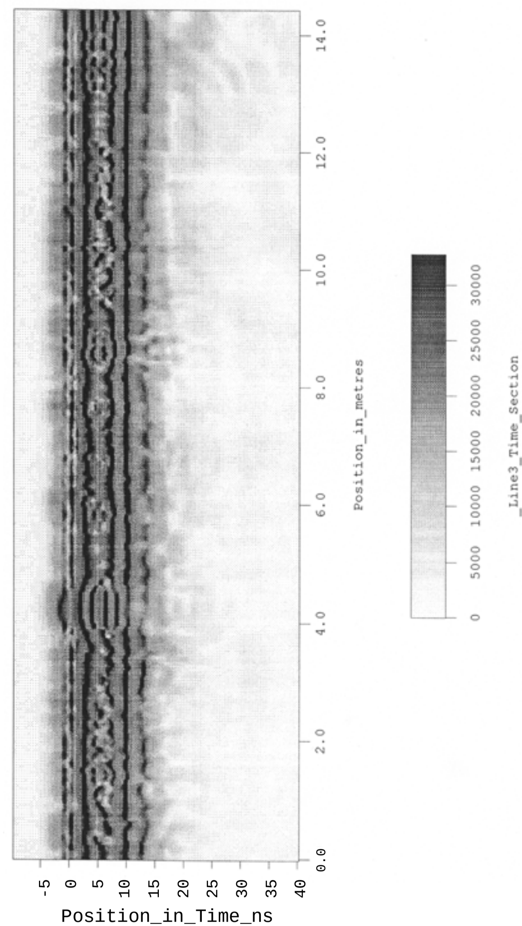

Figure 24. GPR profile across the probable grave east of the stone inscribed with the name of T. S. Prather.

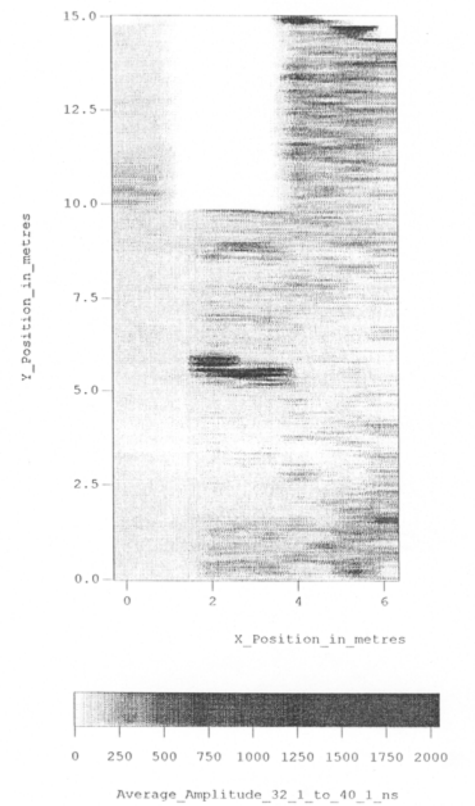

Figure 25. Simulated grid survey across T. S. Prather's grave based on multiple profiles.

Figure 26. Soil resistance survey with Geoscan Research RM15 resistance meter, PA5 multiprobe array, and MPX15 multiplexer; view to the south.

Figure 27. Geonics EM38 ground conductivity meter.

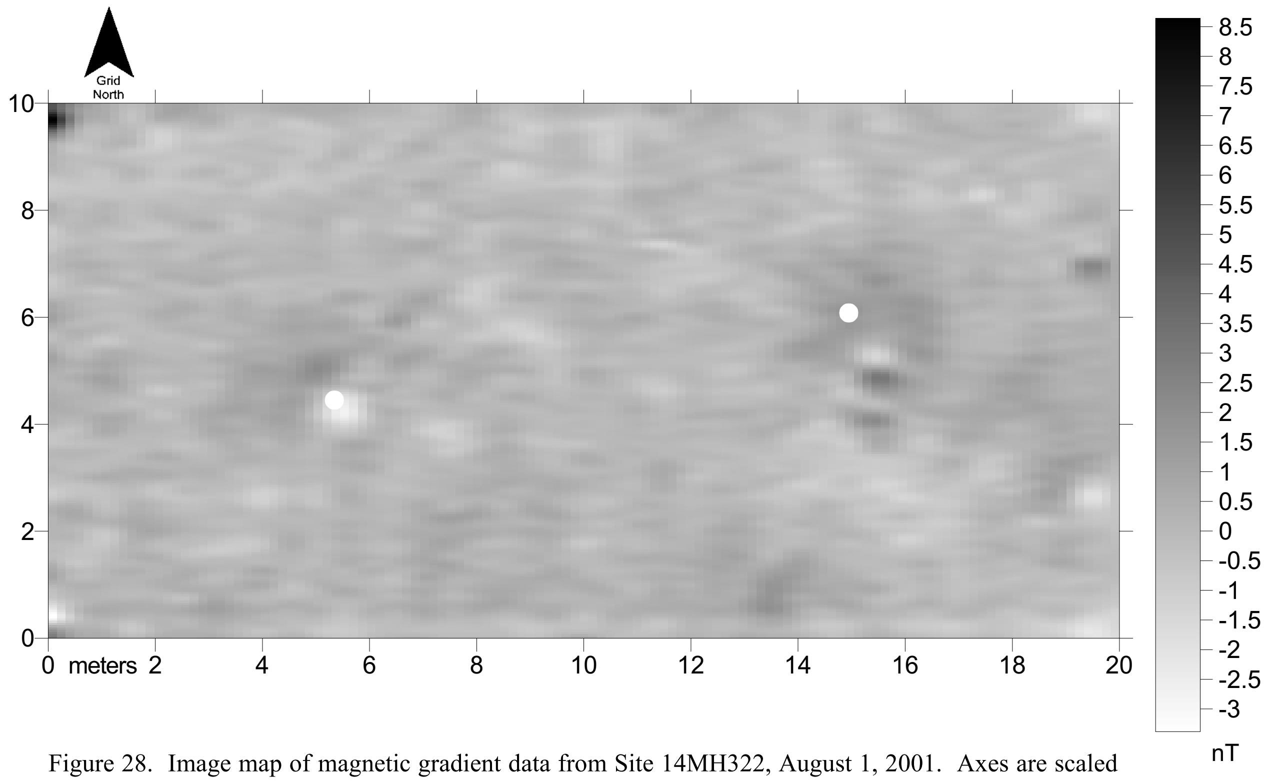

Figure 28. Image map of magnetic gradient data from Site 14MH322, August 1, 2001. Axes are scaled in meters; white dots represent the locations of cairns.

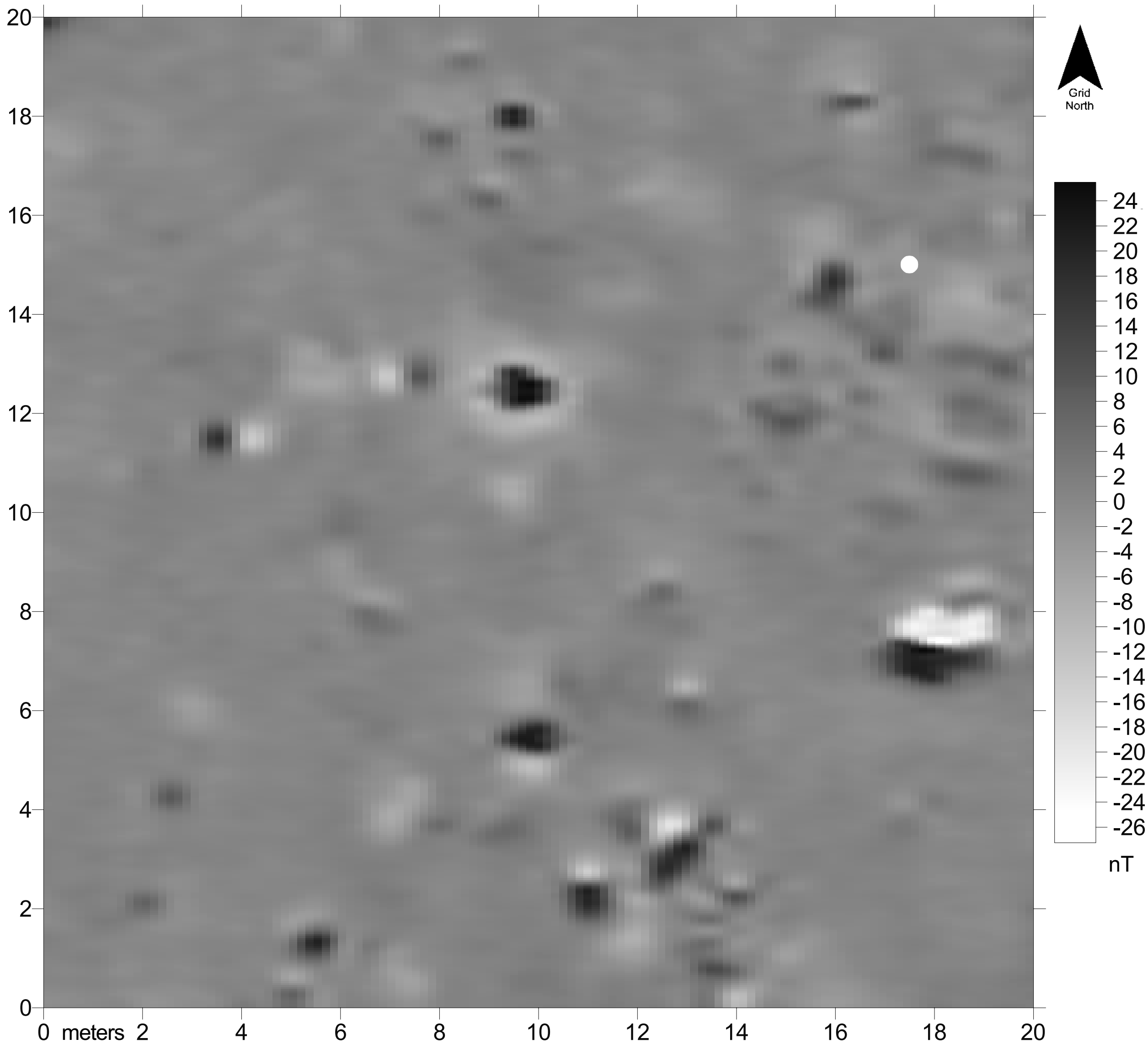

Figure 29. Image map of magnetic gradient data from Site 14MH323, August 1, 2001. Axes are scaled in meters; the white dot represents a marked gravestone.

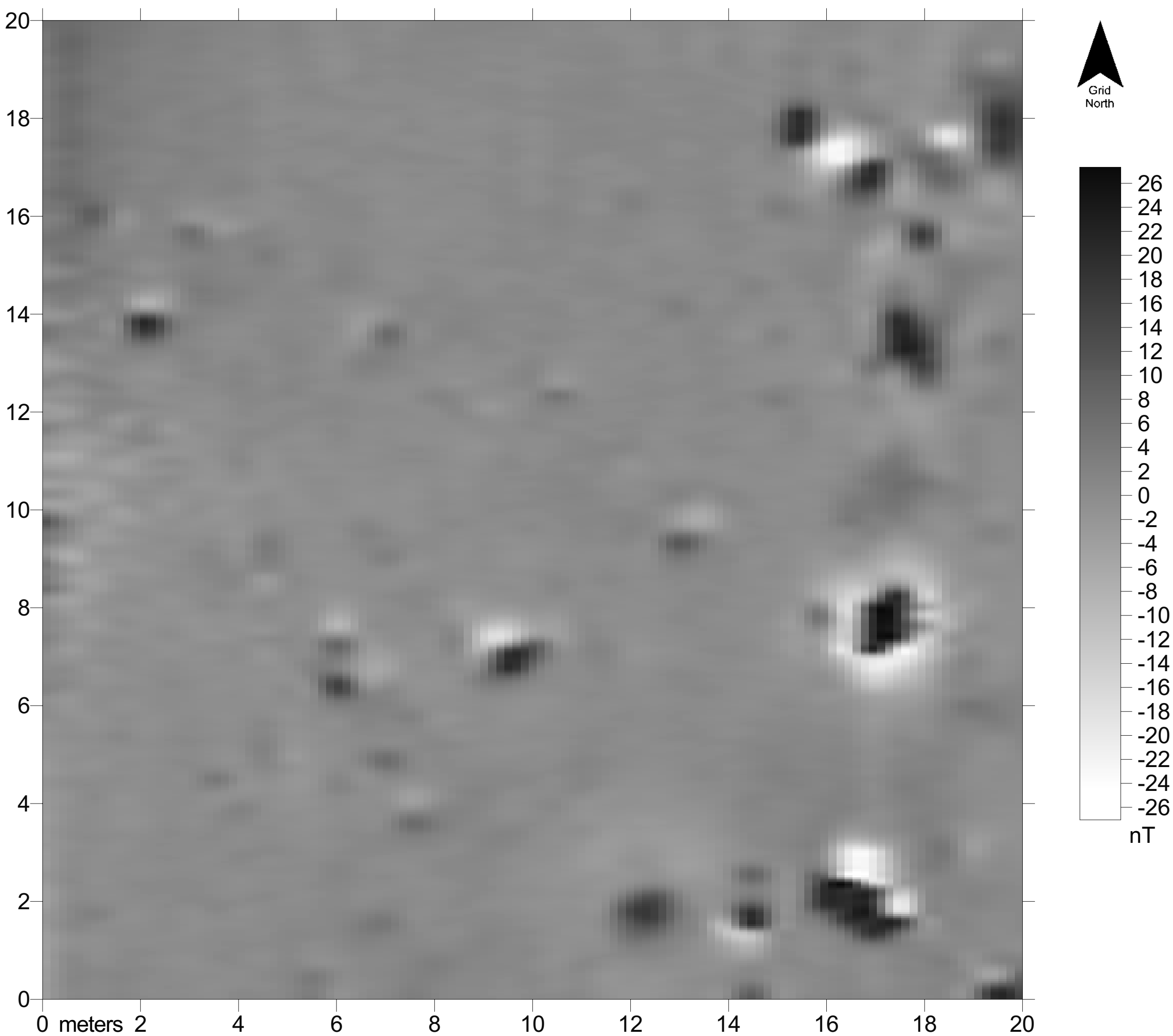

Figure 30. Image map of magnetic gradient data from Site 14PO312, November 14, 2000. Axes are scaled in meters.

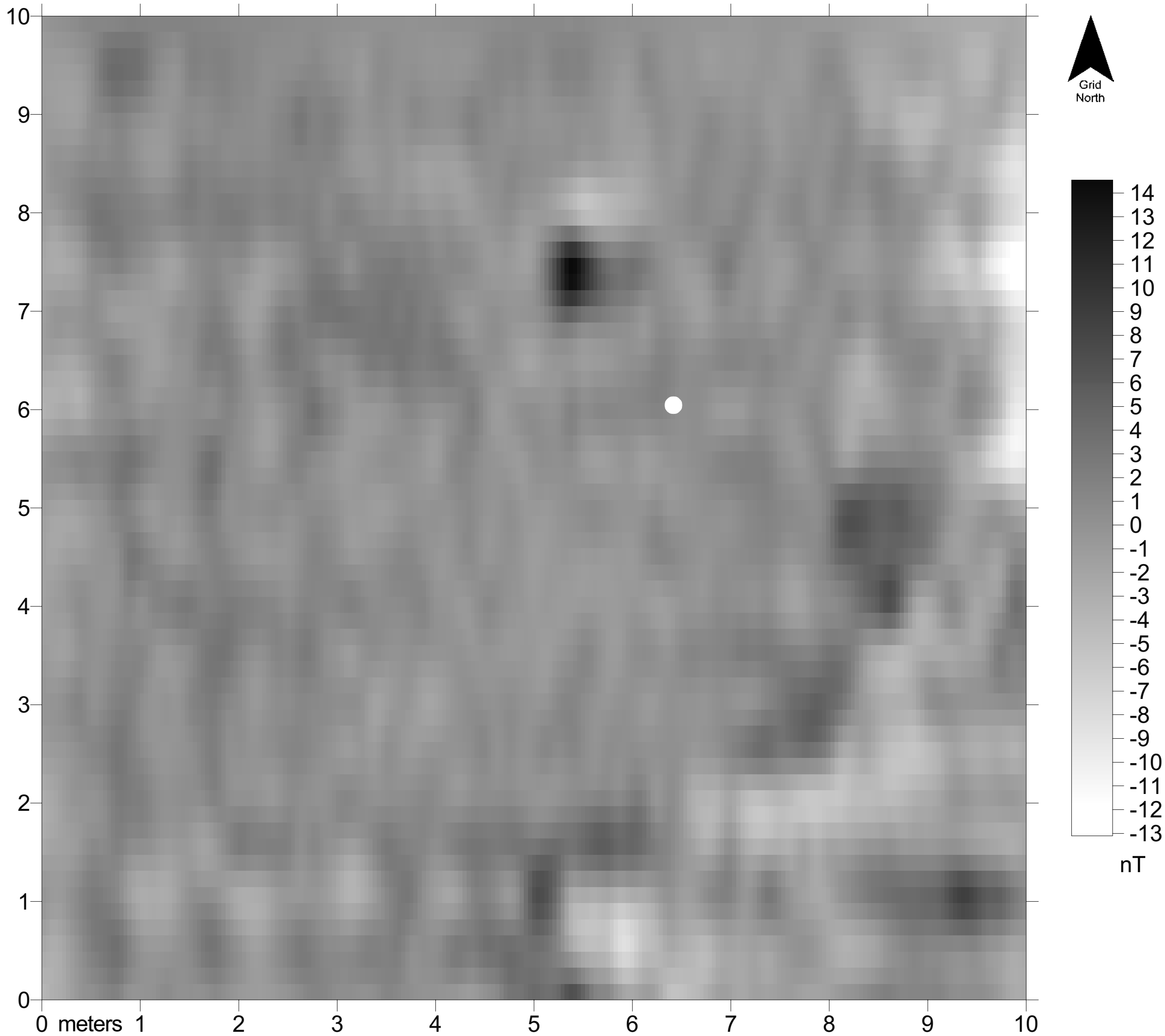

Figure 31. Image map of magnetic gradient data from Site 14PO406. Axes are scaled in meters; the white dot represents location of upright stone.

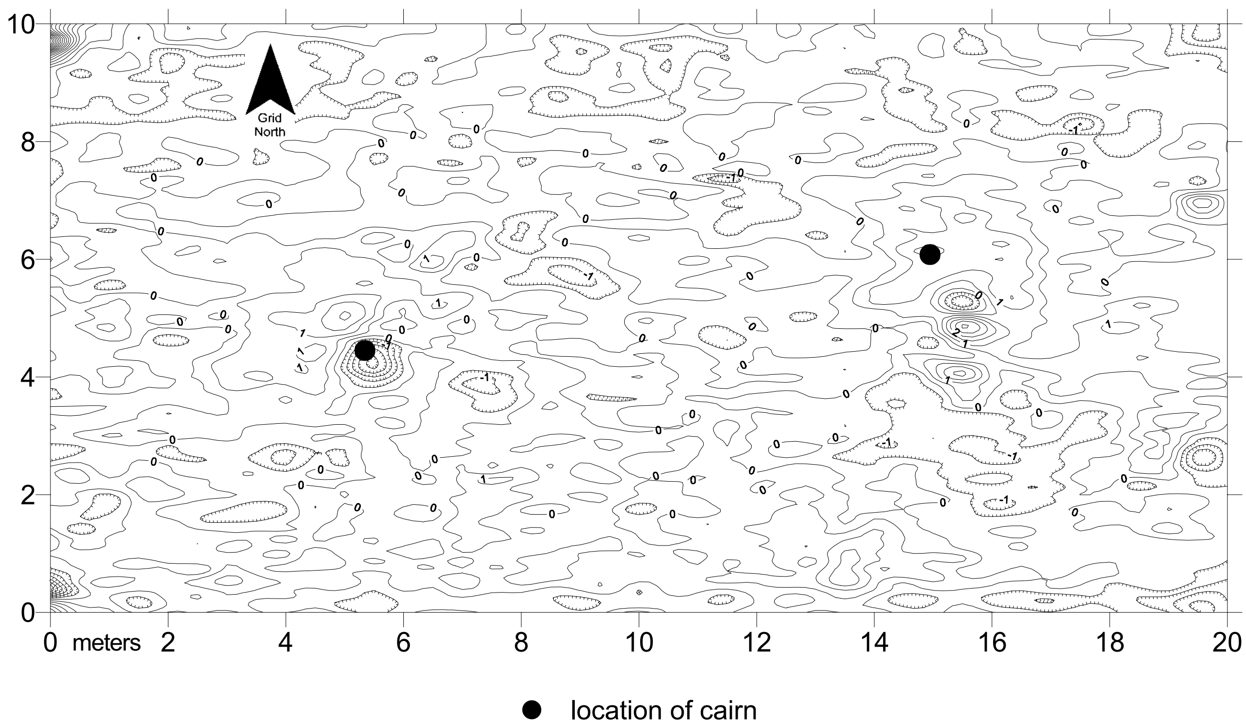

Figure 32. Contour map of magnetic gradient data from Site 14MH322, August 1, 2001. Axes are scaled in meters; the contour interval is 0.5 nT; black dots represent the locations of cairns.

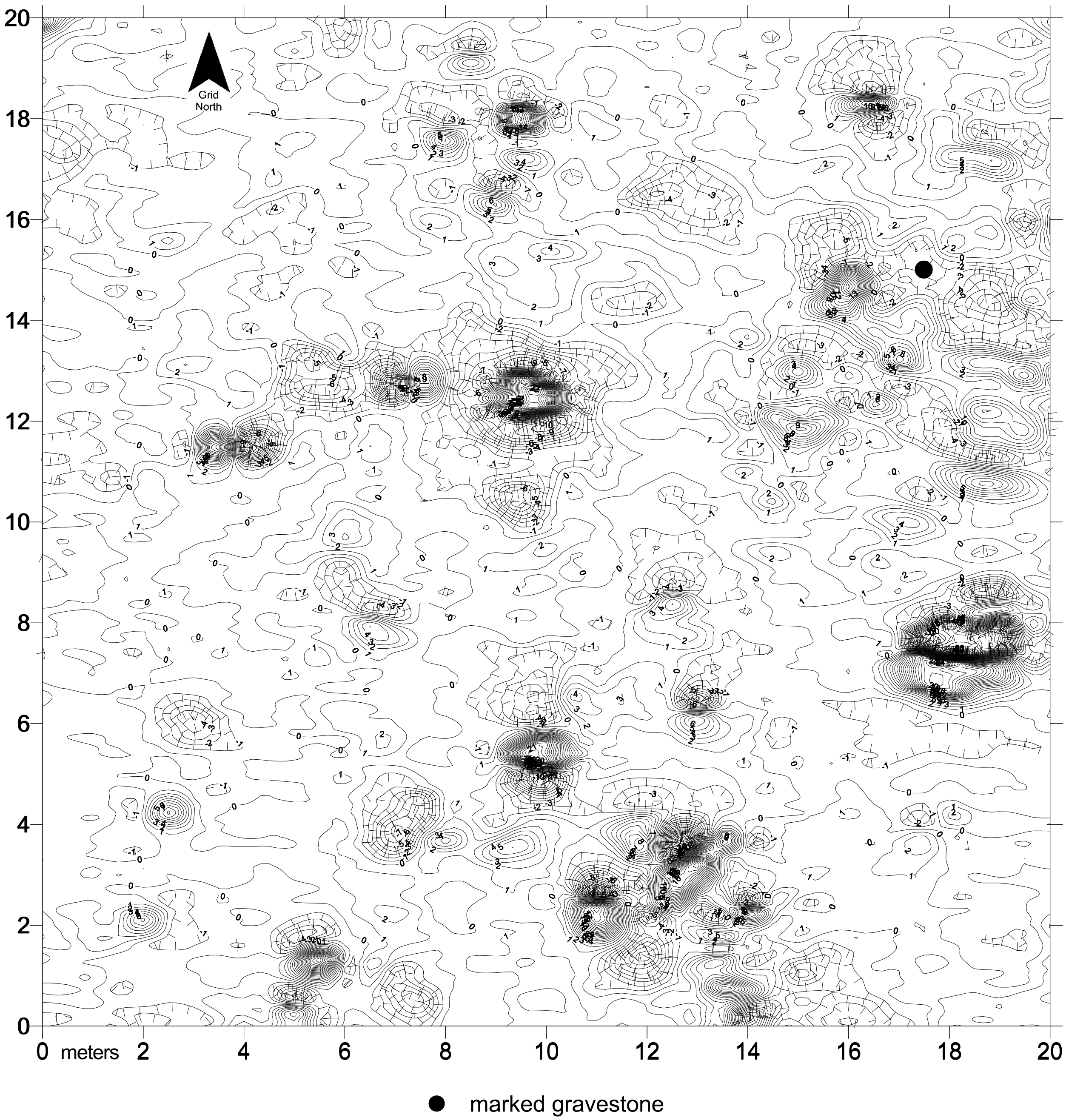

Figure 33. Contour map of magnetic gradient data from Site 14MH323, August 1, 2001. Axes are scaled in meters; the contour interval is 1 nT; the black dot represents marked gravestone.

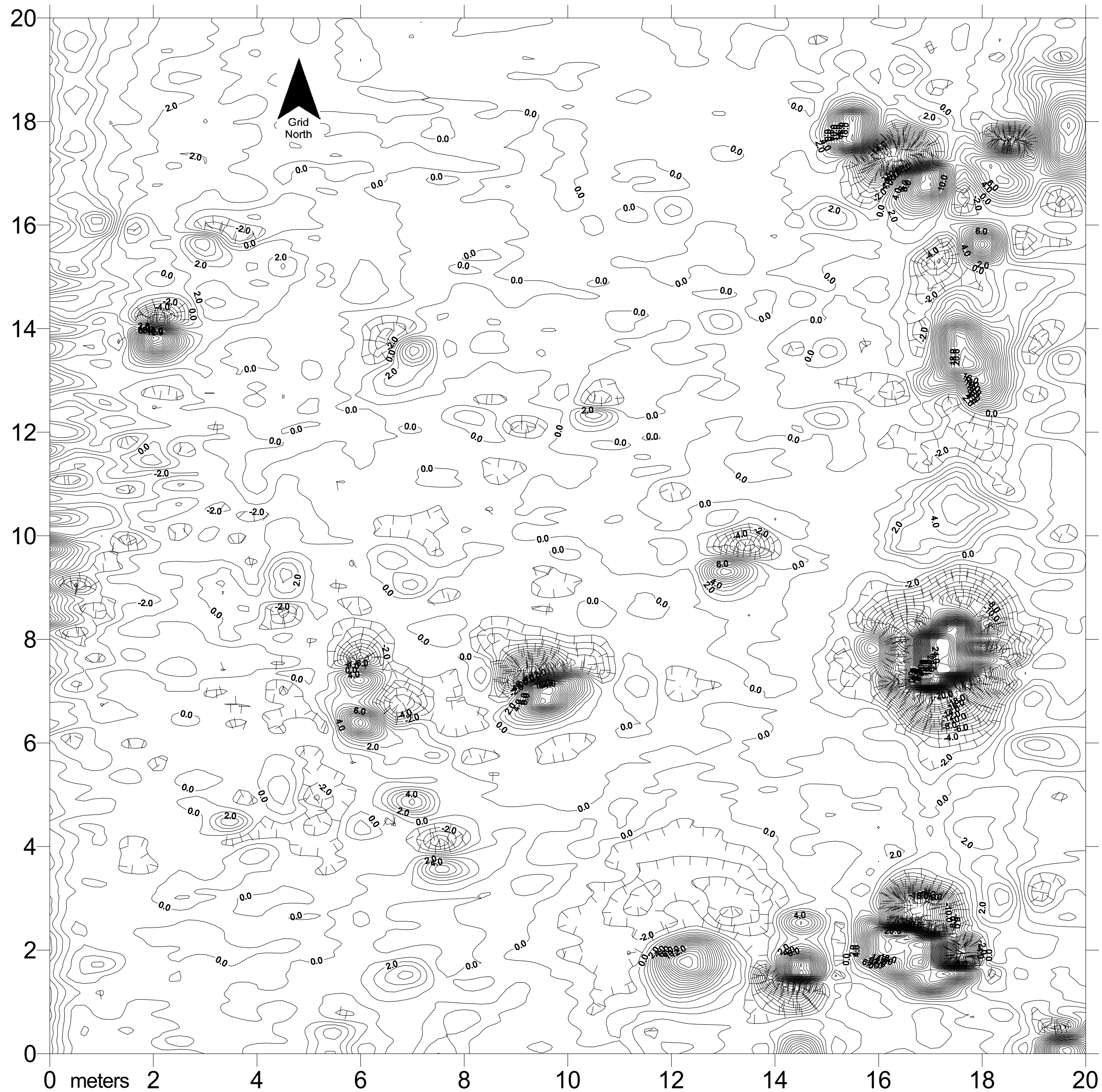

Figure 34. Contour map of magnetic gradient data from Site 14PO312, November 14, 2000. Axes are scaled in meters; the contour interval is 1 nT.

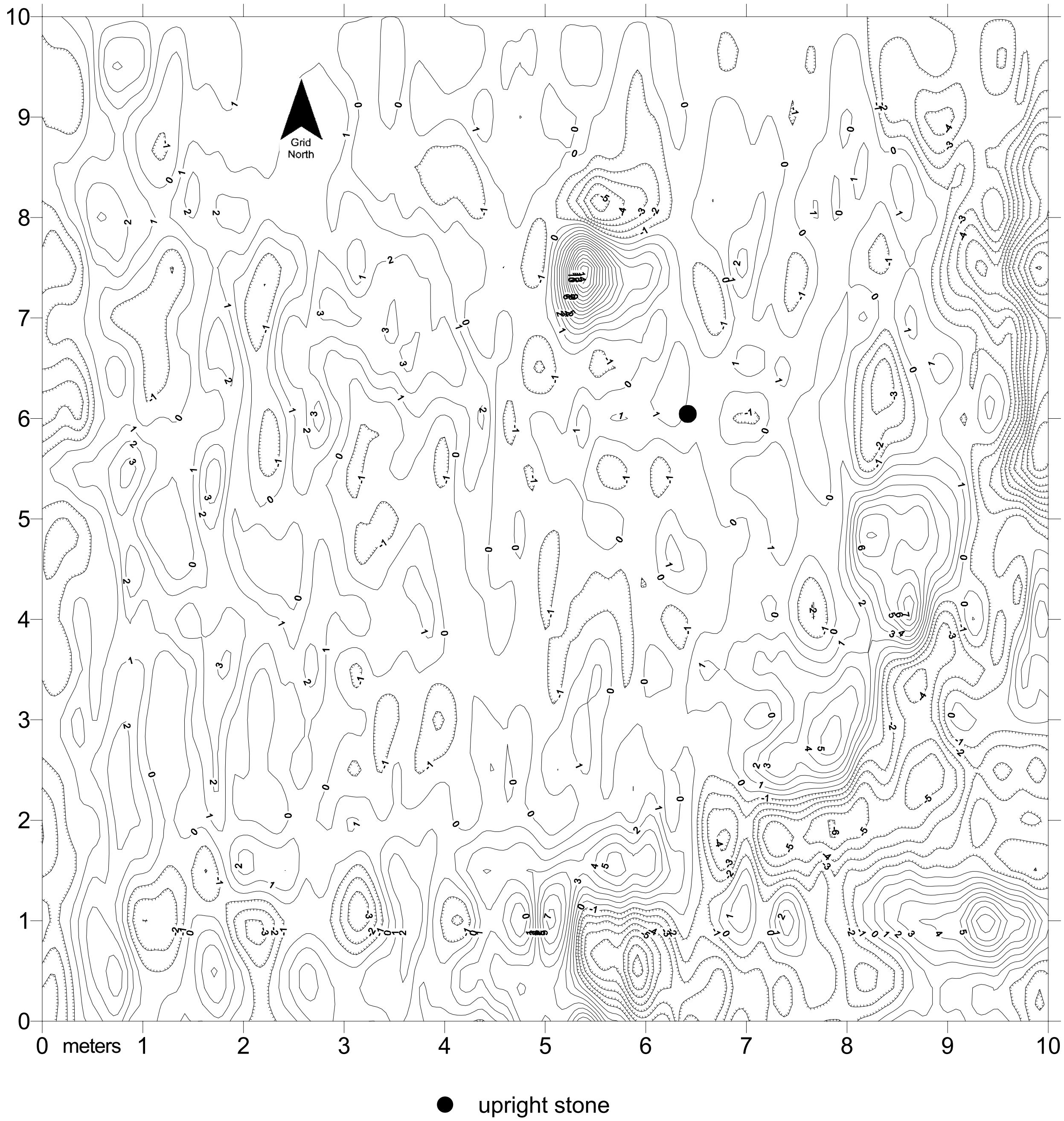

Figure 35. Contour map of magnetic gradient data from Site 14PO406, November 14, 2000. Axes are scaled in meters; the contour interval is 1 nT; the black dot represents the location of upright stone.

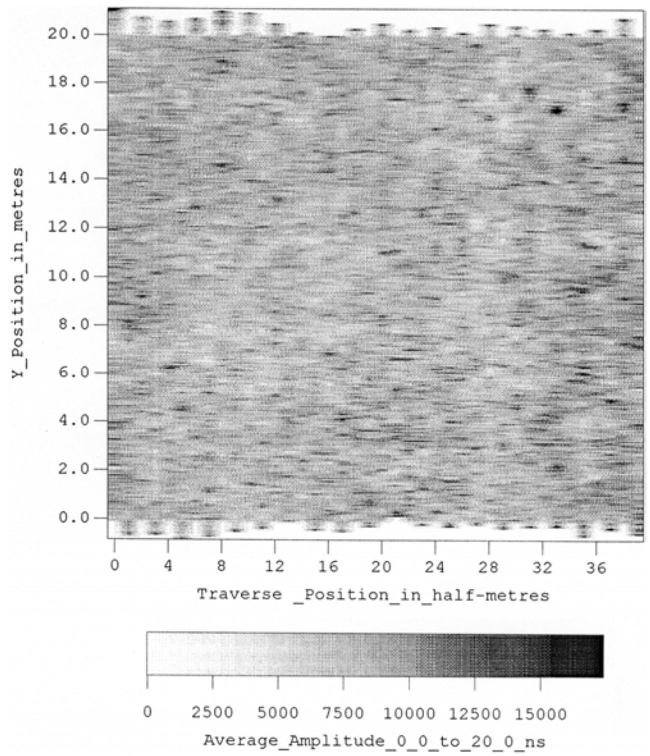

Figure 36. Time-slice (0–20 ns) map of the 20-m grid unit at Site 14PO312; north is at the top of the image.

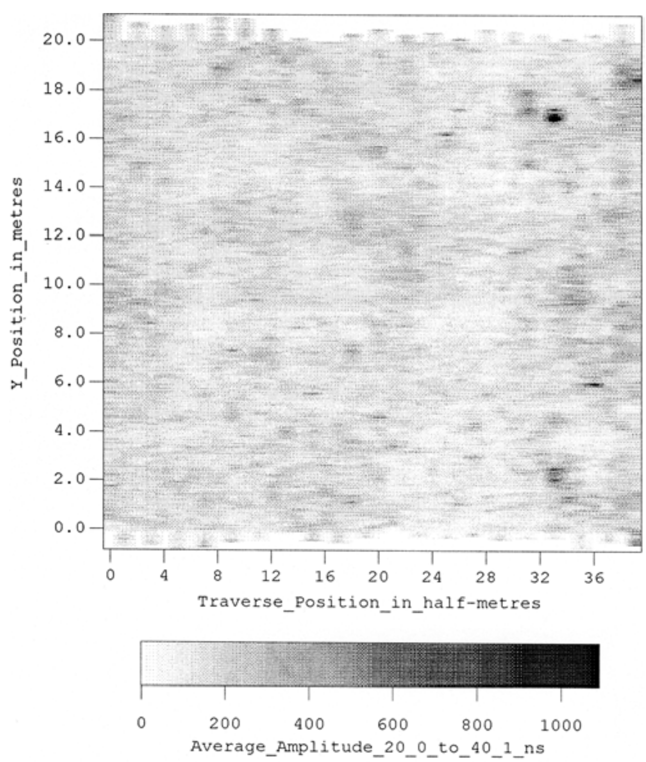

Figure 37. Time-slice (20–40 ns) map of the 20-m grid unit at Site 14PO312; north is at the top of the image.

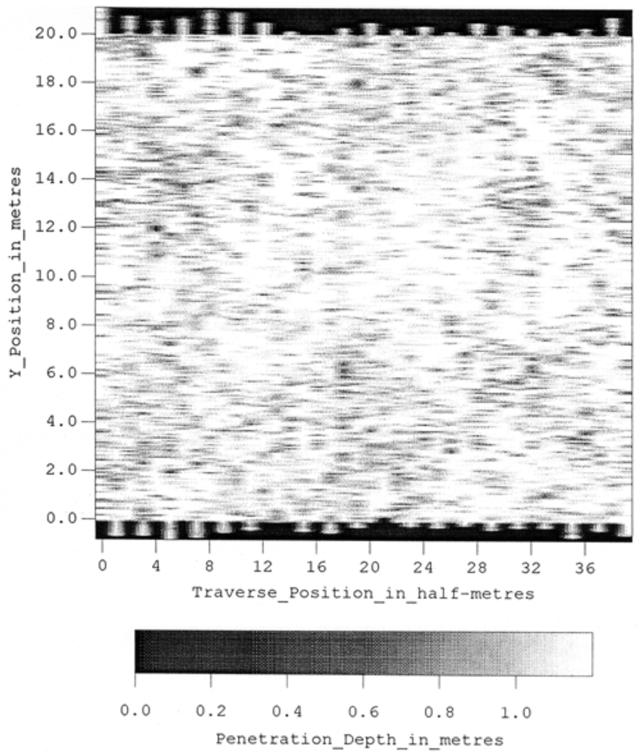

Figure 38. Map of GPR signal penetration at Site 14PO312.

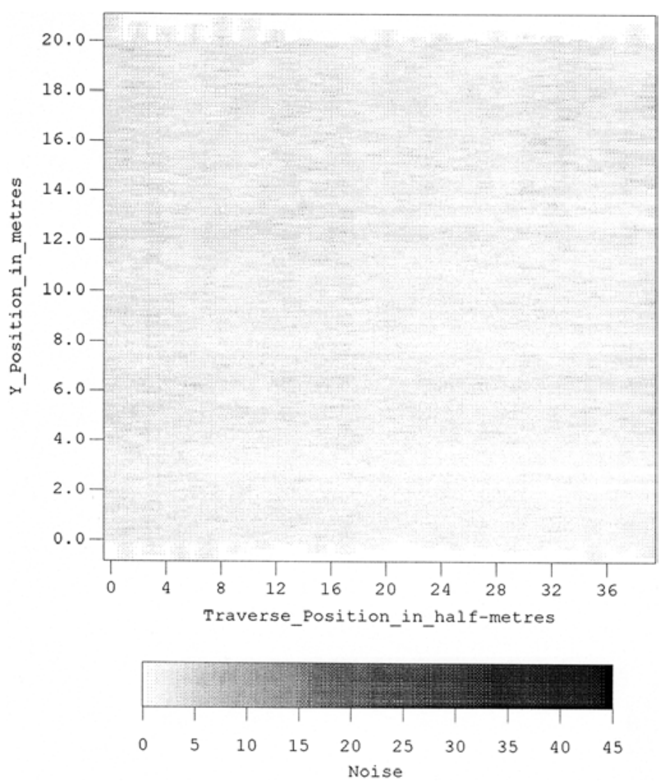

Figure 39. Map of GPR signal noise at Site 14PO312.

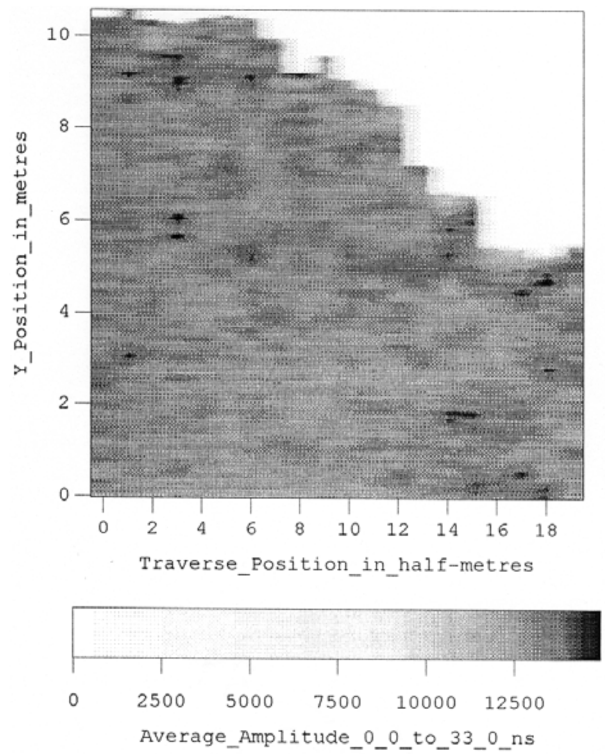

Figure 40. Time-slice (0–33 ns) map of the 10-m grid unit at Site 14PO406; east is at the top of the image.

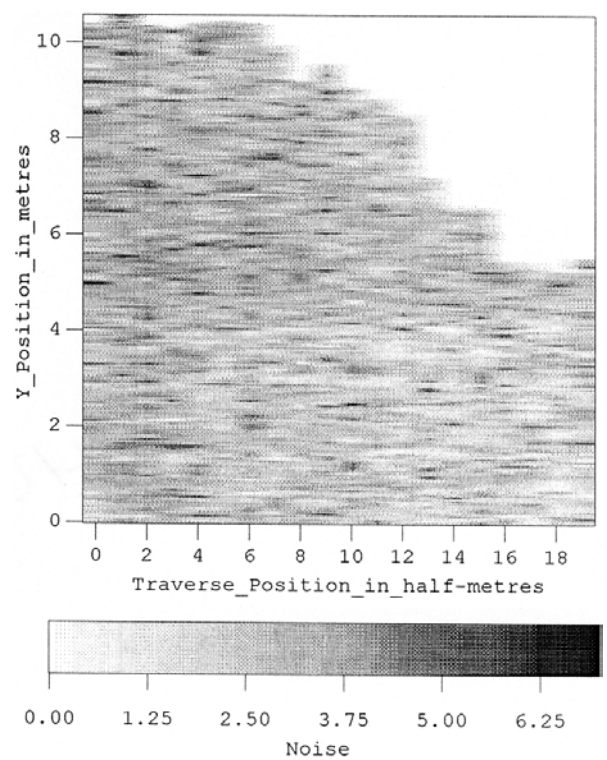

Figure 41. Map of GPR signal noise at Site 14PO406; east is at the top of the image.

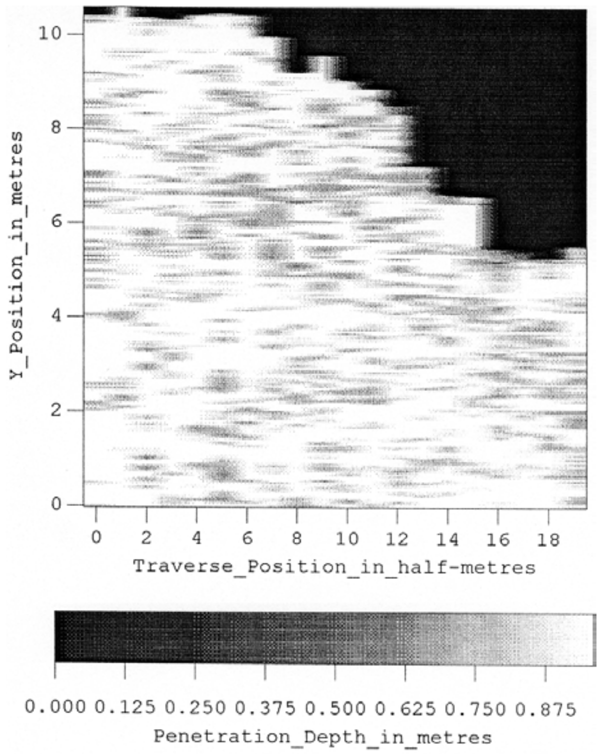

Figure 42. Map of GPR signal penetration at Site 14PO406; east is at the top of the image.

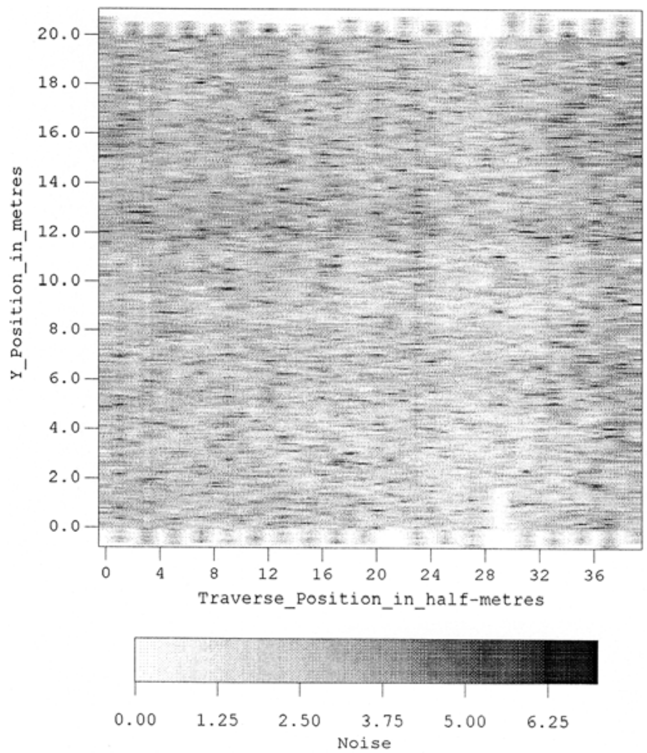

Figure 43. Map of GPR signal noise at Site 14MH323.

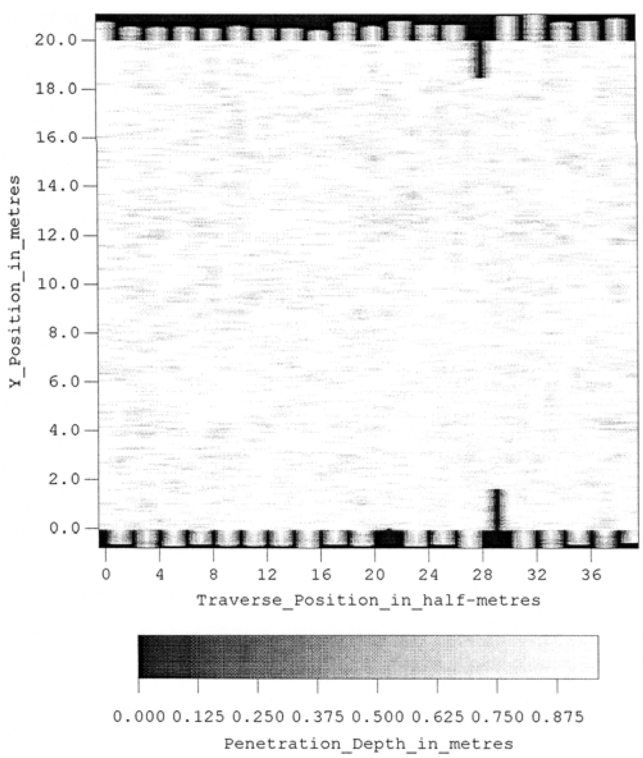

Figure 44. Map of GPR signal penetration at Site 14MH323.

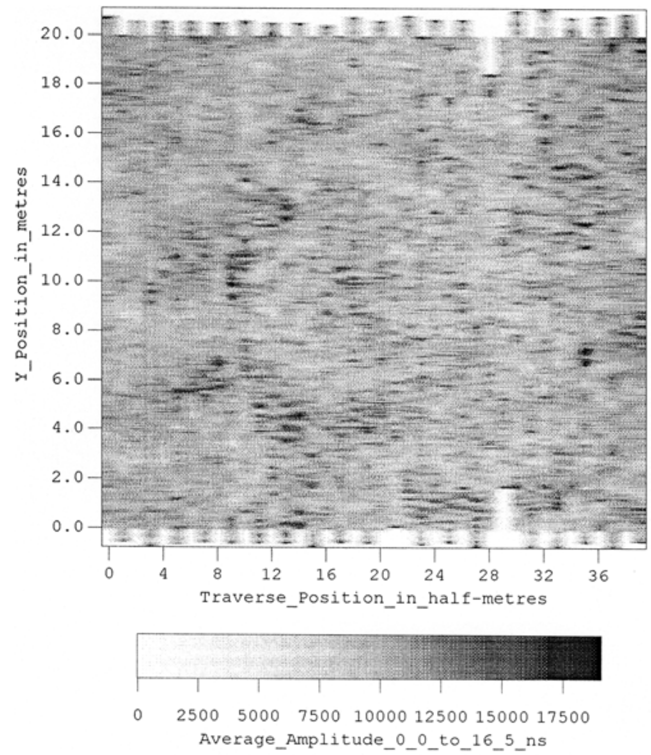

Figure 45. Time-slice (0-16.5 ns) map of the 20-m grid unit at Site 14MH323; north is at the top of the image.

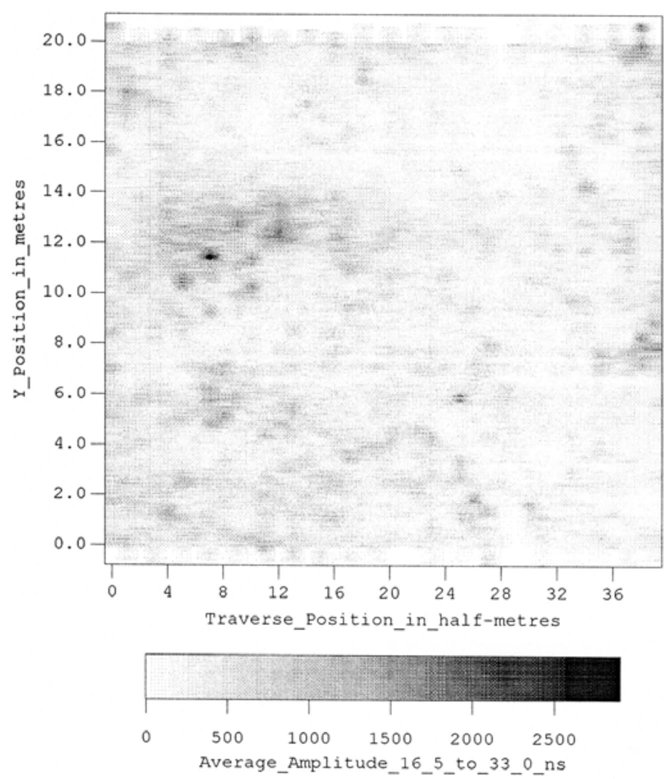

Figure 46. Time-slice (16.5–33 ns) map of the 20-m grid unit at Site 14MH323; north is at the top of the image.

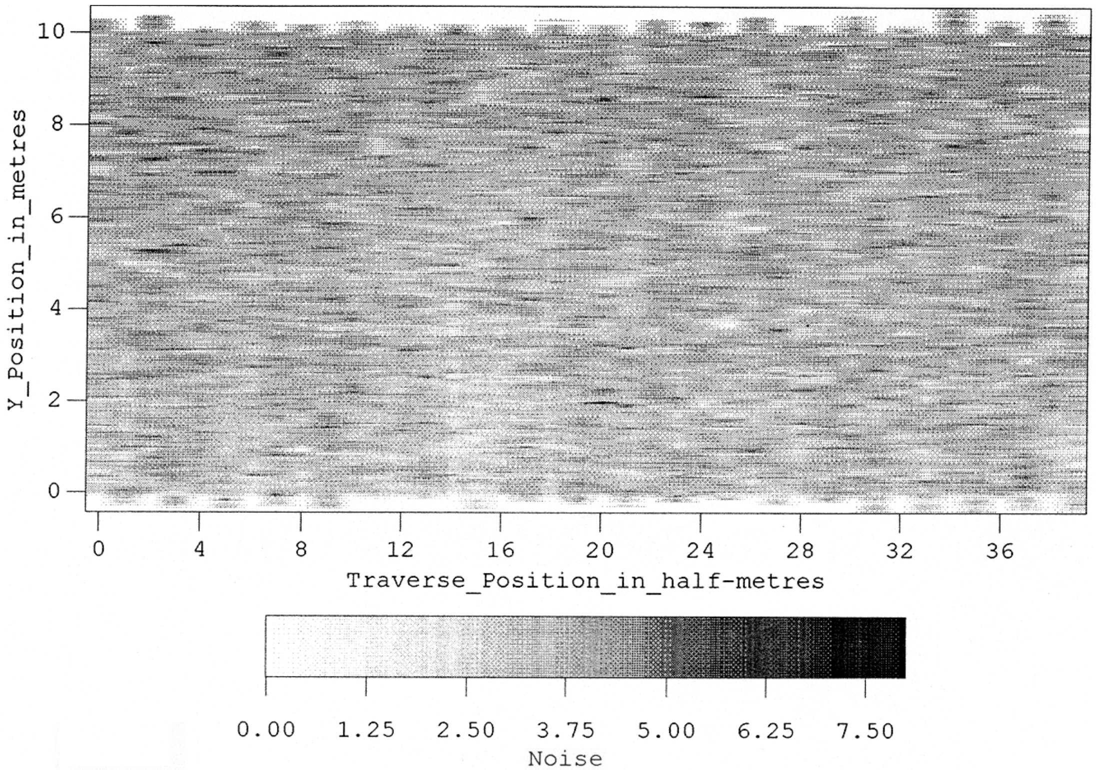

Figure 47. Map of GPR signal noise at Site 14MH322.

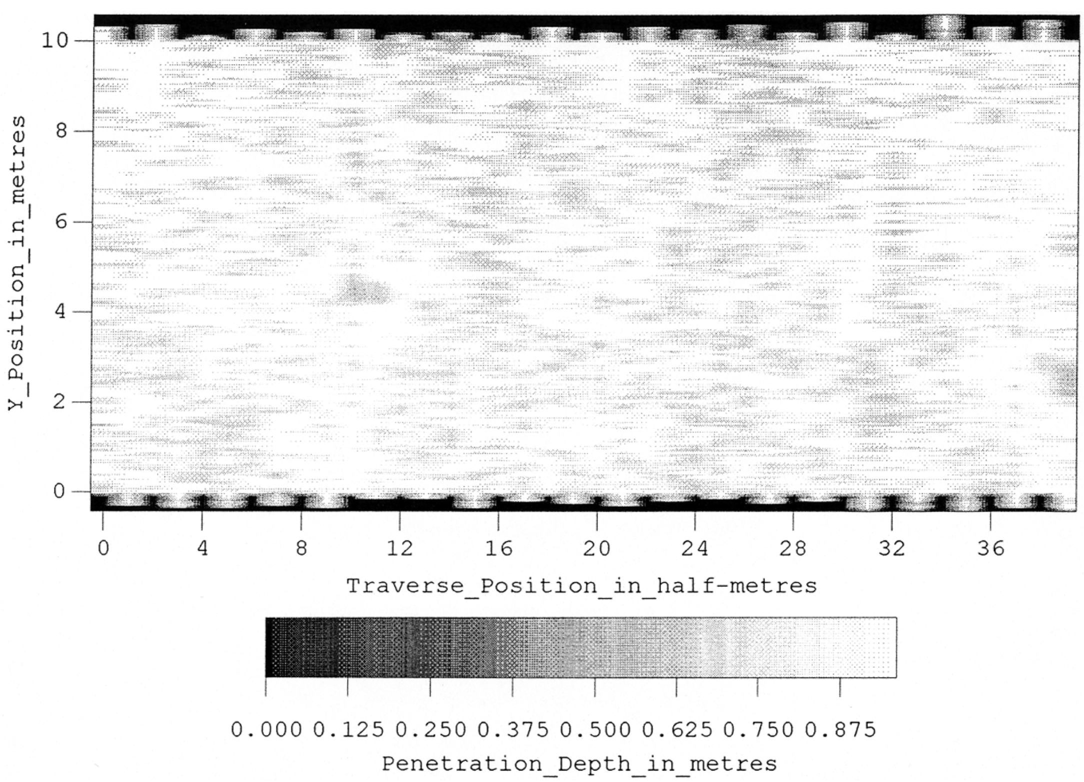

Figure 48. Map of GPR signal penetration at Site 14MH322.

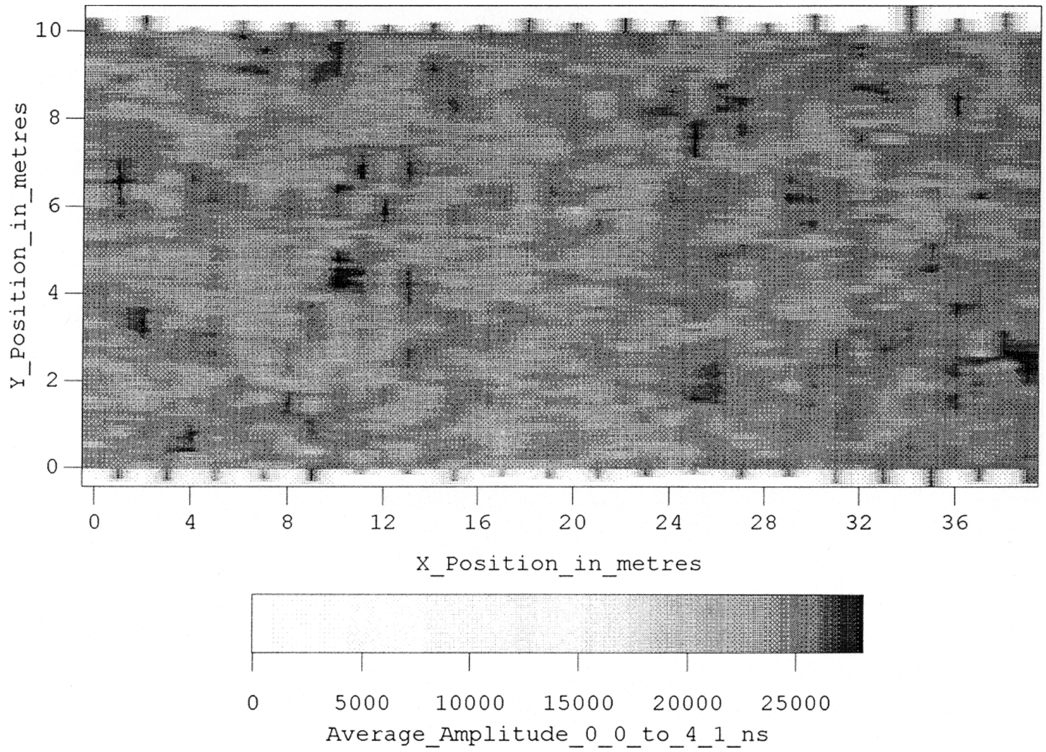

Figure 49. Time-slice (0–4.1 ns) map of the 10-m by 20-m grid area at Site 14MH322; north is at the top of the image.

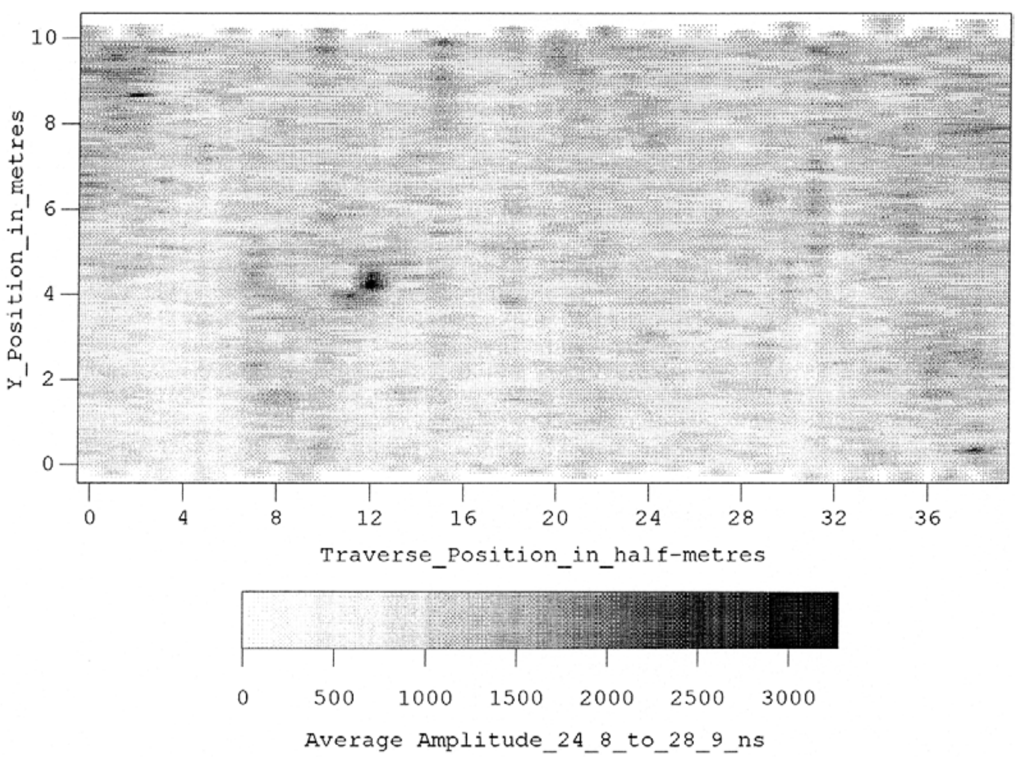

Figure 50. Time-slice (24.8–28.9 ns) map of the 10-m by 10-m grid area at Site 14MH322; north is at the top of the image.

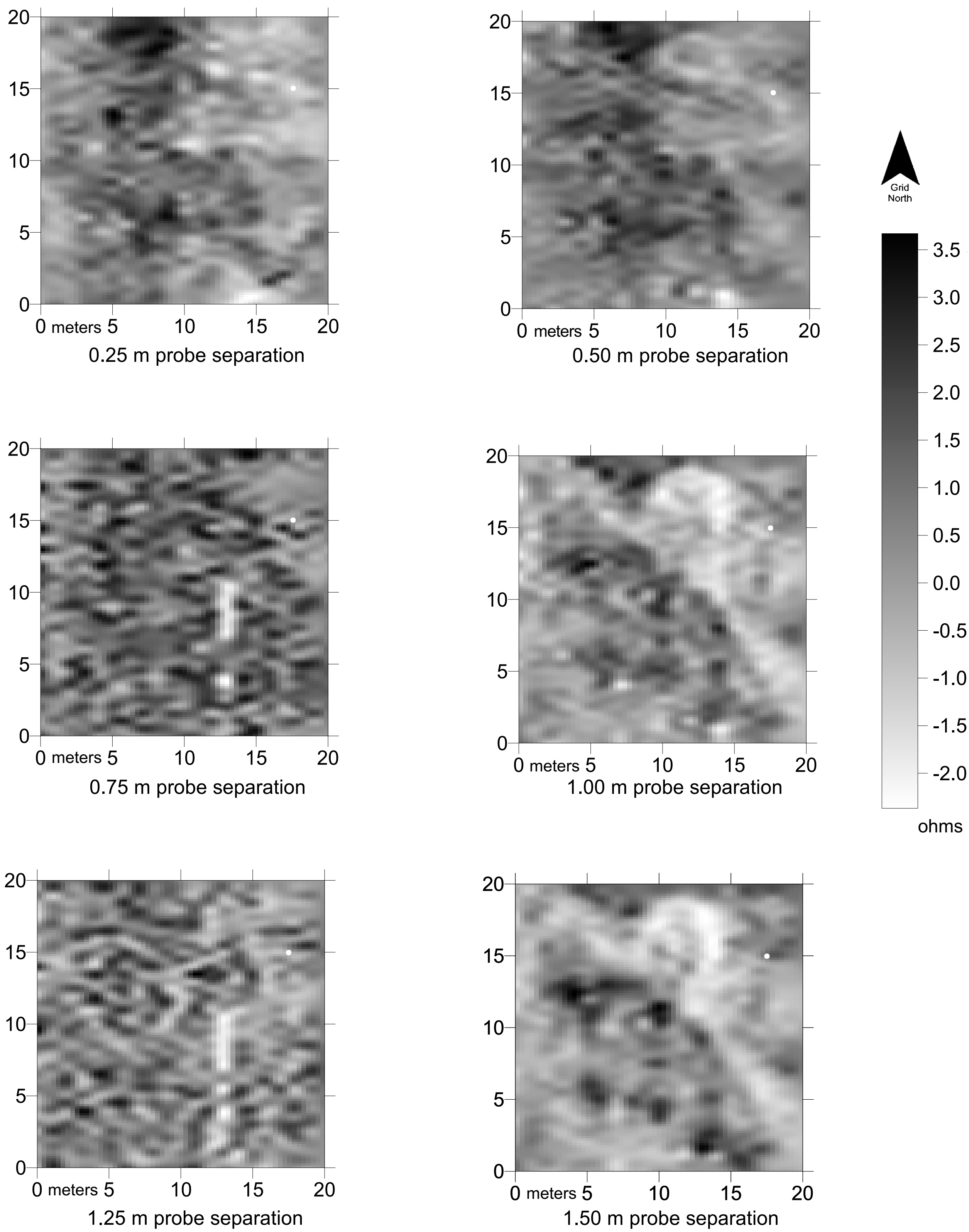

Figure 51. Image map of multiplexed soil resistance data from Site 14MH323. Axes are scaled in meters; the white dot represents marked gravestone.

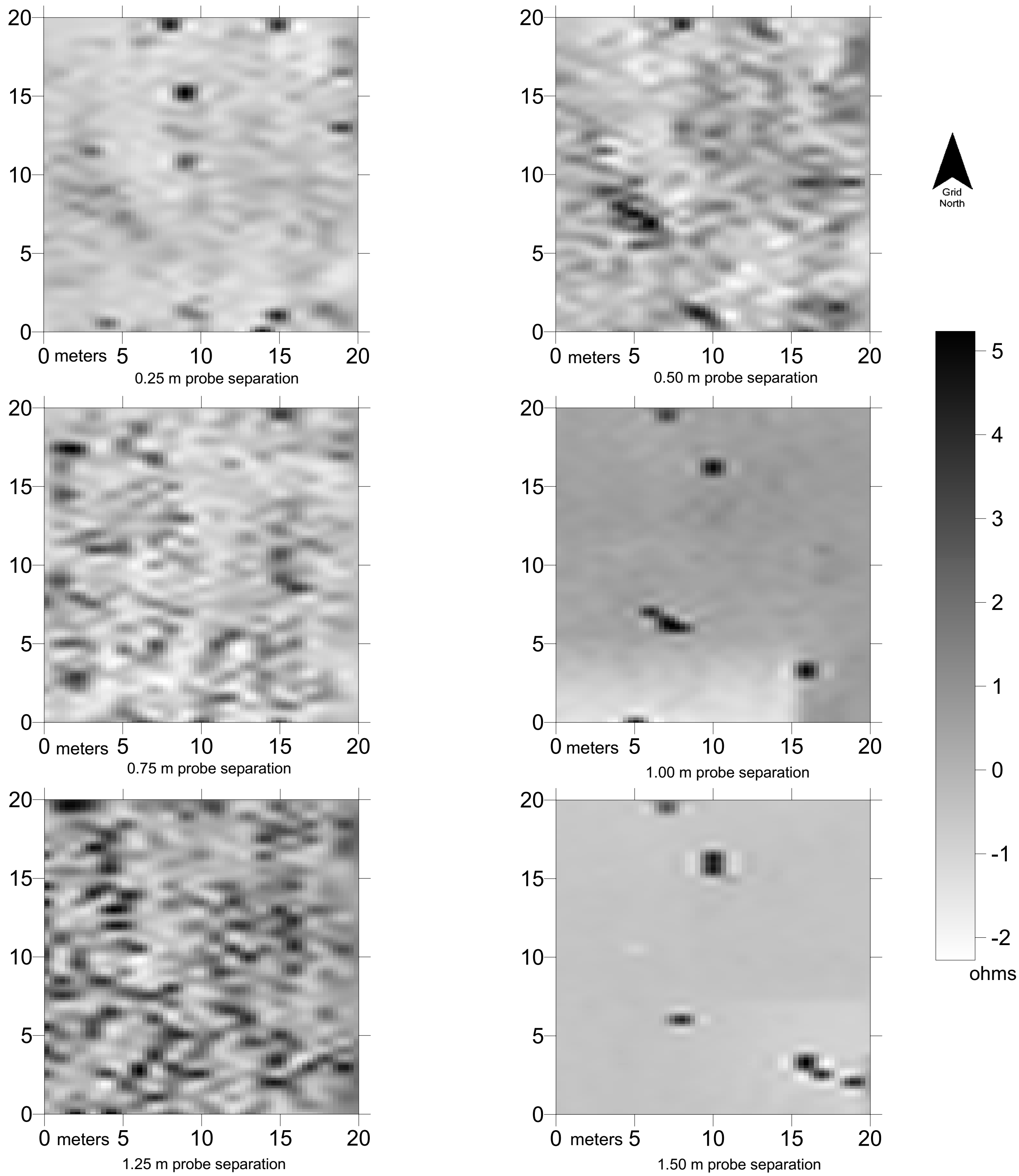

Figure 52. Image map of multiplexed soil resistance data from Site 14PO312, August 1, 2001. Axes are scaled in meters.

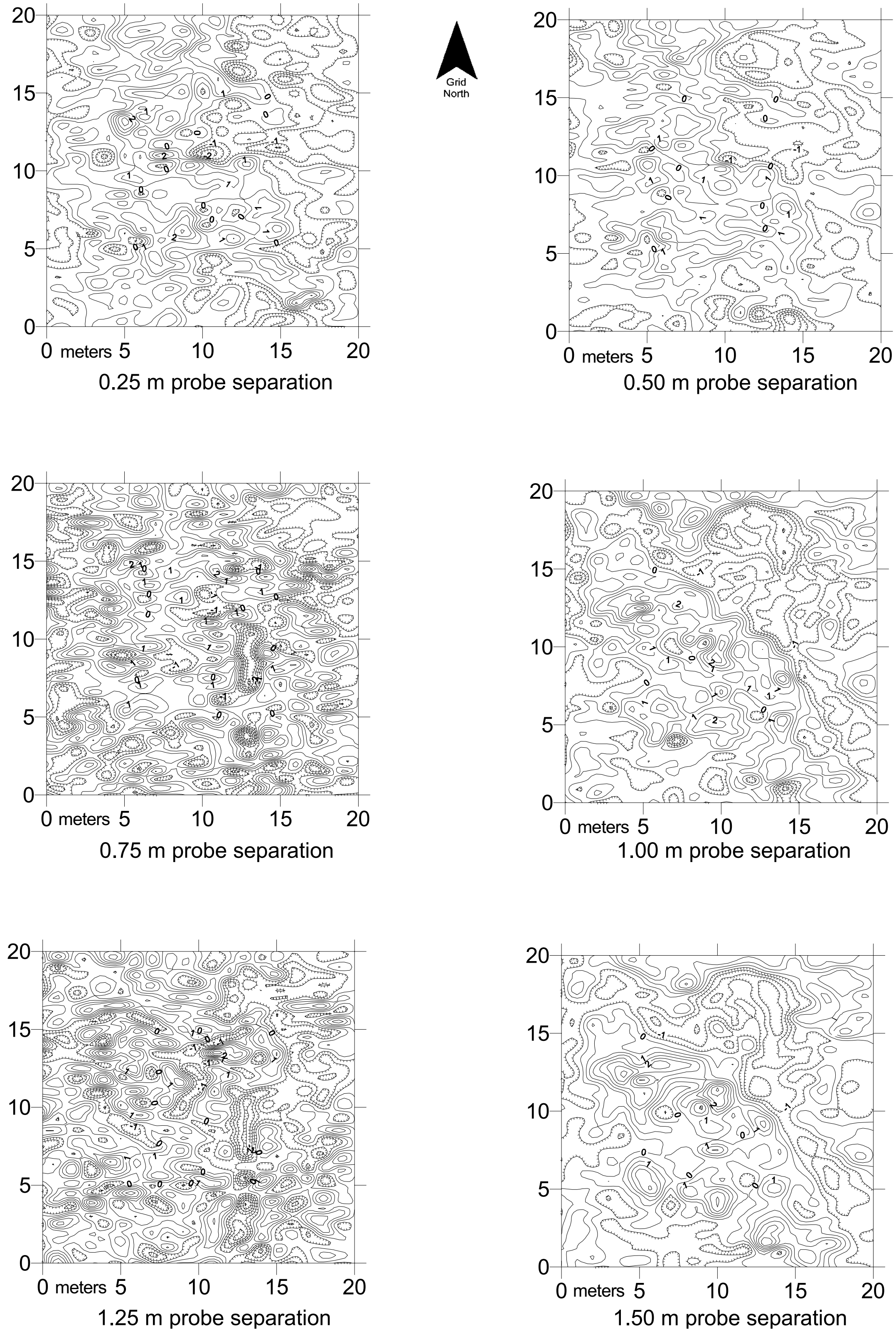

Figure 53. Contour map of multiplexed soil resistance data from Site 14MH323, November 15, 2000. Axes are scaled in meters; the contour interval is 0.5 ohms.

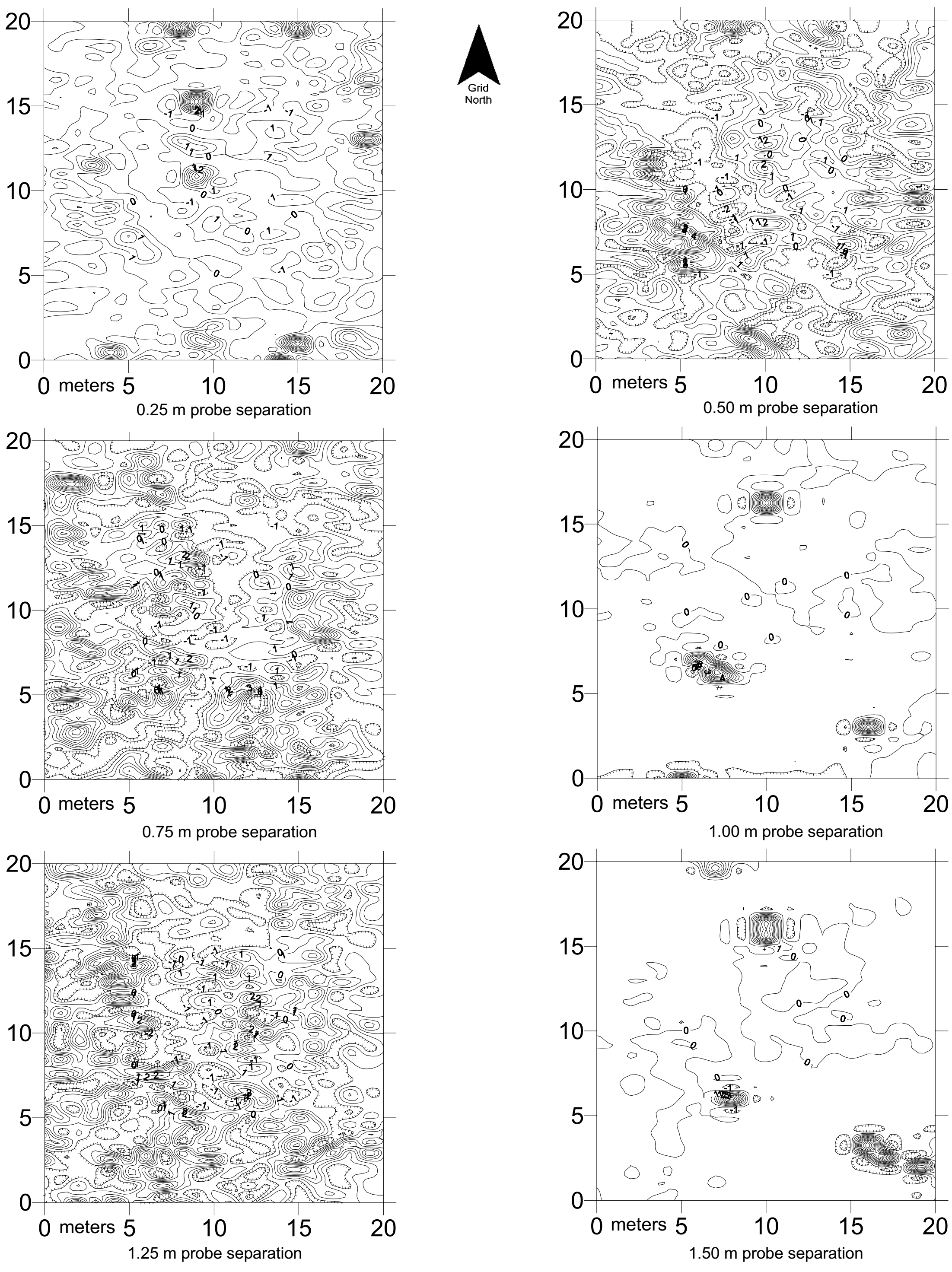

Figure 54. Contour map of multiplexed soil resistance data from Site 14PO312, August 1, 2001. Axes are scaled in meters; the contour interval is 0.5 ohms.

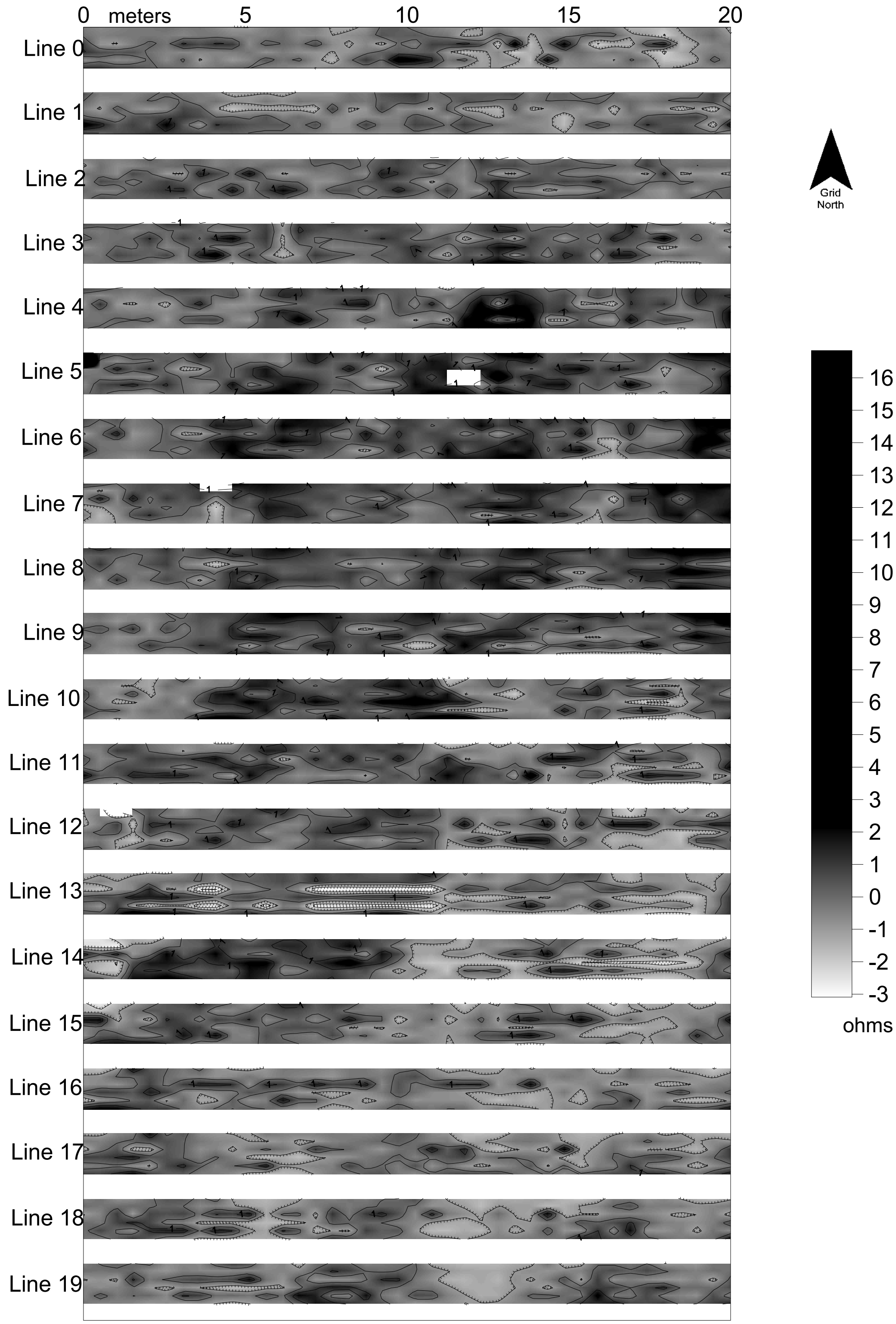

Figure 55. Soil resistance pseudo-sections from Site 14MH323, November 15, 2000; PA5 multiprobe array configuration: 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50 m. The horizontal (E-W) axis is scaled in meters; traverse lines begin in lower left corner of grid.

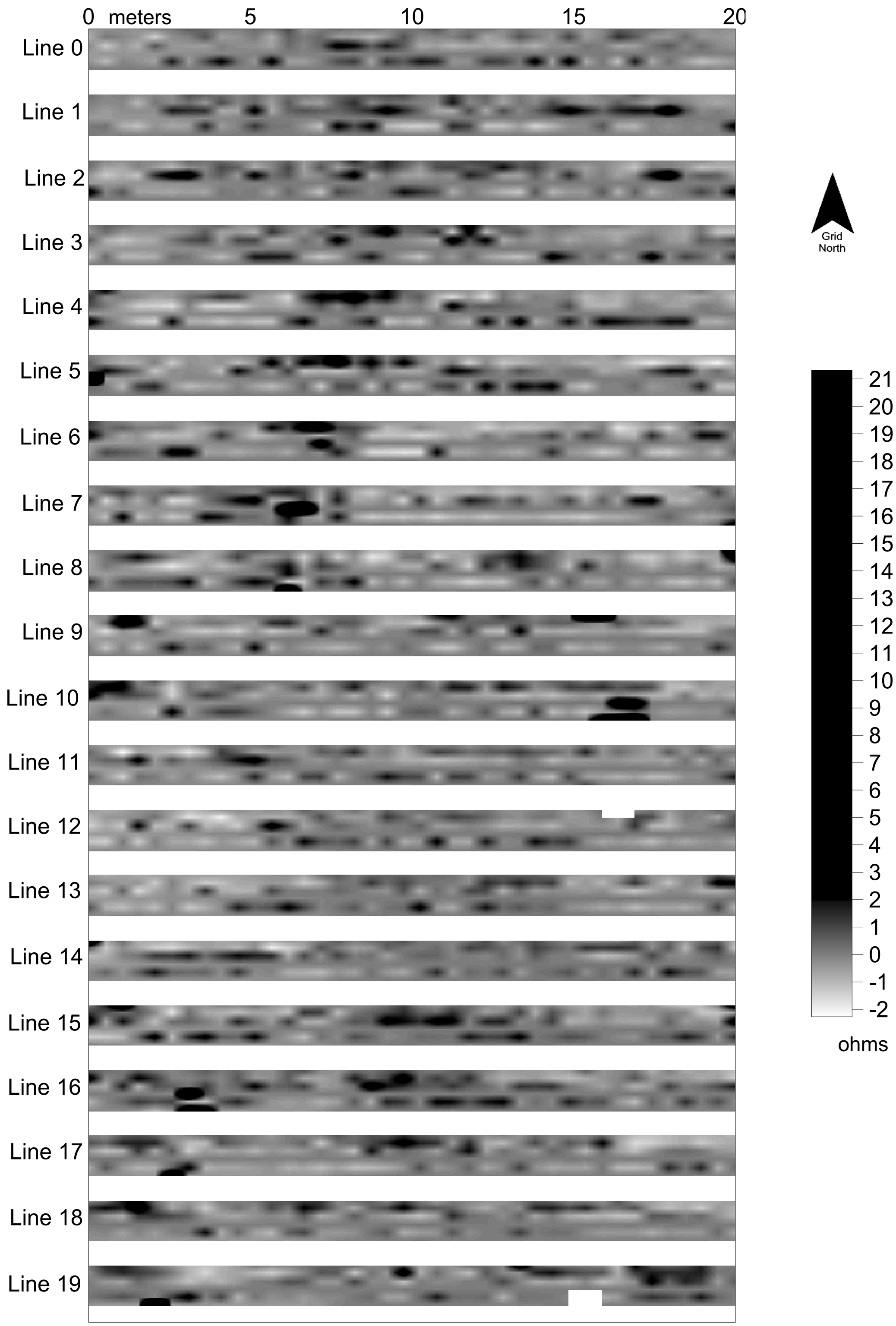

Figure 56. Soil resistance pseudo-sections from Site 14PO312, August 1, 2001; PA5 multiprobe array configuration: 0.25, 0.50, 0.75, 1.0, 1.25, and 1.50 m. The horizontal (E-W) axis is scaled in meters; traverse lines begin in lower left corner of grid.

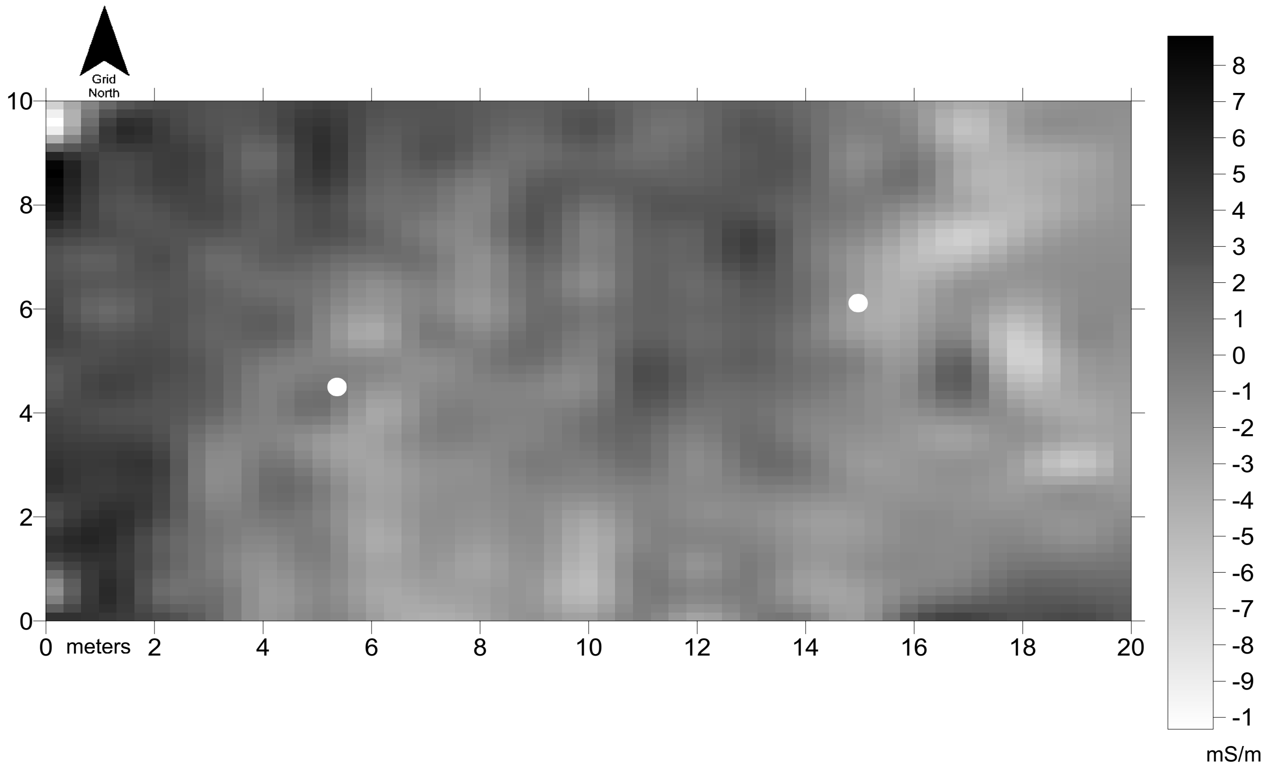

Figure 57. Image map of ground conductivity data from Site 14MH322, August 1, 2001. Axes are scaled in meters; white dots represent the locations of cairns.

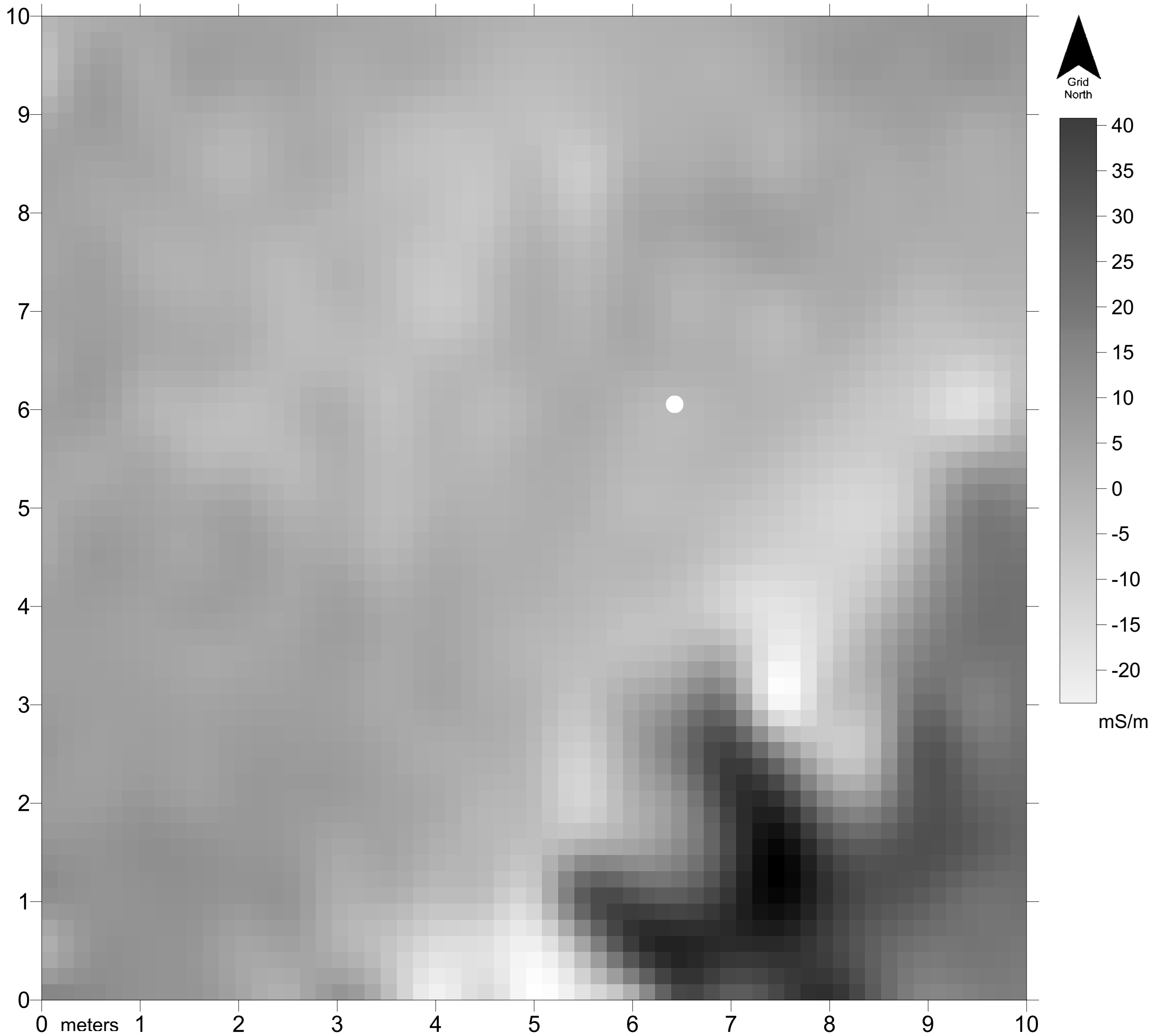

Figure 58. Image map of ground conductivity data from Site 14PO406, August 1, 2001. Axes are scaled in meters; the white dot represents location of upright stone.

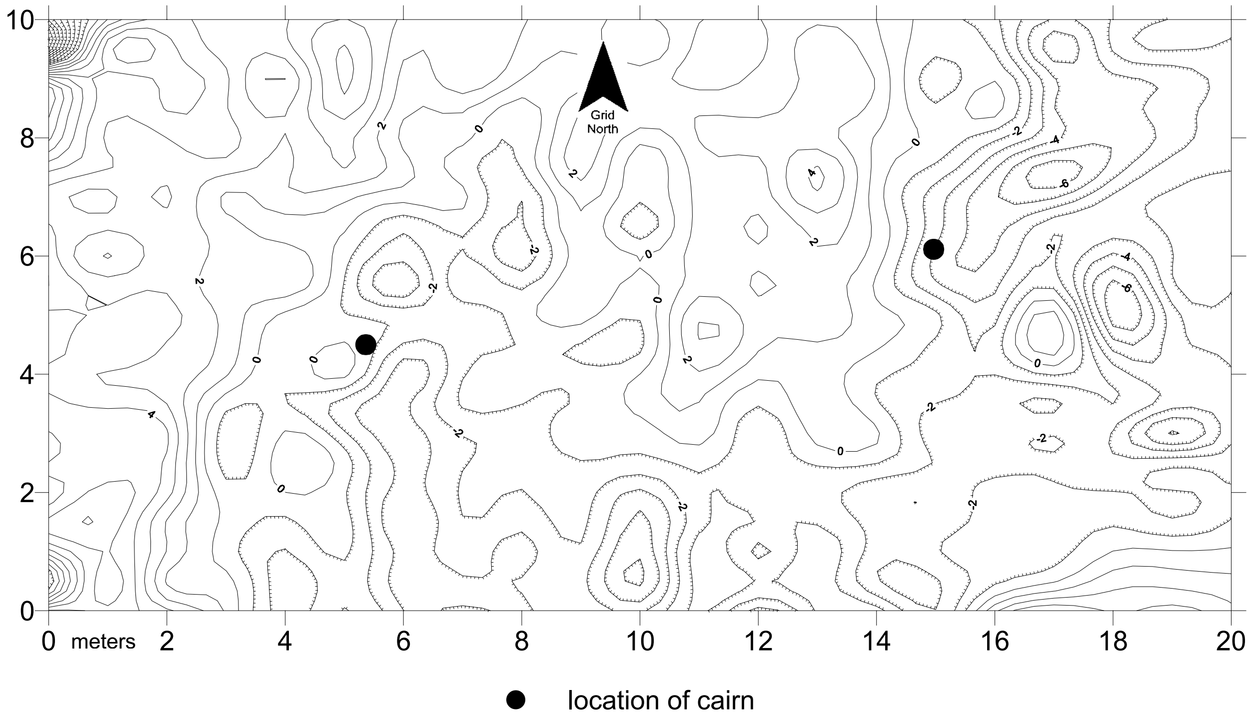

Figure 59. Contour map of ground conductivity data from Site 14MH322, August 1, 2001. Axes are scaled in meters; the contour interval is 1 mS/m; black dots represent the locations of cairns.

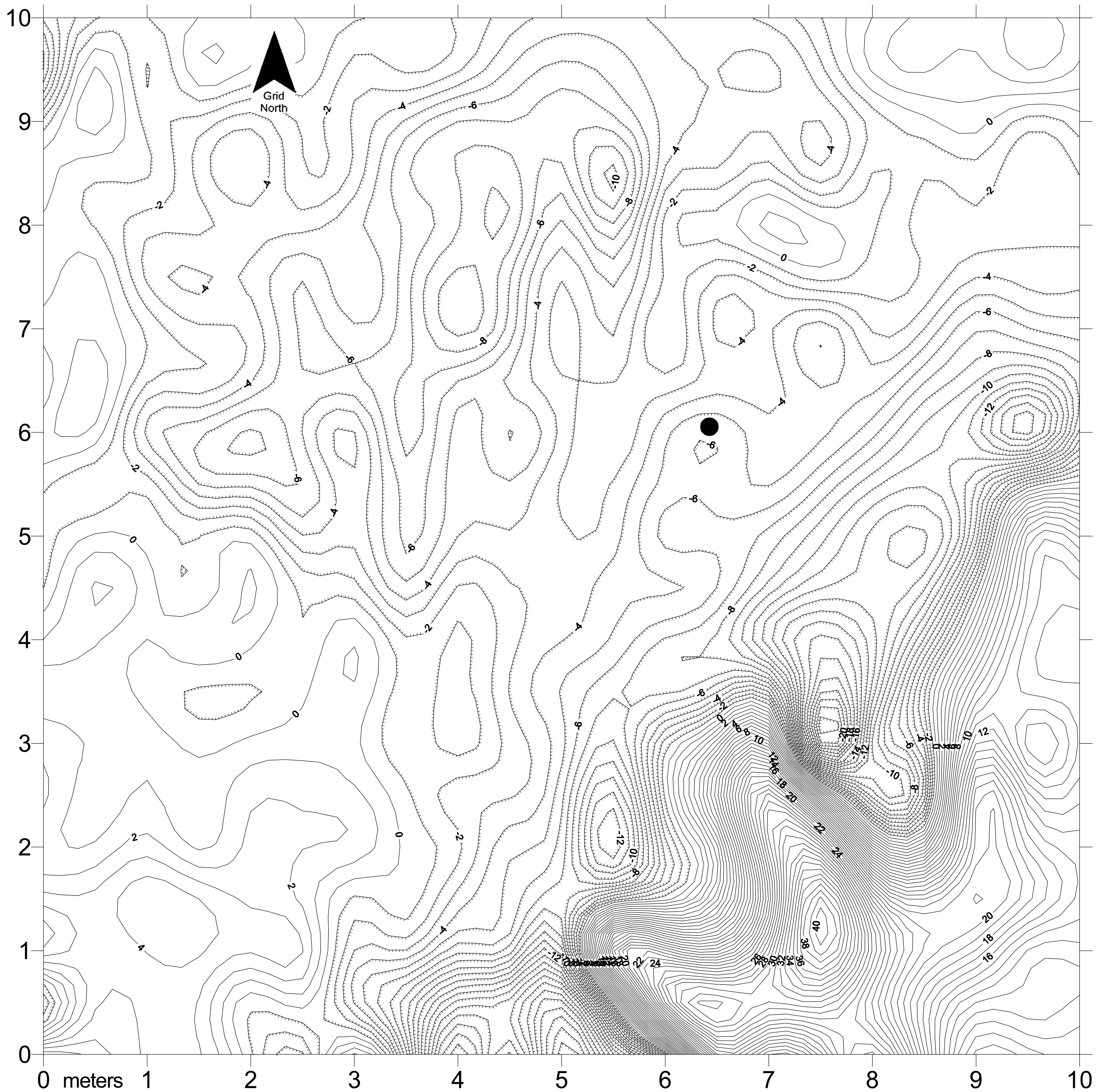

Figure 60. Contour map of ground conductivity data from Site 14PO406, August 1, 2001. Axes are scaled in meters; the contour interval is 1 mS/m; the black dot represents the location of upright stone.

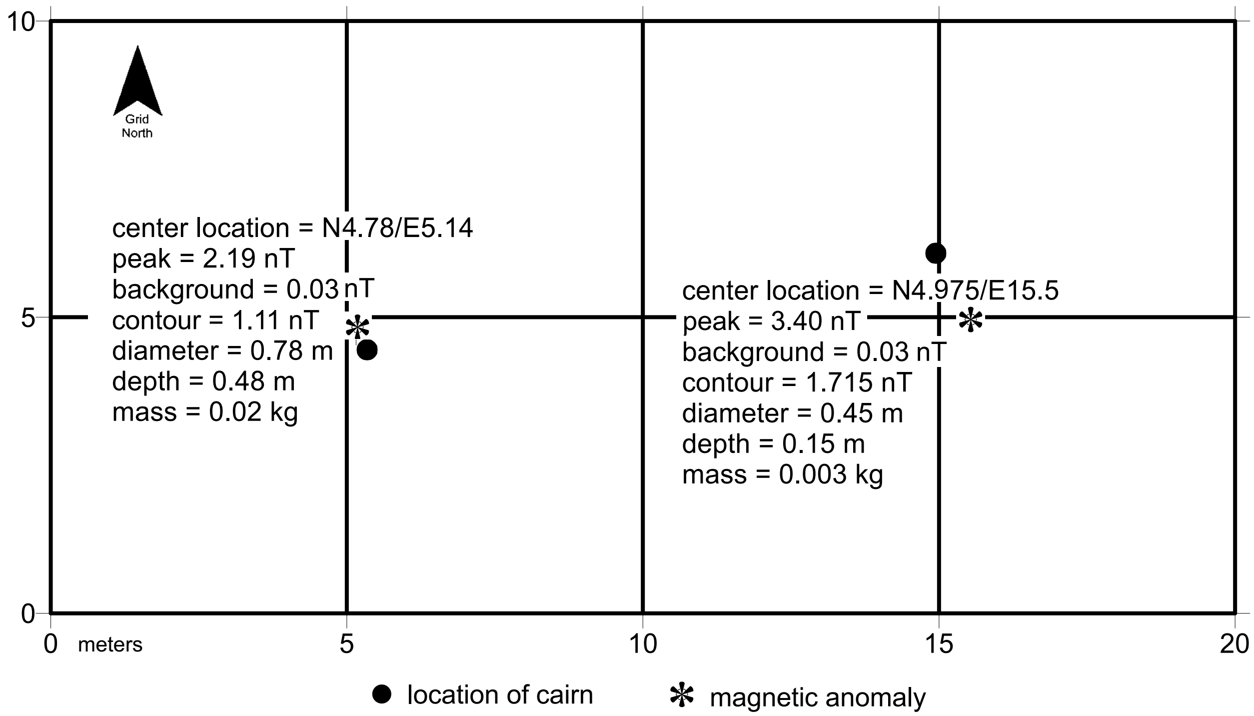

Figure 61. Magnetic gradient survey interpretations at Site 14MH322, August 1, 2001. Axes are scaled in meters; asterisk symbols represent the locations of magnetic anomalies; black dots represent the locations of cairns.

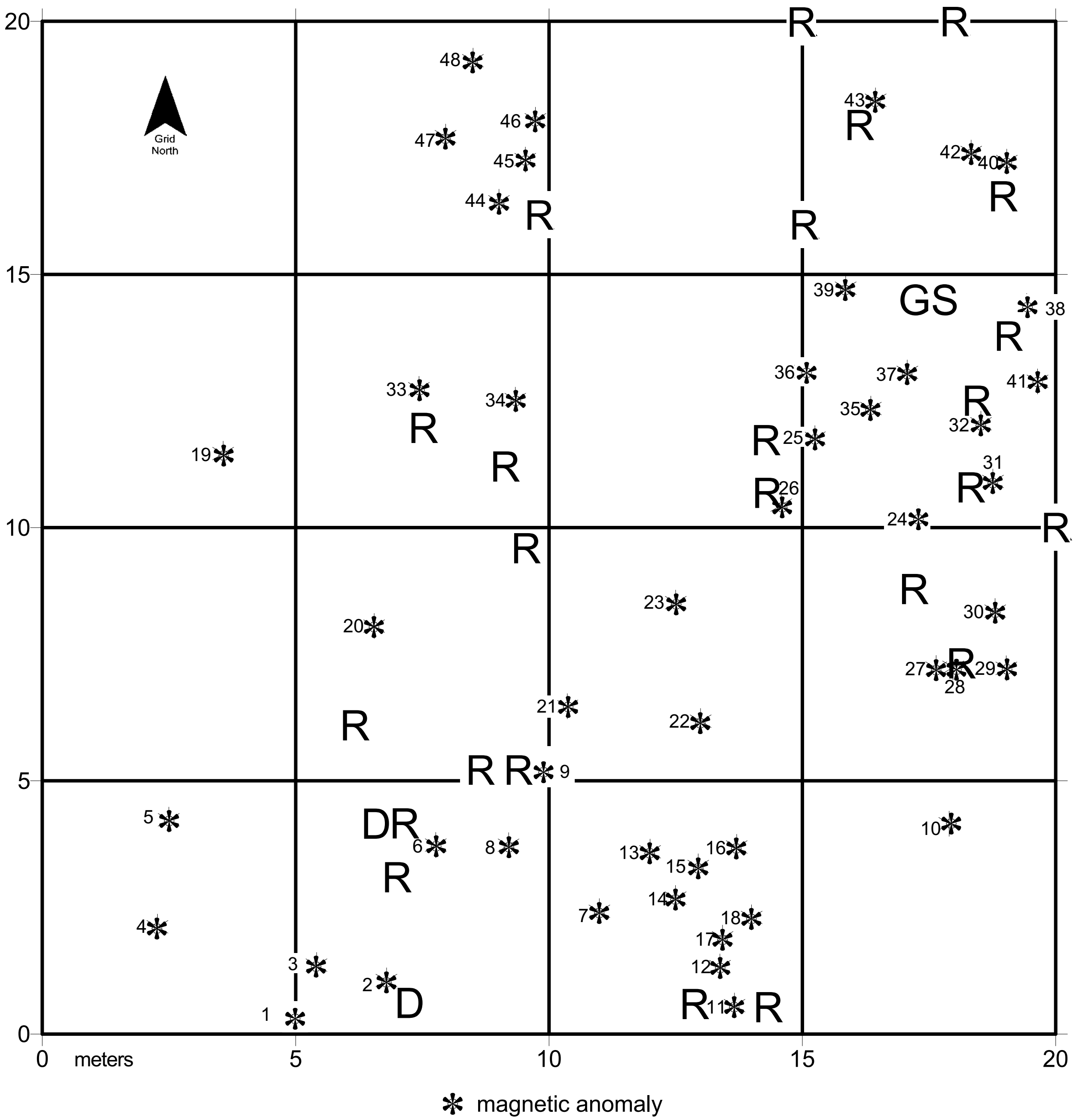

Figure 62. Magnetic gradient survey interpretations at Site 14MH323; August 1, 2001. Axes are scaled in meters; D = depression; R = rock; GS = gravestone; asterisk symbols represent magnetic anomalies.

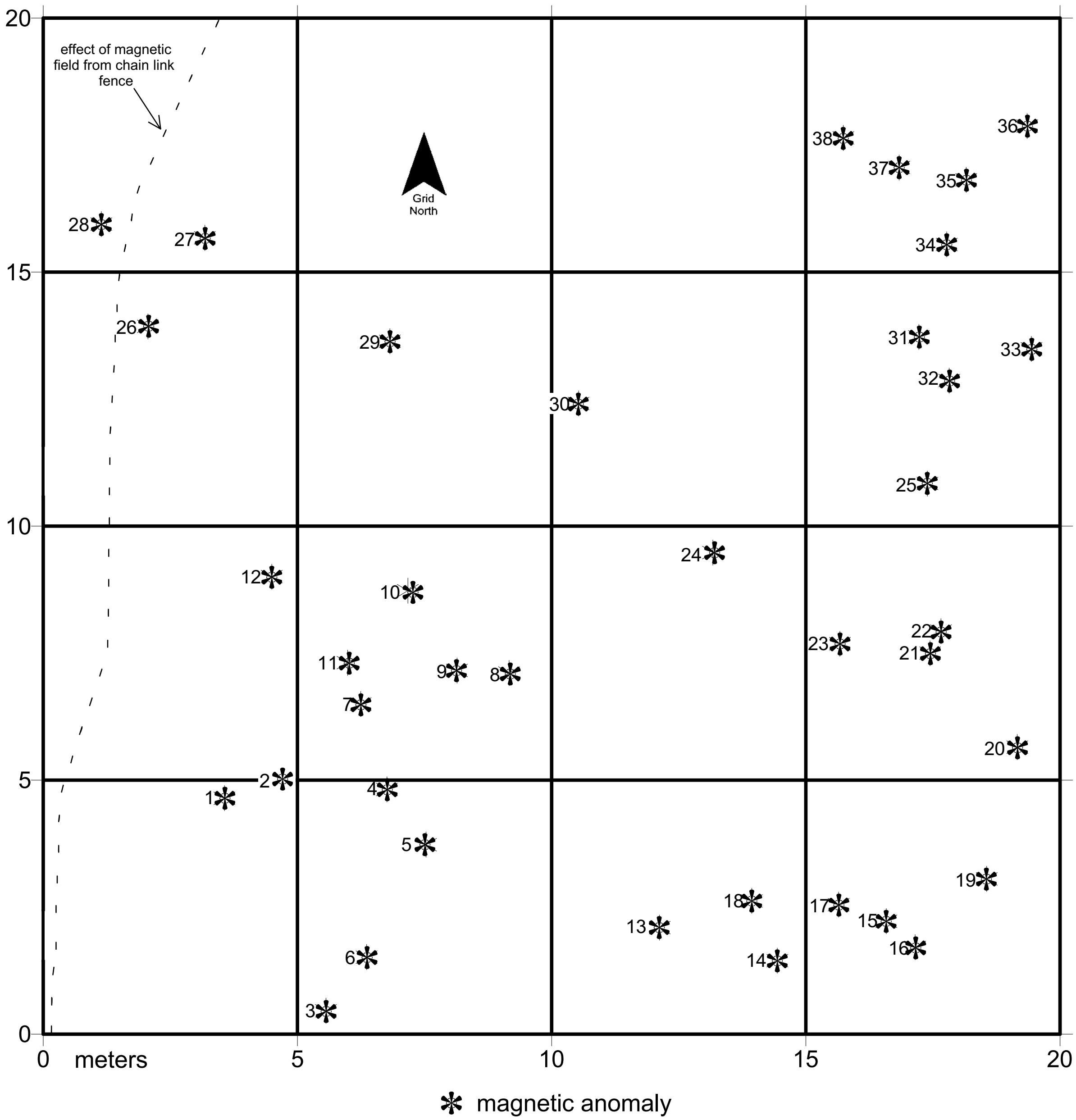

Figure 63. Magnetic gradient survey interpretations at Site 14PO312, November 14, 2000. Axes are scaled in meters; asterisk symbols represent magnetic anomalies.

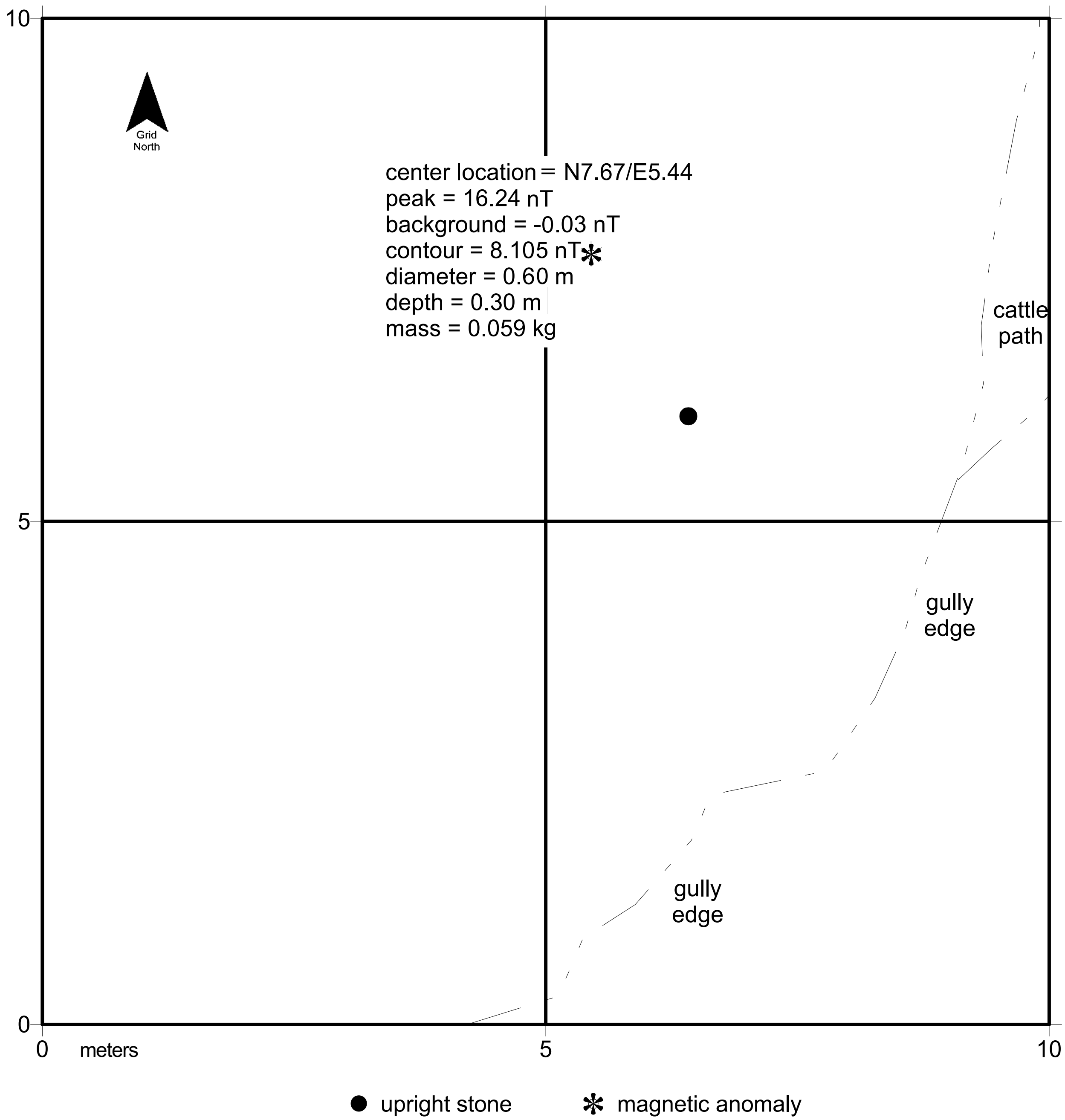

Figure 64. Magnetic gradient survey interpretations at Site 14PO406, November 14, 2000. Axes are scaled in meters; the black dot represents location of upright stone; asterisk symbol represents location of magnetic anomaly.

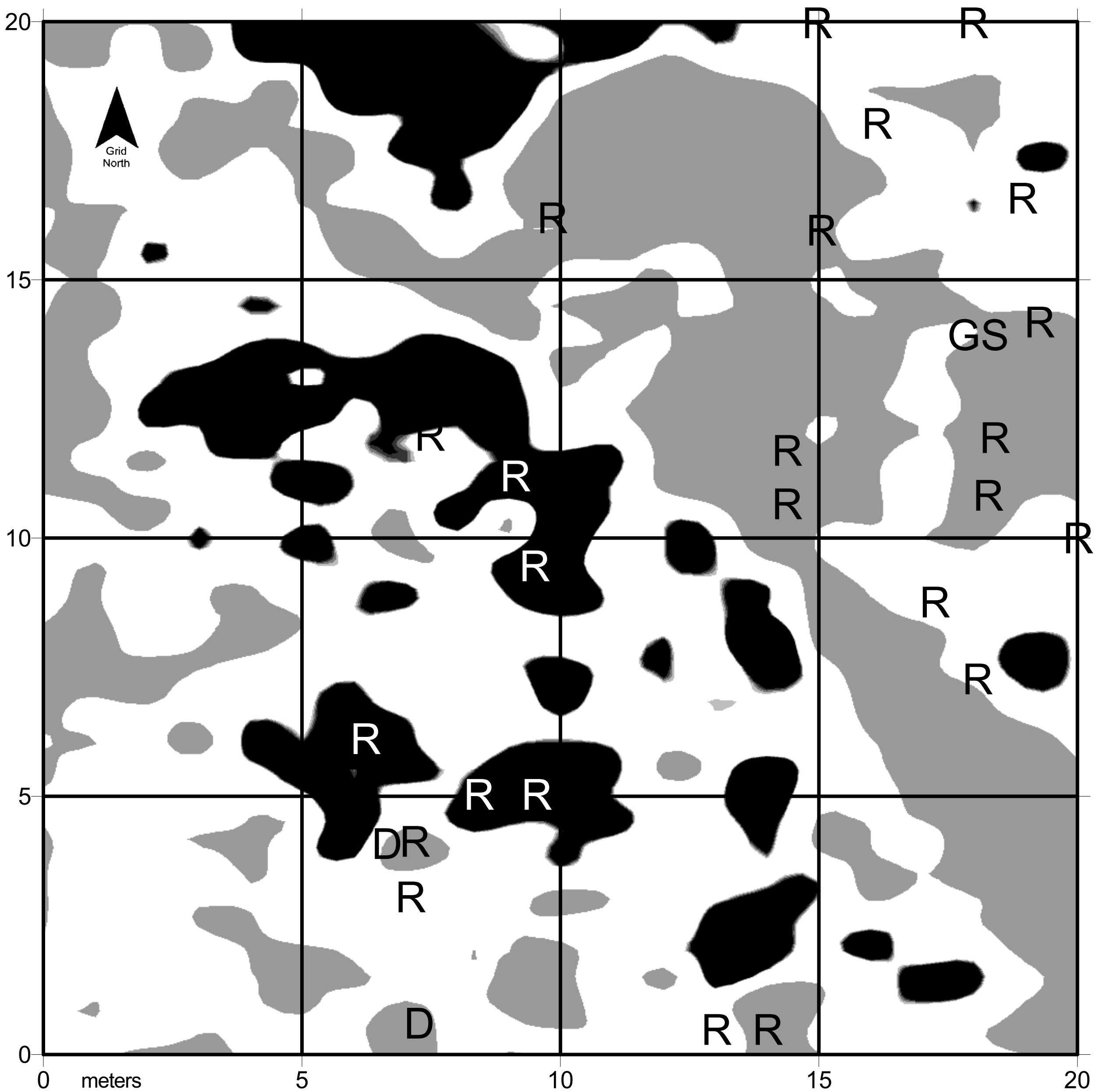

Figure 65. Soil resistance survey interpretations at Site14MH323, November 15, 2000. Axes are scaled in meters; darkest shading indicates high resistance areas, gray shading indicates low resistance areas; D = depression, R = rocks, GS = gravestone;.

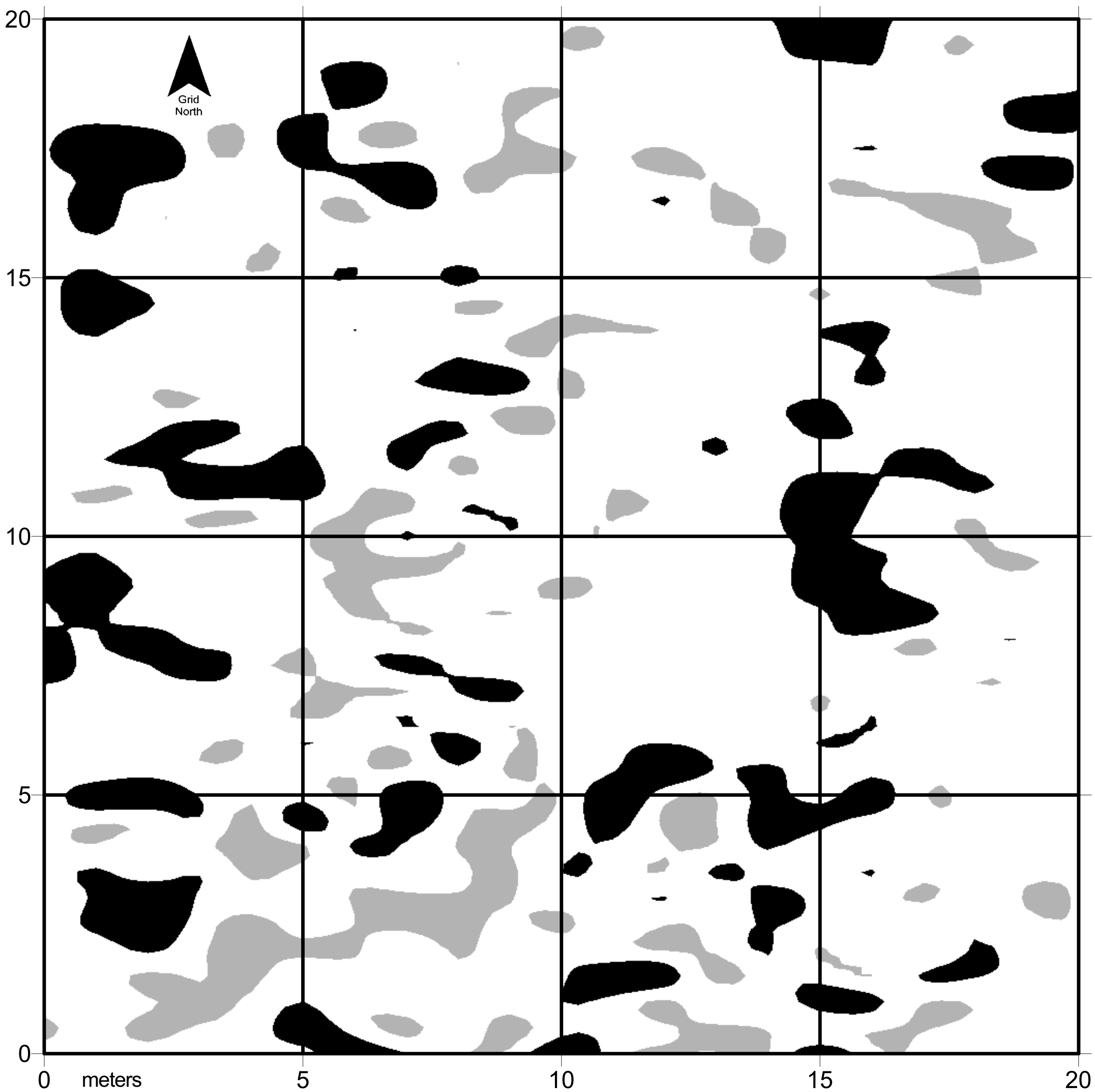

Figure 66. Soil resistance survey interpretations at Site 14PO312, August 1, 2001. Axes are scaled in meters; darkest shading indicates high resistance areas, gray shading indicates low resistance areas.

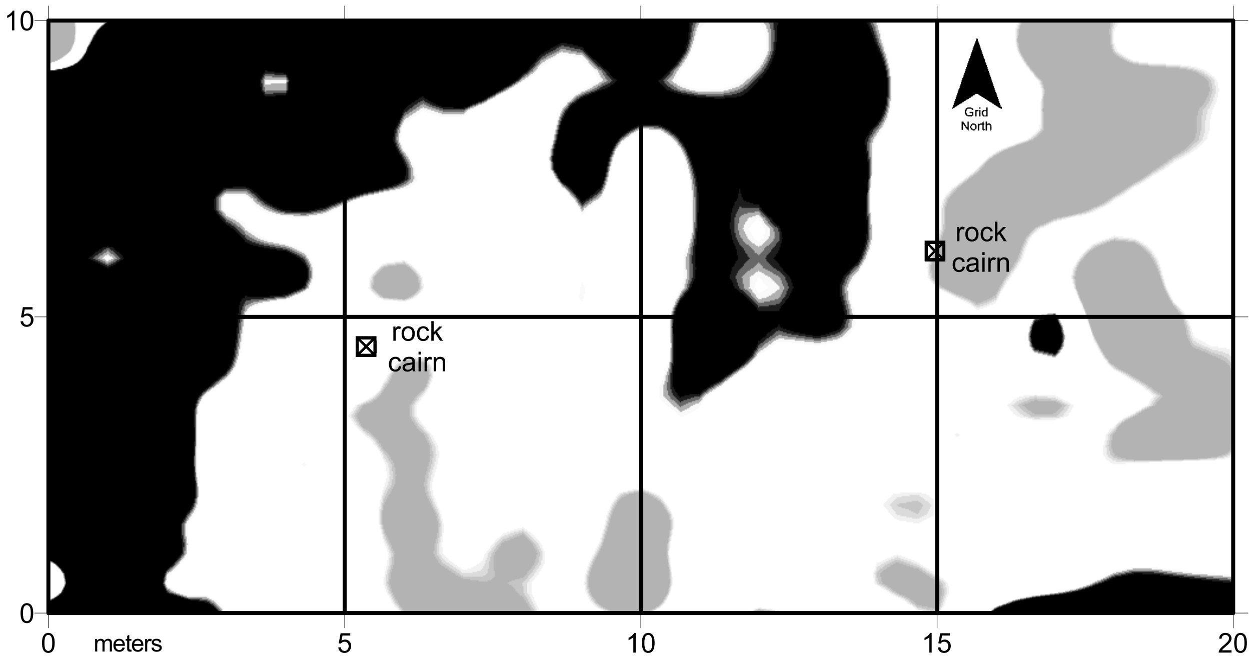

Figure 67. Ground conductivity survey interpretations at Site 14MH322, August 1, 2001. Axes are scaled in meters; darkest shading indicates high conductivity areas, gray shading indicates low conductivity areas.

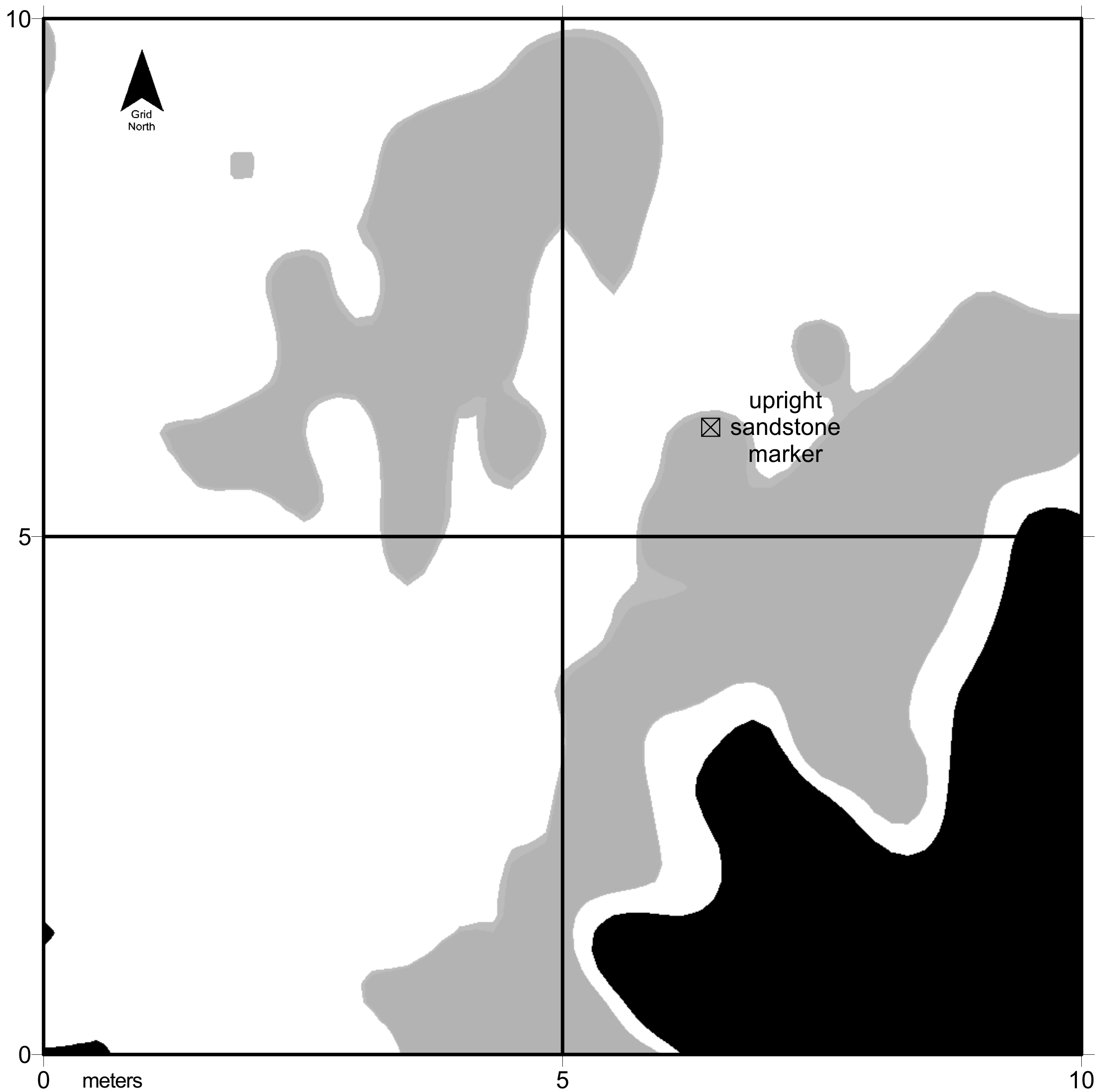

Figure 68. Ground conductivity survey interpretations at Site 14PO406, August 1, 2001. Axes are scaled in meters; darkest shading indicates high conductivity areas, gray shading indicates low conductivity areas.

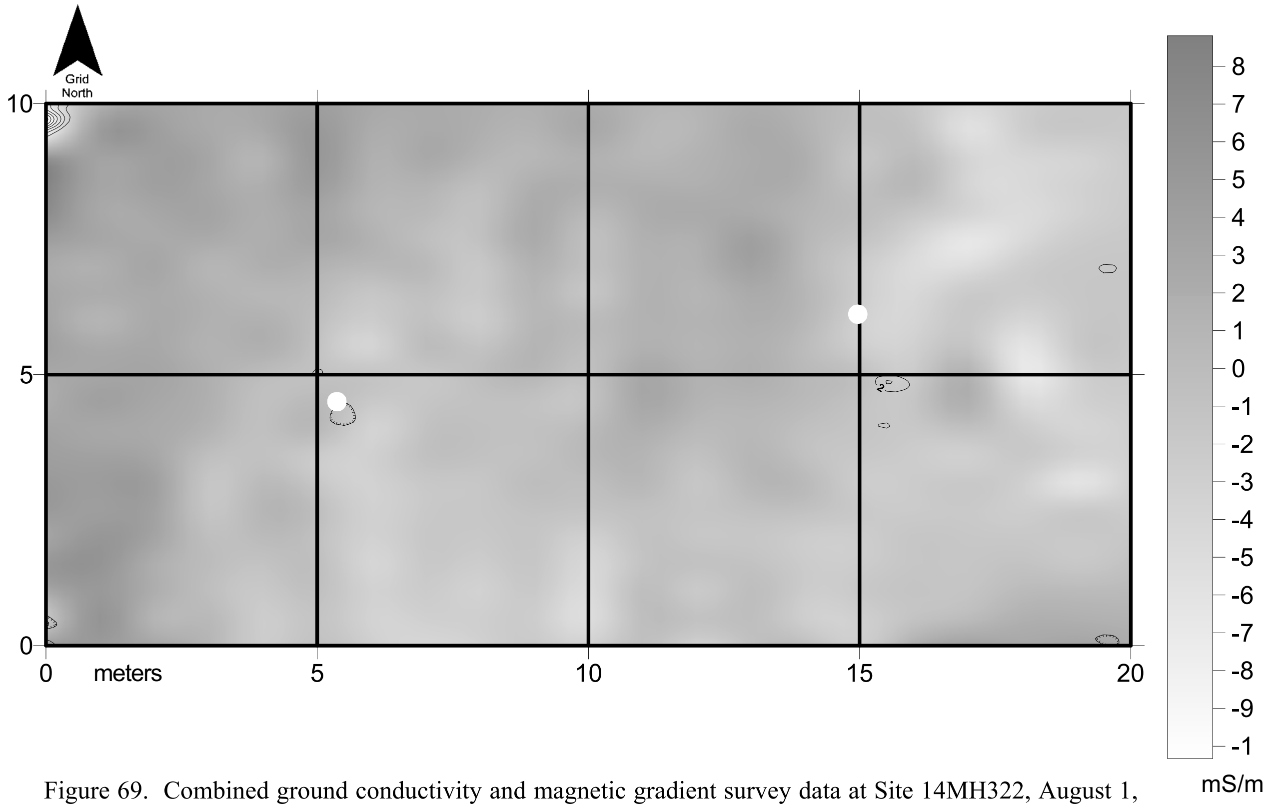

Figure 69. Combined ground conductivity and magnetic gradient survey data at Site 14MH322, August 1, 2001. Axes are scaled in meters; the magnetic gradient contour interval is 1 nT; white dots represent the locations of cairns.

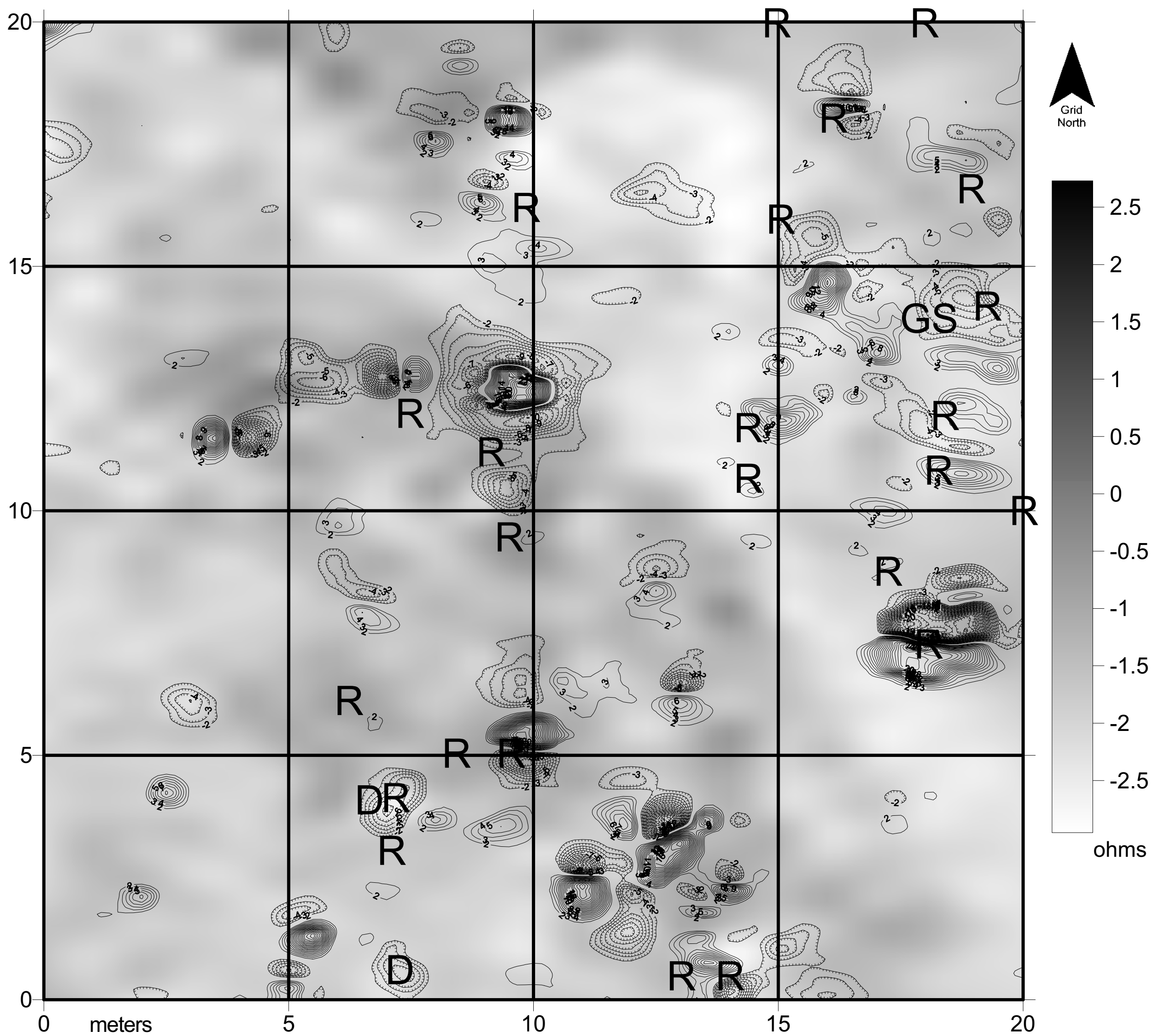

Figure 70. Combined soil resistance and magnetic gradient survey data at Site 14MH323, November 15, 2000, and August 1, 2001. Axes are scaled in meters; resistance probe sepration is 1.00 m; the magnetic gradient contour interval is 1 nT; D = depression; R = rocks; GS = gravestone.

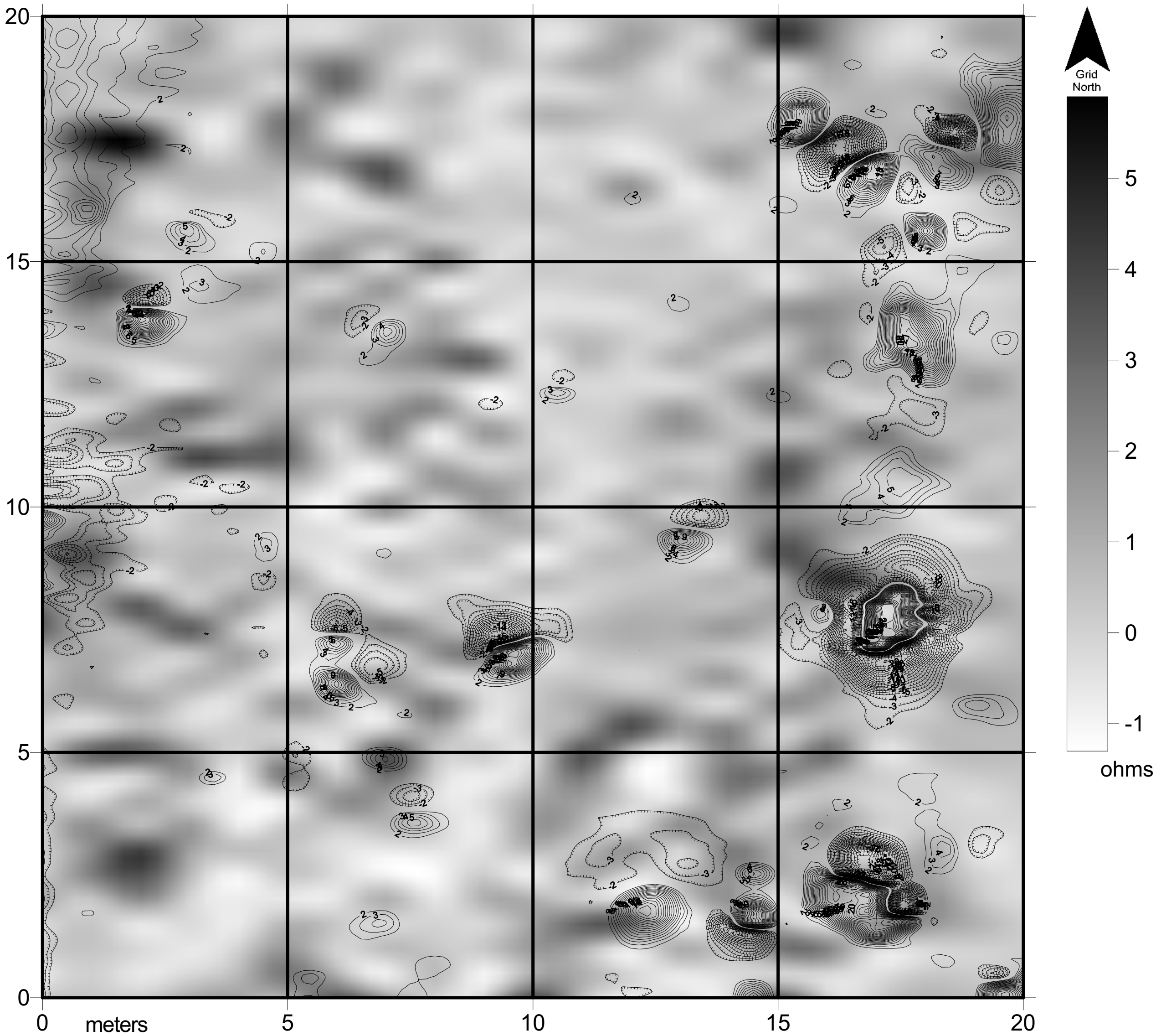

Figure 71. Combined soil resistance and magnetic gradient survey data at Site 14PO312, November 14, 2000, and August 1, 2001. Axes are scaled in meters; resistance probe sepration is 0.75 m; the magnetic gradient contour interval is 1 nT.

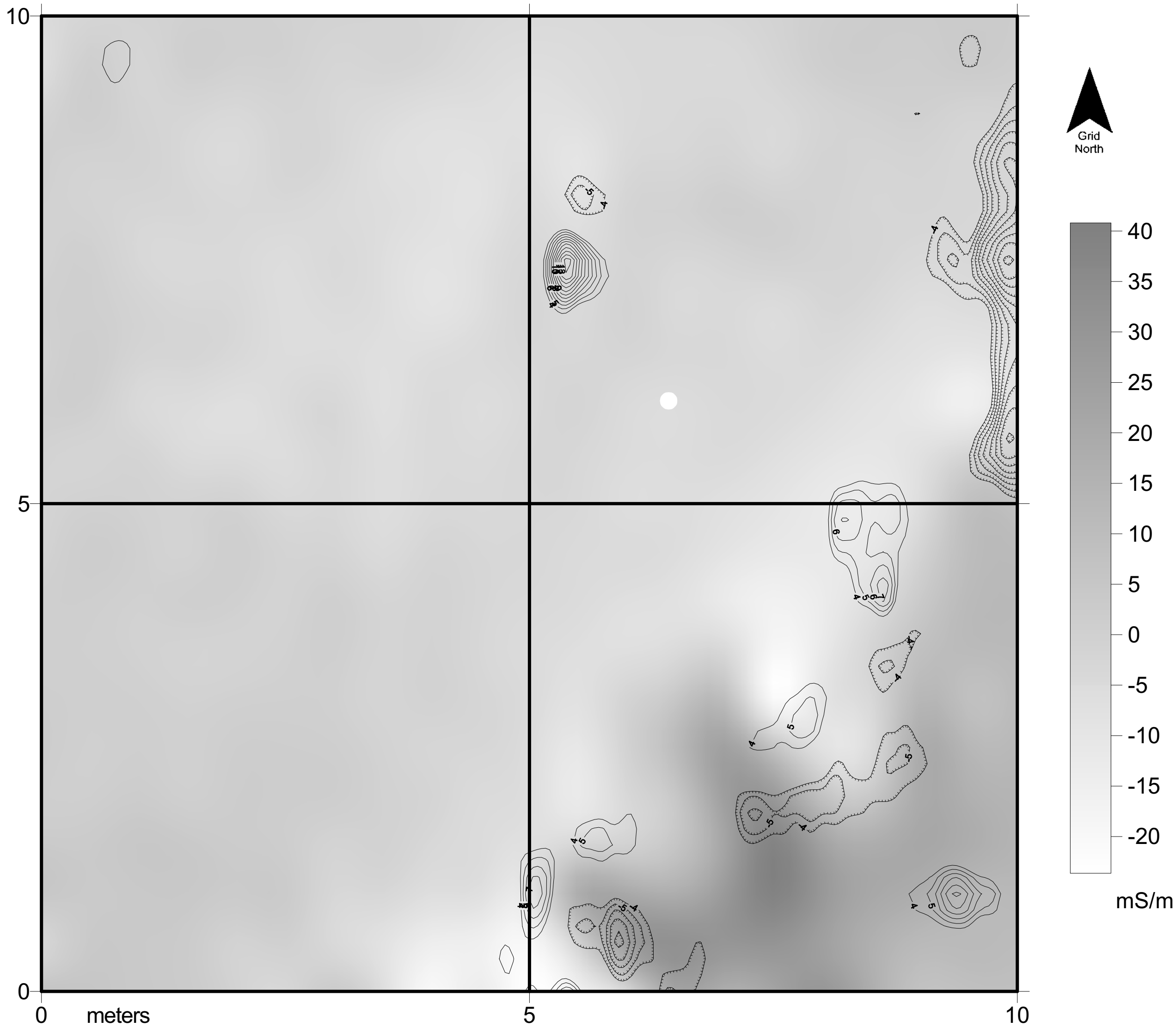

Figure 72. Combined ground conductivity and magnetic gradient survey data at Site 14PO406, November 14, 2000, and August 1, 2001. Axes are scaled in meters; the white dot represents the location of upright stone; the magnetic gradient contour interval is 1 nT.