Detecting Remnants of the Past: Archaeo-Geophysical Prospection of Fremont Sites in Southern Utah Valley

Jacob P. Jepsen
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Detecting Remnants of the Past: Archaeo-Geophysical Prospection

of Fremont Sites in Southern Utah Valley

Jacob P. Jepsen

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Arts

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ABSTRACT

Detecting Remnants of the Past: Archaeo-Geophysical Prospection of Fremont Sites in Southern Utah Valley

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Master of Arts

The variable contexts of Fremont habitation sites in Utah Valley often make the identification of those sites very challenging for archaeologists. Pit houses and other structures throughout the valley are frequently in plowed fields or other disturbed contexts that obscure their more exact location and nature. The application of geophysical technologies at archaeological sites throughout the world, including in North America, has proven to be an effective means of subsurface archaeological survey. However, geophysical techniques have been underutilized in Fremont archaeology. This paper reports on the employment of two geophysical methods, ground-penetrating radar (GPR) and fluxgate gradiometer surveys, at three known Fremont habitation sites in southern Utah Valley – the Wolf Village, Wolf Mound, and Snow Farm sites. The preliminary geophysical surveys and later ground-truthing of various geophysical anomalies reveals the effectiveness of these methods in identifying where architectural or other cultural features exist below the surface.

Keywords: Native Americans, Utah, Fremont, geophysical survey, ground-penetrating radar, magnetometry
ACKNOWLEDGEMENTS

I have been fortunate to have the support of many incredible people during my graduate school years, but I am most grateful to my wife, Bryanna, for her unconditional love and support. I would have never been able to finish graduate school, or this thesis without her continual encouragement to pursue my dreams despite what the cost may be. I am also grateful for my parents, Paul and Kimberly, who have always believed in me, and supported my dreams from day one. I am so grateful for all they sacrificed to provide me with an education. Little did they know that my passion for history and digging holes in the backyard would lead to a career in archaeology. I would also like to thank my sister Heather for always having my back and cheering me on through life. In addition, I am grateful for my in-laws, Richard and Jill for their outstanding example, and their unwavering love and support during my academic career.

I am especially grateful to my thesis committee for their patience and guidance. This project would not have been possible without their support. Scott Ure deserves particular acknowledgment for taking me under his wing these last few years and teaching me all he knows about archaeology, technology, and remote sensing. This thesis would not have been possible without his help, guidance, and friendship. I am grateful for my committee chair, Dr. Michael T. Searcy for his enthusiasm and energy in supporting my ideas, advising my research, and providing me with the resources and knowledge to become a better person. I am grateful for Dr. James Allison for cultivating my curiosity in archaeology, and teaching me how to conduct fieldwork, perform analysis, and think critically to answer archaeological questions. I would also like to thank Dr. John McBride for going out of his way to teach me about geophysics and ground-penetrating radar. His patience and guidance when collecting data in the field, and later processing that data was immensely helpful.

There are also many people who helped me complete my thesis in a variety of ways. I am thankful to Dr. Marion Forest for her valuable advice and guidance with my thesis proposal and
defense. I am especially thankful to Paul Stavast, director of the Museum of Peoples and Cultures, for always being willing to discuss my ideas, and provide sage advice whenever I needed it. I am also grateful for my fellow graduate students who were always there for support and comradery. I would particularly like to thank Ridge Anderson and Sam Jensen for their friendship, as well as their help in collecting geophysical data with me in the field. I could not have collected all the data I needed for my thesis without their help. Finally, I would like to thank the Department of Anthropology, BYU graduate studies, and the Grace Elizabeth Shallit Memorial Student Grant for generous funding to complete my research.
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1 Introduction

This thesis reports the results and interpretations of testing the effectiveness of two geophysical methods (ground-penetrating radar and magnetic gradiometry) at three southern Utah Valley Fremont sites: Wolf Village (42UT273), Wolf Mound (42UT2150), and Snow Farm (42UT2274). Both geophysical techniques yielded variable results, including the successful identification of buried archaeological anomalies that were ground-truthed using auger testing.

Defining the Problem

The prehistoric inhabitants of the eastern Great Basin and northern Colorado Plateau from AD 400 to 1300 are referred to today as the Fremont. Their material culture is found in most of the modern state of Utah and parts northwest Colorado, and eastern Nevada (Figure 1.1). Although there is a great deal of information that archaeologists know about the Fremont over a century of investigation (D. Fowler 1986; Janetski 1997a; Madsen and Simms 1998; Talbot 2000b; Ure 2013), the ephemeral nature of many Fremont habitation sites in certain environmental contexts to allows for site identification to be extremely difficult for Fremont archaeologists today.

The Fremont left little evidence of their habitations across the region. Those that remain include structures now buried below the modern-day surface. The only indicators of these habitation sites are artifacts scattered across the site surface, which include, but are not limited
to, lithic debitage and ceramic sherds, groundstone, adobe fragments and chipped stone tools. Even if artifacts are found, subsurface testing is required to find and investigate these prehistoric habitation sites. Low-rise mounds are occasionally indicative of adobe architecture that once stood above ground, but these are not common at all Fremont sites and still difficult to identify.

Various geophysical survey methods implemented at archaeological sites throughout the world that have proven to be an effective means of subsurface archaeological survey. Although geophysical technologies are by no means new, they have been repeatedly applied to regions throughout Europe, and in various parts of the United States; however, very few geophysical prospection methods have been used to identify subsurface targets in the Fremont archaeological region.

Geophysical methods applied to archaeological problems are increasingly recognized as a valuable tool for characterizing subsurface cultural deposits prior to excavation (Johnson 2006). Archaeological geophysics encompasses an assortment of noninvasive methods for the analysis and delineation of subsurface archaeological deposits. Each geophysical survey method measures different geophysical properties of the earth’s subsurface. When used in combination, these survey methods can provide useful information on the nature of the remaining buried archaeological record (Watters 2015).

**Research Design**

Most Fremont sites are buried in various environmental contexts throughout the Fremont cultural region, but very little geophysical prospection has been used to identify subsurface targets. Following a literature review and standard guidelines regarding remote sensing techniques, I tested the effectiveness of two geophysical methods (ground-penetrating radar and magnetic gradiometry) at three Fremont sites in southern Utah Valley. The combination of ground-penetrating radar and magnetic gradiometry yielded variable results, but by ground-truthing the anomalies, I was able to identify buried archaeological remains using auger testing.
Figure 1.1. Map of the Fremont cultural area (Ure 2013:30).
Scope and Limitations

The scope of my thesis focuses on two geophysical methods. Although there are many geophysical methods that could be implemented in the Fremont cultural region (see Chapter 4 for more information about geophysical instruments), ground-penetrating radar and magnetic gradiometry were the only geophysical instruments known to work effectively in this high desert environmental context and were available to me at the time. Due to various restrictions related to the COVID-19 pandemic, I was required to modify my methods, research timeline, and the specific sites for this project.

My thesis includes geophysical data collected from three Fremont sites in the southern Utah Valley. These sites were chosen based upon their various environmental contexts, prior excavation agreements with landowners, and proximity to Brigham Young University due to COVID-19 travel restrictions. These sites represent only a small portion of Fremont sites in Utah Valley that would be conducive to geophysical surveys. Other suitable sites include Hinckley Mounds (42UT110 and 42UT111), Woodard Mound (42UT102), Jay’s Place (42UT120), and many others. There are also numerous Fremont sites elsewhere in the region that would benefit greatly from preliminary geophysical surveys. This thesis presents promising results, especially when combined, for GPR and magnetometry at Fremont sites in Utah Valley. Testing a multitude of geophysical prospection methods from a wider context would enhance research in remote sensing and geophysical technologies in the Southwest and Great Basin, in Fremont architecture, and Fremont social organization overall.

Summary of Conclusions

This thesis offers new information about implementing geophysical surveys in the Fremont region, specifically the southern Utah Valley. In the following chapters, I demonstrate how two geophysical techniques (ground-penetrating radar and magnetic gradiometry) were employed
and evaluated at three known Southern Utah Valley Fremont sites. The results suggest that magnetic gradiometry provided the clearest information on buried archaeological contexts in Southern Utah Valley and seems best suited for finding burned archaeological features or features associated with burnt soil. Although GPR proved was helpful when combined with magnetometry, the ephemeral nature of cultural deposits in this region, and the lack of more consolidated building materials such as masonry, made GPR less effective on its own. The combination of GPR and magnetometry yielded mixed but complementary results which aided in identifying buried archaeological features.

The results from this research show that archaeo-geophysics can be a useful tool for identifying areas of occupation otherwise discounted based on past interpretations by archaeologists assumptions on what was found on the ground surface. This otherwise underutilized technology has great potential archaeological applications in Utah Valley, particularly in identifying buried archaeological features.

Thesis Organization

This thesis is organized into seven chapters, including the introduction (Chapter 1). Chapter 2 includes an overview of Fremont research, adds my definition of the Fremont, and synthesizes previous Fremont archaeological research in the southern Utah Valley. Chapter 3 details the various physiographic characteristics of the southern Utah Valley and introduces three archaeological sites: Wolf Village, Wolf Mound, and Snow Farm. Chapter 4 introduces the application of geophysical instruments within the discipline of archaeology, the scientific theory behind their functionality, and their use in the context of previous investigations in the Greater Southwest region and within the Fremont Cultural area. Chapter 5 describes the methods used to acquire geophysical data at Wolf Village, Wolf Mound, and the Snow Farm site, as well as the explanation of the subsequent processing procedures for each method. Chapter 6 discusses the
results of the processed geophysical data collected in the field as well as the successive auger testing of the geophysical anomalies. Chapter 7 reviews and reexamines the previous geophysical research conducted in the region and discusses the results of the geophysical survey and auger tests. I also present my interpretation of the data and conclusions regarding the usefulness of geophysical methods as applied to Fremont archaeological remains.
Previous Research in the Southern Utah Valley

This chapter briefly discusses the current state of Fremont archaeology. The discussion provides context for how the Fremont have been viewed, studied, and defined by past and current archaeologists. I then review how scholars have defined and described the Fremont, including a discussion of their subsistence, material culture, social organization, and architecture. After defining the Fremont, I narrow my discussion on the Fremont reviewing previous Fremont research in Southern Utah Valley.

A Brief Overview of Fremont Research

Over the last few decades there have been several in-depth syntheses of Fremont research (see Janetski 1997a; Madsen and Simms 1998; Ure 2013; Mooney 2014); therefore, I only give a brief review of Fremont research. Since the Fremont bordered both the Great Basin and Southwest culture areas, Fremont archaeologists have had a complicated relationship with both regions.

The name “Fremont” was first used by Noel Morss who excavated sites along the Fremont River, and since that time the way the Fremont have been viewed, defined, and studied has been debated. Aside from naming the “Fremont culture,” Noel Morss, also argued that the Fremont stayed at the Basketmaker III level of technology, as evidenced by their plain pottery, figurines, the absence of cotton and turkeys, and other characteristics similar to the early Ancestral
Puebloan people (Morss 1931:76–77). Due to the similarities between the Fremont and Puebloan cultures, the Fremont region was referred to as the Northern Periphery of the Southwest by Alfred Kidder, Julian Steward, and others (Janetski 1997a:114; Janetski and Talbot 2000:2; Kidder 1962). Steward (1933) believed that the Northern Periphery was a result of various traits of the Southwest diffusing into the area, including pottery styles and trapezoidal-bodied anthropomorphic petroglyphs and figurines.

Although early archaeologists regarded the Fremont as peripheral to the Southwest, later researchers believed the Fremont to have derived from indigenous Great Basin hunter-gatherer cultures (Jennings 1955). Some current archaeologists now suggest a perspective more closely aligned with the American Southwest, to better explore Fremont social behavior (Janetski 2008:105–106; see also Allison 2008, 2010; Janetski and Talbot 2014; Searcy and Talbot 2015).

Defining the Fremont

The term “Fremont” in my research refers to diverse groups of people who were horticulturists who supplemented their diet with hunting and gathering, and who lived in much of Utah, as well as parts of Nevada and Colorado from approximately A.D. 400 to 1300 (see Figure 1.1). There are numerous Fremont sites along the eastern edge of the Great Basin and the Colorado Plateau from the Uintah Basin all the way down to Escalante, Utah. Grayson (1984:143) notes that because the Fremont occupation interrupts an 11,000-year sequence of hunting and gathering, archaeologists have spent considerable time researching this cultural phenomenon, and Fremont subsistence practices have been particularly emphasized. As mentioned above, in-depth syntheses of the Fremont people have been offered by others (Janetski 2008; Madsen and Simms 1998; Simms 2008; Ure 2013), and below I provide a brief overview of Fremont material culture, subsistence practices, trade interactions, and architectural styles.
Material Culture

Morss (1931) was the first to use the term “Fremont” to describe the prehistoric people of Utah. He described the Fremont as a distinct culture along the Fremont River near Torrey, Utah, due to a trait package of ceramic pottery types, rock art styles, figurines, moccasins, and more.

The term “Fremont” has been expanded to include prehistoric horticulturalists who occupied most of modern Utah (Janetski and Talbot 2000). Fremont sites are usually identifiable due to their distinctive material culture. There are several cultural traits that appear to be distinctively Fremont, including pottery types, rock art styles, and figurines. Fremont pottery consists of grayware vessels, as well as black-on-white and black-on-gray painted bowls. There are also corrugated pottery types, fingernail impressed, incised, and those with “coffee-bean” applique (Richards 2014; Richens 2000; Ure 2013). Fremont rock art includes many trapezoidal-bodied anthropomorphic figures, some with elaborate regalia, including necklaces, ornaments, and headgear (Janetski and Talbot 2000: Schaafsma 1971, 2014). Fremont figurines manifest similar shapes and designs as Fremont rock art (Yoder 2016). Other material culture recognized by archaeologists as being Fremont are a single rod and-bundle basketry style (Adovasio 1975:68) and a distinct moccasin type made with a deer hock and dew claw still attached on the sole of the moccasin (Aiken and Madsen 1986:159; Morss 1931:64). Material culture not distinctively Fremont but recovered from some Fremont sites includes marine shell beads from shell found along the California coast (Janetski 2002; Castro and Dement 2013; Castro 2015), worked bone gaming pieces (Janetski 2017; Hall 2008, 2009; Robbins and Lambert 2016), turquoise ornaments, and lignite beads (see Janetski et al. 2011; Jardine 2007).

Trade

The Fremont likely traded with other areas of the American Southwest and at least as far as the California coast and Baja peninsula. Imported items such as marine shell, turquoise, jet,
and Ancestral Puebloan ceramics are sometimes found in Fremont archaeological assemblages, suggesting that trade was ongoing. Janetski (2002) viewed trade as a process in which regions may have participated in social and economic interactions. He compared the long distance exchange among the indigenous peoples of Australia, Alaska, California, and at the Big Camas Prairie on the Snake River to the Fremont, and concluded that the exchanges were usually accompanied by trade festivals, which included feasting, gambling, and bartering. Gambling done at these types of festivals in upper Missouri was done with paraphernalia, which included gaming bones or dice. These items are also found at Fremont sites, including the Parowan Valley and Utah Valley (Janetski 2002:348; see also Hall 2008, 2009; Janetski 2017; and Robbins and Lambert 2016). Festivals or trade fairs were also important prehistorically in areas of the Southwest (Janetski 2002:347). The presence of exotic goods among the Fremont (i.e., marine shell, turquoise, and Ancestral Puebloan ceramics) suggests the movement of goods within the Fremont area and between the Fremont and other peoples of the Southwest and the Great Basin (Janetski 2002:349–358; see also Bennyhoff and Hughes 1987, 2011; Castro and Dement 2013; Watkins 2006; Janteski et al. 2011). Exotic materials were probably only a part of the larger volume of trade, which likely consisted of perishable goods such as food, hides, robes, slaves, and more (Janetski 2002:359). Janetski et al. (2011:47) suggest that trade connections among the Fremont were reinforced by participating in regional festivals that may have occurred at central structures.

**Subsistence**

Fremont subsistence strategies consisted of a mixture of wild resources (including plants and animals) and domesticated crops (maize, squash, and beans). Archaeologists have debated Fremont subsistence for decades (see Madsen 1979; Madsen and Simms 1998; Marwitt 1970). Marwitt (1970) argued that the Fremont relied on mixed subsistence practices based on the
local environment. He argued that the environment determined how heavily the Fremont relied on agriculture or hunting and foraging. Others have argued that Fremont subsistence differed depending on environmental conditions and likely varied through time.

Simms (1986) argued that Fremont subsistence was highly variable. He proposes three Fremont subsistence practices based on diverse adaptations to the environment. These three strategies include: (1) full-time farmers who foraged locally to supplement their diet, (2) part-time farmers and gatherers who switched focus at different times of the year, and (3) both full-time farming groups and full-time hunter-gatherers who occupied the same region (Simms 1986:206). Simms (2008:187) later states that after A.D. 900, most of the Fremont people had aggregated into villages, hamlets, and farmsteads to focus more on farming. Recent isotope studies explored aspects of Fremont diet. Coltrain and Leavitt explored the relationship between Fremont reliance on maize, and gender and socioeconomic status using results from analysis on Fremont burials in the Great Salt Lake wetlands. Isotope signatures of these dated burials suggests that diets varied over time as well as by sex (Coltrain and Leavitt 2002:454). Male and female diets among the Great Salt Lake Fremont varied significantly. Isotope data from some male burials with grave goods had elevated carbon and nitrogen values, suggesting greater protein consumption. Coltrain and Leavitt (2002) argue that a social hierarchy may have been present among some Fremont males as evidenced by grave goods. As economic diversity was replaced by a reliance on wild foods, the male-status distinctions were no longer present (Coltrain and Leavitt 2002:479). Likewise, Ure (2009) explored diet from a burial of a sub adult male excavated at Seamons Mound in 1968. Despite living during the height of Fremont maize cultivation in Utah Valley, stable isotope data from that burial suggests that his diet consisted of approximately 50 percent maize, possibly due to the age and physical deformity of the male may have affected his access to C4 resources (Ure 2009:91–93).
**Architecture**

Fremont architectural styles have been described in depth by Talbot (2000a), Johansson et al. (2014), and Johansson (2019). Talbot notes that Fremont architecture is generally understudied, and suggests that Fremont archaeologists should follow Southwestern archaeology, where architecture is an important part of Southwest archaeology research (Talbot 2000a:131). Talbot (2000a) defines five major types of Fremont buildings: (1) pithouses, (2) surface houses, (3) central structures, (4) secondary pit structures, and (5) storage structures. Most pithouses contain common features, such as central hearths, small storage facilities, and internal structural supports such as postholes and post-sockets. Talbot (2000a:136) explains that most pithouses are circular or quadrilateral in shape, although some pithouses are also D-shaped. Pithouses are usually large enough for several people to occupy, or at least have enough room for occupants to perform several activities at the same time.

Surface houses are found throughout the Fremont region, but they are less common than pithouses. They are constructed of freestanding walls of adobe, jacal, or masonry (Talbot 2000a:138). Surface houses probably functioned in the same manner as pithouses since most display the same types of floor features. A central hearth, floor, and subfloor features are present in some surface houses, and both pithouses and surface houses are often similar in size. Surface structures with multiple rooms usually have storage rooms attached to the main habitation room. Talbot (2000a:138–139) notes that ventilation tunnels are usually not present in surface houses since ventilation was probably attained through open doorways.

Central structures are much larger in size than average-size pithouses. Central structures range from 23 to 58 square meters, with a mean floor area of 39 m². Central structures have roughly north-south orientations, and they have large hearths (Allison et al. 2012). Since central structures are quite large, they require larger internal support, as evidenced by numerous postholes and post-sockets (Lambert 2018). There is usually only one central structure at a
Fremont site, and central structures are usually built on the surface (Talbot 2000a:139). Talbot (2000a:139) states that central structures have been identified at several Fremont sites, including but not limited to: Baker Village, the Garrison site, Beaver Mounds, Paragonah Mound, Evans Mound, Five Finger Ridge, Poplar Knob, Huntington Canyon, and Turner-Look. Ure and Stauffer (2010:3) also listed the Blue Trail House and Structure 6 at Wolf Village as central structures. Although, Johansson et al. (2014:49–50) disagreed with Ure and Stauffer’s classification of Structure 6 at Wolf Village as a central structure, due to its small size (22 m²). Ure argues that we cannot look at size alone, but must look at a variety of characteristics when classifying central structures (personal communication with Scott Ure). Johansson et al. also argue that Structures 2 and 8, both oversized pit structures at Wolf Village, were most likely communal places in the community (Johansson et al. 2014:50–51). Richards et al. (2019) state that Structure 2 at Wolf Village may have been used both residentially and communally.

Secondary pit structures are defined by Talbot (2000a:136) as structures that served as temporary habitation areas. These structures may have had specialized functions such as sweat lodges, birthing or menstrual huts, or as places for visitors. A small central hearth is usually present, although other subfloor features are rare. Surface storage structures are separate from pithouses and are common at late Fremont sites (Talbot 2000a:137). Storage structures were likely used for storing excess food. Regardless of what architecture is present at Fremont sites, one thing is certain, architecture is an important medium through which community integration and social organization can be studied. Architecture, along with other material culture such as ceramics and projectile points, can define group boundaries and show distinctions between those within the group and those without (Johansson et al 2014:53-54).

**Previous Research in the Southern Utah Valley**

Over the last few decades there have been many syntheses of archaeological research in
the Fremont cultural region (see Janetski 1997a; Madsen and Simms 1998; Ure 2013; Mooney 2014); however, many of those syntheses tend to focus on the Parowan Valley or the Provo River Delta. Here, I provide a syntheses of Fremont research in the southern portion of Utah Valley,
which includes sites south of Provo and encompassing the Goshen Valley (Figure 2.1).

Utah’s rich archaeological record has attracted scientists and antiquarians alike from around the world to study Fremont Culture. The early explorations, observations, and speculations characterize the early era of archaeological information in Utah Valley. After the mid-nineteenth century, several organized government expeditions traveled west to identify transportation routes and exploitable resources included members who were interested in the aboriginal people and the remains of their past lifeways. Few excavations were conducted and fewer still were reported in any detail (Janetski 1999:101).

The first formal explorations of Fremont sites were performed by Dr. Henry Yarrow and Mark Severance during the 1872 U.S. geographical and geological survey of Utah (Severance 1872; Wheeler 1889). Both Severance and Yarrow mention excavating at mounds in or near the towns of Provo, Paragonah, and Beaver. While at Paragonah, Severance (1872:55) noted, “a congregation of mounds four or five hundred in number and covering an area of at least fifty acres.” Yarrow and Severance recognized similarities between the cultural remains recovered from mounds in Provo with those at Paragonah (Gunnerson 1969; Severance 1872). Other researchers, including Edward Palmer, Henry Montgomery, and Don Maguire, were also early “Fremont” researchers who noted convincing connections between artifacts at Fremont sites and those found in the American Southwest. Edward Palmer, a medical practitioner and professional collector, who visited Utah primarily in the late 1870s, collected archaeological and ethnographic artifacts. Funded by the Smithsonian, he excavated in “mounds” at Santa Clara near St. George, Kanab, Paragonah, and Payson.

Palmer visited Payson in part to explore a rumor that a local farmer had opened a mound in his field and found the skeleton of a giant over six feet tall holding metal weapons that crumbled to dust when touched. As the story went, the mound reportedly contained two sealed stone boxes filled with wheat. Palmer was unable to confirm the story. In a paper published regarding artifacts
found in mounds near modern-day Payson, Utah, Palmer wrote, “the mounds proved to be debris of many dwellings successively built in the same location” (Palmer 1877).

During the 1890s, the collecting of antiquities intensified in search for material to exhibit at the 1893 World’s Columbian Exposition in Chicago. In preparation for its exhibit, the Utah Territorial World’s Fair Commission appointed Don Maguire of Ogden as chief of the Department of Archaeology and Ethnology. His credentials included working with John Wesley Powell and collegiate training in geology, which was his primary interest. Given this grand title, Maguire proceeded with great energy to excavate sites, usually mounds, to collect antiquities for exhibition in the Utah Pavilion at the World’s fair. He dug at archaeological sites near Willard, Plain City, and other sites in or near Ogden, at Provo and Payson in Utah Valley, and at the massive Paragonah site in the Parowan Valley.

Following in the footsteps of Palmer, Montgomery, and Maguire, Neil Judd excavated at various mound sites along the Wasatch front in 1915 (Judd 1926). Judd was the first formally trained archaeologist to work in the state of Utah (Janetski and Talbot 2000a). He was impressed by the presence of pueblo-like, above-ground, adobe-walled houses at Beaver and Paragonah and by Palmer’s description of similar structures at Payson. He was interested in examining whether these mound sites were in any way related to the “ancient habitations south and east of the Rio Colorado” (Judd 1915:1).

Neil Judd was the last formally trained archaeologist to mention the mounds in Payson. Although Judd provided detailed notes on what was found there (see Judd 1926), the location of the mounds where Palmer had excavated cannot be determined. In Judd’s 1926 bulletin, he mentioned that “if any trace of prehistoric habitations is now present in the vicinity it has seemingly escaped the notice of local residents.” Modern agricultural and urban development has made the possibility of identifying these previous excavation areas at the Payson mounds well is nearly impossible.
Julian Steward continued archaeological explorations in the Provo River delta area during the 1930’s. Steward was an anthropologist with the University of Utah from 1930-1933 and conducted extensive anthropological and archaeological work throughout the state of Utah and the Great Basin. He was the first professional archaeologist to work at the mound sites in the Provo River delta. A few years after Steward left the University of Utah, Albert Reagan arrived at Brigham Young University (BYU) and initiated an interest in local archaeology in the fall of 1934, Albert Reagan and others from Brigham Young University reexamined the same mounds that Julian Steward explored three years prior.

The mounds and other archaeological sites in the Provo River delta became the focus of research and several Brigham Young University Master’s theses well into the mid-20th century (Mooney 2014:29). Archaeological fieldwork in the Provo River Delta continued from the 1940’s through the 1970’s by BYU. The area was later revisited by BYU in 2009 and 2015 with a focus on the Provo Mounds (Hinckley Property), and Seamons Mound. Although these explorations are pivotal to the evolution of Utah Valley archaeology, they are synthesized in greater depth in prior master’s theses (see Ure 2013; Mooney 2014).

1960’s to Present

During the summer of 1966, Leland Gilsen (1968) as part of his Master’s thesis at BYU, conducted a reconnaissance survey of Currant and Kimball Creek drainages in Goshen Valley; however, limited excavations occurred as part of his thesis research (mainly at Woodard Mound) (Gilsen 1968:57–60). Gilsen classified sites he found into three categories: village sites, house clusters, and campsites. These classifications were based on the size of the site, surface artifacts, architecture, and indications of potential sub-surface features (Gilsen 1968:21–24). His survey resulted in the identification of two villages, 10 house clusters, and 23 campsites along Currant Creek. Gilsen (1968:28) defined Wolf Village as a village site and dated it within the Fremont
period as indicated by ceramic and projectile point types. Gilsen identified a Fremont campsite site (42UT277) approximately 150 meters northwest of Wolf Village, which Baker and Janetski (2004:50) argue suggests that the ridges around Wolf Village may have contained a cluster of Fremont habitations (see also Gilsen 1968:30).

Following Gilsen’s survey of Currant and Kimball Creek drainages in Goshen Valley, James Mock, a graduate student at Brigham Young University, investigated the prehistoric “use area” found on Mr. J. E. Woodard’s land that Gilsen had identified the year prior. The objective of Mock’s investigation at what was later know as Woodard Mound (42UT102), was to uncover whether or not artifact distribution could be used to determine social structure. The secondary objectives of Mock’s investigation was to uncover a living structure; and to test Gilsen’s hypothesis of a “use area” (Mock 1970: iii). Mock’s primary objective was satisfied when he found that concentration of artifacts (ceramics, lithics, tools etc.) could be used to help determine the social structure of a culture (Mock 1970:70). Although Mock was unable to excavate a complete living structure and accomplish his first secondary objective, he was able to uncover evidence to suggest that the structure at the site was of “Jacal type” (Mock 1970:71). Mock’s second objective was completed when he determined that Gilsen’ hypothesis of a “use area” at the site was incorrect since it was located inside of the structure rather than outside of it.

Several miles west of Woodard Mound, James Mock (1971) as a graduate student at Brigham Young University, excavated at Spotten Cave (42UT104) for several seasons in the 1960’s. The site is located on the north end of Long Ridge three miles west of the modern town of Santaquin. The excavations revealed that the cave was occupied for an extensive period, during the Archaic (c.a. 8000 B.C. to A.D. 400), the Fremont (A.D. 400 to A.D. 1300), and Late Prehistoric Native Americans, who occupied the Great Basin after the Fremont up to the time of contact with European settlers. Artifacts and plant remains from European settlers were found in the cave along with evidence of use by the earlier groups (Dahle 2011).
Brigham Young University’s archaeological field school held at Woodard Mound (42UT102) in 1980 and 1981. Woodard Mound is a Fremont site in Goshen Valley, Utah, and was excavated under the direction of Dr. Dale Berge. Woodard Mound was repeatedly investigated by the Department of Anthropology at Brigham Young University. The 1980 and 1981 projects were designed to collect subsistence data to gain a better understanding of Fremont subsistence in the Utah Lake area. In addition, much-needed information regarding chronology, architecture, and material culture was also collected to better understand the prehistory of the area regarding cultural adaption over time and space (Richens 1983).

A systematic survey project of Goshen Valley was conducted by Colleen Baker and Joel C. Janetski during the summer field seasons of 1990 – 1992. During the project, only 10 percent of the valley was surveyed using 15 east-west transects that were 160 meters wide. Archaeological sites were identified by surface artifacts, architectural features, and non-architectural features (Baker and Janetski 2004:67). The survey resulted in the identification of 55 new sites and re-recordings of seven of Gilsen’s sites from his 1968 survey of Goshen Valley (see Gilsen 1968; Janetski 2004 Lambert 2018). Using diagnostic artifacts and features, Baker and Janetski (2004) identified 18 of the 62 sites as Fremont, seven as Archaic, and six from the Late Prehistoric. The rest of the 62 sites could not be assigned a cultural affiliation (Baker and Janetski 2004:67). They noted that four Fremont sites with structural remains (two had previously been recorded by Gilsen), were located on Currant Creek. The other two were located on a terrace overlooking Goshen Bay but did not contain structural adobe, so Baker and Janetski (2004:67–68) theorize that these two sites may have been temporary structural sites since both are far too from water sources. They suggest that Fremont structural sites in Goshen Valley were usually concentrated along drainages (Baker and Janetski 2004:67–68).

In the spring of 1996, the BYU Field School and staff from the university’s Office of Public Archaeology mapped and dug exploratory trenches at Kay’s Cabin under the direction of Joel
Janetski. Kay’s Cabin (42UT813) is located in Goshen Valley, south of Utah Lake, on Kimball Creek, a small perennial stream that drains water from Long Ridge and the Tintic Mountains. Janetski’s work at Kay’s Cabin was followed by additional excavations in August of that same year with the Utah Valley Chapter of the Utah Statewide Archaeological Society, also under Janetski’s supervision (Janetski 2016). BYU returned to Kay’s Cabin in the early summer of 2000, exposing completely the compact surface and associated features found in 1996 that were thought to define a house. The archaeological findings at Kay’s Cabin point to an intensive occupation late in the Fremont period and contemporary with Woodard Mound to the north in Goshen Valley (Newbold 2006:14).

Wolf Village

A few years after Baker and Janetski’s survey, BYU conducted several archaeological field schools at a Fremont site named Wolf Village (42UT273), located just south of the town of Goshen. Field work started in 2009 under the direction of Joel Janetski (Figure 2.2). Subsequent field schools (2010 to 2013 and 2016) were directed by James Allison with Michael Searcy acting as co-director in 2012, and David Yoder as a co-director in 2016.

The six years of excavations at Wolf Village led to a considerable amount of archaeological data that has yet to be fully published; however, the Wolf Village excavations did influence the topic of five Master’s theses (Bryce 2016; Dahle 2011; Pyper 2011; Lambert 2018; Lambert 2020), seven published articles and book chapters (Lambert 2019; Lambert, Bryce, and Bischoff 2019; Bryce 2019; Johansson 2019; Richards et al. 2019; Castro and Dement 2013; Johansson et al. 2014), and several more publications in the works (personal communication with Jim Allison). Previous and current research has been conducted on the architectural variation at Wolf Village, focusing on communal and residential architecture (Johansson et al 2014; Lambert and Bryce 2016). Johansson et al. (2014:47) define “communal structures” as facilities used by either entire
Figure 2.2. Map of various sites mentioned in Utah Valley and Goshen Valley. Adapted from Scott Ure’s original map.

communities or smaller portions of a community. They assume that communal buildings were built and used by groups larger than single households. These types of buildings would likely have required the cooperation of large portions of the community to build and maintain. Communal
buildings are identified, in part, by being “much larger than the average-sized pit house” (Talbot 2000:183). Talbot (2000a:139) explains that communal architecture requires a higher amount of effort to build and maintain than most other architectural forms, which he states imply communal use. Communal buildings include both pit and surface structures (Johansson 2019).

Dahle’s (2011) master’s thesis researched plant-based subsistence practices and trade at Wolf Village. Dahle (2011) analyzed micro and macro botanical remains collected during the first three field seasons at Wolf Village (2009 – 2011). She argues that farming and foraging were both important parts of Fremont subsistence at Wolf Village. There was an apparent abundance of maize, beans, and wild plants recovered at Wolf Village (Dahle 2011:73). She concludes that farming was a strong economic basis of subsistence for the Fremont at Wolf Village in the latter period (i.e., Period II), but that foraging also played a role in the subsistence practices at the site.

Castro and Dement (2013) analyzed 173 Olivella shell beads recovered from Wolf Village during the first four field seasons and determined that most of the shell originated from the California coast (Castro 2015). Janetski et al. (2011:42) state that a high number of shell artifacts suggests the importance of a site in the Fremont region. Locations with high frequencies of exotic artifacts suggest that the location was a place where people may have traded with others (Janetski 2002:359; see also Renfrew 1977:85). Castro and Dement (2013:57–60) conclude from the shell data that Wolf Village was part of a large trade network between the California Coast and the Great Basin.

Research relating to animal use at Wolf Village include several senior theses (notably Crandall 2017; Holm 2017; and Julian 2017) and Master’s theses (Bryce 2016; and Lambert 2018). Crandall (2017) analyzed faunal bones from Structure 1 in order to investigate whether faunal bone specimens found in the building were associated with activities undertaken at the building or were from secondary contexts. She concludes that most of the faunal bone specimens are from secondary contexts, meaning they cannot suggest specific prehistoric activities carried
out in any of the rooms. They can, however, provide information about the overall diet at Wolf Village (Crandall 2017:16).

Abo (2016) examined evidence of ritual abandonment of some buildings at Wolf Village, a topic also explored by Holm (2017). Holm argued that Structure 9 was ritually abandoned by the Fremont, as evidenced by “offerings” which included animal body parts and ceramic vessels. He further argued that the abandonment characteristics associated with Structure 9 (i.e., burning the building after its disuse, bone and ceramic deposits, etc.) were unique in the Fremont culture region (Holm 2017:2). Lambert (2018) disagreed with Holm (2017) since large game skulls, mandibles, and vertebrae were identified in supposed ritual abandonment contexts at other Wolf Village structures (Structures 2, 6, and 8), and Kay’s Cabin (Janetski 2016:49).

Bryce (2016) investigated the manufacture and use of bone awls at Wolf Village. He analyzed 135 bone awls and concluded that people living there used these tools for basket making, leatherwork, and other activities. Two awls were identified as bighorn sheep elements, two as pronghorn, and three as mule deer (Bryce 2016:56–58). It appears that animals were valued at Wolf Village beyond their meat.

Lambert (2018) also analyzed faunal bones from Wolf Village and focused on large game and its utility, as evidenced by what is known as the modified general utility index (MGUI). Lambert conducted this study in an attempt to add information on animal use at Wolf Village, and to compare Wolf Village to other Fremont sites that have had their faunal bone assemblages compared to Binford’s MGUI. Results from his strontium isotope analysis suggested that many of the large game individuals hunted by the Fremont were not local to the immediate area. Lambert suggests that hunters saw utility in low-caloric elements not related only to food value, but some low-caloric skeletal elements were used by the Fremont to construct bone tools and other objects, and as possible symbolic objects used in abandonment rituals.
Wolf Mound

Later in the summer of 2019, the landowner of Wolf Village showed Scott Ure and me a mound in his alfalfa field north of the town of Goshen. This mound, later called Wolf Mound (42UT2150), is located 1.5 miles east of Currant Creek and is in very close proximity to several dry river channels. Wolf Mound is also about four kilometers north of 42UT273 (Wolf Village) and about a mile southeast of Woodard Mound (42UT102). During the fall of 2019, Scott Ure, Ridge Anderson, and I flew over the mound using an unmanned aerial system with a thermal camera to identify any buried architectural features. Results from that flight show two possible architectural features. Additional ground-penetrating radar explorations were conducted by Dr. John McBride (BYU Geology) suggested similar conclusions. Scott Ure directed test excavations in the fall of 2019. Two test trenches were dug, one north and south and the other east to west. The painted ceramics from the Parawon Valley and the Ivie Creek areas, and other cultural material recovered suggests that this feature could be a Fremont surface structure, but additional excavation is required to test this hypothesis. A single burned corn sample was recovered and dates to about 1100 AD. The results of this excavation are currently in progress as of 2020 (Ure and Jepsen 2021).

Conclusions

This literature review focused on the prior archaeological research in southern Utah Valley up to the present. Although there have been many excavations and research projects conducted in Utah Valley, much of the archaeological excavation data and analysis is missing or has not been published. This is a problem that limits our ability to discover more about the Fremont culture. I recognize that the histories presented in this chapter are of prominent and well-reported archaeological undertakings (many of which are older than 50 years) that can usually be found in published works. I have not included the countless surveys and shovel tests that have been
conducted by various contract archaeology companies and other researchers. Nevertheless, there is a great deal of research that still needs to be conducted in this region in order to understand the unique history of the Utah Valley Fremont.
In this chapter I discuss the various physiographic characteristics of the southern Utah Valley, including a general overview of the geography, geology, hydrology and climate. Next, I introduce three archaeological sites; Wolf Village, Wolf Mound, and Snow Farm. These three sites were the setting for my thesis research. I provide an overview of each site’s geographical setting, history, and geological morphology. Outlining the southern Utah Valley’s basic physiographic features establishes the general environment and context for my thesis.

**Physiography of Southern Utah Valley**

**Geography**

Utah Valley lies near the junction of three prominent physiographic provinces of North America. To the west stretches the Great Basin, a vast expanse of arid intermountain valleys extending from the Wasatch Mountains to the Sierra Nevada’s. To the east lies the western portion of the Rocky Mountains, expressed in central Utah by the high peaks of the Wasatch Mountains rising above the Wasatch Fault, one of the largest of the fractures of the earth’s crust in North America. Not far away to the southeast is the colorful Colorado Plateau Province (Brimhall and Merritt 1981).

Utah Valley sits in the heart of the central Wasatch region of the eastern Great Basin (Figure 3.1). The valley stretches 80 kilometers (50 miles) in length from upper Goshen Valley on the
Figure 3.1. Map of the state of Utah with the area of Utah Valley highlighted. Map courtesy of Scott Ure. Adapted by the author.
southwest to Dry Creek Canyon on the northeast, and nearly 40 kilometers (25 miles) from Soldiers Pass on the west and lower Hobble Creek Canyon on the east. On the southwest and west edge of the valley lie the East Tintic Mountains. To the west but closely bordering Utah Lake are the Lake Mountains. To the north and northwest are the low Traverse Mountains and the considerably higher (up to 3200 meter or 10,500 feet) Oquirrh Mountains, while to the east the massive Wasatch Front rises dramatically with several peaks just shy of 3657 meters (12,000 ft.) in elevation.

Utah Valley lies at the eastern margin of the vast Pleistocene Lake Bonneville. One of the few remaining lakes that made up Lake Bonneville is found in the modern-day Utah Lake. This dominant geographical feature covers 390 square kilometers (150 square miles), and it is one of the largest freshwater lakes in the United States west of the Mississippi River. This lake occupies the central part of the valley, averaging 2.5 meters (8 ft.) in depth, and in a few places as much as 6 meters (20 ft). The Jordan River drains the lake northward into the Great Salt Lake. The lakeshore slopes gently in most places, so slight fluctuations in water level cause large changes in lake area. Utah Lake is about 30.5 kilometers (19 miles) long in a north-south direction and 16 kilometers (10 miles) wide at its widest part east-west, and it covers about one-fourth of the valley (Bissell 1963:103).

The valley bottom, exclusive of the lake, consists of fertile alluvial slopes along the east and west sides of the lake. The wider, gentler east slope is cut by several streams issuing from the Wasatch Range and broadens into extensive, well-watered flatlands to the northeast, southeast, and southwest (Goshen Valley). Extensive marshes are present in Provo Bay on the east and Goshen Bay on the south, and smaller marsh communities rim the lake’s east shore. To the northwest, ephemeral streams drain the Oquirrh Mountains and associated rolling lowlands. The west edge of the valley along the east-facing slopes of the Lake Mountains is less than a mile in
width and contains no streams or springs and only sparse vegetation (Bissell 1963:103).

Geology

Utah Valley is a graben formed by normal faulting during Tertiary and Quaternary time (Clark and Appel, 1985, p. 5). The Wasatch fault zone forms the eastern boundary of Utah Valley. A concealed fault zone lies along the east side of West Mountain and forms the western boundary of southern Utah Valley (Brooks and Stolp 1995:3).

The consolidated rock that forms the mountains surrounding southern Utah and Goshen Valleys ranges in age from Precambrian to Tertiary. The Wasatch Range contains thick limestone layers that are deformed and fractured (Clark and Appel, 1985, p. 31). The East Tintic Mountains are composed mainly of quartzite and limestone of Paleozoic age and igneous rocks of Tertiary age. Faulting is very prevalent in these ranges (Lindgren and Loughlin, 1919, p. 21). Erosion of the mountains has provided the sediment that fills the valleys. The fill consists of unconsolidated to cemented and compacted lacustrine, alluvial fan, and fluvial deposits of Tertiary and Quaternary age (Cordova, 1970, Part II). During the Cenozoic Era, southern Utah and Goshen Valleys contained numerous lakes of varying extent, the largest of which was Lake Bonneville. Southern Utah Valley is floored mostly by sediments deposited in Lake Bonneville and later lakes during the Quaternary period. Younger alluvium and eolian sand and silt locally overlie the lake deposits. Beneath the Lake Bonneville beds are several hundred feet of unconsolidated earlier Quaternary fluvial and lacustrine sediments, in places resting on late Tertiary tuff and fresh-water limestone. Precambrian, Paleozoic, Mesozoic, and Cenozoic sedimentary, metamorphic, and intrusive and extrusive igneous rocks are exposed in the mountains adjoining and within southern Utah Valley (Baker, 1947).
Hydrology

Utah Lake lies in the western portion of Utah Valley and the northern end of Goshen Valley at an elevation of 1367 m. (4488 ft.). The lake covers about 38,075 ha. (94,085 acres), has an average depth of 2.8 m., and a maximum depth of 4.2 m. (Jackson and Stevens 1981:3). According to Brimhall and Merritt (1981:30) the shallowness of the lake “contributes greatly to its turbidity, large evaporation losses, hence slightly saline waters and warm summer temperatures, hence abundant communities of algae.” Utah Lake receives most of its water from major perennial streams which have their headwaters in the Wasatch and Uinta Mountains to the north and east. In addition, the lake receives water from minor perennial and intermittent streams, seepages, springs, and direct precipitation. The Jordan River is the sole outlet of the lake and flows to the Great Salt Lake approximately 64 km. to the north (Richens 1983:3).

The perennial streams that originate in the Wasatch Range and enter the southern Utah Valley are: The Spanish Fork River, Hobble Creek, Maple Creek, Peteetneet Creek (also called Payson Creek), Currant Creek, and Summit Creek. The Spanish Fork is the largest river in southern Utah Valley, and provides about 75 percent of all perennial streamflow that enters southern Utah Valley (Brooks and Stolp 1995:9). The stream is formed by the confluence of the Soldier and Thistle creeks (in Spanish Fork Canyon in the Wasatch Range), where the stream is then quickly joined by the Diamond Fork creek. The stream then flows about 20 miles (32 km) northwest out of the canyon and into Utah Lake, passing through the city of Spanish Fork and then along the borders of the communities of Benjamin, Lake Shore, and Palmyra (Figure 3.2) (Brooks and Stolp 1995:9).

Hobble Creek is the second largest stream in the study area and typically provides about 15 percent of all perennial streamflow that enters southern Utah Valley (Brooks and Stolp 1995:9). Hobble Creek originates to the east of Springville, Utah, in the Wasatch Mountains at an elevation of approximately 9,000 feet.
Figure 3.2. Map of Utah Valley’s major lakes, rivers, and creeks. Map courtesy of Scott Ure. Adapted by the author.
Peteetneet Creek originates northeast of Mount Nebo at the confluence of Shram Creek and an unnamed creek that flows through the Frank Young Canyon. Historically the creek drained down Payson Canyon and cut through the town of Payson and fed into Utah Lake. Today Peteetneet Creek is divided at the mouth of Payson canyon and is diverted into the West Ditch (Brooks and Stolp 1995:9)

Currant Creek, the only perennial stream in Goshen Valley flows northward through Goshen Canyon into Goshen Bay, the southern-most extension of Utah Lake. The natural course of this stream was changed when it was dammed for irrigation purposes by the first Euroamerican settlers in the valley (Richens 1983). An 1856 land survey shows the natural stream course before settlement began in 1857.

Kimball Creek is an intermittent stream which flows from the East Tintic Mountains in the southern end of the Valley through Kimball Canyon. It converges with Currant Creek near the Goshen Reservoir. Other hydrographic features in the valley include White Lake, a shallow playa near the shores of the lake, which usually fills with water during the spring, thermal springs located east of Goshen that flow toward the lake, and extensive salt marshes near the lake margin and east of Goshen (Richens 1983:4).

**Climate**

The climate conditions of Utah Valley would have likely been more temperate than it is presently, with increased summer rainfalls, and warmer spring and fall temperatures that would have allowed longer growing seasons. Today, scientists refer to this as the Medieval Warm Period (900 to 1350 A.D.). This ended shortly after 1300 A.D., introducing a period in western North America generally, though not always, cooler and less arid (Grayson 2018:264).

The climate of southern Utah Valley today is sub humid, and the climate of Goshen Valley is semi-arid (Hyatt et. al, 1969). The climate is characterized by warm, dry summers, cold, moist
winters, and fairly wet springs (Jackson and Stevens 1981; Swenson, et. al. 1972). The Wasatch Mountains are a pronounced physiographic and climatic barrier that largely determines the local distribution of rainfall in the valley. The mountains have much lower temperatures and receive much more precipitation than the valley. The variations in altitude, together with changes of season, the northern latitude, and weather disturbances, have account for maximum temperatures slightly over 110°F, and minimum temperatures as low as -35°F. In the eastern part of the valley, temperatures are lower but precipitation is somewhat higher than in the western part. (Brooks and Stolp 1995:5). Annual precipitation ranges from 200 mm in the Sevier Desert to over 1270 mm in the nearby mountain ranges of the Wasatch. In Goshen Valley, annual rainfall approaches 300 mm. The majority of the precipitation falls in the winter and in the spring. During the growing season, from May to September, average precipitation is about 90 mm. The average frost-free season is 140 days (Richardson n.d.).

**Site Backgrounds**

The following section will introduce each of the three sites used to test the geophysical research methods I discuss in my concluding chapters. Although these three sites are located within the greater Utah Valley region, for the sake of this research, I will be refer to the southern portion of Utah Valley. Southern Utah Valley incorporates both Utah Valley south of Provo bay to Santaquin, and sub valleys like Goshen Valley west of West Mountain in Utah County, north-central Utah. The two valleys cover an area of about 390 mi² from north of Springville to southwest of Santaquin (see Figure 2.1).

**Wolf Village (42UT273)**

Wolf Village is located in Goshen Valley in north central Utah. The valley lies at the eastern margin of the Great Basin approximately 10 km west of the base of the Central Wasatch
Figure 3.3. Map of the site location of Wolf Village (42UT273). Map courtesy of Scott Ure.
Mountain Range. Goshen Valley is approximately 16 km long and 11 km wide, and oriented in a north-south direction. The fertile valley is surrounded by low mountain ranges: the Lake Mountains to the northwest and the Tintic Range to the southwest (Fig. 3.3). Physiographically Goshen Valley is in the southwestern portion of Utah Valley (Bissell 1963). It is separated from the rest of Utah Valley by West Mountain, a barren, isolated peak which rises over 600 m. above the valley floor.

Wolf Village is located on a series of low hills and ridges, just north of the mouth of Goshen Canyon (see Figure 3.4). Vegetation at the site consists of juniper, sagebrush, greasewood, and rabbit brush. In addition, the fields surrounding the site, where the Fremont likely farmed, are now alfalfa fields. The closest water source is Currant Creek, which runs through modern nearby

Figure 3.4. Aerial view of Wolf Village facing south at the end of the 2012 field season. Photo by Michael Searcy. Courtesy of the Brigham Young University 2012 Field School.
fields and right past the edge of the site (Lambert 2018:40).

Wolf Village is located on private property owned by the Wolf family and used for grazing cattle (Figure 3.4). A reconnaissance survey of Goshen Valley was conducted by Leland Gilsen in 1966 as part of his master’s thesis. Gilsen thirteen buildings at Wolf Village, which were visible due to artifact concentrations and decaying adobe walls (Gilsen 1968:28). Archaeological excavations at Wolf Village focused on Fremont structures, and resulted in the excavation of
nine, including six pithouses, two surface buildings, and one oversized pit structure (Figure 3.5) (Johansson et al. 2014). Archaeological excavations began at Wolf Village in 2009 under the direction of Joel Janetski. James Allison directed the excavations from 2010 – 2016, with Michael Searcy co-directing in 2012 and David Yoder co-directing in 2016.

Wolf Village Geology

Wolf Village is located in the Goshen valley, a low-lying, seasonally wet area on the south side of Utah Lake. The geophysical techniques used for this thesis are only able to penetrate 1-3 meters underground, so I will only describe the top layers of stratigraphy for each site based
upon the United States Geological Surveys’ “Interim Geological Maps of Utah”. The geology at Wolf Village consists of stream and floodplain deposited during the Holocene epoch (Figure 3.6). The uppermost 25–30 cm of sediment is sand, silt, and gravel that was deposited from various channels and floodplains.

Below the Holocene alluvium lies the near shore deposits of Pleistocene Lake Bonneville. This light gray to gray sediment is moderately well sorted and evenly bedded layers of silt, sand, gravel, and sparse cobbles (Witkind and Weiss 1991:3). This layer is likely of deltaic origin and its depth is approximately 60–80 cm deep.

**Wolf Mound (42UT2150)**

Wolf Mound is also located in Goshen Valley, near the town of Goshen, Utah. Wolf Mound is owned by the Wolf family and used primarily for growing alfalfa (Figure 3.7). Wolf Mound is located 1.5 miles east of Currant Creek and in very close proximity to several dry river channels and lies about 4 kilometers north of 42UT273 (Wolf Village). The mound is roughly 20–30 cm in height and measures roughly 7 meters (northeast-southwest) by 6 meters (northwest-southeast).

During the fall of 2019, Scott Ure, Ridge Anderson, and I flew an unmanned aerial system over the mound using a thermal camera to identify presumed buried architectural features. Results from that flight indicated two possible architectural features. An additional ground penetrating radar survey was conducted by Dr. John McBride (BYU professor in the Geology Department) soon after the thermal flight. This was conducted to test thermal imagery results. The GPR and thermal data suggested similar inconclusive conclusions about the buried architectural features. The mound was then partially excavated under the direction of Scott Ure in the fall of 2019. Two test trenches were dug, one 8 meters long running north to south, and the
Figure 3.7. Overview photo of the Wolf Mound (42UT2150) and adjacent alfalfa fields facing northwest. Photo taken by author.

Figure 3.8. Illustrated plan map of the 2019 Wolf Mound excavation. With the outline of the mound for reference.
other running 7 meters east to west (Figure 3.8). The cultural material recovered suggests that this could have been a Fremont surface structure. A single burned corn sample was found on what was believed to be the floor, dating to about 1100 AD.

**Wolf Mound Geology**

Similar to the geology of Wolf Village, the sediment surrounding Wolf Mound consists of a sparse upper Holocene alluvium layer (indicated as “Qal” in Figure 3.9). The sediment tends to be dark brown to gray in color, and varies in thickness. The bedded deposits consist of locally massive, unconsolidated clay, silt, sand, granules, pebbles, and sparse cobbles of alluvial origin (Figure 3.9). The next stratigraphic layer consists of Pleistocene Lake Bonneville nearshore and off-shore lake deposits (indicated by the abbreviation “Qbn” and “Qbo” in Figure 3.9). The
soil tends to be either light gray to gray, or light gray to tan in color. The sediments tend to be moderately well sorted, and the even bedded deposits consist of cross bedded silt, sand gravel, and sparse cobbles. This layer is thought to be of deltaic and lacustrine origin with widely varying thicknesses (Witkind and Weiss 1991:3).

Snow Farm (42UT2274)

Snow Farm is located in southern Utah Valley, and is approximately one-mile northwest of downtown Payson, Utah (see Figure 3.3). The site is close to several dry river channels that were likely part of Spring Creek or Peteetneet Creek. The latter once flowed north through the town of Payson about a mile away (before it was diverted), the former lying about one mile to the west of the site. The property is privately owned and the farm is managed by Josh Snow who grows various crops and raises livestock (Figure 3.10). Vegetation in and around the site mainly consists of Gramble oak and oak/maple stands in the lower elevations, sagebrush and dry grasses.
up into the foothills, and Aspen, spruce, and Douglas fir/white fir are present at upper elevations on north-and east-facing slopes of the Wasatch Range (USFS 2003).

In July of 2020, Mr. Snow contacted Scott Ure at BYU about numerous artifacts recently collected at his farm. The artifacts were primarily Fremont based on the ceramics he collected from the surface. There were also a few trade wares and archaic stone tools. Mr. Snow also indicated two areas that appeared to contain structural features. One area was mostly removed through active artifact hunting (Figure 3.11), and the other was heavily damaged by ground leveling and plowing.

**Snow Farm Geology**

Snow Farm is located at the edge of a lake and located between two perineal streams,
therefore, the geology of the Snow Farm site has a diverse stratigraphic history. According to the Interim Geological Map of Utah (Figure 3.12), Snow Farm should mostly consist of upper Pleistocene fine-grained lacustrine deposits (indicated as “Qlf” in Figure 3.12). The sediment is mostly silt and clay with some fine-grained sand; that has weathered to an unstratified appearance but is typically laminated. The lacustrine deposit layer normally grades upslope into more sandy and gravelly lacustrine and deltaic deposits which dates to the age which likely date to the Lake Bonneville regression (Constenius et al. 2018).

Although the geological map suggests the site is mainly located on Bonneville transgressive
lacustrine soils (Qlf) (Figure 3.12), due to its proximity to the Holocene and upper Pleistocene Younger alluvial-fan deposits (or Qafy), it is likely that the Holocene and upper Pleistocene Younger alluvial-fan deposits (Qafy) superimposes much of the site. This stratigraphic later (Qalf) consists of mostly sand, silt, and gravel that is poorly stratified and deposited at drainage mouths of streams. The alluvial fan deposits are mostly Holocene and cover Lake Bonneville deposits or deflect stream channels. This layer varies from 2 m to 12 m in thickness (Constenius et al. 2018).

Another very likely depositional layer found at the site (based upon aerial imagery) is the Holocene to upper Pleistocene spring and marsh deposits (Qs). The sediment consists of fine, organic-rich sediment associated with springs, ponds, seeps, and wetlands in Utah and Goshen Valleys. The soil is commonly wet, but seasonally dry that may contain peat deposits as thick as 1 meter (3 ft). The sediment may include areas of mixed marsh and fine-grained Lake Bonneville deposits (Qlf). The Holocene to upper Pleistocene spring and marsh deposits layer (Qs) often overlies and grades into the upper Pleistocene fine-grained lacustrine deposits (see Qlf cited above). The Holocene to upper Pleistocene spring and marsh deposits layer tends to be present where the water table is high. The thickness of this layer is commonly less than 3 meters (Constenius et al. 2018).

**Summary**

In this chapter I discussed the various physiographic characteristics of southern Utah Valley, which included: geography, geology, hydrology and climate. I introduced Wolf Village, Wolf Mound, and Snow Farm, the three archaeological sites that are the settings for my thesis research. Each site included a brief overview of its geographical setting, its history, and geological morphology. Understanding the geology of each site, and knowing what to expect stratigraphically, helped me to evaluate which geophysical methods would be the most effective
This chapter introduces the application of geophysical instruments within the discipline of archaeology, the scientific theory behind their functionality, and their use in the context of archaeological investigations. I include a brief history of archaeological geophysics and a literature review of archaeo-geophysical applications in the Greater Southwest region and the Fremont Cultural area to support the decision to perform a multi-instrument survey in Southern Utah Valley. This research helped identify certain aspects of geophysical prospection that worked in similar regional environments but are, for the most part, unused in the Fremont cultural area. Finally, I explain how magnetometry and ground penetrating radar work and why I used them for my thesis research.

**Introduction to Geophysics**

Archaeological geophysics, also known as remote sensing, is the measurement of physical properties at the ground surface to create images of the subsurface which can be interpreted by a geophysicist or archaeologist working together to identify subsurface features of cultural origin (Johnson 2005:1). Geophysical instruments are tools to infer the presence of cultural features before excavating. Geophysics can ultimately provide additional context for archaeologists (Johnson 2005:1). Geophysical surveys also help develop more sophisticated sampling strategies and detect the types of features (e.g., prehistoric houses) or data needed to address questions
about cultural history, site function, architecture, and other interests. In addition, the use of large-area geophysical surveys can reveal the overall spatial layout of sites, a scale that is rarely afforded by excavations alone (Ernenwein and Hargrave 2007:164).

The use of geophysical instruments in archaeology can be described as the analysis of spatial contrast. For example, an object/feature may possess or lack some measurable physical property that will make it “stand out” from the surrounding soil matrix. This results in the visual separation of that element from its background during digital processing (Figure 4.1) (Kvamme 2003). Varying levels of electric resistivity, magnetic susceptibility, and dielectric permittivity all influence how geophysical instruments interact with, and detect, archaeological remains; however, not all subsurface features are informative. Utility lines, pipes, trash, and other modern intrusions can litter project areas and obscure interpretations (Wulfrum 2008:12). This is why archaeo-geophysical practitioners use the blanket-term “anomaly” to represent a difference between locations of interest and the surrounding soil, whether ancient or modern; anthropogenic

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Figure 4.1. The visual separation (contrast) between anomalies and sterile background material in plan view. Adapted from Wolfrum 2019.
or natural.

The commonly applied techniques used to detect buried archaeological targets include the following:

*Direct Current (DC) Resistivity* – This method maps electrical variations in the ground. The traditional archaeological application of this method was to map lateral changes in shallow resistance, but recent advances in computer processing have allowed for the possibility of mapping the variations of electrical properties as 2D profiles or as 3D volumes.

*Electromagnetic (EM) methods* – EM methods can rapidly measure variations of soil electrical properties, as well as delineate the distribution of metallic objects. EM measurements are commonly applied to industrial “archaeology” to locate underground tanks or pipes, but certain types of equipment are effective in mapping changes in shallow soil properties.

*Ground Penetrating Radar (GPR)* – GPR can provide the highest resolution of any geophysical method but only when soil conditions are favorable. Typical archaeological applications include the mapping of graves, middens, buried foundations, and industrial targets such as buried waste, pipelines, and other utilities.

*Magnetic Intensity* – Measurements of the magnetic field are good for mapping fire hearths or other fired material and can also be sensitive to subtle variations of the ground where there has been a disturbance. When two magnetic sensors are used at different heights from the ground, the difference in response between the two sensors, the magnetic gradient, is especially sensitive to subtle near-surface variations of magnetic properties and is often the preferred method for surveying at archaeological sites (Johnson 2001:3).

There are many other geophysical techniques, and some have specialized application at archaeological sites, but the previously mentioned methods are the most commonly used for archaeological mapping. The best results are obtained when more than one technique is applied to the problem; however, the two most popular applications of geophysical instruments
in archaeology are magnetometry and GPR (Johnson 2006). These instruments fall into
two basic categories: active and passive. Active instruments emit a physical signal such as
electromagnetic pulses (GPR), into the ground to collect data based upon a response to those
signals (e.g., reflection and diffraction). Examples of passive instruments are magnetometers
and gradiometers, as these machines measure an already existing physical property, the earth’s
magnetic field, to detect anomalies within it (Ernenwein and Hargrave 2009:10-12; Johnson

**Brief History of Archaeological Geophysics**

Although many archaeologists in the United States may still view the use of geophysical
techniques as “high-tech,” none of the methods discussed in this chapter are new. According
to Ernenwein and Hargrave, “the first systematic geophysical survey on a U.S. archaeological
site was conducted at Williamsburg, VA, in 1938 by Mark Malamphy” (Ernenwein 2007:11).
Malamphy used equipotential (a method that is not widely used) to search for a stone vault
suspected to be associated with an early church. A promising anomalous area was identified but
excavation did not reveal any archaeological features. The area was resurveyed some 50 years
later and subsequent ground-truthing suggested that the geophysical anomaly was associated
Electrical resistivity was first used at an archaeological site in 1946 by Richard Atkinson. With a
Megger Earth Tester (then widely used in civil engineering) and a switching system of his own
design, Atkinson was able to detect moist, silt-filled ditches that were excavated into dry natural
gravel at Dorchester-on-Thames, UK (Atkinson 1953; Clark 1996; Gaffney and Gator 2003:14).
In the United States, Christopher Carr (1982) was an early advocate for using resistance survey
in archaeological research.

Another milestone application of archaeological geophysics occurred in 1958, when Martin
Aitken used a proton-precession magnetometer to detect an early kiln near Peterborough, UK (Aitken 1958, 1974; Gaffney and Gator 2003:16-17). Aitken also detected earth-filled pits - a capability that would have important implications for the widespread use of magnetic techniques in the United States.

During the 1970s, geophysics began to be integrated into archaeology in Great Britain and parts of Europe. Roman and late prehistoric sites in those areas often include metal artifacts, stone and masonry architecture, and fired clay roofing tiles. Such materials contrast sharply with their surroundings and were identified using pre-computer era maps that were characterized by relatively few widely spaced data points (Hargrave et al. 2002:89).

John Weymouth and Bruce Bevan conducted several early surveys in the United States that demonstrated the usefulness of geophysics, particularly at archaeological sites characterized by relatively high-contrast features. In the United States, however, the single most common type of prehistoric feature is the low-contrast earth-filled pit. For the most part, ferrous metal artifacts are absent in the prehistoric record in the United States, and stone architecture is found only in limited areas (Ernenwein 2007:12). It was not until the information technology revolution which facilitated the collection, processing, and mapping of thousands of data values that relatively subtle features like earth-filled pits could consistently be detected in magnetic surveys (Hargrave et al. 2002; Kvamme 2001). Ground penetrating radar was a somewhat later addition to the geophysical kit. GPR was initially developed to locate subsurface cavities such as mine shafts and tunnels. It was quickly adopted by geology, civil engineering, and many other disciplines (Conyers and Goodman 1997). In 1975, one of the first archaeological applications of GPR was conducted in an effort to map buried walls at Chaco Canyon, New Mexico (Vickers, et al. 1976).

Other early U.S. GPR surveys focused on historic features such as cellars and buried stone walls (Bevan and Kenyon 1975; Kenyon 1977). Use of GPR in the United States continued through the 1980s and 1990s, demonstrating the technique’s potential for detecting a wide
variety of feature types (Conyers and Goodman 1997:20). Although geophysics is not yet thoroughly integrated into cultural resource management (CRM) in the United States, more contract companies are using these methods than ever before (Kvamme 2001, 2003; Kvamme et al. 2006). A number of large area surveys (many of them unpublished but reported at professional conferences) have demonstrated geophysics’ potential contributions to archaeological investigations of late prehistoric and historic occupations (Butler, et al. 2004; Clay 2001; Hargrave 2004; Hargrave, et al. 2004).

Most of the archaeo-geophysical research in the United States is conducted in the Southeast. Additional geophysical surveys are likely to continue in the Southeast because of the nature of the area’s impressive archaeology, with large settlements, and mound complexes, its largely unknown state (from a geophysical standpoint) and its growing population density and associated development (and the local institutions with geophysical resources as mentioned above. In addition, thick vegetation makes it difficult to identify features and artifacts using typical pedestrian survey methods.

Archaeo-geophysical Applications in the Greater Southwest Region

Various environmental conditions (soil, climate, etc.) must be considered when conducting geophysical surveys using different methods. In order to better understand which geophysical methods work best in the Fremont Cultural area, I searched for archaeo-geophysical applications within the Greater Southwest and Four Corners region because of their fairly similar environmental conditions. A review of several studies in this region demonstrated that the southwest archaeological region has implemented geophysical surveys since Roger Vickers’s GPR survey of Chaco Canyon in 1977 (Vickers 1976). Geophysical application in the southwest region continues well into present-day with Shanna Diedrichs and colleagues (Diedrichs et al. 2017) who implemented a multimethod approach at the Dillard Site that incorporated magnetic
gradiometry, electric resistivity, and conductivity/magnetic susceptibility surveys (see also Conyers 1997; Watters 2013; Ryan 2015; and Sturms 2017). Diedrichs et al. (2017) demonstrated that magnetic gradiometry was the fastest, and most effective geophysical survey technique for consistently locating possible buried pit structures at the Dillard site. However, their combination of electrical resistivity and conductivity/magnetic susceptibility complemented each other by providing more detailed images of each pit structure that was originally discovered by the larger gradient surveys. Their study concluded that the most effective process for collecting geophysical data at Basketmaker III sites in the Southwestern Colorado, is to use a gradiometer to locate probable structures, then survey smaller sections over and adjacent to the gradiometer anomalies with electrical resistivity/conductivity to produce refined imagery of a pit structure. Much of the more recent literature (Kvamme et al. 2006; Ernenwein and Hargrave 2007; Deidrichs 2020; and Deidrichs et al. 2017) suggests that single geophysical techniques have faded in practice, and multimethod geophysical approaches are beginning to be more commonly used in this region.

I was only able to find three examples of geophysical applications specific to Fremont archaeological contexts: Range Creek in 2008, Wolf Village in 2012, and Wolf Mound in 2019. The following literature review was completed to illustrate which methods were used at specific archaeological sites and soil types as well as examine if a lack of archaeo-geophysical research was conducted in these regions.

**Range Creek**

In 2008, PBS filmed an episode of Time Team America in Range Creek Canyon east of Price, Utah. Their crews assisted in the University of Utah’s field school excavations and conducted geophysical scans of Big Village, a Fremont habitation under the direction of Dr. Meg Watters. The magnetometer scans identified several anomalies beneath the ground surface that appeared to have burned both interior and exterior rock alignments. These scans factored into the positioning
of their test trenches relative to the surface alignments (Boomgarden 2014:15). Unfortunately, this small section is all the information Boomgarden includes in her site report regarding the geophysical techniques they implemented at Range Creek.

**Wolf Village**

In 2011, Brigham Young University continued their field school at Wolf Village. The site was named “Wolf Village” after the landowner Buck Wolf. During this field season, Dr. John McBride of the BYU Geology Department conducted a 14 by 10 meter GPR survey exploring an area containing artifacts, an adobe linear alignment, and subsurface charcoal recovered using auger testing. Although the results of the 400 MHz GPR survey seemed unclear at the time due to the uneven ground and encumbrance by sage brush, the subsequent excavation of the area later revealed the remains of what was later called Structure 2. This structure is an unusually large sub-rectangular pit structure with roofed tunnels on the east and west and a small antechamber to the south. It is the largest known Fremont pit structure with a total floor area of 80.5 m² (Johansson et al. 2014:37). It was not until the structure was completely excavated when Dr. Jim Allison realized that he could see the western tunnel of Structure 2 in the GPR data. The GPR survey was conducted over the middle of the structure, and the pattern of the structure in the GPR plan view was not seen until after the Wolf Village field schools concluded in 2016 (Personal communication with Jim Allison 2020).

**Wolf Mound**

In the summer of 2019, Brigham Young University research archaeologist Scott Ure and associates conducted the most recent geophysical surveys in southern Utah Valley at the Wolf Mound site near Goshen, Utah. The mound was named “Wolf Mound” after the landowner Richard Wolf. The preliminary survey involved aerial imaging, aerial thermography, and ground
penetrating radar. Dr. Jon McBride, from Brigham Young University’s geology department, assisted with the GPR survey. The results of the GPR survey produced what appeared to be an approximate thermal image of a sub-rectangular structure (Personal communication, Scott Ure 2020). Following the geophysical survey, two trenches were excavated across the mound, one north-south, and the other east-west. Although the research is incomplete, Ure believes the mound may contain some architectural remains but further excavation is required to substantiate these early theories.

This relatively short section on the history of geophysics in the Fremont cultural area, illustrates that very little archaeo-geophysical surveys have been conducted. While it is possible that other geophysical work has been done and may be reported in less accessible outlets (e.g., technical reports, gray literature, etc.), I have only been able to identify three applications of archaeo-geophysical techniques utilized to detect Fremont architectural remains. All of these surveys were conducted within the last decade and produced sufficient results to influence subsequent excavation strategies, and ultimately the results of those excavations. This section also demonstrates the success of two different geophysical techniques, magnetometry and GPR, that were used within the Fremont cultural area to detect cultural anomalies.

Magnetometry

Magnetometry has been in use since the 1960s and remains one of the quickest, and most useful methods for archaeo-geophysical data acquisition (Armstrong and Kalayci 2015). Magnetometry is a passive data collection method that measures localized variations to the earth’s magnetic field (Figure 4.2). These variations, in the archaeological sense, are features that are magnetically different from the surrounding matrix (Kvamme 2006). Magnetic intensity values are measured in nanoteslas (nT= 10x-9 Tesla), which are a measurement of magnetic flux density or magnetic field strength (Armstrong and Kalayci 2015:2; Aspinall et al. 2008). For
reference, the earth’s magnetic field is approximately 50,000 nT, although this varies based on proximity to the equator or either magnetic pole (Milsom 2013).

Anthropogenic and natural transforms can influence the local changes to the earth’s magnetic field that would be discoverable via magnetometry. These are separated into either remanent or induced magnetization. Remanent, or permanent, magnetism, is a level of magnetization that has ‘remained’ after the initial process that created it has been removed (Kvamme 2006). Induced magnetization is a product of magnetic susceptibility, which is the degree to which a material can be magnetized. Both remanent and induced magnetization are essentially products of the iron mineral (hematite, magnetite, or maghemite) content of a material, e.g. the soil being modified by humans. Commonly, archaeological objects or features exhibiting remnant magnetism are either made of naturally magnetic stone like basalt or other have igneous rock, magnetic elements such
as iron, cobalt, or nickel and their alloys, or have been heated (Kvamme 2006). The application of heat introduces what is known as thermoremanent magnetism.

Thermoremanent anomalies are created by burning soil past the Curie point (approximately 100–600 degrees Celsius depending on the material) that noticeably realigns magnetic fields in certain features. Examples include long extinguished campfires or artifacts such as fired pottery sherds fired in a kiln (Maki et al. 2006; Milsom 2013; Schmidt 2007). Magnetotactic bacteria in soil may produce magnetic minerals in areas used by people in the past which creates a higher level of magnetization in topsoil relative to subsoil (this process is also impacted by natural pedogenesis or alternating dry and wet periods) (Aspinall et al. 2008:24-25; Fassbinder et al. 1990; Kvamme 2006:207-210; Linford 2005; Schmidt 2007).

The most common type of magnetometer used in archaeological surveys is the fluxgate gradiometer. This kind of instrument contains two sensors, usually in a vertical arrangement and separated by 0.5 to 1 m. These sensors (fluxgates) are two cores made of highly magnetic material wrapped in clockwise and counterclockwise coiled wires with a third “detector coil” wrapped around both sensors. If an alternating electrical current is passed through the coils, it creates a hysteresis loop that cancels out the net magnetization of the cores in the absence of an external magnetic field. When magnetic fields, such as that of the earth, are introduced to this system, the sensors are differentially influenced and are no longer “cancelled” out magnetically. The output voltage from the detector coil can be measured and the frequency observed is directly proportional to the magnitude of the introduced magnetic field (Linford 2006:2225). In other words, both sensors are equally influenced by the earth’s natural magnetic field, but their physical separation allows for the measurement of local derivations in magnetic fields directly below them. The lower sensors (those closest to the ground) will be influenced to a greater degree than the top sensors (Kvamme 2006). The subtraction of this difference is the vertical magnetic gradient at a fixed location which is typically recorded to a precision of 0.01 nT.
Ground Penetrating Radar (GPR)

GPR is perhaps the most relatable form of archaeo-geophysical prospection as the general principles of radar are easier to understand. Similar to airborne radar or marine sonar, energy is emitted from a known point and the return, or reflection of that energy, is used to measure distances from a target as well as the physical properties (dielectric permittivity) of the media. GPR is an active form of prospection that uses pulses of electromagnetic waves to record reflections and diffractions from changes in dielectric permittivity (Linford 2006). Electrical conductivity quantifies the ease of passage of an electrical current through a medium (the inverse to this property being resistivity). Dielectric permittivity is a material’s ability to store electrical charge and/or alter the frequency of electric waves which results in the reflection of energy (Linford 2006: 22-34). These waves are generated via an antenna that operates at a specific frequency that may range from 50 to 1000 MHz (Conyers 2004). When a wave changes its velocity, a portion of that energy is reflected back towards the surface and the antenna’s receiver.

As the dielectric permittivity of most soils are known, the depth of buried features can then be calculated. The time between emitting and receiving radar waves (millions of pulses per second) is measured in nanoseconds (ns) and is used as a proxy for depth below the ground surface (Conyers 2004).

As electromagnetic energy is propagated into the ground, it is absorbed at a differential rate based on the material it is passing through, and the waves change velocity accordingly. Impedance occurs at the transition between stratigraphic layers (e.g. sandy soil to clay to gravel) or with the presence of any number of buried features (e.g. graves, boulders, house floors, voids, etc.). The wave energy will eventually dissipate as reflections are attenuated by depth or impermeable mediums such as metal or bedrock. Low frequency waves (e.g. 50–250 MHz) generally penetrate deeper than higher frequency waves (e.g. 900+ MHz). But their ability to
resolve objects whose size is small relative to the wavelength is far reduced. Conversely, higher frequency waves require a denser sampling strategy for archaeological purposes and can delineate thinner strata but at a reduced depth of penetration (Conyers 2004).

GPR’s effectiveness relies on the physical or chemical difference between subsurface mediums, a significant contrast between strata and/or features must exist for meaningful interpretation to occur. GPR antennas are moved across the ground in transects, or straight paths, with millions of reflections being recorded over the course of the transit. As the radar unit is attached to a moving conveyance (e.g., a modified jogging baby stroller), and waves are emitted in a conical shape, the reflections are recorded before, during, and after the antenna has passed over reflective objects or materials (Figure 4.3). This causes distinctive hyperbolic anomalies
for objects that are small with respect to the wavelength of the signal (as the waves appear to “wrap” around them) as well as sloping or flat line anomalies that represent linear surfaces (i.e., the width of the reflector is large compared to the wavelength). These transects can be surveyed in parallel profiles or a regular grid, and the amplitudes interpolated between survey transects to create a volume of data that can be sliced into plan-view images. The advantage of this volumization is the ability of GPR software to take thin sections, measured in nanosecond or centimeter slices to effectively peel the subsurface away and successfully reveal potential features. Three dimensional models of subsurface features can be constructed, using the known depth and relative size of anomalies are known. This makes GPR s unique method compared to other methods of geophysical prospection (Conyers 2018).

Archaeologists have used geophysical techniques for many years, and the basic interpretation strategies have not changed much over that same amount of time. What has changed, however, is an increase in data collection speed. Also, more powerful computers and improved software have revolutionized data processing and presentation, resulting in improved subsurface anomaly identification and subsequent interpretations.

**Summary**

Geophysical prospection in archaeology has a long tradition but is currently more popular in Europe. In his seminal article, Kvamme (2003) brought to the North American archaeological community’s attention the power and potential for geophysical application to the archaeological record. Geophysics in North American archaeology has steadily grown in both the academic and cultural resource management undertakings. The next section of this paper presents the history of data acquisition and processing systems that have been applied in North American settings.

In this chapter I have discussed the application of geophysical techniques in archaeology, including a general overview of how geophysics works, which instruments can be used for
geophysical prospection, and how these methods can benefit archaeological exploration. I provided a brief history of archaeo-geophysical literature in the Greater Southwest region, then narrowed that review to the borders of the Fremont Cultural area in order to illustrate the sparse nature of geophysical application in the Fremont region.
This chapter introduces the methods I used to acquire geophysical data at Wolf Village, Wolf Mound, and the Snow Farm Site. I first review the organization of my methods that are based on Ernenwein and Hargrave’s (2007) guidelines for directing geophysical surveys. I then explain what influenced the survey design for each site and summarize the geophysical fieldwork and data acquisition methods. I conclude the chapter by explaining the data processing methods I used from the geophysical data collected at each site.

**Survey Design**

Ernenwein and Hargrave’s 2007 publication entitled *Archaeological Geophysics for DOD Field Use* aids in: 1) guiding the researcher through the history of geophysics, 2) the basis of geophysical methods, 3) estimating the suitability of a site for geophysical survey, 4) choosing suitable geophysical methods based on environmental conditions, 5) selecting appropriate instruments, 6) designing a field strategy, 7) estimating time and cost, 8) and what to expect during a geophysical survey (Ernwein and Hargrave 2007:9). By using this outline and my review of the literature about the applications of geophysical techniques in this area, the geophysical methods could then be determined based on environmental conditions of each archaeological site.

It is important to understand each site’s physical characteristics and the types of
archaeological deposits that are expected, since the buried features present may simply not exhibit enough contrast with their surroundings to be detected by any given geophysical method.

Certain environmental conditions can be beneficial for some methods but adverse to others. If conditions are dry and desert-like, GPR is best, followed by resistivity. As the percentage of clay minerals increases, conductivity increases, especially when wet, and this can limit GPR depth penetration, but conductivity and resistivity survey are also promising if the clay density does not significantly impede probe insertion (Ernenwein & Hargrave 2007). In the case of magnetic methods, environmental conditions are less important. Moisture, sediment size, and salinity do not generally affect magnetometers. Topsoil thickness and magnetic richness relative to the subsoil (i.e., the contrast between the two), as well as the magnetic properties of local and imported rock usually dictate a successful magnetic survey (Clark 1996). Magnetometry is also useful in environments with very weak magnetic soils because it measures remnant magnetic fields, which are often created by burned archaeological features and features that include magnetic rock. Overall, magnetometry seems to work well in most environments in North America (Kvamme 2006b).

Selecting Sites

Wolf Village and Wolf Mound were selected as test sites given the previous excavation work at both sites, as well as the ongoing support from the current land owner, Mr. Richard Wolf. I initially planned to visit the Paragonah Mounds owned by the Archaeological Conservancy and located in Paragonah, Utah. However, due to the COVID-19 pandemic, BYU restricted travel for all BYU employees and students which eliminated Paragonah as a test area for my thesis. However, as luck would have it, a Payson landowner and employee of BYU contacted Rich Talbot, director of the Office of Public Archaeology at BYU, and showed him some artifacts from the Snow farm in Payson, Utah. Rich Talbot, Scott Ure, and Dr. Michael Searcy visited
the site and observed numerous surface and collected artifacts, as well as a large hole (ca. 4 by 4 m) intersecting the remains of what appeared to be an architectural feature. Talbot, Ure, and Searcy concluded that the Snow farm had substantial archaeological significance. After visiting the site for myself, now designated as 42UT2274, it was clear that the soil at the farm could be conducive to geophysical testing, and since there was parcel of land already cleared next to his crop, it seemed like a great third option for geophysical testing.

As I mentioned in Chapter 3, the geological physiography of each site varied considerably between all three sites. The physical characteristics and environmental conditions at Wolf Village, Wolf Mound, and Snow Farm suggested that magnetic gradiometry and GPR would be suitable geophysical methods for each site. Therefore, I conducted this multi-methodological approach to compare results from each method given the varied environmental conditions between the three sites.

**Selecting Appropriate Instruments**

The magnetometer I used for my surveys is the Bartington 601-2 (Figure 5.1) which consists of two fluxgate gradiometers mounted one meter apart from each other. Each of the gradiometer tubes contains a pair of fluxgates which are separated vertically by one meter. Increasing the vertical separation creates a bigger signal difference for the same gradient which results in increased sensitivity (Oswin 2009). I also used a GSSI SIR-3000 GPR 400MHz acquisition system from the Geology department at BYU. This GPR unit is controlled by the console mounted high on the three-wheeled stroller (Figure 5.1). The antenna is mounted under the stroller and connected to the console and the battery at the top of the stroller. The survey wheel behind the antenna is of known diameter, so that distance moved by the radar can be measured as it turns. In regards to this project, the order of instrumentation at each test site was magnetometry first, and GPR last, due to the slower acquisition, and the need for the soil to be drier.
Designing a Field Strategy

The three sites were surveyed in the order they were made available by the land owners. Mr. Richard Wolf, the land owner of Wolf Village and Wolf Mound, recently relocated his cows grazing on the land where Wolf Village was located, and Wolf Mound was still drying from its late fall irrigation and was about to have its first alfalfa cut of the season. Snow Farm was also in the middle of irrigating a large hemp crop in the beginning of July. Therefore, by default Wolf Village was a better option for the first magnetic gradiometer survey, followed by Wolf Mound, then Snow Farm. GPR was performed later on in August at all three sites so that the soil would be dryer at the end of the summer and in an ideal state.

Magnetic Gradiometer Setup

At the beginning of each magnetic gradiometer survey I turned on the Bartington Grad 601 to warm up for 15 minutes. This prevents any drift in readings due to diurnal changes on the earth’s magnetic field sometimes related to weather disturbances. After the instrument is ready, I enter the parameters for the survey including the instrument operator’s pace and stride. The Bartington
Grad 601 constantly records averages of the magnetic variation it encounters, so walking slowly improves data collection and subsequent results. I set the walking pace to 1.0 meter per second to match my height and stride. These settings follow the parameters recommended by Jason Hermann who created a simple users guide for the Center for Advanced Spatial Technologies in Arkansas. They are as follows:

a. Pace: the walking pace of the operator. Most surveys are between 0.7 and 1.0 meter per second.

b. Grid size: 20 by 20.

c. Starting direction: North to South with the point of origin in the Southwest corner of the grid. The traverse pattern was set to Zig Zag, which is faster than the parallel option.

d. Lines per meter: Two (2) lines per meter is standard (50 cm transect spacing).

e. Samples per meter: Eight samples per meter is the standard setting for a 20 by 20m grid.

f. Range: The 100 nT was selected for higher resolution data.

g. Threshold: 100 nT was chosen so that anything with a value over 100 nT would cause the alarm to sound.

h. Sensors: 2

i. Reject: A frequency of 60Hz was chosen to reduce noise in the data caused by the instrument.

Once the instrument parameters were set, I tuned the instrument to ensure accurate results. This is a crucial step and requires finding a magnetically “quiet” spot. This is done by setting the gradiometer to SCAN and walking back and forth in a straight line in an area totally free of magnetic disturbances until the nT readings of both sensors are low (within -0.15nT of each other). I then used a compass to accurately identify the cardinal directions which are marked
using wooden stakes placed at each cardinal direction around the “quiet spot”.

The next step is to “zero” the instrument which means to calibrate the magnetometer as close to 0.0 nT as possible for more accurate data. The magnetometer should be held as high as possible above the ground to get the best results during this process. The operator should stand on a non-metallic platform (plastic milk crate or something similar) while performing these adjustments. The instrument should be attached to the shoulder harness and held level and at a constant height while rotating to each of the cardinal directions when prompted. Once the instrument is tuned, the operator should run the “scan” function while facing north and make sure both sensors are reading close to 0.0 nT. If this is the case, then the instrument is ready for collecting data.

**GPR Setup**

A SIR Systems-3000 manufactured by Geophysical Survey Systems, Inc (GSSI) was used to acquire GPR data. Upon arriving at each site, the survey cart was assembled. After this, the 400 MHz bistatic antenna was mounted to the cart, as well as connected to the survey wheel. The survey wheel is used for calibration and for setting distance related acquisition parameters. The SIR-3000 control attaches to the survey cart and connects to the 400 MHz antenna (Figure 5.1). A 400 MHz antenna was selected given the silty clay soil. I assumed these soil conditions would offer the most radar wave penetration and highest resolution.

Environmental factors such as local soil, moisture, bedrock and rock inclusions should be considered when setting parameters for data acquisition. Dielectric constant (permittivity) is a critical GPR parameter that influences the propagation velocity of electromagnetic waves through a material. Estimating the expected dielectric constant value is helpful for planning GPR surveys and subsequently interpreting GPR images. The GSSI SIR 3000 manual’s “Dielectric Value for Common Materials” (Table 5.1) is a useful guide for choosing a suitable dielectric
value in the field (Geophysical Survey Systems Inc., 2017:72). The dielectric value was estimated in the field based on the local soil conditions observed.

The “range” is the next parameter to adjust prior to conducting a GPR survey. The range is the time window in nanoseconds (ns) that the SIR 3000 will record radar wave signals. Range can be understood as recording in two-way travel time for reflection, so that a range of 50 ns means that the “deepest” reflector corresponds to one-way travel time of 25 ns. The range was set to 70/ns for each of my surveys so that the deepest reflector corresponds to 35 ns. Next, the “rate” parameter was set. The rate is the number of scans the system will record in its RAM per second. The rate for each survey was set to a value of 64. The “scan” parameter is set last. The Scan setting is the number scans per unit of horizontal distance. This parameter is the scan spacing when collecting with the survey wheel. A smaller scan spacing produces higher spatial mapping but larger file sizes. The Scan parameter was set to 12, meaning that 12 scans would be recorded per foot.

<table>
<thead>
<tr>
<th>Material</th>
<th>Dielectric</th>
<th>Velocity (mm/ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>Water</td>
<td>81</td>
<td>33</td>
</tr>
<tr>
<td>Coastal Sand (dry)</td>
<td>10</td>
<td>95</td>
</tr>
<tr>
<td>Sand (dry)</td>
<td>3 to 6</td>
<td>120-170</td>
</tr>
<tr>
<td>Sand (wet)</td>
<td>10</td>
<td>55-60</td>
</tr>
<tr>
<td>Silt (wet)</td>
<td>10</td>
<td>95</td>
</tr>
<tr>
<td>Clay soil (dry)</td>
<td>3</td>
<td>173</td>
</tr>
<tr>
<td>Clay (wet)</td>
<td>8 to 15</td>
<td>86-110</td>
</tr>
<tr>
<td>Marsh</td>
<td>12</td>
<td>86</td>
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<tr>
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<td>77</td>
</tr>
<tr>
<td>Pastoral Land</td>
<td>13</td>
<td>83</td>
</tr>
</tbody>
</table>

*Table of Dielectric values adapted from Geophysical Survey Systems Inc, SIR 3000 Manual.*
Wolf Village Magnetic Gradiometry Survey

Establishing the Survey Areas at Wolf Village

With the help of Scott Ure and Michael Searcy, we first determined the size, shape, orientation, and exact location of the survey areas at Wolf Village using aerial imagery from Google Earth as a basic guide. The survey locations were determined based on previous excavations and the locations of formally identified structures and surface artifacts. I used a 20 by 20 m grid following the Ernewein and Hargrave (2007) recommendations for magnetic surveys. This size is commonly used in software packages that process magnetometry and resistivity data and requires all grids to be the same size. However, when collecting GPR data, I used a 40 by 40 m grid as they effectively line up with the 20 by 20 m tiles of other surveys. Essentially this convention means there are only one quarter as many tiles to process.

The survey areas were chosen in consultation with Dr. Jim Allison and a surface artifact map created by Scott Ure in 2011. The map marked the location for each surface artifact at Wolf Village found during a systematic survey of the site. This map indicates that some artifacts were found in a clearing southeast of BYU’s field School excavations from 2009–2016. The clear area had little vegetation and proved to be an ideal area for my surveys. I also wanted to include part of a partially excavated pit house (Structure 9) in my survey area as a reference point to previously identified archaeological deposits.

After relocating a secondary datum (F23) just to the north of Structure 1, I established several 20 by 20 meter grids aligned with the established Wolf Village excavation grid. In total, I defined six survey areas in two different regions. The first region incorporated survey areas 1–4 which are east of Structures 1, 2, and 9 (Figure 5.2). The second region includes areas 5–6 and is in a clearing to the north of Structure 2 at the base of the hill. The second regions was placed in this location due to the lack of vegetation and its proximity to other previously excavated structures.
This region includes two 20 by 20 meter areas (5 and 6). A wooden stake was placed on each grid corner with a grid designation written on each corner marker. Each stake was recorded with a total station in the local grid system, as well as on a Trimble 7X GPS equipped with a tornado antenna. The GPS coordinates were recorded using NAD83, Zone 12 north.

**Wolf Village Survey Area Preparation**

Vegetation in the survey areas taller than one foot was removed to improved access. Survey areas 1–3 and 5–6 were mostly clear of vegetation besides low stands of cheat grass, the removal of larger vegetation did not take long. Everything west of the modern ditch in Area 4 was thickly covered in greasewood and required several hours to remove.
Simple metal detectors were used to identify any metal debris that can interfere with magnetometer surveys. Digging was limited to also reduce their presence in the results. This proved useful because Area 4 had metal chaining pins, horseshoe nails, and a battery, all of which would have produced false anomalies in the magnetometry results. Metal debris, or historic trash, was also found in Area 5 which was recorded with the GPS.

Wolf Village Magnetometer Data Collection

Once the Bartington magnetic gradiometer was set up using the methods described earlier, the operator can start collecting geophysical data. A common method in North America is to lay out a survey area with markers every 20 meters. Two long measuring tapes are used at either end. The “ropes” or lines for the operator to follow are placed perpendicular to the measuring tapes and mark the survey lines. Both long tapes were offset by 50 cm so the ropes laid across each meter mark. Using this technique, there were no locations in the grid more than 1 m away from a survey rope, so the data overlap was every 50 cm, which allowed the distances along each transect to be easily estimated for rapid surveying.

I started each survey in the southwest corner, facing north, with the Grad 601-2 attached to the harness and the bottom of the sensor held between ca. 20 to 25 cm above the ground surface (Figures 5.3 and 5.4). I placed my feet on the one meter mark with the left antenna on the 1.5 m mark and the right antenna on the other 0.5 meter mark. This created a 50 cm overlap for each transect. I started each survey by pressing the “enter” key, or the green button on the instrument and then pressed it again at the end of the transect. The Grad601-2 beeped every time I passed over a meter mark on the survey rope and beeped twice at the end of the transect at the 20 meter mark. This pace was established in the instrument settings at 1 meter per second.
Figure 5.3. Photo of the author using the Bartington Grad 601-2 Fluxgate Gradiometer to collect data at Wolf Village. Photo taken by Michael Searcy.

Figure 5.4. Image of the Wolf Village (42UT273) grid 4 with the magnetic gradiometer transect orientation, and starting point.
Wolf Village GPR Survey

GPR Data Collection

Dr. John McBride, a professor of Geology at BYU, used his SIR Systems-3000 GPR manufactured by Geophysical Survey Systems, Inc (GSSI) to acquire GPR data at Wolf Village. We first assembled the survey cart. The dielectric permittivity of loamy/clayey soils varies depending on moisture content. The topsoil was very dry on the day we collected data at Wolf Village. We set the dielectric constant to 10 based on the assumption that we would encounter clay. This value represents an average of the expected dielectric permittivity for wet and dry loamy soil and clay (see Table 5.1). The maximum depth expected for reliable imagery was three feet based on the antenna wavelength (400 MHz) and the selected dielectric constant. This depth was considered more than enough to identify any potential subsurface targets.

In consultation with Dr. McBride, I determined that the area with the highest potential was in grids 3 and 4 due to the close proximity to previously excavated structures and presence of adobe on the surface of grid 4. I created a 20 by 40 meter GPR grid (both grids 3 and 4), and tape measures were used to ensure correct navigation along transects. Sam Jensen and John McBride pulled tape measures for the next traverse while I acquired data using the GPR. I started in the southwest corner of the 20 by 20 m of grid 4, or the southeast corner of GPR grid 1 (Figure 5.5) and moved east 40 meters through grid 3. This process allowed for quick, efficient data acquisition along straight, parallel traverses. Once the data for one traverse were collected, the unit was moved to the start of the next traverse. Each traverse was spaced one foot from the previous one (Figure 5.6).

The control unit displayed data in real time, allowing for rapid, in-field interpretation during data acquisition. Notes were taken of each anomaly as they were seen in real time; however, there were rarely any anomalies observed on the screen while I was acquiring the data. The survey area totaled 64 parallel transects. Protruding stumps from recently cut brush
Figure 5.5. Image of the Wolf Village (42UT273) GPR grid transect orientation and starting point.

Figure 5.6. Photo of the author collecting GPR data at Wolf Village (42UT273) using the GSSI SIR 3000 with a 400 MHz antenna.
and a two-foot-deep dry canal that ran perpendicular through the survey area were problematic obstructions. Although these concerns were valid, later processing revealed that the stumps did not affect the data, but the canal was one of the strongest anomalies in the data.

*Estimating Time and Cost at Wolf Village*

I estimated that a 20 by 20 meter magnetometer survey with transects every meter could be completed in half an hour with a 50 cm internal. I projected that I could complete 14 survey grids in eight hours. I estimated that the magnetometer survey and GPR Survey at Wolf Village would take three days. Setting up the grid, clearing the brush, metal detecting, collecting magnetometer and GPR data took around four days. The extra day was spent setting up the grid and clearing the vegetation. We took longer than anticipated because it was the first time collecting data, so there was a learning curve with the site setup and instrument operation.

*Wolf Mound Magnetic Gradiometer Survey*

*Wolf Mound Survey Area Preparation*

On July 14th, 2020 Scott Ure, Ridge Anderson, and I prepared the Wolf Mound site for magnetic gradiometer surveying. I used the same methods as described at the Wolf Village site just 1.5 miles south. In consultation with Scott Ure, who previously conducted remote sensing and excavations at the site, I first determined the size, shape, orientation, and exact location of the survey grid. I used 20 by 20 meter grid sizes for magnetic surveys because these are the most commonly used sizes in data processing software packages for magnetometry and resistivity. These applications require all survey tiles be the same size.

The survey location was influenced by prior excavations at the mound in 2019. The first 20 by 20 m grids included the area where limited excavations revealed possible adobe wall sections. My plan was to use these known buried features as a control to see if there was anything else to
the mound. I set up the total station on the primary datum and established 20 by 20 meter grids in correlation with the previously established Wolf Mound excavation grid. In total, I created fourteen grids. Grids 1–2 incorporated the mound, and 3–6 were located south of the mound and included the primary datum. This was done in hopes of finding any features possibly associated with the mound (Figure 5.7). Grids 7-12 were all located directly northwest of the mound sharing the same grid corner 974 E. 1032 N. This was done in hopes of finding the source of a false color anomaly identified in Google aerial imagery at Wolf Mound. Grids 13 and 14 were added last and placed directly north and west of grid 1.

A wooden stake was placed on each grid corner and a grid designation was written on
flagging tape. Each grid corner was recorded with the total station using the local grid system, as well as on a Trimble 7x GPS using NAD83 zone 12 for later data processing.

**Wolf Mound Survey Area Preparation**

The site of Wolf Mound is located in an alfalfa field, so the vegetation was easy enough to manage because it had previously been cut relatively short by the landowner a few weeks before and bailed into large square bails. Alfalfa bails did get in the way of some of the grids, so they were rolled ten meters away from the edge of each survey grids so they did not obstruct the magnetometer survey. After the grid markers were staked in, grid designations were written on the markers, and GPS points were taken, I used the metal detectors to remove any surface metal debris from the area that could disrupt the magnetic readings without digging too far into the survey area surface. The metal detector survey uncovered large bolts, barbed wire, nails, and an old tractor wrench.

**Wolf Mound Magnetometer Data Collection**

I set up the magnetometer using the same settings used at Wolf Village. I then placed two long tapes across either end of the grid horizontally, and the survey ropes were placed north to south along survey lines every meter. Both long tapes were offset by 50 cm so the ropes would be placed on each meter mark. I began each grid in the southwest corner facing north (Figure 5.8). Each transect began with my feet located on meter 1 and the left antenna on .5 meters and the right antenna on the other .5-meter mark. This permitted a 50 cm overlap for each traverse. I started with grids 1 and 2 (the grids covering the mound), and then Ridge Anderson collected data at grids grids 3 and 4. Two days later, I surveyed grids 5 and 6 and 6 through 12 were finished soon after. Just to be sure that we were consistent, we re-surveyed grids 1 and 2 that
same day as well. Two days later, grids 13 and 14 were added to the grid (see Figure 5.7) and surveyed with the magnetic gradiometer. A total of fourteen 20 by 20 meter grids were surveyed using magnetic gradiometry.

**Wolf Mound GPR Survey**

**GPR Data Collection**

On August 18th, 2020 we brought out the BYU Geology’s GSSI SIR Systems-3000 with a 400 MHz antenna to acquire GPR data. Similar to the methods at Wolf Village, the 400 MHz antenna was selected with the hopes that it would allow for the greatest depth of penetration in the silty clay soil and with the highest resolution. As described above, the dielectric permittivity
of loamy/clayey soils range drastically depending on moisture content (see Table 5.1). On the
day of acquisition, the topsoil at Wolf Mound was very dry. This, combined with the assumption
that clay would be encountered .30 m down, led to the selection of a dielectric permittivity
constant of 10 that represented an average between the values expected for wet and dry loamy
soil and clay. Using the 400 MHz antenna and the selected dielectric constant, the maximum
depth expected to be reliably imaged to be around one meter, which was close enough to image
the target.

After reviewing the magnetic gradiometer data in the field, it was determined that the area
with the most likely success was going to be in grids 1 and 2 because of the presence of the
mound in these grids and the lack of magnetic anomalies in the other grids. With that in mind, I
decided to make a 20 by 40 meter GPR grid (both grids 1 and 2). Acquisition began immediately
after the GPR unit was set up. In order to assure correct navigation along correct traverses,
tape measures were used. With a team of four (Scott Ure, Ridge Anderson, and myself), they
began stretching out the tape measure for the next traverse, while I acquired data. I began in the
southwest corner of grid 1, or the southeast corner of GPR unit 1 moving east 40 meters through
grid 2 (Figure 5.9).

As GPR data was acquired, the control unit displays the data in real time, allowing for
rapid, in field interpretation. Along the first few traverses, notes were taken of each anomaly as
they were seen in real time. Much like at Wolf Village, there were rarely any anomalies seen
on the screen while I was acquiring the data. Since each transect was one foot apart, the survey
ended up being a total of 64 parallel transects. The 2019 trench excavations on the mound that
were backfilled had been compacted by livestock and sunk down into the trenches leaving
perpendicular ditches in the mound. Much like the ditch at Wolf Village, this proved to be
difficult to navigate with the GPR stroller. On each transect, the antenna would get caught or
jostled, thus concerns arose while acquiring GPR data at this site. Although these concerns were
valid, later processing revealed that the trenches did not appear to affect the surrounding data, but the trenches attenuated through the data, which made it difficult to identify anomalies within the mound itself.

I originally expected the geophysical surveys of Wolf Mound to take no more than 3 days, however, the magnetometer surveys took up three days by themselves, and the GPR survey took on entire day. The average time to survey each 20 by 20 meter grid was much faster than at Wolf Village, with each grid taking anywhere from 20-30 minutes.

Snow Farm Magnetic Gradiometer Survey

Establishing the Snow Farm Survey Area

I arrived at the Snow Farm site on August 20th, aided by Scott Ure and Sam Jensen. I used the same methods established at Wolf Village and Wolf Mound. I first estimated the site size, shape, orientation, and exact location for the survey grid.
The grid location was ultimately influenced by wherever the landowner was not growing his crop. The only areas large enough and clear enough to survey were east of the hemp crop (Figure 5.8) and south into a small hay field. Once the survey areas were identified, a local grid system was set up using a Trimble S8 robotic total station. I set up the total station on a primary datum established south of the crop field, on the south side of the irrigation canal and then defined the 20 x 20 meter grids with wooden corner stakes. I was only able to set up five grids that were outside of the landowner’s crop. These locations were selected primarily based on the presence of surface artifacts (including adobe), as well as out of convenience for the landowner (Figure 5.10).

A stake was placed on each grid corner with a grid designation written on each stake. Then, each stake was recorded with the total station using the local grid system, as well as with a Trimble 7x GPS equipped with a Tornado antenna S using NAD83 zone 12 for later data processing.

**Snow Farm Area Preparation**

The site of Snow Farm is located in various adjacent fields, so the vegetation was easy enough to manage because it had previously been cut and plowed by the landowner a few weeks prior. After the grid markers were staked in, grid designations were written on the markers, and GPS points were taken. Once again, I used the metal detectors to remove the area of any surface metal debris that could influence the magnetic readings without digging too far into the survey area surface. The metal detector survey uncovered a swath of metal debris, which included horseshoe nails, large bolts, barbed wire, and old tractor parts.
Identical to the methods at Wolf Village and Wolf Mound, once the instrument was setup, two long tapes were laid down at either end of the grid horizontally, and the rest of the ropes are laid down vertically along survey lines at all odd meters since I was surveying north to south. Both long tapes were offset by .50 cm so the ropes would be placed on each meter mark. Using this technique, there were no locations in the grid that are more than 1 m away from a survey rope, so like before, the data overlap was every .50 cm, which allowed the distances along each transect to be easily estimated for rapid survey.

With the Grad 601-2 strapped to the harness, the bottom of the sensor was held between ~.25 m to ~.20m off the ground, and I would head to the start point of the survey. Since the transects were oriented north, I began each grid in the southwest corner facing north (Figure 5.11). Each transect began with my feet located on meter 1 and the left antenna on .5 meters and the right
antenna on the other .5-meter mark. This permitted a 50 cm overlap for each traverse. The order to which the Snow Farm magnetic gradiometry data was collected was first with grids 1 and 2 (east of the hemp crop), with the help of Scott Ure and Sam Jensen. Grids 3, 4, and 5, located just 20 meters to the south of grid 1, were then surveyed. A total of five 20 by 20 meter grids were surveyed with the instrument all within that same day.

**Snow Farm GPR Survey**

**Snow Farm GPR Data Collection**

On August 25th, 2020 we brought out the BYU Geology’s GSSI SIR Systems-3000 to acquire GPR data. Similar to the methods Wolf Village and Wolf mound, on the day of acquisition once the instrument was setup, the soil at Snow Farm was examined to determine the dielectric permittivity. The topsoil at Snow Farm was very dry and sandy. This led to the selection of a
dielectric permittivity constant of 6. That represented an average between the values expected for wet and dry loamy soil and clay (see Table 5.1).

After reviewing the magnetic gradiometer data at Snow Farm, it was determined that the area with the most likely success was going to be in grids 1 and 2 because of the amount of the magnetic anomalies present, surface artifacts, and proximity to the looters pit on the south side of the hemp crop. With that in mind I decided to make a 20 by 40 meter GPR grid (both grids 1 and 2). I began in the southwest corner of the 20 by 40 m GPR grid unit (Figure 5.12) moving north 40 meters through grid 2. This process allowed for quick, efficient acquisition along straight, parallel traverses. Once the data for one traverse were collected, the unit was moved to the start of the next traverse. Each traverse was spaced 1 foot from the previous traverse. Since each transect was one foot apart, the survey ended up being a total of 64 parallel transects. The acquisition of GPR data at this site was virtually seamless due to the recently plowed field and no surface impediments.
I originally expected the geophysical surveys of Snow Farm to take no more than two days, and my assumptions were correct. Establishing the grid and the magnetometer surveys took one day, and the GPR survey took one day as well. The average time to survey each 20 by 20 meter grid was much faster than at Wolf Village and Wolf Mound, with each grid taking 15–20 minutes. This was likely due to no surface impediments and more experience using the instruments at the other two sites prior to the Snow Farm surveys.

Data Processing

Data was processed for each instrument directly after the workday, providing an up-to-date look at possible areas of interest. This also ensured that any data collection issues encountered the previous day could be remedied. The software used to analyze each instrument’s data is different, but all of the results were imported into Adobe Illustrator as individual layers using the MAPublisher GIS plugin.

Magnetometry Data Processing

The software used to process the magnetic gradiometer data for this project was the ArchaeoFusion software. ArchaeoFusion was designed as a platform to integrate, as much as possible, the various processes required in a multi-sensor survey approach. The ArchaeoFusion software was developed by the Environment Security Technology Certification Program and is a user-friendly software tool that allows a wide range of users benefit from its increased reliability, reduced invasiveness, and reduced costs. In short, ArchaeoFusion serves as a geophysical infusion tool. ArchaeoFusion provides a full range of data processing and integration options for the expert user as well as preloaded macros designed to guide novice and intermediate practitioners through the processing steps (Ernenwein 2014).

Downloading data from the Bartington Grad 601-2 requires a serial port that connects
directly into a PC. The Bartington “GRAD 601” app converts the magnetic gradiometer files into “.dat” and “.hdr” files that can be renamed and organized for optimized data processing. It is crucial that both file types are located in the same folder for data processing.

Once the magnetometry data is uploaded onto a computer and placed in a single folder location, the data can then be loaded into the ArchaeoFusion software. This program requires defining certain parameters before any files are loaded. ArchaeoFusion allows visualization and organization of individual grids/tiles according to the order they were recorded (Figure 5.13). It was crucial that each file was named with its corresponding grid designation to ensure the correct spatial placement when loading the file.

Several data filters were applied after the data was uploaded and organized. Spatial filters are mathematical processes applied across a series of values. In this case, each magnetometer grid is an image constructed using ~36,000 data points arranged in rows and columns as tabular .txt
(text) files, each with a numerical positive or negative value in nanoteslas. The filters I used were based upon those defined by Eileen Erenwein et al. (2014) in *Streamlined Archaeo-Geophysical Data Processing and Integration for Department of Defense Field Use*. This guide explains that magnetometry data should be destriped, clipped, destaggered, and smoothed (Erenwein et al. 2014:254). I followed this same workflow (Figure 5.14).

The finalized images were imported into MAPublisher after the filtering processes were complete. The data was georeferenced using the local coordinate system based on the primary datum with a false easting and northing of 1000 E 1000 N. Each of the 27 grids surveyed for this project were stitched together at their corresponding sites to form a contiguous mosaic of the surveyed area. Magnetometer and GPR data were placed on different MAPublisher layers.

Figure 5.14. Screenshots of the processing parameters in ArchaeoFusion (Erenwein and Hargrave 2006).
GPR Data Processing

I originally planned to use *ArchaeoFusion* to process the GPR data because it has the capability to run GPR data, as well as overlay and fuse GPR and other geophysical data. I quickly realized, however, that *ArchaeoFusion* GPR processing lacks good resolution and spatial quality.

I decided to use RADAN 7 to process my GPR data instead because it is relatively straightforward to use in most cases. Data processing in RADAN allows users to process large data sets with ease (Geophysical Survey Systems Inc., 2017). This software has a multitude of processing steps available, but in most cases only a select few are needed.

Purpose of Processing GPR Data.

There are many issues affecting the propagation of GPR pulses through the subsurface. This may pose some issues when analyzing and interpreting the resulting data, particular processing steps are employed to minimize these issues. There are many options for processing, however, only a handful of these steps are typically used, and for my research, very few were needed to accurately interpret the data.

Data were collected at each site in parallel directions and were recorded in feet. To ensure that the data were viewed using feet as the scale, the “vertical units” and “horizontal units” options were set as feet on the “home” tab of RADAN 7. Since the data was acquired from west to east, I had to ensure that each file all matched the west to east orientation.

During acquisition, the antenna is held in place and transported on the cart by a small basket that rides slightly above the ground surface. This results in the recorded data include information for the separation between the antenna and the ground surface. This effect (data or gap) must be removed to attain proper apparent depths to interfaces. To remove this data, I selected the “time zero” option in either the “easy processing” tab or the “processing” tab. The “time zero” option is also located in the panel on the left of the screen under the “processing” tab within “step 1”.
Once this option is selected, a “wiggle trace” will appear representing a recorded wavelet. The user simply adjusts this wiggle trace to line up with the first peak, thus removing the antenna-ground surface gap.

In most GPR surveys, the direct arrival and a shallow refracted arrivals are included in the recorded data and propagate over later record times (including the “ringdown” effect). This data can be removed by the user by selecting the “background removal” option which is found on the same tab as the “time zero” tool. If using the left panel, this option is located under Step 2. For this project, the “full pass filter” was used to remove specific frequencies and improve identifying anomalies. After the background noise was removed, the gain was changed to 6 to slightly increase the amplitude of the remaining signals (Figure 5.15).

Figure 5.15. A screenshot of the RADAN software, showing the GPR profiles at Wolf Village after concatenation.
Summary

This chapter described the survey design, data acquisition, and data processing for three Utah Valley archaeological sites. For each of the sites, it was important to establish a survey method best suited for locating the desired targets, in this case 50 cm magnetometer transects across numerous 20 by 20 m grids. Transects at 30 cm intervals across 40 by 20 grids in more potentially archaeologically concentrated target areas were used for GPR data acquisition. The two forms of geophysical data for the surveys were combined in geospatial processing software (MAPublisher) and overlaid to create interpretable visual imagery. Once the data was processed in ArchaeoFusion or RADAN, it was analyzed and areas of interest could be determined. The next chapter will discuss the results of the geophysical surveys, the data processing, and subsequent ground truthing of identified anomalies.
6 Results and Interpretations

In this chapter I will discuss the results of the processed geophysical data collected from each site. First I discuss the magnetic gradiometer results, and then, I examine the GPR results followed by the initial interpretation of the geophysical anomalies. I then share results from auger testing of various anomalies at each site. I conclude with an interpretation of the auger testing results and their contributions to verifying the anomalies identified in the geophysical surveys.

Wolf Village Survey Results

Magnetic Gradiometer Survey

After processing the Wolf Village data using *ArchaeoFusion*, the data was imported into MAPpublisher using a local grid in order to georeferenced the data. The results revealed a total of eleven anomalies thought to be cultural (Figure 6.1). These anomalies were placed in two categories: (1) areas of interest (AOI), and (2) auger test anomalies (ATA). AOIs with high nano Tesla values were highlighted in red in MAPublisher, and other AOI’s were highlighted in orange and investigated if time allowed—these having lower nT values, and therefore, being of lower perceived “quality” in terms of possible cultural affiliation. ATAs were explored using a three-inch auger to determine the depth of some features. This was an effective method that prevented opening a larger excavation area.
Gradiometric visual representations of geophysical anomalies tend to appear as contrasts to the areas around them. In the case of Wolf Village, any burned areas, use areas, or altered soils were areas of interest, so isolated, dark colored features in the output images were selected for further exploration. These can be seen in Figures 6.2 and 6.3, which show dark black anomalies that contrast with the adjacent neutral grey color. Grey represents the natural magnetic background, while other sharp black and white contrasts are considered “noise” or magnetic interference that can come from a variety of sources. In the case of Wolf Village, the amount of background noise is likely due to ferrous minerals in the soil. The sharply contrasting black and white circular, dipolar anomalies, with a visible magnetic positive and negative element are represented in black and white (Jones and Munson 2005).
Figure 6.2. Map of the processed magnetic data with high nano Tesla (nT) values outlined. The anomalies outlined in red indicate those that were later tested, and the orange outlines indicate other potential areas of interest.

Figure 6.3. This map shows some of the high nT values in conjunction with the possible auger test points.
GPR Survey

The ground penetrating radar survey at Wolf Village covered a 20 by 40 meter area in grids 3 and 4. This area was chosen after the magnetic data was processed, and I determined that most of the magnetic anomalies were in these two 20 by 20 meter areas. Due to the slower data acquisition of GPR, I deemed it necessary to only collect GPR data in grids 3 and 4 (Figure 6.4). Since the soil at Wolf Village is sandy to dry clay, I assumed that the site would be ideal for GPR survey; however, due to the presence of a near-surface dry canal, and various cow paths that cut through the middle of the survey area, the GPR antenna picked up highly reflective anomalies directly on the surface that propagated down throughout the GPR profiles.

While the sandy, silty soil at Wolf Village is a perfect soil environment for GPR, the nearness of the irrigation canal, and the livestock path features to the ground surface made its utility questionable in my specific survey area. This became clear in the data as neither plan nor profile imagery would definitively identify features visible in the magnetic data (Figure 6.5). Magnetometry and GPR measure entirely different properties, so these results are not necessarily unexpected, but especially because many of the suspected buried features are likely made of adobe likely produced by local clay and sand. The absence of masonry, rock, or hard-packed surfaces could be the reason for the lack of the usual hyperbolic wave reflections seen in GPR data that would indicate a subsurface feature (Conyers 2006). This may also suggest that the features are too shallow and/or too small to register in the GPR data. The most consistent hyperbolic anomaly is seen in Figure 6.6 which shows the anomaly in profile view and plan view; this consistent anomaly is the modern canal running northeast to southwest.
Figure 6.4. A 20 by 40-meter plan map of the GPR data of Wolf Village at 1.22 meters down with a dielectric value of 10.

Figure 6.5. Screenshot of the Radan software processed Wolf Village GPR data. This plan view represents a GPR slice at 1.38 meters down. In this pallet, the color blue represents negative amplitudes, and the color red represents positive amplitudes.
Figure 6.6. Radar software showing the consistent GPR reflection of the canal at 50 cm down at Wolf Village. The boxes indicate location on plan view (a.) and profile view (b.).
Wolf Mound Survey Results

Magnetic Gradiometer Survey

After processing the Wolf Mound data using ArchaeoFusion, the data was imported into MAPublisher using a local grid in order to georeferenced the data (Figure 6.7). The results from the magnetometer survey at Wolf Mound revealed a total of six anomalies thought to be anthropogenic in origin (Figure 6.8). Similar to Wolf Village, these anomalies were broken into two categories: (1) areas of interest (AOI), and (2) auger test anomalies (ATA).

The AOI’s at Wolf Mound differed from those at Wolf Village because only three AOIs had high nano Tesla values (seen as dark anomaly in Figure 6.8) were highlighted in red, and all the other AOI’s would were highlighted in orange because there was either not time to explore any additional anomalies, they had very low nT values, or extremely high and low values indicating a possible dipole or metal anomaly. These can be seen in Figure 6.7 which shows the sharply contrasting black and white circular, dipolar anomalies (Jones and Munson 2005). This white circle is the site’s primary datum, a piece of rebar that was placed in the ground during the 2019 excavations and whose high iron content inevitably would appear as a dipolar anomaly (Figure 6.7-6.8). The line of dipole anomalies running north to south through the grids are remnants of a barbed wire fence, as indicated by the presence of wire found when clearing the grids of metal debris using metal detectors.

The black anomalies that contrast the neutral grey color in the figures, which represent the magnetic background, were the prime candidates for ATAs at Wolf Mound (Figure 6.8). There were only three dark black anomalies (highlighted in red in Figure 6.8). Many of the other weaker anomalies (orange) were considered for testing since there was a general lack of strong magnetic anomalies, and there was some compelling evidence of subsurface features under the mound. The ATA’s at this site were tested using an 8 cm diameter auger to determine the extent of any features.
Figure 6.7. The Wolf Mound (42UT2150) georeferenced magnetic gradiometer data on MAPublisher with 2019 mound excavations outlined in black.
The ground penetrating radar survey at Wolf Mound covered a 20 by 40 meter area in grids 1 and 2. This area was chosen after the magnetic data was processed, and I determined that the most promising of the magnetic anomalies were located in the two 20 by 20 meter areas in these grids (Figure 6.9). Since the sediment at Wolf Mound consists primarily of clay and clayey silt deposits, I assumed that this site would not be ideal for GPR survey. My assumptions proved true when processing the data, as neither plan nor profile imagery indicated any significant reflections from any subsurface materials or objects outside of the previously excavated trenches which propagated radar ringdown throughout the section below them (Figure 6.10).
The most consistent hyperbolic anomaly outside of the trenches is seen in Figure 6.11, which shows the anomaly in profile view and plan view. This faint hyperbolic anomaly is located at about 58 cm and continues to 1.19 m, or 25 ns (with a dielectric constant of 10), below the ground surface (Figure 6.11). This anomaly seems to reflect and scatter microwaves which could indicate a buried hard packed surface. The lack of hyperbolic reflections at this site could be connected to the soil composition, since this area contains Lake Bonneville deposits with prominent clay and silty soils. In addition, if there are more buried features at the site, they may have been made of locally sourced soils or adobe made from locally sourced clay.
Figure 6.10. Wolf Mound GPR slice at 55 cm. The red line in the middle of the plan view represents the 2019 excavation trench of the mound. The boxes indicate location on plan view (a.) and profile view (b.).
Similar to the other sites in this study, after processing the geophysical data from Snow Farm, the results from the magnetometer surveys revealed a total of 15 anomalies thought to be of

Snow Farm Survey Results

Magnetic Gradiometer Survey

Similar to the other sites in this study, after processing the geophysical data from Snow Farm, the results from the magnetometer surveys revealed a total of 15 anomalies thought to be of
potential cultural origin (Figure 6.12). Similar to the previous sites, these anomalies were broken into two categories: (1) areas of interest (AOI), and (2) auger test anomalies (ATA).

The AOI’s at Snow Farm differed from those at Wolf Village and Wolf Mound because there were so many magnetically rich areas; many of the AOIs with high nano Tesla values (seen as dark anomalies in Figure 6.13) are highlighted in red, and all the lower nT value anomalies are highlighted in orange. Extremely high and low values were also identified, indicating a possible dipole, metal anomaly or river bed.

The stark black anomalies that contrast against the neutral grey color in the figures, which represent the magnetic background, were the prime candidates for ATAs at Snow Farm. It is likely that the substantial amount of background noise is from ferrous minerals in the soil and the presence of various magnetic rocks, but specifically basalt.

Many of the dark anomalies or ATA’s had relatively high nT values, and it was assumed that they were metallic in origin even though they did not look like dipoles. Many dark gray linear anomalies were also visible. I also assumed that since the area was surrounded by metal fences and various metallic debris that the nT values would be relatively high, so the less prominent anomalies may appear more of a gray color that resembled the magnetic background. The thirteen ATA’s were tested using an 8 cm auger to confirm the geophysical interpretations. The anomalies marked with a red dot represent the 8 cm diameter auger test areas (Figure 6.14).

GPR Survey

The ground penetrating radar survey at Snow Farm covered a 20 by 40 meter area in grids 1 and 2. This area was chosen based on results from the magnetic data. I determined that the most promising magnetic anomalies were located in the two 20 by 20 meter areas east of the hemp crop. Since the surficial sediment at Snow Farm consists of sand, silty sand, and silty clay deposits, I assumed that the site would be ideal for GPR survey. The results were mixed after
processing the data. The soil was perfect for a GPR survey, however, the abundance of gravel and river cobbles throughout the survey interfered with the GPR antenna. These highly reflective materials near the surface caused the electromagnetic energy to scatter and attenuate throughout the GPR profiles (Figure 6.15).

The most consistent hyperbolic anomaly from the GPR data was the dry riverbed running southeast to northwest (Figure 6.16). The general lack of hyperbolic reflections at this site could be caused by abundant clay and silt in the soil. Unidentified buried features at the site were likely made of locally sourced organic materials, or loose adobe made from a locally acquired clay source.
Figure 6.13. Map of the Snow Farm magnetometry processed data with higher nT values and subsequent areas of interest (AOI's) outlined in red, and other areas of interest in orange.
Figure 6.14. Map of the Snow Farm areas of interest (AOI’s) and the auger test areas (ATA) in grid 1.
Figure 6.15. Snow Farm GPR slice at 50 cm down. The reflection of the GPR antenna signal through the dry stream bed at Snow Farm.
Auger Testing Results

Auger testing yielded three lines of data. First, the auger testing ground truthed the geophysical anomalies. Second, the auger testing allowed for the presence or absence of archaeological features to be confirmed by either encountering cultural material, fill, or sterile sediments. Third, the archaeological feature’s depth was determined measuring the depth of each auger hole. I avoided selecting high frequency magnetic dipole anomalies typical of surface iron artifacts and opted to auger test locations that had a higher probability of being architectural remains and features represented by monopole and low frequency dipole signatures. In short, I targeted anomalies that had a high probability of being archaeological features, and a low probability of being singular artifacts.

I used magnetic gradiometer data to guide the auger tests because some anomalies resembled archaeological features; however, I did overlay the GPR data over the magnetic data using
MAPublisher at each of the three sites, so if there were any redundancies in both of the data, I could test those areas first. The majority of the auger test areas were based on the combination of both magnetic gradiometry and GPR data. Only one auger test, performed at Wolf Mound (42UT2150), relied solely on the GPR data.

In order to systematically document each layer extracted by the auger, I deposited sediment from each auger bucket onto a 5 ft. by 3 ft. plywood board marked with eight areas for separating and documenting each bucket of soil (Figure 6.17 and Figure 6.18). An “Auger Test Form” was recorded out by either Scott Ure or myself for each auger test. The form includes information about depth measurements in centimeters below the surface (or cmbs) for each layer, artifacts observed, soil color using a Munsell color code, soil textures, soil inclusions, photo numbers associated with each test, and any other notes (Figure 6.19). This form allowed us to systematically document each auger test area and determine the depth for each anomaly.
Figure 6.18. Photo of the author in the process of auguring at Wolf Village (42UT273).

Figure 6.19. A copy of the auger test form used to systematically record the auger test data.

<table>
<thead>
<tr>
<th>Auger Test Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site: __________</td>
</tr>
<tr>
<td>Auger Designation: _____</td>
</tr>
<tr>
<td>Size: __________</td>
</tr>
<tr>
<td>Depth Measurements (cm below surface):</td>
</tr>
<tr>
<td>1. ______</td>
</tr>
<tr>
<td>2. ______</td>
</tr>
<tr>
<td>3. ______</td>
</tr>
<tr>
<td>Mean Height: ______</td>
</tr>
<tr>
<td>Artifacts Observed:</td>
</tr>
<tr>
<td>Lithics</td>
</tr>
<tr>
<td>Faunal Bone</td>
</tr>
<tr>
<td>Projectile Point</td>
</tr>
<tr>
<td>Number of Artifacts Observed: ______</td>
</tr>
<tr>
<td>Soil Description:</td>
</tr>
<tr>
<td>Color: ______/ ______</td>
</tr>
<tr>
<td>Texture: Clay</td>
</tr>
<tr>
<td>Sandy Clay</td>
</tr>
<tr>
<td>Silty Loam</td>
</tr>
<tr>
<td>Inclusions:</td>
</tr>
<tr>
<td>Charcoal</td>
</tr>
<tr>
<td>Pea Gravel</td>
</tr>
<tr>
<td>Gravel</td>
</tr>
<tr>
<td>Cobbles</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Photo Numbers: ______</td>
</tr>
</tbody>
</table>
Wolf Village (42UT273)

The results of the auger test results are detailed below in order of ATA number. Generally speaking, the ground-truthing at this site yielded good results. Of the six areas of interest tested, five proved to have some evidence of cultural material (Table 6.1). Auger tests 1 and 2 were explored first (Figure 6.20), however, after augering down 15 levels to a depth of 118 centimeters at A1. Then, after another 8 auger levels at A2 and finding no cultural material, I quickly realized that I had never flipped the color pallet on the magnetic gradiometer data map. This error caused the positive nT values to show up white instead of black. Only one ceramic sherd was found in the early levels. The results proved to be more productive once this error was corrected.

ATA #3

At levels 2 to 4 (14–20 cmbs), the soil in A3 with a Munsell color of 2.5 YR 6/3 (light yellowish brown). The soil was darker at level 4 and two gray ware pottery sherds were found, one being a rim sherd (Figure 6.21). Charcoal was found at level 5 (39–47 cmbs), and continued down to the beginning of level 8 (70 cmbs) with a Munsell color of 7.5 YR 3/1 (very

<table>
<thead>
<tr>
<th>ATA #</th>
<th>Coordinates (E,N)</th>
<th>Grid #</th>
<th>nT Value</th>
<th>Features Present?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>623 E, 382 N</td>
<td>3</td>
<td>-5.397 nT</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>623 E, 381 N</td>
<td>3</td>
<td>-5.897 nT</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>602.72 E, 379.10 N</td>
<td>4</td>
<td>9.86 nT</td>
<td>Yes - Charcoal</td>
</tr>
<tr>
<td>4</td>
<td>597.5 E, 387.5 N</td>
<td>4</td>
<td>6.19 nT</td>
<td>Yes - Ceramics and Charcoal</td>
</tr>
<tr>
<td>5</td>
<td>596.5 E, 387.5 N</td>
<td>4</td>
<td>5.67 nT</td>
<td>Yes - Faunal Bone</td>
</tr>
<tr>
<td>6</td>
<td>628.65 E, 382.72 N</td>
<td>3</td>
<td>2.94 nT</td>
<td>Yes? - Charcoal</td>
</tr>
<tr>
<td>7</td>
<td>630 E, 383 N</td>
<td>3</td>
<td>2.65 nT</td>
<td>Yes? - Very light Charcoal</td>
</tr>
<tr>
<td>8</td>
<td>616 E, 382 N</td>
<td>4</td>
<td>5.98 nT</td>
<td>Yes - Charcoal and Lithic</td>
</tr>
<tr>
<td>9</td>
<td>616 E, 382 N</td>
<td>4</td>
<td>3.4 nT</td>
<td>Yes - Lithic and Ceramic</td>
</tr>
<tr>
<td>10</td>
<td>615.6 E, 382.5 N</td>
<td>4</td>
<td>3.38 nT</td>
<td>Yes - Charcoal and Faunal Bone</td>
</tr>
<tr>
<td>11</td>
<td>596.5 E, 374.10 N</td>
<td>4</td>
<td>14.24 nT</td>
<td>Yes - Adobe and Charcoal</td>
</tr>
</tbody>
</table>

Table 6.1: Wolf Village Auger Test Area Results
Figure 6.20. Close up view of the auger test locations over the magnetic data in Grids 1 and 2 at Wolf Village (42UT273).

Figure 6.21. Photo of the two grayware sherds found in level 4 (20-39 cmbs) of A4 at Wolf Village.
Figure 6.22. Photo of the auger levels in their corresponding squares at A3. Charcoal and what seem to be burned beam pieces were found in level 7 (58-67 cm).

Figure 6.23. Closer view of the charcoal and burned beam pieces found in level 7 of A3 at Wolf Village.
dark brown) (Figure 6.22). The most charcoal was found in level 7 with what seemed to be burned wood pieces (58–67 cm) as seen in Figure 6.23. Light sand was encountered at level 9 (79cmbs) and sterile soil at level 10 (86–96 cm). This was the largest positive anomaly from the magnetometry data. After testing this area and finding burned wood pieces, I could verify that this anomaly was likely cultural.

**ATA #4-5**

A4 was located about 3 meters west of Structure 9 which was excavated in 2013. I encountered many angular rocks at level 4 which was at 41 cmbs. I recovered one lithic flake and one pottery sherd in level 1 (0–10 cmbs) and one pottery sherd in level 2 at 10–17cmbs (Figure 6.24). Larger rocks were encountered at 41 cm below ground surface, at which point the auger could not penetrate any deeper. I then decided to move west one meter to A5 to try and auger past the rocks. I observed faunal bone in level 1 (0–9 cmbs) and a charred corn kernel in level 2 (9-13 cmbs). At level 4 (20-32 cmbs) I encountered lighter colored charcoal (Figure 6.25). Due to the close proximity of Structure 9, and the presence of artifacts (charcoal and burned corn) I verified that this anomaly was cultural. It is possible that these deposits were associated with Structure 9, however, since I augured at the southern edge of this anomaly (the rest cut off by the grid) this could possibly be associated with another structure, possibly Structure 2, the oversized pit structure, to the northwest.

**ATA #6-7**

Charcoal was noted at level 10 (75-85 cmbs) in A6, however, it was very light and continued down to 120 cmbs. I augered down to level 15 at 129 cmbs, but after negligible results, I moved one meter to the east to A7 and had similar results but with very light charcoal found at level 3 (17-28). Auguring continued to level 8 (62-72 cmbs), and due to the sparseness of the charcoal, I assumed that the charcoal may have eroded and transported downslope to this location.
Figure 6.24. Photo of the artifacts found in A4 at Wolf Village. The lithic and ceramic sherd on the left in level 1 (0-10cmbs) and the ceramic sherd on the right in level 2 (10-17 cmbs).

Figure 6.25. Photo of the charcoal found in level 4 at A5 at Wolf Village.
The west side of the dry canal proved to be the most successful, but there was one slightly faint anomaly with a value of 5 nT that I wanted to test. I started A8 and encountered charcoal in the sidewall of the auger hole at 12 cmbs and one lithic flake in level 2 (10-17cm). The soil color at level 4 (39 cmbs) was more of a reddish yellow, contrasting with levels 5-7. I hit a large rock in the southwest side of the auger hole (about 65 cmbs). I then moved one meter south to A9 and encountered artifacts at level 6 (49 cmbs). More rock was encountered at 50 cmbs, so I decided to move to the west 50 cm to 615.5.6 E, 382.5 N, designated as A10. Levels 1-4 had similar yellowish-brown soil, and levels 5-14 had reddish-yellow soil. At level 7 (62-66 cm) I noted one faunal bone and sparse charcoal, and then at level 8 (66-76 cmbs) I found one lithics and over 20 fragments of faunal bone with more abundantly appearing charcoal (Figure 6.26). Level 9 (75-
Figure 6.27. Photo of levels 9 through 14 in A10 at Wolf Village. Level 9 in the top left corner (75-80 cmbs) had several fragments of faunal bone, which continued again in level 13 (at 106-115 cm).

Figure 6.28. Photo of the adobe chucks from of levels 5 and 6 (between 43 and 50 cmbs) at A11 at Wolf Village.
80cmbs) had over 20 fragments of faunal bone, which was also found in level 13 at 106-115 cm (Figure 6.27). I encountered sterile soil at level 14 (115-126cm).

**ATA #11**

A11 was placed at an anomaly twelve meters southwest of Structure 9 at grid number 596.5 E, 374.10 N. Levels 1-7 had light yellowish brown soil. Level 3 (21-27 cmbs) had one ceramic sherd (grayware), small adobe chunks in level 5 (43 cmbs), and large adobe chucks in level 6 (50 cmbs) (Figure 6.28). After these levels, the soil appeared darker with some flecks of charcoal in levels 8 and 9 and sterile soil in level 11 (83-95 cmbs). The abundance of adobe at levels 5 and 6, as well as darker soil and charcoal, suggest evidence of structural materials.

**Wolf Mound**

The auger test results at Wolf Mound are discussed in order of ATA number and whether the test was successful in identifying cultural material. The results at this site proved to be quite surprising. The areas thought to have cultural deposits (the mound) were not visible in either the magnetic or GPR results. The areas with the highest nT values proved to be metallic objects (metal pipes, wire, nails, datums). The largest area with strong positive values proved to be culturally significant (Table 6.2). Using the same systematic measuring methods as Wolf Village, I auger tested Wolf Mound starting with the first anomaly labeled A1 (1009.4E 989 N) and moved north (Figure 6.29).

**ATA #2-3**

After an uneventful exploration of A1, A2 had an nT of 7.99, but I found a modern screw in the first level (0-10cmbs). I augured to level 12 (94 cmbs) and did not encounter any other artifacts or cultural material. I then moved to A3 to test a linear anomaly. A metal piece of wire was found in level 1 which aligns with the anomaly in the magnetometry data. This was also
Figure 6.29. Close up of the magnetic data map with the auger test locations at Wolf Mound (42UT2150). The red points represent the auger tests influenced by the magnetic data, and the green points represent the auger tests that were attempts to find walls or features within the mound.
within the boundary of the mound that was trenched in the fall of 2019, so dark organic soil was found in levels 1-3 and white flecked clay in level 5. A burned stick and twig was found at 60 cmbs, then sterile soil was noted at 70 cmbs.

**ATA #4-6**

A4 was a large dark, magnetic anomaly in the northwest corner of Grid 2 measuring about 10 nT. At level 5, a light ashy gray soil was noted (35-45 cmbs) and in level 6 sandstone that appeared oxidized was found. Adobe fragments intermixed with the ashy soil were found in level 7 (54-65 cmbs). At 75 cmbs (and 8.5 cm below the primary datum) an extremely hard surface was encountered (level 9). Adobe was continually recovered until level 11 where large chunks of adobe were removed (Figure 6.30). Then level 11 manifested a very coarse sandy sediment with one tiny faunal bone fragment and a few adobe fragments. It is possible that some adobe fell into the auger hole from higher up. In level 13, I encountered organic clay which I believe is sterile.
Figure 6.31. Photo of the adobe chucks at A4 in their corresponding squares at Wolf Mound. This photo shows (reading left to right, beginning at the top left) levels 8 through 15.

Figure 6.32. Photo of adobe chucks at Wolf Mound auger test A6 at 53-55 cmbs.
soil which continued to level 15 at 148 cmbs.

After a successful test at A4, I decided to test 1 meter to the east (A5). Ashy soil was encountered at level 7 (54 cmbs) until level 9 (91 cmbs). A single piece of adobe was found between level 7 and 8 (68 cmbs). Levels 9, 10, and 11 had very ashy soil with some charcoal (at 91 cmbs), and then fine sterile sand at 116-128 cmbs (Figure 6.31).

The auger test at A6 was located 1 meter west of A5. Dark soil was noted at level 5 (43-53 cmbs), then in level 6 I found adobe at 55 cmbs (Figure 6.32) and had difficulty augering through it. Since this auger test encountered adobe at a higher level, I determined that I had successfully ground-truthed the anomaly identified during geophysical survey. I am fairly certain this is some kind of structural material despite the lack of associated artifacts.

**ATA #7-8**

Testing A7 was primarily based on the GPR results (see Figure 6.9). The GPR data shows a linear anomaly in the southwest corner of grid #1. After auger testing the area, I found very dark soil from 37–67 cm, but no cultural material was identified. A8 was a dark magnetic anomaly within the mound. Level 7 (48-58cm) had a very small fragment of faunal bone. At level 8 I broke through a hard clay layer thought to be the surface of the possible structure excavated in 2019 about 58-70 cmbs. I continued augering down twelve levels until 119 cmbs where I encountered very light sterile sand.

**ATA #9-12**

Auger tests A9-A12 were attempts to locate presumed walls or features within the mound where structural features had been identified during excavation in 2019. The testing was not based on geophysical imagery. These three tests did not identify any cultural materials.
The results of the auger tests at Snow Farm are listed below in order of ATA number. The results were somewhat uneventful and revealed, for the most part, not much more than what was visible on the surface or just below the surface: river cobbles and various gravel (Table 6.3).

Figure 6.33. Close up view of the auger test locations at Snow Farm within their 20 by 20 meter grids on the magnetic data map.

Snow Farm

The results of the auger tests at Snow Farm are listed below in order of ATA number. The results were somewhat uneventful and revealed, for the most part, not much more than what was visible on the surface or just below the surface: river cobbles and various gravel (Table 6.3).
The last auger test did manifest a hard packed surface with various artifacts lying on top just 5 cmbs. These artifacts were thought to be so close to the ground surface because the field where they were found had been stripped of over 30 cm of soil and plowed regularly. I augur tested the magnetic and GPR anomalies at Snow Farm using the same systematic measuring method used at the other two sites (Figure 6.33).

**ATA #1-4**

I started in the south alfalfa field with A1 (972.15 E, 946.75 N) and moved north to A2, A3, and A4. These auger tests produced no cultural material, but darker soil was encountered at 50-55 cmbs and small rocks at 85 cmbs. I continued down eight to twelve levels (maximum of 123 cmbs) but did not see any artifacts or cultural material. These anomalies were likely discrete, dipolar anomalies with strong nT values that are likely aberrant ferrous metal.

**ATA #5-7**

At A5 (995 E, 1016.5 N), a great deal of gravel and river rock was encountered at 50 cm, which stopped the test. A metal horseshoe nail was found on the surface at A6, which explains the high nT value identified in the magnetometry survey (Figure 6.34). A ceramic sherd was found in level 1 (0-10cm). The soil in levels 1-5 had a Munsell color of 5YR 4/2 (dark reddish gray, and the soil from 6-7 had a Munsell color of 5YR 2.5/2 (dark reddish-brown). I stopped A6 at level 8 or 66 cmbs. A7 is east of A6 and contained abundant heavy gravel and rocks which prevented auguring any deeper than 25 cm.

**ATA #8**

A8 was chosen due to a correspondance in both the magnetic gradiometry and GPR data (see Figure 6.19). A piece of adobe was found near the surface (0-8 cmbs), and two ceramic sherds were found at level 4 (19-26 cm) (Figure 6.35). No cultural material was found between levels
Figure 6.34. Photo of horseshoe nail and ceramic sherd found near the surface of A6 at Snow Farm.

Figure 6.35. Photo of the adobe and two ceramic sherds from A8 at Snow Farm.
4 and 13 (105 cmbs). The cultural material in this area may have been spread through erosion or plowing.

*ATA# 9-10*

Both auger tests A9 and A10 have an abundance of gravel beginning in level 1 and continue to level 8 where dark clay was found. No cultural material was recovered.

*ATA #11-12*

A11 (990 E, 1019N) was placed one meter south of A8 in an area with high GPR reflections but with a negative nT value. No artifacts were found, however, some sparse charcoal was identified at 37 cmbs, along with river cobbles in levels 4, 5, and 6, and a clay layer in level 12 at 77 cmbs. After little success with A11, I then tested A12 (995.25E, 1016.35 N), located east of A5, but once again rock was encountered at 25 cmbs, and the auger could not penetrate any further.

*ATA #13*

After conducting the twelve auger tests, it appeared that the old river bed was extending past the area northeast of A5, so I moved to the farthest west edge of the magnetic data to 988 E 1035 N (A13) in a darkish gray area of the magnetic data with a 3.9 nT value. Once I put the auger in the ground, I immediately encountered a hard-packed surface. After dusting away about 4 cm of topsoil, I noted a plow cut in the hard packed surface with a mano, red ochre, and a faunal bone resting on the surface (Figure 6.36 and 6.37). The soil had a Munsell color of 5YR 3/3 (dark reddish-brown). I was not able to auger through the surface because it was too hard, so only one level was taken at 0-5 cmbs. I originally thought that this could have been a prehistoric use surface of some kind, however, due to the extent of erosional damage, and damages caused by modern farm equipment, it was difficult to interpret this particular area.
Figure 6.36. Photo of the mano, red ochre, and faunal bone fragment found near the surface at A13 (4 cmbs) at Snow Farm.

Figure 6.37. Photo facing south of the hard-packed surface with plow marks running southeast to northwest, and the red ochre sitting on top at Snow Farm.
Summary

This chapter provides the results of two geophysical methods used at three distinct sites and the results of subsequent auger investigations of anomalies at each site. Geophysically, the magnetometer provided the most useful data for locating burned and buried subsurface features. The 400 MHz GPR antenna did not appear to be as effective, and this may have been because features may have been too ephemeral and too near the surface. However, overlaying the magnetic gradiometry and GPR data using a GIS provided further details about the anomalies that could have been easily missed with just one geophysical method.

Augering tested 36 total anomalies across three sites. Fifteen of those anomalies within nine areas of interest contained either artifacts or possible architectural features of cultural significance. Exploring these anomalies leads me to believe that there are at least four burned activity areas, with three of those including possible architectural features at Wolf Village. At least one other architectural feature was identified at Wolf Mound. The compact surface feature that was heavily disturbed by flooding and plowing at Snow Farm also may have been evidence of architectural or other cultural activity. None of the other areas of interest at each site were investigated, primarily due a lack of time. Some of the AOI’s may be modern metal debris. All three sites have been used for agricultural purposes for at least several decades. This is a factor that must be considered in all geophysical, archaeological investigations. Historic metals, debris, stakes, or other ferrous materials have the potential to impact any geophysical surveys. Both magnetic gradiometer and GPR data indicate that there are more areas with potential prehistoric cultural significance. The AOI’s (outlined in orange in Figure 6.3) at Wolf Village are good locations to test as a great deal of prehistoric activity has already been uncovered at the site.
The objective of this thesis was to test the effectiveness of two geophysical methods (GPR and magnetic gradiometry) at three Fremont sites in southern Utah Valley. This chapter reviews and examines the geophysical research that was conducted in this region for this thesis, and provides a discussion of the results. I also expound on the interpretation of the geophysical data to develop further conclusions regarding the usefulness of geophysical survey methods in Fremont archaeology.

Discussion

The primary purpose of my research was to understand which geophysical methods would work most effectively in identifying buried cultural features in the Fremont cultural region, and more specifically in Utah Valley. After reviewing past archaeo-geophysical studies conducted in and around the Fremont cultural area at other archaeological sites, it was determined that a multi-methodological approach utilizing both magnetic gradiometry and GPR would be most effective at each of the three Fremont sites in Utah Valley. Once these methods were put into practice at each of the three sites, it became clear that not only was the magnetic gradiometer faster at collecting data than the GPR, the magnetic gradiometer also provided more detailed data that could be used for ground truthing anomalies at each site. When both GPR and magnetic data were overlaid onto the local grid system of each site in order to delineate the most promising geophysical anomalies, the anomaly locations were then marked as of areas of interest (AOIs),
and most of those areas of interest included auger test areas (ATAs).

The auger test results demonstrate the effectiveness of these geophysical methods at each site. Although the majority of the auger test areas were based primarily on the magnetic data, there were a few anomalies that the GPR data also aided in identifying. Auger testing the anomalies resulted in marking and testing 36 anomalies across three Fremont archaeological sites. Fifteen anomalies within nine areas of interest contained either artifacts, charcoal, or possible architectural features that were likely culturally significant.

**Interpretations**

Each of the three Fremont sites discussed in this thesis differ greatly in terms of environment, soil morphology, vegetation, overall size, and the extent to which they have been excavated. This was by design so that these methods could be tested in a wider range of conditions and at diverse archaeological sites. Wolf Village is one of the largest Fremont occupation site in Utah Valley, and the largest Fremont village in Goshen Valley. Wolf Mound is a 50 cm high mound located in an alfalfa field. Although the interpretation of this mound is still unclear, the mound did manifest cultural deposits dating to the Fremont time period (Chapter 3). Snow Farm is a newly discovered Fremont sites. This site was not previously excavated, and the surrounding fences and crops limited the areas in which I could perform the various surveys.

Although each site varied widely, clear anomalies were identified at each site with the magnetic gradiometer data. Large, dark anomalies with nano Tesla values ranging from 5 to 15 nT typically indicate anthropogenic origins. It became clear that anomalies with consistent strong positive values were of archaeological interest. Once many of these anomalies were identified in the magnetic data, a closer inspection of the GPR data profiles also denoted that disruptions in the amplitudes of reflected waves were present, although very faint (see Figure 6.12). Additional processing of the GPR data in RADAN and Photoshop isolated various anomalies,
which provided approximate depths and sizes of various anomalies.

While there are some inherent flaws with the auger testing methods discussed in Chapter 6, the results of the limited auger testing at each site were useful in identifying anomalies which were of archaeological importance. The limited auger testings were also useful in recording the depth of the archaeological features discovered. The depth data could then be used to verify the accuracy of the GPR profile anomalies at the same location.

At Wolf Village, the auger test at A3 (see Figure 6.20) was successful in revealing over 20 cm of charcoal with a very dark brown soil. In one of the levels (level 7), most of the materials recovered were large pieces of burned wood. A fine, lighter sand was found at 79 cmbs and below burned material and soil. A3 was the largest magnetic anomaly at the site with a value of 9.86 nT. The abundance of charcoal found in the auger test explains why it was so visible in the magnetic data. The profusion of charcoal and burned wood pieces found in level 7 (58-67cmbs), with an underlying fine sand layer beneath it in level 9 (79cmbs), suggests this could be a burned architectural feature.

The auger tests at A4 and A5 at Wolf Village produced an abundance of artifacts near the surface, and the presence of charcoal pieces further down in level 4 (20-32 cmbs) may indicate that some artifacts eroded downslope from Structure 1 or 2. This may also explain why artifacts were found near the surface. The charcoal, and darker soil below level 4 could be the result of a midden associated with Structures 1, 2, or 9 (see Figure 6.3). More auger tests one meter north of A4 and A5 may have produced better results and aided in the interpretation of this large magnetic anomaly.

The auger tests at A6 and A7 produced negligible results with only sparse charcoal encountered from 75 to 125 cmbs. I assumed that the charcoal may have washed downslope from structures located up-slope. This very well could be the case, however, the depth at which the charcoal was found, and its continuation at 50 cmbs, leads me to believe that this could
be cultural material from an earlier or contemporaneous occupation. Two auger tests near the magnetic anomaly also did not help identify the anomaly. More auger tests placed adjacent and through each anomaly would add more details.

Auger tests A8, A9, and A10 produced substantial faunal bone with sparse amounts of charcoal beginning in level 6 (49 cmbs) down to level 10 (80 cmbs). More faunal bone was found in level 13 (106-115). Although the magnetic data imagery in this area appeared to be a possible structural feature (Figure 7.1), the auger tests recovered abundant faunal remains with charcoal intermittently throughout over 40 cm of sediment, with no architectural material. This leads me to believe that this area could have been a food processing area or midden. Additional auger tests and excavations would help identify the boundaries of the anomaly.

The final auger test at Wolf Village (A11) was placed in a strong circular magnetic anomaly measuring 25 meters long (see Figure 6.20). Only half of the anomaly was visible in the magnetic gradiometer and GPR results. The auger uncovered one ceramic sherd (grayware) and small adobe chunks at level 5 (43 cmbs). In level 6 (50 cmbs), large adobe chunks were encountered. After these levels the soil became darker with some flecks of charcoal in levels 8 and 9 and sterile soil was found at level 11 (83-95 cmbs). The abundance of adobe in two levels, the darker soil and charcoal found directly below the adobe, and the circular nature of the anomaly, suggests this anomaly could be a circular or sub-rectangular structure similar to Structure 5 excavated at Wolf Village (Johansson et al. 2014).

The auger tests at Wolf Mound were not as eventful as Wolf Village (in terms of the number of successful auger test anomalies); however the auger tests of A4, A5, and A6 all encountered a very hard adobe layer (see Figure 6.29). Augers A4 and A5 both encountered adobe mixed with ashy soil at 54 cmbs, and then very hard packed adobe at between 68 and 75 cmbs. The adobe at A4 and A5 continued until level 11 where coarse sand was found with some faunal bone material (106 cmbs). A6 encountered the adobe at 55 cmbs that the auger could not penetrate.
This evidence suggests that A6 likely intersected part of an adobe structure. A6 at 55cmbs could be evidence of the wall, similar to an adobe wall identified during excavations conducted at the mound in 2019. The unconsolidated adobe found at 54 cmbs at A4 and A5 could be more evidence of structural materials. And the floor of a structure could be the hard packed adobe at 68–75 cmbs, which overlays the coarse sand.

The dimensions of the Wolf Mound northeast anomaly in the magnetic data are very similar to the dimensions of a pithouse excavated in 1981 at Woodard Mound which is just under one mile to the northwest. The clay walls of this semi-subterranean pit structure at Woodard Mound appeared at 40-60 cm under the present ground surface. The structure was a square pit dwelling with rounded corners. It measured 4.5 by 5 m. and was dug approximately 20 cm into sterile soil (Richens 1983:32). Although only half of the Wolf Mound anomaly was excavated, the rounded southwest and southeast corners are faintly visible in the data (see Figure 6.29).

As previously mentioned in Chapter 6, the geophysical results and subsequent auger tests at Snow Farm (42UT2274) were negligible. However, the last auger test at A13 (see Figure 6.33) included a hard packed surface of some kind (see Figure 6.36 and 6.37). It was originally interpreted as a prehistoric use surface due to the artifacts found lying on top of it. However, the excavation around the A13 determined that the area was highly disturbed by natural and manmade occurrences, and it was nearly impossible to identify prehistoric usage (Ure and Jepsen 2021).

Overall, the results of this research support my initial hypotheses that geophysics could be a viable remote sensing technique at Fremont sites in southern Utah Valley; however, the results of both the geophysical surveys and the auger testing exceeded expectations. Although I recognized that Wolf Village was in fact a Fremont village and there was a high likelihood that I would encounter a great deal of cultural material beneath the surface, I was pleasantly surprised at the quantity of anomalies within the 20 by 40 meter area that was chosen for further testing.
We also found possible evidence of a subsurface architectural feature at Wolf Mound that would have been completely undetected by pedestrian surveys on the surface. Due to the abundance of alfalfa growth and vegetation, artifacts were not visible on the surface which is typically a key indicator for buried prehistoric sites in the Great Basin. The magnetic gradiometer, however, identified the magnetic signature of a possible feature, and I was able to verify its anthropogenic nature through limited auger testing.

My results also align with the few other geophysical studies in the Fremont cultural region. As noted in Chapter 4, there have only been three applications of archaeo-geophysical techniques used to detect Fremont cultural remains (Range Creek, Wolf Village, and Wolf Mound). All of these surveys were done within over a decade of each other and produced sufficient evidence of cultural material to influence the excavation strategies and ultimately the results of those excavations. Magnetometry and GPR had been used individually in the past within the Fremont cultural area to detect Fremont cultural anomalies; however, in this research, I tested both methods together. I identified why these methods were or were not successful in locating archaeological features, as well as what to look for in the future when using these methods.

Implications

The literature review of archaeo-geophysical applications in Chapter 4 was written to illustrate the deficiency of archaeological geophysics at Fremont archaeological sites. Although only two examples within the Fremont region are cited (Boomgarden 2013; Ure 2022), there are many applications of geophysical methods in the Southwest region of North America (see Conyers 1997, 1998, 2005; Ryan 2015; Diedrichs et al. 2017, Sturms 2017; McKinnon et al. 2017). Many of the earlier geophysical applications focused on the uses of GPR to acquire data at Ancestral Puebloan sites in southeastern Colorado and Southeastern Utah (Conyers
1997; 1998). These studies bolstered the usefulness of GPR in the Southwest for detecting archaeological sites.

Conyers (1997) made the prophetic statement, “that the utility of employing multiple geophysical methods at the same archaeological site is just being realized and will play an increasingly important role in archaeological geophysics”. He was right. At the San Marcos Pueblo in New Mexico in 1998, both GPR and magnetic gradiometry data were collected and provided different but complementary images of the subsurface. In 1998 the Crow Canyon Archaeology Center (CCAC) conducted electrical resistivity and magnetometer surveys over 64,800 m² at Shields Pueblo, an Ancestral Puebloan site at which Conyers had performed a GPR survey the year prior. Another multimethod approach was conducted by Shanna Diedrichs et al. (2017) at the Dillard Site that incorporated magnetic gradiometry and electric resistivity. Their approach demonstrated that magnetic gradient surveys were the most efficient tool for mapping Basketmaker II sites in the Southwestern Colorado region (McKinnon et al 2017:123).

According to Ernenwein and Hargrave (2007:97), when considering which instruments would be best for an arid environment such as the American Southwest, radar penetrates deeply in many areas because the soils and sediments are so dry. Regarding other geophysical methods, Ernenwien and Hargrave (2007:97) also stated that “Electrical resistance is often a poor candidate in desert environments because the dry surface prevents current from entering the ground. Magnetometry is also (sometimes) less successful in arid regions because soil is poorly developed. EMI, however, can be successful because it does not require probes to be inserted into the ground”.

Although this may be true in the more arid lowlands of the American Southwest, both electrical resistance (ER) and magnetometry have proven effective geophysical methods in the higher elevation desert environments with higher annual percentages of rainfall. This was proven at Dillard Site which incorporated magnetic gradiometry and electric resistivity,
and demonstrated that magnetic gradient surveys were the most efficient tool for mapping Basketmaker II sites in the Southwestern Colorado region (Diedrichs et al. 2017:123). This is similar to the results presented in this thesis which indicates that after testing a multimethod approach using magnetic gradiometry and GPR at Fremont sites in Utah Valley, Utah, the combination of magnetic gradiometry and GPR surveys produced mixed but complimentary results: however, the results also indicate that of the two geophysical methods employed in the test, magnetic gradiometry proved to be more effective in identifying subsurface archaeological anomalies.

This is not to say that these are the only geophysical methods that should be applied at Fremont sites in Utah Valley. In fact, there are multiple geophysical methods that would theoretically work at these sites depending on environmental conditions (electrical resistivity, electrical magnetic induction, etc.). Magnetometry and GPR just happened to be the methods that had proven useful in detecting buried prehistoric features in prior research that I felt confident would produce promising results, and happened to be readily available to me. Overall, my research demonstrates that geophysical methods could be used more frequently during the preliminary survey phase of a research project prior to conducting archaeological excavations at Fremont sites in Utah Valley.

**Limitations**

*Ground Penetrating Radar*

As I mentioned previously, the possibilities surrounding the usefulness of GPR data could have easily been due to the ephemeral nature of the cultural deposits in the region, or the settings and filters that were used when running the GPR, or the resolution of the GPR antenna. I used a 400 MHz antenna for my research. This system is repeatedly called the “gold standard” (Kvamme 2006) for GPR surveys due to its versatility and wide range of applications. However,
for my research, a higher resolution antenna may have been a better choice. A higher resolution antenna disperses a higher frequency radio signal which does not penetrate as far into the soil as does a lower frequency antenna. Although the newer GSSI Utility Scan Pro GPR model has a lower 350 MHz antenna, it stacks a 300 and an 800 MHz antenna. This antenna has distinct advantages. These include superior resistance to external electromagnetic interference and improved data quality in less-than-ideal soil conditions (personal communication with GSSI representatives). Therefore, it could be a good option for future surveys in Utah Valley.

As indicated earlier in this chapter, once I was able to review the GPR profiles after finding the various magnetic anomalies, I could then typically see some minor reflections in the data. Knowing what to look for in the GPR data now, applying various filters and parameters in the field when collecting GPR data would allow the data collector to be more sensitive to minor reflections and anomalies below the surface at higher depths above two meters. The data presented in this research was processed generally without any elaborate workflows or filters that could potentially alter the data’s integrity. This contributed to the initial conclusion that GPR was not effective at identifying archaeological features; however, upon closer examination of the data, and further research on GPR studies in the Southwest region, it seems that when attempting to identify pithouses or other ephemeral structures without masonry, it is important to filter out all noise so that the faint amplitudes can be seen scattering across possible archaeological features like adobe or floor surfaces (Conyers 2006).

Software Limitations

I used e software created by Eileen Ernenwein and the University of Arkansas in 2008. The last update to the software was in 2013 (personal communication with Eileen Ernenwein). I had access to Terra Surveyor, the magnetometry processing software provided with the Bartington Grad 601-2 magnetic gradiometer. Terra Surveyor has a steep learning curve, was not user
friendly, and the data was harder to manipulate once it was uploaded into Terra Surveyor. I also only used Radan to process the GPR data because the Geology department at BYU had a license for it, and John McBride was able to instruct me in that software rather than another more unfamiliar software.

Subjectivity

I am relatively new to geophysical studies, and I had to teach myself how to run and operate geophysical instruments. I also had to learn how to process the data, based on information I learned from available literature. There is clearly a possibility for error within my data, having not been conducted by a professional with years of geophysical experience. There may be errors in the way the data was collected, processed, and even interpreted.

There is inevitable subjectivity in interpreting geophysical data. At times, it is truly in the eye of the beholder; the person processing and interpreting geophysical data sometimes sees what they want to see. In the case of this research, the way I interpreted the data changed drastically as I was exposed to processing and testing anomalies. I initially allowed my biases at Wolf Mound to dictate what I saw in the imagery. I was looking for very faint signatures in the magnetic data that could possibly align with aerial thermography results and excavations of Wolf Mound a year earlier (Personal communication with Scott Ure). However, no matter how many times I ran various filters and changed pallets on the magnetic and GPR data, the results seemed consistent and did not fit my preconceived notions. Needless to say, the areas of interest at each of the three sites changed as more data was processed, and areas of interest were tested at all three sites. Each auger test taught me what to look for that correlates to magnetic anomalies. I realized that 5 to 15 nT values is the typical range for values indicative of cultural deposits. Anything higher than 15nT proved to be a metallic anomaly, and anything lower than 5nT seemed to be related to the magnetic richness of the soil.
After conducting this research, it was easy to see what Eileen Ernenwien meant when she said to me, “You have to approach every geophysical survey with zero expectations and preconceived notions, especially when processing the data.” There was a clear bias in testing certain areas of Wolf Mound. Auger tests A8-A12 were loosely based on the magnetic data, but were in conjunction with what we as the archaeologists who had excavated the site had previously known and experienced. These biases led us to test more of the mound itself and not the other areas of interest south of the mound (see Figure 6.29). The anomaly south of the mound was thought to be a plow scar, but it may also be a modern ditch, but there is no way to know until it is tested.

Auger Testing Methodology

Regarding the auger testing approach I took in this research, only the geophysical anomalies with the highest GPR reflections, or nano Tesla values ranging from 5 to 15 nT seemed promising from an archaeological perspective. In some cases, surrounding auger tests were placed near original auger holes if the auger could not penetrate further due to subsurface obstructions. In retrospect, I recognize that there was no standard for the way I went about auger testing. I only tested the anomalies with a single or a few auger holes, but I did not test anomalies along a single transect using intervals, which may have revealed other archaeological features or helped to estimate the size of archaeological features. Any future auger tests based upon geophysical anomalies should follow a transect using a planned interval in order to determine, for example, the extent of a structure.

Summary

The research described here demonstrates how two geophysical techniques were employed and evaluated at three known southern Utah Valley Fremont sites. Following a literature review and standard guidelines regarding geophysical prospection techniques, two geophysical methods
were chosen based on environment suitability and instrument availability.

After the geophysical data from each instrument were collected and processed for each site, the auger testing of selected anomalies followed. Auger tests to investigate anomalies at Wolf Village, Wolf Mound, and Snow Farm revealed evidence of subsurface archaeological features including architectural remains (Chapter 6). Moreover, 15 of 36 total auger test areas based on geophysical anomalies proved to contain significant cultural deposits (see Tables 6.1–6.3).

It is important to note that although scant geophysical evidence was found from the Snow Farm geophysical surveys outside of anomaly A13 (see Figure 6.33), an excavation unit was put in 40 meters west of the survey area in a location previously damaged through uncontrolled digging earlier that year (Ure and Jepsen 2021). A salvage excavation was very successful in finding intact cultural features at Snow Farm (Ure and Jepsen 2021).

The research in Chapter 6 demonstrates that the magnetic gradiometer data provided some of the clearest information about buried archaeological contexts and seems to be well suited for finding Fremont archaeological remains in the southern Utah Valley, particularly features that had been burned or had burnt soil. GPR proved to be helpful when combined with magnetometry; however, due to the ephemeral nature of cultural deposits in this region, and the lack of more consolidated building materials such as masonry in Fremont architecture in this area, GPR was not as effective on its own. Overall, the combination of GPR and magnetometry yielded mixed but complimentary results which aided in identifying buried archaeological features at each of the three southern Utah Valley Fremont sites.

**Future Considerations**

After the geophysical surveys at Snow Farm (42UT2274) a salvage archaeology project began during the summer of 2020. Under the direction of Scott Ure, a 4 meter by 5 meter
excavation of the previous uncontrolled digging area began, and a surprising number of artifacts and cultural material were discovered that were associated with a Fremont occupation. Surface artifacts were also mapped at the site before and after the land owner plowed the fields before the winter of 2020. Although the preliminary report is still in progress, the results of the surface artifact mapping indicate two areas with concentrations of artifacts (Figure 7.1). These areas would be prime candidates for future magnetic gradiometer surveys and testing.

Following the 2020 field season at the Snow Farm site, I was curious to find the location of the Amasa Potter Farm in Payson, which is the farm that Edward Palmer mentioned in his letters to the Smithsonian institute as containing the remains of prehistoric inhabitants (Palmer

Figure 7.1. Kernel density map of Snow Farm surface ceramic artifacts. Indicating two major artifact densities, and two smaller density areas.
1877). After scouring the historical land ownership records of Payson, I found the location of the Amasa Potter Family home in downtown Payson, Utah. According to Amasa Potter’s son George Potter’s autobiography, Amasa owned “20 acres one mile north of their home in Payson”. After plotting their home lot on Google Earth, I measured one mile due north, and found it was relatively close to the modern area of Snow Farm. Once I found the historical land ownership records of that general area, I searched dozens of historical documents dating from 1850 to 1930. After a day of searching, I was able to find four accounts of land ownership between Amasa Potter and his brother Newell Potter, all within 1 square mile of each other. Each land record has Public Land Survey System coordinates with their corresponding grid locations. Using these grid locations, I was able to roughly place their historical land locations over modern Landsat imagery. The results of mapping the historical land ownership showed that not only do the Potter properties surround the modern boundaries of Snow Farm, Newell Potter owned 8.10 acres in 1875 right where Snow Farm is today (Figure 7.2). This not only lines up geographically, but also in the timeline. Palmer visited and excavated the mounds on the Potter property in 1876 (Palmer 1877). The “Payson Mounds” were known to early archaeologists like Palmer, Montgomery, and Judd, but since the late 1800s, archaeologists have been unaware of their precise location.

From the geophysical surveys conducted in the summer of 2020 at Snow Farm, and the rescue excavations in the fall of 2020, to the re-discovery of historical land ownership of this area, the evidence indicates that this area may well have been the location of the Payson mounds (Figure 7.4). This area has incredible potential, not only from an archaeo-geophysical survey perspective, but from a Fremont cultural perspective. This area would allow archaeologists to learn more about Fremont cultural lifeways in the southern Utah Valley, and the cultural region as whole.

The results of the auger tests at Wolf Village indicate that there are five areas that either
Figure 7.2. Historical land ownership areas of the Potter Family in Payson, Utah (outlined in red), with the modern Snow Farm property (outlined in yellow). Land parcels are not the exact size, since they only included the Public Land Survey System coordinates.
had charcoal/burned material, hard packed adobe, or an abundance of artifacts. However, these were not the only geophysical anomalies at Wolf Village. Once the GPR data from Wolf Village was uploaded into ArchaeoFusion, I could then assign a color value to the high reflectance values of the plan view GPR data (green), and overlay the data with the magnetic imagery set to another color value (red). If the anomaly colors combine to create a new color (yellow), then this indicates where the anomalies overlapped and most likely indicates some kind of buried feature (Figure 7.3). Although this method was unfortunately discovered after the auger testing was completed, it became clear that there are at least two more areas (highlighted in orange) that could be tested and may be areas of prehistoric cultural significance (Figure 7.4). Although a great deal of excavation has been conducted at Wolf Village thus far (Lambert 2018, Bryce 2017; Johansson et al. 2014), the results of this geophysical study indicate that there are nine new areas for future testing or excavation.

Additionally, the results of the auger tests at Wolf Mound identified that the anomaly in the northeast corner of our survey area 20 meters away from the mound itself was likely an architectural feature of some kind. Although, only half of the anomaly was surveyed, it would be a logical next step to map the area just north of Grid #2 in order to obtain a full picture of the anomaly and potentially predict its spatial extent.

The sites examined in this project proved to be well-suited for testing the methods discussed in this research. At Wolf Village, for example, the soil was light and dry, and it was far from any outside electromagnetic noises that could affect the geophysical data. In addition, previous excavations at the site provided some idea as to where other buried cultural features might be found. Conducting a large magnetic gradiometer survey of the entire site would likely provide additional data that could guide future excavation. However, the biggest obstacle at Wolf Village in regards to geophysical survey is the ground clearance. The site is covered in tall greasewood which makes all aspects of archaeology more difficult, but especially geophysics. Clearing
Figure 7.3. Map of the magnetic gradiometer data (appearing red), overlaid with the GPR data (appearing green), and yellow where anomalies overlap.

Figure 7.4. Map of areas of interest with explored areas in red, and unexplored anomalies from the GPR and magnetic overlay imagery in orange.
hundreds of square meters is not only extremely labor intensive, but it is also not conducive for the local ecosystem.

A possible solution would be to utilize aerial magnetometry. Unmanned Aerial Systems (UAV) systems have been used at sites throughout the Fremont cultural region to great effect (Personal communication with Scott Ure). They have helped identify and map sites that are difficult to reach or access. Although aerial magnetometry may seem like a simple solution, it is a relatively new remote sensing technique that is not without its flaws. One aerial magnetometer method tethers a magnetometer or magnetic gradiometer from a UAV using long ropes. This is one of the major issues of the design because the elimination of the UAV’s magnetic noise is a constant struggle. However, there are companies like Geometrics Magarrow or Sensys’s Magdrone R3 that have streamlined the aerial magnetometry process by designing magnetometers specifically made for aerial applications, and they have created drones specifically designed to carry them. Similar to any relatively new equipment and associated software, there may be idiosyncratic issues with the user interface or various bugs in the system. Additionally, the upfront investment price on an aerial magnetometer system is quite significant, and until the method “takes off,” the big price tag will not likely change. Nevertheless, this method could be a perfect union of versatility and practicality when attempting to identify subsurface archaeological features in the Fremont or Greater Southwest regions.

Due to the clays and lake deposits at the sites surveyed for this project, it would also be interesting to conduct an electrical resistivity (ER) survey of sites around Utah Lake in the early spring while the soil is still wet and saturated. If the soil conducts enough electricity, it could be a great option for electrical resistivity and may allow for the identification of other characteristics of these sites. Electrical resistivity geophysical methods have been around for over half a century, and ER is relatively inexpensive and requires only one person to operate the equipment. The data acquisition can be slow, the output can appear very pixelated, and there may only be a few times
throughout the year that it would be effective, but it is a method that has rarely been used in the area. Electrical resistivity could prove useful in addition to the other geophysical methods tested for this research.

Overall, understanding which geophysical methods work in which environmental conditions is paramount (see Ernenwein and Hargrave 2007; Conyers 2006, etc.). But generally speaking, magnetic gradiometry proved to be effective at these sites as it includes relatively quick data retrieval and is simple to process. GPR is also a great option in areas with relatively clear surfaces (i.e., free from obstructions such as large vegetation), with dry soils, and with the possibility of archaeological features with hard packed surfaces or masonry. While the data recovery is slower, GPR can provide more detailed data, as well as depths of possible archaeological features.

The results from this research suggest that archaeo-geophysics can be a useful tool in identifying areas of occupation otherwise discounted based on past interpretations. Further archaeo-geophysical or pedestrian survey on each of the Fremont sites discussed in this research is likely to result in the location of additional features, as the instrument survey only covered a fraction of each of the sites. There exists great potential for this otherwise underutilized technology in archaeological applications in Fremont archaeology, particularly in identifying buried archaeological features.
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