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Remote Sensing Insights into Storage Capacities among Plains Village Horticulturalists

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Remote Sensing Insights into Storage Capacities among Plains Village Horticulturalists

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by

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ABSTRACT

Maize was a fundamental component of the diet and economy of Middle Missouri Plains Village groups, sedentary farmers with settlements along the Missouri River during the last millennia. More than a century of study has contributed to our understanding of agricultural production among these peoples, but little effort has been made to consider temporal variation in production. Such an understanding is crucial to examining changes that occurred before and after the arrival of colonists and their trade goods in the seventeenth century. Plains archaeologists have suggested that the storage capacity of Middle Missouri villages increased during the sixteenth through the eighteenth centuries. In fact, the number and size of subterranean storage pits, ubiquitous features within most settlements, are thought to have grown during these centuries, which reflects greater agricultural production. To further examine changes in production and storage capacity during this centuries-long period, I combine information from historical documents, excavations, and geophysical investigations.

At Huff Village, a fifteenth-century community, excavations and magnetic gradiometry surveys reveal the size and distribution of storage pits. Their number and average volume suggest the villagers grew immense amounts of food and contributed to widespread intertribal trade. Furthermore, storage pit excavation data from 20 regional sites, dating from the thirteenth to the nineteenth century, indicate pit volumes increased through the seventeenth century. A sharp decrease subsequently occurred during the eighteenth century due to epidemic disease. However, mean pit volumes were significantly larger during the nineteenth century, evidence of the resilience of Mandans, Hidatsas, and Arikaras and the continued significance of maize. In fact, historical documents and remote sensing data suggest the Mandans and Arikaras, successive occupants of an earthlodge village near the American Fur Company’s Fort Clark, traded crucial resources, namely maize, to neighboring Native groups and fur traders during the early to mid-nineteenth century. While traditional colonial narratives describe the period in terms of culture decline and dependency, my study indicates the Mandans and Arikaras acted in their own self-interest and influenced and accommodated colonial fur traders along the Missouri River in the Northern Plains during the nineteenth century.

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Over the past quarter century, historians and archaeologists have adopted revisionist perspectives of colonial interactions in North America, arguing that relationships between various Native groups and European and American colonists varied geographically and temporally. In this view, colonial processes are recognized as having been more complex than is generally considered, and colonial histories are viewed as the result of interactions among different peoples rather than the impacts of one imposed upon the other (DuVal 2006; Ferris 2009; Hämäläinen 2008; White 2010; Witgen 2012). These revisionist perspectives counter conventional or colonial narratives of engagement, which are based primarily on historical and ethnographic information generated by the colonizers. Until recently, the perpetuation of conventional views has overshadowed and curtailed examinations of Native histories and agency within archaeology (Mitchell and Scheiber 2010).

Conventional narratives of colonial encounters paint a largely one-sided picture of complex sociohistorical and economic processes. Simply put, the arrival of colonists along with new technologies and diseases were portrayed in terms of how these factors impacted previously "pristine" Native groups. In other words, the appearance of European-made technologies and demographic changes caused by epidemic diseases were discussed in relation to dramatic culture change (i.e., decline or loss of culture) and dependency. Epidemic diseases undoubtedly impacted Native populations severely and European-made goods affected the production, trade, and distribution of Native technologies. However, a major shortcoming of such narratives is that the equally important roles of Native histories, institutions, and actions were ignored (Ferris

2009; Mitchell and Scheiber 2010). The assumption that Native technologies were quickly and inevitably replaced because of the superiority of European-made goods was accepted without questioning how such items were actually adopted, sometimes resisted, and even transformed by Native groups for wholly different uses than originally intended by those who produced said items. Historians and archaeologists are now more aware of the varied ways in which technologies as well as social institutions, political systems, and economic practices changed regionally over long periods of time.

The perpetuation of conventional perspectives within archaeology is largely related to the history of anthropological theory in North America. The related concepts of culture contact, acculturation, dependency, and culture loss were popularized within the discipline during the mid-twentieth century, especially with the development of culture-historical archaeology (Mitchell and Scheiber 2010). Despite theoretical shifts within the field in the second half of the century, aspects of colonial narratives have persisted. Furthermore, during the period in which such perspectives became enmeshed within archaeology, researchers who studied post-1500 Native cultures, including archaeologists, gave greater consideration to information drawn from historical documents than complementary archaeological data (Ferris 2009; Mitchell and Scheiber 2010).

However, recent conceptual shifts within the disciplines of history and archaeology have led to a more critically revisionist and reflexive approach to the study of this period. Moreover, different theoretical frameworks have converged, leading to an empirical, problem-oriented archaeology that emphasizes the reproduction and transformation of historical traditions via Native social agency (e.g., Pauketat 2001a, 2001b). Specifically, the unique histories and social, ceremonial, political, and economic institutions of various Native groups involved in colonial encounters are currently being reexamined. One goal of such research is to develop a more comprehensive understanding of the dynamic interplay between Native, European, and American beliefs, actions, and histories. This interplay ultimately affected the outcome of colonial interactions across North America.

The process of revising narratives of colonial interactions among colonists and Native groups that lived along the Missouri River in the Northern Plains of North America, the area of interest discussed further herein, is well underway. Mitchell (2011, 2013) exemplifies the recent trend by examining the extent to which the arrival of European trade goods affected the Mandans who occupied sedentary farming communities continuously from the late fifteenth to the late eighteenth century near the intersection of the Heart and Missouri rivers in North Dakota. Importantly, he questions whether the appearance of trade goods during the seventeenth century can be implicated in the Native political and economic systems documented by explorers, traders, and artists around the turn of the nineteenth century.

Furthermore, Mitchell (2011, 2013) identifies several significant social and economic changes that began prior to the arrival of either colonists or their trade goods in the seventeenth century. For instance, he describes a significant change in population aggregation and settlement clustering near the Heart River, beginning in the fifteenth century. Coinciding with and following these demographic changes, Mitchell (2011) cites evidence for craft specialization, with noteworthy differences in stone tool and pottery production skill and technique among Heart River communities in subsequent centuries. These differences are evident at the community level and perhaps even at the household level. Ultimately, these processes relate to an expansion of trade and interaction among the Mandans and other Native groups living in the Northern Plains and beyond that occurred before the appearance of colonists. However, these changes shaped colonial interactions in the following centuries and continued to do so until at least the 1780s North American smallpox epidemic, according to Mitchell (2011, 2013).

Anfinson (1987) further challenges the conventional narrative of colonialism in the Northern Plains. He argues that the Mandans, having survived the 1780s smallpox epidemic despite a significant population loss, remained autonomous, rather than dependent upon European and American traders and in a state of cultural decline, for several more decades. In fact, Anfinson (1987) notes evidence of continuity in technology, subsistence systems, and settlement patterns for the Mandans and their precursors for centuries prior to and well after the arrival of colonists. Moreover, despite the Mandans' acquisition of vast quantities of trade goods, their appearance did not impact the Mandans significantly for two primary reasons. That is, the Mandans maintained their independence because no single trading entity (European, American, or Native) managed to dictate trade along the Missouri River in the eighteenth and early nineteenth centuries. More importantly, Anfinson (1987) contends that the Mandans' production patterns did not change significantly as a result of the fur trade. However, he speculates that if any change occurred, it involved an increase in horticultural production to meet their own demands as well as those of other Native groups and fur trade entities in the region.

Alternatively, Mitchell (2011, 2013) documents archaeological evidence for subsistence changes among the Mandans in the centuries prior to the 1780s. He suggests that although bison continued to serve as a significant food source after the fifteenth century, a broader range of smaller game was increasingly utilized. Furthermore, Mitchell (2011, 2013) cites circumstantial and limited evidence of intensified agricultural productivity (i.e., an increase in per capita productivity), including an increase in the number and size of storage pits, through the eighteenth century among horticultural groups that lived along the Missouri River. However, a systematic examination of changes in agricultural production, either increased productivity or simply expanded production, in this region of the Northern Plains has not yet been attempted.

My goal is to initiate an effort to fill this void by examining agricultural production among horticultural groups living along the Missouri River in the Northern Plains during a period from about 1200 to 1886. By adopting a long-term perspective that uses archaeological evidence as well as historical information, this investigation can better characterize historical agricultural traditions and secondarily clarify how colonial interactions may have contributed to change and continuity in agricultural production. Consideration of this topic is influenced by recent theoretical developments in both history and archaeology.

Common Perspectives: Historical Approaches and Archaeological Theory

For the past three decades similar revisionist perspectives concerning colonial interactions in North America have developed in the disciplines of history and archaeology. Traditional colonial narratives, supported by more than a century of anthropological theory, described the rapid changes that Native cultures experienced soon after contact with European colonists (Mitchell and Scheiber 2010). Contact placed Native groups on the verge of collapse with many dead due to epidemic diseases and rapid losses of culture among others as Native societies quickly became dependent upon European technologies and lifeways. In both fields, proponents of revisionist perspectives have attempted to demonstrate the complexity of interactions from the fifteenth century through the nineteenth century between various Native groups and imperial powers—the Spanish, French, British, and Americans. By acknowledging and exploring the ways Native histories, institutions, and actions affected European colonialism, the shortcomings of standard colonial narratives for explaining how and why Native societies changed during the period have become more apparent. Far from the traditional linear narrative, colonial processes vary temporally and geographically.

Historical Perspectives

Among historians this approach is sometimes known as “new Indian history," and White’s (2010) concept of the “middle ground” exemplifies one revisionist perspective. As White (2010) describes it, the middle ground occurred in the *pays d’en haut*, or the upper country, a Great Lakes region stretching from Lake Ontario west to the Mississippi River and from the Ohio River north into Canada. The middle ground was made possible by a convergence of economic, social, political, and demographic conditions. Beginning in the mid-seventeenth century, Algonquian peoples (White uses the term Algonquian, a Native language group, to refer to a large, multi-ethnic group of Algonquian, Siouan, and Iroquoian peoples dominated by Algonquian speakers) began fleeing westward across the *pays d’en haut*, both from outbreaks of epidemic diseases and Iroquois attacks. Between the western Great Lakes and Mississippi River, tens of thousands of Algonquian refugees established large, multi-ethnic communities. Ties among disparate people were made possible by Native practices such as gift exchange and intermarriage. More importantly, this regional Algonquian alliance was mediated by Jesuit priests and French traders, and a relationship between the French and Algonquians based on trade and alliance was created and reinforced as a result of continued Iroquois attacks during the second half of the seventeenth century.

According to White (2010), the middle ground developed as a consequence of “creative misunderstandings,” mutual benefit, and accommodation (but not acculturation) of both Native and non-Native beliefs, institutions, and practices, where neither held more political or economic influence. However, the middle ground was a fluid creation. With the defeat of the Iroquois by the Indian-French alliance in the late seventeenth century, the French struggled to maintain peace within and among the refugee centers. As Algonquians left those communities in the first half of the eighteenth century and spread to the east and south, the French—to maintain the alliance upon which their participation in the fur trade depended—were forced to mediate conflicts brought on by the migrants' expansion. The period was characterized by French attempts to restore the alliance by again disbursing gifts, reoccupying trading posts, occasional use of force, and endless negotiations. The character of the middle ground would continue to change for the Native occupants of the *pays d'en haut* in the second half of the eighteenth century until it collapsed in the early nineteenth century. These changes correspond with British colonial dominance following the Seven Years' War, the Revolutionary War, the War of 1812, and the social, economic, and environmental changes brought to the region by more populous Americans. Thus, over a period of several centuries, the experience of both Native individuals and colonists in the Great Lakes region regularly changed and was far from straightforward as would be suggested by conventional narratives.

Like White (2010), Witgen (2012) counters traditional narratives of imperial power and authority and the rapid conquest of indigenous peoples in North America. Importantly, Witgen (2012) acknowledges that Native peoples experienced social disruption and dramatic change as a consequence of the arrival of colonists, their trade goods, new plants and animals, and diseases. Yet, he correctly argues that until at least the mid-eighteenth century, much of North America was occupied and controlled by politically, socially, and economically autonomous Native groups. Contrary to White (2010), the interior of North America was a "Native New World" rather than one controlled by any imperial power or one in which relatively weak Native groups and Europeans compromised to form a "middle ground." Witgen's (2012) geographical and temporal focus overlaps with White's (2010): the *Anishinaabewaki*, or western Great Lakes region occupied by the Algonquian speaking Anishinaabeg, and the northwest interior, where the Dakota lived during the late seventeenth and early eighteenth centuries. When French traders and missionaries first appeared in this region, they lacked influence (Witgen 2012). Notions of imperial power and authority in this region were fantasy. French traders and missionaries transitioned from "foreigner" to "relative" among the Anishinaabeg by participating in certain Algonquian ceremonies and kinship rituals. Whereas the French misinterpreted the meaning of such events to be the formalization of political and military alliances, in reality, their new relationship with the Anishinaabeg as kin simply fostered trade. Trade goods allowed the Anishinaabeg to expand their own alliances and extend their influence in the region, but the French presence in this Native New World remained precarious, as did the British in the eighteenth century.

Similarly, DuVal (2006) provides an alternative view to White's (2010) "middle ground" by further highlighting certain limitations of the concept. According to DuVal (2006), the Arkansas Valley, where European and American colonists and other Native groups were incorporated into local Native practices rather than accommodated or resisted, remained a "Native ground" until the nineteenth century. In other words, diplomacy, warfare, trade, and other inter-cultural relations were shaped more by local Native groups than by any of the colonial powers, each of which lacked the necessary population and authority to determine the outcome of interactions with independent Native populations. For example, during the seventeenth century the Quapaws, recent immigrants to the lower Arkansas Valley, recognized an opportunity to establish the region as their native ground and allied themselves with the

French. In establishing this alliance, the French envisioned two goals: trade and religious conversion. The French were allowed opportunities to hunt, trade, and travel in the region. However, in practice the alliance was formed and carried out on Quapaw terms and depended on the ability of the French to comply with Quapaw interests. French traders entered Quapaw trade networks by becoming kin via their participation in elaborate ceremonies. In particular, the Quapaws desired guns, which they might use to enhance their sovereignty and maintain their native ground. Hunting jointly with French voyageurs, the Quapaw harvested the animals the French desired, which they used to obtain trade goods like guns, but overall, the presence of the French did not alter the Quapaw economy, according to DuVal (2006). Likewise, Jesuit priests were welcomed by the Quapaw, although their attempts at religious conversion were overwhelmingly unsuccessful. Due to their concern with growing Osage power, the Quapaws would extend their alliances to the Spanish, British, and Chickasaws in the latter half of the eighteenth century.

The central Arkansas Valley was home to the Osages, who were similarly eager to establish trade relations with the French in the eighteenth century (DuVal 2006). Unlike the Quapaws, the Osages sought to recruit French and later Spanish trade so that they could expand their economic and military dominance of the Arkansas Valley west onto the Plains. Access to French weapons allowed the Osages to establish and expand a successful commercial hunting operation westward, from which they extracted resources desired by the French. Furthermore, the westward expansion brought them into increased contact and conflict with other Native groups. The military dominance of the Osages over these groups was in part a consequence of their supply of guns and ammunition and their ability to prevent traders and hunters, whom they would occasionally kill, from reaching Native enemies to the west. Despite these deaths, the

Osages maintained their beneficial relationship with the French through the use of diplomacy. At the turn of the nineteenth century, Osage dominance of the region would come to an end as Cherokee settlers moved into the lower Arkansas Valley, a place that afforded them hunting, trading, and other opportunities that they lacked in the east. According to DuVal (2006), the Cherokees quickly made the Arkansas Valley their native ground. They formed alliances with other Native groups such as the Quapaws to isolate the Osages. Additionally, the Cherokees were greater in number, better armed, and more experienced in war than other Osage enemies and successfully fought against the Osages for their lands. More importantly, the Cherokees were more familiar with United States diplomacy and ideology. They argued that their farms and ranches had improved the lands and that they were acting according to their treaties and Indian policy, unlike the Osages. The Cherokees thus achieved approval for their land claims from United States officials. For a brief period, the lower Arkansas Valley was a Cherokee native ground. However, in the early nineteenth century, American settlers began flooding into the region, which ultimately led to a new policy of Indian expulsion. Again, the colonial experience of Native groups and colonists in the Arkansas Valley was complicated and affected largely by Native actions rather than the unilateral efforts of colonists in the region.

Hämäläinen's (2008) revisionist history of the colonial Southwest, where colonial roles were reversed from approximately 1750 to 1850, stands in contrast to the previous examples. According to Hämäläinen (2008), the Comanches would come to dominate the Comanchería, lands extending from eastern New Mexico across western Texas and into northern Mexico, although they had only migrated to the Southern Plains in the early eighteenth century. The Comanches took advantage of the empowering potential of horses and guns, and their military superiority and pragmatic diplomacy enabled them to oust many other Native groups from the region and limit French and Spanish expansion. Their effort yielded greater access to resources, including the large bison herds on Plains, and they experienced rapid population growth as a result. The Comanches furthered their economic dominance of the region in the second half of the eighteenth century by establishing a raid-and-trade strategy. Following this policy, the Comanches stole what was easily plundered (e.g., horses and human captives) and purchased what could not be easily obtained through raiding (e.g., maize). However, their empire would decline rapidly beginning in the 1840s as a result of several ecological and economic factors. For instance, by the first half of the eighteenth century, their commercial and hunting harvests had severely impacted bison herds, and their large horse herds competed for the same resources as bison. Finally, a multi-year drought impacted the region beginning in the mid-1840s, exacerbating these factors and causing bison herds to collapse. Hämäläinen (2008) argues that these factors ultimately led to the collapse of the Comanches' trading network and their empire, which opened the door for American expansion into the region.

At various points during the seventeenth century through the nineteenth century, a period in which horticultural tribes such as the Mandans, Hidatsas, and Arikaras transitioned from indirect to local trade with European and American colonists, the Missouri River region in the Northern Plains might best be viewed as a middle ground or a native ground. That is, colonial interactions in the Northern Plains share certain elements with the revisionist colonial histories of the Great Lakes and Southeast regions described by DuVal (2006), White (2010), and Witgen (2012). For instance, when La Vérendrye arrived at a Mandan village along the Missouri River in December 1738, he claimed to take possession of their lands for France (Smith 1980:63). However, La Vérendrye's visit had little impact on trade or the Native occupants of the Missouri River. Rather, La Vérendrye had encountered a people, who along with their other village-dwelling neighbors, played a crucial role in a long-established continent-wide exchange system (Swagerty 1988; Wood 1980). When European and American fur traders became regular visitors and then permanent fixtures of the Missouri River villages, they were incorporated into a preexisting trade system, one that undeniably underwent important changes as a consequence, however. Even though considerable quantities of trade goods entered their villages in the nineteenth century, the Mandans remained autonomous (Anfinson 1987). The Mandans continued to be a primary source of maize for several Native groups, and they also supplied fur traders with large quantities of agricultural produce. That is, to maintain their pivotal role in this altered trade system, the Mandans relied on a long-standing tradition: maize production. The Arikaras assumed this role following the smallpox epidemic of 1837.

Archaeological Perspectives

Like historians, some archaeologists have countered traditional narratives of colonialism in North America (e.g., Ferris 2009; Mitchell 2011, 2013; Scheiber and Mitchell 2010; Silliman 2001). The general goal of such revisionist works is to generate more nuanced understandings of the various ways Native groups in different regions and during different centuries negotiated colonialism. Rather than the linear trajectory of the conventional narrative, revisionist perspectives detail how Native histories, institutions, and actions affected the trajectory of colonialism in local settings. Critically important to these endeavors is the deep historical context provided by archaeology, a context that serves as a framework to assess varied patterns of economic, social, and technological change and continuity among specific Native groups during the sixteenth century through the nineteenth century.

One problem noted by scholars of colonial interactions is the artificial distinction between “prehistoric” and “historic” Native groups, sites, and artifacts (Mitchell and Scheiber

2010:13-14). Although these terms are temporal markers, they also have processual connotations, and their use perpetuates conventional colonial narratives of Native culture change. Moreover, these terms widen the methodological difference between archaeology and history (Mitchell and Scheiber 2010:14). Native culture change after the arrival of Europeans is viewed as the domain of historical research because of the availability of colonial documents. In contrast, problem-based, empirical research in archaeology is largely limited to periods prior to the appearance of Europeans in North America. Even when archaeologists investigate Native sites dating to the post-1500 period, archaeological data are either given less weight than historical documents or they are used to verify historical accounts (Mitchell and Scheiber 2010:14).

Yet, archaeology is aptly suited for the study of Native-European interactions and the changes that occurred among Native and European societies as a consequence. It is widely accepted that archaeologists can identify subtle variations in economic systems, subsistence practices, settlement patterns, and so forth. Archaeologists are thus uniquely situated to empirically evaluate the development of historical traditions among specific Native groups and compare these with local patterns of continuity and change that occurred with the arrival of Europeans, their trade goods, and epidemic diseases (Ferris 2009; Mitchell and Scheiber 2010). In other words, problem-oriented historical research enables archaeologists to contest conventional narratives of abrupt cultural change and decline among Native groups at the outset of colonialism. Although the ways Native groups negotiated the arrival of colonists varied, Ferris's (2009) concept of "changed continuities" can be used to define the outcome of European-Native interactions in many instances. Despite changes to Native political and economic systems, technologies, and identities during the sixteenth century through the nineteenth century, elements of these were frequently maintained or changes were less dramatic and sudden than previously envisioned. More importantly, changes among Native groups were negotiated. Revisions were influenced by historically informed knowledge and practices that had developed over long periods. The choices of Native groups and individuals affected the course of colonial interactions (Mitchell and Scheiber 2010:15).

Fundamental to these revisionist archaeological perspectives has been a shift toward empirically-based, problem-oriented research that acknowledges the role of Native social agency in the reproduction and transformation of historical traditions over time (e.g., Pauketat's [2001a, 2001b] "historical processualism"). Such views rely on the concepts of agency and practice as defined by Bourdieu (1977) and Giddens (1979, 1984). These concepts have been applied by archaeologists in a multitude ways, oftentimes with very different approaches regarding issues such as the appropriate unit of analysis and the knowledgeability of actors (Dobres and Robb 2000, 2005; Dornan 2002; Joyce and Lopiparo 2005).

Within Missouri River horticultural villages, agricultural production was likely carried out by households as part of a larger community practice. The long-standing tradition of maize production in the region, which occurred for nearly a millennium, was the consequence of "repeated practices" (Joyce and Lopiparo 2005:370). Moreover, generations of experience in the region led to the development of a broad knowledge base regarding subsistence production, one informed by historical circumstances (e.g., climate) and influenced by immediate conditions (e.g., weather, soil conditions, and subsistence requirements). The actions of Northern Plains peoples on a day-to-day basis regarding agricultural production would have been negotiated based on this knowledge and influenced by social, religious, economic, and ecological constraints and opportunities, leading to both reproduction and transformation of such practices through time. Even during the period of colonial engagement, horticultural villagers' subsistence choices and actions were made within the context of and affected by their histories, institutions, practices, knowledge, and beliefs. Based on its long-term perspective, archaeology is ideally and uniquely suited to explain change and continuity in various practices, including subsistence practices, during the period of Native and colonial encounters and interactions along the Missouri River in the Northern Plains.

Research Themes and Questions

My research focuses on one area where change and continuity over a centuries' long period, spanning the time of colonial interactions, can be explored: agricultural production. That changes in agricultural production have not been examined systematically is likely the result of several factors. Despite the abundance of historical and ethnographic information from the nineteenth and early twentieth centuries, these data are generally qualitative and are not easily employed for examining trends in agricultural production. Although they have some utility, such information is best described as circumstantial. More importantly, archaeological data (minus macrobotanical data and the presence of modified artifacts like bison scapula hoes) that would be telling of agricultural practices and changes in cultivation methods are nonexistent for the region. For example, unlike other regions of North America in which Native field systems have been identified by archaeologists (e.g., Damp et al. 2002; Gartner 1999; Sandor et al. 1990; Siemens and Puleston 1972), evidence of agricultural fields or gardens along the Missouri River and its major tributaries is lacking. Pollen and phytolith analyses have been undertaken to identify garden plots near at least one major village, Double Ditch State Historic Site (32BL8) in North

Dakota, with minimal success (Munson-Scullin and Scullin 2009). Additionally, historical maps depict Native gardens at some nineteenth-century sites along the Missouri River (Callaway 2012:Figure 37; Wilson 1917:Figures 36, 37, and 40). Most, if not all, agricultural fields located in the floodplain have been destroyed by the meandering of the Missouri River, modern agriculture, or twentieth-century reservoir construction and inundation. Thus, any attempt to quantify agricultural production among Native horticultural groups that lived along the Missouri River in the Northern Plains must rely on indirect (or proxy) evidence in the form of subterranean storage pits, a well-known and ubiquitous feature within Plains Village sites.

My objective is to investigate systematically historical trends in agricultural production among Plains Village period (dating from approximately 1000 to 1886) sedentary horticultural Native groups who occupied villages along the Missouri River in the Northern Plains in relation to the trends noted by Mitchell (2011, 2013) and the appearance of colonists. Emphasis is placed especially on villages located in the northern half of the Middle Missouri, an ecologically unique subarea within the North American Plains, that were occupied by the Mandans, Hidatsas, Arikaras, and their ancestors (Lehmer 1971; Wood 1998) (Figure 1.1). This area is located primarily in North Dakota and is further subdivided into the Cannonball, Heart, Knife, and Garrison archaeological regions (Figure 1.2). More specifically, to better understand how factors such as colonial interactions, disease, and climate change affected production, I examine agricultural surpluses among villagers who lived at the mid-fifteenth-century Huff Village State Historic Site (32MO11) and the nineteenth-century Fort Clark State Historic Site (32ME2) (Figure 1.3). To further shed light on this issue, I use complementary threads of evidence, including traditional archaeological data in the form of excavation and coring results of subterranean storage pits from 20 sites, geophysical evidence from Huff and Fort Clark, and historical and ethnographic information. These data sources span a time range from approximately the thirteenth century through the early twentieth century.

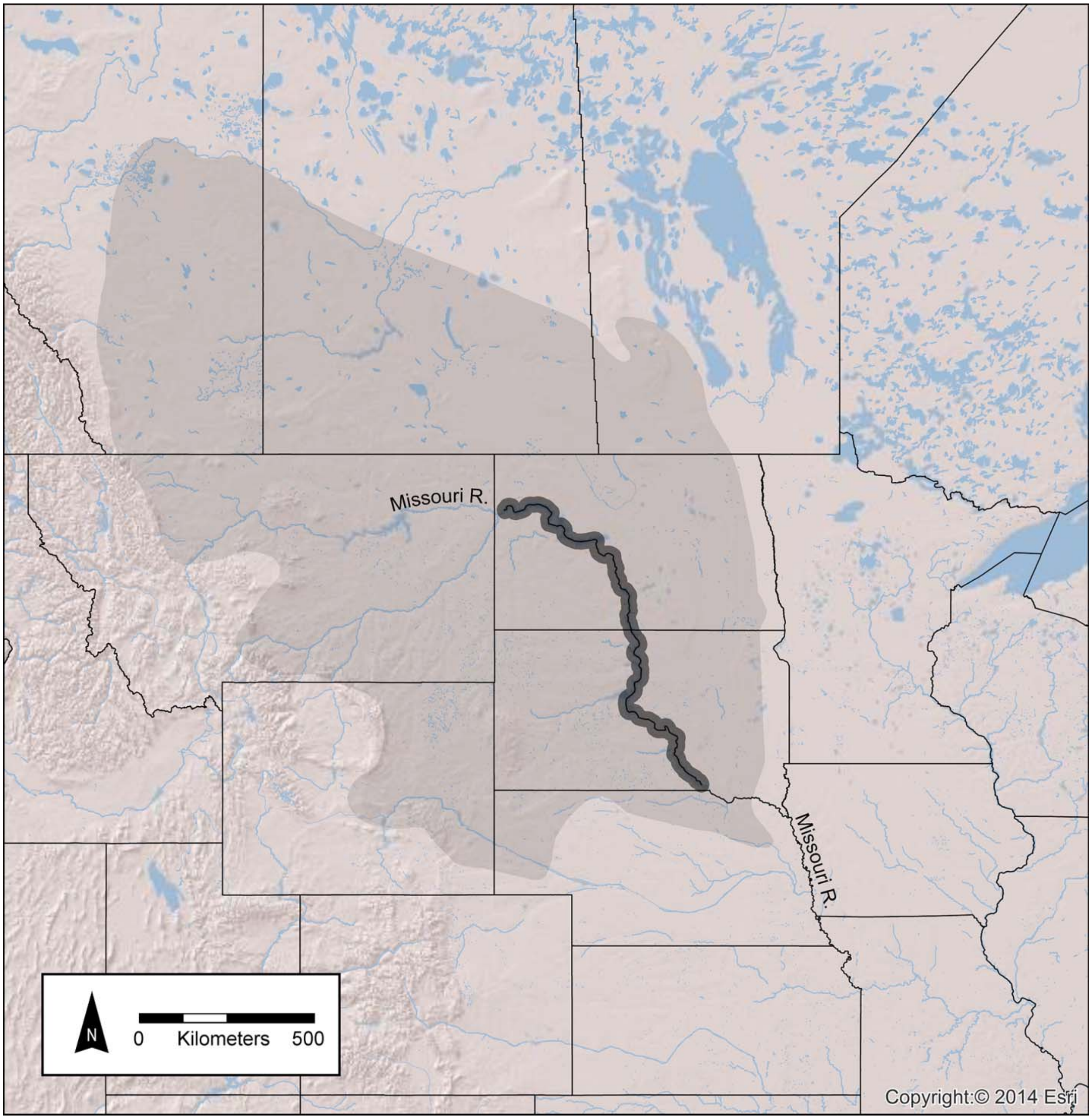

Figure 1.1. Shaded relief map of central North America showing the Northern Plains in gray (After Mitchell 2013:Figure 1.1). The Middle Missouri subarea of the Plains is shown as a dark gray buffered line. Portions of this document include intellectual property of Esri and its licensors and are used herein under license. Copyright © 2014 Esri and its licensors. All rights reserved.

Following the general theme of a conventional narrative of colonialism, one might expect a decrease in agricultural production as Native lifeways were disrupted due to the introduction of trade goods and diseases. In fact, Indian agent reports from the mid- to late nineteenth century often inform on the destitute and helpless condition of the Mandans, Hidatsas, and Arikaras, including their lack of food and the necessity government-supplied rations (e.g., Burbank 1870:209; Latta 1864:170; Manypenny 1856:4). However, these accounts, perhaps incomplete and biased, have not been substantiated with corroborating information. Archaeological data provide evidence of long-term trends in agricultural production so that instances of change or continuity may be identified. In an effort to provide such evidence, I address the following research themes:

1. To begin, few Northern Plains sites have been both surveyed with geophysical techniques and excavated as extensively as Huff Village. As a thoroughly investigated fifteenth-century settlement, Huff Village provides an opportunity to examine agricultural production prior to the appearance of colonists or their trade goods. With these data, I consider several pertinent questions regarding agricultural production and storage within the settlement. For instance, what is the per capita storage capacity given a population estimate of the village and its nutritional needs? To arrive at such an estimate, I attempt to determine the number and average volume of subterranean storage pits present at the Huff site.
2. Although data from Huff Village provide one point of comparison, a much more extensive record of agricultural production is necessary to understand long-term trends. Unfortunately, most surveyed or excavated sites in the region do not offer comparable data. Yet, proxy data for agricultural production are available in the form of storage pit

numbers and sizes. Using available information from excavations and coring at sites in the Missouri River valley in North Dakota occupied from approximately 1200 to 1886, I examine trends in storage pit volumes and numbers. During what periods do significant changes occur, if any, and do they correspond with trends identified by Mitchell (2011, 2013) or other important historical events (e.g., episodes of epidemic diseases, climatic events, or the appearance of European and American colonists)?

3. Like Huff Village, the nineteenth-century Mandan/Arikara village at Fort Clark has been investigated extensively. Moreover, detail-rich but possibly inaccurate historical documentation exists concerning factors such as the number of occupied houses, population totals, and amounts of agricultural produce at various points during the village's nearly four decades of occupation. Given an estimate of the number of storage pits based on remote sensing and coring data, how does storage capacity at Fort Clark compare with earlier and later periods? How do these approximated figures compare with historical information? More importantly, how do these findings correspond with traditional narratives of colonialism and its consequences? Is there evidence for a dramatic decline in agricultural production as might be expected according to a conventional narrative of colonialism in which Native traditions were supplanted? Alternatively, is there evidence for a continuation of earlier trends, or even an increase in production during the nineteenth century (as argued by Anfinson [1987])?

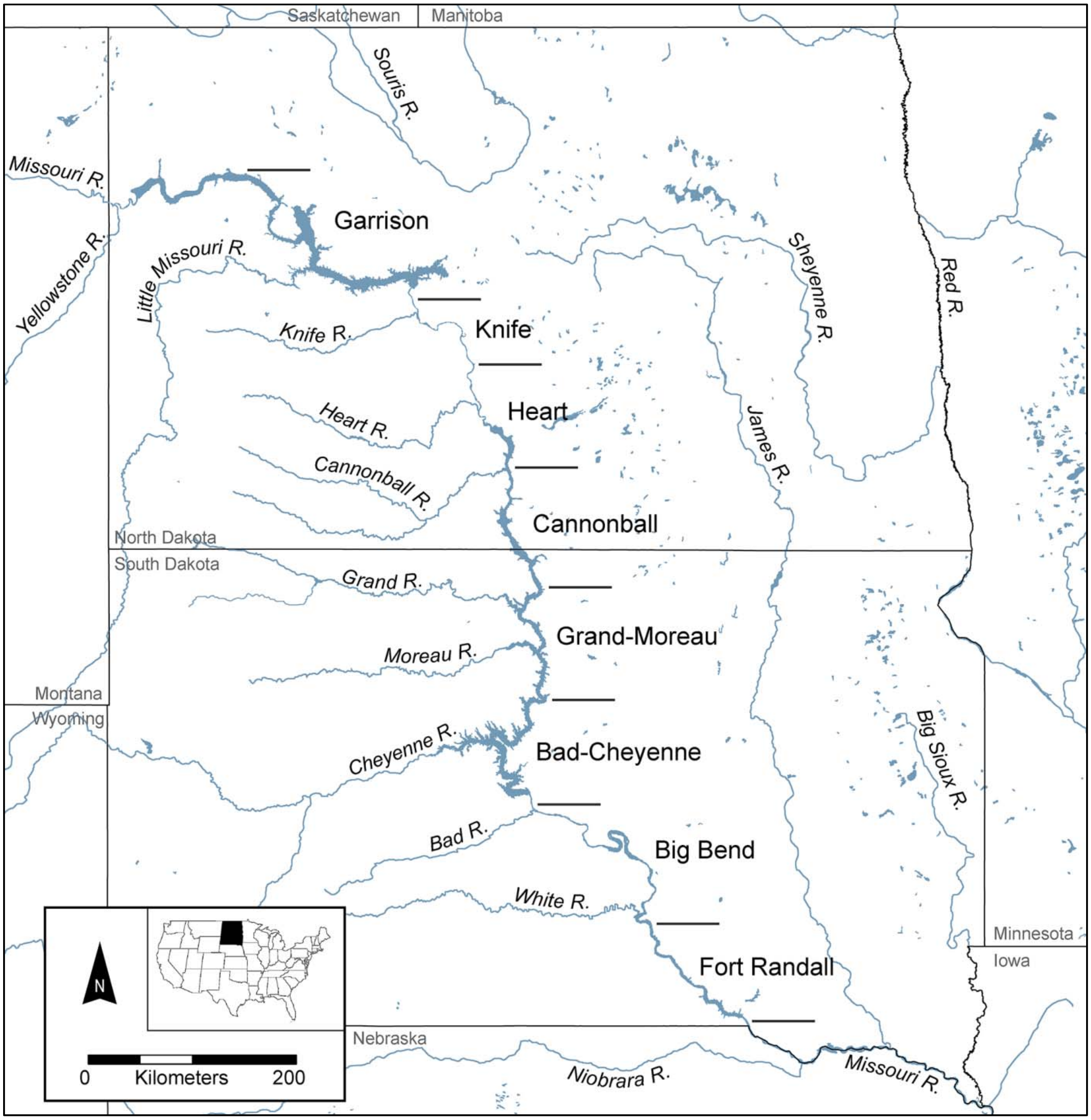

Figure 1.2. Map of North and South Dakota showing the archaeological regions within the Middle Missouri subarea (After Mitchell 2013:Figure 1.2).

My primary goal is provide a better understanding of temporal trends in agricultural production among sedentary horticulturalists along the Missouri River. However, the study indirectly serves as an evaluation of assumptions that have been put forward regarding the immediate effects of colonial encounters between European and American colonists and Native groups in North America. Like recent revisionist studies, consideration is given to the ways

Native histories and practices fostered continuity and change in production on a local level, despite the appearance of colonists. The results of this work, although specific to one region, are widely applicable to colonial era studies and aid understanding of the diverse processes of colonialism. Furthermore, the use of complementary data sources, including geophysical evidence, to address questions of anthropological significance, satisfies a concern of North American archaeologists (Thompson et al. 2011).

Figure 1.3. Map showing the approximate locations of archaeological sites discussed in the text. Excavation data are used from sites shown in black.

Middle Missouri Plains Village Archaeology and Native Groups

The Middle Missouri is one of five subareas within the Plains, an environmentally, climatically, and culturally heterogeneous area occupied by Native peoples for well over 10,000 years (Kay 1998; Lehmer 1971:28-33; Wood 1998:9-13). The Plains area covers a large swath of the interior of the North American continent, bordered by the Rocky Mountains to the west, the mixed forests and grasslands of the Prairie Peninsula to the east, the subarctic forests within Canada to the north, and the Gulf Coastal Plain to the south. North and South Dakota as well as parts of the states of Montana, Wyoming, and Minnesota, and the Canadian provinces of Alberta, Saskatchewan, and Manitoba constitute the Northern Plains (Kay 1998:16-17; Figure 1.1). The Middle Missouri subarea consists of a much smaller area, essentially the Missouri River valley and the intersecting areas of its tributaries from approximately the western border of North Dakota and the southern border of South Dakota (Lehmer 1971:28-33; Wood 1998:9-13; Figure 1.1). Archaeologists further subdivide the area into eight archaeological regions, from north to south referred to as the Garrison, Knife, Heart, Cannonball, Grand-Moreau, Bad-Cheyenne, Big Bend, and Fort Randall (Ahler 1993a; Johnson 2007:1-7; Lehmer 1971:28-33; Figure 1.2). Sites within the northernmost four regions are the focus of this study.

Archaeologists have worked in the Middle Missouri subarea for over a century, and during this period, a large body of data regarding technological, subsistence, and settlement pattern variability has developed. The Plains Village period (ca. 1000-1886) within the Middle Missouri subarea differs from preceding culture periods in significant ways (Ahler 1993b; Johnson 1998, 2007; Krause 2001; Lehmer 1971; Winham and Calabrese 1998; Wood 2001). During this period, Native groups occupied semi-permanent villages consisting of several to well over 100 partially or completely earth-covered circular and rectangular timber-frame houses. Each house typically had a hearth placed near its center as well as several subterranean straight-sided and undercut pits dug into its floor, in which agricultural produce, especially maize (*Zea mays*), was stored. The villagers developed a subsistence economy based roughly equally on horticulture and bison hunting, although they actually took advantage of the wide range of resources available in the diverse physiographic zones of the river valley and surrounding environments (Lehmer 1971:49-55) (Figure 1.4). Thus, Middle Missouri villagers employed a low-level food production strategy (Smith 2001) in which a large number of wild, naturalized, and domesticated plant species (e.g., cucurbits, beans, sunflower, goosefoot, marshelder, chokecherry, grape, plum, buffaloberry, rose, and marshelder) were exploited (Nickel 2007) along with a variety of wild game species (e.g., deer, pronghorn, canids, rabbits, turtles, birds, fishes, and mollusks). Although bison hunting and maize farming were critical dietary elements of Middle Missouri communities, their dynamic subsistence economy was flexible and well adapted to ever-fluctuating conditions of the environment (Mitchell 2013:84-85). Moreover, the hundreds and thousands of subterranean storage pits in each village in which surplus agricultural goods were stored are a testament to the economic productivity of this subsistence system (Mitchell 2013:84-85).

Figure 1.4. Confluence of the Heart and Missouri Rivers just south of present-day Bismarck, North Dakota. Image shows the varied physiographic zones of the river valley, including an upper terrace, the partially forested "breaks," a lower terrace, and the floodplain. Photograph by the author.

Middle Missouri Plains Village Taxonomies

The first widely accepted attempt to develop a culture taxonomy and chronology of Plains Village settlements for the Missouri Missouri subarea was led by Lehmer (1971) following years of salvage archaeology by personnel with the Smithsonian Institution River Basin Surveys program in the Missouri River basin (see discussion in Thiessen 1999) (Table 1.1). Most importantly, Lehmer identifies distinctive differences within Middle Missouri Plains Village sites enabling him to define two cultural traditions, Middle Missouri (MMT) and Coalescent (CT). Continued work in the region has resulted in numerous spatial and temporal revisions to Lehmer's developmental sequence (e.g., Ahler 1993a, 2007; Tiffany 2007; see discussions in Johnson 1998; Winham and Calabrese 1998), although his taxonomic framework continues to serve as the basis of many systematic archaeological investigations in the region today. The most comprehensive revision of Lehmer's (1971) chronology for the entire Middle Missouri subarea was undertaken by Johnson (2007), whose ceramic ordinations of over 200 site components and radiocarbon dating effort greatly refined the temporal sequence and settlement history of Plains villagers (Table 1.1).

Table 1.1. Middle Missouri subarea Plains Village taxonomic systems.

	Lehmer (1971) Taxonomy	**Johnson (2007) Taxonomy**
Tradition	Variant (Date Range)	Variant (Date Range)
Middle Missouri	Initial (900-1400)	Initial (1000-1300)
	Extended (1100-1500)	Extended (1200-1400)
	Terminal (1500-1675)	Terminal (1400-1500)
Coalescent	Initial (1400-1500)	Initial (1300-1500)
	Extended (1550-1675)	Extended (1400-1650)
	Post-Contact (1675-1780) Disorganized (1780-1862)	Post-Contact (1600/1650-1886)

Additionally, due to his research at the Knife River Indian Villages National Historic Site in North Dakota, Ahler (1993a) argues that the archaeological sequence of the Knife and Heart regions is distinct from that of South Dakota, leading him to establish a separate taxonomic system (Table 1.2). Despite numerous problems associated with these archaeological sequences (see discussions in Johnson 2007:9-13; Mitchell 2011:388-392), they still have utility in terms of communicating variability in archaeological patterning (cultural differences) and developing and organizing research with a chronological component. However, for the purposes of this study, I further subdivide the broad temporal ranges of these taxonomic systems, following Johnson's (2007) settlement history and Mitchell's (2011, 2013) divisions of the post-1500 period, based on radiocarbon dating whenever possible, the presence and density of trade artifacts, and historical information. This approach facilitates comparisons among contemporaneous and non-contemporary villages in the northern Middle Missouri subarea to identify variability in storage pit capacities and agricultural production.

Table 1.2. Ahler's (1993a) taxonomic system for the northern Middle Missouri subarea (North Dakota).

Ahler (1993a) Taxonomy	
Complex	Date Range (A.D.)
Middle Missouri	1000-1450/1500
Heart River	1450-1785
Painted Woods	1300-1525
Knife River	1600-1886

A Brief History

Numerous accounts of the culture history of the area exist (e.g., Johnson 1998, 2007; Krause 2001; Lehmer 1971, 2001; Winham and Calabrese 1998; Wood 2001). A brief review of this history is sufficient to highlight its key elements most relevant to this study. Although the development of the MMT is debated (cf. Ahler 2007; Lehmer 1971; Tiffany 2007; Toom 1992), evidence suggests that relatively small aggregated farming villages began to form in the eleventh century from local Late Woodland groups in the Missouri River valley of southern South Dakota and farther east along the Plains-Prairie border of southwestern Minnesota and northwestern Iowa. Denoted by archaeologists as the Initial Middle Missouri variant (IMMV), this development involved a transition in settlement patterning from preceding Late Woodland groups, expanded interaction and interregional trade, and intensive maize farming. IMMV villagers, particularly those located to the east off the Missouri River trench, were prolific traders in the Northern Plains (Henning 2007:69-71). Based on evidence from excavated sites (Mill Creek sites dating from 950 to 1300), they dealt specifically in freshwater snail shell beads, Atlantic and Gulf coast marine shell objects, and lithic materials from neighboring regions, not to mention perishable goods like agricultural produce. IMMV rim sherds have been identified in Late Woodland and Mississippian contexts in surrounding geographical areas as well. Western IMMV villagers, in contrast, participated in a long-standing, extensive exchange network involving contemporaneous Late Woodland groups that brought Knife River flint materials as well as marine shell and native copper to the villages (Ahler 2007).

Although antecedent and contemporaneous Late Woodland groups consumed maize, likely obtained via trade but perhaps produced in small quantities (Lints 2012; Boyd et al. 2008), the adoption of intensive maize agriculture was a “prime mover” in the formation of IMMV villages (Tiffany 2007:7). Climate has been argued to be a driving force in the origin of the IMMV, with Plains village farming developing during a period of improved climatic conditions (i.e., a warm and moist period during the Neo-Atlantic) (Toom 1992). However, other paleoclimatic evidence for the period indicates contradictory conditions (i.e., periods of prolonged drought) (Tiffany 2007:10), meaning the link between climatic factors and the adoption of agriculture in the region is inconclusive.

Aggregated farming villages appeared along the Missouri River valley in northern South Dakota and North Dakota in the thirteenth century, the earliest period of significance to my investigation. The development of these settlements, referred to as Extended Middle Missouri variant (EMMV) communities by archaeologists, is likewise the subject of debate (cf. Lehmer 1971; Winham and Calabrese 1998:281-283; see discussions in Johnson 2007:109-118; Tiffany 2007). However, in the northern Middle Missouri subarea, the origin of EMMV groups is linked directly to preceding Late Woodland groups (Ahler 2007). Extensive excavations and geophysical surveys at a terminal Late Woodland site in central North Dakota, Menoken Village (32BL2), reveal limited evidence of gardening (indicated by an absence of storage pits, limited evidence of bone gardening tools, and relatively few botanical remains of domesticated species) at the small nucleated and fortified village dating to around 1200 (Ahler, ed. 2003a; Ahler 2007:17-21). Other evidence (e.g., architectural, ceramic, and lithic) suggests clear links between

Late Woodland and later EMMV groups with influence from western IMMV communities to the south.

Although certain aspects of village farming life were anticipated in Late Woodland settlements like Menoken, EMMV communities were fundamentally different. These communities adopted a subsistence economy based on a broader range of foodstuffs, including domesticated plant foods. Unlike earlier Late Woodland settlements, evidence of intensive maize agriculture is common at subsequent EMMV villages like Havens (32EM1), Bendish (32MO2), Paul Brave (32SI4), Fire Heart Creek (32SL2), Jake White Bull (39CO6), Cross Ranch (32OL14), White Buffalo Robe (32ME7), Shermer (32ME10), and South Cannonball (32SI19) in the northern Middle Missouri subarea (Figure 1.3). Like earlier IMMV communities, those of the EMMV are small, averaging just under 4 ha and typically consisting of fewer than 50 lodges (Mitchell 2013:171, 218-219). Excavated EMMV dwellings are on average slightly greater than 100 m^2 in area, a lodge size that remained consistent until the nineteenth century (Mitchell 2013:167). EMMV villagers continued to participate in a long-distance exchange network, although trade was oriented more toward the Pacific Coast from which marine shells were obtained, and native copper and red pipestone materials arrived from the Great Lakes and upper Missouri River valley regions (Mitchell 2013:174).

During the period archaeologists have labeled the Terminal Middle Missouri variant (TMMV), subsequent generations of Plains villagers established dramatically different communities. In the fifteenth century, they constructed a small number of short-lived yet large, fortified settlements, including Huff, in the Heart region of North Dakota (Johnson 2007:178-185; Winham and Calabrese 1998:285-290; Wood 1967, 2001:194-195). The Shermer site too has been assigned to the TMMV, although its dating to the mid- to late fourteenth century and ceramic assemblage justify its placement in the EMMV (Mitchell 2013:220-221). Unlike earlier EMMV settlements, Huff has over 100 rectangular lodges, although the mean size of Huff lodges is similar to those from prior centuries (Kvamme 2007a; Kvamme et al. 2009; Mitchell 2013:225-226; Wood 1967). Furthermore, the size of Huff Village is comparable, indicating a nearly threefold increase in lodge density and estimated population (i.e., an estimated population over 1,000 versus an average estimated population of about 300 individuals for EMMV communities), a pattern noted for sites dating to subsequent centuries, even when site size decreased later due to epidemic diseases (Mitchell 2013:171, 223-226). The increase in population density near the Heart River during this period appears to be a consequence of aggregation within villages in the region during the late fourteenth and early fifteenth centuries, perhaps due to migration from the south, and a transition from widely dispersed settlements to a more clustered settlement pattern (Mitchell 2013:171). Additionally, excavations and geophysical surveys at Huff reveal the locations of thousands of large, subterranean storage pits within and outside of each dwelling, the subject of Chapter 3. The ubiquity of such features generally indicates the significance of agricultural produce to these Plains farming villagers (Kvamme 2007a; Kvamme et al. 2009; Wood 1967). Undoubtedly, these perishable foods were part of the regional exchange system that existed at the time, although during the fifteenth and sixteenth centuries, the exchange system expanded and the volume of traded goods increased significantly (Mitchell 2013:173-174). Although circumstantial evidence indicates an increase in storage capacity, and hence agricultural production or perhaps even productivity, for the community of Huff, a complete examination of geophysical, excavation, and coring data from the village has yet to be attempted.

Slightly predating this period, an influx of farming villagers occurred in central South Dakota, a period archaeologists refer to as the Initial Coalescent variant (ICV). The development of these settlements is similarly debated, although it is now widely accepted that the earliest Coalescent villagers represent a northward expansion of Central Plains tradition peoples from Nebraska in the fourteenth century (see discussions in Johnson 1998:313-317, 2007:119-124; Krause 2001:196-202; Lehmer 1971). Besides ceramic styles, the most apparent distinction between these people and contemporaneous Middle Missouri tradition villagers to the north is in house form. Whereas Middle Missouri villagers constructed rectangular houses, their Coalescent neighbors to the south built rounded square or circular timber-frame and earth-covered dwellings (like Central Plains tradition earthlodges). The earliest villages were often fortified with a ditch and interior palisade and with widely dispersed houses numbering fewer than 50. Despite these contrasts, peoples from both traditions shared similar mixed subsistence patterns. The descendants of Initial Coalescent peoples, denoted as the Extended Coalescent variant (ECV), became more widely dispersed in subsequent centuries (beginning in the fifteenth century) due to population growth, eventually occupying locations along the Missouri River from approximately the Nebraska-South Dakota border to the Grand River. These sites include Demery (39CO1), one of most northerly ECV villages located near the North Dakota border and dating to the fifteenth century (Figure 1.3). Unlike their ancestors, Extended Coalescent peoples typically constructed relatively smaller settlements with fewer earthlodges and usually left them unfortified; many villages were elongated and paralleled the Missouri River. Importantly, it is evident that these early Coalescent tradition sites and contemporaneous Middle Missouri sites to the north represent the ancestral villages of historically documented and modern day Native groups: the

Caddoan-speaking Arikara are descended from the former while the latter are ancestral to the Siouan-speaking Mandan and Hidatsa.

The Mandans, Hidatsas, and Arikaras

During the sixteenth century through the eighteenth century, ancestral Hidatsa and Mandan (or more specifically subdivisions of these historically documented groups) established several large, dense, and long-lasting settlements in the Knife and Heart regions of today's North Dakota (Bowers 1992, 2004; Johnson 1998:320-327, 2007:185-199; Lehmer 2001; Wood 1986:13-23). Coincident to this, many ancestral Arikara bands established relatively smaller villages over a geographically larger area, from approximately the Grand River to the Big Bend of the Missouri River in present-day South Dakota (Lehmer 1971; 2001). In particular, ancestral Mandan groups constructed their villages, including sites now known as On-A-Slant (32MO6), Boley (32MO37), Double Ditch (32BL8), Larson (32BL9), and possibly Scattered (32MO31), along a 25 kilometer section of the Missouri River near the mouth of the Heart (Swenson 2007; Figure 1.3). In fact, one of these Mandan villages is believed to have been the first visited by colonists, when Pierre Gaultier de Varennes, sieur de La Vérendrye, a French Canadian trader and explorer travelled to the region in 1738 (Smith 1980). These villages are not significantly larger than earlier ones, averaging about 5 ha in size, although those that are systematically mapped have upwards of 100 lodges (during the period in which community size reached a maximum), continuing the trend that began during the previous century. Additionally, following a transition that likely began during the fifteenth century, most lodges of each site are circular rather than rectangular (Ahler 1993b). Importantly, these sites are located on terraces on both the east and west banks of the Missouri River, and natural features such as steep banks enhance the villages' defensive positions (Mitchell 2007; Swenson 2007). Each is surrounded by at least one fortification ditch, and in some instances multiple ditches (all likely sequentially constructed during different periods of occupation) are present with interior palisade walls, mounded earthen berms, and bastions. These complex natural and human-made defensive systems indicate the prevalence of warfare and the significant position of Heart region communities in regional trade.

Several of these villages were occupied for multiple generations over a period of centuries, a dynamic time for several reasons, including those noted by Mitchell (2011; 2013). In terms of population, the region likely hit its apex around the turn of the sixteenth century (Ahler 1993b; Lehmer 2001), although instances of both population increase as well as decline and reorganization due to epidemic disease occurred, evidenced by historical and archaeological information (see discussions in Ahler 1993b; Dobyns 1983; Johnson 2007:185-199; Ramenofsky 1982:271-343, 1987; Trimble 1985, 1993). In the Heart region, these processes are evident in the periodic contractions of the fortification ditches at Double Ditch and Larson (Ahler, ed. 2005; Kvamme and Ahler 2007; Mitchell, ed. 2007, 2008). Moreover, the period is marked by increased cultural interaction and expanded exchange among the various Native groups in the region (Johnson 2007:185-199; Lehmer 1971:164-172). The Heart River villages were crucial participants in a multidimensional trade network that operated at several different scales, from exchange with mobile foragers that reached continental breadth to local trade with neighboring villages (Ewers 1968; Mitchell 2013:173-178; Swagerty 1988; Wood 1980). Based on the number and size of subterranean storage pits documented in villages during this period, it is thought that agricultural production increased among the Missouri River farming communities, likely due to further intensification to meet trade demands (Lehmer 1971:140; Mitchell 2011, 2013:178-181). Whether this increase in fact occurred is unknown, although this systematic examination of excavation and coring data will facilitate evaluation of this notion. Importantly, colonial trade goods first appeared in the Middle Missouri subarea during the seventeenth century, at least a century prior to the first direct contact with colonists and nearly two centuries prior to regular interactions between Native groups and European or American colonists in the region (Thiessen 1993a).

Several of the traditional Mandan villages near the Heart River were occupied until the 1780s when a historically documented smallpox epidemic dramatically reduced Mandan, Hidatsa, and Arikara populations in the Middle Missouri subarea. The Mandans had consisted of as many as five divisions, although following the epidemic they abandoned the Heart River communities (Bowers 2004; Wood and Irwin 2001). They likely moved first to the Painted Woods area for a short time and then closer to the Knife River in the mid-1790s where they reorganized and established two villages only a short distance from the Hidatsas (Chomko 1986). The three Hidatsa divisions had been living in separate villages near the Knife for lengthy periods prior to the 1780s (Bowers 1992; Johnson 2007:191-202; Wood 1993a). These villages include sites known today as Big Hidatsa (32ME12), Lower Hidatsa (32ME10), and Mahhaha (32OL22), while other villages like Molander (32OL7) and those established by dissident bands were more short-lived (Figure 1.3). Following the smallpox epidemic, the Hidatsa-proper (one division of the Hidatsa) remained at Big Hidatsa while the other divisions relocated and established several new villages, among them the sites named Rock (32ME15), Sakakawea (32ME11), and Amahami (32ME8) (Hanson 1993; Stewart 2001; Wood 1993a) (Figure 1.3).

When David Thompson, a trader with John McDonnell's North West Company, encountered the Mandans and Hidatsas in December 1797-January 1798, he found them living in five villages, including Big Hidatsa, Sakakawea, Black Cat (32ML5), Deapolis (32ME5), and an unnamed Hidatsa winter village (Wood 1977; Wood et al. 2011:30-31; Figure 1.3). At the time, only Black Cat's Village, a Ruptare (Nuptadi) Mandan village located on the east bank of the Missouri River named after the village's principal chief, was occupied solely by the Mandans. Both Sakakawea and Deapolis, a Nuweta (Nuitadi) Mandan village then known as Mitutahank on the west bank, were jointly occupied by Hidatsas and Mandans (Wood 1977; Wood and Irwin 2001; Wood et al. 2011:30-31). Thompson's observation is corroborated by others. One year prior, John Thomas Evans, who set out with James Mackay under the employ of the Spanish Missouri Company on an expedition to discover a route to the Pacific, mapped the locations of five Hidatsa and Mandan villages, including the four well-known communities noted by Thompson as well as Amahami (Wood 2003a; Wood et al. 2011:30-31). These villages were again identified and mapped nearly a decade later, when Meriwether Lewis and William Clark wintered at Fort Mandan in 1804-1805 (Moulton 2003; Wood et al. 2011:30-31). When the Corps of Discovery reached the Knife region, they found that the Mandans were living apart from the Hidatsas in the Ruptare Black Cat and Nuweta Mitutahank (Deapolis) communities (Moulton 2003; Wood et al. 2011:30-31). However, when Lewis and Clark returned in 1806, they noted that many of the Ruptare Mandans from Black Cat's Village had joined the Nuweta Mitutahank (Deapolis) village. The three Hidatsa communities remained relatively stable over the next few decades until April or May 1834 when Sakakawea and Amahami were destroyed by fire during a Dakota attack (Stewart 1974; Wood 1993a). On the other hand, the locations of Mandan settlements besides the Mitutahank (Deapolis) village up to 1822 are unclear, although several vague references indicate that communities were briefly established south of the Painted Woods area and closer to the Heart River (Chomko 1986).

Before the 1780s smallpox epidemic, the Arikaras lived in numerous villages, perhaps between 30 and 40 in number, along the Missouri River in present-day South Dakota, centered in the Bad-Cheyenne region (Johnson 2007:194-199; Krause 1972; Parks 2001). The number of village communities diminished greatly by the late eighteenth century. By the mid-1790s, the Arikaras lived in a smaller number of villages near the Cheyenne and Grand Rivers, although some Arikaras moved north to live near or with the Mandans in the Painted Woods area south of the Knife River (Chomko 1986; Krause 1972; Parks 2001). This group occupied at least one village now known as the Greenshield site (32OL17), jointly with the Mandans for some time, from about 1795 to 1798 (Figure 1.3). The Arikaras then returned to the Grand River where they established three large fortified villages, each documented by explorers and traders, including Lewis and Clark in 1804 and 1806 (Moulton 2003). The two adjacent villages on the Missouri River's west bank, the principal settlement of the Arikaras known as the Leavenworth site (39CO9), were occupied from approximately 1798 to 1833, except for a brief period in 1823-1824 (Chomko 1986; Krause 1972; Parks 2001; Figure 1.3). Until 1837 when they returned to the vicinity of the Knife River in present North Dakota, the Arikaras lived briefly with the Skiri Pawnee on the Loup River in Nebraska and then as nomadic hunters in western Nebraska and South Dakota (Parks 2001).

In 1822, the Mandan occupants of the Mitutahank (Deapolis) village moved a short distance downriver along the west bank of the Missouri and established a new village named Mitu'tahakto's (Mih-tutta-hang-husch), which is one component of the present-day Fort Clark State Historic Site (32ME2) (Wood and Irwin 2001; Wood et al. 2011) (Figure 1.3). All or most of the remaining occupants of the Ruptare village, Black Cat, relocated their village to the Mitutahank (Deapolis) location, where they remained until the mid-1850s. The Mandan, Hidatsa, and Arikara villages had been visited by colonial traders and explorers infrequently beginning nearly a century earlier, but shortly after the establishment of Mitu'tahakto's, traders became a permanent fixture of the community specifically and the Knife region in general.

To facilitate trade with the Mandans and neighboring groups, the Columbia Fur Company tasked James Kipp with construction of Tilton's Fort just below the Mitu'tahakto's in 1823 (Wood 2011; Wood et al. 2011). However, the trading post was abandoned early the next year due to harassment from the Arikaras, although Kipp began trading from an earthlodge in the nearby village (Wood et al. 2011). Wooden timbers from Tipton's Fort were subsequently moved to the Native village where they were used by Kipp to construct the first trading post within or near the village, Fort Clark I (Hardee 2011; Mitchell, ed. 2014; Mitchell and Wiewel 2014; Wiewel and Kvamme 2016; Wood et al. 2011). Although the American Fur Company (Upper Missouri Outfit) acquired the trading post in 1827, it remained in use until the winter of 1830-1831 when Kipp managed construction of Fort Clark (Wood et al. 2011). Fort Clark was built approximately 200 m south of the village and remained in use until 1860. In approximately 1846, the St. Louis Fur Company (or the Union Fur Company), a competitor of the American Fur Company, built Fort Primeau between Fort Clark and the Native village, and it remained in use until the village's abandonment in 1861 (Wood et al. 2011).

During these same decades, the Native occupants of the village changed as well. The Mandans occupied the village from 1822 until 1837, when Northern Plains tribes were infected by a devastating episode of smallpox (Trimble 1993; Wood et al. 2011). After spending the winter of 1837-1838 in their winter village, the Mandan survivors returned to find that the Arikaras had appropriated the village (Wood et al. 2011). Some chose to remain with the Arikaras while others returned to the older Ruptare Mandan (Deapolis) village a short distance upriver. The remaining Mandans settled with the Hidatsas. In January 1839, the village at Fort

Clark was destroyed by fire. The Arikaras thus began rebuilding the village in May overtop of the remnants of Mitu'tahakto's, and they remained in the location until 1861. In 1845, the Hidatsas and Mandans established the village of Like-A-Fishhook (32ML2) nearly 75 km to the north along the Missouri River (Smith 1972; Figure 1.3). That same year, the American Fur Company constructed Fort Berthold (Fort James), a trading post that adjoined the newly created earthlodge village. After abandoning their village at Fort Clark in 1861, the Arikaras moved upriver where they wintered, and the following spring began construction of Star Village (32ME16) on the opposite bank of the Missouri from Like-A-Fishhook (Metcalf 1963; Figure 1.3). However, when their village was attacked by the Dakota in August 1862, the Arikaras joined the Mandans and Hidatsas at Like-A-Fishhook, where they remained until 1886 (Metcalf 1963; Smith 1972). Although substantial material changes and dramatic population declines are apparent for the region during the late eighteenth and nineteenth centuries, left unanswered are questions concerning agricultural practices and whether they remained consistent with earlier periods.

Research Goals

When colonial fur traders became permanent fixtures of the Northern Plains in the early nineteenth century, increasingly greater quantities of trade goods were introduced to the Native villagers. Although episodes of epidemic disease caused dramatic population declines among many of the tribes living in the Northern Plains, researchers have been prompted to make claims of culture decline and dependency, chiefly by the ubiquity of trade goods, while overlooking the complexity of interactions and the continuation of practices, beliefs, and identities. This perspective has been criticized in recent decades. Plains Village farmers in the Middle Missouri subarea were major producers of agricultural goods, in particular maize, as early as the thirteenth century. These perishable goods were sought by nomadic groups, other sedentary villagers, and even colonial traders in the nineteenth century. Thus, the ability of village farmers in the region to produce large agricultural surpluses, which were kept in subterranean storage pits, enhanced their trading prowess over many centuries. One of the major gaps in our understanding of colonial era events concerns the issue of agricultural production and how Native groups altered their practices, if they did, with the arrival of European or American colonists. The aim of this research is to use geophysical, archaeological, and historical data to examine closely this nineteenth-century colonial issue and to compare agricultural production through time to understand how this particular Native tradition was affected by the arrival of colonists and other factors.

In Chapter 2, I describe the data sources I use to address these questions, including remote sensing data, traditional archaeological information, and historical documents. Moreover, this discussion contains a general explanation of field methods and approaches for critically evaluating historical documents. Further information regarding each remote sensing method and specific processing steps for all techniques may be found in Appendix 1.

I illustrate one way such data can be applied to anthropological questions in Chapter 3. Within this section, I use magnetic gradiometry and high-resolution elevation data jointly with soil coring and excavation information to generate estimates of population, storage pit numbers, and total storage capacity at Huff Village State Historic Site. Historical accounts of nineteenth-century agricultural production in the region and experimental data provide supporting evidence. These combined data indicate the large ancestral Mandan population produced vast quantities of agricultural goods, well beyond any amount that would have been necessary strictly for their own dietary needs. This finding is noteworthy given concurrent mid-fifteenth century changes in settlement patterning and expansion of the regional exchange system.

I broaden the discussion of agricultural production among Plains Village period horticulturalists by examining historical trends in subterranean storage pit volumes and numbers in Chapter 4. The hundreds of storage pits, which were excavated in 20 post-twelfth-century archaeological sites located along the Missouri River, serve as surrogate measurements of production and intensification. Moreover, I explore possible explanations such as epidemic disease, climate change, and the arrival of colonists for significant changes in mean pit volumes, particularly a dramatic decrease during the eighteenth century and an equally striking increase in the following century. Historical documents are used to provide further context with which the significant increase in storage pit volumes during the mid- and late nineteenth-century period can be more clearly understood. Brief synopses for each of the 20 archaeological sites from which excavation data are taken are provided in Appendix 3.

Fort Clark State Historic Site offers another opportunity against which the findings from Chapters 3 and 4 can be considered since the site dates to the early and mid-nineteenth century, a crucial period during which colonial fur traders became permanent residents in the Northern Plains. In Chapter 5, I give extensive treatment to written accounts and graphic illustrations of the Mandans’ and Arikaras’ occupation of the village at Fort Clark. These historical references, which include those of George Catlin, Prince Maximilian, Karl Bodmer, Francis Chardon, Lewis Henry Morgan, and others, serve an important purpose. That is, my interpretations of remote sensing data acquired during investigations of the archaeological site rely on these documents. The Mandan/Arikara village was extensively surveyed with several geophysical techniques including magnetic gradiometry, earth resistance, electromagnetic induction (yielding conductivity and magnetic susceptibility), and ground-penetrating radar. These data are integrated with aerial photographs and orthophotographs from multiple decades as well as aerial thermal infrared imagery in a geographical information system, which facilitated my complete interpretation of the data sets and led to the creation of a new map of the Mandan/Arikara village. Among many important findings, I identify a substantial number of previously unknown earthlodges and log cabins. Although it is impossible to assign each structure to the early (Mandan) or late (Arikara) component, I argue that many are likely Arikara dwellings given historical information, limited excavation results, and the typical use-life of lodges. Finally, I examine the distributions of two types of magnetic anomalies, which I think reflect the occupation duration of different areas within the village. Their patterning is important in relation to the distribution of a third type of magnetic anomaly discussed in Chapter 6.

The conclusions I draw in Chapter 6 concerning trade and agricultural production among the Mandans and Arikaras at Fort Clark are based jointly on my comprehensive interpretations and historical information. In this section, I relate findings from both data sets to those from previous chapters to more fully address questions about the agricultural capabilities of the Mandans and Arikaras and the influence of colonial fur traders on Native farmers during the nineteenth century. A void exists in the storage pit volume data during the early to mid-nineteenth century, a significant period between the eighteenth-century decrease and late nineteenth-century increase in mean volumes. Fur traders became permanent residents in the Northern Plains during this time. Thus, comparing data from the Native village at Fort Clark with earlier and later periods is crucial for understanding agricultural production at that time. To accomplish this goal, I reference the letter books from Fort Pierre and Fort Union and other historical accounts. Such data are admittedly problematic, but the total body of historical information suggests both groups produced substantial quantities of maize and other garden goods. These amounts are not inconsistent with what would be expected given estimated Mandan and Arikara populations at Fort Clark either, but are the remote sensing and archaeological data equally corroborative? While comparable pit volume data are lacking, storage pit depths are significantly greater than those from the previous period. This finding suggests the noted nineteenth-century increase in storage pit volumes occurred earlier during the century. Moreover, the distribution of magnetic anomalies and features identified as storage pits differ from other types, which suggest many were created by the Arikaras during the latter part of the occupation of the village at Fort Clark.

In the final chapter, I consider how archaeologists should view the relationship between Native groups and colonial fur traders during the nineteenth century, a perspective that fundamentally differs from traditional narratives. Historical, excavation, and remote sensing data suggest the Mandans and Arikaras produced considerable quantities of maize, which facilitated exchange with both Native nomadic groups and fur traders during the period. For centuries their farming ancestors were influential and powerful characters in a continent-wide exchange system, an experience that informed later interactions with nomadic groups and colonists. Although the arrival of fur traders led to considerable changes, there are certainly continuities in both agricultural production and trade with earlier centuries.

CHAPTER 2: DATA SOURCES

To address questions concerning agricultural production in the Middle Missouri subarea of the Northern Plains introduced in the previous chapter, I utilize a combination of remote sensing data, traditional archaeological information, and historical documents. The following sections provide brief descriptions of these data sources as well as survey strategies used during field investigations at Huff Village State Historic Site (32MO11) and Fort Clark State Historic Site (32ME2) in North Dakota (Figure 1.3). Further discussion concerning remote sensing instrumentation and processing methods is covered separately in Appendix 1.

There is a well-established history of using remote sensing methods in the Plains to discover, map, and interpret archaeological features, sites, and landscapes (Wood et al. 1984). The earliest systematic applications of remote sensing methods by Plains archaeologists involved their use of U.S. Department of Agriculture (USDA) aerial black-and-white photographs in the late 1940s. By the early 1950s, personnel with the Smithsonian Institution's Missouri River Basin Surveys were not only using extant USDA photographs but had also begun performing aerial photographic surveys on their own in planned reservoir areas (Thiessen 1999; Wood et al. 1984). Use of aerial photographs for site reconnaissance, documentation, and the production of topographic maps continued in subsequent decades. Importantly, archaeologists with the University of Nebraska and the National Park Service's Midwest Archeological Center began using ground-based geophysical instruments to investigate Plains Village sites in the Middle Missouri subarea in the 1970s, furthering the tradition of remote sensing studies in the region (Weymouth 1976, 1979; Weymouth and Nickel 1977; Wood et al. 1984). One of the most important findings of these early geophysical prospecting applications was the determination that such technologies could provide significant information regarding subsurface archaeological features (Wood et al. 1984:64).

Recently more consideration has been given to the advantages of multi-instrument geophysical surveys and approaches for integrating multidimensional data (Kvamme 2003a, 2006a). In North America, four ground-based geophysical survey techniques are commonly employed by archaeologists, including magnetic gradiometry, ground-penetrating radar (GPR), earth resistance, and electromagnetic induction (EMI), with varying levels of success depending on a variety of factors (e.g., see papers in Johnson 2006). Each approach may yield results that are relatively similar to one or more of the other methods. In other words, multiple surveys can lead to overlapping results. However, each technique measures different phenomena and generally produces unique, complementary information regarding subsurface archaeological features. For this reason, combining results increases the likelihood of detecting a broader range of subsurface features, facilitates interpretations of geophysical anomalies, and strengthens confidence in those interpretations. Because geophysical instruments are affected differently by factors such as soil moisture content, soil types, geological features, vegetation cover, and the presence of metallic debris, each is more or less likely to deliver useful information in a given environment as well. For the same reasons, further attention has been given to the utility of combining other remote sensing data sets with geophysical surveys, including aerial photography, multi- and hyperspectral satellite imagery, aerial thermography, and topographic information (Kvamme 2008a; Kvamme and Ahler 2007; Sarris et al. 2013).

Remote Sensing Data and Field Methods

The benefits of multidimensional remote sensing investigations of Plains Village sites in the Middle Missouri subarea are well documented (Kvamme 2007a). This investigation uses multiple remote sensing techniques, including geophysical instruments, aerial photographs, aerial thermography, and elevation data. Human activities such as the construction of dwellings, which often include architectural elements like wood, stone, or brick, alter the surface or near-surface (Kvamme 2005). Likewise, other constructions such as pits, ditches, berms, or mounds either add to or subtract from the natural sediments and soils. Features like these are sources of variations in moisture content, soil compaction, magnetism, electrical properties, thermal properties, vegetation patterning, and terrain relief, among other factors. Remote sensing techniques are potentially capable of detecting archaeological features when the physical properties of said features contrast with adjacent sediments and soils (Kvamme 2005). That is, archaeological features are anomalous compared to surrounding sediments and soils that have been unaltered by human activities.

During surveys at Huff Village and Fort Clark, field crews employed a total of five ground-based geophysical techniques, including magnetic gradiometry, earth resistance, EMI (producing conductivity and magnetic susceptibility data), magnetic susceptibility, and GPR (Figure 2.1; Table 2.1). Large area surveys were undertaken with instruments (e.g., magnetic gradiometry and earth resistance) that allow for rapid data acquisition and/or had the greatest likelihood of detecting particular subsurface archaeological features. Smaller areas were surveyed or specific archaeological features of interest were targeted with the remaining methods. Among the most commonly identified features in Plains Village sites in the Northern

Plains are houses, hearths, and storage pits (e.g., Kvamme 2003a, 2007a, 2008a; Kvamme and Ahler 2007). The importance of identifying such features for this investigation is discussed further below.

Each survey was performed within a local coordinate grid consisting of 30 x 30 m blocks accurately placed by an electronic total station prior to the investigations. Within each block, fiberglass surveyor's tapes with metric increments were staked across baselines and along transects (Figure 2.1). This approach facilitated systematic placement of the instruments during surveys and yielded spatially accurate results, which is crucial given the significance of integrating multiple data sets. Furthermore, collecting spatial data in grids composed of rows and columns enabled each data set to be stored, manipulated, and displayed as a raster layer in a geographic information system (GIS). Additional details regarding particular survey methods and the sites at which they were employed are provided in Chapters 3 and 5, and specific technical details regarding instrumentation and data processing approaches are found in Appendix 1.

Besides these geophysical techniques, elevation data were acquired at Huff Village with a Trimble 5600 robotic total station to produce a model of the site's surface topography (Figure 2.2). Although LiDAR (an acronym for light detection and ranging) is certainly a better choice for terrain characterization in many circumstances, Kvamme and colleagues (2006) have illustrated the utility of this approach for producing high-resolution digital elevation models (DEMs) at Plains Village sites owing to the general unavailability of LiDAR data and the high cost of acquiring these data in remote regions. Importantly, elevation models not only facilitate interpretation of other geophysical data sets (e.g., understanding the relationship between topography and magnetism) but may yield unique information concerning buried archaeological features with subtle surface expressions.

Figure 2.1. Geophysical instruments employed in surveys: a) Bartington Grad601 dual fluxgate magnetic gradiometer; b) TR Systems Ltd. TR/CIA resistivity meter (Geoscan Research RM-15 resistance meter not shown); c) Geonics Ltd. EM38B electromagnetic induction meter; and d) Geophysical Survey Systems, Inc., SIR-2000 ground-penetrating radar. Photographs by the author.

Table 2.1. Near-surface geophysical methods with summaries regarding each technique.

Remote Sensing Method	Instrument	Principles	Potentially Detectable Features or Objects
Magnetic gradiometry	Bartington Grad601 dual fluxgate gradiometer	Measures the sum of remanent and induced magnetism; natural sediment differences, burning, the accumulation or removal of magnetic topsoils, and the presence of magnetic materials like bricks or ferrous metal objects cause variation	Hearths and other burned features; mounded soils surrounding earthlodge floors; storage pits; trails and ditches; and ferrous metal items
Earth resistance	(1) Geoscan Research RM15 and (2) TR Systems Ltd. TR/CIA (twin-probe configuration)	Measures the resistance of the soil and objects within the soil matrix to the flow of an electrical current; variation due to soil moisture, grain size, and soil compaction differences	Compacted earthlodge floors and surrounding earthen berm
Electromagnetic induction	Geonics Ltd. EM38B	Measures the soil's capacity to conduct an electrical current; in conductive soils, an electromagnetic field containing two components, electrical conductivity and magnetic susceptibility, is induced; variation depends mostly on soil type and moisture	Compacted earthlodge floors, burned features, hearths, storage pits, and metal items
Magnetic susceptibility	Bartington MS2 with D surface scanning probe	Measures the magnetic susceptibility of soil and other magnetic materials	Magnetically enhanced features such as activity areas, midden deposits, and storage pits
Ground-penetrating radar	Geophysical Survey Systems, Inc., SIR-2000 (400 and 900 MHz antenna)	Measures time or depth to subsurface interfaces that vary in relative dielectric permittivity, which cause changes in velocity and reflections of radar pulses	Compacted earthlodge floors, hearths, storage pits, trails, and ditches

Figure 2.2. The Trimble 5600 robotic total station (left) and wheeled reflector rod (right). A data logger and digital display mounted to the reflector rod allows the instrument operator to view his or her location in real time. Photographs by the author.

At Fort Clark, three aerial remote sensing techniques, including aerial photography and digital imagery, aerial thermography, and LiDAR, were utilized to aid interpretation of the previously discussed geophysical data sets and identification of archaeological features (Table 2.2). Heller (2009) previously examined the most recent aerial color and thermal infrared imagery, although I have since reprocessed the data sets to create seamless mosaics, which I integrated into a GIS and reinterpreted within the context of the entire suite of data. In particular, shadowing and vegetation markings visible in aerial photographs and digital images indicate archaeological features on or near the ground surface (Giardino and Haley 2006:57-61; Scollar et al. 1990:33-58; Wilson 2000:38-87). These same features may exhibit relative differences in radiant temperatures capable of detection using thermography (Avery and Berlin 1992:115-124; Lillesand et al. 2004:347-367; Scollar et al. 1990:591-611). LiDAR further enhances identification and interpretation of archaeological features, including those with only subtle topographic expression, by providing high-resolution elevation data.

Table 2.2. Aerial remote sensing methods with summaries regarding each technique.

Remote Sensing Method	Instrument	Principles	Potentially Detectable Features or Objects
Aerial photography and digital imagery	Konica Minolta DiMAGE A2 and other metric cameras (black-and-white, normal color, and color infrared photographs and digital imagery)	Archaeological features are visible due to shadowing, crop markings, soil markings, and frost or snow markings	Lodge floors, elevated berms, trails, ditches, borrow pits, and storage pits
Aerial thermography	Raytheon Palm IR-250	Measures radiant temperature; archaeological features may be apparent if their thermal properties differ significantly from those of surrounding soils	Lodge floors and surrounding berms; hearths and storage pits; borrow pits; and trails
LiDAR or airborne laser scanning	Leica ALS60 mounted aboard a fixed-wing aircraft	Transmits and detects reflected laser pulses, enabling three-dimensional surfaces like the ground to be measured	Earthlodge and cabin depressions and interior features; borrow pits and collapsed storage pits; fortification ditch; and trails

Recognizing earthlodges, cabins, storage pits, and other features at Huff Village and Fort Clark is of critical importance to this project. The remote sensing investigations at both sites were undertaken with the general goal of yielding better understandings of the layout and content of archaeological features associated with the settlements. A more specific aim of determining the number and area of dwellings within the villages is fundamental to generating estimates of settlement populations. Likewise, identifying potential subterranean storage pits is an important part of approximating storage capacities at both villages, figures that relate to agricultural production. Numerous archaeological features common to Plains Village settlements, including those of most importance to this investigation, may be revealed by the various remote sensing data sets (Tables 2.1 and 2.2). However, integrating the remote sensing data as a means to yielding insights about subsurface archaeological features is an important element of multidimensional investigations. How can disparate spatial data sets be integrated for such a purpose? A GIS enables data integration in an environment that makes further processing and manipulation, visual comparisons and analysis, and end product maps and interpretations of spatial data feasible (Kvamme 1999; 2006a). Among the integration methods employed in this investigation, examples of which are illustrated in Chapters 3 and 5, are two-dimensional overlays, translucent overlays, red-green-blue color composites, and mathematical operations (Kvamme 2006a).

Moreover, my interpretations of potential archaeological features are based on a combination of inductive and deductive approaches to anomaly recognition (Kvamme 2008b). Specifically, my prior experience and that of many other archaeologists in the Northern Plains lends some certainty to the process of identifying anomalies as archaeological features. This process considers several characteristics of anomalies, including their shapes, relative sizes, associations, and distribution or organization within archaeological sites (Kvamme 2008b). At the same time, inferences regarding anomaly interpretation are founded in part on my consideration of how the physical properties of particular archaeological features would “appear” to each remote sensing technique. Despite elements of deductive reasoning, the procedure of visually interpreting anomalies as archaeological features is ultimately based on my own judgment. All remote sensing data were integrated in a GIS and combined with soil coring findings, excavation results, and historical information to interpret subsurface archaeological features at Huff Village, Fort Clark, and several other settlements discussed in Chapter 4. I use these sources of data to provide a better understanding of agricultural production through time among farmers who resided along the Missouri River in the Northern Plains with the aim of considering if and in what ways the appearance of European and American colonists during the eighteenth and nineteenth centuries affected this long-standing tradition.

Soil Coring and Excavation Data

In the following chapter, I use coring and excavation data from Huff Village to aid interpretation of the remote sensing data and provide estimates of the settlement population, storage pit numbers, the average capacity of storage pits, total storage volume, and per capita storage capacity. Further details concerning storage pit excavation and coring at other sites in North and South Dakota and a discussion of the methods used for extracting these data from various sources are reported in Chapter 4. Furthermore, I cored potential archaeological features at Fort Clark in August 2013, the results of which are covered in Chapter 5. The purpose of the coring work was to target a sample of anomalies discernable in the magnetic, aerial thermal infrared, and lidar data sets with a one inch diameter Oakfield soil sampler. The ultimate goal was to determine the source, typically either a subterranean storage pit or a hearth feature, of each anomaly.

Nearly 150 anomalies, many of which exhibited little if any surface expression, were targeted for identification. Coring samples were extracted approximately 30 cm at a time. Coring continued until either the source of the anomaly was determined and the bottom of the identified feature was located or until a depth of just over 2 m, the maximum length of the soil sampler, was reached. When an anomaly source could not be located (e.g., ash and burned earth indicated the presence of a hearth feature), additional cores were typically placed approximately 25 cm away from the initial coring location. Unless the anomaly source was identified, additional sampling continued in up to four directions surrounding the initial sample, at which time a note was made that the source of the anomaly could not be determined. A similar procedure was followed in the event that an impenetrable obstruction was encountered, although additional samples were cored only a few cm from the initial sample.

While an anomaly was sampled, each 30 cm core segment was examined for the presence of archaeological materials and changes in soil texture and color. Detailed notes of these, including measurements of their depth in cm below surface, were made as coring proceeded. Finally, a determination of the probable source of each sampled anomaly was made whenever possible. Importantly, coring yielded information that aided interpretations of anomalies identified in each remote sensing data set.

Historical and Ethnographic Documents

An extensive documentary record of Native peoples who lived along the Missouri River in the Northern Plains during the eighteenth and nineteenth centuries includes written accounts, visual imagery, and ethnographic descriptions. The earliest known account of the Mandans was left by Pierre Gaultier de Varennes, Sieur de La Vérendrye, a French-Canadian fur trader and explorer, in 1738 (Smith 1980). Although other traders and explorers visited the region in intervening years, the La Vérendrye source would not be matched in detail until 1804-1805, when the Corps of Discovery, led by Meriwether Lewis and William Clark, wintered near the Mandans, leading to an extraordinary and lengthy account of the villagers and their surrounding neighbors (Moulton 1987:199-332, 2003). Several artists and explorers left unparalleled descriptions of the Mandans at Fort Clark during the 1830s. These visitors include George Catlin, an American painter who visited the village and fur trade post in 1832 (Catlin 1973 [1844]); Maximilian, Prince of Wied, a German explorer and ethnologist who stayed at Fort Clark during the fall and winter of 1833-1834 (Witte and Gallagher 2010, 2012); and Karl Bodmer, a Swiss painter and illustrator who accompanied Prince Maximilian (Ruud 2004; Wood et al. 2002). One additional document, Francis Chardon's (Abel 1997) journal for the period 1834 to 1839, complements these other resources. As the head clerk of Fort Clark, Chardon had a rare view of life among traders at the post and the Mandans and Arikaras who occupied the adjacent village.

Besides these more notable historical sources, there are many other late eighteenth and nineteenth century documents from traders like Alexander Henry, John Macdonell, David Thompson, François-Antoine Larocque, Charles McKenzie, Charles Larpenteur, Rudolph Friedrich Kurz, and Henry A. Boller; missionaries such as Fathers Nicholas Point and Pierre Jean DeSmet; artists such as Charles Wimar and William Jacob Hays; naturalists like John James Audubon; Indian agents such as Alfred Vaughan and Samual Latta; and the anthropologist Lewis Henry Morgan. Additionally, primary documents such as the letter books from Fort Union in North Dakota and Fort Tecumseh and Pierre Chouteau in South Dakota include considerable correspondence among Upper Missouri fur traders (Casler and Wood forthcoming; Wood and Casler forthcoming). These documents contain letters written by the managers of each post to one another and their subordinates. This documentary record constitutes a rich source of information that provides numerous insights and augments interpretations yielded by the remote sensing data.

A well-developed methodology exists for the critical evaluation of historical documents (Barber and Berdan 1998; Wood 1990). There are two general but very important steps to this process: external and internal analysis (Wood 1990). The first refers to an examination of the authenticity of each historical document, which in the case of the sources previously discussed is unquestioned. However, further consideration must be given to the time between the production of each document and the event(s) they are meant to portray, because the greater the duration, the less credible the source in general. However, a document created well after the event(s) it describes may still be credible, hence the reason for internal criticism. For example, Wood and colleagues (2002) describe the steps taken by Karl Bodmer in his Paris studio, a few years after his journey with Maximilian, to transform his field sketches and watercolors to the compositions on which his final prints are based. Yet, Bodmer is noted for the precision with which he replicated many of his works, despite the lapse in time (Wood et al. 2002:11).

Thus, internal analysis involves the evaluation of the veracity of each historical document (Wood 1990). It includes a sentence-by-sentence or element-by-element examination of each document, a check on the history of their creation, and a comparison to other accounts or depictions of the event(s) they are meant to describe for corroboration. Such critical evaluation is necessary because each historical document has been subjected to a set of processes Barber and Berdan (1998:38-42) refer to as reality mediation. These processes—selection, emphasis, transformation, and fabrication—affect the content of each document and further remove these descriptions from the reality they were meant to portray. Ultimately, evaluating the quality and reliability of the information contained within each historical document requires frequent comparison among the sources and the use of complementary archaeological information. This evaluative process occurs in numerous locations in Chapters 4 and 5 as information derived from historical documents is put forward in the discussion of questions introduced previously. In the following chapter, I examine remote sensing data from recent investigations at Huff Village to generate a complete interpretive map, including the locations of all lodges and probable subterranean storage pits within the settlement. With the aid of coring and excavation results from previous projects at the site, these data are used to establish estimates of the village population, total storage capacity, and per capita storage capacity. The chapter serves as an introduction to agricultural production among Plains Village horticulturalists during the mid-fifteenth century and a base against which findings in subsequent chapters may be compared.

CHAPTER 3: EXCAVATION AND REMOTE SENSING INVESTIGATIONS AT HUFF VILLAGE STATE HISTORIC SITE, NORTH DAKOTA

A general goal of recent studies of colonial interactions among Europeans, Americans, and Native groups across North America has been to clarify the varied ways their histories, institutions, and actions affected the process of colonialism regionally. The overall objective of this project is to examine patterns of continuity and change in agricultural production among Northern Plains horticultural groups such as the Mandans and Arikaras during the period of colonial engagement. Importantly, the long-term history of production among horticultural groups in this region provides an explanatory framework with which these colonial period patterns can be explained. To this end, I pose questions concerning agricultural production, including the number of storage pits, total storage capacity, population size, and per capita storage capacity at Huff Village State Historic Site (32MO11) by combining magnetic gradiometry and high-resolution elevation data with soil coring and excavation information.

Huff Village is a Plains Village (Terminal Middle Missouri variant) fortified settlement located on the west bank of the Missouri River in present-day North Dakota (Figure 3.1). Radiocarbon dates indicate the village was occupied for a brief period during the mid-fifteenth century (circa 1440-1460) (Ahler 2000). The site has been the subject of archaeological inquiry for over a century (Howard 1962; Will 1924:336-338; Will and Hecker 1944:19-23, 94-96; Wood 1967:24-28). The earliest investigations of Huff in the first decades of the twentieth century, performed by historians, archaeologists, and professional surveyors such as E. R. Steinbrueck, A. B. Stout, George F. Will, and Herbert J. Spinden, were undertaken with the goal of mapping the extent of features visible on the ground surface (Wood 1967:26). The results of these investigations varied widely in terms of the estimated number of lodge depressions, illustrating the difficulty of mapping a large village without the benefit of an aerial photograph, even though features are visible on the ground surface (Wood 1967:28).

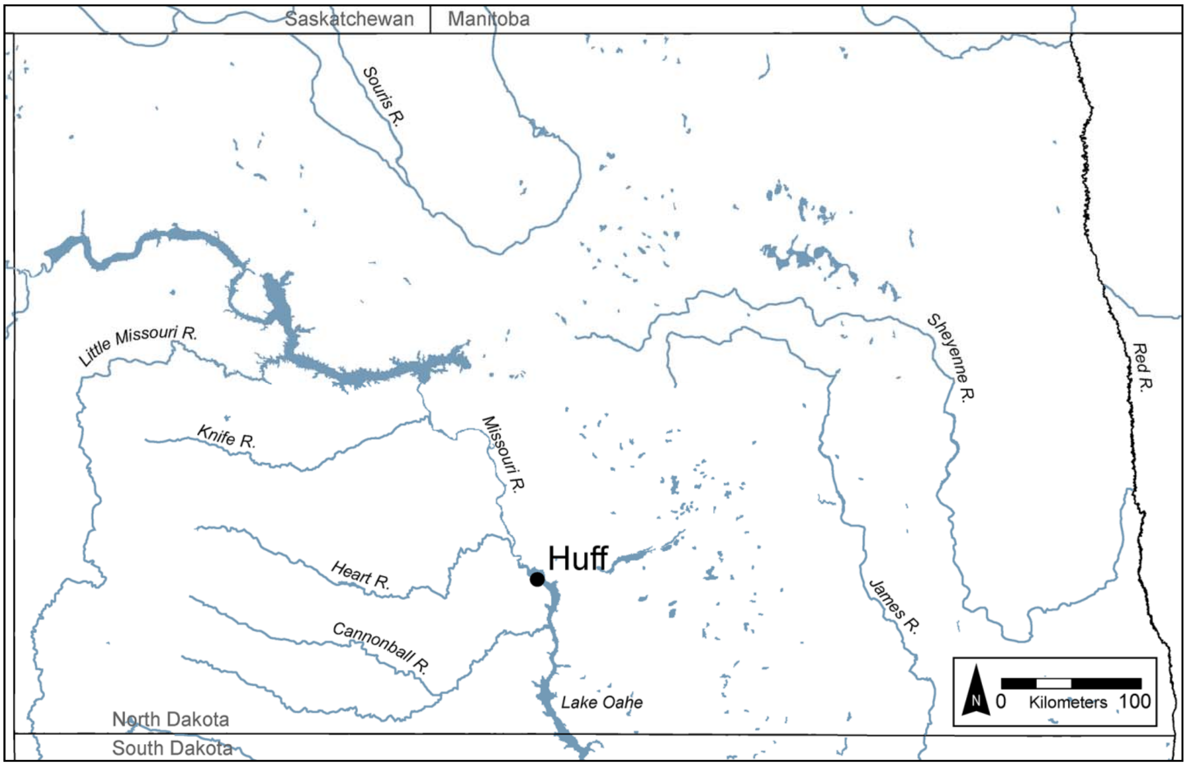

Figure 3.1. Map showing the approximate location of Huff Village State Historic Site (32MO11) in present-day North Dakota.

Limited excavations were performed at the site in 1938-1939 by Thad. C. Hecker (Will and Hecker 1944:19-23, 94-96) and more extensive salvage excavations were begun by James H. Howard in 1959 (Howard 1962). A more comprehensive study at Huff was undertaken by W. Raymond Wood in 1960 (Wood 1967). At the behest of the State Historical Society of North Dakota (SHSND) and the National Park Service, his salvage work focused on an approximately 30 m wide strip of the site along the cut bank of the Missouri River, an area that had been targeted for leveling and bank stabilization efforts by the U.S. Army Corps of Engineers due to the planned impoundment of Lake Oahe (Wood 1967:28-29). Wood’s (1967:28-31, Map 4, Plate 1b) investigation included 1) excavations of portions of the fortification ditch and palisade line;

2) excavations of eight houses; 3) exposure, complete excavation, remapping, and description of three houses previously excavated by Hecker and Howard; and 4) accurate mapping of the site with the aid of an aerial photograph and repetitive field checks (Figure 3.2).

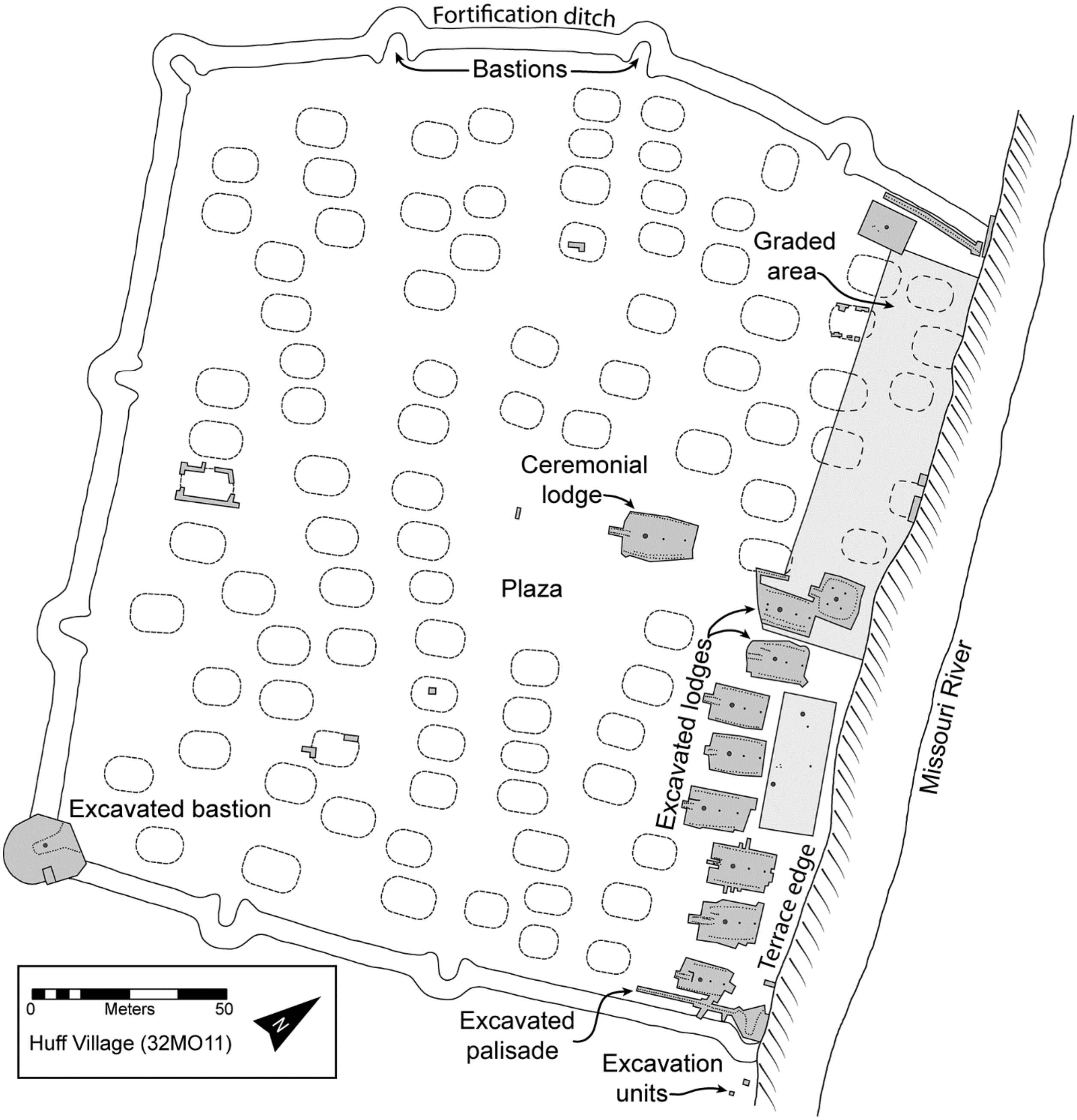

Figure 3.2. Plan view map of Huff Village registered to recent magnetic gradiometry and topographic mappings showing lodges, fortification system, and excavations up to 1960 (After Wood [1967:Map 4]).

The village is roughly rectangular in shape and is surrounded by a fortification system on three sides and bordered by the Missouri River on the fourth (Figure 3.2). Based on the remote sensing data and Wood's (1967:Map 4) map, the village is approximately 4.8 ha (48,301 m^2) in total area, or 4.4 ha (44,256 m^2) when the fortification ditch is excluded. The fortification system is nearly 650 m in total length and consists of a shallow ditch, a palisade wall, and ten regularly spaced bastions. Wood (1967:Map 4) mapped 103 surface depressions indicating the locations of houses. Excavations revealed that most are rectangular, although at least one exhibited four-post, rounded square architecture (Figure 3.3). The houses were roughly constructed in rows that parallel the river, each with its long axis oriented northeast-southwest, with their entryways facing the southwest. An open area or plaza, which encompasses an area around .18 ha (1,832 m^2) toward the village center, is indicated by its notable lack of house depressions.

Importantly, Wood's (1967) work at Huff Village played a crucial role in the definition of the Huff focus or Terminal Middle Missouri variant, an archaeological taxon that represents the final stage of the Middle Missouri tradition, of which Huff is the type site (Ahler 1993a; Lehmer 1971). Among many differences with preceding settlements, archaeologists have noted changes in settlement patterning during the mid-fifteenth century, most notably an increase in settlement density and a decrease in settlement number (Lehmer 1971:120-128; Mitchell 2013:67-71, 170-173). Additionally, limited excavation data indicate changes in agricultural productivity beginning in the fifteenth century and continuing into the eighteenth century (Lehmer 1971:140; Mitchell 2013:178-179). Specifically, it is thought that the total number and size of subterranean food storage pits within northern Middle Missouri Plains Village sites increased through time (Mitchell 2013:178-179). Pits were used to store agricultural produce such as beans, sunflowers, squash, and especially maize for the purposes of later consumption and trade (Wilson 1917:87), so quantitative data regarding the quantities and volumes of storage pits within sites have clear and important implications for village occupants' capacity to produce an agricultural surplus and for their participation in intertribal trade. However, no systematic attempts have been made to determine the number of storage pits, total storage capacity, and per capita storage capacity within any Plains Village settlement. Short of completely excavating entire sites, one is left to use alternative data sets to yield these estimates. I use excavation and soil coring data along with the results of extensive magnetic gradiometry and topographic mappings at Huff Village for this purpose.

Storage Pits at Huff Village

Within the ten houses described in detail by Wood (1967:31-52) (approximately 10 percent of the total number of houses mapped at Huff in 1960), 48 straight-sided or cylindrical pits and undercut or bell-shaped pits were documented. This count excludes other pit-type features such as postholes or molds, hearths, and basin- or irregularly-shaped features. The latter are generally small (less than .5 m in diameter) and shallow (less than .25 m in depth) and appear to have been utilized for purposes other than food storage (Wood 1967:32-54). The excavations revealed that many were filled with refuse, including mixed earth, clay, ash, stone, bone, and other artifacts. Several were filled with calcined granite, a material used for pottery temper (Wood 1967:44). Additionally, straight-sided and undercut pits less than .1 m^3 in volume, sometimes referred to as "pocket caches," were excluded. The excavated houses contained as few as one and as many as nine straight-sided and undercut pits. The pits were generally found lining the structures' walls, near their corners, and within or close to entryways (Figure 3.3).

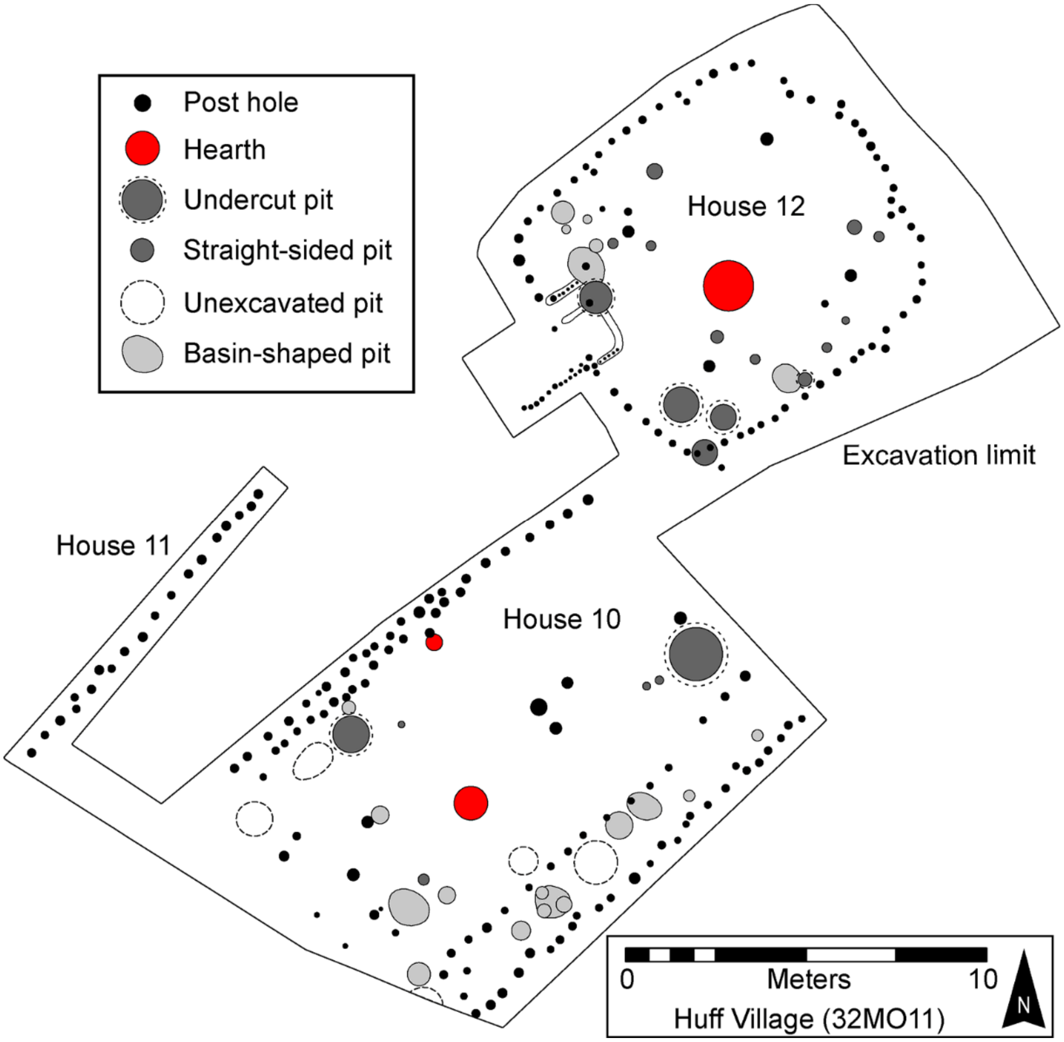

Figure 3.3. Plan view of subrectangular and rectangular lodges at the Huff site showing typical locations of hearth and storage pit features (After Wood [1967:Map 14]).

I estimated the volume of undercut pits with an equation for the volume of a conical frustum:

$$V = (1/3) * \pi * h * (r_1^2 + r_2^2 + (r_1 * r_2))$$

where r_1 is the lower radius, r_2 the upper radius, and h the height, while I calculated straight-sided pit volumes with an equation for the volume of a circular cylinder

$$V = \pi r^2 h$$

Estimated pit volumes vary from a low of .1 m^3 to as much as 4.8 m^3, with a mean pit volume of 1.03 m^3 (s = .83 m^3) and a total storage capacity of 49.6 m^3. With a total of 103 houses, this would suggest approximately 494 pits across the site and a total storage capacity of nearly 509 m^3. One apparent problem with this estimate is that it is based almost entirely on storage pits excavated within a 10 percent nonrandom sample of dwellings, and a pilot magnetic gradiometry survey undertaken by Kvamme (2003a; Kvamme and Ahler 2000) at Huff Village in 1999 indicates a problem with this biased sample.

Previous Geophysical Surveys at Huff Village

The earliest geophysical investigations at the Huff site occurred in 1977 when John W. Weymouth and Robert K. Nickel performed a magnetic survey of a single lodge (discussed in Wood et al. [1984:56-61]). Their study clearly documented the utility of the approach for identifying house perimeters and internal features such as central hearths and storage pits. Nickel surveyed the same lodge in 1998 with Lewis Somers (Kvamme et al. 2009:18). Kvamme's (2003a; Kvamme and Ahler 2000) initial geophysical surveys at the site were undertaken in 1999 with the goal of sampling a variety of the site's features, including its fortification system, lodges, and plaza. The largest survey was by magnetic gradiometry and covered approximately .71 ha (Figure 3.4). Although the survey area covered only a portion of the entire village (approximately 15 percent), it revealed several significant insights. Most importantly, the gradiometry survey indicated that many more likely storage pits were located outside rather than within houses, particularly in the spaces surrounding each house (Kvamme 2003a:136-139; Kvamme and Ahler 2000). To aid interpretation of the considerable number of magnetic anomalies, systematic coring in a 900 m^2 block encompassing multiple dwellings, part of the plaza, and an area devoid of houses was performed immediately after the survey (Kvamme and Ahler 2000:16-33). Within this area, mapped magnetic anomalies were found to be more common in outside-house locations (density of 9.4 versus 6.4 per 100 m^2). This is an important consideration given that excavations had previously focused on within-house contexts. Additionally, magnetic features within houses appeared to be significantly smaller (one-third to one-quarter the diameter) than anomalies outside dwellings. This finding could perhaps indicate extramural storage pits have even greater volumes, an inference that would have important implications for the total storage capacity of the village. The volumes of few exterior pits are known, so a meaningful comparison with intermural pits is not possible.

A total of 35 discrete magnetic anomalies were cored and identified as storage pits (*n* = 26 or 74 percent), hearths (*n* = 5 or 14 percent), midden (*n* = 2 or 6 percent), or indeterminate *(n* = 2 or 6 percent). Using these figures, Kvamme and Ahler (2000:33-34) estimated a total of 2,046 pit features, 386 hearths, and 165 middens across the entire village. Many of the latter probably correspond with basin- or irregularly-shaped features filled with magnetic refuse, similar to those documented by Wood (1967). Given an approximate volume of nearly 1.2 m^3 (an estimate based on a hypothetical pit depth of 1.5 m and a diameter of 1 m), the total storage capacity of the village would have approached 2,500 m^3.

Figure 3.4. Huff Village showing the magnetic gradiometry data collected in 1999 by Kvamme and Ahler (2000) overlaid on a 1960 aerial photograph. Photograph courtesy of the State Historical Society of North Dakota (Archives Accession #32348, North Dakota National Guard Records). Used with permission.

Interestingly, Kvamme and Ahler (2000:33-34) utilized a larger storage pit volume (1.2 m^3) than the average volume derived from Wood's excavated pits (1.03 m^3), a difference that has significant implications given the site's many storage pits. This difference may relate to the apparent dissimilarity in storage pit sizes within and outside of houses noted by Kvamme and Ahler, although their observation was based on the diameter of magnetic anomalies rather than the actual size of excavated features. Wood's excavation data from 48 storage pits are enlightening. While the mean orifice diameter of 1 m is similar to Kvamme and Ahler's hypothetical diameter, the data reveal a significantly different mean base diameter of 1.2 m compared to the same proposed diameter ($t = 4.579$; $df = 47$; $p < .001$). Moreover, Wood's mean pit depth is only 93 cm ($s = 32.7$ cm; n = 48), significantly different from Kvamme and Ahler's postulated 1.5 m ($t = -12$; $df = 47$; $p < .001$). Kvamme and Ahler's own soil coring data, consisting mostly of extramural pits, shows a similar mean pit depth ($\bar{x} = 93.8$ cm; $s = 22.2$ cm; n = 26), counter to their own postulated value. In light of these results, an average storage pit depth of just less than 1 m and a volume of approximately 1 m^3 is likely a better estimate for storage pits at the site. This mean volume would indicate a total storage capacity closer to 2,100 m^3, considerably less than Kvamme and Ahler's initial estimate of nearly 2,500 m^3.

2009 Geophysical Surveys at Huff Village

Because of the success of the initial limited survey of the site, expanded remote sensing investigations were undertaken at Huff Village in 2009 at the request of the SHSND (Kvamme et al. 2009). The work was performed by Kenneth L. Kvamme along with two graduate students, including me. The goal of this project was to completely survey the settlement, identifying subsurface features with magnetic gradiometry and documenting the site's surface with a robotic total station. Complete and close-up views of the data sets are presented in Appendix 2. Importantly, this work provides an opportunity to estimate the population of the community, storage pit numbers, and per capita storage capacity.

Methods and Instrumentation

A more detailed discussion of instrumentation, survey methods, and data processing is provided in the previous chapter, Appendix 1, and Kvamme et al. (2009). To summarize, the surveys were conducted within a local 30 x 30 m coordinate grid system established with an electronic total station. The magnetic gradiometry survey was performed with a Bartington 601-2, a dual fluxgate instrument. Survey transects were separated by a distance of .5 m and eight measurements were acquired per meter for a total of 16 measurements per m^2. Overall, a total of 42 complete and 28 partial 30 m blocks were surveyed, covering approximately 5 ha (50,269 m^2). This area includes the entire village, extending beyond its fortification system to the state park's boundary fence and the terrace edge on the east side of the site (Figure 3.5).

Elevation data were collected with a Trimble 5600 robotic total station. A total of 42 complete and 35 partial 30 m grids were surveyed with the instrument. A 5.1 ha (51,395 m2) raster digital elevation model (DEM) of the entire site was produced from the recorded points at a spatial resolution of .5, and a local relief model was generated by subtracting the linear trend of the ground surface (Figure 3.6a) (Kvamme et al. 2009). Additionally, a sky view factor visualization was generated to illustrate the topographic surface differently (Figure 3.6b). These data sets were integrated in a geographic information system (GIS) with Wood's (1967:Map 4) map and a 1960 black-and-white aerial photograph (Wood 1967:Plate 1b) of the village (Figures 3.2 and 3.4), aiding comparison, interpretation, and digitization of past excavations and features of archaeological significance.

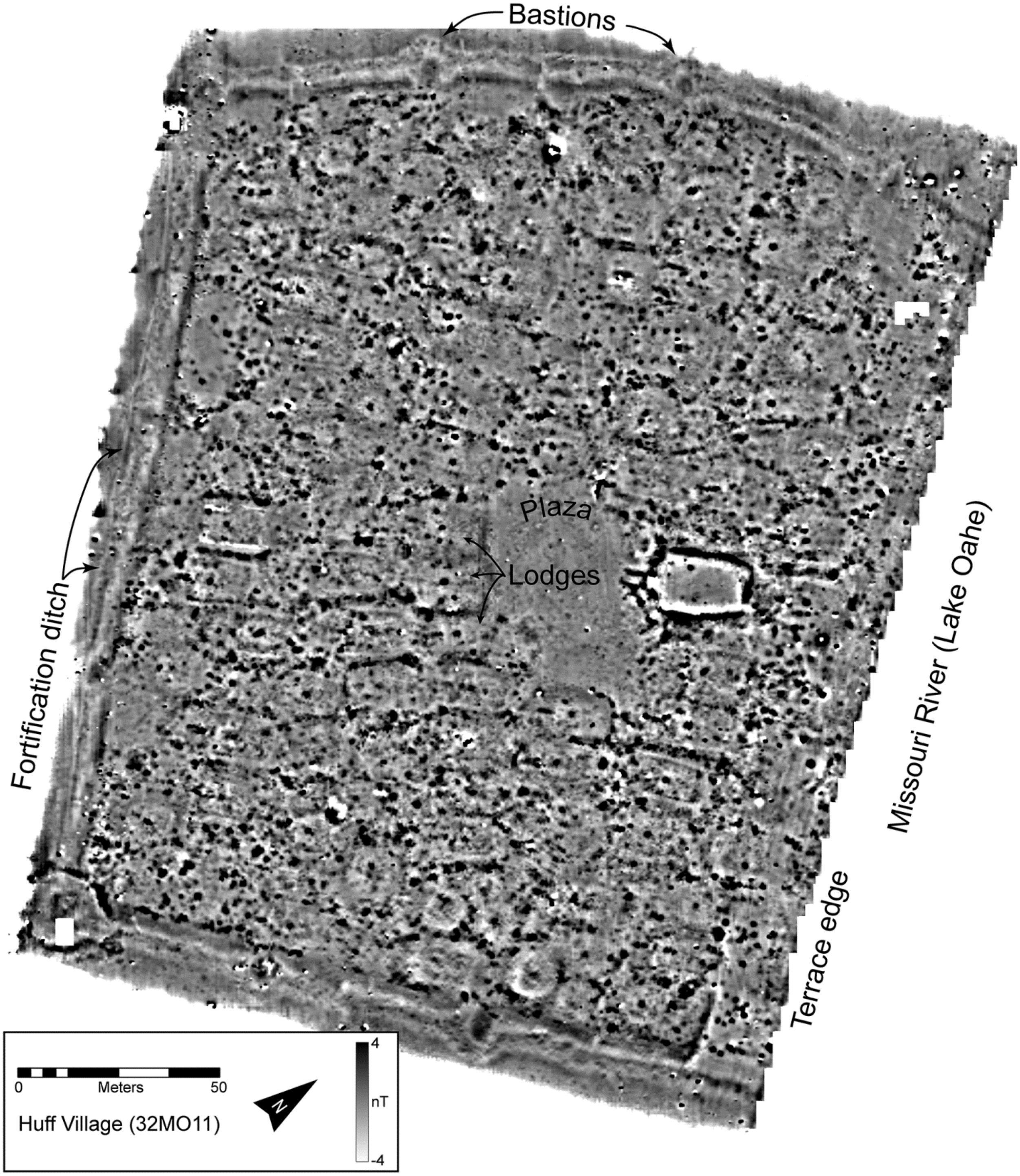

Figure 3.5. Plan view map of magnetic gradiometry survey results at the Huff site.

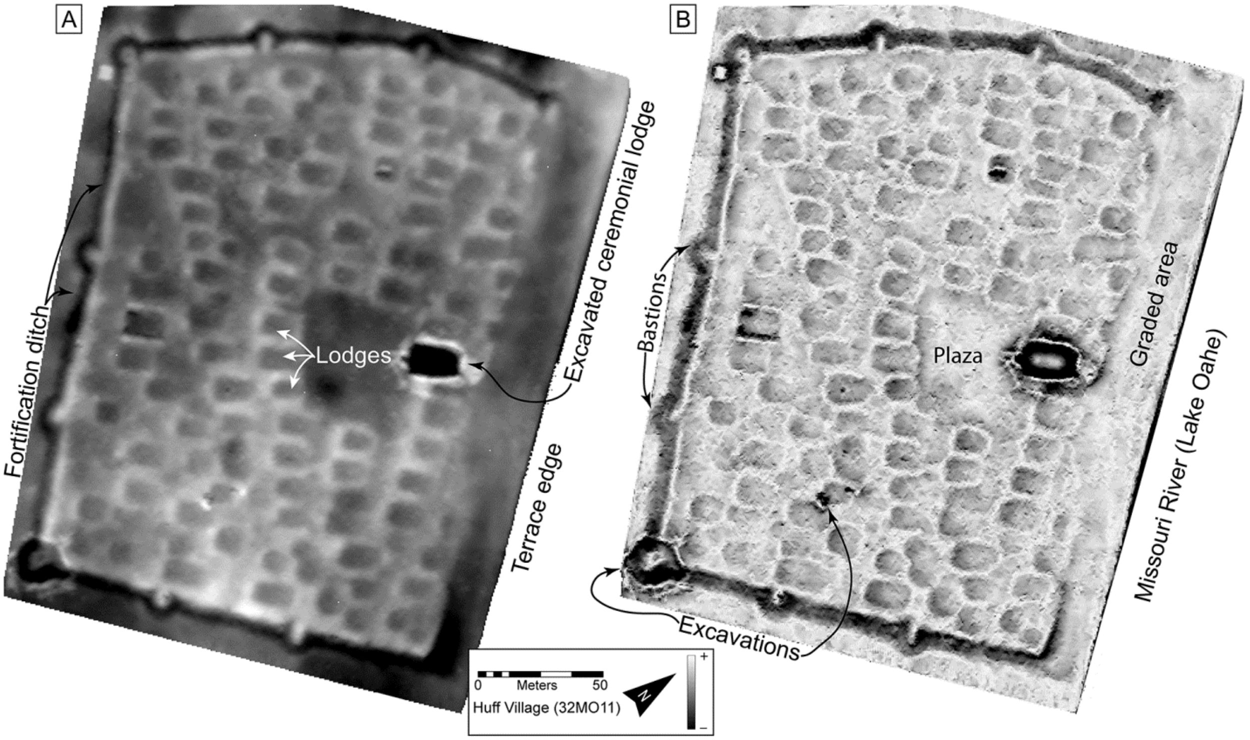

Figure 3.6. Topographic surface of Huff Village, including a a) DEM following removal of the trend surface and b) a sky view factor visualization.

Interpretation of Features at Huff Village

Many of the features mapped by Wood (1967:Map 4) are visible in both the magnetic gradiometry and elevation data sets (Figures 3.5 and 3.6) (Kvamme et al. 2009). For instance, the fortification ditch system with an interior berm (likely associated with the palisade identified in 1959-1960 excavations) and nine U-shaped bastions are clearly discernable (Figure 3.7). The distinctive magnetic signature of the fortification (parallel patterning of high [positive] and low [negative] magnetism) is a product of its construction and subsequent natural infilling (Kvamme et al. 2009:23). That is, magnetically enriched topsoil was removed during the ditch's excavation, causing its negative magnetic signature. These soils were mounded adjacent to the ditch but primarily on its interior to form an elevated berm on which the palisade line was placed. These berms exhibit higher magnetism than the excavated ditch. Due to natural infilling and soil formation, the ditch bottom shows positive magnetism. The plaza is evident topographically as a relatively broad, level space near the village center. Magnetically, it exhibits relatively fewer anomalies than adjacent village areas (Figures 3.5 and 3.6).

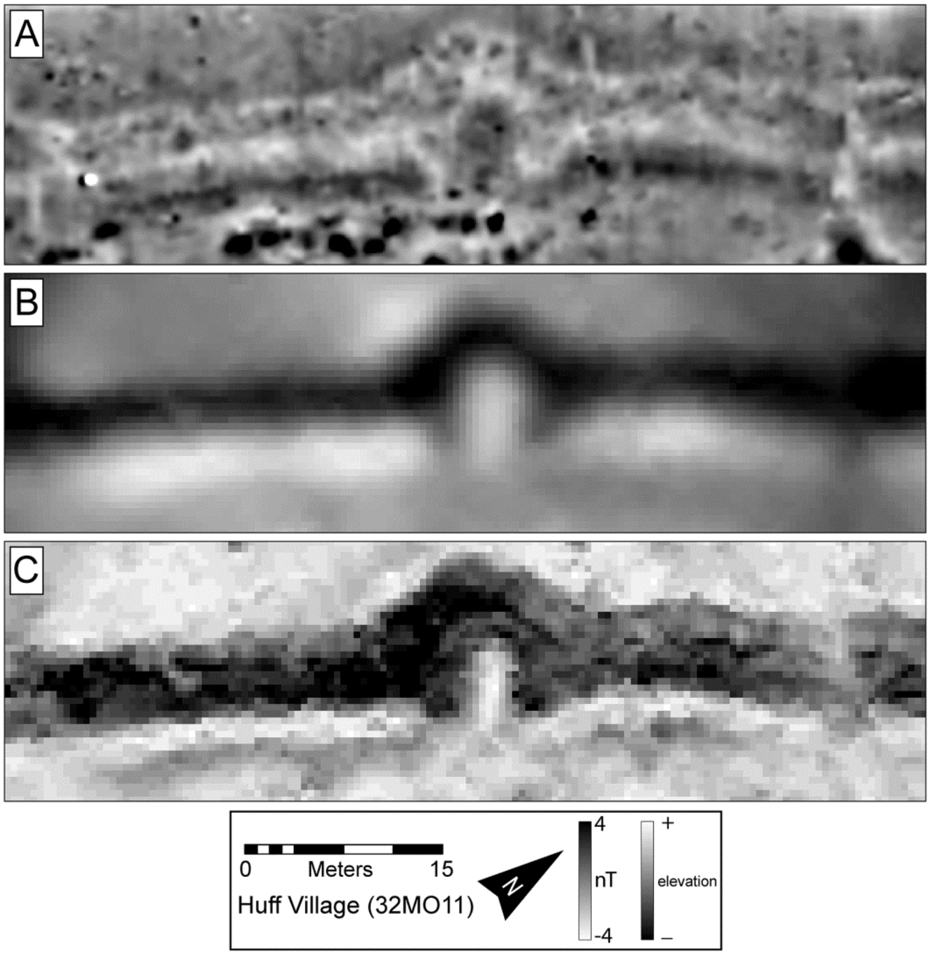

Figure 3.7. Close-up views of the fortification system at Huff Village, showing a portion of the ditch and one bastion in a) low-pass filtered magnetic gradiometry data, b) de-trended DEM, and c) sky view factor visualization.

Moreover, anomalies associated with excavations performed in 1938-1939 (Hecker), 1959 (Howard), 1960 (Wood), and 1999 (PaleoCultural Research Group and SHSND) are quite apparent (Figure 3.8). They are visible topographically where backdirt remains surrounding unfilled excavations (e.g., House 2, the ceremonial lodge and the southwestern-most bastion, both excavated by Howard [1962] in 1959) and magnetically due to disturbed and mounded soils but also the likely presence of metal debris (e.g., steel nails or datums).

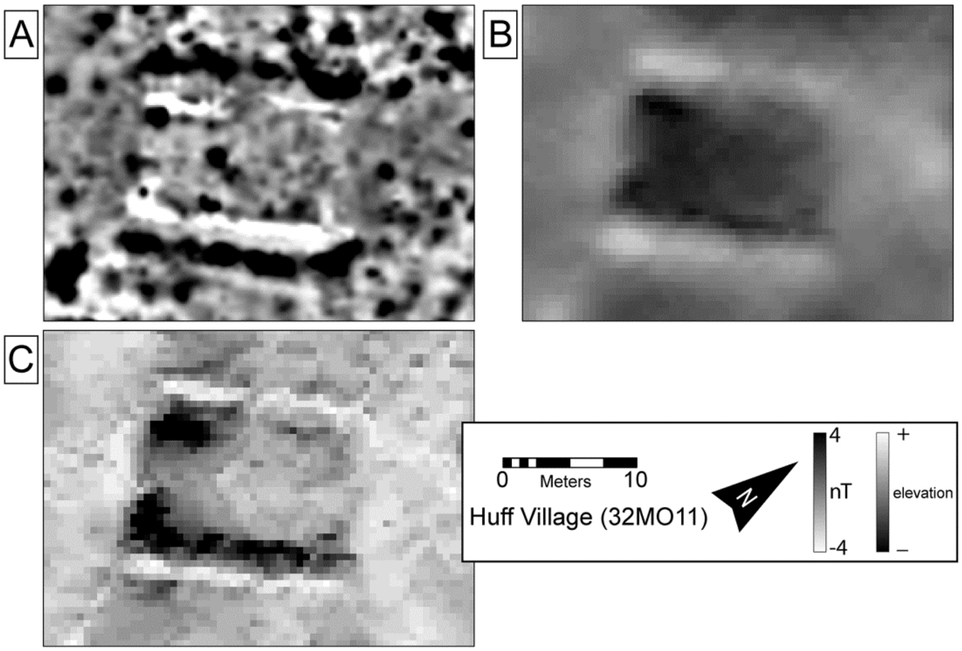

Figure 3.8. Close-up views of Hecker's (Will and Hecker [1944:19-21]) 1939 excavation of the perimeter of House 18 shown in a) low-pass filtered magnetic gradiometry data, b) de-trended DEM, and c) sky view factor visualization.

Notably, many anomalies of likely archaeological significance are magnetically visible in the area of Wood's investigations adjacent to the Missouri River (Kvamme et al. 2009:20). During the course of his salvage fieldwork in 1960, overburden was removed by grading with heavy machinery in multiple areas to hasten the excavation of probable underlying features (Figure 3.2). The entire strip adjacent to the terrace edge was then leveled further to aid river bank stabilization. This work greatly impacted the topography of the river bank, largely removing evidence of previously visible lodge depressions (compare Figures 3.4 and 3.6). The present-day smoothed ground surface contrasts considerably with the adjacent village area (Figure 3.6). Yet, many magnetic anomalies are visible in this area, perhaps indicating the presence of deep storage pit features that were not completely removed by the grading activities (Figure 3.5).

Lodges. The general form of each lodge at Huff is expressed both topographically and magnetically. Their overall layout, roughly aligned in rows and mostly oriented with their entryways to the southwest, appears similar to the map produced by Wood (1967:Map 4) (compare Figures 3.2, 3.5, and 3.6). However, the data provide significant insights regarding their construction, size, shape, number, and content (Kvamme et al. 2009:26-27). The long rectangular form of most houses are visible in the elevation data due to their relatively level interior floor spaces and because the mounded soil that once made their walls now surrounds their perimeters, which also exhibits elevated magnetism (Figure 3.9a-c). Additionally, narrow linear magnetic anomalies mark the long perimeters of many lodges. These anomalies may result from lodge construction practices, where the more magnetic sod was cut and removed before preparation of a level floor on the underlying soil (Figure 3.5). Alternatively, these magnetic anomalies may indicate rows of burned perimeter posts. Both factors likely contribute to this magnetic signature, since excavation data support either interpretation (Wood 1967:32). That is, house floors were dug approximately 30 cm below the former ground level, and more than half of the excavated houses appeared to have been burned. Importantly, the magnetic gradiometry data provide considerable detail regarding houses, closely paralleling Wood's (1967:33-55) plan maps of excavated lodges (Figures 3.3 and 3.9a). Combining the data sets yields additional context that aids interpretation of features. The data sets clearly indicate the presence and locations of interior features such as entryways, hearths, and storage pits (Figure 3.9).

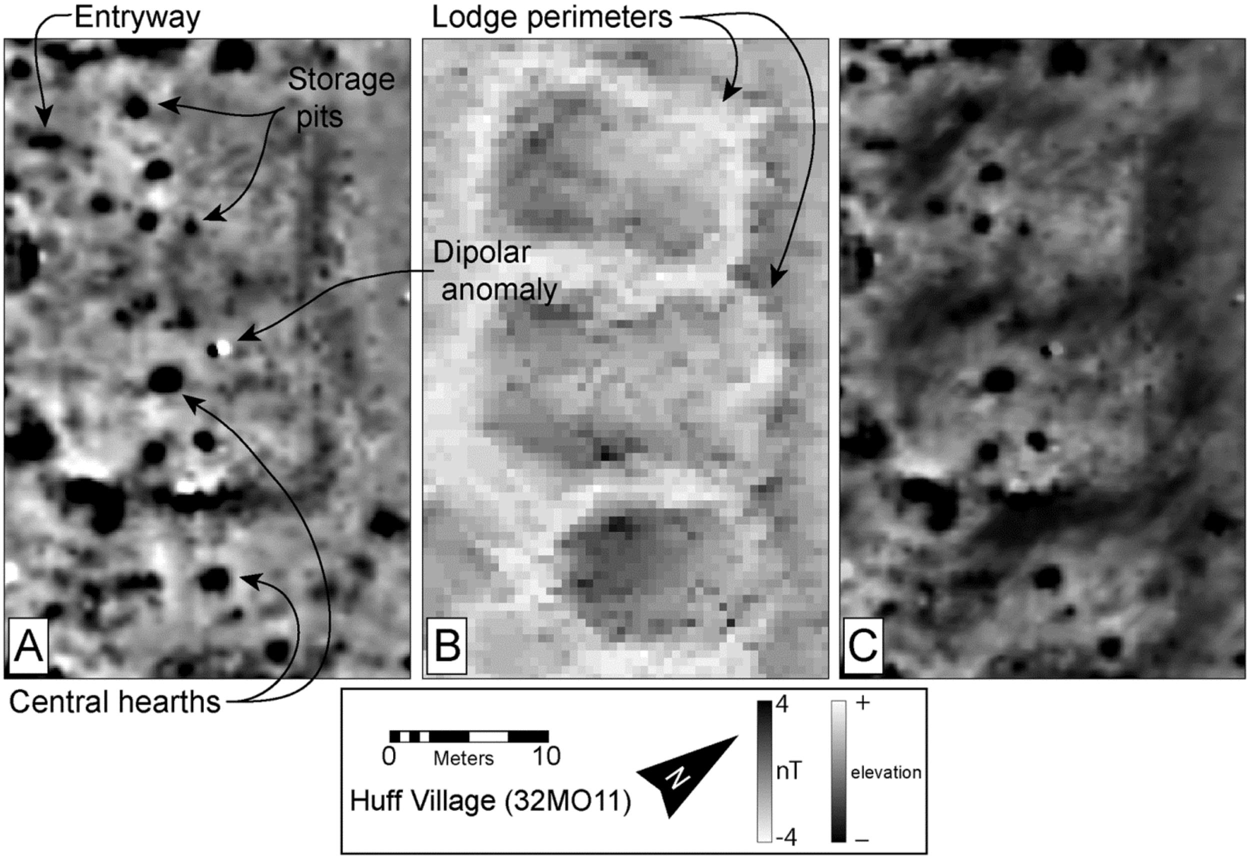

Figure 3.9. Close-up views of lodges adjacent to the plaza at the Huff site, showing architectural details and interior features in a) the magnetic gradiometry data, b) a sky view factor visualization, and c) a pseudo-three-dimensional view (magnetic gradiometry data overlaid on the DEM with shading to emphasize topography), which highlights the relationships among features.

Discrete Magnetic Anomalies. Discrete magnetic anomalies approximately 1-3 m in diameter, roughly circular in shape, and with magnetic values ranging from about 2 to 20 nT (*nanotesla*) are nearly ubiquitous across the settlement, with the exception of the central plaza (Figure 3.5). These anomalies are largely the result of modern metal debris, hearths, and storage pits. The first are relatively easy to identify because of their distinctive magnetic signatures. That is, high-value magnetic anomalies indicative of recent iron or steel exhibit dipolar forms (paired positive and negative measurements) (Figure 3.9a). Sources for the metal debris (and the many dipolar anomalies) include the property's many visitors, tractors used for mowing, objects such as nails and rebar from past excavations, and a fence that once crossed at a diagonal from the northwestern-most bastion across the plaza to the river bank (Will 1924:Figure 12). Over 260 dipolar anomalies were identified. On the other hand, hearths and storage pits are more difficult to distinguish because they are roughly similar in size and magnitude (Figure 3.9a). Positive monopolar[1] magnetic anomalies indicative of the two feature types are generated by different processes. That is, hearths form thermoremanent anomalies while pit features filled with magnetically enriched midden material result in induced anomalies. Yet they are not easily differentiated because magnetic gradiometers measure the sum of all forms of magnetism and are not capable of distinguishing them.

Previous studies of storage pits and hearths in Northern Plains villages have shown that hearths exhibit statistically greater magnetism than storage pits, although their distributions overlap considerably (Bales and Kvamme 2005; Kvamme and Ahler 2007). Still, reasonable interpretations may be made by drawing on a wide body of knowledge regarding features in Northern Plains settlements derived from previous excavations, coring, historical documents, and geophysical surveys. Importantly, a soil coring program performed at Huff Village immediately after the magnetic surveys in 1999 validated anomaly identifications and played a crucial role in my own interpretations (Kvamme and Ahler 2000:16-33).

A method for identifying discrete magnetic anomalies at Huff Village was adapted from a procedure developed by Kvamme and Ahler (2000). This process involved the creation of several different layers in the GIS (Figure 3.10). The full magnetic survey area exhibits thousands of anomalies, many blending together, causing identification of discrete anomalies and

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[1] In fact, every magnetic anomaly is dipolar in form, but weaker anomalies often appear to be monopolar for several reasons. The inclination angle of the earth's magnetic field is nearly vertical at our latitude. Thus, the south-seeking (negative) pole of a buried magnetic dipole is located farther from the gradiometer and is less likely to be detected. Moreover, the soils of North Dakota are relatively young and are weakly magnetic compared to other regions of the world.

visualization of their patterning to be difficult (Figure 3.5). For this reason, a circular low-pass filter 1 m in diameter was applied to the magnetic data set (Figure 3.10b). The result is a smoothed magnetic map, where much of the subtle magnetic noise is reduced, and discrete, roughly circular anomalies are made more apparent. Additionally, threshold maps were employed to produce maps of magnetism above a certain level (Figure 3.10c, d). In this case, threshold values of 3 nT and 5 nT were chosen, effectively eliminating magnetic noise less than those values and better approximating the sizes and shapes of magnetic anomalies. By comparing the two threshold maps, multiple sources (e.g., adjacent storage pits) for large, irregularly-shaped magnetic anomalies were frequently revealed. Combined, these magnetic maps were used to identify and digitize magnetic anomalies of likely archaeological significance greater than .25 m^2 in area (Figure 4e).

Results

Complete interpretation of these data sets yields a map of the village that differs remarkably from that produced by Wood (Figure 3.11; compare with Wood [1967:Map 4] and Figure 3.2). Although there are several similarities, including the general layout of houses and the form of the fortification system, there are important differences. The difference in house number is perhaps not immediately apparent. In his investigation, Wood (1967:Map 4) mapped 103 dwellings, mostly rectangular in form with at least one four-post, rounded square structure. Accounting for the houses lost to erosion and excavation, examination of the magnetic gradiometry and elevation data reveals 12 additional houses. Subtle topographic depressions hint at the presence of a few more lodges in open spaces, although these potential houses are less apparent, and correspondences with the magnetic gradiometry data are less obvious (e.g., a clear central hearth is not visible). They are not identified as such for this reason. These new dwellings bring the total number of lodges at the Huff site to 115 (a nearly 12 percent increase) at a density of 26 houses per ha, a calculation based on the area of the village within the fortification ditch, which corresponds to the extent of features identified with magnetic gradiometry. Additionally, at least 15 houses appear to be circular or rounded square in form, like House 12 excavated by Wood (1967:50-52), rather than rectangular.

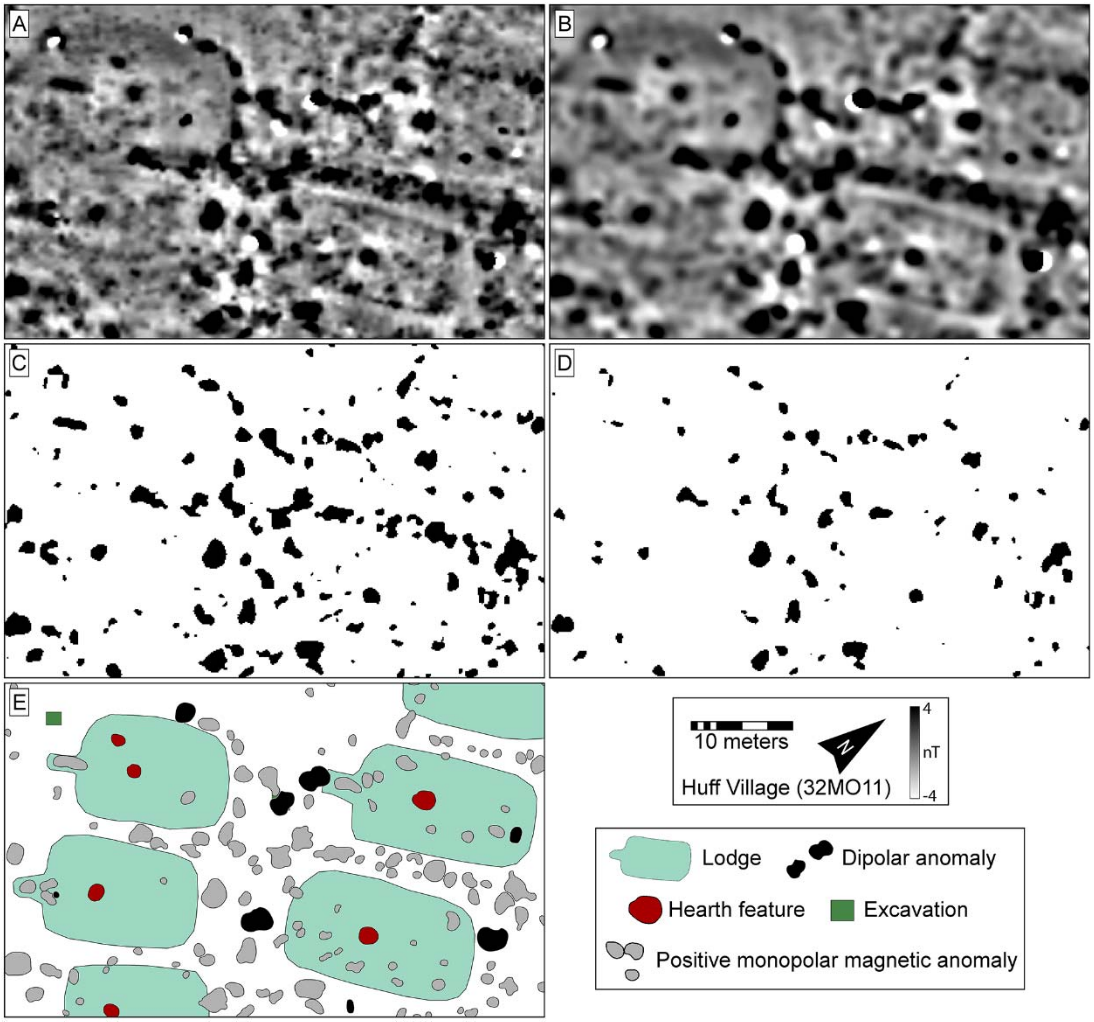

Figure 3.10. Close-up views of lodges at Huff showing different feature types in a) the magnetic gradiometry data, b) the circular low-pass filtered data, c) a 3 nT threshold layer, d) a 5 nT threshold layer, and e) an interpretive map with a key for that map.

Figure 3.11. Interpretive map of Huff Village. Note the immense number of positive monopolar magnetic anomalies, many indicating subterranean storage pits.

Wood’s excavated houses are on average 122.8 m^2 ($s = 37$ m^2; $n = 10$; lodge area data were acquired from Mitchell [2011:415], who followed Johnson’s [1979:Figure 15, 130] method of measuring area with mid-width and mid-length dimensions) while the area of the remaining unexcavated houses is somewhat larger ($\bar{x} = 129$ m^2; $s = 32$ m^2; $n = 94$). A Mann-Whitney test indicates that the difference between the two means is not significant ($U = 518$; $z = .52$; $p = .60$). Still, lodges adjacent to the river’s edge, the location of Wood’s excavated dwellings, may be somewhat smaller, especially considering what appear to be much larger lodges encircling the plaza. In fact, Pearson’s *r* indicates a moderately high negative correlation ($r = -.62$; $df = 102$; $p < .0001$) between house size and distance from the plaza center. In other words, dwellings near the plaza tend to be larger than those farther from the plaza, perhaps signifying status differences among households at Huff Village, a notion that is supported by ethnographic evidence. For example, Orin G. Libby (1908:Plate 2, 499) stated that prominent Mandans occupied earthlodges around the perimeter of the plaza within the Native village at Fort Clark during the nineteenth century. The smallest lodge is only 55.6 m^2, while the largest (excluding the ceremonial structure) is 189.4 m^2. If the validity of area estimates in both data sets is accepted, the combined mean house size is 128.4 m^2 ($s = 32.4$ m^2; $n = 104$). The dimensions for the 11 remaining houses are unknown because they were leveled as part of the 1960 salvage and bank stabilization efforts but not completely excavated, or in the case of one excavated lodge (Wood's [1967:49] House 9), had unclear dimensions. House size becomes a relevant statistic below.

Wood’s (1967:31-32) excavations at Huff Village revealed a regular pattern for features within houses. For instance, he noted that most houses contained a primary fireplace along the centerline of the structure, with possible adjacent auxiliary hearths. Additionally, storage pits were located along the walls and in the corners of most lodges (Figure 3.3). Similar patterning is evident in the interpretive map of Huff Village, which shows a total of 2,311 positive monopolar magnetic anomalies (excluding dipolar anomalies) greater than .25 m^2 in area in the space that has been unaffected by erosion or complete excavation (Figure 3.11). If the area of the plaza (approximately .18 ha) and the village fortification are excluded, the density of positive monopolar magnetic anomalies across the unexcavated portion of the village (approximately 38,526 m^2) is 6 per 100 m^2, an overall feature density lower than that estimated by Kvamme and Ahler (2000:33) from their limited sample. Based on this figure, it is estimated that another 234 features would have been located in the excavated portion of the site and the area lost to erosion (approximately .39 ha), for a total of 2,545 (note that the portion of the site lost to erosion prior to Wood's work is unknown, although some houses were truncated by the cut bank at the time of his fieldwork). Given the results of the previous intensive soil coring program at the site, which showed that 74 percent of cored anomalies were storage pits, 14 percent were hearths, and 6 percent were middens, there are an estimated 1,883 storage pits, 356 hearths, and 153 middens within the village. Magnetic anomalies indicative of primary hearths are evident in each of the mapped houses at Huff, with the exception of houses impacted by erosion and excavation, and account for 101 of the anomalies (two cored hearths are found in a single house). This leaves approximately 250 central and auxiliary hearths within and outside houses. Thus, the overwhelming majority of the discrete anomalies likely represent storage pits.

As discussed above, previous investigations of hearths and storage pits in Northern Plains villages have demonstrated their statistical difference in terms of magnetism (Bales and Kvamme 2005; Kvamme and Ahler 2007). Comparing the magnetism of hearths and magnetic anomalies at Huff Village provides some support as to my interpretation of these anomalies as primarily storage pits. Excluding one outlier with robust magnetism characteristic of a metal object, those anomalies that can be identified confidently as hearths based on their context and magnitude (i.e., large magnitude anomalies located along the centerline of the long axis or the center of lodges) exhibit a mean maximum of 9.15 nT (s = 4.9 nT; n = 100) with a range of 3.32-25 nT. Interestingly, storage pits confirmed through coring have a mean maximum of 7.76 nT (s = 4.07 nT; n = 26) and a range of 2.36-19.46 nT. Although the mean maximums vary, the difference is not significant according to a t-test (t = 1.33; df = 124; p = .092). On the other hand, the mean maximum of the proposed storage pit magnetic anomalies, excluding one outlier, is 6.75 nT (s = 3.71 nT; n = 2209) with a range of 2.98-57.82 nT, a mean value that is statistically less than that calculated for 100 hearths (t = 6.22; df = 2307; $p < .0001$). This finding is expected given that most of the magnetic anomalies are likely storage pits, which tend to be less magnetic than hearths. In fact, over 65 percent of the magnetic anomalies fall between 3 to 7 nT, low values that are more characteristic of pits. Many of the larger magnitude magnetic anomalies are also probably storage pits, although those with very high maximum values may instead be hearths.

Agricultural Production at Huff Village

Examination of these anomalies reveals interesting patterns (Kvamme 2007a:219; Kvamme et al. 2009:33-34). For one, storage pits are common around the exteriors of most houses and are particularly evident between adjacent structures (Figures 3.10e and 3.11). Additionally, many house entryways contain an elongated storage pit, an unusual feature that was confirmed during the coring program (Figures 3.9a and 3.10e). Discrete clusters of storage pits are common in locations away from houses as well, including lines of pits paralleling the fortification ditch. Within lodges, there is no appreciable difference between the mean number of excavated storage pits in ten houses ($\bar{x}$ = 4.4; *s* = 2.2; *n* = 44) and magnetic anomalies (potential storage pits) identified within 94 houses ($\bar{x}$ = 4.68; *s* = 3.3; *n* = 440) that have not been impacted significantly by grading, excavation, or erosion. This result is unexpected since the magnetic anomalies would presumably include storage pits, auxiliary hearths, and middens, meaning the average number of anomalies located within houses should be higher. However, this finding likely reflects the conservative nature of my anomaly interpretations, where anomalies smaller than .25 m^2 were not digitized, even though some probably point to features of these types.

Based on the average volume of excavated storage pits (1.03 m^3) and the estimated number of pits at Huff Village, the projected total storage capacity is nearly 1,939.5 m^3 (a volume of maize that would weigh approximately 1,397,967 kg [55,038 bushels]). This value represents a significant difference from the total storage capacity of nearly 2,500 m^3 estimated by Kvamme and Ahler (1999) based on their limited geophysical survey of the village. Still, the number is impressive and attests to the great deal of time, labor, and land that village occupants dedicated to agricultural production and the construction of storage facilities. Moreover, the storage pit estimate is conservative since weakly magnetic anomalies less than 3 nT in magnitude likely result from other storage pits and from the fact that some closely adjacent pits may be interpreted as single storage pits.

Mitchell (2013:81-84) argues historical data concerning agricultural yields among Plains groups are problematic because most documents postdate 1850, after which some fields were cultivated for the Indian agencies along with their own, the federal government provided supplementary support, new crops and activities were introduced, and production methods were undergoing change (e.g., see Will and Hyde's [1917] discussion of agriculture among Plains groups, production yields, and these other factors). This specific issue is discussed further in the following chapter. Despite potential problems with historical data, it is reasonable to assume that horticultural groups such as the Mandans, Hidatsas, and Arikaras were capable of producing between about 1,255 to 1,883 kg of maize per hectare (20-30 bushels/ac) under normal conditions (Mitchell 2013:81-84). Will and Hyde (1917:141-143) suggest, based on cited and uncited reports, that Native groups along the Missouri River could expect maize yields of about 1,255 kg/ha (20 bushels/ac) in a year without inclement weather (e.g., drought) or detrimental insect predation and even higher yields given more favorable conditions. In contrast, Schroeder (1999) references quantitative censuses and reports on maize productivity among ten Native groups in the Eastern Woodlands and Northern Plains without plows to estimate a mean yield of around 1,186 kg/ha (18.9 bushels/ac). Given other factors, however, Schroeder (1999) argues that a mean yield of only about 565-627 kg/ha (9-10 bushels/ac) is a more realistic estimate for maize available for consumption. Baden and Beekman (2001) model maize productivity and account for environmental factors to produce an optimal yield for Mississippian period agriculture of approximately 1,129-1,883 kg/ha (18-30 bushels/ac). The model indicates an average yield of only 502-753 kg/ha (8-12 bushels/ac), however.

Experimental garden plots were constructed by Munson-Scullin and Scullin (2005) in south-central Minnesota to produce maize yield estimates under conditions approximating those that the Mandans, Hidatsas, Arikaras, and other regional horticultural groups would have experienced in the past. The garden plots, located on a river terrace, were modeled and cultivated according to methods described in historical accounts (e.g., Wilson [1917]). An heirloom variety of Northern Flint maize, a type used by the Native peoples of the region, was planted in the plots for three growing seasons without the aid of fertilizer. Over the three years, a period of less than ideal weather conditions, including drought, maize yields averaged 2,390 kg/ha (38 bushels/ac), 1,824 kg/ha (29 bushels/ac), and 1,510 kg/ha (24 bushels/ac). Along with the weather, Munson-Scullin and Scullin (2005) noted soil nutrient depletion as the greatest factor affecting maize yields. Likewise, Demchik and Demchik (2011) created experimental maize, bean, and squash polyculture garden plots in central Wisconsin to estimate potential maize yields, among other considerations. In this instance, soils were fortified with nitrogen fertilizer and a maize landrace developed for its suitability to the region was grown. Maize yields varied during the four years from approximately 690 to 3264 kg/ha (11 to 52 bushels/ac [14 to 67 lbs/1000 ft^2]). These studies demonstrate that numerous factors, including but not limited to local weather, cultivation techniques, soil nutrients, soil moisture, and the abundance of crop predators, affect maize yields, leading to a wide range of variation. However, for horticultural groups who lived along the Missouri River, an average maize yield of 1,255-1,883 kg/ha (20-30 bushels/ac) appears to be mostly consistent with these investigations.

Given these potential yields, approximately 742-1,114 ha (1,834-2,753 ac) would have been necessary to account for the estimated total storage capacity at Huff Village (ignoring other cultivated plant foods, maize that was consumed during or soon after harvest, or foods that were traded prior to storage). Clearly, the total storage pit capacity is a cumulative estimate of pits constructed over the lifetime of the village. Yet, Will and Hyde (1917:103-108) refer to several instances of Plains groups cultivating anywhere from 202 to 810 ha (500 to over 2,000 ac) during the 1850s-1870s. Historical and ethnographic documents (e.g., Bowers 2004:23, 32; Will and Hyde 1917:65, 99-102; Wilson 1917) provide a general understanding as to the location and organization of field or garden sites among Missouri River communities. Fields were used by separate households, with each mature woman in the household owning and working a discrete area of approximately .4-1.2 ha (1-3 ac) with the assistance of family members, or about .1-.4 ha

(.3-1 ac) was cultivated per person in a group. Fields were located in the floodplains and along the lower terraces on both sides of the Missouri River and nearby tributaries. They were expanded annually as needed, depending on the size and productivity of each family. Additionally, crops were cultivated in an area until it no longer produced an adequate yield, at which time it would be left fallow. For these reasons, fields often extended great distances from a village.

Approaching the question of cropland and storage requirements from a different direction, by estimating the population of Huff Village and considering nutritional needs, yields additional insight. Most methods for estimating the population of settlements using archaeological data rely on either total floor space or site size. Naroll's (1962) average of 10 m^2 of floor space per person and Cook and Heizer's (1968) 1.86 m^2 of floor space per person up to six and then 9.29 m^2 of space per person thereafter are commonly cited in demographic studies. Using the average lodge size of 128.4 m^2 for 115 houses, Naroll's method yields an estimate of approximately 1,475 people while Cook and Heizer's approach suggests more than 18 persons per lodge (nearly 2,100 people). Alternatively, Wedel (1979) used historical data from Central Plains village groups to argue that 5 m^2 of floor space per person was more appropriate. This figure yields an unreasonably high estimate of over 25 persons per dwelling, however, and a total population of about 2,950. Other factors such as family status may also have influenced house size, a fact that led Roberts (1977) to produce a regression equation based on historically documented Mandan populations in which this is known to be true. His zero-intercept equation for Mandan populations yields an estimate of approximately 1,470 individuals at Huff Village (which is considered an ancestral Mandan village), a number similar to that derived from Naroll's method and one that is supported by other historical information (Mitchell 2013:63-64).

This population likely resided in the village for only a short period, perhaps less than a decade, considering the lack of evidence of long-term occupation and data concerning lodge use life (Roper and Pauls 2005). The brevity of the occupation is supported by other archaeological evidence, including limited midden accumulation and few (if any) superimposed houses or house floors, rebuilt houses or house walls, or truncated pit features (Kvamme et al. 2009; Wood 1967). Given the population estimate of approximately 1,470 people, the per capita storage capacity for the settlement would have been around 1.3 m^3 (a volume of maize that would weigh approximately 937 kg [37 bushels]). Of course, this estimate assumes that all storage pits were used simultaneously, which is unlikely given historical accounts of occasional pit failure and abandonment, although they were reportedly used for multiple years (Bowers 2004:32; Will and Hyde 1917:138; Wilson 1917). An estimate of the amount of cropland needed to meet the nutritional requirements of Huff Village may be determined by adapting the strategy used by Mitchell (2013:83).

Factors such as village composition, nutritional requirements, dietary composition, and fallowing practices are dynamic rather than static. However, to reach a reasonable conclusion in this analysis, some basic generalizations must be made about each factor. According to Wilson's (1917:113-114) early twentieth-century Hidatsa informant, Buffalo Bird Woman, a family's gardens were never in use every year. Instead, some land was always left fallow for a two year period, after which time it would be productive for several years. Assuming such practices held true for the fifteenth-century inhabitants of Huff Village, it is plausible that 60 percent of cropland was in use at any one time while the remainder was left fallow. Following Schroeder (1999:Table 5), the village's total population of 1,470 individuals is assumed to have been composed of 40 percent adults who, given standard nutritional requirements, would need 2,500 calories per day while children would require fewer (1,910 calories/day) (National Research Council 1989; World Health Organization 1991). Maize played an important role in the subsistence practices of Middle Missouri communities, but its caloric contribution to the diet likely varied among different communities, and environmental and social factors added to this variability (Mitchell 2013:84-85). In this case, maize is assumed to have contributed 35 percent, or about one-third of the settlement's caloric requirements (with maize contributing 3,600 calories/kg [Ensminger et al. 1994:838]), although in any given year, maize likely made up a greater or lesser proportion of the diet. An unknown amount of maize would have perhaps been consumed during its "green corn stage" and immediately at harvest time as was observed among the Mandans during the nineteenth century (Wood et al. 2011:71). Moreover, an indefinite, although likely significant amount would have been traded after the harvest. To meet just their own caloric needs, the occupants of Huff Village would have required approximately 112,019 kg (4,410 bushels) of maize. Assuming a yield of 1,255-1,883 kg/ha (20-30 bushels/ac), that amount of maize could have been cultivated on about 99-149 ha (245-368 ac), an area that includes fallow land. Of the total estimated storage capacity at Huff Village, just less than 10 percent of the pits would have been necessary for maize storage on its own at any one time. These estimates would also suggest a total storage capacity of around 155 m^3 or a per capita maize storage capacity for the settlement of around .11 m^3 (a volume of maize that would weigh approximately 76 kg [3 bushels]).

Discussion

Given the anecdotal nature of arguments to date regarding temporal variation in agricultural production among Plains Village peoples, the significance of the preceding results from Huff Village is manifold. Granted, estimates of the total number of storage pits and capacity derived from extensive remote sensing data and limited excavation and soil coring are less desirable than an approach like more comprehensive excavation of the village, which would yield results with more certainty. Given current economic and social constraints, however, such undertakings are rare.

Still, important inferences may be drawn from these estimates. Information concerning storage pit numbers and capacity provide one of the few windows to understanding production and potential intensification in the region through time. Although historical documents offer an important source for understanding field or garden systems in the region during the nineteenth century, no such features, including those associated with sites from earlier periods, are extant along the Missouri River today. Likewise, evidence of changing agricultural practices that would have enhanced productivity is lacking.

These estimates are insightful, especially with respect to the abilities of one village's occupants. More importantly, the results from the analysis of remote sensing and archaeological data at Huff Village serve as a starting point to which information from other sites may be compared. However, understanding long-term trends in agricultural productivity requires an examination of storage pits across a range of archaeological sites in the Northern Plains region. Such an undertaking has implications for significant issues like the effects of climate or the influence of European and American colonization on subsistence.

CHAPTER 4: STORAGE PITS AND AGRICULTURAL PRODUCTION IN NORTHERN PLAINS VILLAGE SITES ALONG THE MISSOURI RIVER

In the previous chapter I provided a synchronic view of agricultural production among a single group of horticulturalists, the fifteenth-century ancestral Mandans at Huff Village. Excavation and historical data from Plains Village sites along the Missouri River in North Dakota, which date from approximately 1200 to 1886, can be utilized to broaden this analysis to examine agricultural production during this centuries-long period. This long-term perspective is advantageous since trends or patterns in agricultural production, and perhaps evidence of intensification, may be identified. Furthermore, significant changes in agricultural production may be explained by or shown to correspond with instances of epidemic disease, climate change, or the appearance of colonists in the Northern Plains.

Middle Missouri Subarea Archaeological Sites

To explore historical trends in agricultural production among Plains Village period horticulturalists along the Missouri River in the Northern Plains, I use quantitative excavation and coring data from 20 archaeological sites spanning a period of nearly 700 years (Appendix 3 includes a description with relevant information concerning each site's investigation and chronology). The sites fall within four of the eight archaeological regions within the Middle Missouri subarea discussed previously in Chapter 1, including the Cannonball, Heart, Knife, and Garrison regions (Figure 1.2). More specifically, they are located primarily in North Dakota or just south of the state's present-day border with South Dakota (Figure 1.3). Multiple taxonomic systems, each introduced in Chapter 1 and described in detail by Johnson (2007) and Ahler (1993a), have been used to classify the sites. Limiting the sample of sites to the four archaeological regions was one factor in site choice, since the collection would consist primarily of sites occupied by ancestral Mandan groups. The Leavenworth site (39CO9) was included in the sample since the village was occupied by the Arikaras prior to their reconstruction of a settlement at Fort Clark State Historic Site (32ME2), which is discussed further in the following chapter. Moreover, Leavenworth dates to the period following the 1780-1781 smallpox epidemic, a period that likewise included Hidatsa sites due to a lack of settlements occupied strictly by Mandans in which useful data were available. Importantly, a larger number of sites were initially examined, including other villages from the Knife River region, but many lack storage pit dimension data in published literature. Of course, potential bias exists in the fact that the sites were excavated during different decades and by different archaeologists, meaning excavation and data recording standards varied. However, one reason for generating a large sample of storage pits from multiple sites is that the effect of discrepancies or inaccuracies is minimized.

Decades of research has yielded a thorough, although still debated, understanding of the occupational and settlement history of the region. Intensive maize agriculture served a crucial role during the most recent millennium (Tiffany 2007:7). Its introduction was a significant factor that led to the formation of aggregated and sedentary communities along the Missouri River during the initial centuries of the last millennium. In the northern portion of the Middle Missouri, these Extended Middle Missouri variant (EMMV) groups are thought to have transitioned directly from Late Woodland populations, some of which lived in permanent and fortified villages (e.g., Menoken [32BL2]) in the late twelfth century or early thirteenth century (Ahler

2007). Unlike later horticulturalists of the region, however, these Late Woodland populations relied very little on maize agriculture.

Menoken Village is a small, fortified community, approximately .59 ha in size, along Apple Creek east of Bismarck, North Dakota that dates to approximately 1200 (Ahler 2003a; Ahler, ed. 2003a; Ahler 2007:17-21). Topographic depressions clearly indicate the presence of eight houses, including two outside of the fortification ditch (Ahler 2003b). Several other houses within the ditch have more subtle expressions. Most of these houses were confirmed and a few other surface houses were identified with greater certainty by way of remote sensing and coring investigations performed from 1997 to 1999 (Ahler 2003c, 2007:17-21; Kvamme 2003b, 2007a). Extensive excavations of two houses in 1998 and 1999, one a pithouse and the other constructed on the surface, revealed their oval forms, posts for their central ridgepoles, and basin-shaped central hearths (Ahler 2003d, 2007:17-21; Ahler et al. 2003). More importantly, these excavations revealed a single refuse-filled pit feature within one house but many surrounding their exteriors. However, these were mostly basin-shaped borrows pits, which averaged only 25 cm in depth, unlike the much deeper, straight-sided (cylindrical) and undercut (bell-shaped) storage pits of later Plains Village sites. Additionally, the botanical remains at Menoken contain only small amounts of maize, consisting mostly of cupule fragments and a few kernels (Ahler 2007:17-21; Nickel 2003, 2007).

Domesticated plant foods, especially maize, became a vital part of the subsistence economies of communities in the Middle Missouri subarea in the following decades and centuries. In fact, by the mid-fifteenth century and during later centuries, maize was fundamental to supporting the large populations of many settlements, which sometimes held well over 1,000 people, near the Heart-Missouri confluence in North Dakota. Mitchell (2011, 2013:170-190) identified several long-term developments that occurred in this region during the fifteenth century through the seventeenth century. These include demographic shifts related to the clustering of more densely populated communities, household- and community-level specialization in lithic and ceramic craft production, and the expansion of trade, both in terms of the quantity of exchanged goods and the size of the regional network. Transformations to long-standing traditions such as these serve as examples of Ferris's (2009) concept of "changed continuities." Likewise, the subsistence economy of the communities near the Heart River underwent profound changes around 1500 (Mitchell 2013:178-181). Although bison remained a central element of their diets (and a source of other non-dietary goods), a wider variety of lower-ranked animal species were increasingly consumed.

Storage Pits: An Indirect Measure of Agricultural Production and Intensification?

Several circumstantial lines of evidence indicate that occupants of the villages near the Heart and Knife Rivers intensified agricultural production during this period as well. For instance, Mitchell (2013:178) suggests that subterranean storage pits appear to have increased in both volume and number from about the thirteenth or fourteenth century through the eighteenth century. Mitchell (2013:179) also notes that bison scapula hoes make up the largest proportion of bone tool assemblages during the late eighteenth and early nineteenth centuries among the Hidatsas at Knife region sites, perhaps indicating increased agricultural production during that period (Weston and Ahler 1993:281-282). Similarly, the Mandans arguably placed greater emphasis on horticulture during the late eighteenth and early nineteenth centuries, growing more maize and other garden produce to initially meet the mounting demands of intertribal trade and later those of the American Fur Company and its competitors (Anfinson 1987).

Identifying temporal trends or shifts in agricultural productivity among Middle Missouri horticultural communities is problematic. Historical documents provide a possibly biased but useful glimpse of cultivation methods and agricultural capabilities during the nineteenth century. However, archaeological data concerning potentially different cultivation methods and quantitative data regarding agricultural production are lacking for earlier periods (Mitchell 2013:178). As noted by Mitchell (2013:178-179), the volumes and numbers of subterranean storage pits within households and communities are a surrogate source of data, variations of which may indicate changes through time in agricultural production and perhaps even intensification. These undercut and straight-sided pits offered a well-protected space to store primarily surplus agricultural produce, especially maize, that were later consumed, traded, and used as seed in subsequent years (Wilson 1917). In this way, quantitative data regarding storage pit numbers and volumes are more indicative of the storage capacities of individual pits, households, and communities. Yet, an increase in the volume or number of pits within a particular area such as lodge floors, which are remarkably similar through time, presumably indicates greater productivity (Mitchell 2013:178-179). Excavation and coring data for hundreds of storage pits in 20 archaeological sites dating from the thirteenth century through the nineteenth century are used to document temporal patterning in agricultural production in the northern portion of the Middle Missouri subarea.

Study Sample of Sites

Although the traditional taxonomic systems (i.e., Johnson's [2007] and Ahler's [1993a] taxonomies) are utilized in this study for the purposes of discussion, the broad temporal ranges of many of the variants or complexes make comparisons and identification of potential short-term changes in storage pit numbers and sizes within the study sample more difficult. Following Mitchell (2011, 2013), I assigned each site to one or more of the periods of Johnson's (2007:167-202) settlement history reconstruction for the Middle Missouri subarea. This history for the Mandans, Hidatsas, Arikaras, and related ancestral groups ranges from 1000 to 1886 and is subdivided into 13 periods, primarily 50 or 100 years in length (Table 4.1). For the purposes of this investigation, however, some of the periods were altered to account for the relative chronologies of the sites located in the Heart River region, an issue discussed further below. Importantly, the reconstruction is based on an extensive dating effort involving hundreds of site components in the Middle Missouri subarea (Johnson 2007). The temporal positioning of many sites or components is based principally on a series of conventional and AMS radiocarbon dates (Ahler et al. 2007) and ceramic ordinations, although other evidence such as site stratigraphy, European and American trade goods, historical documents, oral traditions, linguistic information, and craniometrics analyses facilitated Johnson's (2007) interpretation of these results.

Table 4.1. List of time periods with date ranges from 1200 to 1886. Adapted time periods used in the current study are listed in the center column. Period codes on the right are used in Appendix 3 in place of date ranges and are similar to those used by Mitchell (2011, 2013).

Johnson's (2007) Time Periods (A.D.)	Adapted Time Periods (A.D.)	Period Code
1200-1300	1200-1300	3
1300-1400	1300-1400	4
1400-1500	1400-1500	5
1500-1550 1550-1600	1500-1600	6/7
1600-1650	1600-1650	8
1650-1700	1650-1700	9
1700-1750	1675-1725	10
1750-1785	1725-1785	11
1785-1830	1785-1830	12
1830-1886	1845-1886	13

Quantitative excavation and coring data were obtained from unpublished gray literature and published reports of fieldwork at 20 sites located in the northern half of the Middle Missouri subarea (Table 4.2). Additional sites were excluded from the analysis because their excavation results lacked comparable information. The positioning of sites predating 1500 largely follows Johnson's (2007) chronology. However, multicomponent sites such as Amahami (32ME8) and White Buffalo Robe (32EM7), which have components dated to drastically different periods, were considered differently. Following the authors of these reports, each particular feature was assigned to a specific time period when possible based on its context or location within a site, its association with other features such as a house, and its contents. Although all pit features were documented, even those dated to components with very broad time periods, those lacking explicit assignment to one of the short-term periods were excluded from the current analysis.

Table 4.2. List of sites in the study sample with their time period(s) and references. Features from multicomponent sites were assigned to more specific periods when possible. Period codes for each feature are shown in Appendix 3.

No.	Site	Period (A.D.)	Reference(s)
1	Paul Brave (32SI4)	1200-1300	Wood and Woolworth 1964
2	Jake White Bull (39CO6)	1200-1300	Ahler 1977
3	Fire Heart Creek (32SI2)	1200-1300	Lehmer 1966
4	Bendish (32MO2)	1200-1300	Thiessen 1995
5	Havens (32EM1)	1300-1400	Sperry 1995
6	South Cannonball (32SI19)	1300-1400	Griffin 1984
7	Cross Ranch (32OL14)	1300-1400	Calabrese 1972
8	White Buffalo Robe (32ME7)	1300-1400	Lee 1980
9	Shermer (32EM10)	1300-1400	Sperry 1968
10	Huff (32MO11)	1400-1500	Ahler and Kvamme 2000; Wood 1967
11	Demery (39CO1)	1400-1500	Woolworth and Wood 1964
12	Double Ditch (32BL8)	1500-1785	Ahler, ed. 2003b, 2004, 2005
13	Larson (32BL9)	1500-1650	Mitchell, ed. 2007, 2008
14	Scattered (32MO31)	1500-1700	Ahler 2002
15	On-A-Slant (32MO6)	1600-1785	Ahler 1997
16	Boley (32MO37)	1500-1785	Ahler, ed. 2006
17	Amahami (32ME8)	1785-1830	Lehmer et al. 1978
18	Rock (32ME15)	1785-1830	Hartle 1960; Lehmer et al. 1978
19	Leavenworth (39CO9)	1785-1830	Krause 1972
20	Like-A-Fishhook (32ML2)	1845-1886	Smith 1972

Likewise, sites located near the Heart River, including On-A-Slant (32MO26), Scattered (32MO31), Boley (32MO37), Double Ditch (32BL8), and Larson (32BL9), have continuous or nearly continuous occupations of up to about 300 years. Due to plateaus in the calibration curve during the sixteenth century and after about 1650, samples from different periods of the occupations produce similar radiocarbon ages and are therefore uninterpretable (Mitchell 2011:132-137, 2013:91-94). Rather, the spatial and stratigraphic contexts of features as well as the presence of different types of and frequency of trade goods are more important for dating purposes and the development of relative chronologies in these cases. Although each site varies, there is a general trend in the types and densities of specific artifacts (Mitchell 2011:132-137, 2013:91-94). Copper artifacts are the earliest trade goods, dating to the mid-seventeenth century, although iron artifacts become much more common by the end of the century. During the early eighteenth century, glass beads appear, and along with iron artifacts, they become increasingly common after 1750. Since the relative chronologies used in different investigations of Heart River region sites varied somewhat, I made minor adjustments to the dating brackets so that they would match Johnson's (2007) periods (Table 4.3). This procedure is justifiable given that the dates are relative rather than absolute. However, as these time periods contained few samples, they were also grouped into larger pre-1600, 1600 to 1700, and post-1700 groupings, a step taken by Mitchell (2011:136-137, 2013:94), for the examination of changes in storage pit depth in the following chapter.

Table 4.3. List of time periods showing the relative chronologies of each Heart River site and their reclassification for the current investigation.

Period (A.D.)	**Double Ditch (32ML8)**	**Boley (32MO37)**	**Larson (32BL9)**	**Scattered (32MO31)**	**On-A-Slant (32MO6)**
1500-1600	1490-1600	Pre-1600	1500-1600	1550-1600	
1600-1650	1600-1650	1600-1650	1600-1650	1600-1650	1575-1625
1650-1700	1650-1700	1650-1700		1650-1700	
1675-1725	1675-1725	1675-1725			1625-1725[a]
1725-1785	1725-1785	1725-1785			1725-1785

[a]Due to small sample sizes, the periods are further combined (1600-1700 and 1675-1785) in the following chapter in the discussion regarding mean storage pit depth. In the comparison of pit depths, data from 1625 to 1725 at On-A-Slant are grouped with the 1600-1700 period.

Although an increase in the average volume of storage pits may provide evidence of agricultural intensification, or per capita productivity, this phenomenon would be more solidly recognized by identifying changes in storage pit densities within sites. However, counting the total number of storage pits at each site in the study sample is impossible. Among these sites, very few have been investigated extensively with remote sensing technologies, one approach to identifying subterranean storage pits. Even with such data, storage pits that date to different periods in multicomponent sites would be difficult or impossible to differentiate. Moreover, none of the sites have been completely excavated. Yet, large areas, especially complete lodges, were excavated at some sites during the mid-twentieth century, yielding data that may indicate variations in per capita storage capacity and perhaps agricultural intensification. Since the mean floor area varied little from about the thirteenth to the early nineteenth century, averaging somewhat over 100 m^2 for both EMMV sites and later communities, one might reasonably assume that mean household size remained similar (Mitchell 2013:65-66, 167). Thus, an increase in the mean size or number of storage pits within houses would presumably indicate an increase in agricultural productivity (Mitchell 2013:178-179). Importantly, houses lacking excavated storage pits were not considered. Although storage pits were possibly never constructed during the use of some lodges, such occurrences more likely represent dwellings that were incompletely excavated or houses that were occupied for only a brief period before their abandonment. Finally, I generated a measure of the ratio of total storage pit volume within each house to house floor area to facilitate such comparisons, using data from the 1200-1300, 1300-1400, 1400-1500, 1785-1830, and 1845-1886 periods. Equivalent data are lacking for the intermediate time periods.

House floor areas for EMMV sites were obtained from Johnson (1979:Table 20). These measurements were subsequently reviewed by Mitchell (2011:400-408) for inaccuracies and in such instances the floor area data were acquired from Mitchell. The floor areas for these long rectangular lodges were calculated from published drawings, using each dwelling's mid-width between its lateral wall posts and mid-length from front to rear, following the method described by Johnson (1979:Figure 15, 130). Floor areas for lodges post-dating 1400, which mostly have circular forms, were obtained primarily from Mitchell (2011:414-420). These measurements were acquired from published plan maps of excavations and include the area defined by the outer ring of wall support posts but not the *atuti* or outer storage area, a feature of many nineteenth-century circular lodges (Mitchell 2011:413). House floor areas for two sites, Demery (39CO1) and Leavenworth, were calculated by the author using published plan maps (Krause 1972; Woolworth and Wood 1964). The floor areas of lodges at Leavenworth, which are circular in form, were measured from the outer wall support posts following the outline illustrated by Krause (1972). On the other hand, wall support posts for circular dwellings at Demery were not depicted, so the perimeters of the floors shown by Woolworth and Wood (1964) were used to determine their areas. All dimensions in U.S. standard units were converted to metric (i.e., floor areas in square feet were calculated in square meters).

This assessment is undoubtedly affected by the duration of each site's occupation. Specifically, remodeled or rebuilt and superimposed lodges likely exhibit greater numbers of subterranean storage pits. For this reason, evidence that would be indicative of a site's occupation length was documented. Johnson (2007:66) and Mitchell (2011:398-398) describe various factors that can be used to assess occupation length. Johnson's (2007:66) "PELTO" or "primary evidence of long-term occupation" includes ceramic assemblages from different cultural variants and time periods, lodge remodeling and superimposition, and midden accumulation. Published plan maps of lodge excavations and descriptions of midden excavations are revealing of these different lines of evidence. However, even in cases of superimposition, the original investigators were often capable of differentiating subterranean storage pits that were associated with a particular house floor, meaning those that pre- or postdate that dwelling can be excluded from the analysis. More importantly, the contents of storage pits often facilitate this determination, especially in cases of multiple occupations separated by long periods of time. Storage pits are discrete features that include "contained deposits" (Mitchell 2013:94). At the end of their use-lives, they were often rapidly filled with refuse, which includes dateable materials that were likely used concurrently with the storage pits.

Recorded Storage Pit Attributes

Subterranean storage pits are among the most common feature types at Middle Missouri Plains Village period archaeological sites. Depending on several factors, including occupation duration and settlement size, they number in the hundreds and thousands per site and are located within and outside of lodges. Additionally, pits vary in form and size, having either a general undercut or straight-sided shape. They extend as deep and wide as several meters. Aside from largely anecdotal evidence, however, in what ways storage pits vary through time is unclear. Possible changes in pit numbers and sizes after 1200 have clear and important implications with regard to potential agricultural intensification. To address this question, I compiled several attributes of hundreds of excavated and cored storage pits from the study sample of 20 from published and unpublished documents (Table 4.2).

This undertaking mirrored the method described in the previous chapter for the analysis of storage pits at Huff Village. Several quantitative variables were recorded when possible for all storage pit-type features (Appendix 3). Other features such as hearths and post holes or molds were excluded. Likewise, basin-shaped features, which vary considerably in diameter but are often quite shallow, were omitted. The general shape of each storage pit was listed, typically as either undercut or straight-sided, following the designations provided by the original investigators. In a small number of cases or when documenting cored storage pits, the type was simply labeled “pit.” This notation served as a check on the quantitative data discussed below. Additionally, each pit’s context or association with a contemporaneous lodge, whether intramural or extramural, was taken from each site’s report. Importantly, the period(s) to which each storage pit dates was recorded when it is defined by the authors of each report.

Several other variables were documented for each storage pit. Total depth refers to the depth from the ground surface to the bottom of a storage pit, an important measure since it is often the single variable recorded for cored features. For excavated storage pits, total depth is calculated in two primary ways when it is not explicitly provided by the original investigator. Whenever the depth at which the orifice or mouth of a storage pit was encountered during excavations is noted, it can be summed with the pit depth to determine total depth. Importantly, these measurements can occasionally be checked against profile maps of the excavations. Alternatively, the average depth from the ground surface to the tops of several storage pit features, such as those located at the level of a lodge floor or the occupation surface, is sometimes provided by the investigator instead of feature-specific depths. The average depth can be summed with pit depths to find total depth as well. Determining total depth in this manner is less accurate, but it is comparable to total depth measurements yielded by coring.

On the other hand, the attribute pit depth refers to the actual depth of a pit during the period in which it was utilized for storage purposes. It is measured from a pit's orifice at the occupation or house floor surface to its base and excludes midden deposits and soils that have subsequently accumulated. Pits that were noticeably truncated after their use, which occurs frequently at villages that were occupied for many centuries and that experienced considerable anthropogenic landscape modification (e.g., planar borrowing at Double Ditch [Ahler, ed. 2005; Kvamme and Ahler 2007]) were noted and used in the analysis, primarily due to small sample sizes, when a substantial portion of the feature remained (e.g., the pit orifice was truncated, but the undercut portion was apparent). Most importantly, a comparison of complete ($\bar{x}$ = 1.099 m^3; s = .877 m^3; n = 33) and truncated ($\bar{x}$ = 1.247 m^3; s = .954 m^3; n = 39) pits from the Heart River sites indicates that truncated pits are actually somewhat larger than complete pits on average, although the difference is not significant (*t* = -.677; *df* = 70; *p* = .250). While the use of truncated pits may seem to be a concern, if anything, the mean volume of storage pits during the periods in which Heart River sites were occupied should be somewhat larger. Additionally, a small number of pits were incompletely excavated to their bases, often due to lack of time. In such cases, the original investigators often used a soil corer to determine the remaining unexcavated portion of the pit. This circumstance is noted in the comments in each instance.

Depending on the form of each storage pit, two additional variables were documented. For straight-sided pits, a single measure was recorded in the "base diameter" category while both "mouth diameter" and "base diameter" were recorded for undercut pits. In a small number of instances in which these measures were not provided in the reports, they were acquired directly from plan view and profile maps. Whenever the quantitative data were provided in U.S. standard units, they were converted to metric. Frequently, investigators provide just two measures indicating the shape of excavated undercut storage pits: minimum (mouth) and maximum (base) diameters. However, better documented excavations indicate that pit shapes are more variable, often with an orifice diameter that can equal the pit's maximum diameter, a neck that is greatly restricted, and a rounded, narrower base. In such cases, the minimum diameter of the neck and the maximum diameter of the pit's body were documented. In other words, the variables were recorded as either mouth or minimum diameter and base or maximum diameter. Straight-sided pits with tapered walls are an exception with slightly wider orifices than base diameters. Finally, an average diameter was calculated for oval-shaped pits when two dimensions were provided for either their mouths or bases.

In recent decades, investigators have frequently reported the volume of excavated material from each pit feature. This variable was recorded in each instance with the understanding that it would provide a useful comparison with estimated volumes, although during this same period, pit features were more commonly bisected so that they could be profiled during excavations. Thus, only in a small number of examples, discussed further below, does the excavated volume equal the total pit volume. At a single site in the study sample, White Buffalo Robe, the volumes for completely excavated pits rather than their dimensions were reported. Since total pit volume was the crucial measure for this investigation, however, the dimensions discussed previously—pit depth, mouth diameter, and base diameter—were used to estimate the volumes of each pit at the remaining 19 sites.

The volumes of standard straight-sided pits were estimated with an equation for the volume of a circular cylinder:

$$V = \pi r^2 h$$

The mouth diameters for undercut pits were not given in a few instances, in which case their estimated volumes were determined as if they were straight-sided. The volumes of undercut pits and straight-sided pits with tapered walls were calculated with an equation for the volume of a conical frustum:

$$V = (1/3) * \pi * h * (r_1^2 + r_2^2 + (r_1 * r_2))$$

where r_1 is the lower radius, r_2 the upper radius, and h the height. A conical frustum is a cone lacking its tip, a model that approximates the shape of an undercut pit. Admittedly, the model may inaccurately represent the variable shapes of undercut pits. These include 1) the shape of a conical frustum in which the walls are tapered toward the orifice and widest at the base, 2) a pit with a narrow orifice that immediately widens and exhibits a parallel-sided, cylindrical shape to its base, 3) globular-shaped pits which widen gradually to their greatest diameter near their mid-depth at which point they narrow to a rounded base, and 4) irregularly-shaped pits that have one nearly vertical wall while the opposite side is undercut. Is such variability accounted for when the volumes of all storage pits are estimated with only two equations? Although this approach likely introduces some inaccuracy, a paired *t*-test comparing the means of 15 completely excavated storage pits in which excavated volumes were reported and estimated volumes were calculated indicates the difference is not significant ($t = 1.66$; $df = 14$; $p = .119$). Finally, undercut pits with estimated volumes of less than .1 m^3 were consistently omitted because some may be similarly-sized but misidentified post holes and animal burrows.

Nineteenth-Century Historical Documents

Although the assessment of storage pit variability relies exclusively on quantitative data from reports on excavations, the larger consideration of agricultural production in this chapter also draws on information derived from historical documents. In particular, an historical series, the *Annual Report of the Commissioner of Indian Affairs*, was used to supplement the quantitative data discussed previously for the nineteenth-century period. These historical data, which date from 1855 to 1886, provide additional context and facilitate interpretations of diachronic trends and periodic changes in storage pit volumes and densities.

Examining Storage Pit Variation

Following the arguments of Mitchell (2011, 2013) and Anfinson (1987), one might expect that agricultural production among Plains Village communities increased from approximately the thirteenth or fourteenth centuries onward. Production intensified during the fifteenth and sixteenth centuries, perhaps reaching its height during the seventeenth and eighteenth centuries among the Heart River Mandans and other regional groups prior to the smallpox epidemic of the early 1780s. Yet, other evidence suggests that among both the Mandans, Hidatsas, and Arikaras, production continued to increase during the late eighteenth and early nineteenth centuries. However, the exact nature of any changes in agricultural production is unclear. Considering the impact of epidemic diseases in the Northern Plains, which dramatically affected the populations of sedentary groups, agricultural production would have presumably declined as a consequence. Likewise, regional or larger-scale climatic events such as drought likely affected agricultural production at various points from 1200 to 1886. Finally, the arrival of European and American colonists would have possibly resulted in a dramatic shift toward reliance on imported foodstuffs and a decline in agricultural production during the nineteenth century. The timing of such events perhaps corresponds with variations in storage pit volumes and numbers.

Storage Pit Volume

While excavations at the Late Woodland site of Menoken, a late twelfth- or early thirteenth-century fortified village, revealed many shallow, basin-shaped borrow pits; none of the typical straight-sided or undercut storage pits were identified. In contrast, these varieties of large storage pits are numerous within Extended variant communities relatively soon after, during the thirteenth and fourteenth centuries. For instance, the mean volume of excavated storage pits from four thirteenth-century EMMV villages is .451 m^3 (Table 4.4). The mean volume of excavated storage pits from five later EMMV settlements, sites occupied during the fourteenth century, is .753 m^3 or about 67 percent higher.

Based on excavated storage pits at two fifteenth-century settlements, including Huff village, pits are nearly 12 percent larger in volume with a mean of .843 m^3 during the next century. Thus, over a period of only a few centuries, storage pits nearly doubled in mean volume. Although the sample sizes of excavated storage pits from sites that date to the sixteenth, seventeenth, and first part of the eighteenth centuries are much lower, the trend toward increased storage pit volume clearly continued. In fact, the mean volume of pits nearly doubled during this period, and a small number of storage pits that date to the early eighteenth century are over four times larger in volume (with a mean of 1.954 m^3) than those from the thirteenth century.

The dramatic increase in storage pit volume is even more impressive considering the sharp decline that apparently occurred during the eighteenth and early nineteenth centuries, when mean storage pit volume decreased by approximately half. Again, this period is represented by a relatively small number of samples from sites with components that date from approximately 1725 to 1785. However, given that the mean storage pit volume, determined by considerably more excavated pits, is comparable around the turn of the nineteenth century, the decline appears to be real rather than the result of bias. During the mid-nineteenth century, the volume of excavated storage pits is noticeably higher than the previous century, with a mean of 1.886 m^3.

Table 4.4. Descriptive statistics regarding excavated storage pit volumes (m^3) subdivided by time period.

Period (A.D.)	1200-1300	1300-1400	1400-1500	1500-1600	1600-1650	1650-1700	1675-1725	1725-1785	1785-1830	1845-1886
Min.:	.100	.101	.102	.140	.102	.315	.859	.414	.114	.139
Max.:	2.147	4.617	4.813	4.079	3.506	3.542	4.122	2.287	3.498	10.399
Mean:	.451	.753	.843	1.082	1.124	1.313	1.954	.962	.793	1.886
Median:	.270	.502	.749	.953	.896	.934	1.180	.514	.691	1.257
s:	.465	.749	.713	.896	.921	.805	1.355	.700	.641	1.896
n:	71	180	84	23	22	15	5	7	103	52

Notably, the data are non-normally distributed and the group variances are unequal, conditions illustrated by a box-and-whisker plot of the storage pit volume data (Figure 4.1). In fact, the Shapiro-Wilk test for normality indicates that the data from only a single period are not significantly different from normality, and Levene's test for homogeneity of variance shows that group variances are significantly different ($F = 4.939$; $df = 9$; $p < .0001$).

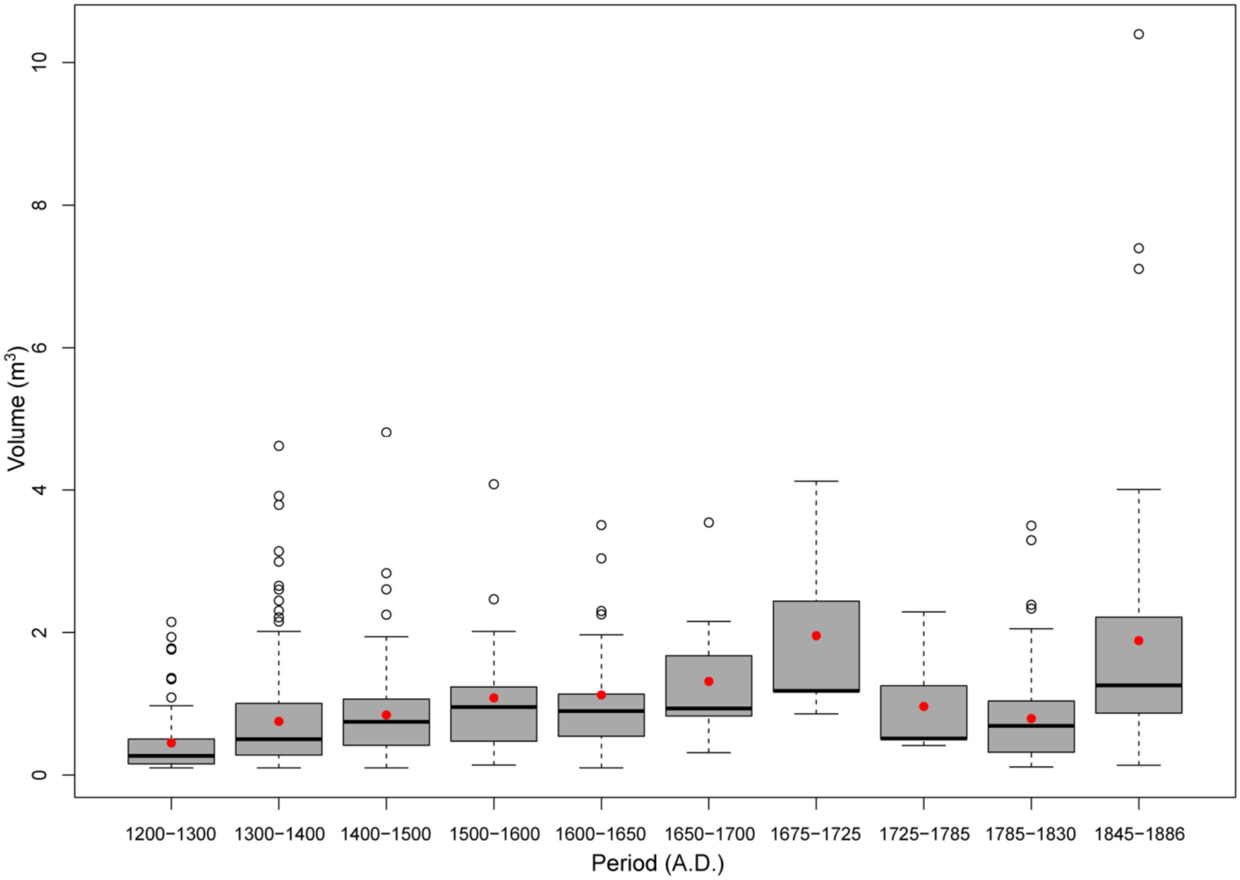

Figure 4.1. Box-and-whisker plot of the storage pit volumes, with red circles indicating mean volumes, during different time periods.

Since the data are non-normally distributed and group variances are unequal, two nonparametric tests, Kruskal-Wallis and Wilcoxon rank-sum, were utilized to compare differences among the mean volumes from each time period. The Kruskal-Wallis test shows that there is a significant difference between mean volumes ($x^2 = 94.641$; $df = 9$; $p < .0001$). More importantly, subsequent pairwise comparisons using Wilcoxon rank-sum tests with a Bonferonni correction indicates significant differences between mean volumes for several periods (Table 4.5). In particular, the volume of excavated storage pits that date to the nineteenth century (1845-

1886), with a mean of 1.886 m^3, differ significantly from those that date to the thirteenth century through the fifteenth century as well as those from the late eighteenth and early nineteenth centuries (1785-1830). Likewise, excavated storage pits that date to the second half of the seventeenth century, with a mean volume of 1.313 m^3, differ significantly from those that date to the thirteenth and fourteenth centuries.

Table 4.5. *P*-values from pairwise comparisons using Wilcoxon rank-sum tests with a Bonferroni correction with significant differences in bold.

Period (A.D.)	1200-1300	1300-1400	1400-1500	1500-1600	1600-1650	1650-1700	1675-1725	1725-1785	1785-1830
1300-1400	**.0030**	-	-	-	-	-	-	-	-
1400-1500	**<.0001**	1	-	-	-	-	-	-	-
1500-1600	**.0027**	1	1	-	-	-	-	-	-
1600-1650	**.0038**	.9582	1	1	-	-	-	-	-
1650-1700	**.0001**	**.0285**	.3679	1	1	-	-	-	-
1675-1725	.0606	.2846	.5002	1	1	1	-	-	-
1725-1785	.2582	1	1	1	1	1	1	-	-
1785-1830	**.0001**	1	1	1	1	.1635	.399	1	-
1845-1886	**<.0001**	**<.0001**	**.0001**	1	1	1	1	1	**<.0001**

Given the skewness and small sample sizes, additional statistical tests were undertaken, with largely similar results, after the data were normalized with a log transformation (Figure 4.2). Importantly, the log-transformed data exhibit no significant variance differences based on Levene's test ($F =.673$; $df = 9$; $p = .7333$). Likewise, the Shapiro-Wilk test shows that the data are not significantly different from normality for seven of the ten time periods (i.e., 1200-1300 [$W = .93297$; $p < .001$], 1300-1400 [$W = .98446$; $p < .05$] and 1400-1500 [$W = .97034$; $p < .05$] differ significantly from normality). A one-way ANOVA test, assuming homogeneity of variance, indicates that there is a significant difference ($F = 12.914$; $df = 9$; $p < .0001$). Moreover, a Scheffe's post hoc test shows that significant differences occur between log-transformed samples that date to the nineteenth century (1845-1886) and those that date to the earliest periods (1200-1500) as well as the late eighteenth and early nineteenth centuries (1785-

1830). The thirteenth-century sample is significantly different from samples in every period but the eighteenth-century group (1725-1785). Finally, pairwise comparisons using *t*-tests with a Bonferroni correction yield comparable, although somewhat less conservative, results among the samples (Table 4.6).

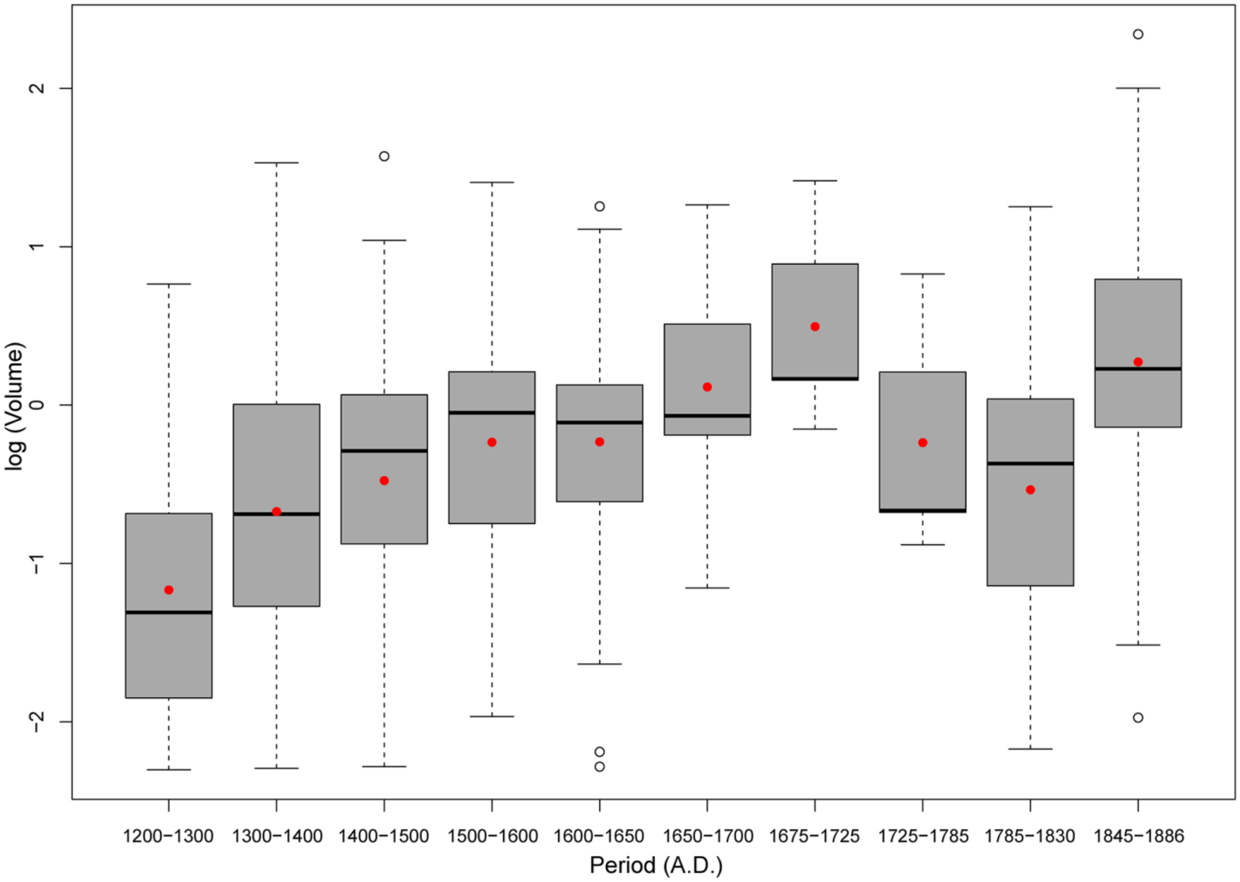

Figure 4.2. Box-and-whisker plot of the log-transformed storage pit volumes during different time periods.

Thus, in both nonparametric tests of raw data and parametric tests of log-transformed data, significant differences are apparent between samples from the earliest (1200-1500) and latest periods (1845-1886). Likewise, samples from the earliest periods (1200-1400) and late seventeenth-century period are significantly different. Clearly, these differences in storage pit volumes support Mitchell's (2011, 2013) and Anfinson's (1987) arguments that agricultural production among Plains Village communities increased through time, with significant increases in the second half of the seventeenth century and nineteenth centuries. However, a significant decrease in agricultural production apparently occurred during the late eighteenth and early nineteenth centuries as well.

Table 4.6. *P*-values from pairwise comparisons of the log-transformed data using *t*-tests with a Bonferroni correction with significant differences in bold.

Period (A.D.)	1200-1300	1300-1400	1400-1500	1500-1600	1600-1650	1650-1700	1675-1725	1725-1785	1785-1830
1300-1400	**.0020**	-	-	-	-	-	-	-	-
1400-1500	**<.0001**	1	-	-	-	-	-	-	-
1500-1600	**.0022**	1	1	-	-	-	-	-	-
1600-1650	**.0088**	1	1	1	-	-	-	-	-
1650-1700	**<.0001**	**.0057**	.1154	1	1	-	-	-	-
1675-1725	.1261	.6096	1	1	1	1	-	-	-
1725-1785	.3708	1	1	1	1	1	1	-	-
1785-1830	**.0001**	1	1	1	1	**.0442**	.9170	1	-
1845-1886	**<.0001**	**<.0001**	**.0001**	1	1	1	1	1	**<.0001**

Index of Floor Area to Storage Pit Volume

Differentiating between agricultural intensification, or per capita productivity, and an increase in total production as a consequence of population growth is difficult (Mitchell 2013:181). Although one avenue for identifying per capita storage capacity among the horticultural occupants of Huff Village was identified in the previous chapter, this approach cannot be easily replicated for other archaeological sites in this analysis. Whereas the total number of dwellings is known for Huff, from which its population could be estimated, and the total number and mean volume of subterranean storage pits can be derived from magnetometry and excavation data, comparable information is lacking for the other sites. However, limiting the analysis to excavated house floor areas and intermural storage pits offers an objective approach that may yield evidence of changes in per capita storage capacity and agricultural intensification after the thirteenth century. Importantly, mean floor areas were roughly similar through time, averaging approximately 100 m^2 from the thirteenth century through the early nineteenth century, indicating that household sizes likely varied little (Mitchell 2013:65-66, 167). Hence, agricultural intensification would be a reasonable explanation for any observed increases in the mean sizes and numbers of storage pits within houses (Mitchell 2013:178-179). To generate a dimensionless index of storage pit volume to floor area, a cube root transformation of storage pit volume and square root transformation of floor area was first calculated (Figure 4.3). Higher ratios would indicate greater storage volume per floor area.

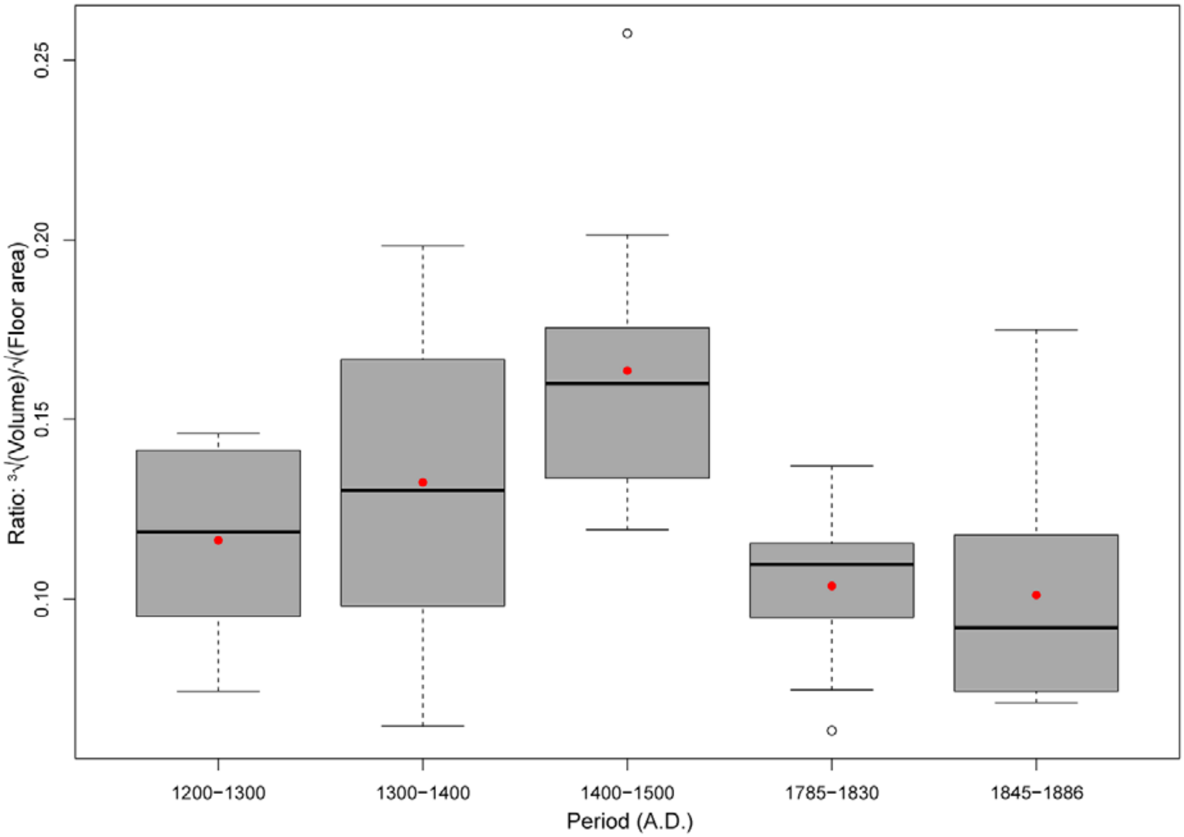

Figure 4.3. Box-and-whisker plot of the dimensionless ratio of cube root-transformed storage pit volume to square root-transformed floor area.

Although equivalent data are lacking for the sixteenth century through the latter part of the eighteenth century, important patterns are apparent. Most importantly, there is an increase in the ratio during the fifteenth century compared to the previous two centuries, a pattern that lends support to Mitchell's (2011, 2013:178-179) argument concerning intensification. Additionally, the late eighteenth and early nineteenth-centuries period (1785-1830) is characterized by a lower ratio, matching the pattern identified with the storage pit volume data. Interestingly, the mid-nineteenth-century period (1845-1886) exhibits a similarly low ratio despite the greater storage pit volume observed previously. The Shapiro-Wilk test for normality indicates that the groups are not significantly different from normality, and Levene's test for homogeneity of variance shows that group variances are not significantly different ($F = 1.5295$; $df = 4$; $p = .2076$). Furthermore, a one-way ANOVA suggests that there is a significant difference ($F = 6.184$; $df = 4$; $p < .001$). Scheffe's post hoc test indicates that the fifteenth-century period is significantly different from the late eighteenth and early nineteenth century ($p < .01$) and mid-nineteenth century ($p < .01$) periods.

These findings perhaps suggest that the increase in storage pit volume noted previously for the mid-nineteenth century cannot on its own be used as a proxy measure of agricultural intensification. That is, although storage pits increased in volume during the period, there were fewer per household (Table 4.7). However, other important factors may affect the ratios. Although storage pits identified during excavations as predating or postdating each house were excluded from this analysis, sites such as Havens (32EM1) in particular exhibit considerable evidence of long-term occupation and rebuilding, meaning some storage pits were possibly incorrectly associated with excavated house floors. If true in this instance, the ratio for the fourteenth-century period would be too high.

Table 4.7. Mean numbers of excavated storage pits per house and mean intermural storage pit volume for each time period.

Period (A.D.)	No. of Excavated Houses	Mean No. of Pits per House	*s*	Total No. of Pits
1200-1300	8	6.4	3.3	51
1300-1400	15	6.3	4.6	95
1400-1500	13	4.6	1.7	60
1785-1830	11	2	.8	22
1845-1886	9	2.3	1.5	21

Mean house floor area is a more significant consideration (Table 4.8). Although the mean floor areas are similar for most of the time periods, averaging approximately 100 m^2, houses from the final period (1845-1886), all from Like-A-Fishhook (32ML2), are uncharacteristically large. In fact, the mean floor area of nine excavated houses at Like-A-Fishhook is 196.2 m^2, nearly double the floor area of houses from other periods. Herein lies a problem with this analysis. Mean household size, inferred from house size, is thought to have changed little after the thirteenth century until the early nineteenth century (Mitchell 2013:167). Following this reasoning, changes in the ratio of storage pit volume to house floor area would indicate variation in per capita storage (and likely productivity). In this particular situation, the lower ratio for the mid-nineteenth-century period would suggest a decrease in per capita storage capacity due to the supposed larger household size at Like-A-Fishhook. However, if the higher mean house size was not accompanied by a larger household size at Like-A-Fishhook, then the ratio of the final period would incorrectly indicate a decrease in per capita storage capacity. Short of knowing household sizes at Like-A-Fishhook, this approach provides an inconclusive answer to the question of agricultural intensification during the nineteenth century.

Table 4.8. Mean house floor areas and mean storage volume per house for each time period.

Period (A.D.)	No. of Excavated Houses	Mean Floor Area (m^2)	*s*
1200-1300	8	104.5	22.6
1300-1400	15	119.2	50.9
1400-1500	13	99.4	48.6
1785-1830	11	95.5	30.8
1845-1886	9	196.2	48.7

Explaining Storage Pit Variation

Although numerous factors may account for the observed variations in mean storage pit volume, several proximate causes could explain the dramatic decline and subsequent increase in volume in the eighteenth and nineteenth centuries. Climate would have presumably played a critical role in the agricultural potential of the Northern Plains over the last millennium, with both temperature and precipitation fluctuations potentially leading to significant shifts in production. However, population declines due to epidemic diseases perhaps significantly affected Northern Plains groups beginning during the sixteenth century.

Droughts

In general, paleoclimate reconstructions of the Northern Plains suggest considerable variability on multiple temporal scales, including sub-decadal, decadal, and multi-century periods. This variability is evidenced by multiple lines of proxy data, among them fossil diatom assemblage-inferred lake salinity levels, Ostradcod shell chemistry, and tree-ring reconstructions (Cook et al. 2004; Fritz et al. 2000; Herweijer et al. 2007; Laird et al. 1996; Stahle et al. 2007).

On the broadest temporal scale, the elevated aridity and warmth of the Medieval Warm Period (MWP) from approximately 900 to 1350 contrasts with the generally wetter and cooler era of the Little Ice Age (LIA), a period from about 1400 to 1850 (Cook et al. 2004; Herweijer et al. 2007; Laird et al. 1996; Loehle 2007). Fritz and colleagues (2000) suggest that these periods were more hydrologically complex, however, with alternating periods of wet and dry conditions. In fact, the summer Palmer Drought Severity Index (PDSI), a measure of drought and wetness based on a gridded network of tree-ring reconstructions, indicates the occurrence of three multi-decade, sub-continental droughts from the fourteenth century through the sixteenth century (i.e., during the LIA) (Stahle et al. 2007). The sixteenth-century “megadrought” from about 1571 to 1586 was longer in duration and severity than any other drought during the last 500 years, including those of the instrumental period (e.g., the 1930s Dust Bowl drought), although the drought appears to have been centered over the Southwest (Stahle et al. 2007). The sixteenth-century drought was preceded by two other droughts that perhaps impacted the Northern Plains (Stahle et al. 2007). One occurred around 1387-1402 and the other from 1444 to 1481. The geographical center of the latter was the Central Plains while the former was centered over the Northern Plains, although the focal points of the both appear to have fluctuated on a sub-decadal scale. More importantly, the reconstructions may be biased given limited tree-ring data for the Plains region (Stahle et al. 2007).

Droughts prior to the thirteenth century (i.e., during the MWP), including during a period from about 1000 to 1200 appear to have been more frequent, long-lasting, and severe based on diatom and Ostracod data (Fritz et al. 2000; Laird et al. 1996). Tree-ring reconstructions support these findings, indicating the occurrence of several droughts across the West, including a multi-decade drought during the mid-twelfth century that appears to have been more severe than any instrumentally recorded drought (Cook et al. 2004, 2007; Herweijer et al. 2007).

Although apparently less severe, tree-ring reconstructions also indicate the occurrence of numerous droughts during the eighteenth and nineteenth centuries (Edmondson et al. 2014; Fye et al. 2003; Herweijer et al. 2006, 2007; Meko 1992; Shapley et al. 2005; Stahle et al. 2007). These droughts, generally lasting less than a decade, occurred around 1703-1712, 1752-1760, 1818-1824, 1841-1848, and 1855-1865 (Fye et al. 2003). They apparently affected large areas of the continental U.S., including the Northern Plains in the eighteenth and nineteenth centuries. Fye and colleagues (2003) suggest that the 1752-1760 drought resembles the 1930s Dust Bowl in spatial extent, although the former did not match the latter in severity and length (Fye et al. 2003). Still, the drought occurred during a period in which mean storage pit volumes declined in the Northern Plains, suggesting a potential link between climate and a decrease in agricultural production. However, the effects of a drought nine years in duration would likely not be reflected in changing storage pit volumes. The climate data have an approximately decadal-scale temporal resolution while the storage pit volume data are grouped in much longer time periods. Thus, the mean volumes would better indicate capacities over a greater period, including many years of average or even above average agricultural production. Hence, mean storage pit volumes do not indicate droughts of even greater severity and duration such as the sixteenth-century "megadrought," if this climatic event in fact impacted the Northern Plains.

Additionally, regional patterns of moisture variation during the mid-eighteenth century, which are indicated by the summer PDSI, may not correspond directly with local variation, particularly in areas with poor tree-ring data coverage like North Dakota (Cook et al. 1999; Fritz et al. 2000; Fye et al. 2003). In fact, the 1855-1865 drought, one that likely affected the Northern Plains (Fye et al. 2003), is only briefly mentioned in the *Annual Report of the Commissioner of Indian Affairs* during the period. In 1855 Alfred J. Vaughan (1856), an agent with the Upper Missouri Agency, reported that due to both drought and a severe frost, the Arikaras' harvest would be limited to about one-third of normal production. Yet, the harvest would still be sufficient to meet their consumption requirements (Vaughan 1856). Vaughan (1857) recalled the severity of the 1855 drought and frost in his report the following year, although weather conditions were apparently more favorable during 1856 as an improved harvest was expected. Such conditions were not reported again for the region until 1870 when the Governor of Dakota Territory, John A. Burbank (1870) noted the effects a severe drought and early frost were expected to have on the harvest of the three tribes at Fort Berthold. Bearing in mind these historical documents, the effects of drought during the mid-nineteenth century appear to have been short-term rather than the decade-long impact suggested by climate data for the region. Climatic fluctuations cannot be said to have had an obvious long-term effect on agricultural production during the eighteenth and early nineteenth centuries.

Epidemics

Although climate change cannot be directly linked to the decrease in mean storage pit volume that occurred in the latter eighteenth and early nineteenth centuries, another reasonable explanation for this sudden change is population decline due to epidemic diseases of European origin. Importantly, the earliest historically documented instance of disease in the region is the 1780-1781 smallpox epidemic (Ramenofsky 1982, 1987; Trimble 1985, 1993). However, numerous documented epidemics are known to have affected Plains or neighboring populations as early as the sixteenth century, centuries prior to direct contact between Native groups and Europeans in the region.

Using the estimated rate of pottery production in villages in the Knife and Garrison regions as a proxy measure of population, Ahler (1993b) developed a history of population change from about 1200 through 1780. Specifically, Ahler (1993b) noted that the population of the region increased dramatically during the fourteenth and the first half of the fifteenth centuries. After reaching its peak mid-century, the population declined sharply, perhaps due to early epidemics (Ahler 1993b). Moreover, the population decline continued until the early part of the seventeenth century. Pottery production data suggest that at this time the population was only about one-ninth of its size at its peak (Ahler 1993b). Likewise, there is a corresponding decline in settlement size by the late sixteenth century, paralleling the decrease in population. Sites in the

Heart region such as Double Ditch and Larson also contracted as evidenced by their four, successively smaller fortification ditches (Ahler, ed. 2005; Kvamme and Ahler 2007; Mitchell, ed. 2007, 2008). However, the population appears to have increased gradually afterwards, continuing to rise steadily until 1780-1781, at which time smallpox is thought to have significantly reduced the population of the region (Trimble 1985, 1993). The combined population of Mandans, Hidatsas, and Arikaras that remained, only several thousand in number, was drastically reduced from the pre-epidemic level of perhaps over 10,000 Mandans and Hidatsas in the Heart and Knife regions and possibly twice as many Arikaras between the Big Bend of the Missouri River and the Grand River in present-day South Dakota (Bowers 1992:486; Lehmer 1977).

This epidemic occurred at the beginning of the late eighteenth and early nineteenth-centuries period (1785-1830), a time characterized by a significantly lower mean storage pit volume than one century earlier or than later decades. The previous period (1725-1830) has a similarly low mean storage pit volume, although the sample consists of only a small number of storage pits. Given the widespread impact of this particular smallpox epidemic, and the possibility of earlier undocumented epidemics (Lehmer 1971:172-174; Trimble 1985, 1993), it is reasonable to suggest that a sharp decline in population (and necessary labor) would lead to reduced productivity, perhaps even for a period of many decades. At the same time, mean storage pit volumes increased through the centuries in which Ahler (1993b) noted a declining population for the Knife and Garrison regions. However, for the Heart region at least, Mitchell (2013:178-181) suggests that the population probably declined slightly or perhaps remained stable as evidenced by the absence of related changes in mean village size during the sixteenth and seventeenth centuries. A stable population or even a declining one alongside an increase in mean storage pit volume suggests agricultural intensification.

Mean storage pit volumes again increased following another well-documented smallpox epidemic that occurred in 1837, during a period of several decades characterized by population change for the Mandans, Hidatsas, and Arikaras (Figure 4.4). Joshua Pilcher (1839), an agent for the tribes of the Upper Missouri, noted the difficulty of estimating populations with precision in his report of 1838, a problem that still held true decades later. L. B. Sperry (1874), an agent for the three tribes, described the issue in greater detail, relaying how significant portions of the tribes were often absent from the agency, greatly hindering the effort to determine their populations. More importantly, there was a general distrust among the tribes' members, having linked the agents' efforts to the occurrence of epidemics, which led to their reluctance to be counted (Sperry 1974; Wilkinson 1865a). Rudolph Kurz, a Swiss painter who traveled to the Upper Missouri and served as a clerk for the Upper Missouri Outfit in 1851-1852, reported on this phenomenon (Kelly 2005:18, 35-36). In fact, a cholera epidemic, for which Kurz was blamed, spread among the Mandans and Hidatsas at Fort Berthold in August 1851 and led to his departure for Fort Union the next month (Kelly 2005:45-46). Despite these problems, the estimates generally illustrate a gradual decline in population during the middle and latter half of the nineteenth century following a rapid drop attributed to the 1837 epidemic (Figure 4.4). Given this decline, can the increase in storage pit volume, and presumably productivity, be easily attributed to the arrival of European and American colonists in the Northern Plains?

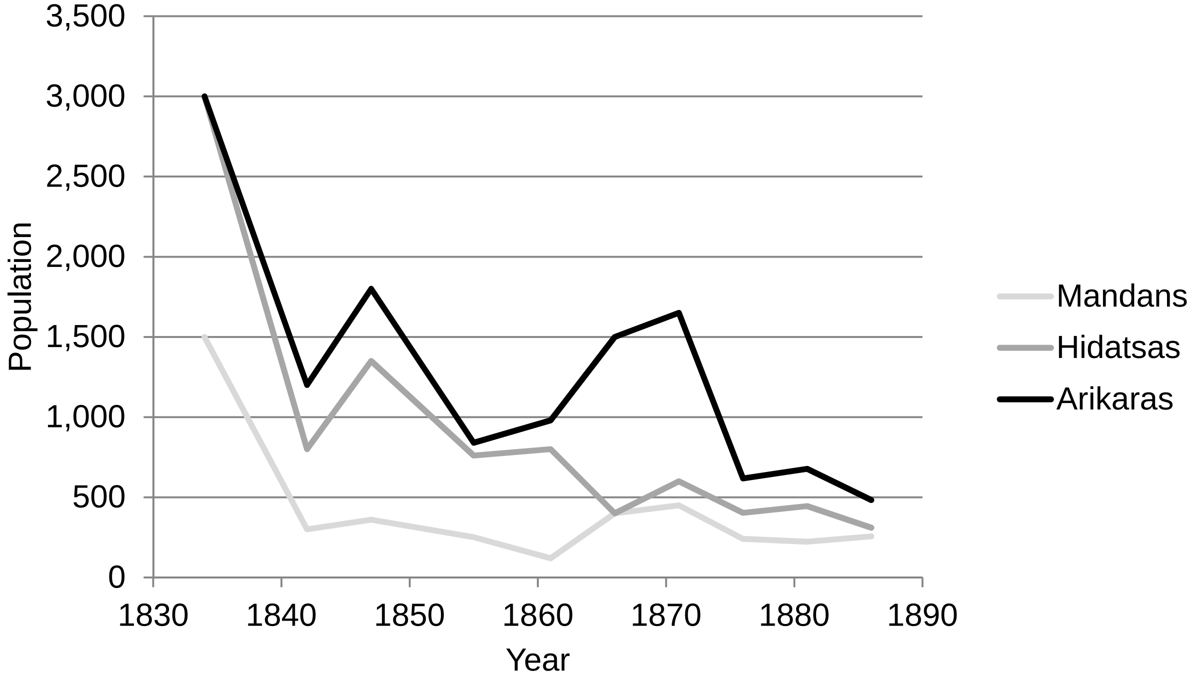

Figure 4.4. Graph of population estimates reported in *Annual Report of the Commissioner of Indian Affair* series.

A Nineteenth Century Historical Point of View

Recall, Anfinson (1987) suggests that the Mandans possibly increased or intensified production during the early nineteenth century, yielding a surplus sufficient to meet trade demands, both with neighboring tribes and European and American traders. Accounts of agents conveyed in the *Annual Report of the Commissioner of Indian Affair* series suggest this development continued among the Mandans, Hidatsas, and Arikaras during the latter half of the century. That is, the three tribes apparently continued to yield large quantities of produce, especially maize. Besides other foods such as beans and squash, the three reportedly harvested 203,200 kg (8,000 bushels) of maize in 1854, according to Vaughan (1857). In 1863 the tribes purportedly farmed 85 ha (210 acres) combined, yielding 106,680 kg (4,200 bushels) of maize, a low total considering production in subsequent years (Indian Affairs 1864:503, 505). Three years later, the Mandans, Hidatsas, and Arikaras apparently grew 381,000 kg (15,000 bushels) of maize (Indian Affairs 1866:352), perhaps on about 243 ha (600 acres) of land (Wilkinson 1865b). During a drought year in 1870, the tribes managed to produce only 76,200 kg (3,000 bushels) of maize compared to 254,000 kg (10,000 bushels) the previous year (Burbank 1870).

The 1870s were a productive period (Figure 4.5). In 1871 a yield of 355,600 kg (14,000 bushels) of maize grown on 263 ha (650 acres) was reported (Indian Affairs 1872a:626). Harvests the following year were said to be a combined 723,900 kg (28,500 bushels) of maize cultivated on 405 ha (1,000 acres) (Indian Affairs 1872b:406). Although this total figure seems implausible, a yield of about 1,883 kg/ha (30 bushels/ac) (considering other crops were also grown on the 405 ha) would have likely been unusual but not impossible considering the results of experimental studies discussed previously in Chapter 3. From 1876 to 1878, maize yields averaged 279,400 kg (11,000 bushels) on about 297 ha (733 acres) (Indian Affairs 1876:226-227, 1877:306-307, 1878:300-301). Particularly noteworthy is the fact that reported acreage estimates generally include all cultivated acres while in some years a breakdown is provided for particular crops. During the 1880s, however, reported maize yields were relatively lower, averaging just over 116,840 kg (4,600 bushels) grown on about 243 ha (600 acres) (Gifford 1884; Indian Affairs 1885:370-371, 1886:426-427; Kauffman 1880, 1881, 1882, 1883).

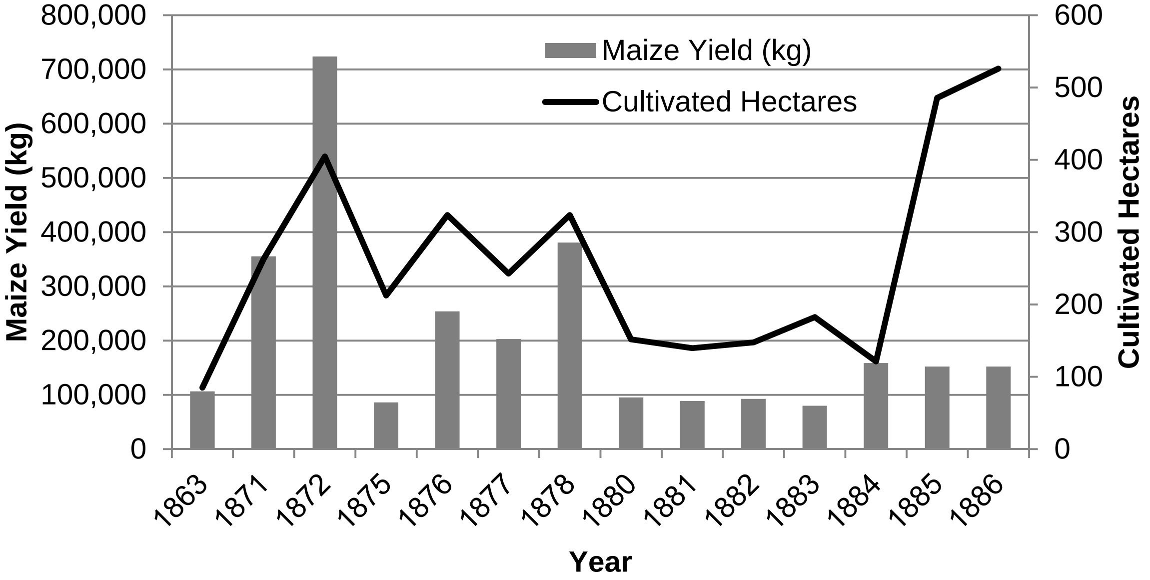

Figure 4.5. Graph of combined maize yields (kg) and cultivated hectares for the Mandans, Hidatsas, and Arikaras reported in *Annual Report of the Commissioner of Indian Affair* series. Values were given in U.S. standard units (i.e., bushels and acres) and were converted to metric by me.

There are multiple reasons for this possible decline. The *Annual Reports* clearly indicate that crops besides those traditionally cultivated by the three tribes, including maize, beans, and squash, among others, were increasingly grown after the mid-1870s. Walter Clifford (1870), an agent for the Mandans, Hidatsas, and Arikaras, conveyed in 1869 his belief that potatoes would grow well and benefit the tribal members. Two years later, 18,711 kg (750 bushels) of potatoes (given a weight of 55 lb per bushel) were reportedly grown and harvested by the tribes (Indian Affairs 1872a). After 1874, however, annual potato harvests increased significantly, but the high yields of potatoes required considerably less land. Yet, wheat and oat harvests, which require much more land, became quite large in the 1880s. For instance, only 10,160 kg (700 bushels) of oats (given a weight of 32 lb per bushel) were harvested in 1878 (Indian Affairs 1878:300-301). In 1882, though, the agent for the Fort Berthold Agency reported estimates of 70,760 kg (2,600 bushels) of wheat (given a weight of 60 lb per bushel) grown on 59 ha (146 acres) and 59,221 kg

(4,080 bushels) of oats grown on 55 ha (136 acres) (Kauffman 1882). Thereafter, the acreage devoted to maize appears to have decreased while that for wheat and oats apparently increased. Hence, the upturn in cultivated acres in 1885 and 1886 may be a reflection of increased production of these crops (Figure 4.5).

Even more important, however, is the likely imprecision of estimated acreage and yields. The most significant source of inaccuracy for estimated yields was the date at which agents were required to report to the Commissioner. For example, Kauffman (1882), a Fort Berthold agent, noted that the early date near the end of August at which reports were required meant that fall harvests had either not begun or were only beginning. A more accurate report of yields would be generated if the annual reports were submitted later in the year, according to Kauffman (1882). Thus, in some years agents described their estimates as low (Darling 1876; Wilkinson 1865a) while others thought estimates were too high (Courtenay 1879).

Another reason for this difficulty relates to the manner in which crops were grown, which led to problems estimating acreage. John Tappan (1872:521), the Fort Berthold agent in 1871, conveyed the difficulty of estimating the amount of cultivated land due to the way "irregular patches" or individual plots were scattered across the bottomlands. Hence, William Courtenay (1879:31), the acting agent of Fort Berthold who replaced another agent mid-year in 1879, wrote that yields in previous years had been "grossly over-estimated." After 1879 maize yields were regularly estimated at about 628 kg/ha (10 bushels/acre). Stating that the 1880s estimates are more accurate is problematic, however, since estimates from both periods (prior to and after 1879) fall within the accepted range of yields determined from experimental studies (Chapter 3).

More importantly, the maize yields for the Mandans, Hidatsas, and Arikaras during the second half of the nineteenth century are not substantially different than the estimate for production at the fifteenth-century Huff Village based on storage capacities (Chapter 3). It is reasonable to contend that the introduction of various tools and agricultural implements would have had an immediate and considerable impact on production during this period. However, the reality is not so apparent. For instance, Vaughan (1857:79) reported in 1856 that he had distributed a "few agricultural implements" to the three groups. De Smet (1865:282) noted that despite relying on "few and rough tools," the Mandans, Hidatsas, and Arikaras were quite productive. Moreover, De Smet recommended that annuities should thereafter consist mainly of agricultural implements such as plows and oxen.

De Smet's letter followed Samuel N. Latta's (1863:194-196) report of 1862, in which he urged the Commissioner to provide funding for a farmer who might provide instruction in agriculture. Until that time, the three groups had cultivated without assistance and did so with hoes rather than plows. In fact, Washington Matthews (1877:19), who served as a post surgeon at Fort Berthold, suggested that scapula hoes were still regularly used in 1867. In 1866, Newton Edmunds (1866:179), then the General and ex-officio Superintendent, made requests similar to De Smet's in his letter to the Commissioner. Not until 1873 does Tappan (1874:235) report that the Fort Berthold Agency had plowed 100 acres for the Mandans, Hidatsas, and Arikaras. However, William Courtenay (1875:243), a farmer with the Fort Berthold Agency, reiterated the same view of others when he suggested that more effort should be put toward instruction in proper tool use and management of crops. Courtenay's attitude is further clarified in 1879, when he writes:

> Indians are slow in learning to farm successfully, and it is up-hill work teaching them to run mowing-machines, reapers, etc. They very soon break the machines, and then become discouraged and fall back on the old implements they had been accustomed to [Courtenay 1879:30].

The apparent reluctance of the Mandans, Hidatsas, and Arikaras to utilize Euroamerican agricultural implements is supported further by archaeological evidence. Based on an analysis of bone and antler tools from five Plains Village sites, Griffitts (2006) argues that the processes of technological change were more complex than the unilinear process that is typically assumed as part of the conventional narrative of colonialism. Taking scapula hoes, the quintessential tool for cultivation on the Northern Plains, as an example, Griffitts (2006:429-431, 435-436) notes that they were not abandoned immediately with the availability of iron hoes. Scapula hoe use continued, although iron and steel cutting tools were sometimes used to alter their typical forms, indicating a process of experimentation. Multiple factors, including the technical function, ease of procurement and manufacture, and symbolic value (Griffitts 2013), were likely all considered by Mandans, Hidatsas, and Arikaras during this period of technological change.

Discussion

Storage pit data for 20 Plains Village sites, which date from the thirteenth century through the nineteenth century and are located within the Cannonball, Heart, Knife, and Garrison regions, reveal an important pattern. Mean pit volumes increased significantly from the fifteenth century through the second half of the seventeenth century. Importantly, others (Lehmer 1971:140; Mitchell 2011, 2013:178-181) have suggested this trend, without the aid of systematic data, meaning the results largely support earlier hypotheses and perhaps provide evidence of increased agricultural productivity among Missouri River farming communities during the period. Moreover, this intensification coincided with other significant changes, including an increase in population density, specialization in stone tool and ceramic production, and an expansion of trade, which occurred around the confluence of the Heart and Missouri River (Mitchell 2011, 2013).

The data also reveal a sharp decrease in mean storage pit volumes during the eighteenth century and beginning of the nineteenth century, a change that is likely associated with widespread epidemic diseases. In fact, the 1780-1781 smallpox epidemic (Ramenofsky 1982, 1987; Trimble 1985, 1993) appears to be associated with the decline, although the decrease in store pit volume appears to begin somewhat earlier during the eighteenth century, perhaps due to other epidemics that are not historically documented in the region. This explanation is not unreasonable given the likelihood that a dramatic depopulation of the region would have significantly decreased the pool of necessary labor while at the same time lowering demand for the products of that labor, perhaps including a temporary disruption of regional trade.

Although the findings yielded by nineteenth-century historical documents such as the *Annual Report of the Commissioner of Indian Affairs* series should perhaps be viewed with greater skepticism, the sources provide context with which the findings of the analysis of mean storage pit volumes during the nineteenth century can be better understood. During this period, mean volumes were significantly larger, perhaps lending credence to multiple accounts of the Mandans, Hidatsas, and Arikaras producing hundreds of thousands of kilograms of maize at the village of Like-A-Fishhook during the second half of the nineteenth century. Counter to some claims of the colonial narrative, which rely on notions of dependence and culture loss, the Mandans, Hidatsas, and Arikaras continued their traditional agricultural practices into the second half of the nineteenth century. Their traditional practices continued despite significant population declines during the late eighteenth and early nineteenth centuries due to epidemic diseases as well as the introduction of other foodstuffs and technologies. The resiliency of these practices is no doubt a consequence of their fundamental significance to members of the three groups.

That said, change is an aspect of even long-standing traditions, which Ferris (2009) refers to as “changed continuities.” Historical documents and archaeological evidence provide several examples. Despite the continued use of bone and antler tool implements by the Mandans, Hidatsas, and Arikaras during the nineteenth century (Griffits 2006, 2013), metal tools were widely available due to the permanent presence of traders and government officials. Such tools were likely commonly used, at the very least by some individuals and perhaps frequently alongside traditional implements. Likewise, labor was increasingly devoted to the cultivation of other crops such as potatoes, wheat, and oats, especially during the 1880s.

A similar process occurred among Hidatsa pottery-makers during the late eighteenth and nineteenth centuries (Hollenback 2012). That is, certain elements of pottery making, including manufacturing techniques, vessel form, and vessel function, remained consistent while others like raw material preparation, wall thickness, and design motifs changed (Hollenback 2012:420). Despite the availability and use of metal pots, production and use of ceramic pots persisted. The production and use of such implements served as a means of group identity maintenance and enculturation and signaled devotion to traditional practices (Hollenback 2012:421). Fort Clark State Historic Site, which was occupied by both Mandans and Arikaras during the early to mid-nineteenth century when mean storage pit volumes increased, provides another case study with which these processes can be examined.

CHAPTER 5: HISTORICAL DOCUMENTS AND REMOTE SENSING INVESTIGATIONS AT FORT CLARK STATE HISTORIC SITE, NORTH DAKOTA

My examination of excavation data from 20 Plains Village sites occupied by farmers along the Missouri River in the previous chapter revealed several compelling developments in mean storage pit volume over the period of 1200-1886. From the fifteenth century through the early eighteenth century, mean pit volumes increased significantly, a notable trend that was perhaps necessitated by the successful efforts of Northern Plains villagers to increase agricultural productivity. However, mean storage pit volumes sharply decreased over the next century, a change possibly driven by depopulation as a result of epidemic disease. Despite the effects of epidemic disease and prolonged interactions with colonists, mean pit volume apparently increased during the nineteenth century. Moreover, historical sources from the period support the idea that the Mandans, Hidatsas, and Arikaras, although diminished in numbers, remained prolific farmers.

Yet, the ostensible increase in mean storage pit volume during the nineteenth century is based on data from one site, Like-A-Fishhook (32ML2), a village inhabited by members of all three groups during the mid-to-late part of the century (Smith 1972). Star Village (32ME16), a contemporaneous settlement constructed by the Arikaras in 1862 was only briefly occupied (Metcalf 1963) and yielded no data relevant to the issues of concern. On the other hand, Fort Clark State Historic Site (32ME2), which is located on the west bank of the Missouri River in central North Dakota approximately 40 miles northwest of present-day Bismarck, was occupied by the Mandans and Arikaras during the first half of the nineteenth century (Figures 5.1 and 5.2).

The earthlodge village offers an independent case study against which the findings from previous chapters can be considered, although the analysis is not straightforward.

In this chapter I provide an historical account of the Mandans' and Arikaras' nearly four decade-long occupation of the Native village at Fort Clark. This review serves a crucial purpose since I follow with a discussion of recent remote sensing investigations of the settlement. Fort Clark was a significant destination along the Missouri River during the early nineteenth century, and as such, the adjacent village was visited frequently by individuals who documented their observations both in writing and artistically. Beyond this historical summary, this chapter details my comprehensive interpretations of the remote sensing data, which draw extensively on the historical documents. Complete and close-up views of the data sets are presented in Appendix 4. These data are used to support my arguments concerning trade and agricultural production among the Mandans and Arikaras at Fort Clark in the next chapter.

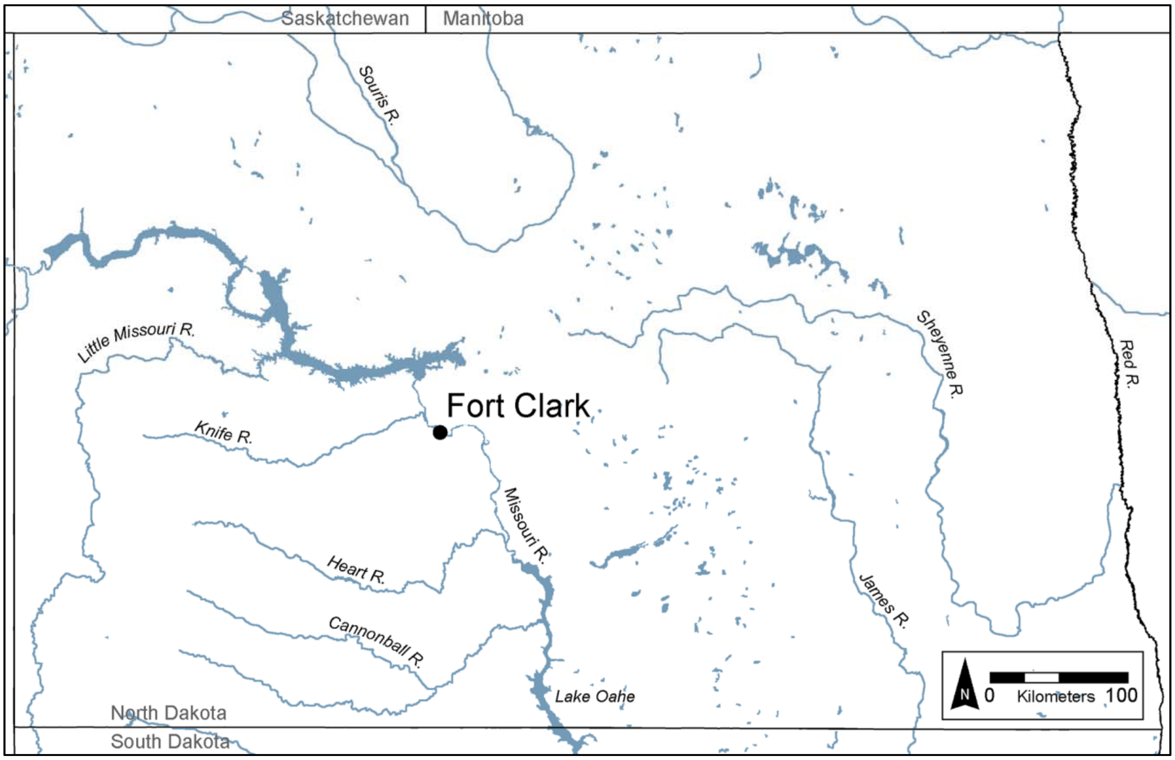

Figure 5.1. Map showing the approximate location of Fort Clark State Historic Site (32ME2) in present-day North Dakota.

Mitu’ahakto’s, the Mandan Village

The village at the Fort Clark State Historic Site, which the Mandans called Mitu’ahakto’s, was established around 1822 (Wood 1993b; Wood et al. 2011). Divided among as many as five subgroups during the eighteenth century, the Mandans had lived in many communities on the east and west banks of the Missouri River near its confluence with the Heart (Wood et al. 2011). The communities reorganized in the decades following the smallpox epidemic of 1780-1781, moving north toward the Knife where they were encountered by Meriwether Lewis and William Clark in 1804.

Figure 5.2. Bird’s-eye view from the south of the Mandan/Arikara village at Fort Clark State Historic Site, North Dakota. At the time of the village’s occupation, the Missouri River flowed adjacent to the terrace edge, just east and north of the community. Photograph by Tommy Hailey. Used with permission.

At that time, the Mandans lived in two villages, the Ruptare (Black Cat [32ML5]) settlement on the east bank and the Nuweta Mitutahank (Deapolis [32ME5]) community on the opposite riverbank of the Missouri (Moulton 2003; Wood et al. 2011). On their return in 1806, Lewis and Clark noted that the Ruptare had reconstructed their village and many Ruptare Mandans had joined the Nuweta at Mitutahank (Figure 5.3). This village would remain occupied by Mandans until the mid-nineteenth century, although the Mitutahank and many Ruptare would move approximately five km downstream in 1822 where they founded a new village, Mitu'ahakto's.

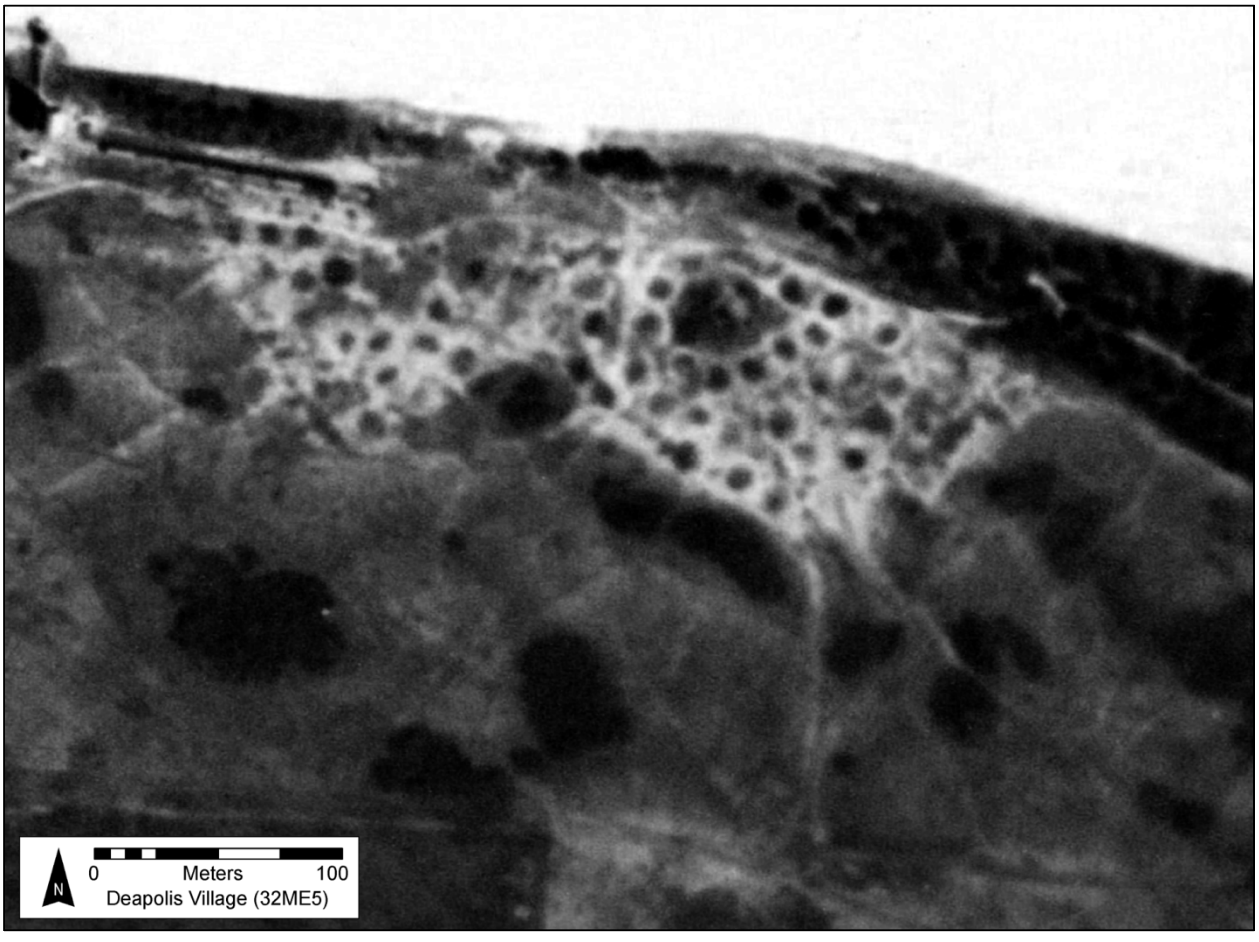

Figure 5.3. Aerial photograph from July 8, 1938, which shows the combined Mitutahank and Ruptare community known today as Deapolis Village (32ME5) prior to its destruction during the mid-twentieth century. U.S. Department of Agriculture, National Archives and Records Administration (BAO-23-50).

The Forts: Tilton's, Clark I, Clark, and Primeau

Mitu'ahakto's would become one of the best historically documented Native settlements in the Northern Plains due to its significant role in the fur trade (Wood 1993b; Wood et al. 2011). In fact, the Mandan village was a focus of trade between various American enterprises and Native groups from its beginning. In May 1823, a member of the recently formed Columbia Fur Company, James Kipp, began construction of Tilton's Fort a short distance downriver from the Mandan village (Thiessen 1993b:58-59; Wood 2011; Wood et al. 2011:48-55). Although the trading post was completed by November 1823, its use was short-lived due to harassment by the Arikaras, who had moved north and settled nearby, following U.S. Army Colonel Henry Leavenworth's attack on their village (Leavenworth Village [39CO9]) in August 1823. Due to the hostility, Kipp lived in the lodge of a Mandan chief, Tóhpka-Singkä (Four Men), at the village until construction of the post was completed (Witte and Gallagher 2012:118).

Tilton's Fort was abandoned the following spring, although the Columbia Fur Company still sought to trade with the Mandans (Thiessen 1993b:59-61; Wood 2011; Wood et al. 2011:55-58). Kipp remained in the lodge of Tóhpka-Singkä until December 1824, at which time he "built a house beside the village" (Witte and Gallagher 2012:119). During the summer of 1825, Kipp had the timbers from Tilton's Fort brought upriver, which were used to expand and fortify the post he had constructed the previous winter. The precise location of the trading post—now referred to as Fort Clark I—is unknown, a fact discussed further below (Wood et al. 2011:5-58). The magnitude of operations at the newly established Fort Clark I are evident based on a Columbia Fur Company ledger, which includes the accounts of fifteen men for the period of July 1824-April 1825, and a secondhand account of events from Prince Maximilian of Wied-Neuwied

(Hardee 2011; Mitchell 2014a; Witte and Gallagher 2012:119-120). The post would remain in operation until the better known Fort Clark was built, although it would be controlled by the Upper Missouri Outfit after July 1827 when the Columbia Fur Company was brought under the control of the American Fur Company (Wood 2011; Wood et al. 2011:55-58).

Prince Maximilian described the construction of Fort Clark as well (Witte and Gallagher 2012:120-121; Wood et al. 2011:72-76). During the winter of 1830, Kipp had timbers cut for the fort, and the palisades were completed the following spring. The completed fort, which measured about 33.5 m (110 feet) long and 29.9 m (98 feet) wide with blockhouses on opposite corners, entrances facing toward and away from the river, and buildings enclosed within the palisades, sat only a few hundred feet south of the Mandan village (Witte and Gallagher 2012:124-125; Wood et al. 2011:72-76). During its three decades of use, Fort Clark was twice enlarged (Wood et al. 2011:77). Evidence of these architectural features and the changes that occurred during the fort's lifespan were identified during archaeological excavations by the State Historical Society of North Dakota (SHSND) in 1973-1974 (Hunt 2003a), PaleoCultural Research Group (PCRG) in 2000 (Ahler et al. 2000), and the Midwest Archeological Center, National Park Service (MWAC) in 2001 (Hunt 2003b) as well as multi-instrument geophysical surveys in 2000-2001 (Kvamme 2002). Simultaneous investigations at Fort Primeau revealed much about the opposition to Fort Clark.

Several former employees of the Upper Missouri Outfit, who together established the St. Louis Fur Company (or Union Fur Company), likely constructed Fort Primeau in the spring or summer of 1846 (Thiessen 1993b:67-68; Wood et al. 2011:192-207). The post was conveniently positioned just north of Fort Clark, between that post and the Native village. Relatively little is known about Fort Primeau, although William Jacob Hays sketched the trading post from a position aboard the steamboat *Spread Eagle* on the Missouri River on July 14, 1860 (Figure 5.4). The sketch indicates a room block was located on the post's south side, a palisade and entryway faced the river, and additional structures were positioned on the north side. These architectural details were corroborated by excavations by the SHSND in 1973-1974 (Hunt 2003c) and geophysical surveys performed in 2000 (Kvamme 2002). In 1860, Fort Primeau was purchased by Pierre Chouteau, Jr., & Company, which since the 1830s had operated the Upper Missouri Outfit and Fort Clark (Wood et al. 2011:72, 193). Fort Primeau was brought into use by members of Pierre Chouteau, Jr., & Company when Fort Clark burned, which occurred sometime after Hays's visit in July 1860 (Wood et al. 2011:193). Fort Primeau was operated until the next year when it was abandoned, after which the occupants of the village also left the settlement.

Figure 5.4. A detailed sketch made by William Jacob Hays in July 1860, which shows Fort Primeau adjacent to the Native village at Fort Clark State Historic Site. William Jacob Hays, "Fort Primeau, Upper Missouri," 1860, pencil on light brown paper, Collection of Glenbow Museum, Calgary, Canada, 59.16.10. Used with permission.

The Mandan/Arikara Village through the Eyes of Traders, Artists, and Explorers

As the longest operated trading post near the confluence of the Knife and Missouri Rivers, Fort Clark was a crucial component of the fur trade in the region and by extension Native life for the Mandans, Hidatsas, and Arikaras. Importantly, during its three decades of use, most traders and explorers who passed through the region visited the post (Thiessen 1993b:61-64; Wood et al. 2011). Many individuals left detailed written accounts and visual depictions of the adjacent earthlodge village (Wood 1993b). The size of the collection is important because it provides a means for assessing the authenticity and credibility of each document. That is, crucial details may be corroborated. Judging the historical information as reliable is particularly relevant in subsequent sections. Later, I make use of remote sensing data, and with the aid of written accounts and visual imagery, attempt to distinguish between components of the earlier Mandan and later Arikara village. Furthermore, historical documents facilitate interpretation of one common feature within the village. These circular depressions are likely collapsed storage pits that date to the latter part of the Arikaras' occupation. Finally, the historical documents yield telling information about the number of earthlodges and Mandan and Arikara populations at different points during the history of the settlement. Ultimately, I argue that the Mandans and Arikaras produced and traded vast quantities of agricultural goods, a hypothesis that is supported by historical documents.

George Catlin

George Catlin, a self-taught portrait artist, traveled up the Missouri River aboard the steamboat *Yellow Stone* in 1832 as a guest of Pierre Chouteau, Jr. (Wood et al. 2011:142-146). Catlin arrived at Fort Clark sometime after mid-July, having traveled downriver from Fort

Union, and would remain in the region for several weeks. The length of his visit provides some authority to his ethnographic notes and illustrations, although the accuracy of both has been questioned (Hunt 2002:101-102; Wood 2002:12-13; Wood et al. 2011:142-146).

Catlin (1973 [1844]:81, 87-88) notes that the Mandan settlement contained many densely packed circular earthlodges 40 to 60 feet in diameter. An open or public space, which had a circular form 150 feet in diameter, was located in the village center, and a large "medicine" lodge faced the plaza. A wooden palisade, with an inner ditch approximately three to four feet in depth, surrounded the settlement on the side opposite the steep bank and river. Two of Catlin's paintings, *Bird's-eye View of the Mandan Village* (Figure 5.5) and *Back View of Mandan Village, Showing the Cemetery* (Figure 5.6), corroborate his observations. The two illustrations were created from opposite perspectives, the former looking from atop an earthlodge across the plaza and village toward the southwest. The latter depicts a view from outside the village, looking back toward the northeast. The wooden palisade is visible in both paintings. Although Catlin's (1973 [1844]:80, 87, 184, 203) estimates of several hundred earthlodges and a population of about 2,000 people (combined with the neighboring Mandan village) are certainly inaccurate, his other observations are similar to those of other visitors.

Figure 5.5. A view of the Mandan village, including its plaza, numerous lodges, and a vertical timber palisade painted by George Catlin. After George Catlin, "Bird's-eye View of the Mandan Village, 1800 Miles above St. Louis," 1837-1839, oil on canvas, Smithsonian American Art Museum, Gift of Mrs. Joseph Harrison, Jr., 1985.66.502. Used with permission.

Prince Maximilian of Wied

Maximilian, a German explorer and naturalist, traveled aboard both the *Yellow Stone* and *Assiniboine* the following year and arrived at Fort Clark on June 18, where he remained for a single day, before continuing upriver (Witte and Gallagher 2010, 2012; Wood et al. 2011:147-156). He would return on November 8 and stay near the trading post and village until April 18, 1834. Although many individuals visited Fort Clark and the adjacent village during their almost four decades of use, Maximilian's ethnographic account is among the most trustworthy and is unparalleled in its level of detail (Wood et al. 2011:147-156).

Figure 5.6. A view of the Mandan village from the west showing closely space earthlodges and the vertical timber palisade. After George Catlin, "Back View of Mandan village, Showing the Cemetery," 1832, oil on canvas, Smithsonian American Art Museum, Gift of Mrs. Joseph Harrison, Jr., 1985.66.392. Used with permission.

According to Maximilian (Witte and Gallagher 2010:199, 2012:64, 152), Mitu'ahakto's included about 65 circular earthlodges densely arranged in an irregular circle, with a large, circular plaza near their center. If the lodges were organized in any particular manner, the pattern was not understood by Maximilian (Witte and Gallagher 2010:199), who describes them as having "no definite order." Wooden racks, meant to be used for drying maize, were located between the lodges (Witte and Gallagher 2012:153). Like Catlin, Maximilian (Witte and

Gallagher 2012:64) notes the presence of a large “medicine” lodge on the side of the plaza toward the river. Moreover, Maximilian (Witte and Gallagher 2010:199, 2012:64, 152) describes the fortification as consisting of a ditch and wooden palisade, although the palisade was in a state of disrepair by the time of his arrival in November 1833. However, he observes that the palisade included four equally separated bastions constructed of earth sandwiched between two layers of interwoven willow branches. Maximilian’s stylized map of the Mandan village, which depicts a roughly circular settlement surrounded by a palisade with four triangular bastions, substantiates his descriptions of Mitu’ahakto’s (Figure 5.7). Of note is the absence of lodges shown outside the fortification.

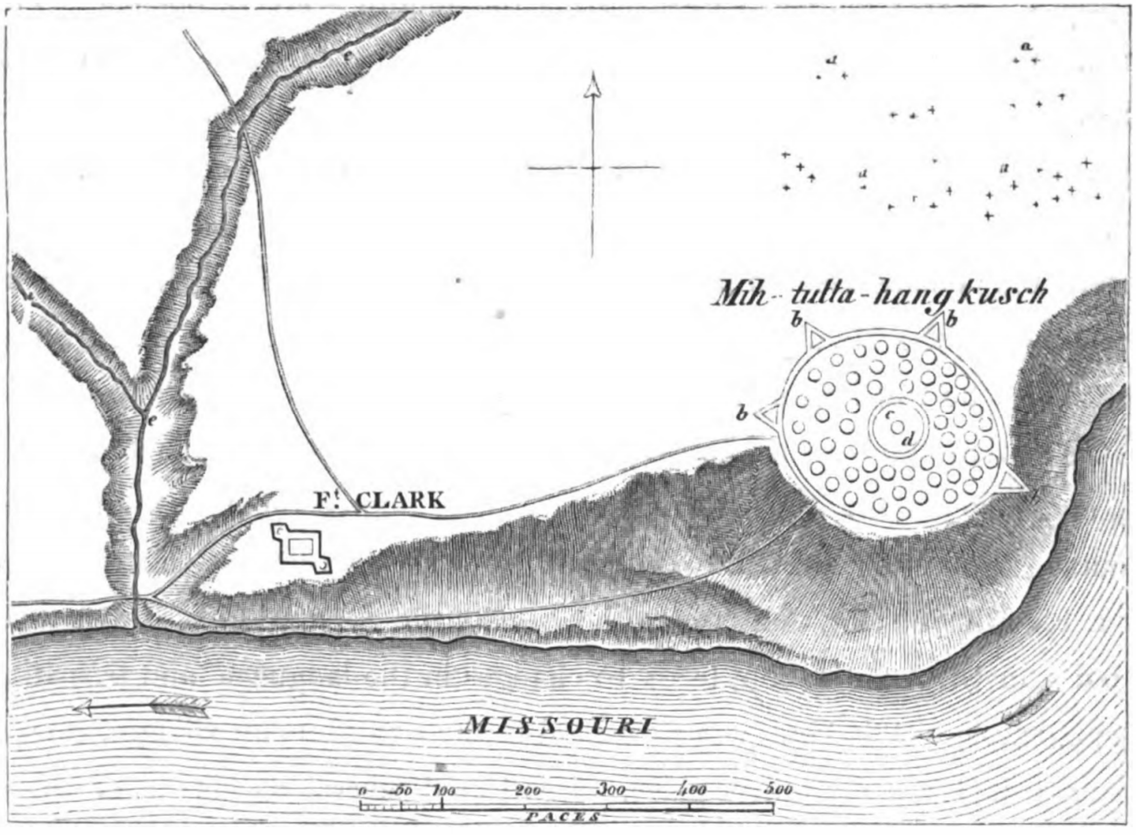

Figure. 5.7. A stylized map of Mitu’ahakto’s, the Mandan village at Fort Clark (Maximilian 1843:394).

The neighboring Mandan village (Ruptare/Mitutahank) reportedly had around 38 earthlodges organized around a plaza (Witte and Gallagher 2010:199, 205; 2012:78, 144). It too was surrounded by a wooden fence, with large gaps indicating its poor condition, but the fortification apparently lacked the triangular bastions of the larger settlement (Witte and Gallagher 2010:205, 2012:50, 152). However, the village contained a unique structure, which Maximilian (Witte and Gallagher 2010:205) describes as "an as-yet-unfinished log house, which the Indians wanted to construct in the manner of the white man."

Maximilian's observations communicate a vivid image of the Mandan settlement at Fort Clark, although the journey his notes took from the field to publication is complex. Upon his return to Germany, Maximilian undertook the process of rewriting his notes in a three-volume journal (Porter 2002:78-79). After his notes were copied, Maximilian destroyed the originals, although a few sections remain, including portions from his time among the Mandans. These sections indicate the journals were nearly exact copies. Maximilian later published an abridged version of his three-volume journal, and subsequent English translations were shortened further. However, an English translation of Maximilian's three-volume journal was recently made available (Witte and Gallagher 2008, 2010, 2012). Karl Bodmer's illustrations, which accompanied Maximilian's publications, rival Maximilian's ethnographic accounts in detail.

Karl Bodmer

Bodmer participated in Maximilian's 1833-1834 Missouri River expedition, serving as an illustrator of their travels (Wood et al. 2002; Wood et al. 2011:147-156). Mitu'ahakto's and its residents would be the subjects of many of Bodmer's watercolors and sketches. Bodmer began producing aquatints to be published in an atlas, which would illustrate Maximilian's account, while in Paris in 1836, well after his time on the Missouri River (Hunt 2002:104). Ultimately, 81 prints were created, including 48 tableaux and 33 vignettes, based on a more significant number of sketches and watercolors from his and Maximilian's field studies (Hunt 2002:104, 107; Wood

2002:11). As a scientific illustrator, Bodmer is noted for his realism (Wood 2002:12-15; Wood et al. 2011:153). Some of Bodmer's final prints were duplicated from field imagery (Wood 2002:11). However, other prints were composites. Scenes and figures were combined and modified by Bodmer to yield a desired illustration (Hunt 2002:107; Wood 2002). Importantly, Bodmer's many field studies and other works created in his Paris studio on which his final prints are based are extant in various collections (Wood 2002). The collections illuminate the process by which Bodmer transformed his field images to final prints and indicate the precision with which the prints were produced.

The Mandan village is the primary subject of a single Bodmer print, Tableau 16 (*Mih-Tutta-Hangkusch. A Mandan Village*), although the settlement is apparent in the background of Tableau 15 (*Fort Clark. On the Missouri.*). Another version of the Tableau 16 aquatint, in watercolor and pencil on paper, shows the same scene, although more of the village is visible to the west (Ruud 2004:Plate 294). The illustrations depict a prominent view of the village from the north and substantiate several of Maximilian's observations (Figure 5.8). First, the circular earthlodges appear to be arranged without any apparent pattern. Numerous drying racks or scaffolds, constructed of wooden poles, are visible between the closely spaced lodges. However, the village plaza is not evident due to the low-angle perspective. Bodmer shows the plaza, several lodges along its northern perimeter, including the "medicine" lodge, and drying racks along the edge of the open space, in a separate ink and pencil sketch on paper (Ruud 2004:Plate 304). A single triangular bastion, visible in Tableau 16 is located on the steep terrace edge facing the north. A short length of the palisade wall with closely spaced vertical posts connected to the bastion is visible to the west, although the lack of a palisade beyond appears to confirm Maximilian's (Witte and Gallagher 2012:64, 152) suggestion that the fortification was in poor condition. Another illustration of the village, made in watercolor and pencil on paper from approximately the same location as Catlin’s *Back view of Mandan village* (Figure 5.6), depicts at least one and possibly all three triangular bastions that faced the open plain away from the river (Ruud 2004:Plate 301). However, large gaps are noticeable between several parts of the vertical timbers of the palisade. The Mandans were subsequently observed by Francis Chardon (Abel 1997:30, 60) on April 30, 1835 and February 28, 1836 repairing the fortifications. Like Catlin, Bodmer’s (Ruud 2004:Plate 301) view of the village from the southwest shows no lodges constructed beyond the fortification, although a single tipi is visible at the perimeter of the settlement.

Figure 5.8. The Mandan village as seen from the north in Bodmer's Tableau 16. After Karl Bodmer (Swiss, 1809-1893), Friedrich Salathé, engraver, Mih-Tutta-Hang-Kusch, a Mandan Village, aquatint, hand-colored on paper, Joslyn Art Museum, Omaha, Nebraska, Gift of the Enron Art Foundation, 1986.49.517.16. Used with permission.

Francis Chardon

As the manager at Fort Clark from 1834 to 1842, Chardon's experience was unlike that of most visitors in that he observed the daily activities of and interacted with the neighboring Mandans for many years. Importantly, Chardon (Abel 1997) kept a day-to-day journal from 1834 to 1839. Although his brief entries lack the comprehensiveness of Maximilian's ethnographic narratives, the account yields important information about trade at Fort Clark, trade with the

Mandans, and trade between the Mandans and nomadic groups. Moreover, Chardon witnessed the 1837 smallpox epidemic that decimated the Mandans. His journal provides a detailed narrative of the events.

Chardon's account of the arrival of the steamboat *St. Peters* at Fort Clark on June 19, 1837 is nondescript. Writing of his arrival aboard the boat, Chardon (Abel 1997:118) states "Started at daylight and arrived at the Mandans at 3 P.M., onloaded [*sic*] the Merchandises for the Fort […]." The boat also carried three Arikara women who were ill with smallpox (Wood et al. 2011:156-167). Chardon (Abel 1997:121) recorded the first death from smallpox on July 14, less than a month later. His reports of the outbreak and frequent deaths among the Mandans and neighboring villages were common through the fall and winter. Perhaps as few as 125 Mandans survived the epidemic, a population loss of approximately 90 percent (Wood et al. 2011:165; Wood and Irwin 2001:350). With so few Mandans remaining, the Arikaras took possession of the village (Wood et al. 2011:167-170). Arikara families began arriving from their downriver winter village on March 20, 1838 (Abel 1997:153).

Chardon was an eyewitness to the destruction of the Mandan village as well, which he reported on January 9, 1839. Chardon (Abel 1997:181) writes that he "went out to see what was going on, when I beheld the Mandan Village all in flames, the Lodges being all made of dry Wood, and all on fire at the same time, Made a splendid sight […]." The Arikaras would return from their winter village in May and rebuild the settlement, which was referred to by Arikara elders as nuuneesawatuuNU (Wood et al. 2011:171-178). Although the Arikaras would occupy the village for nearly a quarter century, several years longer than the Mandans, the comprehensiveness of subsequent historical accounts and depictions decreased with the end of Chardon's journal in 1839 (Wood et al. 2011:176). Yet, numerous well-known individuals, including Father Pierre-Jean De Smet, the naturalist John James Audubon, the Swiss painter Rudolph Friederich Kurz, the trader Henry Boller, and others visited after 1840 (Wood et al. 2011:179-192).

Lieutenant Gouverneur Kemble Warren

Among the most useful records from the period are the highly detailed sketch maps created by Lieutenant Warren and his assistants W. H. Hutton and J. H. Snowden during their 1856 expedition of the Missouri River (Callaway 2012, 2013; Callaway and Wood 2012). Of particular interest is Warren's sketch of the Arikara village, where they arrived on July 5 (Figure 5.9). In illustrating the village, Warren depicts what appears to be both circular earthlodges and log cabins (Callaway 2012:88). Hays, who visited Fort Clark four years later in July 1860, more clearly shows log cabins in his sketch of the Arikara village (Figure 5.4). His sketch depicts at least three, and perhaps four, cabins located along the terrace edge, which faced the Missouri River. The cabins are rectangular in shape, with an entryway on their long axes. One cabin has a single chimney while another has two located on opposite ends of the structure. The rounded tops of several circular earthlodges are noticeable behind the cabins, and at least two tall drying racks are visible. Warren's assistant, W. H. Hutton (Hanson 1996:133), notes that "Their village is circular in form of about 500 yds. in diameter, defended on the vulnerable side by a strong picket of palisades […]." The location of the fortification is unknown as it has never been identified, although a portion of the palisade, shown as a series of vertical posts on the terrace edge, was possibly documented by Hays (Figure 5.4). Warren also depicts the smaller Mandan village (Ruptare/Mitutahank) just upriver, which at that time was still occupied (Figure 5.9).

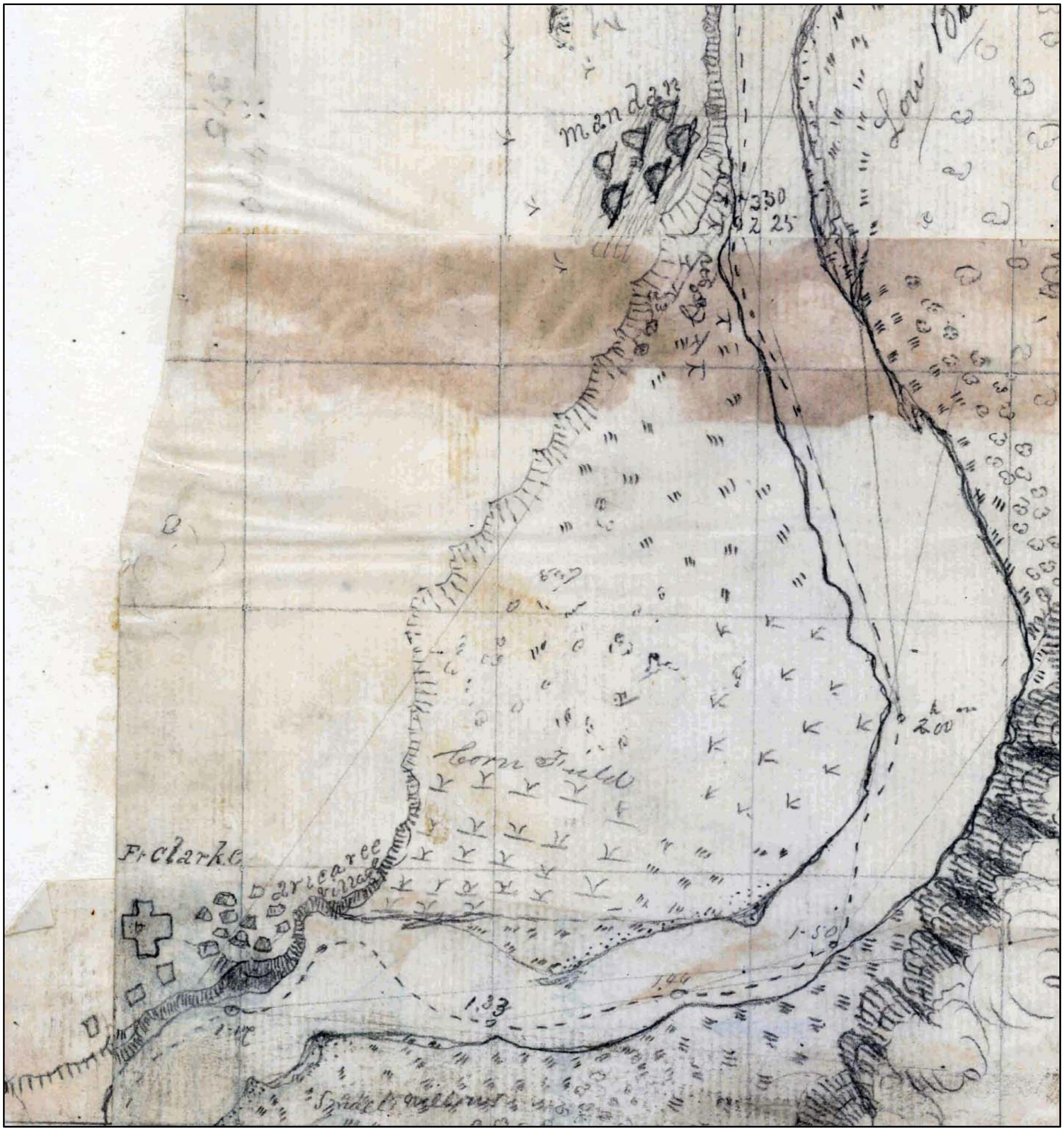

Figure 5.9. Detail of Lieutenant Warren's 1856 map, which shows the area around Fort Clark, including the neighboring Arikara and Mandan villages (Callaway and Wood 2012:Plate 30). National Archives and Records Administration, Record Group 77, Q579, Sheet 30.

Carl Wimar

Wimar, a German-born artist from St. Louis, traveled up the Missouri River in the years 1858 and 1859 to observe firsthand a subject matter that would become the dominant theme of his later paintings (Stewart et al. 1991; Wood et al. 2011:188-190). The two trips yielded many sketches, rich with ethnographic information, and some of the earliest photographs of Native peoples on the Upper Missouri River. Both trips took him to Fort Clark, where he first arrived aboard the steamboat *Twilight* on June 19, 1858. Fort Clark was the subject of two pencil on paper sketches made on that day, but the Arikara village is only vaguely visible in one (Stewart 1991:Figure 12; *Fort Clark, Two Views*). The following year, Wimar journeyed upriver on the steamboat *Spread Eagle* and arrived at Fort Clark on June 25. Among several illustrations made that day, Wimar (Stewart 1991:Figure 54; *Interior of an Arikara Medicine Lodge, Fort Clark*) illustrated the interior of the Arikara ceremonial lodge, using charcoal with white chalk on paper. A plan of the structure is apparent in the lower left corner of the sketch and shows its unusual construction with eight (rather than four) primary support posts (Stewart 1991:125).

Lewis Henry Morgan

When Morgan visited the Arikara village in June 1862 he had a unique experience because the settlement had been abandoned the previous year (Morgan 1871; Wood et al. 2011:173-175). Morgan (1871) made numerous observations about various items he located during his tour of the village. More importantly, his account includes descriptions of various aspects of the village. For instance, Morgan (1871:41, 42) states that the timber-framed, earth-covered lodges, which according to his count numbered 48, were approximately 40 feet in diameter, with four central support posts and a centrally located stone-lined hearth. Many of the lodges were in good condition, although the roofs had collapsed on others, leaving only the outer walls (Morgan 1871:42). The lodges were protected by a palisade composed of vertical timbers, although it was in poor condition, located on the side facing away from the terrace (Morgan 1871:41). The houses were closely spaced within the fortification, which made movement through the unfamiliar village difficult (Morgan 1871:43). Drying racks stood in the spaces between each house and were quite large, which Morgan (1871:43) estimated at nearly 20 feet in length and 12 feet in width. An open plaza was located near the village center. Finally, Morgan (1871:42) identified "several rectangular houses constructed of hewn logs […]." Such structures, log cabins constructed by the Arikaras, are discussed further below.

The written accounts of Maximilian, Chardon, and Morgan combined with the graphic images created by Catlin, Bodmer, Warren, Wimar, and others yield an unparalleled view of a nineteenth-century Native settlement in the Northern Plains. On their own, these historical documents provide a compelling story about the lives of Native peoples and traders in the region. More importantly, the documents aid interpretation of a growing body of archaeological and geophysical data from Fort Clark.

Archaeological Investigations at Fort Clark State Historic Site

Ignoring Lewis Henry Morgan's (1871) visit to the Mandan/Arikara village in 1862, the earliest investigation of the settlement following its abandonment was undertaken by Theodore H. Lewis in 1883 (Wood et al. 2011:213, 214). Lewis (Wood et al. 2011:214) created a sketch map of the settlement during his October 18 visit. The sketch map depicts the steep terrace edge, rough measurements along the village perimeter, and trails leading several directions away from the settlement. The earliest archaeological excavations occurred in 1904, when a representative of the Minnesota Historical Society, E. R. Steinbrueck, investigated several Mandan sites in North Dakota (Brower 1904:143-145; Wood et al. 2011:213-217). Among his work was a sketch map of an enclosure on the north side of Fort Clark, which included a single earthlodge depression that was occupied by Pierre Garreau sometime during the latter occupation (Wood et al. 2011:176-178, 214, 216). Steinbrueck excavated the stone-lined central hearth in Garreau's lodge as well as several Arikara graves, work that angered still-living former occupants of the village (Brower 1904:145; Wood et al. 2011:216-217).

In 1906, Orin G. Libby, the secretary of the SHSND, coordinated with Frank J. V. Kiebert to survey and map the Mandan/Arikara village, a task that was completed the following year (Wood et al. 2011:217-218). Unlike the earlier map produced by Lewis, Kiebert's map depicts the locations of lodges and portions of the fortification ditch that were visible at the time of the investigation. Moreover, Kiebert's illustration (Wood et al. 2011:218) of 71 lodges is sufficiently representative of extant features that most can be associated. Production of the map was part of an effort by Libby to provide guidance to the state in its purchase of the property, which ultimately occurred in 1931 (Wood et al. 2011:217-218).

The first systematic excavations were carried out within the Mandan/Arikara village in 1968 by W. Raymond Wood and Donald Lehmer (Wood 2003b; Wood et al. 219-220). The test excavations were limited to four units, the precise locations of which were unrecorded (Wood 2003b). Burned roof fall was identified in one test unit, which was located within a lodge depression, and suggested the house had been destroyed by fire (Wood 1993c:17). Another unit located near the center of a lodge depression revealed a large, stone-lined hearth, with an estimated diameter of about seven feet (Wood 2003b:17). Wood and Lehmer's work at Fort Clark was followed soon after when Chris Dill, then the Site Supervisor, led excavations in six areas across the village (Ahler 2003e). Although limited in scope and documentation, the excavations revealed several important findings, namely sheet midden depths outside lodges (Ahler 2003e). On the east side of the village, midden depths of upwards of about 75 cm were identified while the depths to sterile soil were shallower toward the west (Ahler 2003e:22). Such results are relevant in regard to the findings of more recent investigations.

In July 1985 a series of aerial black-and-white, infrared, and color infrared photographs of the site were acquired by KBM, Inc. (Grand Forks, North Dakota), which are among a collection of photographs that have been incorporated into the current project (Appendix 1). One set of overlapping black-and-white photographs was used to generate a 15 cm contour map of the village, published in Wood (1993b:Figure 2), and all photographs facilitated mapping work the following year by the University of Missouri-Columbia, the University of North Dakota, and the SHSND (Wood 2003c). Additionally, a crew from the MWAC, led by Robert K. Nickel, performed limited magnetometer surveys of several areas across the property, including the village plaza, although the results are unpublished (Wood 2003c). Besides the mapping program, several excavation units and soil profiles were placed at various locations across the village in 1986 (Wood 2003c:32-40). One test unit placed to bisect the perimeter of a house revealed shallow fill, approximately 20 cm in depth, above the lodge floor and evidence that the house was burned (Wood 2003c:34). Another excavation unit located across the village fortification exposed a shallow, steep-sided ditch, about 60 cm in depth and 80 cm wide (Wood 2003c:38). Most importantly, however, was the preparation of a detailed planimetric map, which covers an area of about 37 ha (Wood 1993b:Figure 3; Wood 2003c:26-32). The map depicts the locations of nearly 1,800 surface depressions, which vary between 20 cm to 3 m in diameter, soil borrows, 86 earthlodge depressions, the fortification ditch, two corrals, Native trails, the remains of a late nineteenth-century stage road, and the two trading posts (Wood 1993b). The surface depressions represent collapsed storage pits, Native and Euroamerican graves, and looted storage pits and graves.

Along with the more extensive work performed at both trading posts in 2000 and 2001, limited excavations, coring, and geophysical surveys were carried out in the Mandan/Arikara village in 2000 (Ahler 2003f; Kvamme 2001, 2007a). Three test units were excavated in the village (Ahler 2003f:55-61). Two of the units, one within and the other outside the fortification ditch, revealed midden deposits of substantially greater depth near the village core, similar to the findings of earlier excavations. Moreover, Kvamme (2001, 2007a) surveyed a 20 m x 400 m transect, oriented east-west across the village. Magnetic gradiometry and earth resistance were used most extensively, but smaller areas were also surveyed with electromagnetic induction (EMI) and ground-penetrating radar (GPR). Features such as earthlodges, including the large Arikara ceremonial lodge located within the plaza, central hearths, the fortification ditch, and trails were discernable in the magnetic gradiometry and earth resistance data sets. Among these significant results was the identification of a buried and previously unknown circular earthlodge with multiple instruments.

To facilitate interpretation of the geophysical anomalies, particularly the discrete magnetic or “point” anomalies that typically indicate hearths, storage pits, and midden, an intensive soil coring program was undertaken within the village (Ahler 2003f:48-55). Systematic coring at equally spaced 1 m intervals was carried out within three 20 m x 20 m survey blocks with the goal of better understanding differences in the midden deposits at several locations. Additionally, targeted coring of discrete magnetic anomalies revealed by gradiometry was undertaken within four grids, including the three that were systematically cored. Soil coring in the westernmost block, located beyond the fortification ditch, indicated relatively little midden accumulation outside lodges (Ahler 2003f:49-50). Similarly, coring within another grid, located in the village core just east of the fortification ditch, revealed shallow midden deposits (Ahler

2003f:50-53). In contrast, systematic coring of two adjacent blocks near the village center found considerably deeper midden deposits (Ahler 2003f:52-56). Thus, excavation and soil coring data show that the depths of midden deposits are greater toward the village core, or near the plaza, but tend to decrease with distance. This finding is meaningful since it corresponds with occupation length; the core was used most intensely over the village's four decades while the area outside the fortification ditch was inhabited only briefly, most likely near the end of the village's use. Out of the 140 targeted anomalies, only 27 (19 percent) were identified as cultural features, including hearths or possible hearths (*n* = 9), pits or possible pits (*n* = 16), or other (*n* = 2). Another 23 pits were identified by systematic coring in three grids. However, determining the source of magnetic anomalies was generally difficult since features were not easily differentiated from midden (Ahler 2003f:52, 55). Layers of ash and burned earth were characteristic of hearths, but only in instances when pits extended deeper than midden could the features be definitively identified.

Following this work, aerial color and thermal infrared imagery was acquired by Tommy Hailey (Northwestern State University of Louisiana) in 2004, the analysis of which suggested the possibility of several more earthlodges (Heller 2009). The images collected by Hailey are among several data sets from previous investigations used in my current project (Appendix 1). Finally, the SHSND acquired .5 m resolution LiDAR data for the entire property in 2012, a complementary data set that is employed here for the first time. Given the success of the latter investigations, further extensive and intensive multi-instrument geophysical investigations were undertaken within the Native village during 2011 and 2012 (Kvamme and Wiewel 2012; Wiewel and Kvamme 2016). Another soil coring program was carried out by me in September 2013 to aid interpretation of the remote sensing data sets.

2011-2013 Investigations at Fort Clark

From 2011 to 2013 Kenneth L. Kvamme, Jo Ann Kvamme, and several graduate students, including me, undertook additional investigations at Fort Clark at the request of the SHSND. As work progressed over the course of the two field seasons, the ultimate objectives of the project evolved. The general goal of the geophysical work was to completely survey the settlement, which would improve understanding of the layout and content of features associated with the Mandan/Arikara village. More specifically, the aims of the investigation were to (1) locate other undocumented earthlodges like the single dwelling identified by Kvamme (2001, 2007a), (2) acquire evidence of rectangular log cabin style structures described and illustrated in historical documents during the latter part of the Arikaras' occupation, (3) obtain information about the number and distribution of storage pits across the village, and (4) potentially define the locations of camps used by nomadic groups that annually visited for the purpose of trade (Wiewel and Kvamme 2014). Such information, which is revealing of population and storage pit capacity, is especially important considering the decrease in the detail of written accounts and artistic depictions concerning the Arikaras' quarter century of occupation.

Instrumentation and Survey Areas

Instrumentation, survey methods, and data processing are described in greater detail in Chapter 2 and Appendix 1. A total of five geophysical instruments, including magnetic gradiometry, earth resistance, EMI (yielding soil conductivity and magnetic susceptibility data), magnetic susceptibility, and GPR were employed in surveys at Fort Clark (Figure 5.10). The most extensive survey was carried out with magnetic gradiometry and covered the entire Mandan/Arikara village south to a modern walking path, a large space west of the village extending to the state park's boundary fence, and a 30 m wide transect south to the cut bank of Chardon Creek, a total area of just less than 12 ha (119,995 m^2). The earth resistance survey, undertaken with two instruments simultaneously, covered an area of about 7.9 ha (78,645 m^2), which includes the entire fortified portion of the village as well as the space outside the ditch where previously recorded earthlodge depressions are located. Relatively smaller areas, mostly within the village core, were surveyed with EMI and GPR due to the slower survey speeds of both instruments. The main EMI survey covered a contiguous area of nearly 2.6 ha (25,764 m^2) inside the fortification ditch and a separate 400 m^2 area, which encompassed a single earthlodge depression near the western edge of the village. The primary GPR survey, which targeted the village plaza, covered an area of just under 1 ha (approximately 9,300 m^2). Another 1,200 m^2 area located near the fortification ditch on the west side of the village core was surveyed separately with GPR. Lastly, a 400 m^2 area was surveyed with all methods using higher sampling densities and multiple GPR antennas to better define a single Arikara log cabin structure, the results of which are described by Mitchell and Wiewel (2014). On the other hand, the locations of separate magnetic susceptibility surveys designed specifically to better understand nomadic group encampments at Fort Clark are discussed by Wiewel and Kvamme (2014). Notably, all geophysical surveys avoided historically documented Mandan and Arikara burials, which are found primarily in a broad arc southwest of the village (Figures 5.5 and 5.6).

Black-and-white aerial photographs from 1938, 1965, 1967, and 1985; color infrared aerial photographs from 1985; and color aerial photographs from 1985 and 2004, which cover a greater part of the site, were inspected alongside these geophysical data sets (Chapter 2 and Appendix 1). In particular, the aerial photographs proved useful for documenting changes to the use of the property during the twentieth century. However, many of the small circular depressions mapped by Wood (1993b:Figure 3) are visible in various years, suggesting the features have great time depth and are not the result of recent impacts like rodent burrowing. Likewise, aerial thermal infrared still frames collected in 2004, which were composited in a geographic information system (GIS) by me, serve as a useful comparison to other data sets. Features such as the small circular depressions are especially apparent. Finally, numerous relief visualizations such as a local relief model, sky view factor, and multi-directional hillshade were generated from airborne LiDAR data obtained in 2012. These data have been combined in a GIS. Several methods were employed to integrate the various data sets, including the generation of two-dimensional overlays, translucent overlays, red-green-blue color composites, and mathematical operations (Kvamme 2006a). These approaches facilitated interpretation, digitization, and analysis of relevant archaeological features.

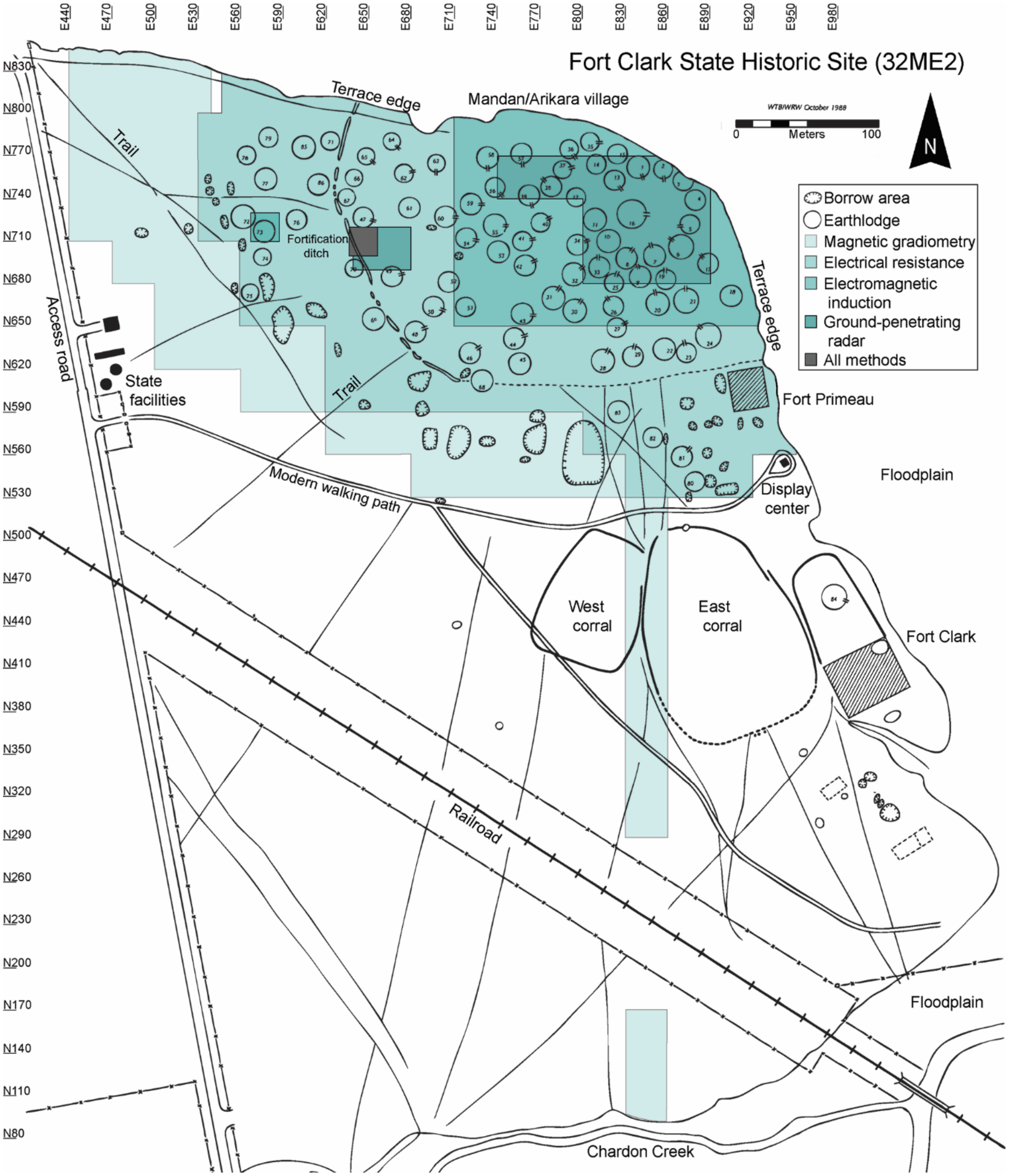

Figure 5.10. Planimetric map (adapted from Wood 1993b:Figure 3) of Fort Clark State Historic Site (32ME2) showing the locations of geophysical surveys. During the nineteenth century, the Missouri River flowed adjacent to the terrace along the eastern and northern edges of the site. Basemap courtesy of the State Historical Society of North Dakota. Used with permission.

Integrating Remote Sensing Data Sets

Following Kvamme (2006a:60) several unique operations were performed beyond the typical processing steps discussed in Appendix 1 prior to data integrations. First, sampling densities varied among the data sets. Since data integrations require uniform sampling densities, each data set was resampled to .25 m x .25 m. Additionally, each remote sensing data set had a different scale, range, and distribution, which make integrations problematic. For instance, if one data set has significantly larger values, it will dominate and obscure variables with smaller values in an integration. To avoid such problems, the distributions of each data set were normalized with power or logarithmic functions. Furthermore, each was standardized with the equation $z = (\chi_i - \mu) / \sigma$. That is, the mean ($\mu$) was subtracted from the data, and the difference was divided by the standard deviation (σ). As a consequence, the resulting data sets have similar means ($\mu = 0$) and standard deviations ($\sigma = 1$), generally with ranges less than four standard deviations.

Several examples suffice to illustrate advantages of combining data sets. For instance, two or more data sets may be simultaneously represented by overlaying (Kvamme 2006a:62-63). A straightforward approach is to overlay one or more translucent layers on an opaque background image. Alternatively, one may represent a background layer as a pseudo-three-dimensional surface with a second color or grayscale image overlaid. In fact, a color shaded relief visualization of the local relief model of Fort Clark with a palette designed for bathymetry creates the illusion of three dimensions (Figure 5.11). With a high-resolution black-and-white photograph overlaid, visible features such as house depressions and trails are enhanced by the color palette and shading. Further complexity may be added to overlays with isoline contours.

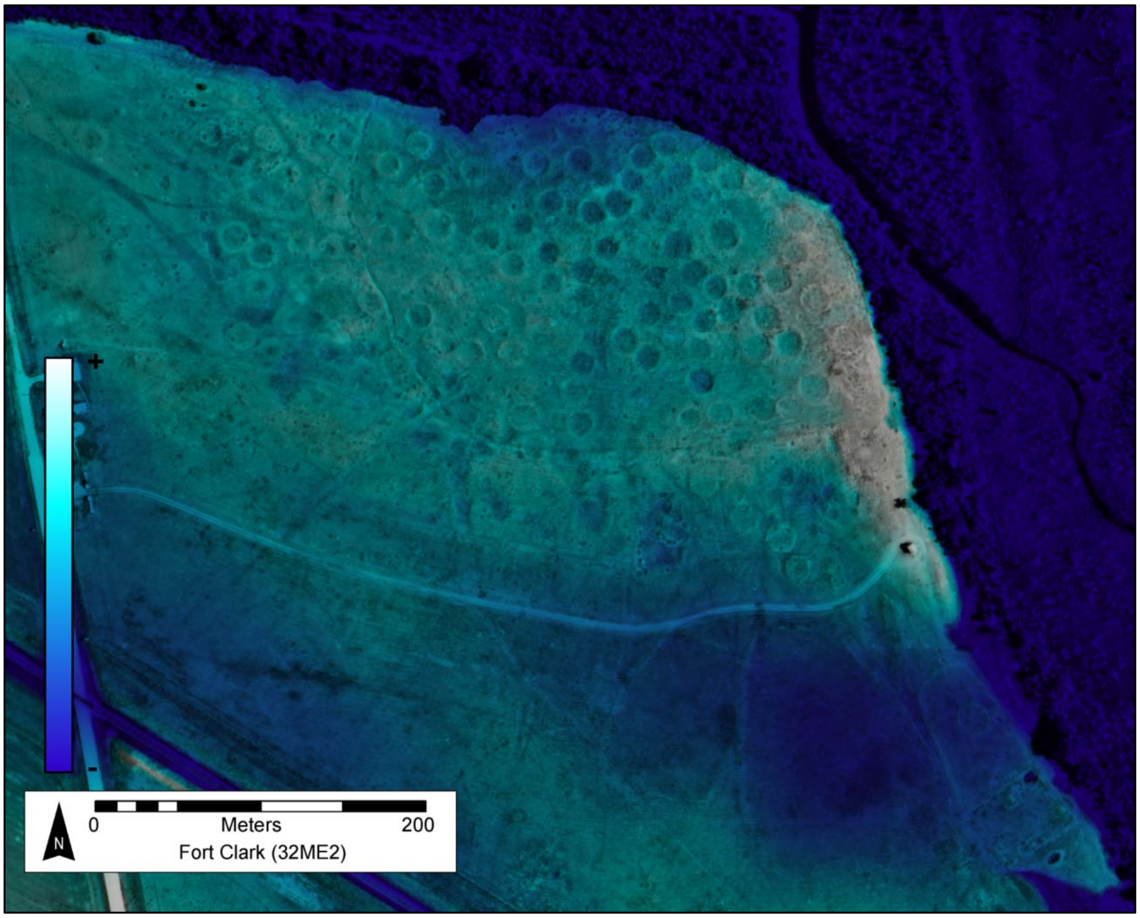

Figure 5.11. A pseudo-three-dimensional view of Fort Clark, with a black-and-white aerial photograph from 1985 overlaid on a color shaded relief visualization of the local relief model. The color scale indicates elevation. Photograph courtesy of the State Historical Society of North Dakota. Used with permission.

Another approach to integrations involves the creation of red-green-blue (RGB) color composites, where the three bands of an image are represented by different combinations of data sets (Kvamme 2006a:62-63). One advantage of RGB color composites is that a large number of unique displays may be generated. For instance, three data sets are sufficient to create six composites, each of which depicts features in unique ways. In general, RGB color composites created from data sets acquired at Fort Clark depict hundreds of features, including earthlodge depressions (i.e., house floors and their surrounding earthen berms), the fortification ditch, trails, borrow pits, and many smaller features (Figure 5.12). The appearance of a primary color in a composite indicates high values in the data set assigned to that particular color while yellow, cyan, or magenta indicate elevated values in pairs of data sets (Kvamme 2006a:62). Although RGB color composites can simplify interpretations, the technique is less effective for those who are color blind.

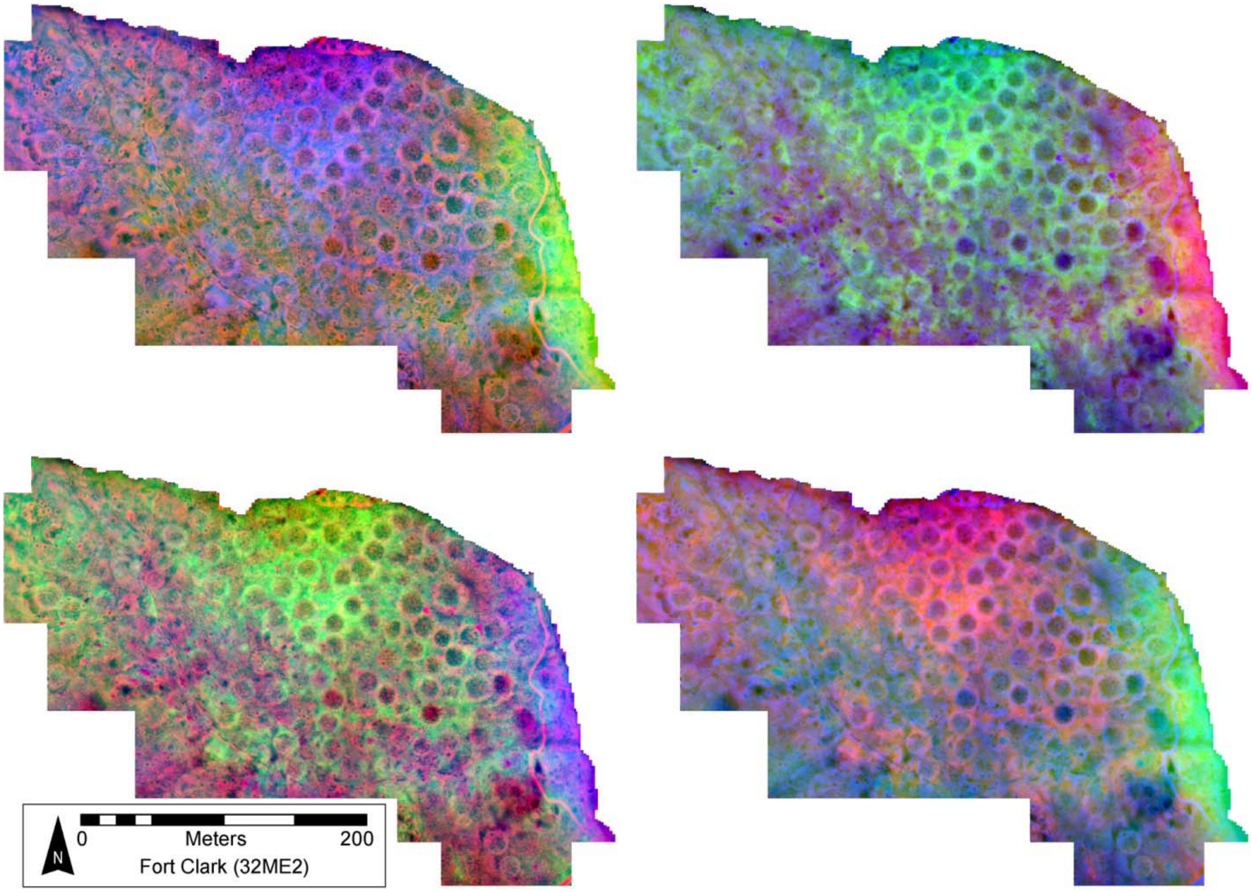

Figure 5.12. Four RGB color composites consisting of different combinations of the local relief model, earth resistance, and thermal infrared data at Fort Clark.

A third method of integration involves the use of basic mathematical operations. That is, one may sum or calculate the product of an unlimited number of data sets (Kvamme 2006a:66-67). For instance, anomalies from multiple sources may be depicted simultaneously by summing data; such is the case when the Fort Clark local relief model, sky view factor visualization, and thermal infrared data are combined mathematically (Figure 5.13). The visualization clearly shows many circular earthlodge depressions. Equally apparent are hundreds of circular depressions approximately 1-3 m in diameter, which are located within and outside the houses and are thought to represent collapsed storage pits. Smaller features such as depressions indicating central support posts and hearths are also noticeable within many lodges.

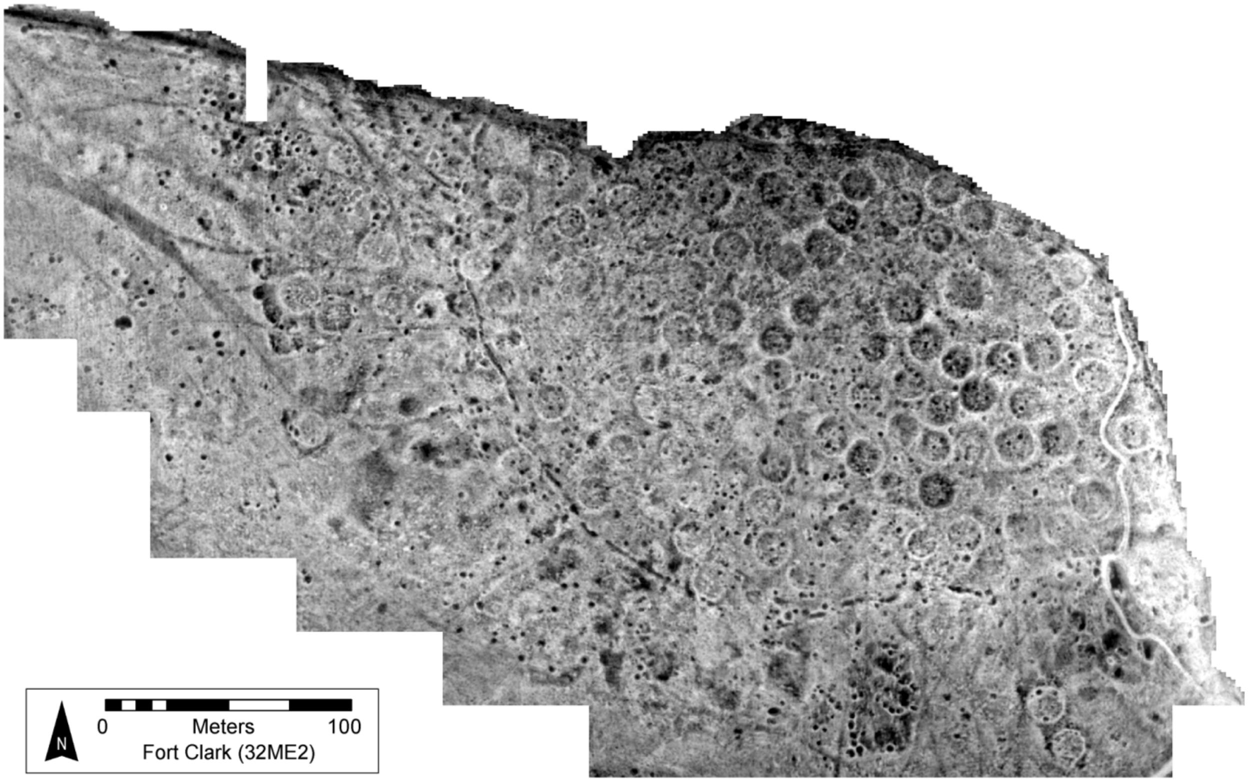

Figure 5.13. Continuous data integration generated by summing the local relief model, sky view factor visualization, and thermal infrared data at Fort Clark.

Interpretation and Analysis of Features at Fort Clark

As demonstrated by the data integrations (Figures 5.11-5.13), the remote sensing data reveal thousands of anomalies, many of which indicate significant archaeological features associated with the Mandan and Arikara occupation. Many of the features mapped by Wood (1993b:Figure 3), including 86 earthlodge depressions, the village plaza, a fortification ditch, several large borrow areas, and numerous trails extending away from the settlement, are apparent. Thousands of smaller features, including hearths, storage pits, post holes, and probable small middens, were detected. Even more common are thousands of magnetic anomalies that point to the locations of ferrous metal artifacts. Yet, many other anomalies indicate previously unrecorded features. I describe these anomalies and their associated archaeological features in greater detail in the following sections.

Importantly, the remote sensing data augment understanding of the occupational history and organization of the village at Fort Clark. Moreover, these data provide significant information about the number and distribution of storage pits, particularly during the later Arikara occupation when historical documents are comparatively silent on agricultural production among the group. I examine this topic further in Chapter 6.

Fort Clark and Fort Primeau

The location of Fort Primeau, a flat area on the southeast corner of the Native village adjacent to the terrace edge, is nondescript, meaning few features associated with the structure are clearly apparent on the ground surface (Figures 5.10 and 5.14a). On the other hand, the magnetic data reveal much about the size, content, and construction of the fort (Figure 5.14b). Specifically, a dense cluster of dipolar anomalies, or high-value anomalies with paired positive and negative measurements, indicates a U-shaped structure approximately 30 m x 25 m in size and open to the east. The outline of the fort, particularly along its south side, is evident as a linear series of positive magnetic anomalies, which indicate a builder's trench (Hunt 2003c). The patterning is significant since it is resembles the pencil sketch of Fort Primeau made by Hays in July 1860 (Figure 5.4). Thus, the open end of the U-shape represents the fort's entrance and interior courtyard, an area that exhibits significantly fewer magnetic anomalies. Numerous factors contribute to the density of magnetic anomalies, which generally relate to the room blocks illustrated by Hays. Magnetic construction materials such metal nails or spikes and local sandstone, previously shown to be magnetic (Kvamme 2002:12), are possible sources of many anomalies. Moreover, metal items such as rebar and nails from extensive excavations carried out at the fort in 1973-1974 are another likely cause of dipolar anomalies (Hunt 2003c).

In contrast, vegetation markings and subtle topographic differences indicate the outline of Fort Clark, a structure approximately 39 m x 47 m in size (Figures 5.10 and 5.14d, e). Moreover, the outlines of interior structures are noticeable in the southernmost corner and along the northwest facing wall. Two gates, which historical documents indicate faced toward and away from the river (Wood et al. 2011:74), are also visible in those locations. A large depression at the northernmost corner of the fort likely represents its icehouse while another depression outside the southeast facing wall is probably a powder magazine (Wood et al. 2011:238). Another prominent feature is a low, U-shaped earthen embankment that is connected to the northwest facing side of Fort Clark. The feature marks the location of a former enclosure with vertically oriented wooden posts, illustrated in July 1860 by Hays (Wood et al. 2011:176, 178). The enclosure surrounds a single earthlodge depression approximately 17 m in diameter, where Pierre Garreau lived during the Arikaras' occupation. Adjacent to the lodge depression are several small pits, likely indicating the locations of storage pits that were mapped by E. R. Steinbrueck in 1904 (Brower 1904:145; Wood et al. 2011:178, 214, 216).

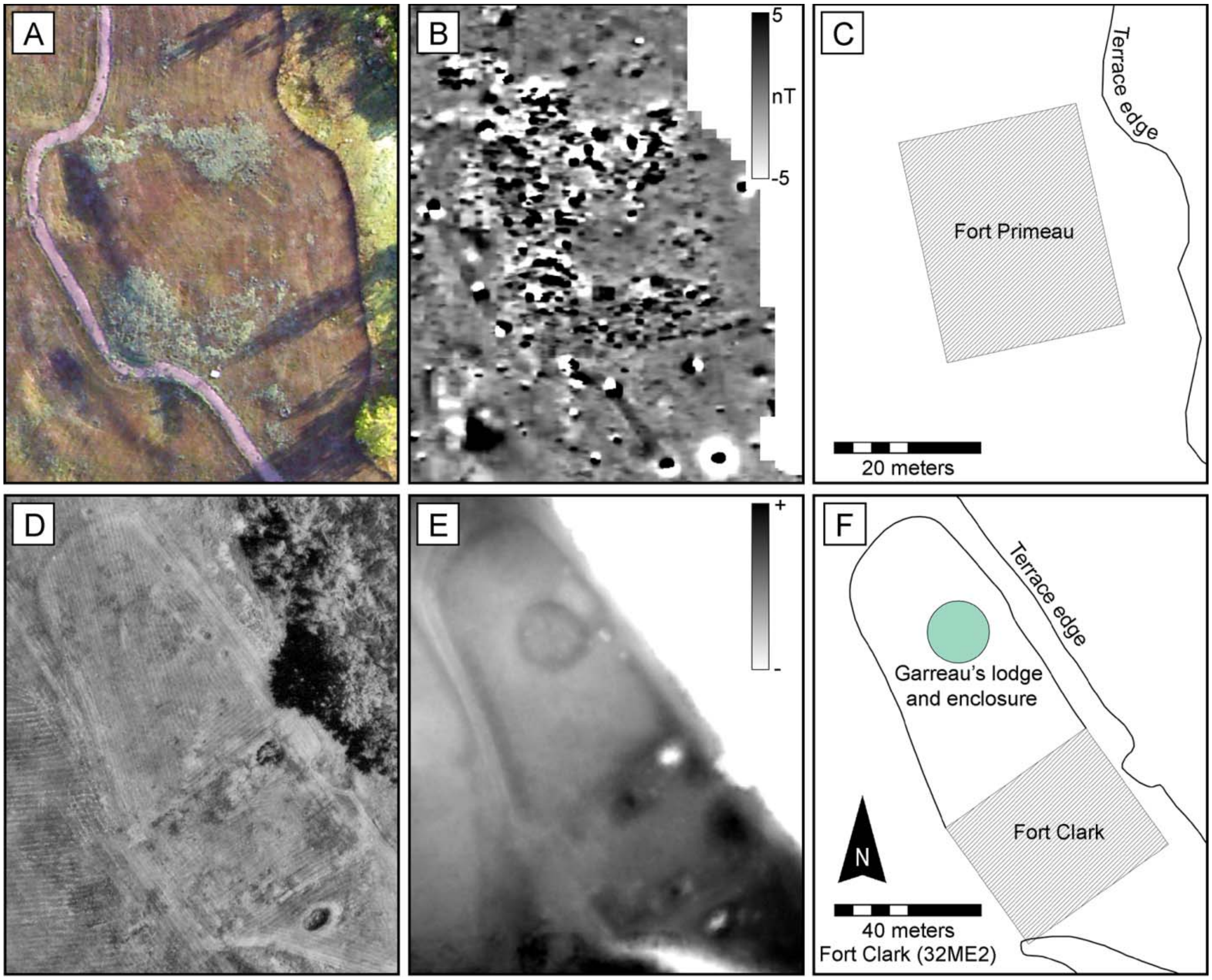

Figure 5.14. Views of Fort Primeau in a) a 2004 aerial color orthophotograph, compared against b) the magnetic gradiometry data, with c) an interpretation of the structure, and Fort Clark in d) a 1985 black-and-white aerial photograph, the corresponding e) local relief model, and f) an interpretation of the structure and adjacent features.

Corrals

Directly west of Fort Clark are two low, earthen embankment features that appear similar to the enclosure that surrounds Garreau's lodge (Figure 5.15). The oval-shaped features are apparent in aerial photographs due to vegetation markings and shadowing, and the mounded sod marking their perimeters is visible in the local relief model (Figure 5.15). The features have been referred to as "gardens" and "corrals," although two lines of evidence support the latter function (Wood 1993b:551-552; Wood et al. 2011:223-224). Specifically, the features resemble a horse corral constructed by an Arikara man at Like-A-Fishhook village (Smith 1972:56; Wood 1993b:551-552). That enclosure consisted of a bullberry brush fence, which over time trapped sediments, creating a comparable earthen embankment. More importantly, soil chemistry tests indicate high levels of available phosphorus and total carbon, particularly in the easternmost enclosure at Fort Clark (Wood 1993b:551-552). The two elements would increase with the buildup of animal waste.

Although the south ends of both enclosures are unclear, the west corral encompasses an area of approximately 5,230 m^2 while the larger corral to the east covers about 12,500 m^2. Additionally, an entrance with overlapping sides, identified during the mapping project in 1986, is visible on the northeast side of the east corral (Wood 1993b:553). A subtle ridge visible in the local relief model extends south from the entrance and perhaps indicates an older section of the enclosure that was removed when the corral was expanded to the east (Figure 5.15c). The corrals were presumably constructed by the Arikaras. Neither Catlin nor Bodmer depict the enclosures in their illustrations of the area (Wood 1993b:551). Furthermore, many trails weave around and between the two corrals, although the route of at least one well-worn path extends directly through the east enclosure (Figure 5.15c), meaning the trail was already in use when the corral was constructed.

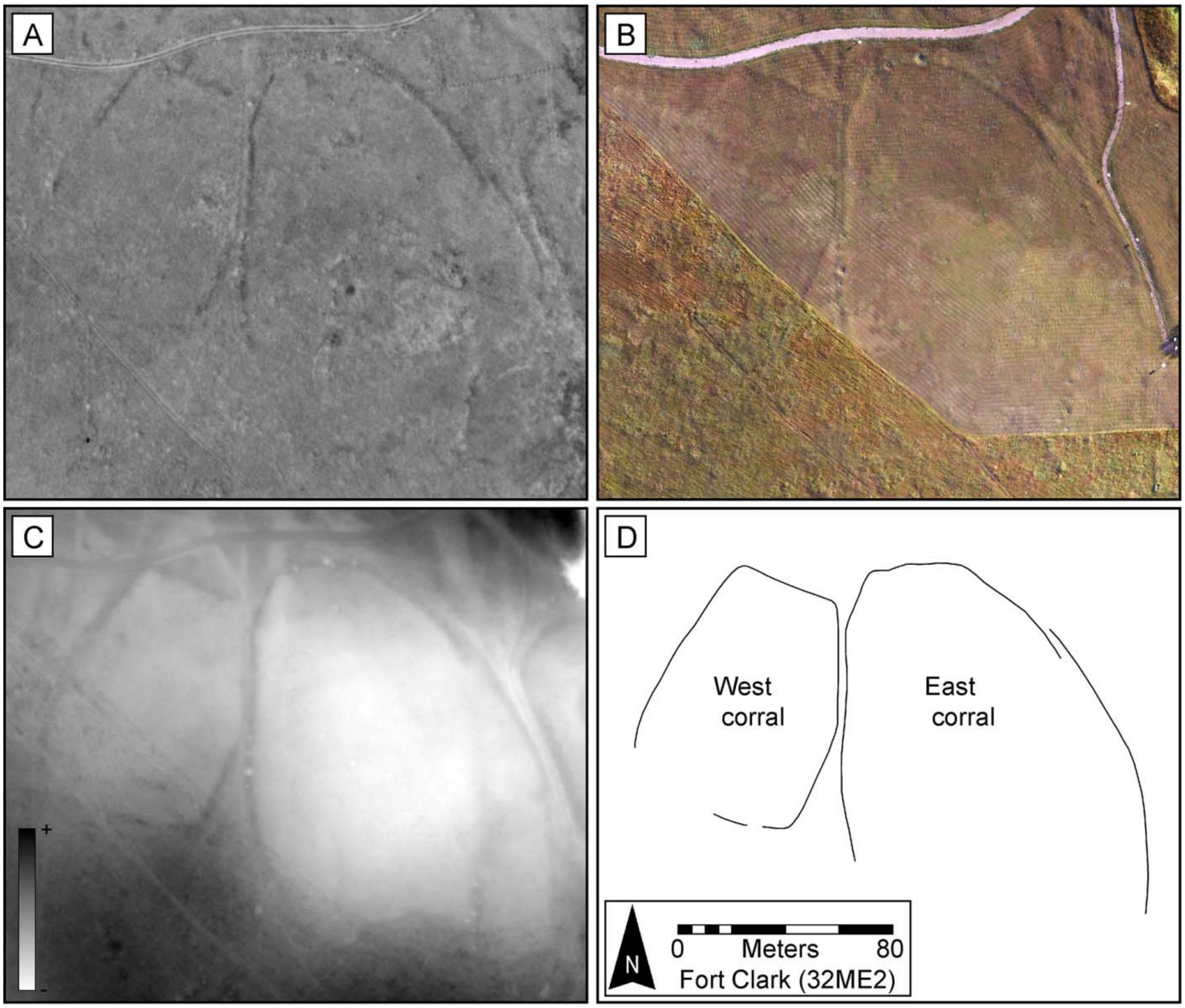

Figure 5.15. Views of two corrals at Fort Clark in a) a 1965 black-and-white aerial photograph and b) a 2004 aerial color orthophotograph compared with c) the local relief model and d) an interpretation of the features.

Trails

A series of trails are visible radiating from the fortification ditch, particularly on the west and south sides of the village (Figures 5.15 and 5.16). Although the network of trails does not resemble the crude sketch match made by Theodore H. Lewis in 1883, the general groupings of southern, southwestern, and western trails confirm his early account (Wood et al. 2011:214, 224-225). Many trails extend outward for several hundred meters before disappearing, merging with other trails, or encountering the property boundaries of the site including Chardon Creek to the south, beyond which cultivation has obscured evidence of the features. At least three trails begin at the western facing entrance to Fort Clark rather than the village (Wood et al. 2011:224-225). The most intensely used or well-established trails, evident based on their greater breadth and depth, are conspicuous from ground level. Such trails to the west would have connected the Mandan/Arikara village with the neighboring Mandan village (Ruptare/Mitutahank) and the Hidatsa villages at Knife River (Figures 5.3 and 5.16).

The most extreme routes were created over decades of use by humans, dogs with travois, and horses. Through continued use, the topsoil was eroded away, leaving a shallow to deep pathway worn into the subsoil. This process explains the features' magnetic signature: low or negative magnetism due to the absence of magnetically enriched topsoil. However, subtle trails are equally, if not more apparent, in other remote sensing data sets, including aerial photographs, thermal infrared imagery, and relief visualizations (compare Figures 5.10, 5.13, and 5.16). As the trails were worn into the ground surface, they became compacted through continuous use. Thus, the trails tend to have different or denser vegetation and greater moisture content. These two factors are evident in aerial imagery (Figure 5.16a, b). Trails appear darker in the black-and-white aerial photograph from 1985 due to vegetation health differences, where vegetation within the features remains healthy because of high soil moisture content. For the same reason, trails appear darker or cooler in the thermal infrared imagery. Several other linear features exhibit similar signatures, although a review of aerial photographs from various years shows that their origins are more recent. Most have a "two-track" form and are related to site maintenance.

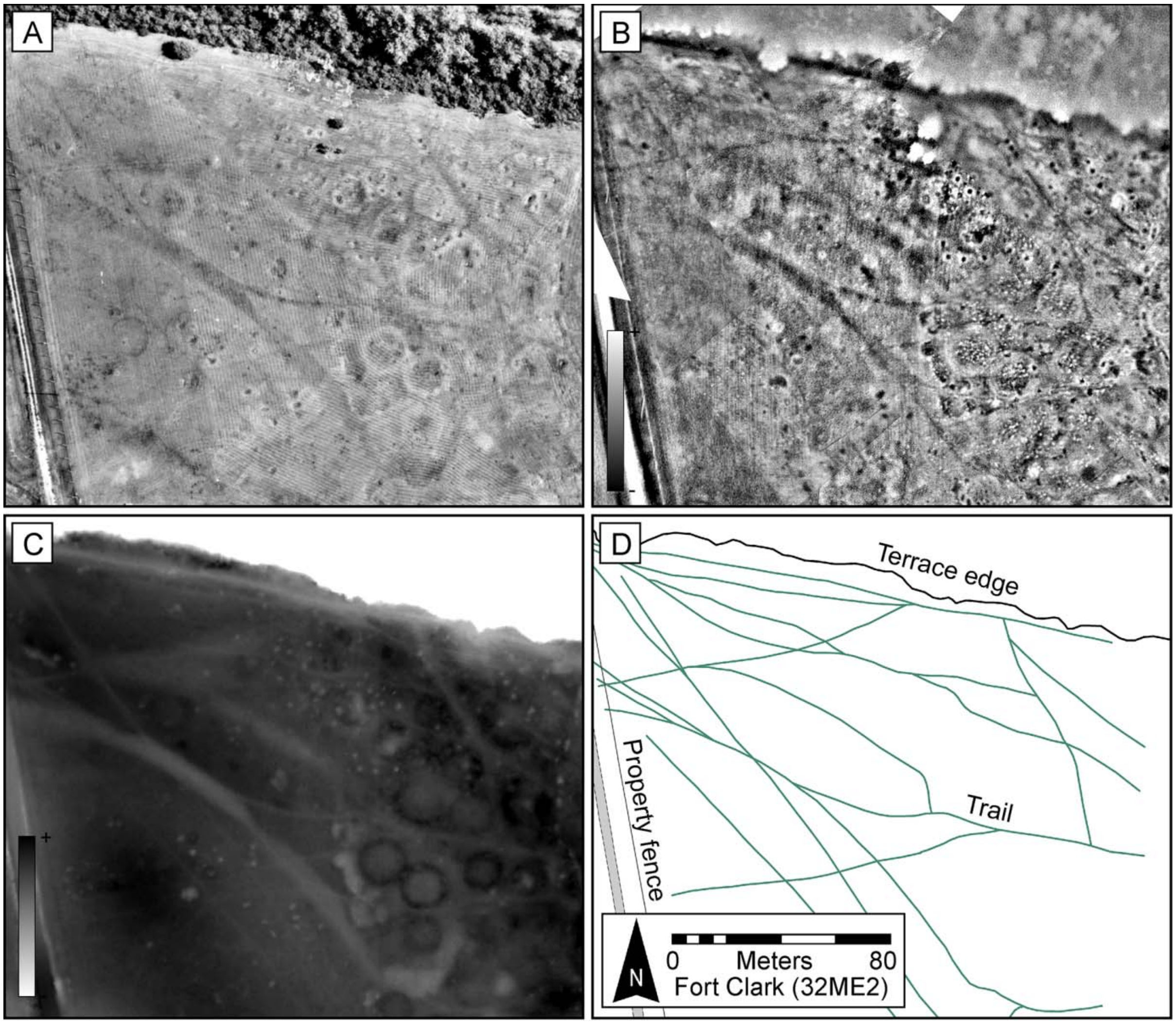

Figure 5.16. Views of trails on the west side of the Mandan/Arikara village in a) a 1985 black-and-white aerial photograph, compared against b) thermal infrared and c) the local relief model, with an d) interpretive map showing the extent of trails.

Fortification Ditch

The fortification ditch is represented by a discontinuous series of linear depressions that are most clearly visible on the west and southwest sides of the village (Figures 5.10, 5.13 and 5.17). Like trails, the ditch exhibits low or negative magnetism due to the removal of magnetically enhanced topsoil during its construction (Figure 5.17a). However, when the topsoil was removed it was distributed on either side of the ditch, creating a subtle mound with higher magnetism. Moreover, the outside edge exhibits higher magnetism along much of its length, which may be explained by Catlin's (1973 [1844]:81) observation of a palisade constructed outside the ditch. The excavated topsoil was likely used to support the palisade. Although excavations revealed the ditch was once at least 60 cm in depth and 80 cm wide (Wood 2003c:38), the feature is very shallow today, and many sections have been completely backfilled and leveled. Despite being discontinuous, the feature's course can easily be traced from ground level or on aerial photographs and relief visualizations along the west and southwest sides (Figure 5.17b, c).

Fewer sections of the fortification ditch are visible on the south side, although extant portions are apparent in multiple remote sensing data sets (Figure 5.17d). The entire length of the ditch is about 460 m, and it surrounds an area of about 47,575 m^2. Presumably, the fortification ditch is part of the vertical timber palisade depicted by Catlin in his painting *Bird's-eye view of Mandan village*, which surrounded Mitu'ahakto's (Figure 5.5). Whether the Arikaras constructed a palisade along the same course is unclear, but the location of the fortification described by Lieutenant G. K. Warren's assistant, W.H. Hutton, in 1856 (Hanson 1996:133) and Lewis Henry Morgan (1871:42) in 1862 is unknown. Similarly, the locations of several triangular-shaped bastions described by Maximilian (Witte and Gallagher 200:199, 2012:64, 152) and depicted by Bodmer (Ruud 2004:Plate 301), which were part of the Mandans' prior fortification system, are unclear. Heller (2009:71-72) identified two potential bastions in the thermal infrared imagery, but the features are not visibly evident in any other data sets. The difficulty in identifying the structures may be explained by the use of impermanent construction materials (i.e., earth between two layers of interwoven willow branches, or wicker, according to Maximilian [Witte and Gallagher 2010:199, 2012:152].

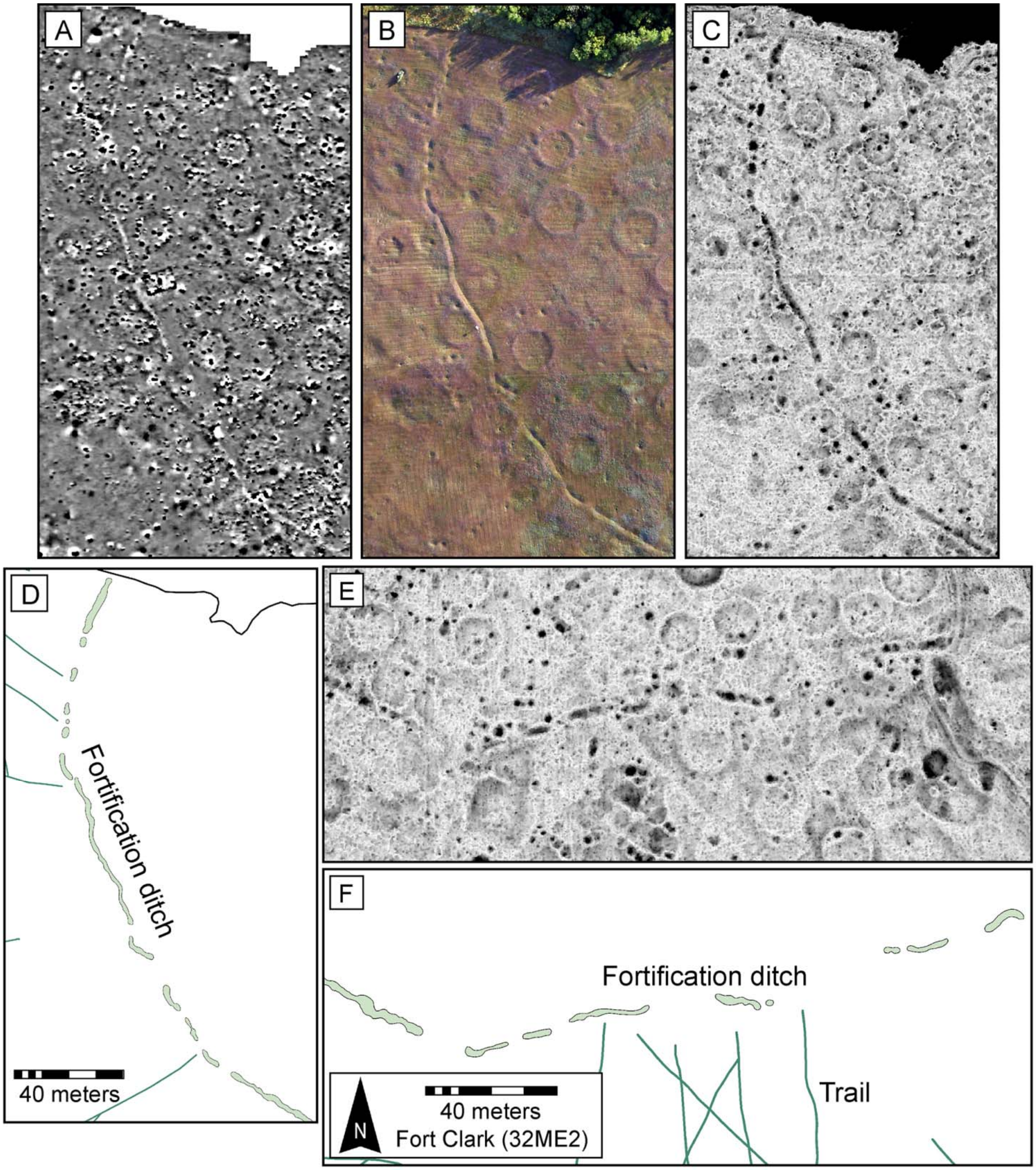

Figure 5.17. Two sections of the fortification ditch at Fort Clark. Views include the west side in the a) magnetic gradiometry data, b) 2004 aerial color orthophotograph, c) sky view factor visualization, and d) an interpretation, and the south side in e) the sky view factor visualization and f) an interpretation.

Borrow Areas

Many irregularly shaped depressions with varying depths of up to approximately .5 m surround the village outside the fortification ditch (Figures 5.10 and 5.18). Most are around 10 m in breadth, although a few are much larger, reaching about 30 m wide with volumes of about 100 m^3. Roper (2005:115) estimated that an earthlodge with a diameter of about 12.5 m, which is at the low end of the range for lodge areas at Fort Clark, would require about 25 m^3 of earth to form its cover. Thus, a single borrow area could be the source of soil for several adjacent dwellings. Importantly, a small number of borrows exhibit roughly circular forms and appear much like an earthlodge depression. Unlike an earthlodge, however, borrow areas lack magnetic anomalies characteristic of central hearth features. Instead, borrow areas mostly show lower magnetism because the magnetically enriched topsoil has been removed. The depressions are most clearly visible in various relief visualizations such as local relief and hillshade models (Figure 5.18a, b).

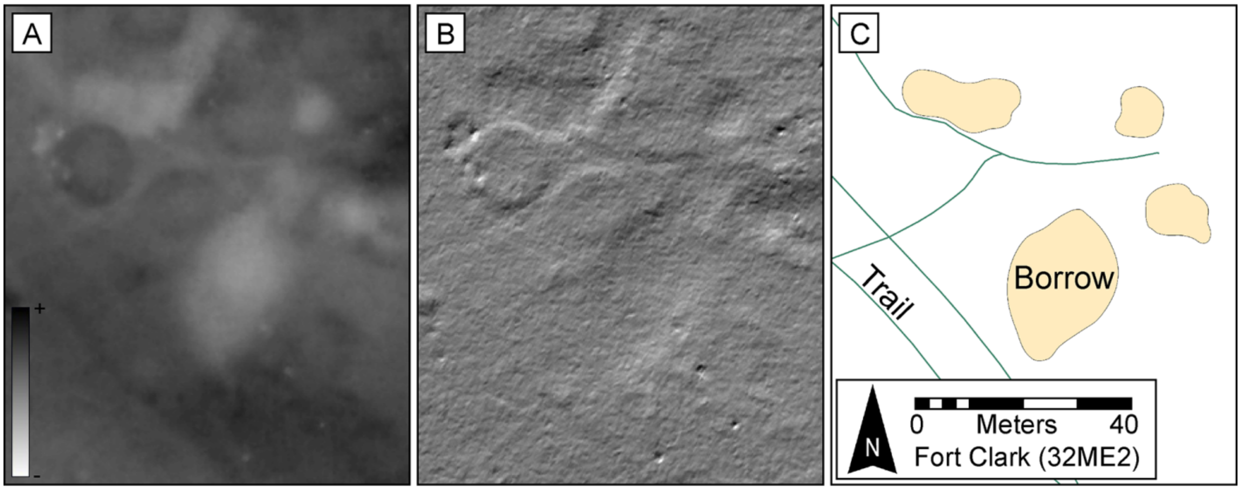

Figure 5.18. Examples of borrow areas in a) local relief and b) hillshade models and c) an interpretation of the features and adjacent trails.

Village Plaza

The plaza, a level space approximately 1,675 m^2 in area (minus the ceremonial lodge), is located within the village core near the terrace (Figure 5.19a). The plaza is encircled by earthlodges, although a single lodge about 18.5 m in diameter, the Arikara ceremonial lodge, was constructed on the west side of the space. The plaza lacks much of the magnetic variation characteristic of the surrounding lodges, which exhibit a considerable number of magnetic anomalies, particularly those with dipolar forms (Figure 5.19b). Of the smaller number of magnetic anomalies, many may represent burned posts or postholes infilled with topsoil from drying racks or scaffolds that were documented along the perimeter of the space.

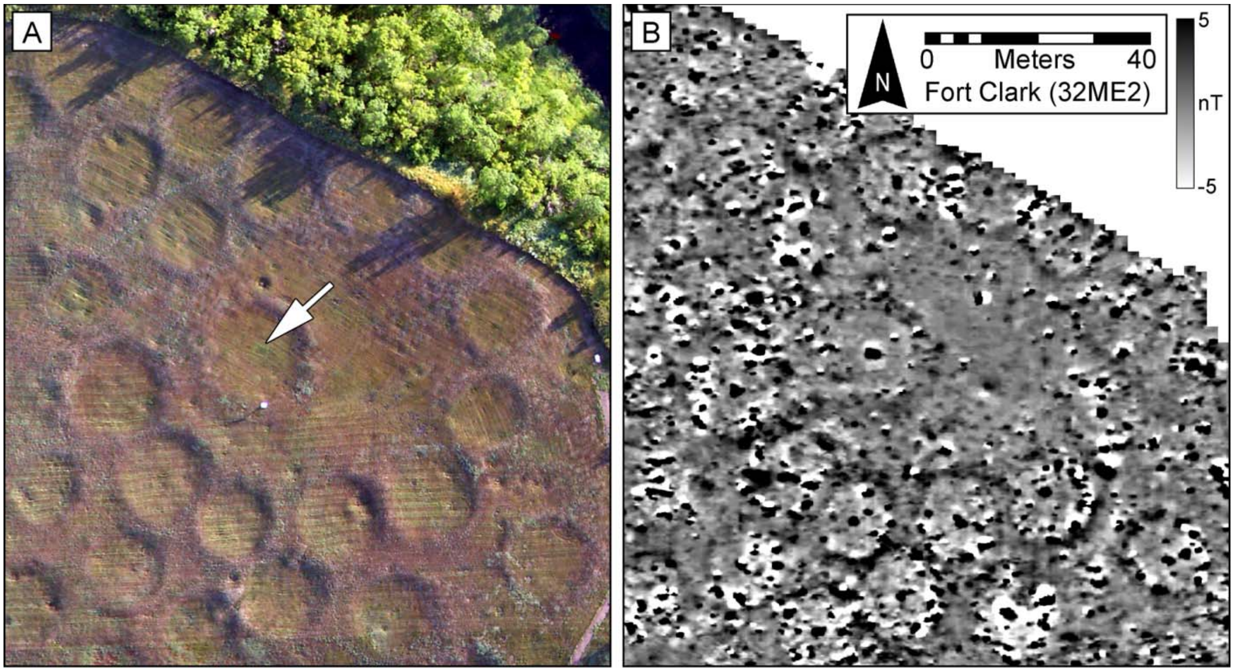

Figure 5.19. The village plaza revealed by a) a 2004 aerial color orthophotograph and b) magnetic gradiometry data. A white area points to the center of the Arikara ceremonial lodge.

Presumably, the extant plaza is the same open space illustrated by Catlin (Figure 5.5) and Bodmer (Ruud 2004:Plate 304). The plaza was described by Bad Gun, a Mandan who lived in the village until 1837, when he visited the site with Orin G. Libby (1908:499; Wood et al. 2011:63-66) in 1906. Bad Gun recalled the Mandan occupants of lodges that surround the current plaza, although the extent to which the Arikaras modified or changed the space is unclear. However, the Hays sketch from July 1860 (Figure 5.4) depicts structures on the east side of the plaza (although the plaza itself is not visible), and additional evidence discussed further below suggests the Arikaras likely reconstructed lodges after the fire that destroyed Mitu'ahakto's in 1839.

Earthlodges and Architectural Features

Numerous circular depressions with depths of about 5-65 cm and typical diameters of approximately 13-17 m are conspicuous across the site. Although most are clearly visible from ground level, the lodges are more pronounced from above due to shadowing and vegetation markings (Figures 5.19a and 5.20). All of the structures mapped previously by Wood (1993b:Figure 3) exhibit definite berms, or mounded soil, around their perimeters. The berms are the remnants of each lodge's outer wall and topsoil that eroded from their rooftops prior to its collapse. Dwellings near the village core have some of the greatest depths due to the accumulation of sheet midden deposits outside the structures (Figures 5.19a and 5.20). As a result, these lodges appear to have been excavated below the surrounding ground surface. On the other hand, lodges farther from the core tend to be level with the surrounding ground surface and have more shallow depressions. In fact, Pearson's r indicates a moderately high negative correlation ($r = -.59$; $df = 82$; $p < .0001$) between the depth of each lodge depression and its distance from the plaza center, a finding that is meaningful in terms of the length of occupation in different parts of the village.

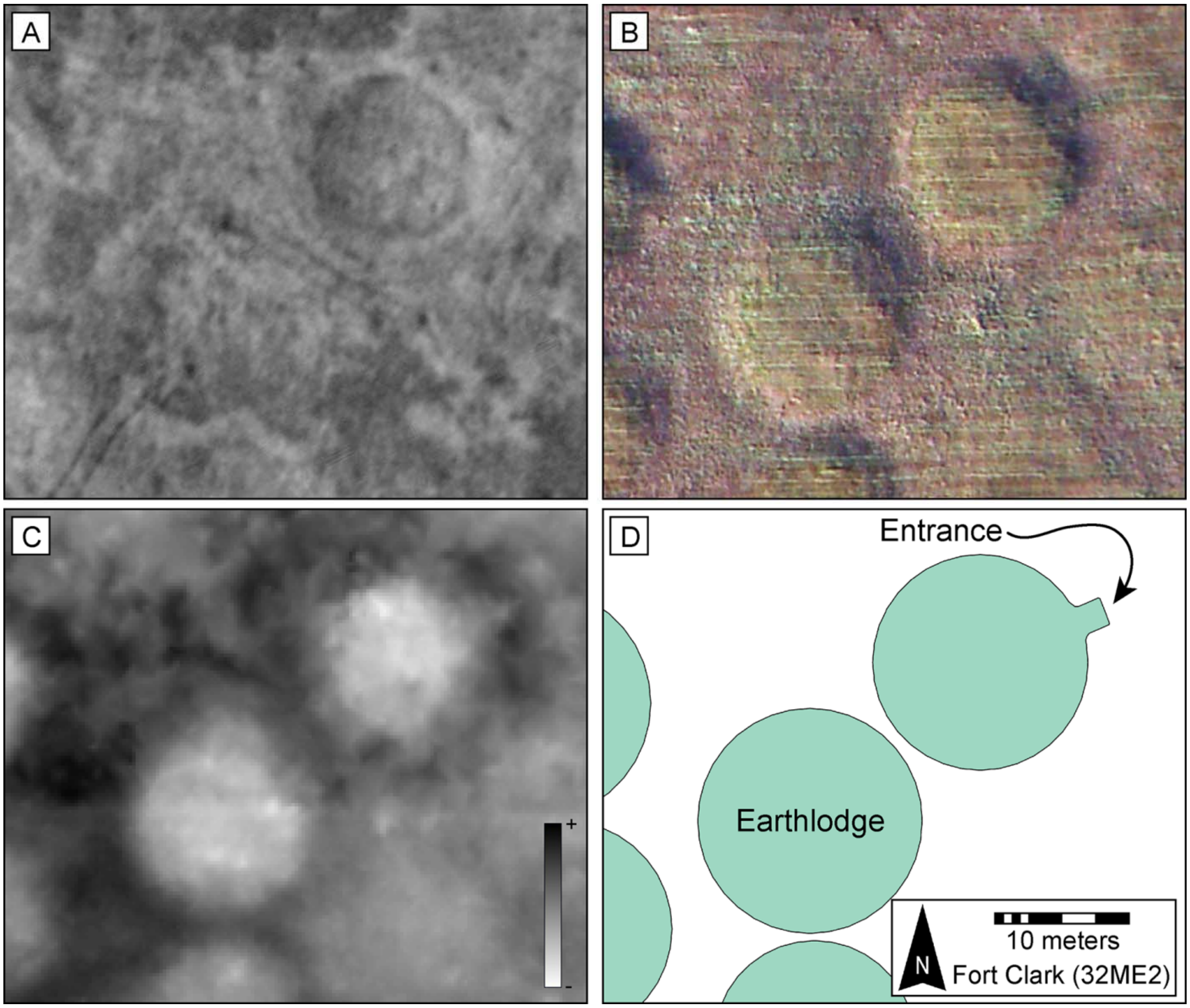

Figure 5.20. Examples of earthlodges in a) a 1965 black-and-white aerial photograph and b) a 2004 color aerial orthophotograph compared with c) the local relief model and d) interpretations of the features.

Based on the diameters recorded by Wood (unpublished data used with the permission of the W. Raymond Wood and the State Historical Society of North Dakota), the 86 earthlodges average 164.5 m^2 ($s = 39.8$ m^2) in area. In contrast, the same 86 digitized lodges average 175 m^2 ($s = 33.4$ m^2) in area (Wiewel and Kvamme [2016] report an average of about 160 m^2, an area calculation that includes new lodges as well). A paired *t*-test indicates the difference is significant ($t = 3.94$; $df = 85$; $p < .0002$), although it is worth noting that small variations in corresponding diameters (e.g., a .5 m difference) are magnified in large area differences. Thus, minor inaccuracies, including my own and those of earlier investigators, likely contribute to the different means. Lodges near the village core generally appear to be larger than more distant structures. The Arikara ceremonial lodge has an area of about 280 m^2, and other nearby structures are nearly as large (Figure 5.19a). The 12 dwellings that encircle the plaza and the ceremonial lodge average 185.8 m^2 ($s = 41.4$ m^2) in area. Numerous dwellings of less than half the size of the ceremonial lodge are located farther from the core, but the average area of other structures is 173 m^2 ($s = 31.7$ m^2; $n = 73$). However, lodge size varies considerably across the village, and Pearson's *r* indicates that the relationship between area and distance from the plaza is only weakly negative ($r = -.35$; $df = 84$; $p < .001$) (Figure 5.21).

Spatial autocorrelation yields further insight into house size variation across the village. Moran's *I* statistic ($I = .2267$) indicates that the lodges are clustered ($z = 2.799$; $p = .0051$) rather than randomly distributed. Anselin Local Moran's *I*, which provides a measure of the relationship for individual locations, provides additional clarification (Figure 5.22). First, most dwellings, particularly those near the center of the village, have z-scores near zero, meaning they do not exhibit significant clustering. Yet, a statistically significant cluster of large lodges (high-high cluster) is apparent near and south of the plaza toward Fort Primeau and Fort Clark. Interestingly, a few particularly small houses around the plaza are identified as statistically significant outliers (low-high outliers). That is, the lodges have low negative z-scores but are surrounded by houses with high positive z-scores. Lodges near the west side of the village are similarly clustered (low-low cluster). These structures are mainly smaller in area, although three large houses (high-low outlier) are interspersed. Large dwellings near the plaza are perhaps an indication of the high status of their occupants, an idea that is explored further below. Similarly, the especially small lodges toward the west side of the settlement could indicate the low status of their occupants. An alternative explanation, however, is that these lodges, which are thought to have been constructed later during the Arikaras' occupation, are smaller as a consequence of the gradual degradation of timber necessary to build such structures. The scarcity of timber was noted by later visitors (Wood et al. 2011:8, 59, 176, 192, 195, 201)

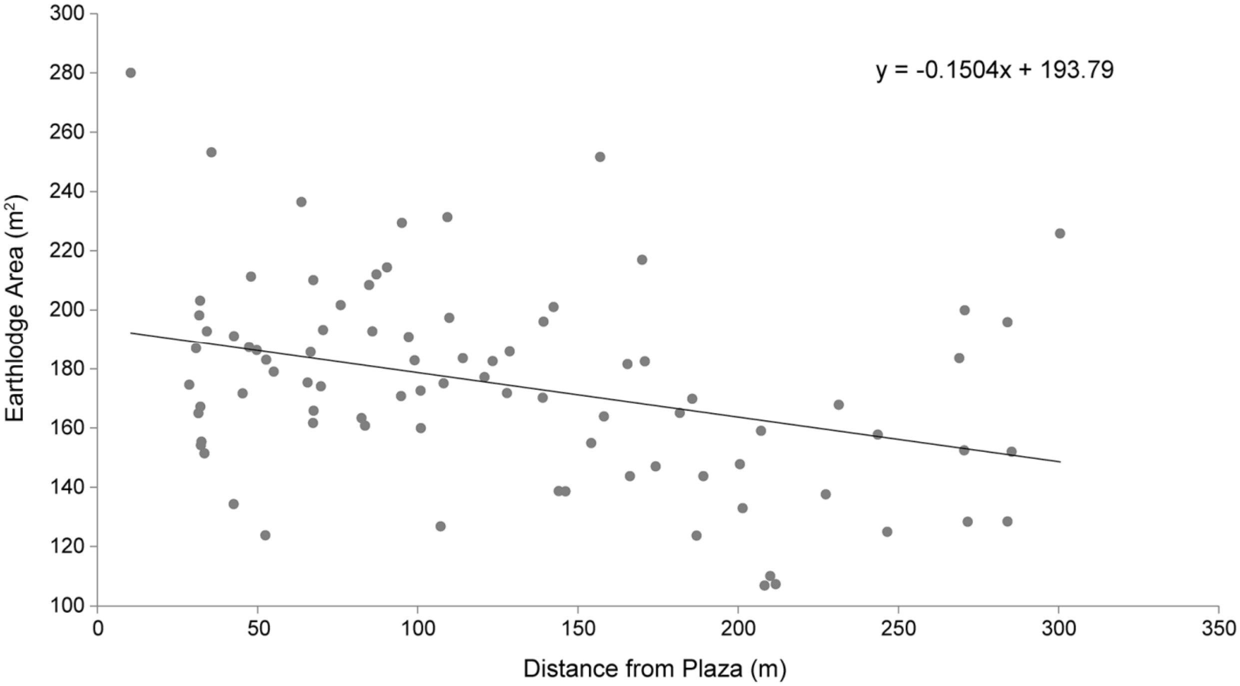

Figure 5.21. A scatterplot showing the relationship between lodge area and distance from the plaza.

The geophysical characteristics of earthlodges vary across the village as well. Most structures exhibit a ring of high magnetism around their perimeters. The ring corresponds with the raised earthen berm, composed of more magnetic soils, that surrounds each house (Figures 5.20 and 5.23a). Roughly circular clusters of dipolar anomalies, which generally indicate the presence of ferrous metal items, mark the locations of other dwellings (Figures 5.19b and 5.23b). Each lodge has a centrally located anomaly about 1-2 m in diameter that signifies its central hearth (Figures 5.19b and 5.23). The central hearths of all 86 lodges were confirmed by soil coring, which showed layers of ash and burned earth (Wood 1993b:550).

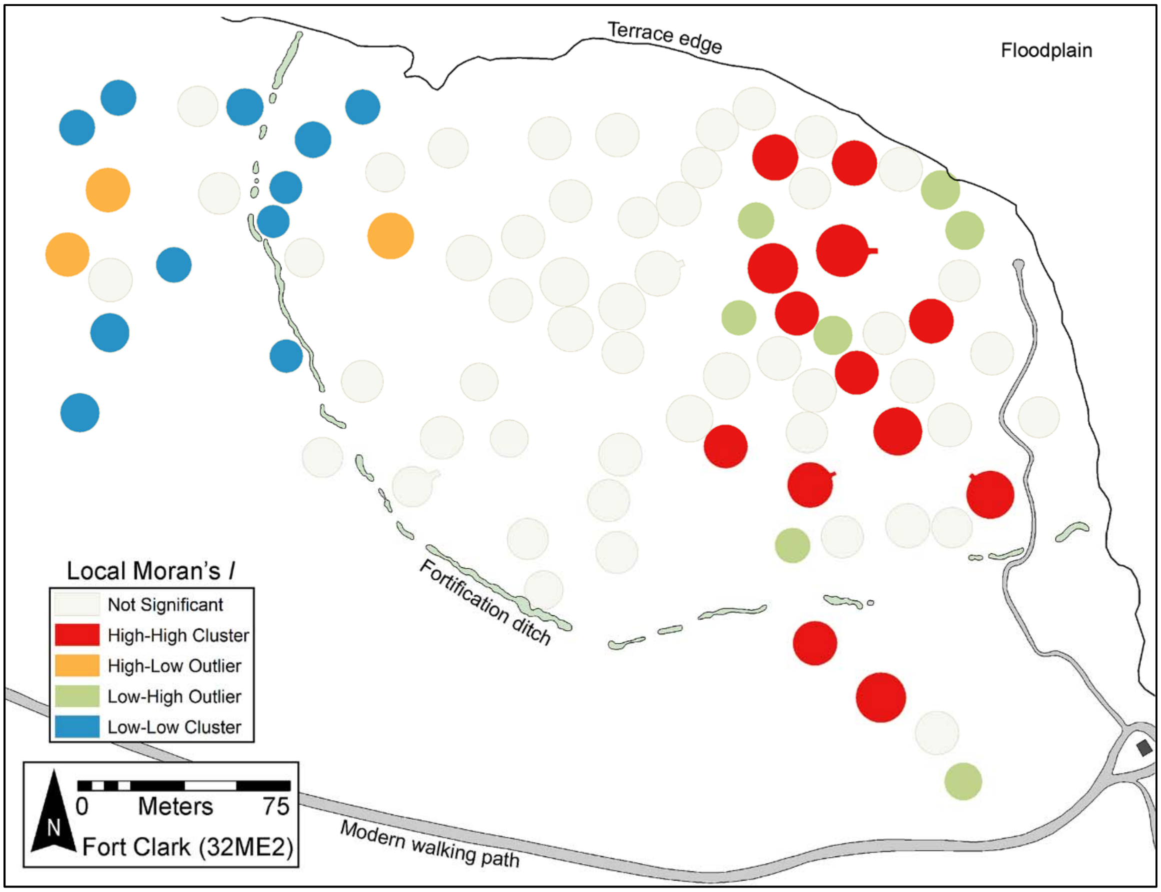

Figure 5.22. Choropleth map illustrating the results of an Anselin Local Moran's I test. The test indicates statistically significant clusters of large houses (high-high), small houses (low-low), and outliers.

Moreover, the entrance passages of many lodges were identified during the intensive mapping program in 1986, particularly among the structures located within the fortification ditch (Wood 1993b:550). Each entrance was identified by a subtle depression along the rim of the surrounding earthen berm. In contrast, only a few entryways were observed by airborne LiDAR (Figure 5.20c, d). An equally small number of entrances were noted in the magnetic gradiometry data, perhaps due to the large number of dipolar anomalies that obscure such subtle features (Figure 5.23c). One of the clearest examples, however, includes the entryway of the Arikara ceremonial lodge (Figure 5.23c, white arrow). The entrance, which faces east toward the plaza, is marked by parallel linear magnetic anomalies approximately 2.5 m in length. Additionally, an earthen altar documented by Wood (1993b:550) located at the rear of the ceremonial lodge opposite of the entrance is characterized by a dipolar anomaly (Figure 5.23c), although the feature's topographic expression is more obvious in the relief visualizations.

Besides the magnetic anomalies associated with central hearths, each lodge contains one or more positive or negative point anomalies. Many of the positive point anomalies, which look similar to hearths, likely represent subterranean storage pits (Figure 5.23a). Other anomalies, both positive and negative, indicate the locations of central support posts (Figure 5.23d, e). For instance, four support posts equally spaced about 3.5 m apart surround the central hearth of one earthlodge on the west side of the village (Figure 5.23d, white arrows pointing toward the lodge center). The posts are represented by low or negative magnetism, which may be attributable to subtle topographic depressions that were observed by me in their locations. At least two similar anomalies are visible in the Arikara ceremonial lodge (Figure 5.23c), a structure that purportedly had eight rather than the typical four primary support posts (i.e., according to Wimar's plan of the structure [Steward 1991:125]). The wooden support posts were perhaps removed and used as a source of fuel for steamboats following the abandonment of the village (Wood 2011:206-207), an event that would leave depressions in the absence of posts. Weakly magnetic point anomalies appear to indicate support posts in other lodges, which are perhaps visible due to burning (Figure 5.23e, white arrows point to the support posts).

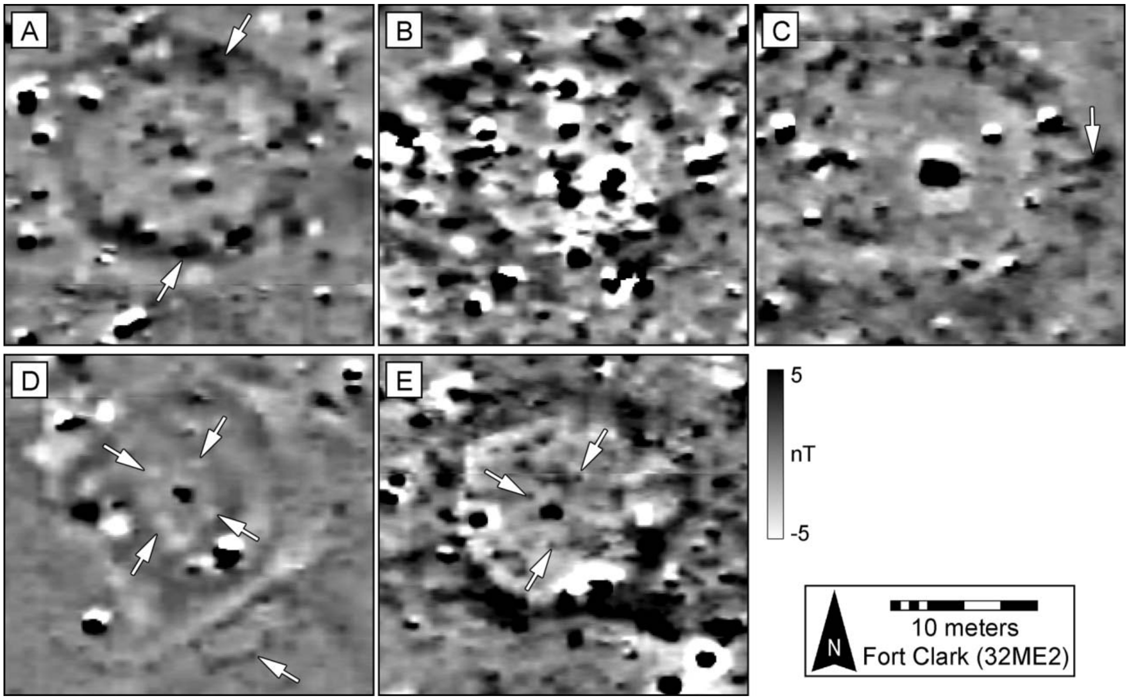

Figure 5.23. Magnetic expressions of earthlodges at Fort Clark, including a) a typical lodge with elevated magnetism indicating its earthen berm and possible storage pit features, b) a lodge indicated by a roughly circular cluster of numerous dipolar anomalies, c) the Arikara ceremonial lodge and its east facing entrance, and d-e) lodges with magnetic anomalies related to central support posts. Arrows point to particular architectural features discussed in the text.

Earthlodges are equally, if not more, apparent within the village in other remote sensing data sets (Figure 5.24). For instance, the circular forms of lodges are especially evident in the earth resistance data (Figure 5.24a). The floor areas within most lodge depressions exhibit high resistance, likely due to their compaction from preparation and long term use, while low resistance characterizes the surrounding earthen berm that marks the perimeter of each house. This result differs from the earlier geophysical survey at Fort Clark. In 2000, Kvamme (2003a:140-141) found that house floors were of low resistance and were surrounded by a circular ring of high resistance. The difference in findings is perhaps a consequence of weather-related conditions during both surveys. The earlier survey was performed during a dry period while the latter occurred in a wetter year. The results of the earlier survey can thus be explained in terms of moisture variation, where the higher surrounding berm of each lodge is drier (high resistance) and the depressed lodge floor is wetter (low resistance). When the latter survey was performed, the floors and circular berms of each lodge were equally moist.

The electromagnetic conductivity survey yielded results that are comparable to the findings of the resistance survey (Figure 5.24b). The perimeters of lodges are clearly visible due to conductivity differences between floors and the surrounding earthen berms. As would be expected due to the relationship between resistivity and conductivity, house floors generally exhibit low conductivity. On the other hand, the raised berm and exterior spaces between lodges, where excavations revealed thick midden deposits, are indicated by high conductivity. Moreover, a subtle ring of high conductivity apparent within several lodges, which appears to define the floor area, corresponds with the floors visible in resistance data (Figure 5.24b, white arrows). Although the source of the anomalies is uncertain, excavations at Fort Clark (Wood 2003c:34-35) and at Star Village (Metcalf 1963:85-86) and an illustration of a lodge interior by Carl Wimar (Stewart et al. 1991:Figure 54) suggest one reasonable explanation. That is, the ring of high conductivity may indicate the locations at which the outermost posts of the lodge make contact with the ground. Such "leaner" posts are structural elements positioned at an angle between the outer wall support posts and ground surface into which the beams are secured. The high conductivity anomalies may represent the actual location at which the posts were inserted into the ground.

Lodge outlines are only vaguely noticeable in the magnetic susceptibility data (Figure 5.24c). Instead, the data indicate numerous areas of high susceptibility. The most obvious sources of many high susceptibility anomalies are hearths (Figure 5.24c). Other adjacent susceptibility anomalies within lodges may indicate activity areas, where organic matter associated with the processing and cooking of food led to enhanced susceptibility. Likewise, susceptibility anomalies perhaps signify auxiliary hearths, which exhibit high susceptibility due to repeated firing, or storage pits and middens, features that contain or consist of magnetically enhanced materials.

Every dwelling identified by Wood (1993b:Figure 3) is revealed by thermal infrared, a remote sensing technique with results that correlate with the findings of the other methods at Fort Clark. The house floors clearly exhibit healthier and denser vegetation due to soil moisture, which causes cooling through evapotranspiration (Figure 5.19a). Thus, floor areas appear darker than the surrounding earthen berms (Figure 5.24d). Moreover, numerous small depressions related to storage pits, hearths, and post features are similarly indicated by "cool" anomalies. The same features are less frequently visible in the resistance and conductivity data sets, a consequence of the lower sampling density of both instruments. Although limited to a relatively small area within the village core, the GPR survey yielded results that substantiate the findings of other surveys (Figure 5.24e). The contrast between lodges and intermediate spaces is considerable. In fact, large amplitude reflections are characteristic of areas between lodge depressions. Such "noise" likely indicates substantial midden deposits between lodges that were purposely placed to fill and level the surface. Since the village core was occupied for the greatest duration, midden accumulated over time and elevated the ground surface, an idea that is supported by excavation data. Additionally, central hearth features are apparent within each lodge surveyed by GPR.

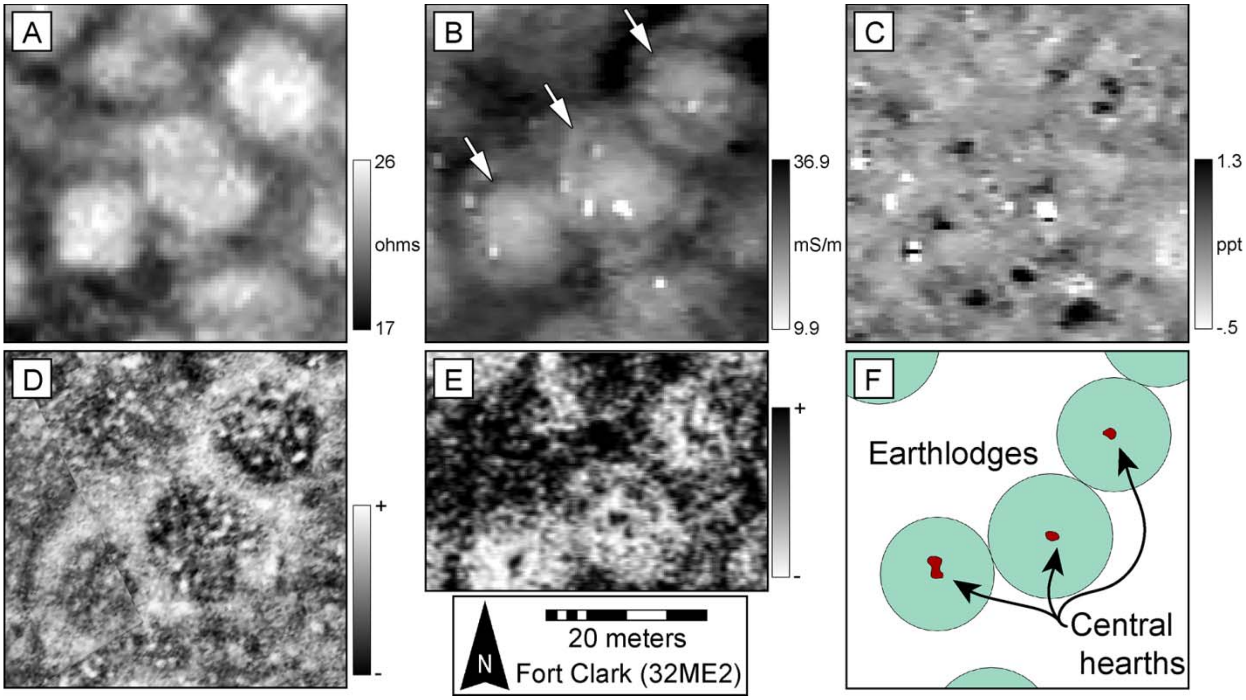

Figure 5.24. Examples of earthlodges visible in several remote sensing data sets, including a) earth resistance, b) electromagnetic conductivity, c) magnetic susceptibility, d) thermal infrared, e) ground-penetrating radar depth slice from approximately 75 cm below surface, and f) interpretations showing the locations of lodges and central hearths. White arrows point to particular architectural features discussed in the text.

Previously Unrecorded Earthlodges

One finding of earlier geophysical surveys within the village at Fort Clark was the identification of a single earthlodge not visible on the ground surface (Kvamme 2007a:214). Rather, the ground surface in the location of the previously unknown lodge is relatively level with adjacent areas between lodge depressions. Many dipolar anomalies are apparent in the magnetic gradiometry data in a roughly circular area that corresponds with the outline of the lodge. The anomalies indicate the presence of a considerable number of ferrous metal items while a metal detector survey of the area points to an abundance of nonferrous items such as brass, copper, and lead artifacts (Kvamme 2001:14-15). The abandoned and collapsed lodge was likely filled with refuse to level the surface after its occupation ended, much like other areas between houses near the village core. For this reason, the lodge had gone unrecorded until surveys within the village were undertaken in 2000. Moreover, Heller's (2009) analysis of aerial color and thermal infrared imagery suggested the potential for additional dwellings.

Considerable evidence of previously unrecorded earthlodges within the Mandan/Arikara village at Fort Clark exists among the various remote sensing data sets. Collectively, four data sets—magnetic gradiometry, earth resistance, thermal infrared, and airborne LiDAR—proved most useful in the task of identifying lodges, although subtle indications are evident in others (Figure 5.25). As depicted (Figure 5.25a-c), corroborating evidence of unrecorded lodges was common. Thus, potential dwellings with a magnetic signature such as a ring of high magnetism (lodge perimeter) surrounding a magnetic point anomaly (hearth) generally corresponded with thermal anomalies ("cool" floor) and in some cases very subtle topographic expressions (a berm or depression), which were more common farther from the village core. In other words, the same characteristics of earthlodges discussed previously were revealing of unrecorded lodges (Figure 5.25d).

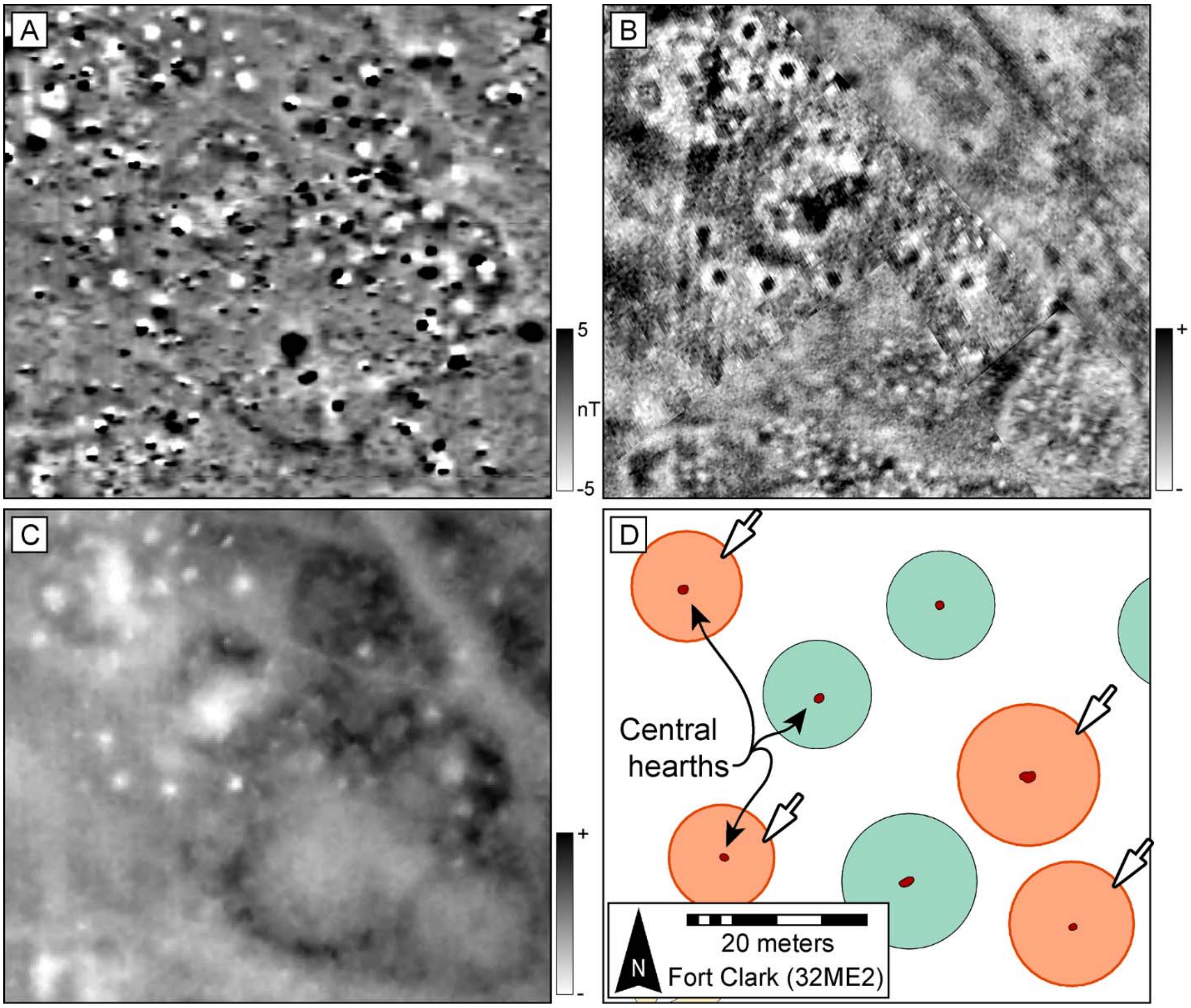

Figure 5.25. Examples of previously unrecorded earthlodges in a) magnetic gradiometry, b) thermal infrared, and c) elevation data. White arrows in the d) interpretation point to new structures (also identified by their orange color) with central hearths confirmed by soil coring.

Although each data set was examined independently for evidence of unrecorded lodges, data integrations such as those discussed previously were also generated and reviewed (Figures 5.11-5.13 and 5.26). Of the various approaches to integrating multiple remote sensing data sets, continuous data sums and products proved most useful (Figure 5.26a-d). The advantage of summing multiple data sets is that all are depicted simultaneously (Kvamme 2006a:66-67). Thus, anomalies that are only faintly visible in any particular data set often appear more evident in the data sum. For example, the perimeter of the earthlodge discovered by Kvamme (2007a:214) in

2000 appears roughly circular when the Fort Clark local relief model, thermal infrared, magnetic gradiometry, and earth resistance data are summed (Figure 5.26a). Features along its edge, including midden deposits and subterranean storage pits, and interior features like its central hearth are also noticeable, as is a northeast facing entrance to the dwelling just to the right (Figure 5.26a). Similarly, two adjacent houses on the west side of the village just outside the fortification ditch are clearly visible, more so than in the magnetic gradiometry, thermal infrared, or elevation data alone (Figure 5.26b, compare with the same two structures in the lower right of Figure 5.25a-c). On the other hand, the data product is generated by multiplying several data sets (Kvamme 2006a:66-67). As a consequence, prominent anomalies are even more evident in the data product, although the opposite is true for subtle anomalies. Yet, the result of multiplying the Fort Clark sky view factor visualization, thermal infrared, magnetic gradiometry, and earth resistance data is similar (Figure 5.26c, d). Lodge perimeters mark the locations of four previously unrecorded houses, three of which contain clearly visible central hearths. The fourth hearth, which was confirmed by my own soil coring, is less distinct in the magnetic gradiometry data. Thus, it is absent in the data product (Figure 5.26d).

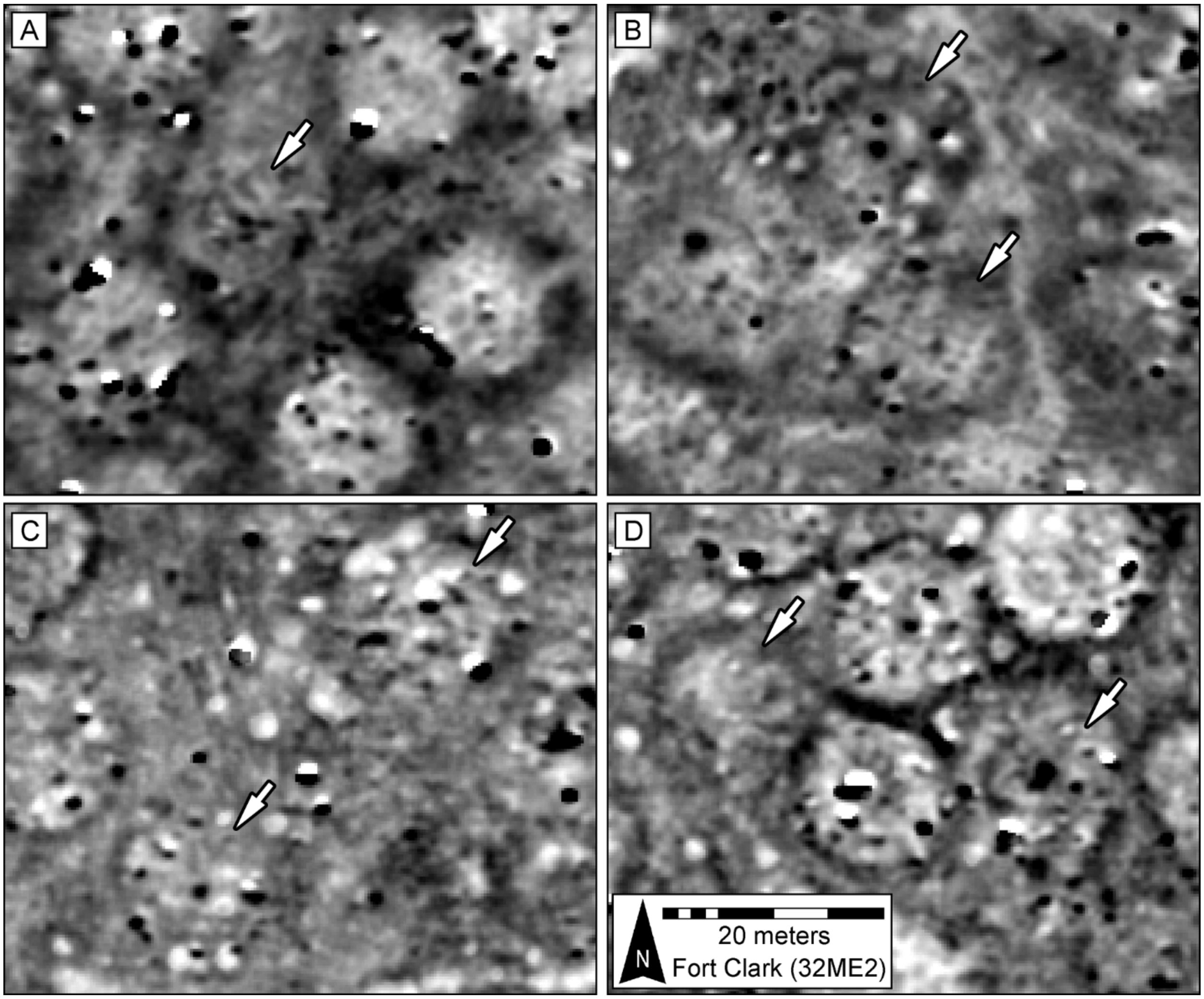

Figure 5.26. Previously unrecorded earthlodges revealed by continuous data integrations, including the sum of the local relief model, thermal infrared, magnetic gradiometry, and earth resistance data (a and b), and the product of the sky view factor visualization, thermal infrared, magnetic gradiometry, and earth resistance data (c and d). White arrows point to new structures.

A total of 89 potential unrecorded lodges were identified initially, although many were noted as unlikely. That is, limited evidence of many potential lodges was observed in single data sets. Still, an attempt was made to test each with a soil corer by me in September 2013. Coring was meant to detect central hearths, which are easily identifiable due to obvious layers of ash, charcoal, and burned earth. Thus, magnetic anomalies that appeared to be central hearths were cored. Likewise, in situations where dipolar anomalies obscured the locations of possible hearths, the centers of potential lodges were cored instead. A total of 37 hearths were confirmed by soil coring, indicating the locations of previously unrecorded lodges, each of which was apparent in at least two independent data sets and the data integrations (Figures 5.25 and 5.26). The digitized lodges are on average about 135 m^2 (s = 29.4 m^3) in area, substantially smaller than the houses mapped by Wood (1993b:Figure 3). This finding is perhaps a consequence of inaccurately digitizing the perimeters of the lodges, which in many cases were difficult to identify. Although some exhibited clear topographic expressions and were accurately mapped (Figure 5.25c), the perimeters of many were subtle because refuse has been deposited overtop of the lodges, the structures overlap adjacent dwellings, or surface indications have been obscured by other processes. A second explanation is that later structures at Fort Clark, or those that are visible on the ground surface, are in fact larger while earlier dwellings are smaller. Mean house floor areas of lodges in villages that pre- and postdate Fort Clark are discussed in Chapter 4. Notably, there is a clear trend toward larger houses later in time. Another 15 potential lodges are apparent in multiple data sets, although soil coring failed to locate a central hearth (Figure 5.27). The lodges are labeled differently for this reason. Again, many other potential lodges are located within the village, although their subtle signatures make positive identification difficult or impossible. An example discussed below further illustrates this point.

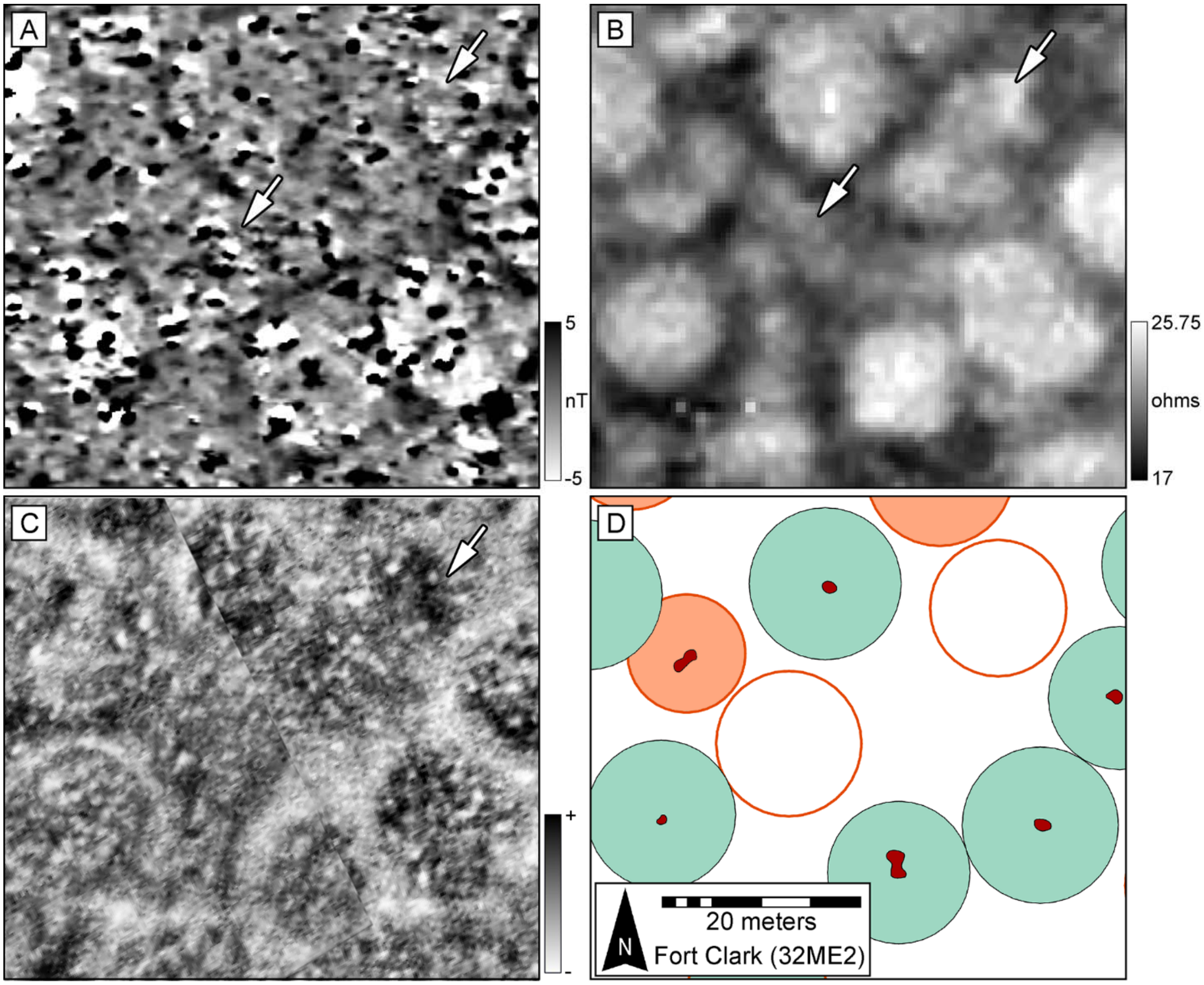

Figure 5.27. Examples of potential unrecorded earthlodges in a) magnetic gradiometry, b) earth resistance, and c) thermal infrared data. White arrows and the d) interpretation (circular structures outlined in orange with white centers) indicate potentially new lodges that were not confirmed by soil coring.

Log Cabins and Other Rectangular Structures

Besides the identification of a considerable number of previously unrecorded circular earthlodges, many rectangular log cabin features were documented within the village at Fort Clark by magnetic gradiometry, magnetic susceptibility, GPR, and airborne LiDAR. One feature, a partitioned rectangular structure with dimensions of approximately 7 m x 10 m, was initially identified due to its magnitude and unique shape among many circular anomalies in the magnetic gradiometry data (Figure 5.28). The anomaly was at first thought to represent a log cabin used by the Arikaras during their occupation of the site. After all, William Jacob Hays illustrated at least three rectangular cabins near the eastern terrace edge north of Fort Primeau in a sketch dated July 14, 1860 (Figure 5.4). The previous year, Elias J. Marsh (1936:99) traveled upriver on the steamboat *Spread Eagle* and observed on June 26 that some Arikaras "also have square log cabins." Similarly, Lewis Henry Morgan (1871:42) documented the presence of "several rectangular houses constructed of hewn logs" when he visited the settlement at Fort Clark in June 1862, a year after the site's abandonment. As he spoke of these structures in the same context as the village's abandoned earthlodges, the structures to which he referred were presumably occupied by the Arikaras and were not related to either trading post. Moreover, log cabins were built by the Arikaras at two subsequent villages, Star and Like-A-Fishhook (Latta 1863:194; Matthews 1877:3-4, 6-7; Metcalf 1963; Smith 1972). However, another reasonable possibility was that the rectangular anomaly instead indicated Fort Clark I, the first trading post constructed by James Kipp in 1824 beside the Mandan village (Witte and Gallagher 2012:119). The potential structure's large size and position near the fortification ditch on the west side of the village, which closely matches the location of Fort Clark I as relayed to Maximilian by Kipp (Witte and Gallagher 2012:119), was sufficient evidence to prompt test excavation by the PCRG in 2012. Prior to the excavations, more intensive geophysical surveys were undertaken with each instrument, the results of which are discussed elsewhere in further detail (Mitchell, ed. 2014; Mitchell and Wiewel 2014).

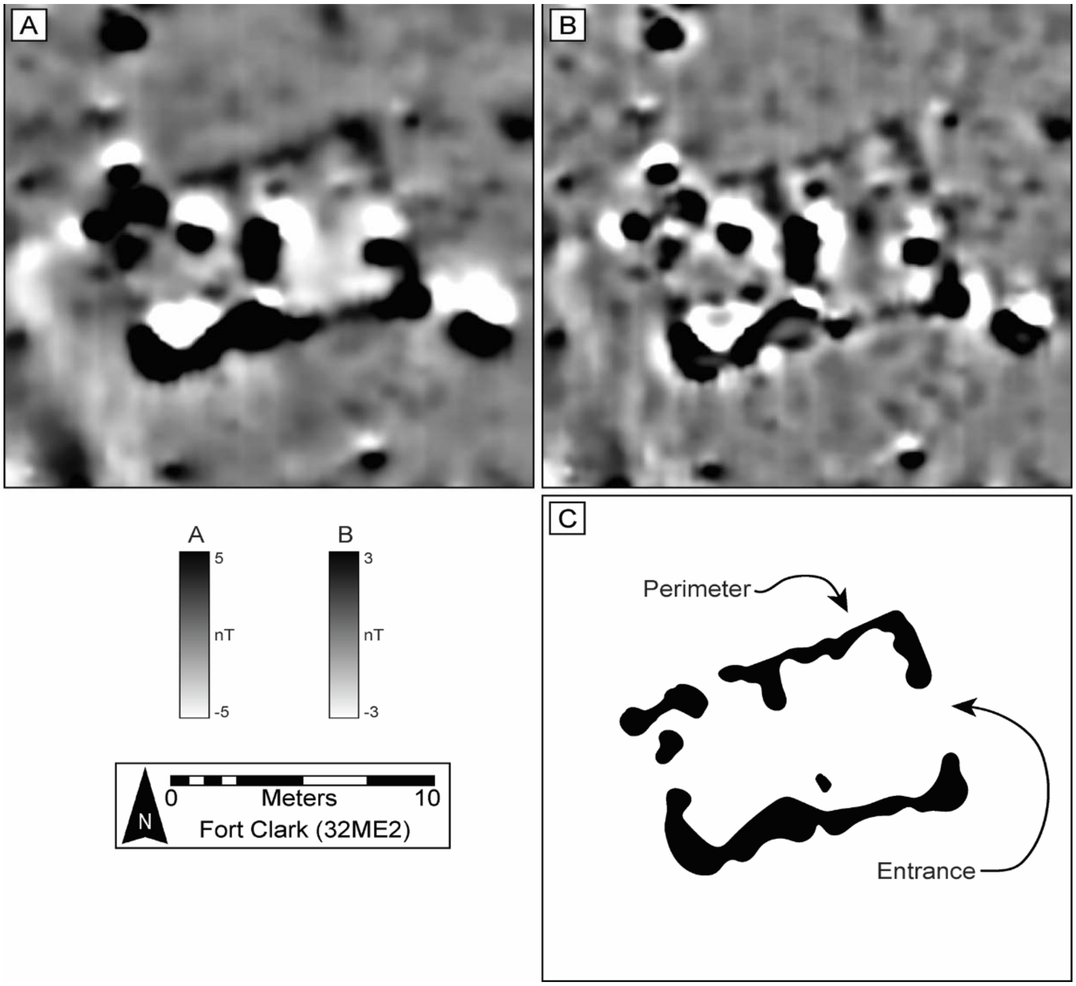

Figure 5.28. Magnetic gradiometry results, including a) processed gradiometry data, b) high-pass filtered data, and c) an interpretation of the Arikara log cabin.

The roughly rectangular structure appears robustly magnetic in the gradiometry data set (Figure 5.28a). Its longer walls are not parallel; rather, a slight flare of the walls on the eastern half of the feature is vaguely perceptible. The feature exhibits a partition near its center, creating two spaces or rooms nearly equal in area. Due to the flare of the walls, the eastern room is somewhat wider. The data appear to indicate a doorway near the center of the structure's eastern wall (along its short axis). A second door may be located opposite of this along the western wall. A high-pass filter reduces the magnitude of the dipolar anomalies and better illustrates the perimeter of the structure (Figure 5.28b). The filtered data appear to confirm the location of the doorway, a pattern that differs from Hays's sketch of Arikara log cabins (Figure 5.4). That is, Hays clearly depicts doorways near the centers of the longest walls of three cabins, although this minor detail may be portrayed inaccurately in his sketch. Perhaps his cabins are simply stylized representations, although they do exhibit some variation, indicating Hays's attempt to realistically portray them. The difference between his sketch and the interpretation may indicate that doorways generally faced away from the typical prevailing wind direction.

When initially discovered, several potential reasons for the robust magnetic signatures of this and several other rectangular anomalies were considered (Kvamme and Wiewel 2012:15). One possibility is that small builder's trenches were dug to socket vertical posts used for walls, a construction practice observed at the nearby Fort Clark trading post for its palisades (Hunt 2003b:138-161; Kvamme 2002:19-20). The decay of wooden posts would certainly elevate magnetism (Aspinall et al. 2009:24-25), and infilling of trenches with magnetically enriched soils would enhance susceptibility as well. Likewise, subtle mounding of topsoil around the perimeters of the structures would contribute to their elevated magnetic signatures. Another probable source of their elevated magnetism is that magnetic footing or foundation materials were used during construction. In fact, Kvamme (2002:12) confirmed that the local sandstone used during the construction of the trading post's western bastion is indeed magnetic. Additionally, two of the Arikara cabins illustrated by Hays have chimneys, and the local magnetic sandstone was perhaps used in their construction. Furthermore, the rectangular outlines of several structures are quite noticeable due to a considerable number of ferrous metal artifacts as indicated by their associated strong magnetic dipolar anomalies. Finally, their apparent elevated magnetism is possibly due to burning, which increases magnetic susceptibility, although the features perhaps acquired thermoremanent magnetization if their burning was intense.

The magnetic susceptibility survey results largely parallel the findings produced by magnetic gradiometry, although additional insights are yielded (Figure 5.29). The EM38B electromagnetic induction instrument is less responsive to ferrous metals (although it detects non-ferrous metals). For this reason, the data lack many of the robust dipoles visible in the gradiometry data, the presence of which obscures the structure's perimeter and makes its interpretation problematic. The structure's outer walls, its interior partition, and the northeast-facing doorway are better illustrated by susceptibility (Figure 5.29a). In fact, the broad linear susceptibility anomaly that represents the building's perimeter closely corresponds with excavation results discussed further below.

Moreover, the structure's general shape is revealed by airborne LiDAR as its outer walls and partition are approximately 5 to 10 cm higher than the surrounding ground surface and interior floor areas (Figure 5.29b). A two-dimensional integration, with the susceptibility data overlaid on a shaded relief surface generated from the elevation data, clearly shows the relationship between the two data sets. Specifically, the mounded soil around the structure's perimeter likely contributes to the enhanced magnetic signature of the building (Figure 5.29b).

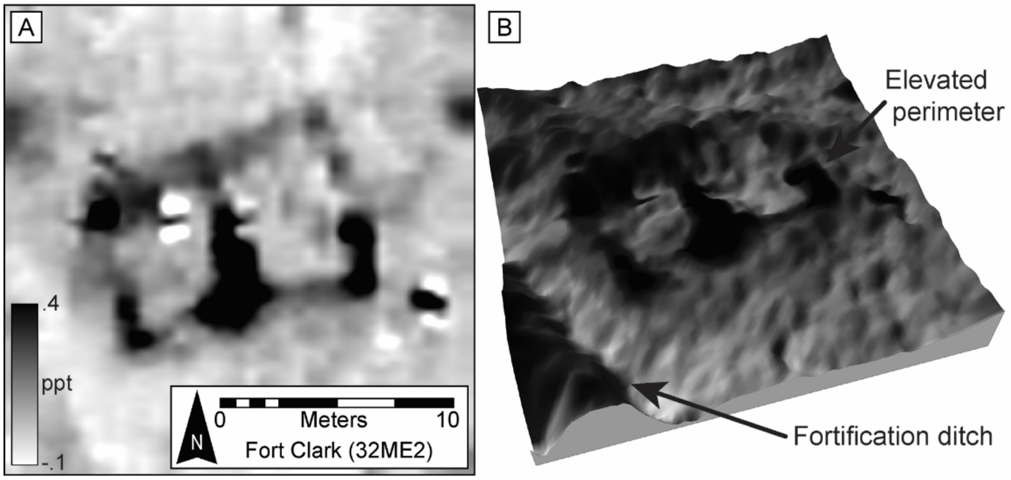

Figure 5.29. Views of the Arikara log cabin, including a) magnetic susceptibility results and b) susceptibility data overlaid on airborne LiDAR elevation data.

Multiple GPR data sets were acquired in the area of the rectangular structure in question, and each produced unique and useful information regarding the feature and other significant features which underlie it. Depth slices generated from a radar survey with a 400 MHz antenna and transects oriented north-south only vaguely indicate the rectangular outline of the structure, although some interior linear anomalies, which may point to partitions or separate rooms, are visible (Figure 5.30a). However, the data suggest the structure is located at a depth of less than 20 cm, an inference later confirmed by excavation. More importantly, deeper depth slices reveal a roughly circular anomaly, approximately 12.25 m in diameter with a smaller circular anomaly near its center (Figure 5.30b). Given these findings, it would appear that a circular earthlodge with a possible northeast facing entryway is located below the rectangular structure.

A second radar survey with a 900 MHz antenna with north-south transects separated by 25 cm reveals additional architectural details. The depth slices appear largely similar to those from the initial survey. The rectangular outline of the structure is visible at a depth of approximately 13 cm, and a possible entrance is noticeable in the same location suggested by the magnetic data (Figure 5.30c). Moreover, the radar data show small “point” anomalies marking the sides of the potential doorway, which may be related to vertical posts that framed the entrance and serve as a door jamb. On the other hand, the interior partition is hardly visible, although other linear anomalies or linear alignments of small point anomalies may suggest additional partitions within the structure. Additionally, the outline of the underlying circular earthlodge is vaguely visible in the 13 cm depth slice, hinting that its depth is shallower than was suggested by the initial survey (Figure 5.30c). Still, the lodge and its central hearth are only partially revealed in a 28 cm depth slice, although the northeast-facing entryway is clearly visible (Figure 5.30d).

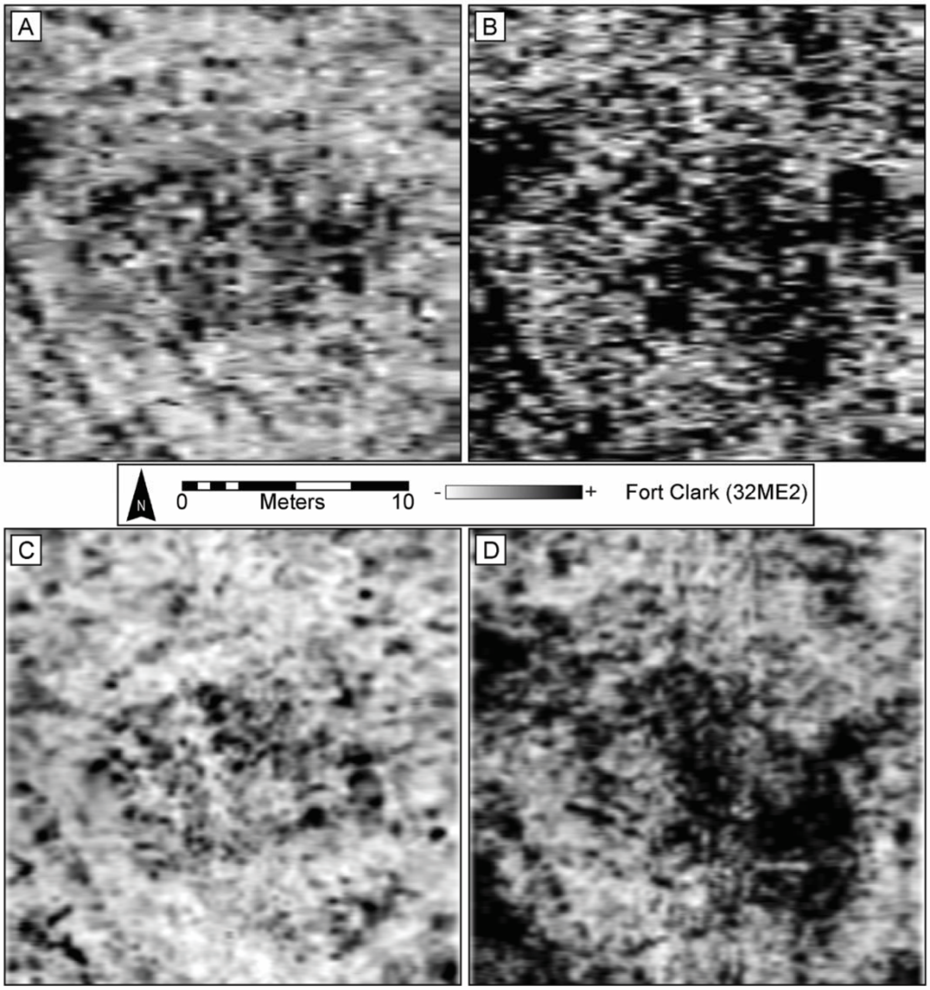

Figure 5.30. Ground-penetrating radar survey results in the area of the Arikara log cabin, including 400 MHz north-south data at approximate depths of a) 16 cm and b) 51 cm. Comparable data from a 900 MHz antenna at approximate depths of c) 13 cm and d) 28 cm.

Finally, a third GPR survey of a larger area with a 400 MHz antenna and east-west transects yielded better results (Figure 5.31a). The rectangular structure's walls and inner partition are clearly indicated, a result comparable to that shown by the magnetic data (Figure 5.31a). Two pairs of point anomalies separated by about 1.5 m near the structure's center suggest a possible opening in the inner partition, framed by posts as described above for the northeast-facing doorway (note that the interpretive illustration [Figure 5.31d] depicts the partition as a single wall). Although multiple postmolds were revealed in this location during excavations, each appeared to be support posts associated with the underlying earthlodge rather than a structural element of the superimposed log cabin (Mitchell and Wiewel 2014). However, the known features do not correspond definitively with the radar point anomalies, meaning the anomalies may indicate additional lodge supports or framing posts associated with the rectangular structure. More importantly, the GPR data plainly show a circular lodge with a northeast facing entryway (Figure 5.31b). Interestingly, the possible doorway of the overlying building is positioned in nearly the same location (Figure 5.31a-d). The central hearth of the lodge is clearly visible in the 16 cm and 35 cm depth slices as well (Figure 5.31a-d).

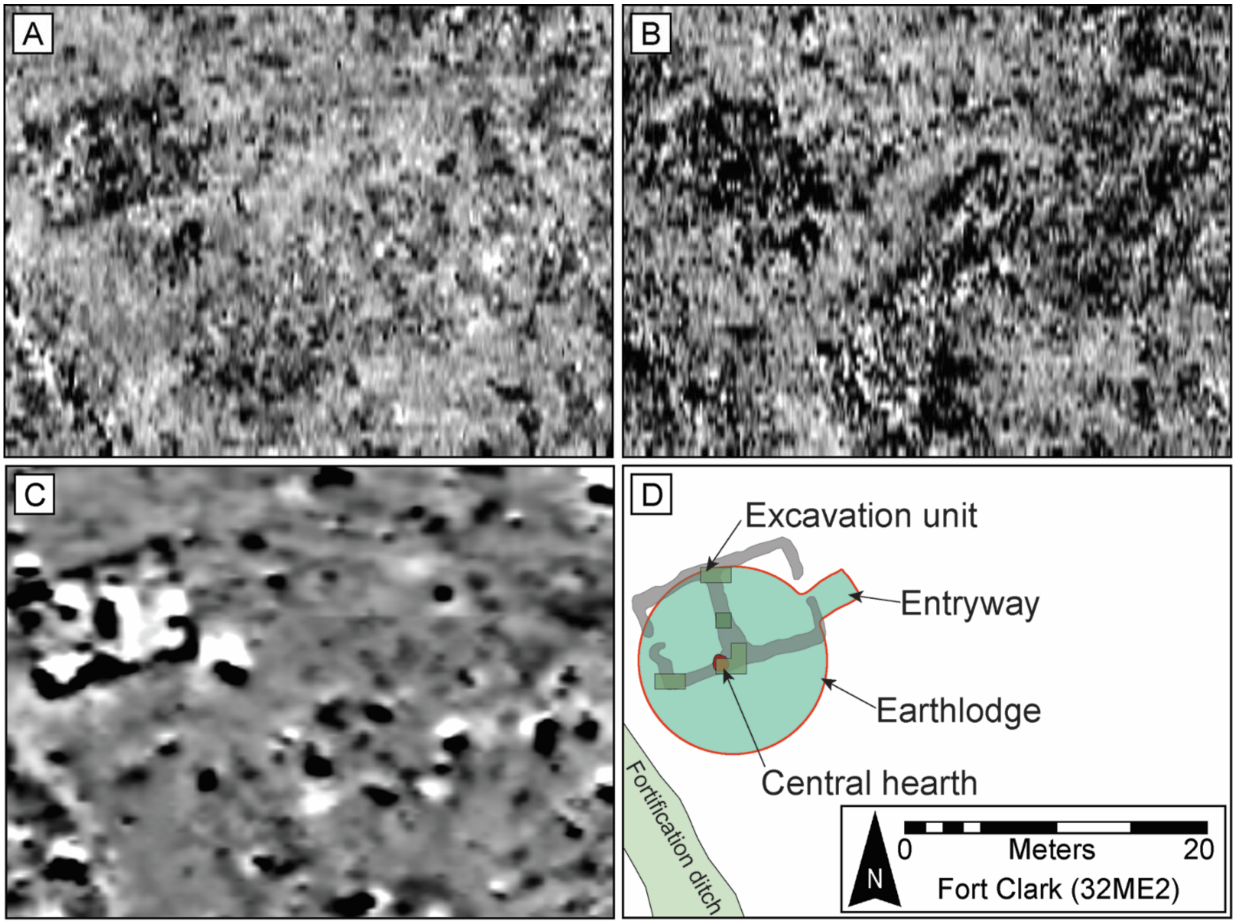

Figure 5.31. Additional ground-penetrating radar results in the area of the Arikara log cabin , including 400 MHz east-west data at depths of a) 16 cm and b) 35 cm as well as c) gradiometry data for comparison and combined d) interpretations from GPR data sets.

Among numerous findings, the anomaly thought to represent a central hearth feature was confirmed during excavations by the PCRG in 2012 (Mitchell and Wiewel 2014). The stone-lined hearth measures approximately 1.2 m in diameter and extends to an approximate depth of 58 cm below the surface (Figure 5.32, *left*). The hearth in particular and perhaps other features revealed during excavations factor into the rectangular structure's magnetic signature. Another insight yielded by the excavations is the correspondence between dipolar anomalies and ferrous metal objects, of which several were excavated. Likewise, several potentially magnetic stone artifacts appear to be associated with large dipolar anomalies along the structure's perimeter. Burning was probably the greatest contributing factor to the structure's elevated magnetism. Excavations revealed several burned wooden posts and sill planks, some of which are structural elements of the building (Figure 5.32, *right*). The burned wood was associated with substantial quantities of charcoal, ash, and burned earth at depths of about 10-18 cm below the surface. Although the charcoal, ash, and burned earth concentrations were generally diffuse, they correspond with the loci of the burned wooden elements and together align with the outer walls and inner partition of the structure as indicated by the magnetic data, a result that supports the premise that the structure's potential burning was one reason for its apparent magnetic signature. Moreover, multiple lines of evidence, including temporally diagnostic artifacts, site chronology, and use-life estimates of structures indicate the feature in question is an Arikara log cabin that dates to the mid-1850s rather than Fort Clark I (Mitchell 2014b, 2014c; Mitchell and Wiewel 2014).

Figure 5.32. A stone-lined central hearth identified during excavation of an Arikara log cabin (left). Charcoal, ash, and burned earth indicated the outer wall of the cabin (right). Left photograph by Kenneth L. Kvamme. Used with permission. Right photograph by the author.

Initially, across the site 18 additional rectangular anomalies were identified in the magnetic gradiometry, magnetic susceptibility, thermal infrared, and airborne LiDAR data sets, although several were only subtly indicated by a single method (Mitchell and Wiewel 2014). However, further inspection of the anomalies eliminated two potential cabins, one of which protruded into a deep earthlodge depression and the other which overlapped with a sloping borrow area, leaving a total of 16 tentative Arikara log cabins within the village at Fort Clark besides the cabin confirmed by excavation (Figure 5.33). Like the cabin discussed previously, most exhibit robust magnetic signatures that are likely caused by a combination of ferrous metal artifacts, magnetic stone, and burning. However, the outlines of several cabins are obscured by the high density of dipolar anomalies, such that the structures are more clearly evident in the susceptibility and elevation data sets. Among the 16 structures are two located on the terrace edge that likely represent cabins depicted by Hays in July 1860.

Most of the structures measure between approximately five to seven meters on a side (Figure 5.33). However, at least three, including the one discussed previously in greater detail, are around 10 m in length on at least one side. Several exhibit interior partitions that split the structures into at least two rooms, although more subtle linear anomalies possibly indicate additional partitions within some structures. Their average area is approximately 43.9 m^2 (s = 12.5 m^2; n = 17), although they vary from about 17.5 to 72.6 m^2. Thus, the average size of cabins is considerably smaller than that of earthlodges at Fort Clark. This finding is significant, particularly in terms of population estimates for the later Arikara occupation.

Beside log cabins, three subtle anomalies with rectangular forms are evident in the magnetic data (Figures 5.23d [white arrow] and 5.34). Although the anomalies vary somewhat in size, their dimensions are roughly 3.5 m x 7.5 m on average. Rather than log cabins, the anomalies may represent drying racks or small corrals, the first of which are illustrated by Bodmer within the Mandan village (Ruud 2004:Plate 304). Likewise, Hays's (Figure 5.4) sketch of the Arikara village includes two drying racks or scaffolds near the plaza, and Morgan's (1871:43) description of drying racks within the abandoned Arikara village include estimated dimensions, which closely match the sizes of the anomalies. Two of the anomalies are located west of the village (Figure 5.34a, b). While the first is isolated from other structures, the second is situated southeast of an earthlodge on the opposite side of a trail (Figures 5.23d [white arrow] and 5.34b). The third anomaly is located on the south side of the plaza and exhibits elevated susceptibility, perhaps due to the introduction of organic matter associated with drying racks (Figure 5.34c). Presumably, many other subtle magnetic anomalies indicate features like drying racks, but differentiating them from more robust anomalies is difficult or impossible.

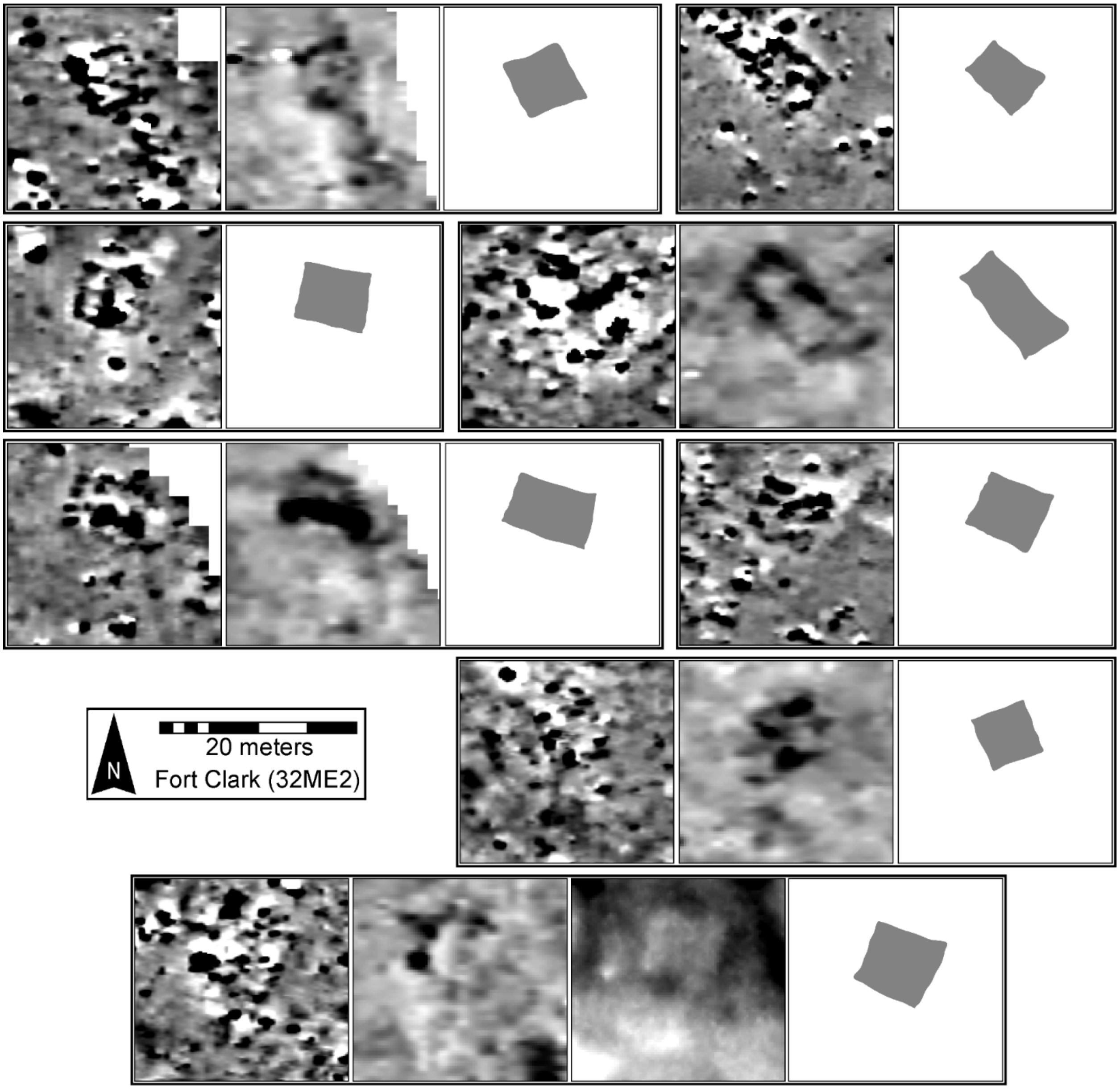

Figure 5.33. Views of eight Arikara log cabins at Fort Clark shown in magnetic gradiometry, magnetic susceptibility, and elevation data. Interpretations of each cabin are to the right.

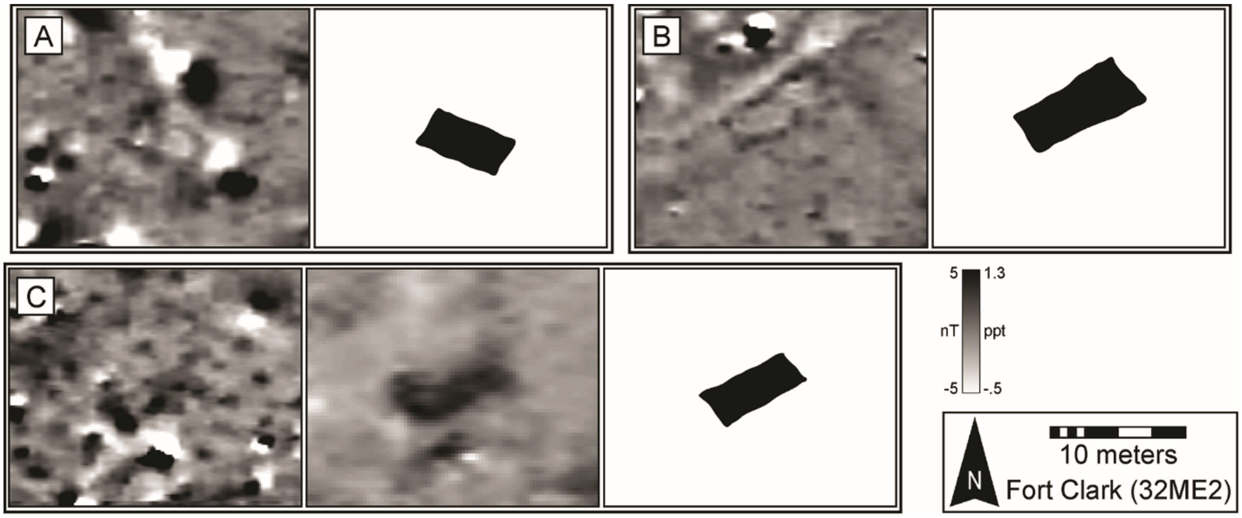

Figure 5.34. Examples of rectangular anomalies that likely indicate drying platforms or small corrals, located a) west of the village, b) west of the village adjacent to an earthlodge, and c) on the south side of the plaza.

Discrete Magnetic Anomalies and Associated Features

Discrete magnetic anomalies are undoubtedly the most common anomaly type within the Native village at Fort Clark. In general, the roughly circular anomalies are about 1-3 m in diameter, although there are several forms, including dipolar, robust monopolar, positive, and negative anomalies (Figure 5.35). Importantly, the type of expression is meaningful in terms of each anomaly's potential source. Among the most common are thousands of anomalies with dipolar forms (Figure 5.35, *upper right*). Again, dipolar anomalies, or those with high-value positive and negative pairs typically indicate ferrous metal, including both artifacts related to the nineteenth-century occupation and recent debris. Although the site is uncultivated, maintenance activities, nearly a century of recreational visitors, and archaeological investigations have introduced ferrous metal, meaning examples of both would be expected within the Mandan/Arikara village. In fact, numerous dipolar anomalies are associated with most earthlodges, an unsurprising finding given the proximity of Fort Clark and Fort Primeau. In fact, the density of dipolar anomalies in some areas is such that individual anomalies cannot be discriminated. Given the documented significance of trade, many dipolar anomalies likely represent iron artifacts as small as nails or as large as a hoe blade, like those items recovered during the excavations of the Arikara log cabin (Mitchell and Wiewel 2014). Of course, the anomalies would represent a fraction of the metal items since small iron objects may be buried too deeply to be detected and many other artifacts consist of brass, copper, or lead, an inference supported by limited metal detector surveys within the village (Kvamme 2002).

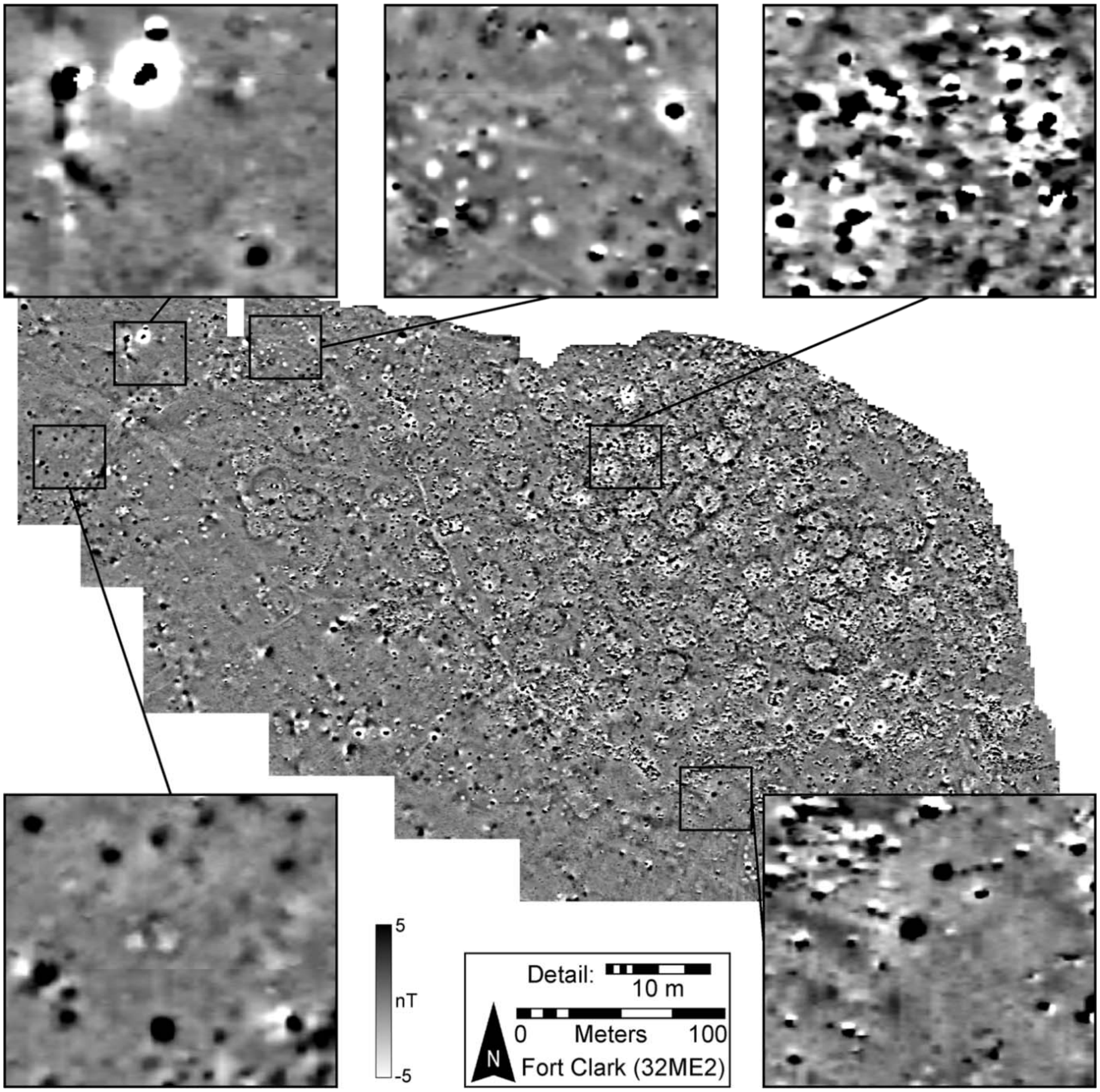

Figure 5.35. Examples of discrete magnetic anomalies revealed by magnetic gradiometry, including dipolar (all but especially upper right), robust monopolar (upper left), positive (bottom left and right), and negative anomalies (middle top).

Hypothetically, one could compare nonferrous and ferrous metal distributions since magnetic gradiometry is sensitive to the latter while EMI detects all metals. In this instance, however, such a comparison is impractical (compare magnetic gradiometry and magnetic susceptibility data in Figure 5.33). First, the sampling density of EMI was half that of gradiometry (Appendix #). Thus, fewer metal items were detected by susceptibility simply due to the difference in survey coverage. Moreover, the lateral sensitivity of the gradiometer is greater; the EMI instrument only responds to metal items when it is placed adjacent to or directly above said objects. What difference, if any, exists in the distributions of nonferrous and ferrous metal is therefore impossible to ascertain based on the given data sets.

Still, the density of dipolar anomalies in different areas of the village is telling. That is, dipolar anomalies are concentrated in certain lodges rather than randomly distributed (Kvamme 2007a:220). If dipolar anomalies were concentrated within houses near the plaza, it would be reasonable to infer that the lodges were occupied by higher status families or families with greater access to metal trade goods. After all, household status varied considerably among the Mandans, and prominent Mandans were said to have occupied houses around the plaza of Mitu'ahakto's during the nineteenth century (Bowers 2004:27-28; Libby 1908:Plate 2, 499). The Arikaras had a highly stratified social organization as well, and distinguished families allegedly surrounded the plaza of Star, the village they built after leaving the community at Fort Clark (Libby 1908:506; Parks 2001:374-375).

GIS methods like those discussed in Chapter 3 were used to identify dipolar anomalies. First, two threshold layers, one with all magnetic values above 7.5 nT (*nanotesla*) and the other with values below -7.5 nT, were created from the gradiometry data set. A .5 m buffer was applied to both layers, and a Boolean AND operator was used to produce a new layer showing locations where the buffered layers overlap. In other words, the layer shows locations where adjacent strong positive and negative magnetism co-occur (i.e., dipolar anomalies), which total 1,543, but does not include isolated (i.e., monopolar) positive or negative anomalies. GIS methods were then used to quantify the number of dipolar anomalies within each earthlodge. The count of dipolar anomalies per lodge at Fort Clark shows a pattern that differs from the expected (Figure 5.36). Houses near the plaza generally have moderate and low counts of dipolar anomalies. Likewise, dwellings far from the plaza tend to have very few dipolar anomalies. On the other hand, most lodges with moderate and high counts of dipolar anomalies are located nearer the center of the village. An alternative explanation is that dipolar anomaly counts are related to lodge size, with the highest counts of dipolar anomalies found in the largest structures (Figures 5.22 and 5.36). Yet, Pearson's *r* shows that the relationship between structure size and dipolar anomaly count is only weakly positive ($r = .31$; $df = 83$; $p < .005$).

Instead, the distribution of dipolar anomalies appears to be primarily associated with the intensity and duration of occupation in different areas of the village, a topic discussed previously in relation to midden deposits. That is, dipolar anomalies (±7.5 nT) are generally densest within the village core, an area that was occupied continuously for nearly four decades (Figure 5.35). Optimized hot spot analysis, an automated tool that determines the local Getis-Ord Gi* statistic from aggregated incident data, further illustrates clustering of dipolar anomalies within the village. Specifically, the tool reveals areas with significantly higher or lower densities of dipolar anomalies from a random distribution. Although the dipolar anomaly count per lodge varied considerably across the village, clustering of all dipolar anomalies is more apparent (Figures 5.36 and 5.37). Several clusters with high z-scores are visible within the village core, the largest cluster of which surrounds the plaza. Overall, much of the village core exhibits moderately high and high z-scores, which show the density of dipolar anomalies is greater than would be expected with a random distribution of anomalies. The central z-scores, which indicate a distribution of dipolar anomalies that is not significantly different from random, parallel the fortification ditch. In contrast, moderately low and low z-scores are common outside the fortification ditch and represent areas with a lower density of dipolar anomalies. The significance of such patterning is discussed further in Chapter 6.

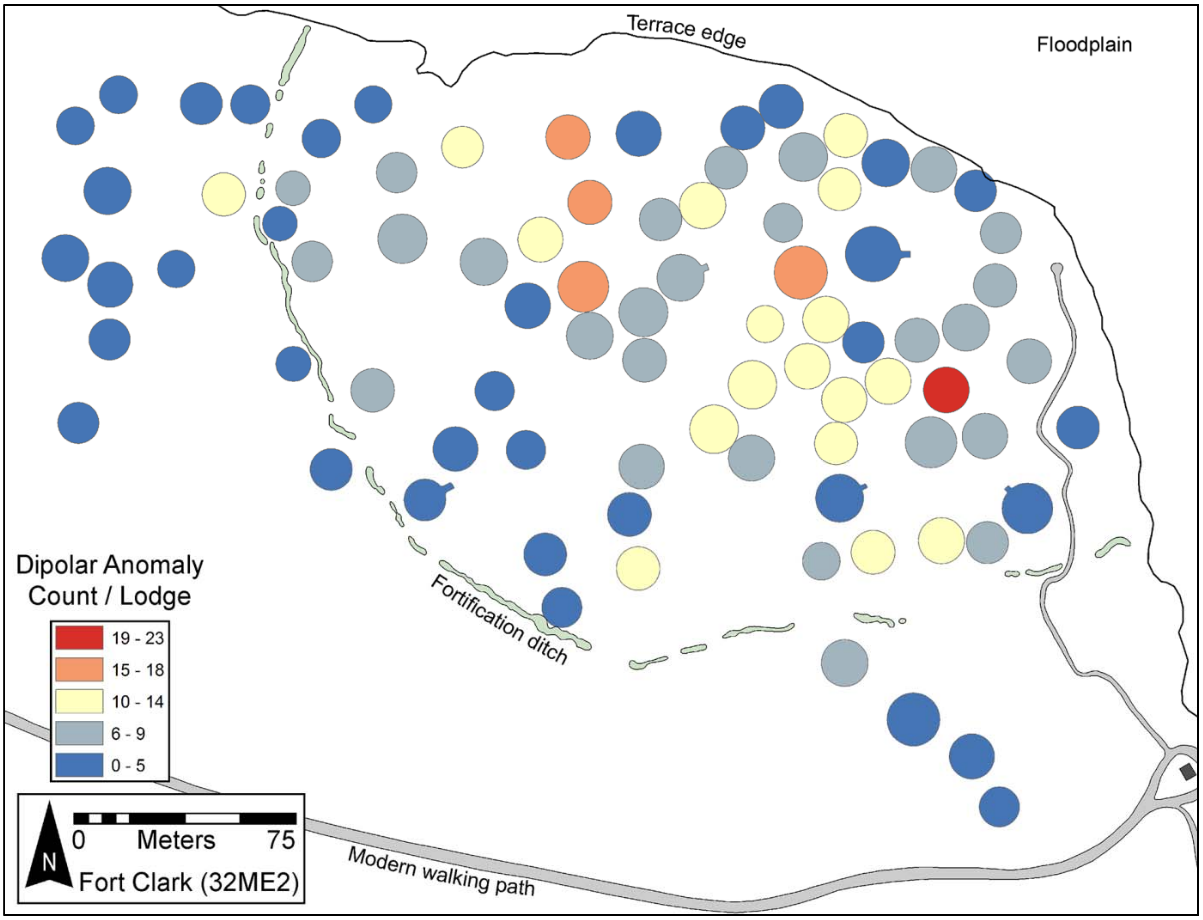

Figure 5.36. Choropleth map illustrating the count of dipolar anomalies (±7.5 nT) per lodge at Fort Clark.

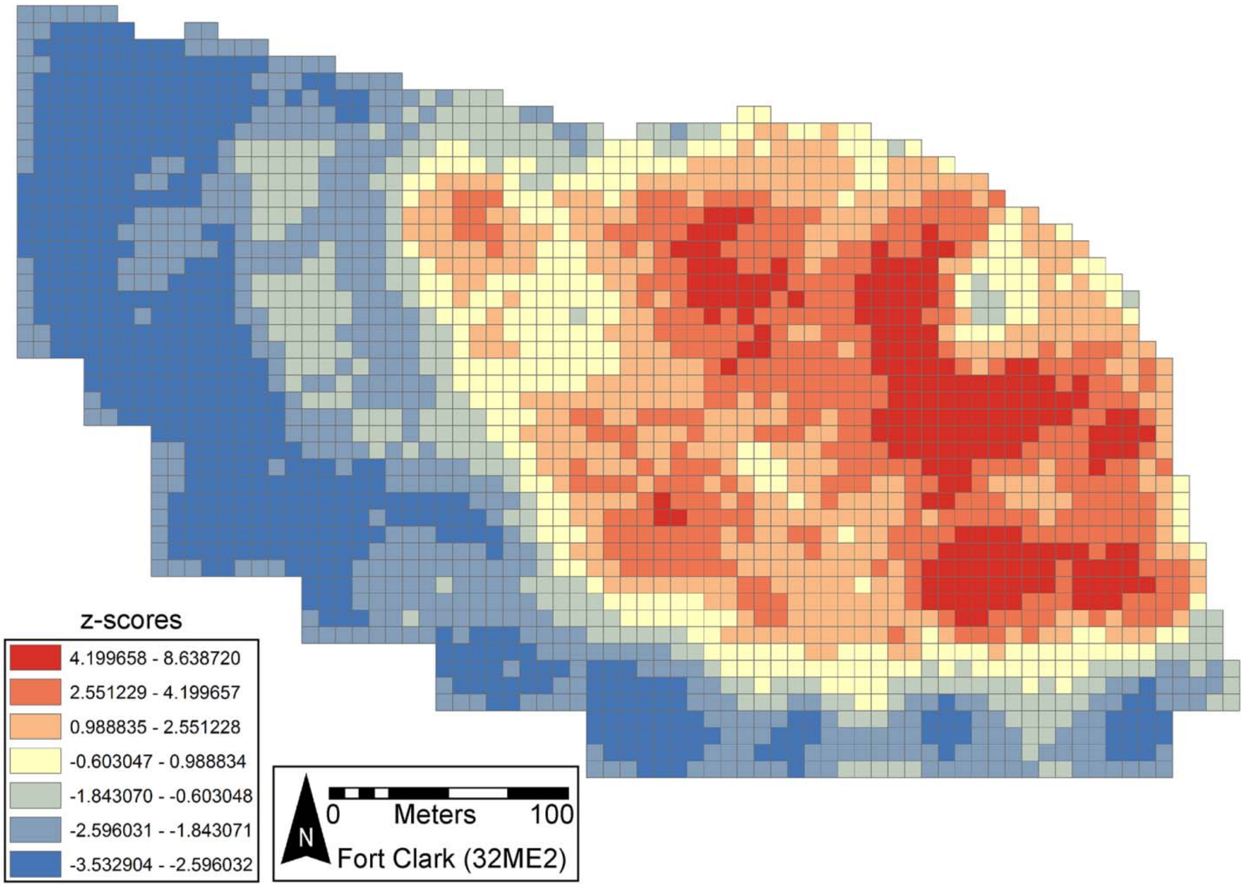

Figure 5.37. A fishnet grid generated with an optimized hot spot analysis showing the density of dipolar anomalies (±7.5 nT) represented by z-scores.

A related type of anomaly, a robust monopole, exhibits a unique signature in which the positive pole (black) is surrounded by the negative pole (white) that indicates an object with its long axis oriented vertically (Figure 5.35, *upper left*). At least one example of a robust monopolar anomaly at Fort Clark relates to a site datum, although others may indicate nails or rebar near excavation units. Moreover, the magnetic gradiometry data reveal the locations of thousands of positive monopolar[2] magnetic anomalies (Figure 5.35, *bottom left and right*). Such anomalies are generally associated with hearths, storage pits, midden, and burned support posts. The most common of these features are hearths and storage pits, although as discussed previously, differentiating their magnetic signatures is difficult, if not impossible. Magnetic

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[2] As mentioned in Chapter 3, the anomalies appear monopolar but are in fact dipolar in form.

anomalies representing hearths and storage pits are roughly similar in size and magnitude, although they are formed by different processes. Hearths exhibit statistically greater magnetism (Bales and Kvamme 2005; Kvamme and Ahler 2007) due to thermoremanent magnetism from their long-term and regular use at high temperatures, although some storage pits appear similar magnetically. Storage pits are represented by induced anomalies since the features are typically filled with magnetically enriched refuse or eroded topsoil once their use ends. Context facilitates interpretations in some instances. Given a wealth of excavation results, historical documents, and geophysical surveys, it is reasonable to assume that each earthlodge contains a central hearth. Other magnetic anomalies within lodges likely represent storage pits, especially anomalies located around the perimeters, although some could instead indicate auxiliary hearths or burned posts.

Again, GIS methods were used to identify positive monopolar magnetic anomalies at Fort Clark. Given the density of magnetic anomalies, distinguishing the positive magnetic anomalies from others is difficult. For this reason, a circular low-pass filter 1 m in diameter was applied to the gradiometry data set (Figure 5.38a, b). The filter served two purposes: the data were smoothed, meaning subtle magnetic variation was removed, and the rounded discrete magnetic anomalies became more obvious. Moreover, two threshold maps were generated to isolate all magnetic values above 3.5 nT and 5 nT from low magnetic noise (Figure 5.38c). A second layer depicting dipolar anomaly locations was generated from the smoothed gradiometry data set following the steps discussed previously. To better approximate the rounded shapes of most dipolar anomalies, however, a second .5 m buffer was applied followed by the 1 m circular low-pass filter (Figure 5.38d). This final layer was particularly useful since many of the anomalies visible in the threshold layers are related to dipolar rather than positive monopolar anomalies. All layers were used in combination to identify and digitize positive monopolar magnetic anomalies greater than .25 m^2 in area (Figure 5.38e). Again, central hearths were confirmed by coring, but many other positive magnetic anomalies may represent several other types of features.

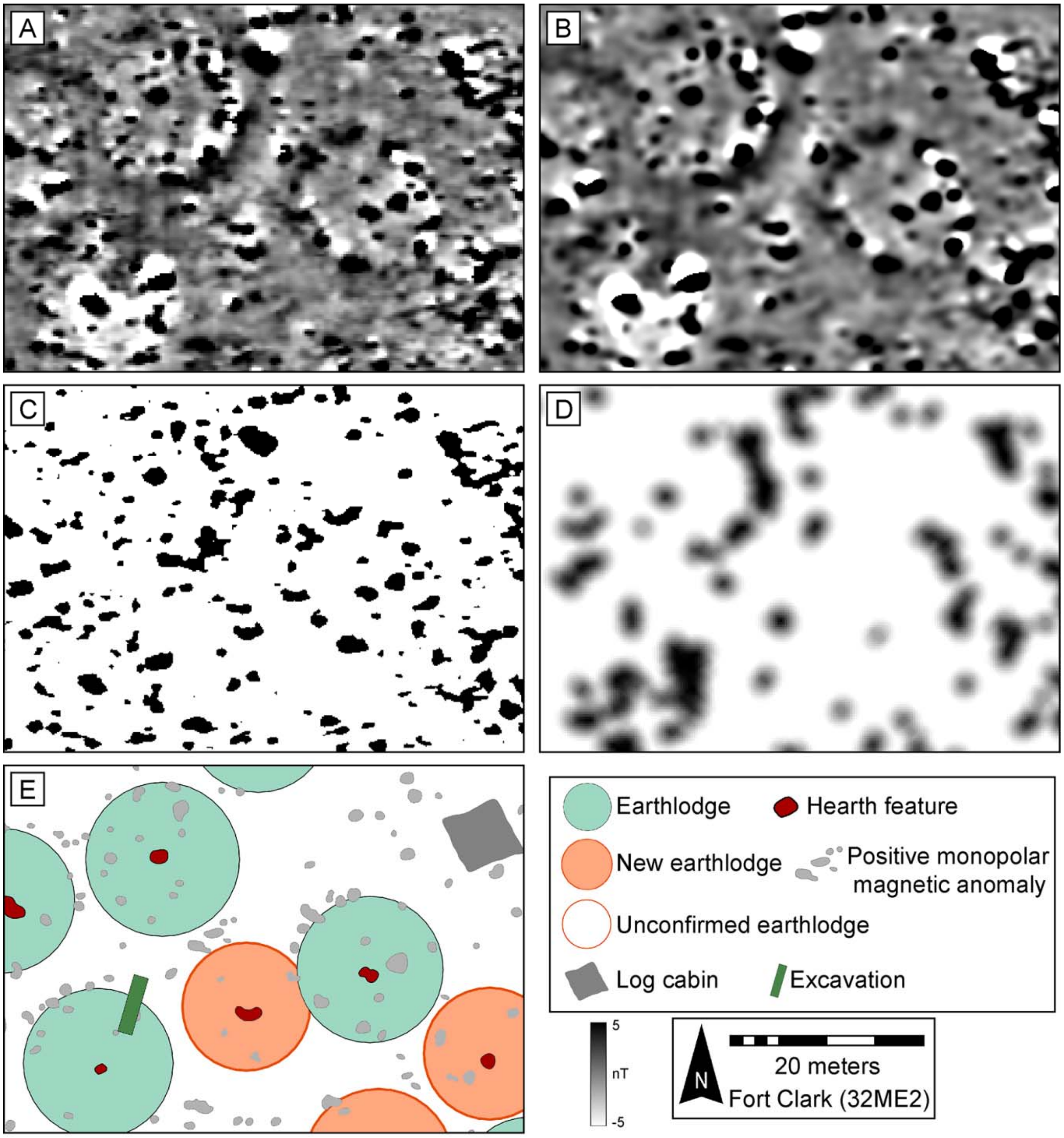

Figure 5.38. Close-up views of lodges and a single log cabin at Fort Clark showing different feature types in a) the magnetic gradiometry data, b) the circular low-pass filtered data, c) a 3.5 nT threshold layer, d) a layer illustrating the locations of most dipolar anomalies, and e) an interpretive map with a key for that map.

Interestingly, the distribution of 2,708 positive monopolar magnetic anomalies greater than 3.5 nT in magnitude parallels that of dipolar anomalies (Figures 5.37 and 5.39). That is, the density of positive monopolar magnetic anomalies is greatest within the village core near the plaza, a finding revealed by optimized hot spot analysis (Figure 5.39). In this particular case, aggregation polygons generated during the initial test of dipolar anomaly clustering were used to yield a similar fishnet grid. Outside the fortification ditch, positive monopolar magnetic anomalies are significantly less dense than would be expected with a random distribution of points. Thus, multiple lines of evidence, including midden deposit depths, dipolar anomaly clustering, and the density of positive monopolar magnetic anomalies, are indicative of occupation duration within different areas of the village.

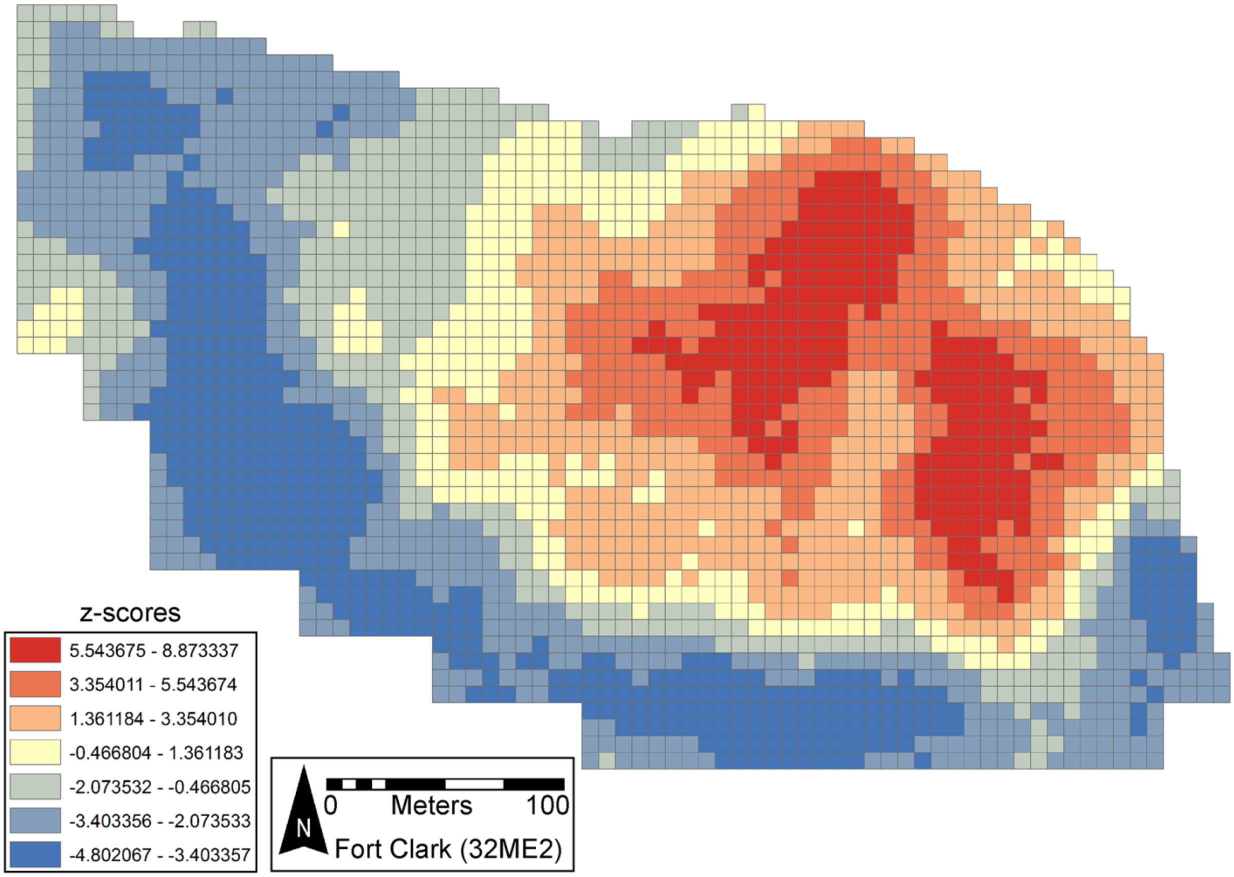

Figure 5.39. Results of an optimized hot spot analysis showing the density of positive magnetic monopolar anomalies (>3.5 nT) represented by z-scores.

Additionally, a considerable number of monopolar negative magnetic anomalies and associated “small pit” features are evident within several data sets, including magnetic gradiometry, thermal infrared, airborne LiDAR, and aerial color imagery (Figure 5.40). These pit features, which are approximately 1-3 m in diameter and typically around .25 m in depth, are usually visible magnetically because of an absence of soil, which results in a low or negative magnetic anomaly (Figure 5.40a). Like earthlodge depressions, the smaller pit features trap moisture and foster vegetation growth, which leads to cooling through evapotranspiration and a dark signature in the thermal infrared imagery (Figure 5.40b). In fact, soils within depressions consistently show greater moisture than surrounding soils based on coring undertaken in 2013. The correspondence between the magnetic and thermal infrared anomalies and features visible on the ground surface is made evident by the sky view factor visualization and aerial color imagery (Figure 5.40c, d). Importantly, Wood (1993b:550) interpreted the pit features primarily as collapsed storage pits and graves. Most burials were located southwest of the village in an area that was generally avoided during the recent investigations.

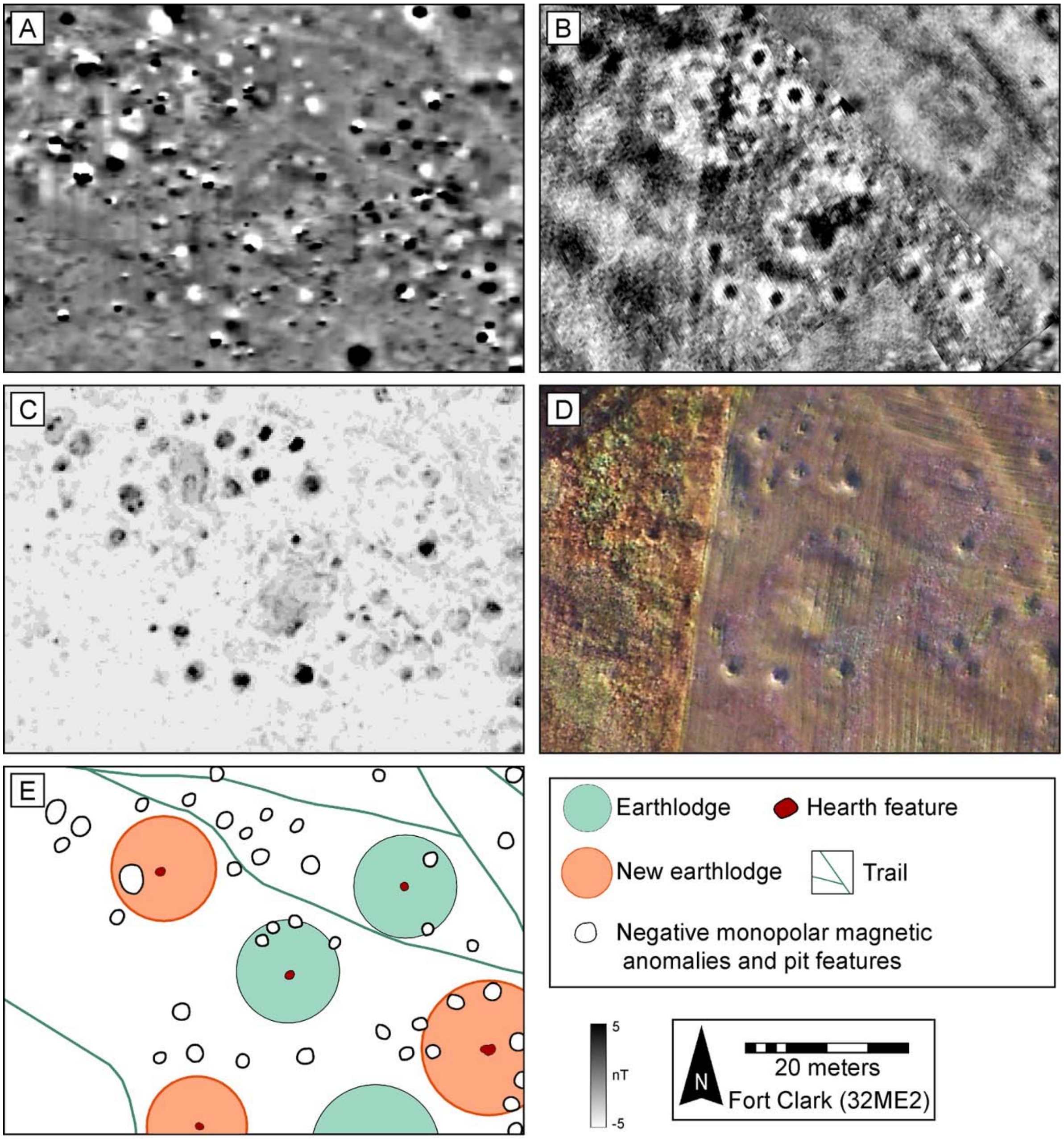

Figure 5.40. Examples of negative monopolar magnetic anomalies and pit features visible in various remote sensing data sets, including a) magnetic gradiometry, b) thermal infrared, c) the sky view factor visualization, and d) a 2004 aerial color orthophotograph. An e) interpretive map with a key for that map illustrates the locations of pit features and negative magnetic anomalies.

Presumably, the Arikaras would have emptied the contents of many storage pits when the village was abandoned in 1861, meaning most would have backfilled naturally over time. Whatever organic materials were left would have decayed, causing the pits to subside over time. In fact, Lewis Henry Morgan (1871:40) observed multiple empty storage pits within the abandoned Arikara village during his visit in 1862 based on his description of their average dimensions. E. R. Steinbrueck observed these same storage pits within the village during his visit to the site in 1904 (Brower 1904:144). Additionally, many extant depressions are visible in aerial photographs as early as the 1960s, suggesting the features are not a consequence of recent rodent burrowing. Although some pits were likely looted in the past, such activities would have enhanced their surface expressions (1993:553). Thus, the monopolar negative magnetic anomalies and associated pits within and around the village likely represent subterranean storage pits used by the Arikaras.

A New View of the Mandan/Arikara Village at Fort Clark

When combined, the interpretations of the remote sensing data sets of the Mandan/Arikara village at Fort Clark yield a considerably different view of the settlement than that produced by Wood (1993b) (Figure 5.41). Among the most important of differences is the identification of 37 additional circular earthlodges confirmed by soil coring. The newly identified dwellings are located in various spaces across the village, including one alongside the perimeter of the plaza. Ten are found outside the fortification, bringing the total number of confirmed lodges in that area to 27. Similarly, 15 unconfirmed (i.e., central hearths were not located by soil coring) structures are apparent in multiple remote sensing data sets, which combined with the confirmed lodges is a 60 percent increase over the previously documented dwellings.

Although it is tempting to argue that many of the newly identified lodges within the village core represent Mandan habitations that were buried by Arikara modifications of the original settlement, it is equally reasonable to assume that most of the earthlodges were constructed and occupied by the Arikaras. After all, the Mandan village was destroyed by fire in January 1839 and subsequently rebuilt by the Arikaras beginning in May 1839 (Abel 1997:181, 194). Assuming at most a 15 year use-life for earthlodges (Lensink 2005:139), the Arikara dwellings would have deteriorated and required reconstruction sometime during their nearly quarter century in the village. Of course, such a use-life assumes the use of ideal construction materials (i.e., wood species most resistant to decay due to moisture exposure), which by the 1840s and 1850s was probably difficult as a result of extreme overuse of timber along the river (Roper 2005; Wood et al. 2011:8, 59, 176, 192, 195, 201).

Despite the impossibility of assigning each lodge a temporal period without additional information, it is reasonable to argue relative dates for many structures based on historical accounts and archaeological evidence. For instance, neither George Catlin (Figures 5.5 and 5.6) nor Karl Bodmer (Ruud 2004:Plate 301) depict lodges beyond the fortification ditch in 1832 and 1833, which indicates the 27 lodges in this location were constructed by the Arikaras (Wood 1993b:550; Wood et al. 2011:171). Likewise, the relatively shallow midden deposits toward the west side of the village compared to its core are telling of the short occupation of this area. Other supporting lines of evidence include the relatively low densities of dipolar anomalies (Figure 5.37) and positive monopolar magnetic anomalies (Figure 5.39) outside the fortification ditch. Taken together, these observations suggest earthlodges outside the fortification ditch were built late during the Arikaras' occupation.

Similarly, evidence yielded by PCRG excavations of one rectangular structure indicates log cabins were constructed during the last decade of the Arikaras' occupation. Four of the cabins lie overtop of lodge depressions mapped by Wood (1993b:Figure 3) while another three are superimposed on previously unrecorded earthlodges (Figure 5.41). Although each lodge depression mapped by Wood (1993b:Figure 3) is clearly visible on the ground surface, some were apparently no longer occupied when the village was abandoned by the Arikaras. Indeed, Lewis Henry Morgan (1871:42) noted both standing and collapsed lodges during his 1862 visit, just one year after the Arikaras abandoned the settlement. Such findings are significant since inferences regarding population may be made based on the number of occupied dwellings, a task that is undertaken in the next chapter.

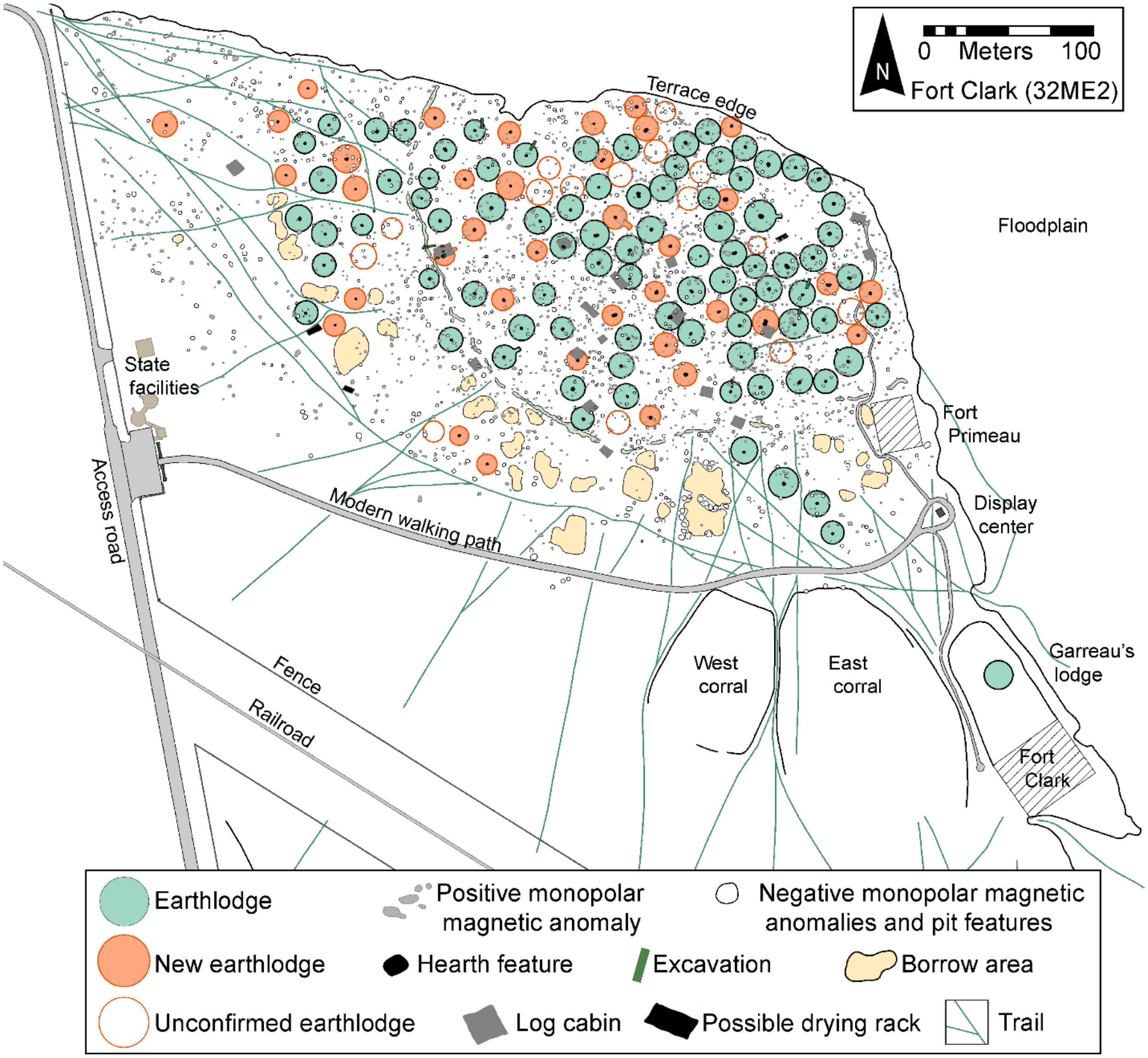

Figure 5.41. Interpretive map of the Mandan/Arikara village at Fort Clark.

Discussion

During its nearly four decades of occupation, the village at Fort Clark was initially occupied by the Mandans and later inhabited by the Arikaras. Considering the settlement was destroyed by fire in 1839, it was likely reconstructed at least three times during this period. This fact speaks to the complexity of the surface and subsurface archaeology, which includes significant sheet midden deposits mixed with superimposed and truncated dwellings and thousands of other smaller features. Additionally, the Native village has been the subject of limited excavations in only a few instances. Consequently, our understanding of the occupation is based primarily on historical documents. These extensive written and graphic documents produced by numerous traders, explorers, artists, and others during the nineteenth century help fill the void and facilitate inquiry into the site's unique history (Wood 1993b:545).

In the absence of more extensive excavations, remote sensing data serve a significant role as a primary source of information about the Native village. For instance, the combined remote sensing data yield considerable information about the general organization and contents of the settlement, including the presence of many previously unknown earthlodges. Furthermore, these data provide evidence that supports historical accounts of lodge numbers and populations, both of which are discussed further in the following chapter. Other details such as the presence of many log cabins constructed by the Arikaras, which are entirely absent from or only alluded to in historical records, are made apparent by the remote sensing data. Most importantly, I use these data jointly with historical documents to support broader arguments concerning trade and agricultural production among the Mandans and Arikaras during the first half of the nineteenth century in Chapter 6.

CHAPTER 6: TRADE AND AGRICULTURAL PRODUCTION AMONG THE MANDANS AND ARIKARAS AT FORT CLARK

Inferences about agricultural production among Mandans, Hidatasas, and Arikaras during the latter part of the nineteenth century based on storage pit volume estimates are supported by independent information drawn from historical documents. Together, the data suggest that the occupants of Like-A-Fishhook Village grew and harvested vast quantities of produce, including maize. However, a multi-decade gap exists in my analysis of storage pit volumes, an early to mid-nineteenth-century period during which the Mandans established Mitu'ahakto's, possession of which was taken by the Arikaras following the 1837 smallpox epidemic. However, this period is significant since it falls immediately after the noteworthy eighteenth-century decrease in storage pit volumes. In the last chapter I delivered a comprehensive discussion of the history of the Native village at Fort Clark (32ME2), information that was subsequently used to inform my interpretations of remote sensing data. Although lengthy, the discussion provided a crucial background for the argument that follows in this chapter concerning nineteenth-century trade and agricultural production among the Mandans and Arikaras at Fort Clark.

The Mandans

Historical sources also highlight the broader trade relationships among various groups in the Northern Plains. Although traders entered the region to generate wealth from bison robes and the pelts of fur-bearing animals acquired by Native and Euroamerican hunters, the agricultural goods produced by Native farming communities were fundamental to this endeavor. The

Mandans played a crucial role in a trade network at both regional and continental scales for centuries prior to the arrival of European and American colonists (Swagerty 1988; Wood 1980), and although the nature of their trade relationships would change with the arrival of colonists during the late eighteenth and early nineteenth centuries, the Mandans' part remained prominent (Anfinson 1987).

Native Trade

Before the smallpox epidemic of 1780-1781, intertribal trade with various groups, among them the Assiniboines and Crees from the north; Crows from the west; Cheyennes from the south; and Lakota and Dakota Sioux from the east increased and brought trade goods into the Heart River Mandan villages in exchange for horticultural produce (Anfinson 1987:79-90; Swagerty 1988; Wood 1980). Thus, European and American trade goods entered the region either indirectly via Native middlemen or through infrequent meetings between the Mandans and traders such as the La Vérendryes (Anfinson 1987:79-90; Smith 1980; Thiessen 1993a). As discussed in the previous chapter, the mean volume of storage pits increased until the eighteenth century, possibly indicating that the Mandans may have intensified or increased production to meet growing trade demands. The Mandans experienced a significant population decline due to the 1780-1781 smallpox epidemic if not earlier as a result of undocumented epidemics, but their abandonment of the Heart River communities to settlements nearer the Hidatsas was in part a response to increased pressure from different bands of the Lakota and Dakota Sioux (Anfinson 1987:118-126; Wood et al. 2011; Wood and Irwin 2001:349-350).

At the turn of the nineteenth century, British and Canadian traders with the North West and Hudson's Bay Companies bypassed the Assiniboines and Crees to establish direct, yet irregular, trade with the Mandans (Anfinson 1987:127-138, 146-150; Wood 1977; Wood et al.

2011; Wood and Thiessen 1985). Spanish traders from the south, who faced resistance from the Arikaras and Sioux, were less successful in reaching the Mandans, although Jacques D'Eglise and John Evans managed to do so in 1792 and 1796, respectively (Anfinson 1987:138-145; Wood 2003a; Wood et al. 2011). However, after the 1804-1806 Lewis and Clark expedition, competition from American traders traveling upriver from St. Louis increased (Anfinson 1987:150-157; Wood et al. 2011). Led by Manuel Lisa, the Missouri Fur Company constructed a fort north of the Hidatsa villages at the Knife River in 1809, although it was abandoned a few years later. During this period, the Mandans appear to have sought guns and ammunition, in exchange for which they traded bison robes, horticultural produce, and the goods most desired by traders, the pelts of fur-bearing animals (Anfinson 1987:146-150, 158-160).

Trade between Euroamericans and the various tribes in the Northern Plains was not a distinct process from the well-established intertribal trade network. Rather, European and American trade items were integrated into the older system and did not interrupt intertribal trade during the late eighteenth and early nineteenth centuries (Anfinson 1987:175-185). Despite the demand that the Mandans likely faced for agricultural produce, the analysis of storage pits in the previous chapter, which indicates a steep decline in mean volume during this period, suggests needs may have outstripped supply. The arrival of fur traders in the Northern Plains was not a static event either. Instead, as their numbers increased during the early decades of the nineteenth century, so did their demand for the agricultural produce yielded by Mandan gardens.

The War of 1812 brought a hiatus to American trade in the region, although direct and regular trade began again with the Missouri Fur Company's construction of Fort Vanderburgh near the Hidatsa villages in 1822 and the Columbia Fur Company's establishment of Tilton's Fort close to the Mandan villages in 1823 (Anfinson 1987:217-233; Thiessen 1993a, 1993b:56-

59; Wood et al. 2011). Given the circumstances, including the Arikaras' attack on traders led by William Henry Ashley who attempted to circumvent their villages near the Grand River, the subsequent attack on the Arikaras led by Colonel Henry Leavenworth, and their move upriver near the Knife River, the Columbia Fur Company's position was initially precarious. However, Tilton's Fort, the predecessor of Fort Clark, would mark the beginning of four decades of direct trade with Mandans and Arikaras at their village. More importantly, the expansion of the Columbia and American Fur Companies in the 1820s and 1830s and the construction of trading posts north and south of the Mandans affected intertribal trade (Anfinson 1987:235-241). Although access to trade goods did not prevent nomadic groups from traveling to the Mandan villages, the construction of posts at strategic locations along the Missouri River meant goods were more readily available to groups in their own territories like the Cheyennes to the south and the Crows, Crees, and Assiniboines to the north.

As the demand for bison robes and other pelts increased, the Mandans' role in regional Native trade remained prominent. Other Native groups, especially Lakota and Dakota bands, became a major source of such goods for the Mandans (Anfinson 1987:260-273). Thus, the Mandans continued a centuries-old tradition by exchanging agricultural goods, especially maize, in return. Historical documents provide some insight on the potential demand of such groups. For instance, Maximilian (Witte and Gallagher 2010:199) observed "seventy leather lodges of the Crows" behind the fort about "300 paces" from the Mandan village upon his arrival at Fort Clark on June 18, 1833. When he returned on November 8, 1833 from his upriver travel, Maximilian (Witte and Gallagher 2012:52) reported second-hand information that "Two hundred tents of Yanktonais [Dakota] had camped on the prairie behind Fort Clark and stayed there three to four days" in September. Similarly, Chardon (Abel 1997:48) reported a visit of "400 lodges" of

Lakota and Dakota Sioux in September 1836. Chardon's (Abel 1997) journal is telling of the frequency with which nomadic groups, not to mention Hidatsas and Arikaras, visited Fort Clark and the Mandan village, although trade was admittedly not the purpose of every visit. Still, hundreds or perhaps thousands of people would have annually descended on the Mandan village following the fall harvest. Areas of increased magnetic susceptibility and clusters of magnetic anomalies several hundred meters away from the Native village likely indicate the locations of short-lived but frequented camps of these nomadic groups (Wiewel and Kvamme 2014).

Fort Clark

With the demand for maize heightened, the Mandans not only had to meet their own needs and the needs of nomadic groups, but also those of a growing number of traders. That is, the Mandans supplied much of the maize and other agricultural produce, not to mention meat, required by the American Fur Company's (later Pratte, Chouteau & Company and Pierre Chouteau, Jr., & Company) Forts Clark, Pierre, and Union and the posts of opposition traders (Anfinson 1987:280). Here again, Chardon (Abel 1997) often notes the traders' efforts to acquire maize from the Mandans, beginning each year after the fall harvest. The limited quantitative data suggests that in each instance of trade the amounts were small (Abel 1997:10, 83), but the accumulated quantity was apparently considerably larger. In a November 1833 journal entry, Maximilian (Witte and Gallagher 2012:53) states: "There is always a large quantity of corn on hand, often 600 to 800 bushels [15,240-20,320 kg]." Maximilian (Witte and Gallagher 2012:126) repeats this observation, when he notes "Often there are 500 to 800 bushels [12,700-20,320 kg] of this grain on hand in the fort." The maize was stored in an attic, on drying racks constructed by traders, and like their Mandan neighbors, in subterranean storage pits (Abel 1997:128; Witte and Gallagher 2012:126, 274). On March 14, 1834, Maximilian (Witte and Gallagher 2012:274) mentions that the traders “opened a cache in the courtyard of the fort today; it was filled with corn and [was] fairly dry.” Thus, a sufficient quantity of maize was supplied by the Mandans and presumably the Hidatsas to traders at Fort Clark so that some was placed in long-term winter storage. An additional amount came from the traders’ gardens (Wishart 1973). However, tens of thousands of kilograms of maize were likely traded annually to the American Fur Company traders at Fort Clark for their own use and the use of others at Fort Pierre and Fort Union (Anfinson 1997:281-282).

Fort Pierre

Letters from traders at Fort Pierre indicate that their own garden (Farm Island) supplied some food. For instance, in a letter written to Pierre Chouteau, Jr. on January 10, 1834, William Laidlaw[3] reports that the garden at Fort Pierre had produced 2,794 kg (110 bushels) of maize along with other crops (Casler and Wood forthcoming). Other farms at least occasionally supplied food. For example, in an October 6, 1834 letter to Pratte, Chouteau & Company, Jacob Halsey[4] writes that Bloomfield farm had delivered 7,620 kg (300 bushels) of maize to Fort Pierre (Casler and Wood forthcoming). Moreover, the Arikaras provided the fort with a substantial amount of maize. An entry in the Fort Tecumseh (a Columbia Fur Company post and the predecessor to Fort Pierre) journal on September 22, 1830[5] notes that Emillien Primeau had returned from a two week trip to an Arikara village with nearly 2,540 kg (100 bushels) of maize (Casler and Wood forthcoming).

Yet, provisioning the fort was more difficult in some years, particularly during the 1830s when the Arikaras became a less reliable source of agricultural goods (Anfinson 1987:283).

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[3] William Laidlaw to Pierre Chouteau, Jr., Fort Pierre, January 10, 1834

[4] Jacob Halsey to Pratte, Chouteau & Company, Fort Pierre, October 6, 1834

[5] Fort Tecumseh Journal, September 22, 1830

Thus, in a letter to Pierre Chouteau, Jr. dated August 14, 1832, William Laidlaw[6] writes that provisions were low and requests that a large amount of maize be delivered aboard a supply boat from St. Louis (Casler and Wood forthcoming). This appeal must not have achieved the desired result. In a subsequent letter written to James Kipp on September 13, 1832, Jacob Halsey[7] states that William Laidlaw wished maize to be delivered from Fort Clark since none would be obtained from the Arikaras that year. An attempt was made to deliver "a boat Load" of maize in November of that same year from the Mandan village, although ice on the river to the north was a problem and held up its arrival until January 27, 1833[8] (Casler and Wood forthcoming). A second delivery of maize from the Mandan village arrived on April 15, 1833[9] (Casler and Wood forthcoming). In February of the following year, James Kipp was asked by Laidlaw[10] to send another 1,016-1,270 kg (40-50 bushels) of maize (Casler and Wood forthcoming). When that request went unfulfilled, Laidlaw pleads with Kipp in a letter written on April 30[11] to send 2,540-3,810 kg (100-150 bushels) (Casler and Wood forthcoming). Recalling the trouble faced by Fort Pierre traders during the previous spring, Laidlaw wrote Francis Chardon at Fort Clark on January 11, 1835[12] asking for a supply of maize from the Mandans (Casler and Wood forthcoming).

Fort Union

Fort Union traders faced the same problem—a shortage of maize—as their downriver counterparts, although its use for the manufacture of alcohol differed. Still, supplies of maize

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[6] William Laidlaw to Pierre Chouteau, Jr., Fort Pierre, August 14, 1832

[7] Jacob Halsey to James Kipp, Fort Pierre, September 13, 1832

[8] Fort Tecumseh Journal, November 30, 1832 and January 27, 1833

[9] Fort Tecumseh Journal, April 15, 1833

[10] William Laidlaw to James Kipp, Fort Pierre, February 24, 1834

[11] William Laidlaw to James Kipp, Fort Pierre, April 30, 1834

[12] William Laidlaw to Francis Chardon, Fort Pierre, January 11, 1835

were regularly requested from the Mandans at Fort Clark. In December 1833, Kenneth McKenzie wrote Joshua Pilcher[13] at Council Bluffs seeking maize and a separate letter to Pierre Chouteau, Jr.[14] included additional detail concerning the request (Wood and Casler forthcoming). Some unsaid amount of maize had been provided by the Mandans, although it was too small, and McKenzie was looking for an additional 5,080-7,620 kg (200-300 bushels) from Council Bluffs. Apparently not satisfied with the likely response, McKenzie wrote a letter to Honoré Picotte on January 18, 1834[15] in which he asks the addressee to transport to Fort Union as much maize as James Kipp could provide at Fort Clark (Wood and Casler forthcoming). Later that same spring, McKenzie again sought the assistance of Kipp[16] at Fort Clark (Wood and Casler forthcoming). In this particular instance, McKenzie acknowledges the scarcity of maize at Fort Clark, but having little at Fort Union, asks that 12,700 kg (500 bushels) be provided. Moreover, McKenzie reminds Kipp that some maize must be held in reserve for boats that would travel downriver from Fort Union the following spring.

The preceding records are clearly incomplete. That is, the Fort Pierre and Fort Union letter books provide a perspective that is skewed toward the letters' authors. The responses of the recipients, oftentimes a manager at Fort Clark, are absent. Moreover, numerous sections of the letter books are missing. Thus, the exact frequency with which the Mandans at Fort Clark provided maize to the other trading posts of the American Fur Company (or Pierre Chouteau, Jr., & Company) and a cumulative amount that was supplied is unclear. Yet, the documents provide glimpses of the period and strongly suggest that the Mandans often contributed significant quantities of maize to the traders' food stocks. Between the supplies at Fort Clark, those

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[13] Kenneth McKenzie to Joshua Pilcher, Fort Union, December 16, 1833
[14] Kenneth McKenzie to Pierre Chouteau, Jr., Fort Union, December 16, 1833
[15] Kenneth McKenzie to Honoré Picotte, Fort Union, January 18, 1834
[16] Kenneth McKenzie to James Kipp, Fort Union, April 7, 1834

provided to Fort Pierre and Fort Union, and additional maize sent to opposition posts (e.g., Maximilian [Witte and Gallagher 2012:38] observed a canoe leaving Fort Clark loaded with maize en route to an opposition post), upwards of 25,400 kg (1,000 bushels) or more of maize was exchanged annually with traders. What does this figure suggest about the total amount of maize the Mandans were capable of producing annually during the 1830s? Given the limitations of the evidence, the question is difficult to answer, but a rough estimate is possible.

Mandan Production

One method for addressing the question is to consider the dietary requirements of the Mandan population, an approach similar to that taken for the ancestral Mandans at Huff village in Chapter 3. However, to understand the dietary requirements, the population of the Mandans prior to the smallpox epidemic of 1837 must first be determined. Documentary sources provide one line of evidence to estimate the population. John F. A. Sanford, the agent for the Mandans and other Upper Missouri tribes from 1826 to 1834 reported a population of only 600 in 1829 (U.S. Congress, Senate 1829:103). On the other hand, Catlin (1973 [1844]:80, 184, 203) gave a count of nearly 2,000 people between the two Mandan villages when he visited in 1832. One year later, Maximilian (1843:335) suggested a combined population of between 900 and 1,000 people. Moreover, Maximilian (1843:336) cited an estimate of 1,250 Mandans given by Jedidiah Morse (1822:252, 367) over a decade earlier, although he favored his own. Then, a year after the smallpox epidemic, Joshua Pilcher (1839), the Indian agent on the Upper Missouri, reported that the Mandans numbered approximately 1,600 prior to the disease. Given the apparent difficultly of estimating populations, each count varies considerably. Sanford's (U.S. Congress, Senate 1829:103) estimate may refer only to the population of Mitu'ahakto's, the larger of the two Mandan villages, although no such indication is provided. On the other hand, Catlin's (1973

[1844]:80, 184, 203) approximation is significantly higher, but so too are his counts of lodges at both Mandan villages, so his estimate can safely be regarded as inaccurate.

Other evidence suggests the population remained stable during the 1820s and 1830s. When an expedition led by General Henry Atkinson and Indian agent Benjamin O'Fallon visited the Mandan villages in 1825, Atkinson (Jensen and Hutchins 2001:136-137) noted 150 warriors at the lower village and 100 at the other in his July 26 journal entry. Nearly a decade later Maximilian (Witte and Gallagher 2012:144) would record comparable figures—150 warriors at Mitu'ahakto's and 83 warriors at Ruptare/Mitutahank (elseswhere, Maximilian [Witte and Gallagher 2010:201] counts 250-300 warriors combined)—in his own journal. This similarity suggests that an increase in population does not account for the difference in population estimates by Sanford and Catlin. Rather, the upper and lower counts are simply inaccurate, but the other estimates vary widely between these extremes. A general method for approximating the total population size when only a count of warriors is given is to quadruple that number (e.g., Krause 1972:14), which in this case yields a population of 1,000 people (given a warrior count of 250), a reasonable figure that falls about midway between other estimates.

Another approach, which may provide additional insight into the Mandans' population prior to the smallpox epidemic of 1837, is to consider the number of lodges present at the two Mandan villages. According to a Fort Tecumseh journal entry from March 17, 1830,[17] one Mandan village had 30 lodges and the other had 60 (Casler and Wood forthcoming). Maximilian (Witte and Gallagher 2010:199) counted around 38 lodges at the smaller village and about 65 at Mitu'ahakto's. Given the similarity of the sources, it appears plausible that the two villages combined contained approximately 100 earthlodges. An estimate of group size can be derived

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[17] Fort Tecumseh Journal, March 17, 1830

based on this count and historically documented Mandan populations, which Roberts (1977) used to develop a group-specific regression equation. A zero-intercept equation for Mandan populations yields estimates of about 830 people at the larger village and 450 individuals at the smaller village, assuming the settlements contained 65 and 35 lodges, respectively, or a total of about 1,280 people.

Population estimates can also be derived from occupied areas, such as Naroll's (1962) average of 10 m^2 of floor space per person. Although archaeological and geophysical data would provide more precise estimates of house sizes, identifying lodges inhabited by Mandans is impossible given the latter Arikara occupation. At least two references are made to the diameter of lodges within the Mandan villages. First, an entry in the Fort Tecumseh Journal[18] in 1830 suggests the structures were 9.1-18.3 m (30-60 feet) in diameter (Casler and Wood forthcoming). Catlin (1973 [1844]:87) gives a similar diameter of 12.2-18.3 m (40-60 feet). If this range of diameters is assumed to be correct, an average diameter of 13.7 m (45 feet), an estimate within the range of lodges at Fort Clark, is plausible. Based on this average diameter and a house count of 100, Naroll's (1962) method yields an estimate of about 1,475 people between the two villages, or about 960 individuals for the larger village (given a house count of 65). Of the various estimates, most fall between about 1,000 and 1,500, a range that has been suggested previously for the post-1780-1781 smallpox epidemic population (Wood and Irwin 2001:352).

A population of 1,250 for the Mandans is reasonable given the different estimates. How much maize would be necessary to feed a population of this size, and given other factors such as trade, what quantity of maize would have been harvested in a year? Following the nutritional requirements described previously (Chapter 3), adults would need 2,500 calories per day while

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[18] Fort Tecumseh Journal, March 17, 1830

children would require 1,910 calories/day. Given a population composed of 40 percent adults (or 500 individuals), approximately 95,255 kg (3,750 bushels) of maize would have been required to meet 35 percent of the settlement's nutritional needs (with maize contributing 3,600 calories/kg [Ensminger et al. 1994:838]) for a year. That said, a significant amount of maize was likely traded to nomadic groups, and perhaps as much as 25,400 kg (1,000 bushels) were exchanged with traders. An unknown quantity was probably consumed by brown rats, a non-native species that appeared in the region during the early nineteenth century (Fenn 2014: 290-294). Thus, a total amount of approximately 139,700 kg (5,500 bushels), would have been sufficient for all circumstances, including the Mandans' own dietary needs, trade, seed for the following year, and some loss. On the other hand, about 136,078 kg (5,357 bushels) of maize would have been necessary to meet half of the village's caloric requirements, to say nothing of the quantities that would be traded and reserved. Unfortunately, there are no historical accounts from this period that refer specifically to the quantity of maize produced at the Mandan villages. Yet, historical sources cited previously (Chapter 4), which refer to production during the second half of the nineteenth century, suggest that yields of such sizes were possible. Although evidence is lacking to make such an argument with complete certainty, it would appear that the Mandans prior to the 1837-1838 smallpox epidemic had resumed a well-developed tradition of producing considerable quantities of maize for trade, a practice that was perhaps affected by epidemic disease during the eighteenth century based on storage pit volume data. If the arrival of European and American traders in the Northern Plains can be said to have altered the system, it would probably be that a greater quantity of maize was produced and exchanged with traders rather than other nomadic groups. Equally important is what occurred in the aftermath of the smallpox epidemic when the Arikaras took possession of the village. Archaeological and geophysical evidence from Fort

Clark State Historic Site reveal much about the village during the Arikaras' occupation (Wiewel and Kvamme 2016), including crucial data regarding storage pits.

The Arikaras

Findings concerning the number of occupied dwellings, which were discussed in the previous chapter, are particularly relevant to a discussion of population estimates for the Arikaras at Fort Clark. In 1855, the agent for the Upper Missouri Agency, Alfred J. Vaughan (1856:73) stated that the Arikaras lived in 60 lodges, with about 14 individuals per lodge, giving a total population of 840. Vaughan (1856) either did not observe or failed to mention log cabins within the village. When Lewis Henry Morgan (1871:42) visited the village in 1862, he counted 48 earthlodges within the villages besides a number of Arikara log cabins. Although his source is unclear, Morgan (1871:44) noted that the Arikaras numbered 900 when the village at Fort Clark was abandoned. Wood and colleagues (2011:171) note that Star Village and an adjacent settlement constructed by the Arikaras after they left Fort Clark contained approximately 100 dwellings, which would account for all of the depressions visible on the ground surface. Acknowledging the newly identified log cabins, some of which overlap previously documented lodges, Mitchell (2014c) similarly suggests that the Arikara village contained about 100 households.

Assuming that about one-quarter of the lodges visible on the ground surface were not occupied, meaning Vaughan's (1856:73) count of 60 dwellings is correct, the Arikaras would have had a population of somewhat less than 1,000 people based on Roberts (1977) group-specific regression equation. Those that lived within log cabins would have brought the total population over 1,000 individuals. Similarly, Naroll's (1962) average of 10 m^2 of floor space per person yields a population estimate of 1,050 (i.e., given 60 earthlodges with an average size of 175 m^2), with another 75 people based on the average size of 17 log cabins. A larger number of households in the two subsequent Arikara villages could be accounted for if fewer individuals occupied each dwelling, meaning the average size of households declined. After all, with declining timber resources around Fort Clark, more people perhaps lived in fewer houses. In fact, Samuel N. Latta (1863:195), the agent for the Upper Missouri Agency in 1862, reported that the Arikaras numbered around 1,000 people when he observed them at their newly constructed village. It would seem reasonable to assume that the population of the Arikaras during the mid-nineteenth century was approximately 1,000-1,100 based on both estimates and historical reports.

Like the Mandans nearly a quarter century prior, the Arikaras reportedly produced vast quantities of maize at their village at Fort Clark that was sufficient for their own consumption and a surplus that could be exchanged with traders and other Native groups. For instance, Vaughan (1855:80) wrote in 1854 that the Arikaras requested that no maize should be provided by agents as part of their annuity since a sufficient amount was raised for their own use as well as a surplus that was sold to traders and other groups. Vaughan (1856:72-73) reiterated this notion the following year when he stated that the Arikaras generally produce an abundance of maize, but due to a drought yields were expected to decline to one-third the typical amount, a quantity that would still be enough for their own needs. In 1856, Vaughan (1857:79) reported that the Arikaras had harvested 101,600 kg (4,000 bushels) of maize in the fall of 1854. Edwin Denig, an American Fur Company trader who spent more than two decades among the Upper Missouri tribes, wrote that the Arikaras were capable of harvesting 50,800-76,200 kg (2,000-

3,000 bushels) of maize besides other produce (Ewers 1961:45-46). Of this maize, the Arikaras traded from 12,700 to 20,320 kg (500 to 800 bushels) to the American Fur Company fort adjacent to the village. Similarly, Lieutenant Rufus Saxton (1855:265), who visited the village in October 1853 while surveying for a transcontinental railroad, wrote that the Arikaras had produced 127,000 kg (5,000 bushels) of maize that year, some of which they would exchange with the Crow and Dakota Sioux. As many as 2,500 Dakota Sioux had traded at the village before Saxton's (1855:265) arrival. Alexander Redfield (1858:136), an agent for the Upper Missouri, observed over 600 lodges of Lakota and Dakota Sioux at the village in 1857 who had assembled in such great numbers to trade for maize from the Arikaras. Although such historical data are intriguing, a significant question remains. Can the number of storage pits identified in remote sensing data from Fort Clark account for this level of maize production?

Storage Pits and Agricultural Production during the Arikara Occupation

Besides the targeted coring of positive monopolar magnetic anomalies thought to be associated with central hearths within previously unrecorded lodges, another 62 soil cores were performed primarily in four locations around houses. About three-quarters of the cores targeted positive monopolar anomalies, although some negative monopolar anomalies related to depressions visible on the ground surface were tested. Of the 47 cores that targeted positive magnetic anomalies, only three storage pits were identified, a somewhat lower rate than occurred during the previous coring program (Ahler 2003f). Again, distinguishing soils characteristic of storage pits from surrounding midden proved difficult. Thus, making inferences with any certainty regarding the number of storage pits based on the 2,708 positive monopolar magnetic anomalies (a total that does not include confirmed central hearths) identified across the village is impossible. The anomalies are located in areas characteristic of storage pits, including within lodges and around their perimeters. A considerable number of the anomalies undoubtedly indicate storage pits and auxiliary hearth features, although many positive magnetic anomalies may be related to ferrous metal, midden, or areas of relatively thicker topsoil.

In contrast, 13 of the 15 cored surface depressions indicated magnetically as negative anomalies are clearly storage pits (Figure 5.40). Most extend well beyond 1 m in depth and generally contain darker colored and mottled soils that were more easily differentiated from the lighter colored subsoils. Wood (1993b:550) previously suggested the depressions visible on the ground surface around the village indicate storage pit features, and the findings of the most recent coring program confirm his interpretation. A total of 612 negative monopolar anomalies (i.e., pit features) were identified based on aerial imagery and magnetic gradiometry, thermal infrared, and airborne LiDAR data. Granted, the total number is lower than that mapped previously by Wood (1993b), although depressions south of the modern walking path are not included in the total. Moreover, very small depressions, which are more frequently related to rodent burrows, are not among those identified by the remote sensing data. Most lodges contain one to four depressions, although many pit features are located outside dwellings. More importantly, an optimized hot spot analysis, which used aggregation polygons produced during a previous test dipolar anomaly clustering, reveals important patterning in the distribution of pit features (Figure 6.1).

Once more, earthlodges located outside the fortification ditch were likely constructed by the Arikaras during the latter part of their occupation as evidenced by the relatively shallow midden deposits in this location. Similarly, low densities of dipolar anomalies and positive magnetic monopolar anomalies are revealing of the relatively brief occupation of this area (Figures 5.37 and 5.39). Multiple lines of evidence indicate that log cabins were constructed by the Arikaras during the decade prior to their abandonment of the village. The depressions visible on the ground surface probably represent storage pits used by the Arikaras during this period. High density clusters of surface depressions are located in several places. The highest density of pit features is outside the fortification ditch near the northwest side of the village (Figure 6.1). The pits appear to be associated with numerous lodges located in the area (Figure 5.41). Other pit features outside the fortification ditch surround a large borrow on the south side of the village. Although the depressions may be associated with the larger feature, one cored depression was clearly identifiable as a storage pit. More likely, the pits were conveniently located around the borrow so that their locations could easily be recalled. Several clusters of pits are located toward the southwest side of the village core. Importantly, many of the anomalies that indicate Arikara log cabins are located in this same area (Figure 5.41). Overall, the distribution of likely storage pits differs noticeably from those of dipolar anomalies and positive magnetic monopolar anomalies (Figures 5.37, 5.39, and 6.1). The latter two are revealing of the long-term occupation of the village core. In contrast, the negative monopolar magnetic anomalies and pits appear to be associated with features that date to the Arikaras' occupation of the village, particularly the final decade.

Based on the results of the coring program, nearly 87 percent (or an estimated 530 of the 612 anomalies) of the depressions indicated by negative monopolar magnetic anomalies are storage pit features. A larger sample of cored anomalies interpreted as storage pits average 114.7 cm in depth below the ground surface (s = 24.4 cm; n = 54). Importantly, previous excavations showed house floors were typically 20-30 cm below the ground surface, meaning the depth may not be an accurate measurement of storage pit depth. However, some soil cores apparently stopped short of the actual complete depth once the features were confirmed (Ahler 2003f:50). A total of 13 depressions identified as storage pits were cored at their centers, which were typically at least 20-30 cm below the adjacent ground surface. Still, the 13 pits average about 118.8 cm in depth (*s* = 19.2 cm), meaning the original storage pit depth approximation of about 115 cm is a reasonable estimate.

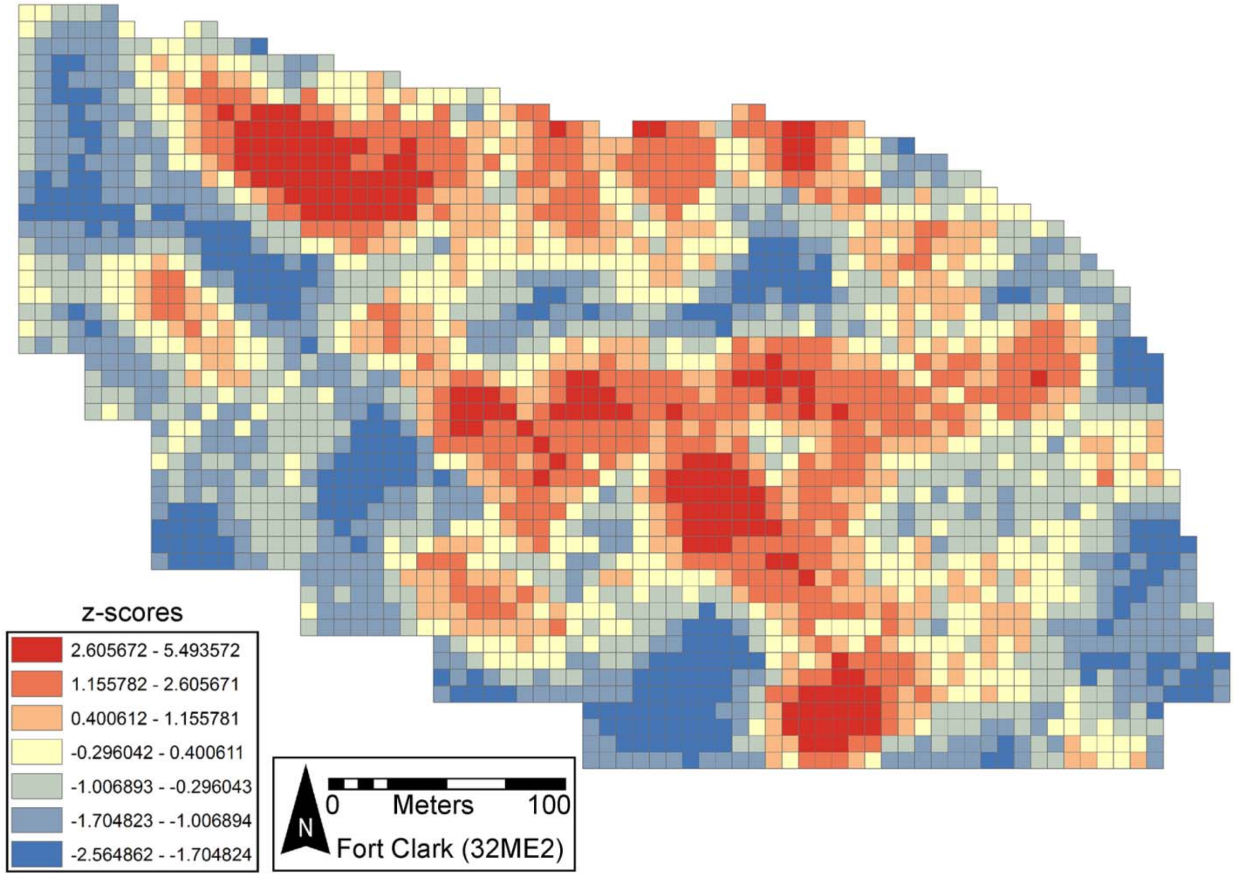

Figure 6.1. Results of an optimized hot spot analysis showing the density of likely storage pits, which are represented by z-scores, across the Native village at Fort Clark. Aggregation polygons produced during a test of dipolar anomaly clustering were used to yield a similar fishnet grid.

How does an approximate depth of 115 cm compare to that of storage pits from other periods? Recall from Chapter 4 that the mean volume of storage pits unmistakably increased through time with the exception of a significant decrease during the late eighteenth and early nineteenth centuries. Comparable storage pit volume data are not available due to a lack of extensive excavations at Fort Clark. A single quantitative variable, storage pit depth, may be a suitable alternative, however. That is, a box-and-whisker plot of pit depths parallels that of pit volumes (compare Figures 4.2 and 6.2). Specifically, the plot shows that storage pit depths increased from about 60.8 cm to 116.9 cm, a change of more than 90 percent, from the thirteenth to the eighteenth century. Then, in the decades following the 1780-1781 smallpox epidemic, mean storage pit depths decreased by about one-quarter before rebounding to the previous average depths during the mid- to late nineteenth century (Figure 6.2). Importantly, the increase in mean storage pit depth occurred during the occupation of the Native village at Fort Clark.

Yet, the data appear to be non-normally distributed (Figure 6.2). The Shapiro-Wilk test for normality shows that five of the nine time periods are non-normal, and Levene's test for homogeneity of variance indicates that group variances are significantly different ($F = 10.498$; $df = 8$; $\mathrm{p} < .0001$). Still, a non-parametric Kruskal-Wallis test indicates a significant difference between mean storage pit depths ($x^2 = 166.31$; $df = 8$; $p < .0001$), and pairwise comparisons using Wilcoxon rank-sum tests with a Bonferonni correction show significant differences for a number of periods (Table 6.1). Furthermore, parametric statistical tests of log-transformed data yield results that are consistent with the findings of the Kruskal-Wallis and Wilcoxon rank-sum tests.

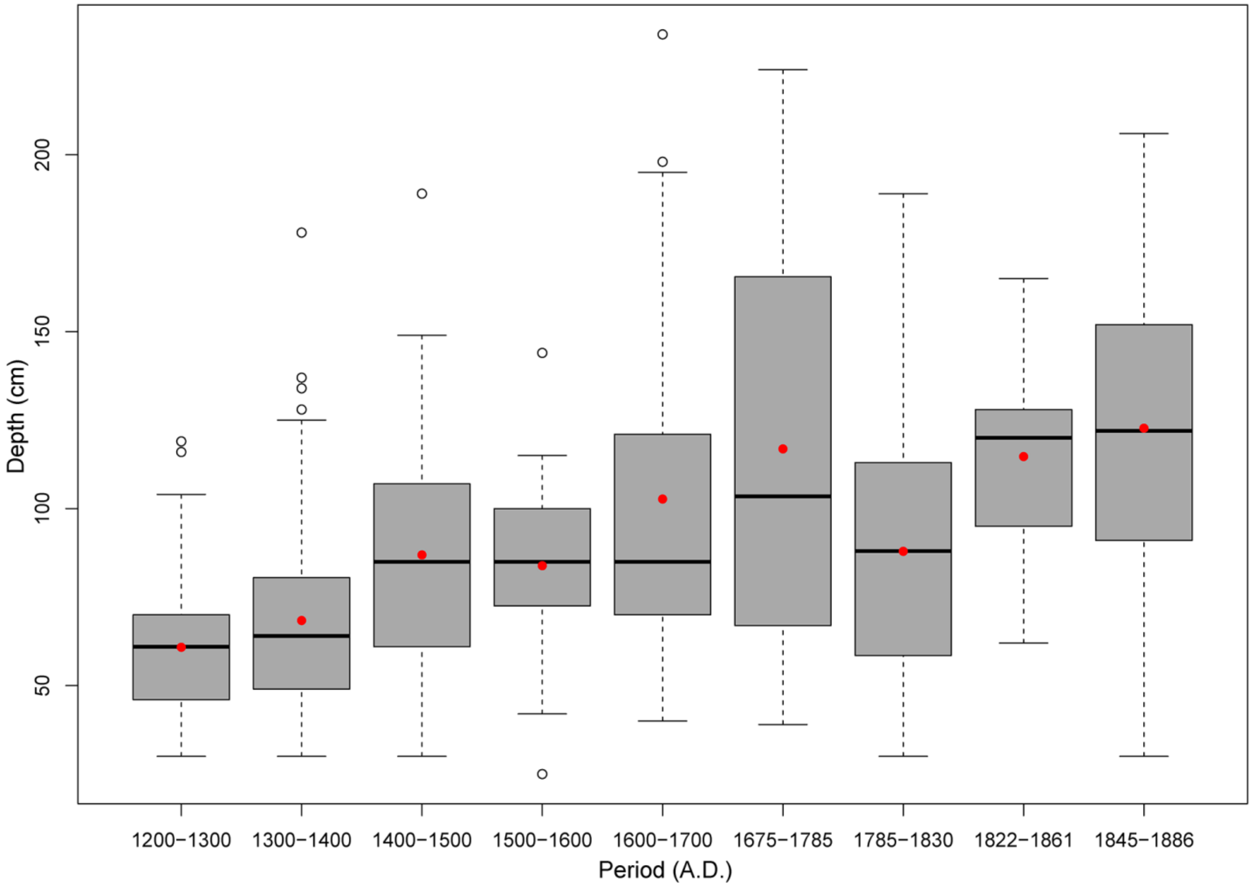

Figure 6.2. Box-and-whisker plot of storage pit depths, with red circles indicating mean depths, during different time periods. The 1822-1861 period includes storage pit depths from the Mandan/Arikara village at Fort Clark.

Table 6.1. *P*-values from pairwise comparisons using Wilcoxon rank-sum tests with a Bonferroni correction with significant differences in bold. Outlined *p*-values highlight comparisons between late eighteenth and nineteenth-century periods.

Period (A.D.)	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1675-1785	1785-1830	1822-1861
1300-1400	1	-	-	-	-	-	-	-
1400-1500	**<.0001**	**.0001**	-	-	-	-	-	-
1500-1600	.0687	.6215	1	-	-	-	-	-
1600-1700	**<.0001**	**.0002**	1	1	-	-	-	-
1675-1785	.4095	1	1	1	1	-	-	-
1785-1830	**<.0001**	**.0003**	1	1	1	1	-	-
1822-1861	**<.0001**	**<.0001**	**<.0001**	**.0118**	.7772	1	**.0001**	-
1845-1886	**<.0001**	**<.0001**	**<.0001**	**.0242**	.4616	1	**<.0001**	1

Thus, the results of both non-parametric and parametric tests suggest significant differences in storage pits depths occurred between multiple times periods (Table 6.1). For instance, pit depths during the nineteenth-century periods are significantly different from those in the thirteenth century through the sixteenth century. Storage pits are about one-third to two-thirds times greater in depth during the latter periods, a finding that mirrors the results of the comparisons of storage pit volumes. Likewise, storage pits that date to the fifteenth and seventeenth centuries have statistically significant greater depths than pits from the earliest centuries. Notably, the mean depths of storage pits for the latter two periods (i.e., mid- to late nineteenth century) are significantly different from the period subsequent to the 1780-1781 smallpox epidemic, when mean storage pit depths decreased to levels similar to those during the sixteenth century. The significantly lower mean storage pit depth during the late eighteenth and early nineteenth centuries is likely due to depopulation resulting from disease. Interestingly, it was during December 1797-January 1798 that David Thompson, a trader with the North West Company, found the Mandans and Hidatsas co-occupying several villages in the vicinity of the Knife River (Wood 1977; Wood et al. 2011:30). Similarly, James Mackay, who visited the five villages a decade prior in 1787 observed the Mandans and Hidatsas living “jointly” (Wood 2003a:39). Thus, the sharp decline in storage pit depths (and storage pit volumes) in the decades following the 1780-1781 smallpox epidemic co-occurs with a consolidation and reorganization of the Mandans with the Hidatsas near the Knife River. However, when the Corps of Discovery reached the villages in 1804, Lewis and Clark found the Mandans living separate from the Hidatsas (Moulton 2003; Wood et al. 2011:30-31).

If historical accounts are accurate, the continued demand of Native groups as well as that of an increasingly greater number of fur traders during the 1820s and 1830s, led the Mandans at

Mitu'ahakto's to continue a centuries-old tradition of producing considerable quantities of agricultural goods. That is, the Mandans resumed a pattern of change—increasing levels of production to meet not only their own requirements but also the demands of trade—that had begun prior to the arrival of European and American colonists. But what of the Arikaras who occupied the village following the smallpox epidemic in 1837 that significantly reduced the Mandan population? While the Arikaras' reconstructed village at Fort Clark was inhabited for nearly a quarter century, historical accounts and depictions of the settlement are relatively sparse compared to the earlier period. Still, archaeological and geophysical evidence help fill the void in the absence of historical information. If the depth of storage pits is a reflection of agricultural production, then the Arikaras appear to have continued the trend of producing prolific amounts of maize and other agricultural goods during the mid-nineteenth century, a result that supports findings from the examination of storage pit volumes in Chapter 4.

Although archaeological work at Fort Clark is not favorable for generating estimates of storage pit volumes and total storage potential with the certainty as was done in previous chapters, it is possible to approximate very roughly the volume of storage pits at Fort Clark. Across all time periods, excavated storage pits of greater depth generally exhibit larger base diameters. In fact, Pearson's r indicates a moderate correlation ($r = .53$; $df = 540$; $p < .0001$) between storage pit depth and base diameter. The regression of the storage pit base diameter values on the depth values yields the function $Y = 71.406 + .532 * X$. The regression equation produces a hypothetical base diameter of 132.4 cm given the average depth of 114.7 cm for 54 cored storage pits at Fort Clark. Excavated storage pit mouth diameters are more variable through time but average about 91.8 cm ($s = 32.7$ cm; $n = 388$). While storage pits would include both straight-sided and undercut types, using an equation for the volume of a conical frustum results in a more conservative estimate of about 1.14 m^3 per pit. Based on findings from Chapter 4, the hypothetical volume falls between the mean storage pit volumes of excavated pits from the periods just before (1785-1830) and after (1845-1886) the Arikaras' occupation at Fort Clark. Importantly, one sample *t*-tests comparing the hypothetical mean storage pit volume with volumes from the two periods indicate significant differences with both (1785-1830: $t = -5.4942$; $df = 102$; $p < .0001$; 1845-1886: $t = 2.8365$; $df = 51$; $p = .0033$).

Discussion

Such results are certainly speculative but provide a starting point against which additional data may be compared in future investigations. The total storage capacity would have been about 604 m^3 (given the storage pit volume estimate of 1.14 m^3) based on the pits identified by remote sensing data, which are thought to date to the latter part of the Arikaras' occupation rather than the earlier Mandan settlement. A storage capacity of such size would have been more than sufficient to meet the annual dietary requirements of a population of Arikaras about 1,000-1,100 individuals. A sizable amount of space would have remained for agricultural goods allocated for exchange with other Native groups and traders.

My examination of storage pit data from 20 Plains Village sites along the Missouri River in North Dakota and northern South Dakota in the previous chapter revealed several significant changes in mean pit volume through time. Among the findings was an increase in mean volumes from the fifteenth century onward, a trend that coincides with population changes, increased specialization, and trade expansion among the Mandans in the Heart River region prior to the eighteenth century (Mitchell 2011, 2013). The results certainly indicate increased agricultural production and perhaps even productivity. A steep decline in mean pit volume is evident during the eighteenth and early nineteenth century, a result that likely reflects the devastating consequences of the 1780-1781 smallpox epidemic. However, the storage pit data and historical documents suggest that the Mandans, Hidatsas, and Arikaras at Like-A-Fishhook produced considerable amounts of agricultural goods during the mid- to late nineteenth century.

Likewise, historical documents and archaeological data suggest the Mandans and Arikaras harvested vast amounts of agricultural goods, most importantly maize, decades prior to this period at Fort Clark. While the desire to trade with nomadic groups remained an impetus for the production of huge surpluses, exchange with fur traders whose presence became permanent during the period was equally significant. In this way, the decrease in mean pit volumes that occurred during the eighteenth and early nineteenth centuries can be viewed as an irregularity in what was otherwise a general trend of increased production among Northern Plains farmers to meet trade demands, a pattern that continued much longer than previously understood. This trend continued despite the arrival of European and American colonists. Again, the circumstances during the nineteenth century, where traditional practices persisted when the Mandans and Arikaras met contingencies brought on by the arrival of colonists, are best summed by Ferris's (2009) notion of "changed continuities."

CHAPTER 7: A NEW PERSPECTIVE OF AGRICULTURAL PRODUCTION AMONG MIDDLE MISSOURI FARMING COMMUNITIES

Although indirectly related, the nature of the relationship between colonial fur traders and Native groups in the Northern Plains is of importance to my research focus. Concepts from “new Indian history” such as the middle ground, Native New World, Native ground, and Native empire have been used elsewhere to characterize the complexity of relationships in other regions during the sixteenth century through the nineteenth century (DuVal 2006; Hämäläinen 2008; White 2010; Witgen 2012). Elements of these revisionist colonial histories certainly apply to the relationships between Native groups and European and American colonists in the Northern Plains. Clearly, these interactions changed in scope and intensity as colonial trade transitioned from indirect to local and enduring interaction.

During the latter period, which began around 1822, traders maintained a permanent presence along the Missouri River in North Dakota and constructed trading posts near the Mandan, Hidatsa, and Arikara villages (Thiessen 1993a:39-41). Tilton’s Fort, the construction of which began in May 1823, was the nearest trading post to the recently established Mandan village of Mitu’ahakto’s. From a traditional colonialist point of view, the Columbia Fur Company’s establishment of Tilton’s Fort and the coinciding increase in the quantity of trade goods would be indicative of the growing dependency and acculturation of local Native groups and the disruption of Native trade networks.

However, another view of this complex historical process is conceivable. Colonial fur traders and their trade goods undoubtedly altered Native trade systems. Numerous groups, including the Assiniboines, Crees, Cheyennes, and Lakota and Dakota Sioux participated in trade with the Mandans in their Heart River villages prior to the 1780-1781 smallpox epidemic (Anfinson 1987:79-90; Swagerty 1988; Wood 1980). Columbia and American Fur Company operations along the Missouri River in the 1820s and 1830s brought trade goods directly to many of the nomadic groups that had previously traveled to the Mandan villages annually (Anfinson 1987:235-241). These events did not wholly interrupt intertribal trade, though, as the Mandans' position in regional Native trade remained prominent. For instance, trade between the Mandans and Lakota and Dakota Sioux became more frequent during the early decades of the nineteenth century (Anfinson 1987:260-273). Moreover, traders themselves became recipients of substantial amounts of agricultural produce and other goods supplied by the Mandans and Arikaras, both of whom were active participants in the development and continuation of this political and economic system.

Conflict and Cooperation

One cannot comprehensively explain such dynamic processes without acknowledging the contributions of Native participants. Admittedly, historical documents are one-sided and largely lack this perspective, but glimpses may be gleaned from nineteenth-century historical accounts. Intertribal relations among Northern Plains groups during the eighteenth and nineteenth centuries, and likely during earlier periods, were simultaneously cooperative and competitive (Mitchell 2007a). Meriwether Lewis and William Clark were made aware of the complexity of such relationships in October 1804 when the Corps of Discovery paused at the Grand River Arikara villages. Lewis and Clark naively sought to convince the Arikaras, who to the outsiders appeared to be in a position of exploitation, to end their relationship with the Teton Sioux

(Ronda 2002:42-62). Doing so would ideally weaken the Sioux and limit their interest in preventing the delivery of manufactured goods upriver (Ronda 2002:42-62). Despite assurances to the contrary, however, the Arikara-Teton Sioux connection remained in place due to the shared economic advantages it facilitated (Ronda 2002:42-62).

These same cultural institutions—cooperation and conflict—would influence interactions with colonial fur traders. Negotiations led Lewis and Clark to believe that the Arikaras were receptive to American trade policies and willing to allow upriver access to traders (Ronda 2002:42-62). Despite allowing the expedition to ascend the river to the Mandan villages in October 1804, the Arikaras would adopt a more hostile position toward traders in the coming years (Ronda 2002:60; Wood et al. 2011:50). This antagonism, meant to thwart a St. Louis-Mandan connection, culminated in June 1823 when the Arikaras attacked a group of fur traders led by William Henry Ashley, killing at least a dozen of the party (Krause 1972:15; Parks 2001:367; Ronda 2002:60; Wood et al. 2011:50).

The Mandans were equally skeptical of the efforts of Lewis and Clark to organize an intervillage alliance against nomadic groups and bring them into the fold of the American trade system (Ronda 2002:77, 82-84, 90). Yet, the Mandans understood the economic advantage of hosting the Corps of Discovery. Thus, during negotiations with Lewis and Clark, Sheheke, the principal chief of the Nuweta Mitutahank community, voiced concern over the expedition’s 1804-1805 winter quarters location (Ronda 2002:87-88). Constructing the fort nearby would ensure that the Mandans could provision its occupants, according to Sheheke, but its proximity would also inhibit Hidatsa access (Ronda 2002:88). To assuage the explorers’ concerns, Sheheke also assured Lewis and Clark of the Mandans’ intentions to make peace with the Arikaras, a diplomatic act that would have little effect on village relations (Ronda 2002:87-88). Instead, the

Hidatsas were further alienated by the Mandans, who spread rumors about an American-Sioux alliance, a pending attack, and the explorers' intentions to kill them (Ronda 2002:92-93). These actions were meant to limit the supply of trade goods to others and facilitate a steady flow to Sheheke and the Mandans. The Americans encountered unfavorable circumstances among the Hidatsas, however, given the latter's partiality toward British traders of the North West Company (Ronda 2002:93).

Clearly, the Missouri River was not controlled by colonial fur traders or explorers such as Lewis and Clark during the early nineteenth century. These recent arrivals were simply new components of a complex and dynamic political and economic system. Inter-group relations included long-standing institutions where Native peoples like the Arikaras and Mandans were simultaneously willing to cooperate, or if necessary, commit violent acts, both of which were means to achieve their own ends.

Following the Arikaras' 1823 attack on Ashley, the subsequent reprisal by U.S. Army Colonel Henry Leavenworth, and the burning of the Arikaras' Grand River villages (Leavenworth Village [39CO9]), some Arikaras responded aggressively. After settling upriver near the Mandan village of Mitu'ahakto's, an employee of Tilton's Fort was targeted and killed by the Arikaras (Witte and Gallagher 2012:117; Wood et al. 2011:52-53). Another five traders with the French Fur Company were killed near the Cannonball River (Witte and Gallagher 2012:117-118). James Kipp informed Prince Maximilian that such actions were retribution for Colonel Leavenworth's attack (Witte and Gallagher 2012:118). Although the Mandans considered retaliating against the Arikaras, they instead chose to protect Kipp by lodging him within the village, an action that would lead to his construction of Fort Clark I within the settlement (Witte and Gallagher 2012:118-119). These deliberate actions on the part of the

Arikaras and Mandans were meant to place the groups in more prestigious and powerful positions with direct access and control of trade goods.

The significance of the Mandans and Arikaras to the American Fur Company (Pierre Chouteau, Jr., & Company) is further highlighted by the consideration given by Francis Chardon and others to the two groups. When Chardon contemplated the possibility of moving Fort Clark downriver to the location of Tilton's Fort in July 1837, he first deliberated with the Mandans and Arikaras, although the move did not occur (Abel 1997:120). Following the devastating smallpox epidemic of that same year, which significantly reduced the Mandan population, the Arikaras would assume control of the settlement and access to Fort Clark (Abel 1997:153; Wood et al. 2011:167-170). With the construction of Fort Berthold near Like-A-Fishhook Village (32ML2), the fur company again contemplated abandoning Fort Clark in 1845, a prospect that greatly dissatisfied the Arikaras (Wood et al. 2011:194-197). In fact, a December 7, 1845 letter from Honoré Picotte to Pierre Chouteau, Jr., & Company[19] states that the Arikaras threatened reprisal for Chardon's desertion of Fort Clark (Casler and Wood forthcoming). A letter written the following spring by Picotte to Chardon[20] indicates that the traders were sufficiently concerned about the Arikaras that plans were made to continue staffing Fort Clark (Casler and Wood forthcoming). Moreover, another letter by Picotte to Pierre Chouteau, Jr., & Company[21] at the same time suggests that despite a lack of tradeable robes, Fort Clark would remain supplied so that Arikara maize could be acquired (Casler and Wood forthcoming). Ultimately, the trading post would remain in operation until 1861.

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[19] Honoré Picotte to Pierre Chouteau, Jr., & Company, Fort Pierre, December 7, 1845
[20] Honoré Picotte to Francis A. Chardon, Fort Pierre, March 12, 1846
[21] Honoré Picotte to Pierre Chouteau, Jr., & Company, Fort Pierre, March 11, 1846

Countering Traditional Colonial Narratives

Counter to a conventional colonial narrative, the Mandans and Arikaras, acting in their own self-interest, influenced and accommodated colonial fur traders along the Missouri River in the Northern Plains during the early nineteenth century. Still, notions of traditional perspectives are pervasive. Among these ideas is the concept of acculturation, or the view that the adoption of European and American material culture was rapid and ever-increasing and led to detrimental and unavoidable culture change among Native groups (Mitchell and Scheiber 2010:7). An example drawn from my own work (Mitchell and Wiewel 2014; Wiewel and Kvamme 2016), the appearance of log cabins among the Mandans and Arikaras during the nineteenth century, illustrates a shortcoming of this view.

One of, if not the earliest, reference to the presence of Native cabins is Maximilian's (Witte and Callagher 2010:205) June 19, 1833 description of "an as-yet-unfinished log house, which the Indians wanted to construct in the manner of the white man" at the Ruptare/Mitutahank community (Deapolis [32ME5]) near Fort Clark. The earliest observation of such architecture within the village at Fort Clark was made by Elias J. Marsh (Mitchell 2014c:139). In his June 26, 1859 journal entry, Marsh (1936:99) noted that some Arikaras "also have square log cabins." At least three log cabins are illustrated by William Jacob Hays north of Fort Primeau in a sketch dated July 14, 1860 (Figure 5.4). Likewise, during his June 1862 visit to the abandoned settlement, Lewis Henry Morgan (1871:42) acknowledged the presence of "several rectangular houses constructed of hewn logs." Elsewhere, Morgan (White 1993:186) stated that "there were a number of hewn log houses and huts mixed in" with the circular earthlodges. Of course, remote sensing investigations of the entire village revealed a total of seventeen rectangular structures (Chapter 5; Wiewel and Kvamme 2016). Test excavations indicated one is an Arikara residential or domestic structure that dates to the mid-1850s (Mitchell 2014b, 2014c).

Samuel N. Latta (1863:194), an agent with the Upper Missouri Agency who traveled aboard the *Spread Eagle* to Like-A-Fishhook with Morgan that same year, observed on June 5 “now and then a [Mandan and Hidatsa] log cabin, well built, with fireplaces and chimneys, after the western style.” That same day, Latta (1863:194) noted the Arikaras had “here and there a log cabin put up in good style, with fireplaces and chimneys” at Star Village (32ME16), their briefly occupied settlement near Like-A-Fishhook. Each reference to Native cabins is secondary to that of earthlodges, however, which suggests the latter remained the more common architectural form in the region. Circumstances changed by the 1870s. Washington Matthews (1877:3-4), an ethnographer and surgeon at Fort Berthold during the mid-1860s offered a secondhand tabulation provided directly to him by Dr. Charles E. McChesney in 1872. At that time, McChesney served as the physician at Fort Berthold. McChesney identified about one-third of the Arikara buildings and two-thirds of the Mandan-Hidatsa dwellings, or over 50 percent of structures at Like-A-Fishhook, as log cabins.

Speaking about various manifestations of change, Smith (1972:178) states that “[t]he adoption of this new type of dwelling may be the most far-reaching change in the material culture of these peoples.” Furthermore, Smith (1972:178) suggests that items would have been adopted only after a trial period during which Native groups deemed them more effective than their traditional functional equivalents. Although dated, such statements clearly perpetuate a view of European and American technological superiority as a driving force for culture change among Native peoples. A significant problem with this perspective is that it hinders inquiry into a broader range of important anthropological questions regarding the processes by which material culture was adopted, resisted, and transformed. For instance, what are the reasons for the transition in architectural forms? If one assumes the structures were simply superior to earthlodges, other reasonable explanations may be overlooked. Perhaps cabins were more convenient and practical than lodges, particularly by the mid-1850s when timber shortages were reported in the vicinity of Fort Clark (Wood et al. 2011:8, 59, 176, 192, 195, 201).

On the other hand, how were the structures used? As previously discussed, test excavations point to a residential use of one rectangular structure by the Arikaras at Fort Clark (Mitchell 2014b, 2014c). Yet, some rectangular structures possibly had non-domestic uses. For instance, three unusual features were excavated at Star Village, the settlement constructed by the Arikaras after their abandonment of the community at Fort Clark (Metcalf 1963:90-97). Metcalf (1963:90-97) describes several possible functions for the features, including drying platforms, arbors, stables, or brush-fenced gardens. In fact, when Star Village was mapped by A. B. Stout, an Arikara informant, Bull Neck, identified one of the excavated features as a horse stable (Libby 1908:Plate 6, 506-507). However, Metcalf (1963:94-96) favors a different interpretation based on historical photographs of buildings on the Fort Berthold Reservation (Mitchell 2014c:142). Metcalf (1963:94-96) suggests the “log cabins” described by Latta at Star Village were in fact pole and brush buildings thinly covered by earth, or a crude form of wattle and daub. Other historical photographs and illustrations indicate that Native cabins were typically constructed in a more familiar manner with either stacked round logs or square timber (Mitchell 2014c:143-147).

If one assumes the buildings functioned primarily as domestic residences, though, another question concerning the occupants of the cabins at Fort Clark becomes apparent. What was the social standing of Arikara families that inhabited the dwellings? Were these primarily prominent families or otherwise? Furthermore, what are the implications of this change? Traditional earthlodges were occupied by extended families, but cabins at Fort Clark, which average about one-quarter the area (Chapter 5; Wiewel and Kvamme 2016), were possibly single-family residences that housed considerably fewer people. That said, what changes occurred in family living arrangements and relationships to accommodate this shift in architecture? Gender roles related to the construction of dwellings, primarily the domain of women (Bowers 2004:82; Krause 2016; Stewart 2001:338), perhaps changed with the new architectural form as well (Mitchell 2014c:145).

These anthropological questions currently remain unanswered, but such inquiry requires a shift away from conventional narratives of culture change. Several other regional counterexamples further challenge traditional colonial perspectives of technological change and identity. For instance, Griffitts (2006) contends that the transition from bone and antler to metal tools was complex among Plains Village farmers in the Northern Plains. Some tools such as bone fishhooks, which are time-consuming to manufacture, were quickly replaced once metal hooks became available or could be easily fashioned (Griffitts 2006:482). Other tools like bone awls remained in use during the nineteenth century, although use-wear indicates the range of activities for which they were employed narrowed (Griffitts 2006:480). Use of scapula hoes and metapodial fleshers likewise continued into the nineteenth century (Griffitts 2006:480). Matthews (1877:19) observed that scapula hoes were used as late as 1867 at Fort Berthold. However, Griffitts (2006:480) suggests the techniques by which hoes and fleshers were manufactured differed since metal implements used to shape the tools replaced stone ones. A related anecdote comes from the Lewis and Clark expedition (Ronda 2002:104). In 1804 the

Mandans were given a corn mill, which they dismantled and fashioned into various useful implements unrelated to corn grinding. Thus, a wide range of factors, including raw material availability, the cost of manufacture, functional utility, and symbolic value (Griffitts 2013), influenced decision-making processes related to the avoidance, adoption, or adaptation of European and American material goods. In other words, the pattern of technological replacement was neither rapid nor inevitable.

Additionally, glass trade beads were used in unique and experimental ways. Although such syncretic examples are rare, the Arikaras and neighboring groups like the Cheyennes occasionally produced bead-decorated ceramic vessels during the eighteenth and nineteenth centuries (Green et al. 2016; Waselkov et al. 2015). A remnant of one such vessel, a Knife River ware rim sherd with three white, donut-shaped beads embedded in its flat lip, was discovered during fieldwork at Fort Clark in 2012 (Green et al. 2016). Similarly, the Native manufacture of glass pendants is well known among the Arikaras as well as the Mandans and Hidatsas (Billeck 2016). To produce the triangular-shaped pendants, a wet paste was first formed from crushed glass trade beads. The paste was then heated atop a piece of metal, which caused the crushed glass to fuse. In this way, trade items were transformed into more desirable and culturally meaningful objects (Billeck 2016). Archaeological specimens and historical accounts indicate the practice began in the Plains area during the late seventeenth century and continued until the mid-nineteenth century.

Although metal pots were available and often used during the late eighteenth and nineteenth centuries, Hidatsa production and use of ceramic pots similarly persisted and changed in complex ways (Hollenback 2012:420-422, 445-447). Several aspects of pottery production, including raw materials, manufacturing methods, surface treatments, vessel form, and vessel function (culinary purposes), remained consistent through time (Hollenback 2012:420). However, elements of pottery production like raw material preparation, wall thickness, and design motifs changed, probably as a consequence of disease-related depopulation and time and labor considerations. The continued production and use of pottery by the Hidatsas was likely critical for several reasons, including as an enculturation practice, a signifier of adherence to traditional practices, and a mechanism for group identity maintenance (Hollenback 2012:421).

Group identity maintenance is relevant since the Mandans, Hidatsas, and Arikaras coinhabited a single village, Like-A-Fishhook, during the mid- to late nineteenth century. Historical references, particularly those from the *Annual Report of the Commissioner of Indian Affairs* series, suggest that their identities became more indistinct during this time (Murray 2016:9). At the same time, separate Mandan-Hidatsa and Arikara sections of the village were recognized during its occupation (Smith 1972:11, 25-27). Although Like-A-Fishhook was a coalescent community, space syntax analyses indicate that distinct tribal identities persisted (Murray 2016:12). That is, the spatial organization of the village was such that within group interactions were prioritized. Yet, other indicators point to integration between the Mandan-Hidatsa and Arikara sections of the village, although this interaction occurred primarily between leaders and high-status individuals who occupied lodges near both plazas (Murray 2016:12).

Changed Continuities: Storage Capacity and Agricultural Production

These examples, which conflict with conventional colonial narratives, are compatible with Ferris's (2009) concept of "changed continuities." Ferris (2009:1) envisions changed continuities as a process in which Native groups "maintained identity and historically understood notions of self and community, while also incorporating substantial material changes and revision to those identities.” The concept, which is broadly applicable to both material and ideological dimensions of the lives of Native peoples, defines change and continuity as constant, simultaneous, and related processes shaped by historically informed trajectories. Archaeology is ideally situated to examine these trajectories and gain insight into the ways Native groups negotiated the onset and era of colonialism (Ferris 2009). Like the previous examples, “changed continuities” aptly explain the process by which farmers who occupied villages along the Missouri River in the Northern Plains met contingencies that arose with the arrival of colonial fur traders during the nineteenth century.

Archaeologists have developed a vast body of data concerning technological, subsistence, and settlement pattern variability for the Middle Missouri subarea during the Plains Village period. These villagers generally exploited a wide range of resources that were available in their diverse environment, although horticulture and bison hunting are typically considered the most significant components of their subsistence economy. Moreover, each village contains hundreds or thousands of subterranean storage pits within which surplus agricultural goods were stored. These features are testimony to the horticultural capabilities of the people and the dramatic productivity of their gardens. Of course, this aptitude developed over generations of experience in which a body of knowledge concerning the climate, inconsistent weather, soil conditions, and cultivation practices, among many other variables, developed.

The size of and patterning among settlements shifted through time as well. A transition is evident during the late fourteenth and fifteenth centuries along the Missouri River in North Dakota. During this time, settlements became fewer in number, significantly larger in population, and more clustered, a trend that would continue in subsequent centuries. Craft specialization, with noticeable differences in stone tool and ceramic production skill and technique, occurred concurrently with this transition. Additionally, the villages were primary centers of trade in a continent-wide exchange system at the time of colonial fur traders' arrival in the eighteenth century. The trade system had expanded and the volume of trade had increased substantially in preceding centuries. By all accounts, nomadic groups and other sedentary villagers were drawn to the settlements to obtain the perishable goods, especially maize, harvested in their gardens.

Despite our awareness of these circumstances, no systematic effort has ever been undertaken to identify the magnitude of or trends in agricultural production among horticultural groups in the region. Circumstantial evidence has been cited to propose that production was expanded or intensified to meet growing intertribal trade demands prior to the arrival of European and American colonists. However, what occurred during the eighteenth and nineteenth centuries is unclear. Historical documents offer one line of evidence for understanding garden systems in the region during the nineteenth century. However, no fields, including those associated with sites from earlier periods, are known to exist along the Missouri River today. Modern cultivation, dam construction, and a meandering river have destroyed most, if not all, traces of these features. Quantitative data in relation to storage pit numbers and capacity provide an alternative avenue for understanding the scale of agricultural production in the region.

I used extensive magnetic gradiometry and elevation data combined with the results of salvage excavations at Huff Village State Historic Site (32MO11), a mid-fifteenth century settlement, to generate an initial figure of maize production (Chapter 3). Among several important findings, my interpretations of the remote sensing data sets yielded two crucial results. First, the settlement contains at least 115 structures, which are mostly long rectangular in form and have a mean floor area of about 128 m^2. Approximately 1,470 people likely occupied the village given the total number of houses and mean floor area. Second, I identified a total of 2,311 positive monopolar magnetic anomalies using GIS methods. These anomalies are located within and surrounding the perimeters of every lodge. Coring revealed that most are storage pit and hearth features. Of this total, there is an estimated 1,883 storage pits.

Excavations carried out at Huff during the mid-twentieth century indicate that both straight-sided and undercut pits are common. Their dimensions suggest an average volume of just over 1 m^3. A total storage capacity of about 1,940 m^3 can be inferred from the average volume of excavated storage pits and the number of identified pits. This estimate is substantially higher than would be necessary for a village of such population, even considering other factors like trade. The figure is not surprising, however, since most pits were probably only used at most for a few years. That is, only a portion of the total number would have been used at any one time.

To arrive at estimates of the amount of maize produced and cropland required in a normal year, I considered several other variables, including the likely village composition, nutritional requirements, dietary composition, and fallowing practices. The occupants of Huff Village would have required about 112,000 kg of maize considering only their own dietary needs, an amount that could have been cultivated on about 100-150 ha. Neither figure is unreasonable. Historical accounts of agricultural production in the region during the nineteenth century contain numerous references to comparable amounts of cultivated maize grown on similar amounts of land.

What this analysis lacks, however, is a long-term view of production in the Middle Missouri subarea of the Northern Plains (Chapter 4). Such a view provides insight into historical trends or variation in agricultural production and the potential reasons for differences through time. Again, I relied on quantitative excavation and coring data to generate estimates of storage pit volume, a proxy measure of production. To examine trends in production, I compiled data for

562 storage pits from 20 archaeological sites spanning a period of nearly 700 years. The sites, most of which are located in present-day North Dakota, are situated along the banks of the Missouri River. The earliest sites date to the thirteenth century while the last, Like-A-Fishhook, is the nineteenth-century coalescent village of the Mandans, Hidatsas, and Arikaras. The data revealed several significant findings.

First, Late Woodland sites such as Menoken (32BL2), which dates to the turn of the thirteenth century, lack evidence of subterranean storage pits. Moreover, the few identified botanical remains of domesticated species at the site, including maize, indicate their relative insignificance at that time. Yet, the importance of domesticated plant foods developed rapidly during the thirteenth century. Extended Middle Missouri variant settlements from that century contain a substantial number of straight-sided and undercut storage pits, which excavation data show have an average volume of .451 m^3. Extended Coalescent and Terminal Middle Missouri variant villages like Huff, a settlement occupied about two centuries later, have a dramatically larger mean volume of about .843 m^3. Mean storage pit volumes more than double over the next 250 years, with an average of 1.954 m^3.

The mean volume of storage pits that date to the second half of the seventeenth century are significantly greater than those of the thirteenth and fourteenth centuries. This finding is important in light of hypotheses concerning the likelihood that agricultural production was expanded or even intensified before the arrival of colonial fur traders to accommodate flourishing intertribal trade requirements. The substantial increase in production is associated with population aggregation in the region and craft specialization within villages. This increase, however, is followed by a dramatic decline in mean storage pit volume during the eighteenth century. Reasons for such a change include climatic events and epidemic disease. Climatic fluctuations, which typically occur on an order of a decade or less, are not obviously linked to either the gradual increase or the sudden decrease observed in agricultural production. On the other hand, diseases of European origin are known to have affected Native groups in the Plains or neighboring regions as early as the sixteenth century. In particular, the 1780-1781 smallpox epidemic, the earliest historically documented case of disease in the region, was the source of a substantial population decline. Clearly, a sharp decline in population, an event that would have decades-long consequences, would lead to reduced productivity due to a lack of necessary labor.

The mean volume of excavated storage pits increased again during the mid- to late nineteenth century. The mean volume of 1.886 m^3 is significantly greater than the preceding period and the earliest centuries, a finding that suggests agricultural production remained important to the Mandans, Hidatsas, and Arikaras. To make additional connections between these results and those from the previous chapter, I examined the accounts of nineteenth-century agents in the *Annual Report of the Commissioner of Indian Affair* series. Although not without bias, these documents include multiple references to the three groups who occupied Like-A-Fishhook producing hundreds of thousands of kilograms of maize. More labor was devoted to the cultivation of other crops, including potatoes, wheat and oats, during the 1880s, a period during which maize harvests declined. However, multiple lines of inquiry indicate the Mandans, Hidatsas, and Arikaras continued their traditional agricultural practices into the second half of the nineteenth century.

Still, a multi-decade gap exists between the period during which mean storage pit volumes declined and the mid- to late nineteenth-century increase at Like-A-Fishhook. During this early to mid-nineteenth-century period, a well-known Native village was established by the Mandans. A trading post known as Fort Clark was established soon after near the village, which meant the Native occupation was documented by a series of explorers, artists, traders, and others. Historical data have been used to argue that the Mandans increased or intensified production during the early decades of the nineteenth century to meet the demands of trade with other tribes and colonial fur traders. After the smallpox epidemic of 1837, however, the village was inhabited by the Arikaras for nearly a quarter century. Data yielded by extensive remote sensing investigations, limited excavations and coring programs, and historical documents provided me with an independent but less than straightforward means of considering the preceding results (Chapters 5 and 6).

I relied extensively on the vast documentation that exists for the settlement in interpreting a suite of remote sensing results. Among numerous important findings, the village contains substantially more earthlodges than were mapped previously. In fact, I identified 37 additional earthlodges using a combination of several integrated data sets, including magnetic gradiometry, earth resistance, thermal infrared, and LiDAR data. Furthermore, I confirmed the presence of a central hearth feature within each new lodge by soil coring.

The village was destroyed by fire in January 1839 and lodges were typically rebuilt every 10-15 years, so I suspect most of the previously mapped structures and the newly identified dwellings relate to the Arikara rather than the early Mandan occupation. Several other lines of evidence support this inference. No lodges are depicted outside the palisade fortification in the illustrations of George Catlin, Karl Bodmer, or Prince Maximilian during their visits in the early 1830s, just a few years prior to the Arikaras' appropriation of the settlement. Moreover, excavated midden deposits toward the west side of the village are relatively shallow compared to those within its core, a finding that is telling of the area's brief use. I used GIS methods to isolate different types of magnetic anomalies, including dipolar and positive monopolar anomalies.

Dipolar magnetic anomalies, which typically point to ferrous metal items, exhibit very low densities outside the fortification ditch. Positive monopolar magnetic anomalies, or those which are often relate to hearths and storage pits, are similarly patterned. Considered together, these observations suggest the area outside the fortification ditch was used for a short period. Most earthlodges in this area were likely constructed during the latter part of the Arikaras' occupation.

Another feature type, shallow depressions that are typically 1-3 m in diameter, is evident in multiple data sets, including continuous data integrations generated from LiDAR and thermal infrared data as well as aerial photographs. The features are visible as monopolar negative anomalies in the magnetic gradiometry data. They are thought to represent mostly storage pits, an interpretation that I consider correct. Lewis Henry Morgan visited the village one year after it was abandoned and documented the presence of emptied storage pits, presumably because the Arikaras removed their contents prior to their upriver move. The empty pits would have backfilled naturally over time while other pits probably subsided as their organic contents decayed. These open storage pits were still visible within the village, as noted by E. R. Steinbrueck after his site visit, in the first decade of the twentieth century (Brower 1904:144). Additionally, historical aerial photographs show that many of the features I identified as storage pits were present as early as the mid-1960s. I cored a small number of the features and found that most are in fact deep storage pits.

Unlike the distributions of dipolar and positive monopolar anomalies, these negative monopolar magnetic anomalies and pit features are clustered in several areas outside the fortification ditch and toward the southwest side of the village core. This difference in patterning is significant. The negative monopolar anomalies and pit features appear to be related to other features of the Arikara occupation such as lodges and log cabins. Historical documents and illustrations show that the Arikaras constructed several log cabins during their occupation of the village. I identified 17 likely cabins based on magnetic gradiometry, magnetic susceptibility, and LiDAR data. Limited excavations confirmed that one structure was indeed a log cabin built during the last decade of the Arikaras' occupation, and historical information suggests most, if not all, were constructed during this same period. Thus, the small pit features visible on the ground surface likely represent storage pits used by the Arikaras during the latter part of their occupation. Storage pit volume data comparable to that discussed previously are not available due to a lack of extensive excavations at Fort Clark.

Historical documents, particularly the Fort Pierre and Fort Union letter books, include many instances in which fur traders requested maize harvested by the Mandans to be delivered to both locations. Neither precise amounts of maize nor the frequency with which these requests were fulfilled is apparent. However, Maximilian indicated that over ten thousand kilograms of maize were provided annually by the Mandans to Fort Clark as well. Also, several references indicate that nomadic groups continued to visit the Mandan village during the 1830s to obtain maize after the fall harvest. With an estimated population of about 1,250 people, nearly one hundred thousand kilograms of maize would have been necessary just to meet the settlement's nutritional requirements (i.e., the assumed 35 percent contribution of maize to the diet). Considering trade demands evident in historical sources, the Mandans likely produced substantially more maize in years with ideal weather.

Likewise, the available information indicates the Arikaras harvested sizeable amounts of maize after taking possession of the village at Fort Clark. About 1,000-1,100 Arikaras occupied the village based on historical accounts and estimates yielded by the total number of houses and average floor areas of both lodges and log cabins. Other sources indicate the Arikaras typically produced tens or hundreds of thousands of kilograms of maize, substantially more than was necessary for their own dietary requirements. Large quantities were apparently traded to fur traders and nomadic groups as well. Such historical data are persuasive. Importantly, remote sensing and limited coring data can account for this level of maize production.

In the absence of storage pit volume data, I compared pit depths instead. This comparison is meaningful since there is a moderate correlation between pit depth and base diameter among the sample of storage pits excavated at 20 sites. That is, pits of greater depth typically exhibit larger base diameters. Moreover, plots of pit depths parallel those of pit volumes. Patterning such as the gradual increase in pit size through the seventeenth century and the subsequent decrease during the eighteenth century is apparent. Within the Native village at Fort Clark, monopolar positive and negative magnetic anomalies that were cored and interpreted as storage pits averaged about 115 cm in depth, an amount that is significantly greater than the previous late eighteenth and early nineteenth-centuries period. Pits excavated at Like-A-Fishhook exhibit comparable depths. Thus, the increase noted in pit volume occurred as early as the Arikara settlement at Fort Clark.

Furthermore, I identified 612 negative monopolar magnetic anomalies or small depressions within the village using GIS methods, 530 of which are probably storage pit features given the results of the coring program. I derived a volume estimate using the formula for a conical frustum, with an average depth of nearly 115 cm, a hypothetical mouth diameter of approximately 92 cm (an estimate produced with the mouth diameters of all excavated pits), and a hypothetical base diameter of about 132 cm (an estimate yielded by regression analysis). The estimated volume of 1.14 m^3 indicates a total storage capacity of about 604 m^3 given the number of storage pits identified by remote sensing and coring. A storage capacity of this volume would have held a considerable supply of maize as well as other perishable goods. In fact, the amounts would have been more than sufficient to meet the population's own dietary needs and the trade demands of Native groups and colonial fur traders.

In a state of decline brought on by epidemic disease and the introduction of trade goods, traditional colonial narratives would have one believe that the Mandans and Arikaras differed substantially from their ancestors in many ways, including their farming abilities. Prior to the arrival of colonial fur traders, both Native groups had powerful roles in and influence over a continent-wide exchange system from their villages along the Missouri River. The demands of intertribal trade were a significant factor that led these farming villagers to expand or intensify production of their garden crops. These demands did not diminish initially with the arrival of colonial fur traders. On the contrary, nomadic groups continued to trade at the villages as did an increasingly larger number of traders during the late eighteenth and nineteenth centuries. The Mandans and Arikaras were capable of meeting these contingencies based on their historically informed knowledge of farming and trade. Various cultural institutions, including cooperation and conflict, influenced their participation and interactions with fur traders and other Native groups during the period. Both actively sought to maintain their prestigious and powerful positions. Despite obvious changes brought on by the arrival of European and American colonists, there are clear continuities in terms of agricultural production and trade with earlier centuries. Moreover, cultivating maize was significant for more than just dietary and economic reasons for the Mandans, Hidatsas, and Arikaras. Maize was in fact an integral symbolic element of their origins, ritual lives, and belief systems (Bowers 1992, 2004:183-205; Parks 1996:153-159). Maize was inextricably linked to other cultural institutions of the three groups, and thus, growing and harvesting the crop was crucial to the maintenance of cultural identities. The persistence of maize agricultural traditions is unsurprising given the spiritual mandates associated with it.

Remote Sensing: A Fundamental Tool for Archaeology

Beyond these significant theoretical aspects, archaeology itself has changed significantly in the United States in recent decades. During earlier decades, particularly those of the mid-twentieth century, government-sponsored archaeology projects proliferated. Numerous large-scale archaeological investigations, many salvage related in nature, were carried out across the country under the auspices of New Deal era programs (Means 2013) and later the Interagency Archeological Salvage Program and River Basin Surveys (Banks and Czaplicki 2016).

Investigations of comparative scale are relatively sparse today, although such work is a fundamental element of efforts to explore site content and spatial patterning in artifact and feature distributions. Budgets of funding institutions, including academic programs and the federal and state governments, are limited. Excavation, analysis, and curation are labor intensive and costly, and the destructive nature of excavation is politically and ethically objectionable. These factors have inhibited archaeological undertakings.

Although they too have limitations, remote sensing technologies are critically important tools for these reasons. Archaeologists are well aware of many of the most impressive results of remote sensing investigations from recent decades. Extensive geophysical surveys reveal much about the prehistoric landscape surrounding Stonehenge, an area that saw relatively little study despite intensive research involving the site (Gaffney et al. 2012). Large-scale gradiometry surveys of the Roman city of Wroxeter in England show significant detail concerning the organization of the city and better defined possible settlement and industrial areas (Gaffney et al. 2000). Remote sensing methods have been combined in a program of study involving the Iron Age city of Kerkenes in Turkey, results of which indicate its occupation was short, construction involved centralized planning, and many buildings likely served as storage facilities (Summers and Summers 2006). At the medieval temple complex at Angkor in Cambodia, LiDAR data suggest widespread anthropogenic modification of both the urban and agricultural landscape. LiDAR data similarly reveal the extent of landscape modification, degree of terrace construction, and scale of the Maya settlement of Caracol in Belize. Geophysical investigations in the U.S., including those of the prehistoric earthworks of Ohio (Burks and Cook 2011) and Plains Village period settlements in North Dakota (Kvamme and Ahler 2007), have also yielded invaluable insights that would otherwise not be attainable without destructive and costly archaeological excavations.

In recent years improvements in instrument reliability and data acquisition speed have greatly benefitted geophysical surveys (Kvamme 2003c). Vast spaces, tens of thousands of square meters in area, may be surveyed. An area like this is beyond the scope of traditional archaeological excavation and takes geophysical surveys into the realm of a landscape perspective (Kvamme 2003c). That is, geophysical surveys may yield primary data that facilitate investigations of site-scale and broader questions such as those concerning distributions and relationships among features and variations between sites. Likewise, software processing capability and visual display techniques have improved. Geographical information systems (GIS) in particular provide a mechanism for processing, analyzing, and visualizing geophysical data (Kvamme 1999). In fact, GIS have simplified the process of integrating multidimensional data sets (Kvamme 2006a). This is significant since multiple methods produce a more comprehensive depiction of the subsurface and enable more nuanced interpretations of spatial patterning among anomalies or archaeological features.

Despite these advances and the widespread availability of geophysical instruments, archaeological feature discovery remains their primary use (Thompson et al. 2011). This use is valid and crucial to the discipline, though, especially in cultural resource management contexts. Geophysical investigations may be used strictly for guiding excavations. All too often, however, archaeologists stop short of the more difficult task of applying remote sensing data to anthropological inquiries. To this end, I have addressed questions concerning change and continuity in storage capacity and agricultural production among Plains Village farmers in the Middle Missouri subarea by combining insights drawn from historical documents, excavations, and remote sensing data.

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APPENDIX 1: REMOTE SENSING AND DATA PROCESSING METHODS

Multi-instrument geophysical surveys were performed at Huff Village State Historic Site (32MO11) and Fort Clark State Historic Site (32ME2) in North Dakota to identify potential archaeological features necessary to address questions concerning agricultural production among Plains Village horticulturalists raised in Chapter 1. I offer further discussions of these investigations, including survey areas, results, and interpretations in Chapters 3 and 5. Complete and close-up views of all remote sensing data sets are presented in Appendices 2 and 4. The following sections provide greater detail on specific remote sensing techniques and data processing methods.

Magnetic Gradiometry

Magnetometry is a passive geophysical method (Aspinall et al. 2009:31-44; Clark 2001:64-71; Gaffney and Gater 2006:36-42; Kvamme 2006b; Weymouth 1986:341-344). Unlike active instruments that transmit or generate a signal into the ground and measure the subsequent response, magnetometers detect a naturally occurring property. The technique measures local, near-surface variations in the strength of the earth's magnetic field related to natural and cultural phenomena. A gradiometer, one type of magnetometer, measures the difference between two sensors separated by a fixed distance rather than the magnitude of the magnetic field, which had the strength of about 56,500 nT (nanotesla, a measure of magnetic field strength) in the project locations (NOAA 2016). Thus, broad geological sources of magnetism and the earth's magnetic field affect both sensors similarly while archeological features, which typically exhibit much weaker magnetism varying between about ±5 nT, are detected primarily by the lower sensor. Differencing the measurements effectively eliminates temporal variability (e.g., diurnal variation, but also other intermittent magnetic "noise") and broad changes in the magnetic field. Spatial variation related to smaller archaeological and geological features as well as iron or steel items remains.

Magnetometers measure induced and all types of remanent magnetism but cannot differentiate among the forms (Aspinall et al. 2009:21-26; Clark 2001:64-66; Gaffney and Gater 2006:36-42; Kvamme 2006b; Weymouth 1986:341-344). Remanent magnetism is the permanent type of magnetism that materials exhibit, even in the absence of a magnetic field. Materials that have been intensely heated exhibit thermoremanent magnetism, which is of considerable importance to archaeology. Archaeological features like hearths acquire thermoremanent magnetization due to the presence of iron oxides, which naturally occur in small amounts in most soils, sediments, and rocks. In general, the magnetic domains of the minerals are randomly oriented in natural soils, meaning the net magnetization is weak. However, when the minerals are heated beyond their Curie temperatures (around 600º C, but varies depending on the material) and then cooled, their domains realign with the earth's magnetic field. The consistent orientation of the domains is the source of the strong, residual magnetism of the feature.

On the other hand, magnetism may be induced in materials due to their susceptibility, or tendency to become temporarily magnetized in the presence of a magnetic field (Aspinall et al. 2009:21-26; Clark 2001:64-66, 99-101; Gaffney and Gater 2006:36-42; Kvamme 2006b; Weymouth 1986:341-344). In archaeological contexts, susceptibility varies as a consequence of the concentration of iron oxides in soils (Aspinall et al. 2009:24-25; Kvamme 2006b:214-221). Importantly, several natural factors enhance topsoil susceptibility in particular, either through the concentration of magnetic minerals or the conversion of weaker to more magnetic iron oxides. Human behaviors, including burning and the introduction of organic waste and magnetic materials (e.g., items like ceramic sherds, brick fragments, fire-cracked rock, magnetic stone, and iron artifacts), further increase topsoil susceptibility. Thus, subsequent human activities that accumulate magnetically enhanced soil (e.g., backfilling a ditch or pit feature) are a source of susceptibility contrasts, which presumably can be detected during a magnetic survey.

The utility of magnetic gradiometry for detecting subsurface features like structures, hearths, and storage pits, especially in the Northern Plains, is well established (Table 2.1) (Kvamme 2006b:205-206, 2007). A Bartington Grad601-2, a dual fluxgate gradiometer instrument with sensors vertically separated by 1 m, was used for surveys at Huff Village and Fort Clark (Figure 2.1a). The instrument is capable of measuring magnetism to a resolution of .1 nT and is sensitive to a depth of about 1.5 m depending on several factors such as the buried feature or object's size, shape, and composition (Bartington Instruments 2014a; Clark 2001:78-80).

Earth Resistance

Resistance instruments measure the resistance of the soil matrix to the flow of an electrical current (Clark 2001:27-37; Gaffney and Gater 2006:26-36; Schmidt 2013; Somers 2006; Weymouth 1986:318-321). Variation in resistance is caused by a number of interrelated factors, including soil structure (e.g., porosity), the moisture content of the soil, and its ion content. Human actions affect earth resistance by altering these factors. For instance, humans may compact or loosen the soil, which subsequently alters moisture content, or they may construct intrusive features that either impede or facilitate the flow of electricity. While an electrical current will easily pass through conductive soils, compacted soils and other inclusions within the soil matrix like rocks inhibit the flow of the current, creating a measurable difference in voltage and a contrast in resistance. Systematically measuring these variations over an area is the basis of earth resistance investigations in archaeology.

Two nearly identical instruments, a Geoscan Research RM15 and a TR Systems TR/CIA meter, were used to perform resistance surveys at Fort Clark (Figure 2.1b). Although the instruments are sometimes configured in different ways for archaeological applications (Clark 2001:27-37; Gaffney and Gater 2006:26-36; Schmidt 2013; Somers 2006; Weymouth 1986:318-321), a twin-probe array was utilized for this investigation with two remotely-placed stationary probes and two probes, separated by .5 m, fixed to the mobile platform. Each pair includes a current electrode, which supplies an alternating current, and an electrode that monitors voltage. According to Ohm's law ($R = V/I$), resistance (reported in ohms) is equal to voltage divided by current. The current electrodes supply a constant current, meaning any change in voltage would indicate a change in resistance. Thus, earth resistance is considered an active technique unlike magnetometry. Kvamme (2003a, 2007a) has had considerable success using the method to define features like house depressions and fortification ditches within Plains Village settlements in the Northern Plains. Importantly, the twin-probe configuration, with .5 m between the probes fixed to the mobile platform, is capable of measuring resistance to about an equal depth, which is adequate for the many near-surface features at Fort Clark.

Electromagnetic Induction

The operation of electromagnetic induction (EMI) instruments is based on the same principle, the soil's capacity to conduct an electrical current, although they measure conductivity, the inverse of resistivity (Clark 2001:34-37; Clay 2006; Dalan 2006; Gaffney and Gater 2006:42-46). The survey at Fort Clark was conducted with a Geonics EM38B (Figure 2.1c). The instrument has two coils, a transmitter and receiver separated by 1 m, and actively emits electromagnetic energy at a frequency of 14.6 kHz (Geonics Limited 2003).

The instrument functions by introducing an alternating current into the transmitter coil, which induces a magnetic field in the ground (Clark 2001:34-37, 105-106; Clay 2006; Dalan 2006; Gaffney and Gater 2006:42-46; Geonics Limited 2003; McNeill 2013). This primary magnetic field subsequently creates electrical currents in conductive soil near the instrument. A secondary magnetic field is generated from these currents and, along with the primary field, is measured by the receiver coil. Importantly, the secondary magnetic field contains two components. One component, referred to as quadrature phase, is 90º out of phase with the inducing magnetic field and is proportional to the conductivity of the soil (measured in millisiemens per meter or mS/m). The other response is in-phase with the initial magnetic field and relates to magnetic susceptibility. It is expressed in parts per thousand (ppt) of the secondary to primary magnetic fields. Thus, EMI instruments are capable of generating two types of data; the EM38B records both simultaneously.

One advantage of employing both magnetic gradiometry and EMI instruments is that an examination of the magnetic data sets my lead to a better understanding of the likely sources of anomalies (Kvamme and Wiewel 2013). Whereas gradiometers record all types of remanent and induced magnetism, EMI instruments record only the induced form. This difference is significant since some magnetic anomalies are primarily of the thermoremanent type while other anomalies are caused more by induced magnetism (e.g., hearths vs. storage pits). Moreover, gradiometers are incapable of detecting flat and thin features that contain susceptible materials while such features can be detected by EMI instruments (Clark 2001:101-102; McNeill 2013:8).

EMI instruments offer several advantages over earth resistance as well (Clark 2001:34-37; Clay 2006; Gaffney and Gater 2006:42-46). For instance, EMI instruments such as the EM38B are carried over or placed on the ground surface as data are recorded continuously whereas the electrodes of resistance meters must be inserted into the ground for every measurement. The survey speed of the former is therefore faster than that of the latter. For this same reason, EMI instruments are more suitable for use in dry climates or on dry surfaces. Resistance is more likely to produce poor results due to contact resistance between the dry soil and electrodes. Yet, EMI instruments are highly sensitive to both ferrous and non-ferrous metals on or near the ground surface while resistance meters are not. Thus, both approaches may prove fruitful in different circumstances.

Within Plains Village components, EMI surveys are capable of detecting many common features with enhanced magnetic susceptibility, including earthlodge perimeters, hearths, subterranean storage pits, and activity areas (Kvamme 2007a, 2008a; Kvamme and Ahler 2007). When carried in the vertical dipole mode (as occurred during surveys at Fort Clark), the EM38B has a maximum effective depth of 1.5 m and is therefore well suited for the near-surface features at Fort Clark (Clay 2006:86-87; Geonics Limited 2003:10-11). In fact, the instrument's sensitivity varies between the two components. The quadrature phase (conductivity) component increases in sensitivity with depth, is most sensitive around 40 cm, and declines with greater depth (Clay 2008:86-87; Geonics Limited 2003:10-11). In contrast, the peak sensitivity of the in-phase (magnetic susceptibility) component is about 20 cm, and it is effective to a depth of around 50 cm since the response switches signs (i.e., negative rather than positive) at depths greater than 60 cm (Dalan 2006:171, 2008:4).

Magnetic Susceptibility

Additionally, a single-coil magnetic susceptibility meter, the Bartington MS2, was used to acquire near surface magnetic susceptibility data at Fort Clark, with results presented in greatest detail by Wiewel and Kvamme (2014). Unlike the EM38B, which records magnetic susceptibility to a depth of approximately 50 cm, the MS2 is sensitive to a depth of only 10 cm when paired with the Bartington D surface scanning probe (Bartington Instruments 2014b). Its sensitivity decreases to 50 percent by 1.5 cm (Bartington Instruments 2014b). Yet, systematic comparisons with the two instruments indicate moderately similar results (Kvamme and Wiewel 2013:28-29). The Bartington MS2 operates by producing an alternating magnetic field, the frequency of which changes and is scaled to the magnetic susceptibility of materials introduced to the field (Clark 2001:102; Gaffney and Gater 2006:44-46). The results are expressed as volume susceptibility (κ), a dimensionless quantity in the SI system of units (Dalan 2006). Although studies of magnetic susceptibility are comparatively rare in North American archaeology, the technique's frequency of use has increased in recent years (Dalan 2008).

Ground-penetrating Radar

Ground-penetrating radar (GPR) instruments have been used less extensively in surveys of village settlements in the Northern Plains because results have often been overshadowed by those of techniques like magnetic gradiometry (Kvamme 2003a, 2007a, 2008a; Kvamme and Ahler 2007). However, in some instances the instruments have been shown capable of clearly indicating the locations of significant subsurface features such as earthlodge floors, hearths, and storage pits. Ground-penetrating radar instruments emit pulses of electromagnetic energy, which vary in frequency from about 10 to 1,500 MHz, downward into the earth from an antenna (Clark 1996:118-120; Conyers 2006, 2012, 2013; Conyers and Goodman 1997; Gaffney and Gater 2006:47-51; Weymouth 1986:370-374). These radar pulses reflect off natural discontinuities such as soil layers and bedrock as well as discontinuities related to archaeological features. The instrument measures the time (in nanoseconds) between the transmission of the radar pulses and their return to the antenna, a value that may be converted to depth if the velocity of the energy can be determined.

Several factors, including soil type and moisture content, affect radar energy's downward movement. More specifically, the velocity at which radar energy is transmitted and its depth of penetration relates to the relative dielectric permittivity (or dielectric constant, the ability to store and transmit energy) of different subsurface materials. Contacts between materials with significantly contrasting dielectric properties cause greater changes in velocity and produce stronger or larger amplitude reflections. Surveys were performed with a Geophysical Survey Systems, Inc. (GSSI), SIR-2000 radar with two antennae (400 and 900 MHz) at Fort Clark (Figure 2.1d). The higher frequency antenna produces a shorter wavelength; its main advantage is that it yields higher resolution data but only to shallow depths. Due to the slower speed of ground coverage with the instrument, a much smaller area of the village was surveyed compared to the other geophysical techniques. Details regarding sampling densities and survey areas at Fort Clark and Huff Village are summarized by geophysical instrument in Table A1.1.

Table A1.1. Geophysical instruments used at Fort Clark and Huff Village with details concerning sampling densities and survey coverage.

Remote Sensing Method	Instrument	Sampling Density	Surveyed Area (m^2)[b]
Magnetic gradiometry	Bartington Grad601 dual fluxgate gradiometer	a) .125 x .5 m[a] b) .125 x .25 m	a) 119,995 m^2 (Fort Clark) and 50,269 m^2 (Huff Village) b) 400 m^2
Earth resistance	(1) Geoscan Research RM15 and (2) TR Systems Ltd. TR/CIA (twin-probe configuration)	a) 1 x 1 m b) .5 x .5 m	a) 78,645 m^2 b) 400 m^2
Electromagnetic induction	Geonics Ltd. EM38B	a) .5 x 1 m b) .25 x .5 m	a) 26,164 m^2 b) 400 m^2
Ground-penetrating radar	Geophysical Survey Systems, Inc., SIR-2000 (400 and 900 MHz antenna)	a) .025 x .5 m b) .025 x .25 m	a) ~10,500 m^2 b) 400 m^2

[a] The same sampling density was used for large area magnetic gradiometry surveys at Fort Clark and Huff Village.

[b] A 400 m^2 area that covered an Arikara log cabin structure at Fort Clark was surveyed with all methods using higher sampling densities.

Robotic Total Station Surveys at Huff Village

Elevation data were acquired with a Trimble 5600, a robotic total station that contains an electronic distance measuring system as well as automatic aiming and tracking technology, at Huff Village (Kvamme et al. 2006). A control pad, which communicates with the total station via a radio link, is attached to the reflector rod (Figure 2.3). The rod is mounted on a wheel so that a single operator can control the system from the control pad and easily move it across the ground surface at a relatively normal walking speed. The total station automatically tracks the reflector rod and continuously records position and elevation data, in this case at a rate of one measurement per second. Surveys were performed within the same 30 x 30 m blocks established for the magnetic gradiometry survey. The reflector rod was moved in a zigzag pattern, with guidance provided by fiberglass pin flags placed along baselines and the real time display on the control pad. These enabled the operator to move the reflector rod at a pace of less than one meter per second. First, transects separated by 1 m were surveyed in a north-south direction to yield uniform coverage across a block, and visually perceptible landscape features were subsequently targeted. The goal was a sampling density of at least one measurement per meter. An area nearly equal in size to the magnetic gradiometry survey was covered with the instrument, and the resulting data points were used to generate a 51,395 m^2 raster digital elevation model (DEM) at a spatial resolution of .5.

Aerial Techniques at Fort Clark

Besides the aforementioned ground-based techniques, three aerial remote sensing techniques were employed in my interpretation of archaeological features at Fort Clark. These include aerial photography and digital imagery, aerial thermography, and LiDAR.

Aerial Photography and Digital Imagery

Multiple high-resolution aerial photographic series, including recent digital images and historical photographs, were utilized. The most recent images were collected in 2004 by Tommy Hailey from a powered parachute flying at approximately 250-300 m above the ground (Hailey 2005). He acquired over 100 digital color images using a Konica Minolta DiMAGE A2, of which 34 nearly vertical photographs were selected (Table A1.2). Four sets of photographs taken by KBM, Inc. in 1985 were acquired from the State Historical Society of North Dakota (SHSND) (Wood 2003c). These include a set of four black-and-white photographs taken from an altitude of approximately 300 m as well as sets of two black-and-white photographs, three normal color photographs, and three color infrared photographs, each taken from an altitude of approximately 730 m. Two sets of three black-and-white single frame photographs acquired from altitudes of approximately 2,750 and 3,050 m and dating to 1965 and 1967, respectively, were obtained with the U.S. Geological Survey Earth Resources Observation and Science Center's EarthExplorer data access tool (EarthExplorer 2013). Finally, a single black-and-white photograph dating to 1965 and three black-and-white photographs dating to 1938 were acquired from the SHSND, although the latter were originally held by the National Archives and Records Administration (NARA).

Table A1.2. Summary of aerial photograph and digital image data sets for Fort Clark.

Image Type	Date	No.	Source	Product
Color	2004	34	Dr. Tommy Hailey[a]	Orthophotograph
Thermal infrared	2004	64	Dr. Kenneth L. Kvamme[b]	Georeferenced photos
Black-and-white	1985	4	KBM, Inc. (SHSND) [a]	Orthophotograph
Black-and-white	1985	2	KBM, Inc. (SHSND) [a]	Georeferenced photo
Color	1985	3	KBM, Inc. (SHSND) [a]	Orthophotograph
Color infrared	1985	3	KBM, Inc. (SHSND) [a]	Orthophotograph
Black-and-white	1967	3	USGS[c]	Orthophotograph
Black-and-white	1965	3	USGS[c]	Orthophotograph
Black-and-white	1965	1	SHSND[a]	Georeferenced photo
Black-and-white	1938	3	NARA[d]	Georeferenced photo

[a] Used with permission.
[b] Used with permission.
[c] There are no restrictions on the use of data received from the U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center. Data available from the U.S. Geological Survey.
[d] Permission is not required to use NARA images.

Aerial photographs have long been used by Plains archaeologists for the purposes of site identification, mapping, and interpretation. Aerial photographs lend themselves well to such endeavors because a number of factors, including shadowing, crop markings, soil markings, and frost or snow markings, highlight subtle topographic relief and near surface archaeological features (Table 2.2) (Giardino and Haley 2006:57-61; Scollar et al. 1990:33-58; Wilson 2000:38-87). Of these factors, shadowing and crop markings are more significant in the current study because of the time of year in which each photograph was taken and the vegetated state of the site. Archaeological features with topographic relief, even low relief features that may go unnoticed during conventional ground investigations, are often more clearly visible from above, where shadowing exaggerates their signatures. Additionally, subsurface features and features exhibiting topographic expression may be apparent due to crop markings, or subtle differences in the growth of ground surface vegetation. In particular, vegetation may exhibit variation in height, color, thickness, and even plant type. These responses are due to more or less favorable growth conditions (e.g., varied water and nutrient content) resulting from underlying archaeological features that impede or promote particular plants, their growth, and overall vigor. Whereas normal color photography records the visible parts of the electromagnetic spectrum, from approximately .4 to .7 µm (micrometers), color infrared imagery records only green and red as well as the near-infrared wavelengths, altogether from about .5 to 1 µm (Avery and Berlin 1992:32-48; Scollar et al. 1990:95-97, 105-112). Importantly, plants reflect not only green wavelengths but also near-infrared wavelengths. Thus, color infrared photographs provide a different perspective than standard color imagery, accentuating in particular plant health, and therefore they may reveal subsurface archaeological features that have impacted surface vegetation conditions.

Aerial Thermography

In contrast to color infrared photography, which records *reflected* visible and near-infrared wavelengths of the electromagnetic spectrum, thermal infrared or long-wavelength infrared energy is *emitted* and can be sensed in two ranges from 3 to 5 µm and 8 to 14 µm (Avery and Berlin 1992:115-124; Lillesand et al. 2004:347-367; Scollar et al. 1990:591-611). All materials above absolute zero (0 K or -273 ºC) emit thermal radiation. The radiation's magnitude and spectral distribution relates to the emissivity and temperature of the material from which it is emitted. In the 8 to 14 µm spectral region, the emissivity, or the ability of a material to absorb and emit radiation, of different objects varies considerably due to contrasts primarily in their composition, roughness, and condition. For example, variation in moisture content causes the same soil to exhibit different emissivities. Furthermore, aluminum serves as an excellent material for ground control points because it exhibits a very low emissivity (i.e., it absorbs electromagnetic radiation poorly although it reflects it quite well) while soil has a much higher emissivity.

Thermal sensors measure the radiant temperature of objects, which vary from their kinetic (i.e., real or contact) temperature, due to their emissivity, meaning that two objects with the same kinetic temperature but different emissivities will exhibit dissimilar radiant temperatures. Thermal sensors may be used to measure the relative difference in radiant temperature of objects, including near surface archaeological features and the surrounding soils. Importantly, the radiant temperature of objects within the soil matrix varies diurnally. The rate and amount of temperature change these objects exhibit is determined by several factors, including heat capacity, thermal conductivity, thermal diffusivity, and thermal inertia, with moisture content contributing significantly to these factors as well (Avery and Berlin 1992:122-124).

Thermal video, from which still frames were extracted, was acquired in 2004 from a powered parachute flying at an altitude of approximately 250-300 m with a Raytheon Palm IR 250 (Table A1.2). The camera consists of an uncooled BST (barium strontium titanate detector), connected to a digital video recorder, that detects thermal infrared radiation in the 7-14 µm band of the electromagnetic spectrum at a sensitivity of about .1 ºC. The Palm IR 250 has a resolution of 320 x 240 and records 8-bit video at a frame rate of 30 Hz. Results are indicated simply in shades of gray indicating relative differences in radiant temperature, with darker shades relating to cooler radiant temperatures and lighter shades indicating warmer radiant temperatures.

LiDAR

LiDAR data were collected in 2012 by a commercial vendor, Watershed Sciences, Inc., for the SHSND. Laser scanning data were collected with a Leica ALS60 Airborne Laser Scanner mounted aboard a small fixed-wing aircraft. The instrument operates by transmitting laser pulses in the near-infrared spectrum at a rate of approximately 115 kHz (115,000 pulses per second). The ground surface and objects above it, including vegetation and rooftops, reflect the pulses, which are subsequently detected by the scanner (Beraldin et al. 2010; Optiz 2013). The instrument precisely measures the time each pulse takes between its transmission and detection. Because the speed of light is constant, the distance between the laser scanner and the object from which the pulse was reflected may be calculated. These measurements and coordinate data are compiled in a point cloud from which detailed topographic information may be derived. Additionally, multiple discrete returns from the same laser pulse may be detected when it reflects off of vegetation, potentially enabling characterization of both vegetation (first return) and the ground surface (last return).

During this investigation, an approximately 900 x 1,200 m area was surveyed, achieving an average first return point density of 16 points per m^2 and an average ground or last return density of 4 points per m^2 with an absolute accuracy (root mean square error) of 2.4 cm horizontally and vertically. This level of detail and precision enabled archaeological features with topographic expression to be recorded, including clearly visible features as well as nearly imperceptible ones that would otherwise likely go unnoticed by conventional terrestrial (i.e., pedestrian walkover) and aerial surveys. These included cabin outlines, shallow trail depressions, and numerous small subtle features like storage pits, some of which only became apparent with the availability of the laser scanning data set. One of the primary advantages of LiDAR lies in its ability to complement these other approaches (Bennett el al. 2011).

Remote Sensing Data Processing

Raw geophysical data were processed following procedures meant to correct operator and instrument errors and to enhance visibility of subtle anomalies. DW Consulting TerraSurveyor, Geoscan Research Geoplot 3.0, and GSSI RADAN, software intended for geophysical data processing, were employed for this undertaking. Mosaicked, orthorectified, and georeferenced images were derived from aerial photographs and digital imagery using Agisoft PhotoScan. Fully processed data sets were co-registered and digitized in a Geographical Information System (GIS), with Clark Labs IDRISI Selva and Esri ArcGIS used equally. Additionally, graphic displays illustrating the data and interpretations were produced using these as well as Golden Software Surfer, Adobe Illustrator, and Adobe Photoshop.

Geophysical Data

With the exception of GPR data, which require specialized processing, a series of processing steps were completed with each geophysical data set with only minor differences for each instrument. More detailed explanations regarding each procedure and the reasons for their use are provided elsewhere (e.g., Kvamme 2006c). The initial processing step for each data set involved the creation of a composite grid from the survey grids through *concatenation* (Figure A1.1a). Extremely high and low measurements were a common issue and are caused by the presence of ferrous metal in magnetic data sets or poor probe contact in the case of resistance. These isolated data spikes were minimized with a *despiking* function, which replaces the high or low value with the mean or median value of a data window that surrounds the measurement (Figure A.1.1b, c). Furthermore, the raw magnetic gradiometry data exhibited two types of noise because transects were surveyed in an alternating or zigzag pattern. One is a striping defect caused by misalignment of the instrument away from the correct heading (an issue that is magnified during zigzag surveys) and the other a “zipper” pattern error due to staggering or mistiming the pace in opposite survey directions (Figure A1.1a). The latter was corrected with a *destraggering* function, which shifts alternating lines forwards or backwards by a set amount to adjust for the slower or faster pace of the instrument operator (Figure A1.1d, e).

The striping defect, which is caused by heading errors, was made worse due to an issue where one of the two gradiometers more frequently required balancing. In fact, instrument drift, or a shift in an instrument’s calibrated zero point, was apparent in EMI data, and to a lesser extent magnetic gradiometry data, as a gradual increase or decrease in values across grids. This instrument noise was removed using a *dedrift* or *deslope* function. The striping defects caused by heading errors and an unbalanced sensor were corrected with a *destriping* or *zero mean traverse* algorithm (Figure A1.2a-c). Finally, many adjacent resistance and EMI grids exhibited different average measurements, resulting in discontinuities between grid edges. This defect was corrected with an *edge match* function.

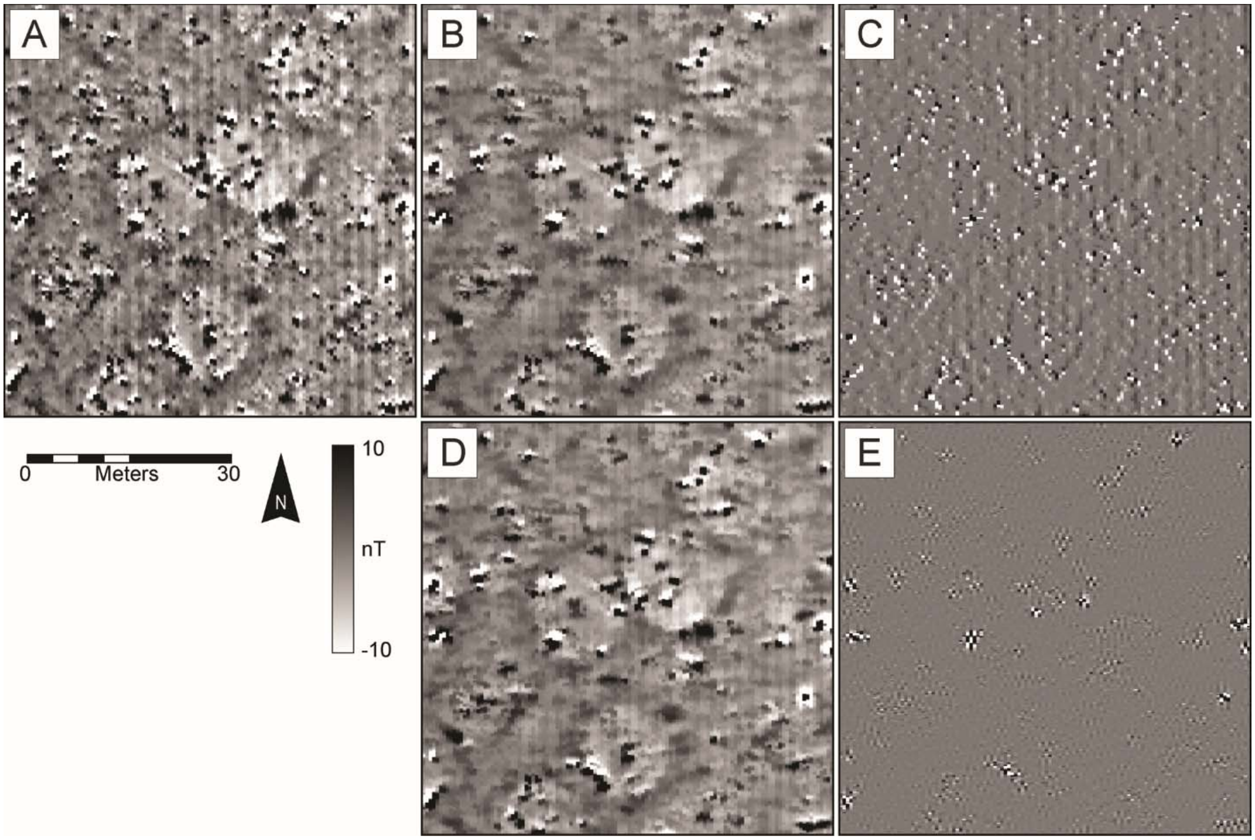

Figure A1.1. Example of magnetic gradiometry data processing, showing a) nearly seamless concatenated raw data composed of four 30 x 30 m grids, b) despiked data, c) difference between images a and b illustrating data spikes, d) destaggered transects, and e) difference between images b and d, which highlights staggering defects.

After these common errors were addressed, additional steps were taken to enhance image quality. For instance, *interpolation* was used to produce uniform sampling densities (e.g., magnetic gradiometry data, which was collected with a sampling density of .125 m x 5 m, was interpolated to .25 m x .25 m), a procedure that requires the estimation of additional values between transects and the averaging of measurements along transects (Figure A1.2d). This step serves two functions: averaging measurements reduces noise, and increasing the pixel density decreases the pixelated appearance of the image, creating a more continuous and visually appealing result (Figure A1.2d). To further reduce image noise caused by both the instrument and small but unimportant natural features, a *low-pass filter* was applied to some data sets to smooth the final raster image.

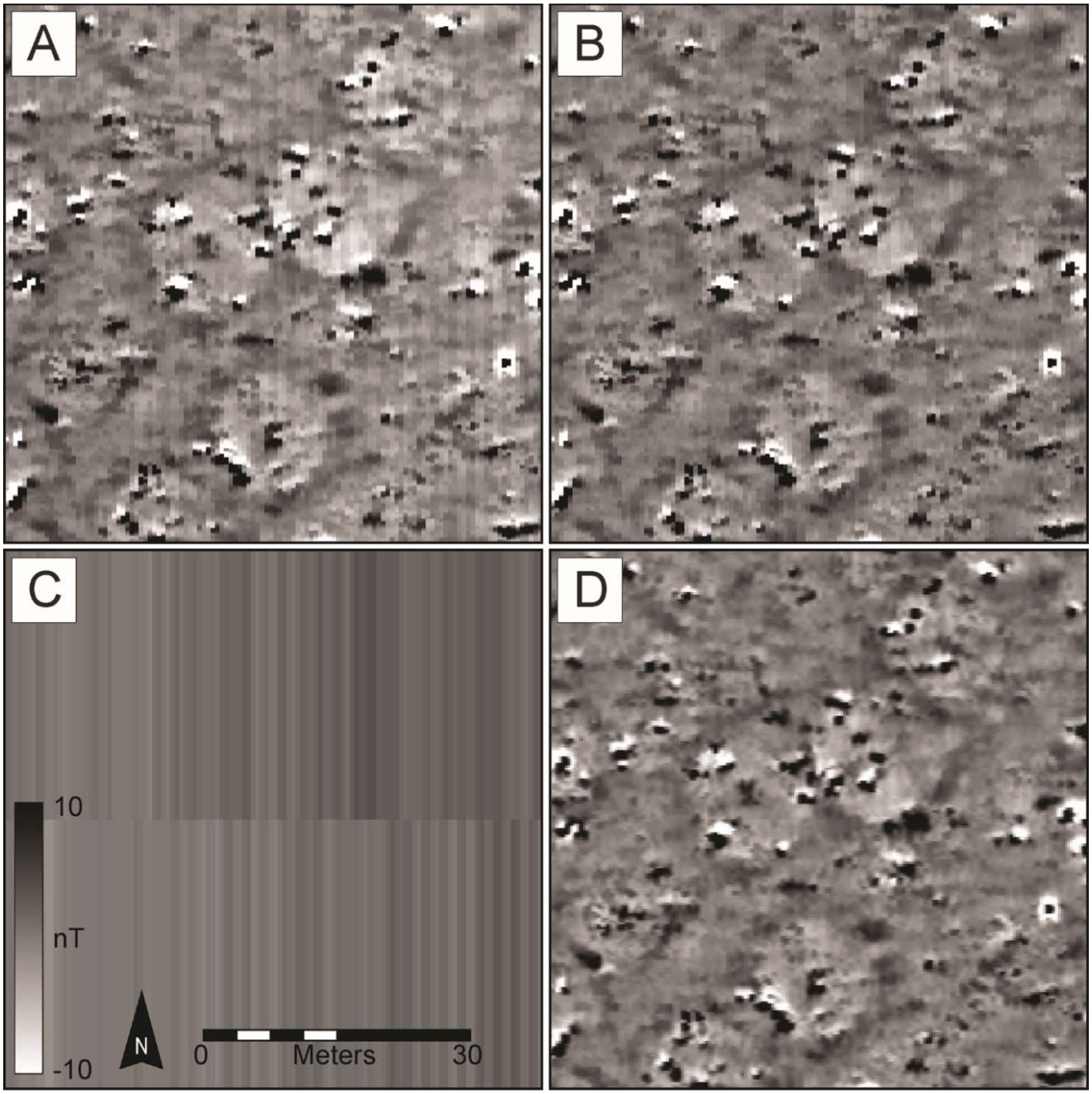

Figure A1.2. Example of magnetic gradiometry data processing, showing a) destaggered transects, b) destriped data, c) difference between image a and b indicating the removal of stripes caused by heading errors and an unbalanced sensor, and d) interpolated data.

The GPR data were processed with a series of steps specific to the instrument to produce a three-dimensional grid and depth slices compiled from single reflection profiles or radargrams. These procedures are described in greater detail by Conyers (2013:126-148) and Ernenwein and Kvamme (2008). The initial step involved the creation of separate three-dimensional grids for each survey block. A *time zero* function was then performed to vertically adjust each reflection profile. In this case, the approximated ground surface was automatically identified by the first positive peak of the reflection profile. Subsequently, a full pass *background removal* filter was applied to each profile to rid the data of horizontal, low frequency noise or banding. After this step, adjacent grids were composited in a single three-dimensional grid, and a *gain* function was applied to increase the data amplitudes. Finally, the *velocity* of the radar pulses was estimated using the hyperbola fitting module to convert travel time to depth. Selected depth slices were then exported to IDRISI Selva where the raster layers were resampled and smoothed. Results are displayed with a grayscale palette with larger amplitude anomalies indicated by darker shades.

Trimble 5600 Robotic Total Station Elevation Data

Data collected with the Trimble 5600 robotic total station were processed following a procedure described by Kvamme and colleagues (2009:6-7). These steps include 1) thinning data points by excluding those closer than 40 cm, 2) using a Delaunay triangulation of the vertices to generate a triangulated irregular network (TIN) model, and 3) creating a DEM by interpolating elevation values every 50 cm across the polygonal model. Since the reflector rod was occasionally tilted during the robotic total station survey, the initial DEM exhibited subtle striping artifacts. These minor defects were isolated and subtracted from the DEM using a filtering algorithm developed by Oimoen (2000).

Aerial Photographs and Digital Images

Agisoft PhotoScan was used to generate digital surface models (DSM) and orthoimages from overlapping aerial photographs and digital images. Advances in feature detection and computer vision have rendered digital photogrammetry a largely automated process with only minimal input such as the placement of ground control points (GCP) required from users (Verhoeven et al. 2012). To produce a DSM and orthoimage, a series of overlapping two-dimensional images were aligned with PhotoScan, which identifies corresponding image features across neighboring images (Figure A1.3a) (Agisoft 2014; Verhoeven et al. 2012). The software estimates the locations of these points, yielding a sparse three-dimensional point cloud model. Importantly, external and internal camera parameter information (i.e., camera locations and orientations, focal length, and principal points of symmetry) are also calculated by the program, meaning knowledge of these parameters beforehand is unnecessary. Ground control points were then manually identified, although the software is capable of guided marker placement. In this case, a marker can be manually placed on a single image, after which the software identifies the same location on other images. Minimal refinement to its placement for every image was subsequently necessary, however, but the process is expedited. Marked GCPs were then assigned coordinates. PhotoScan uses these coordinates to translate, rotate, and scale the point cloud model. Moreover, the alignment and estimated camera parameters are optimized by the software at this stage, which removes possible non-linear deformations. Subsequently, the program calculates depth maps, or distance measurements from the camera to each pixel in every view, from which a dense three-dimensional point cloud and polygonal mesh model of the surface are generated (Figure A1.3b). A high resolution orthoimage and DSM were generated from each reconstructed model.

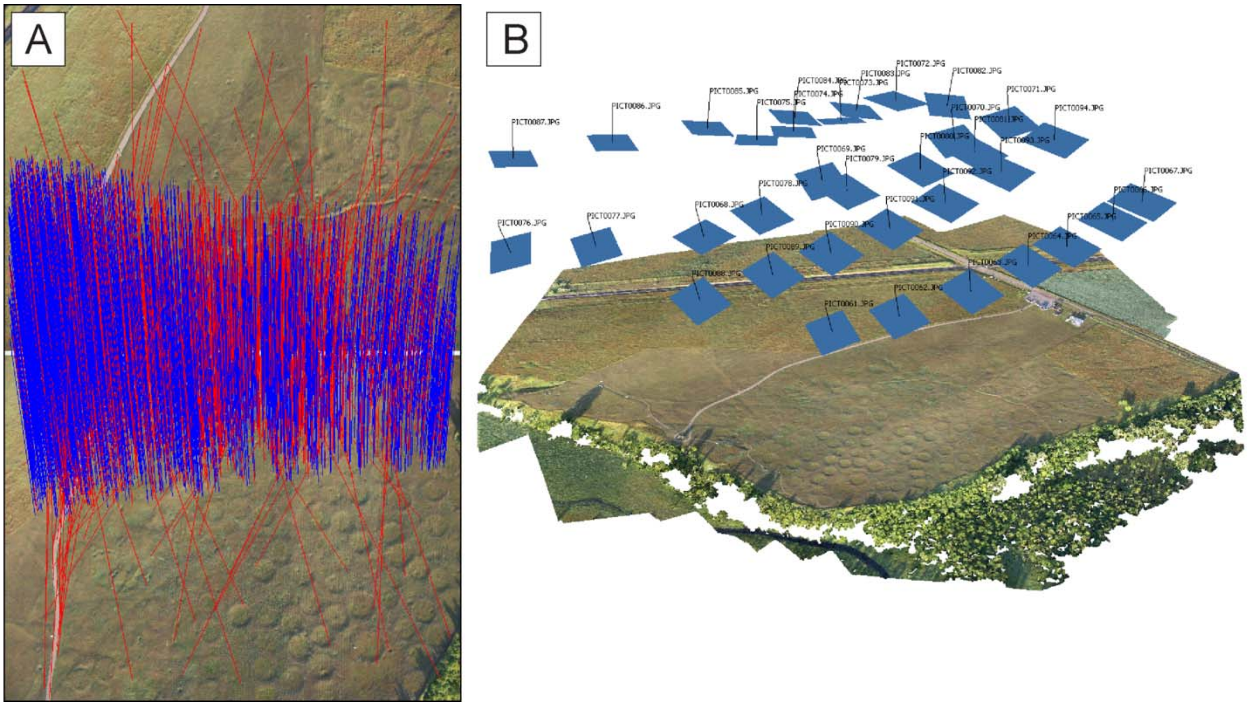

Figure A1.3. Processing aerial imagery from Fort Clark using Agisoft PhotoScan, showing a) two overlapping images with nearly 1,700 valid (blue) and many invalid matches (red), and b) a dense point cloud comprised of nearly 49 million points and generated from 34 aligned images. Note the visible camera location, which were estimated by the software.

Single Frame Aerial Photographs and Thermal Infrared Still Frames

On the other hand, single frame, or non-overlapping, vertical photographs were georeferenced in a GIS since digital photogrammetry (Agisoft PhotoScan) requires considerable overlap between adjacent images. To georeference each photograph, many widely distributed control points were typically identified (i.e., over 30). A spline transformation was then applied to guarantee local accuracy across each photograph, or at least in the area of interest. Similarly, since the thermal infrared still frames did not overlap sufficiently, they too were georeferenced in a GIS (Figure A1.4). When possible, a large number of control points were identified and a spline transformation was applied. However, fewer control points were typically identified (each still frame covers only a small area), and a first or second order polynomial was used to georeference each image.

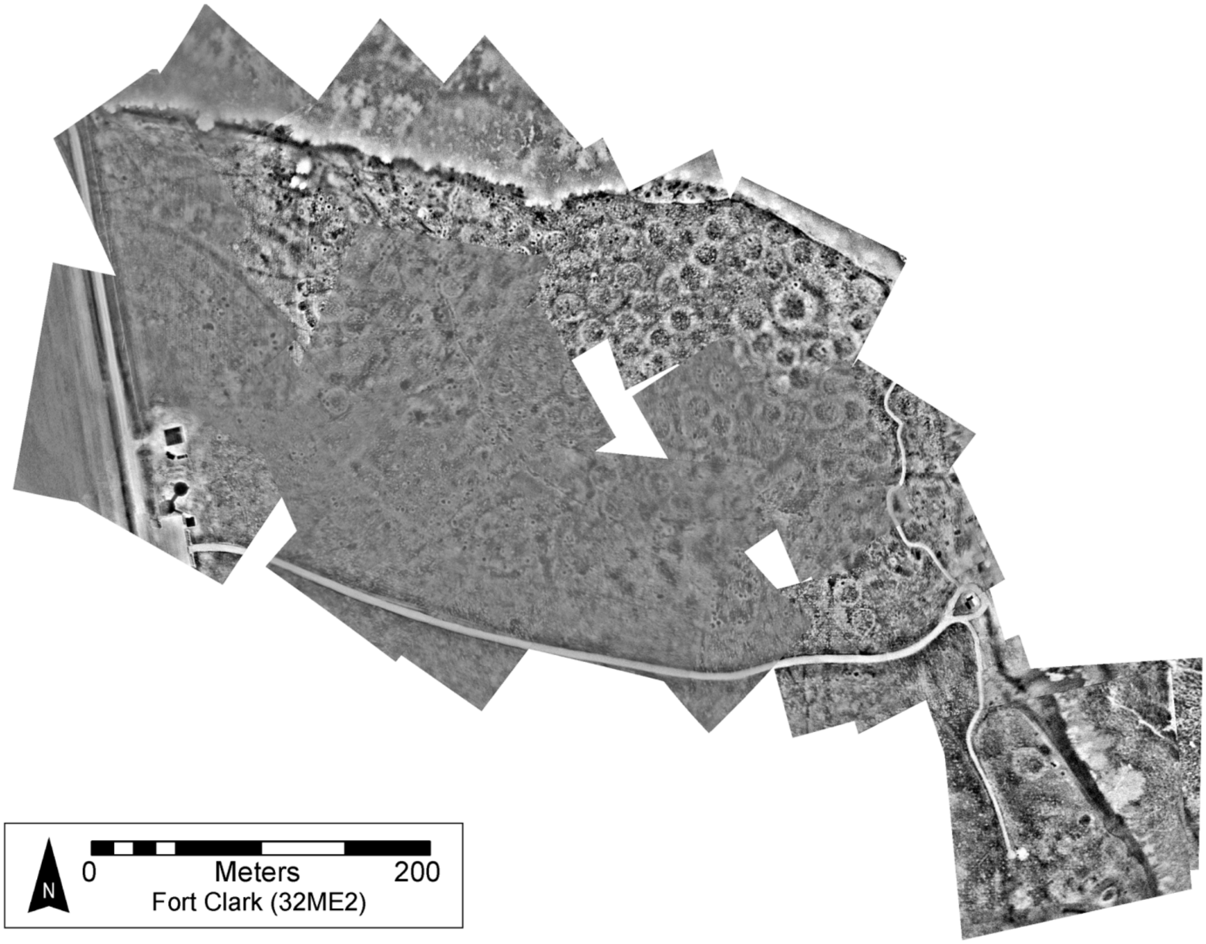

Figure A1.4. Partially mosaicked thermal infrared image of Fort Clark that when completed was composed of 64 georeferenced still frames. Adapted from frames by Kenneth L. Kvamme. Used with permission.

LiDAR and Elevation Data

The LiDAR data were delivered from Watershed Sciences, Inc. in several formats, including point data with all returns and an intensity image as well as fully processed highest hit and bare earth elevation models, each .5 m in spatial resolution. Any further discussion of the laser scanning data or DEM refers only to the bare earth data set. To better visualize the ground surface and subtle archaeological features, the elevation models derived from the robotic total station, digital photogrammetry, and LiDAR were used to produce several terrain products. These visualizations include a standard hillshade, multi-directional hillshade, principal component analysis of a multi-directional hillshade, local relief model (generated by subtracting the trend of the ground surface from the DEM), and sky view factor (Figure A1.5) (Bennett 2011; Challis et al. 2011; Hesse 2010; Kokalj et al. 2011, 2013; Zakšek et al. 2011). They were produced in various ways, including manually with IDRISI and SAGA (System for Automated Geoscientific Analyses) GIS and with toolkits like DEM Surface Tools for ArcGIS (Jenness Enterprises) and Relief Visualization Toolbox (Institute of Anthropological and Spatial Studies). As discussed previously, these relief visualizations were integrated with the remote sensing data sets in a GIS to aid interpretation of subsurface archaeological features visible in other data sets.

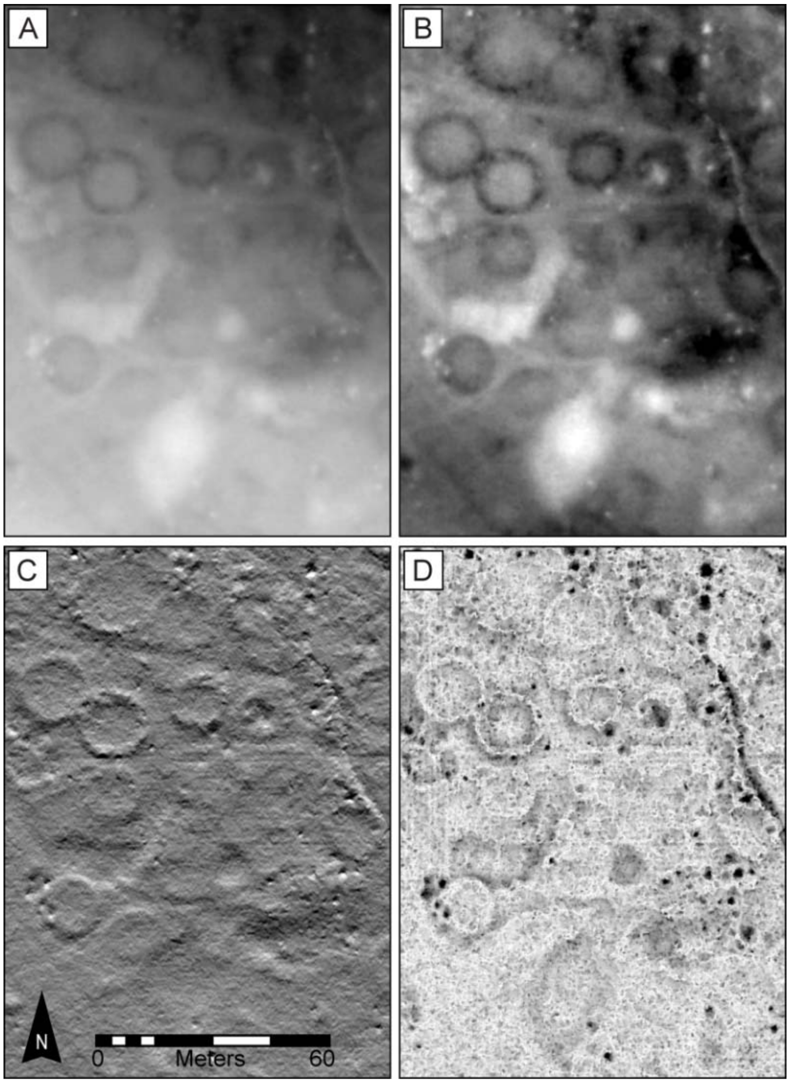

Figure A1.5. Relief visualizations generated from the Fort Clark LiDAR data, including a a) DEM, b) local relief model, c) multi-directional hillshade, and d) sky view factor image.

APPENDIX 2: HUFF VILLAGE STATE HISTORIC SITE (32MO11) REMOTE SENSING DATA AND INTERPRETATIONS

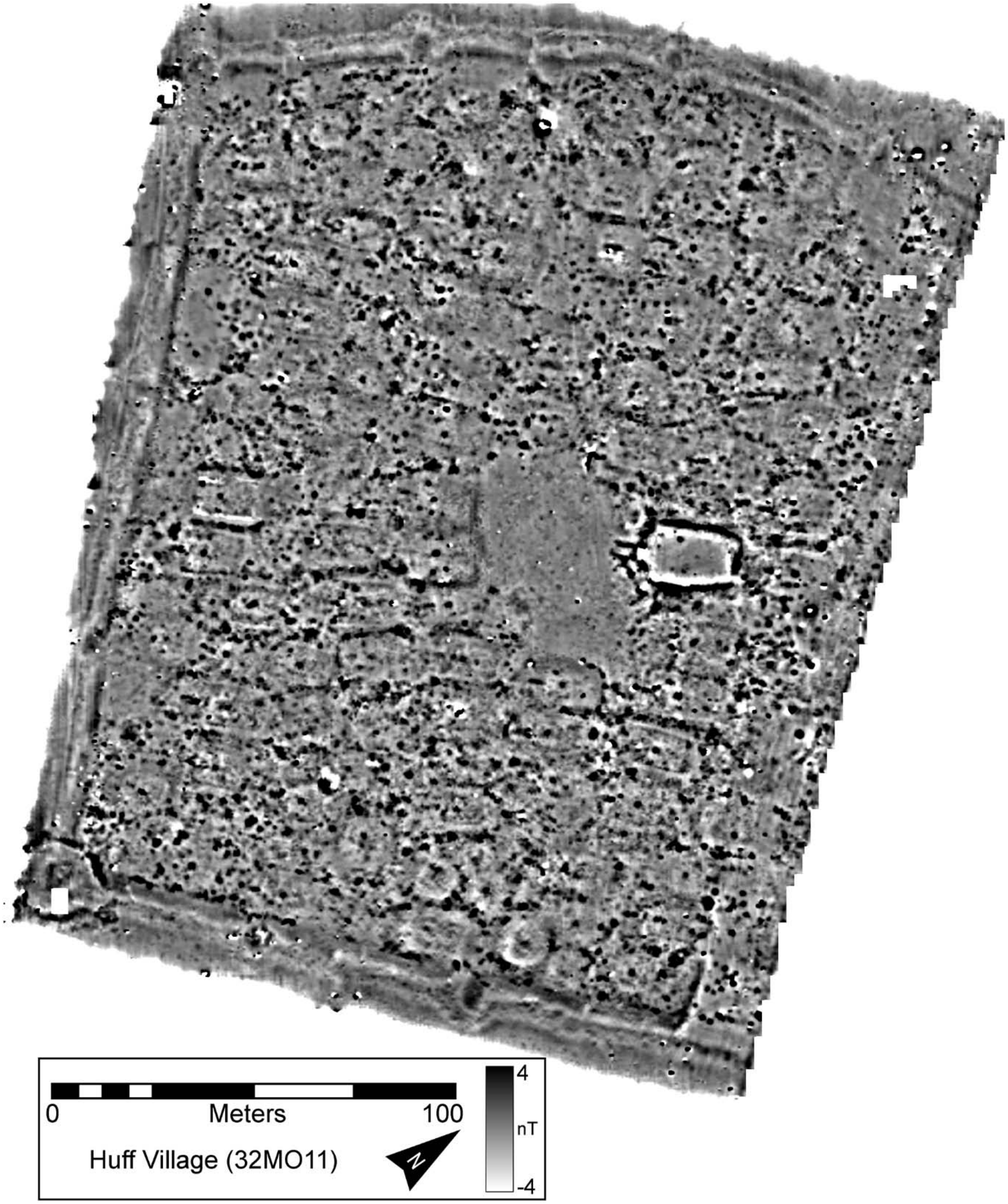

Figure A2.1. Village-wide magnetic gradiometry survey results at Huff Village.

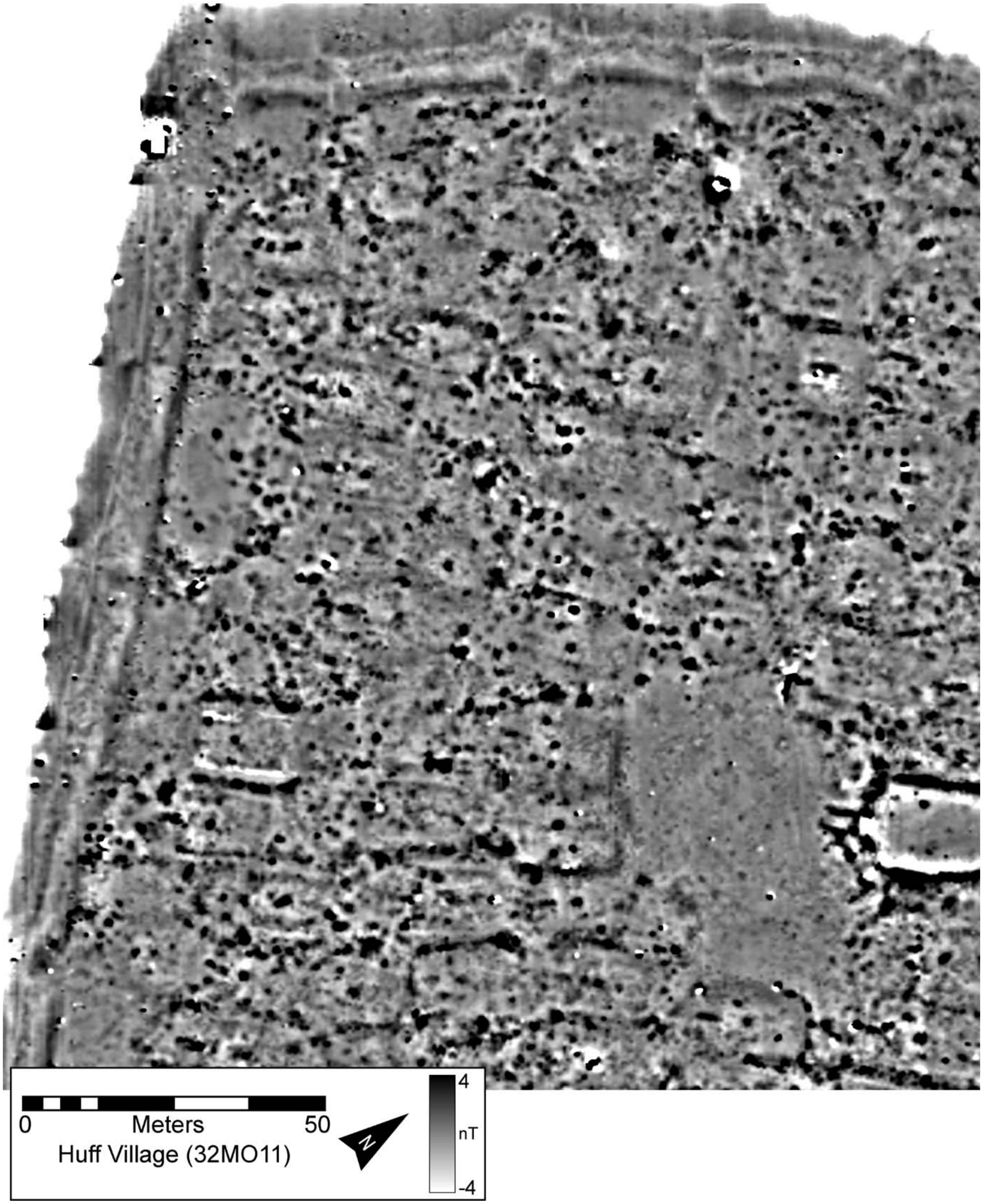

Figure A2.2. Magnetic gradiometry results at Huff Village (west section).

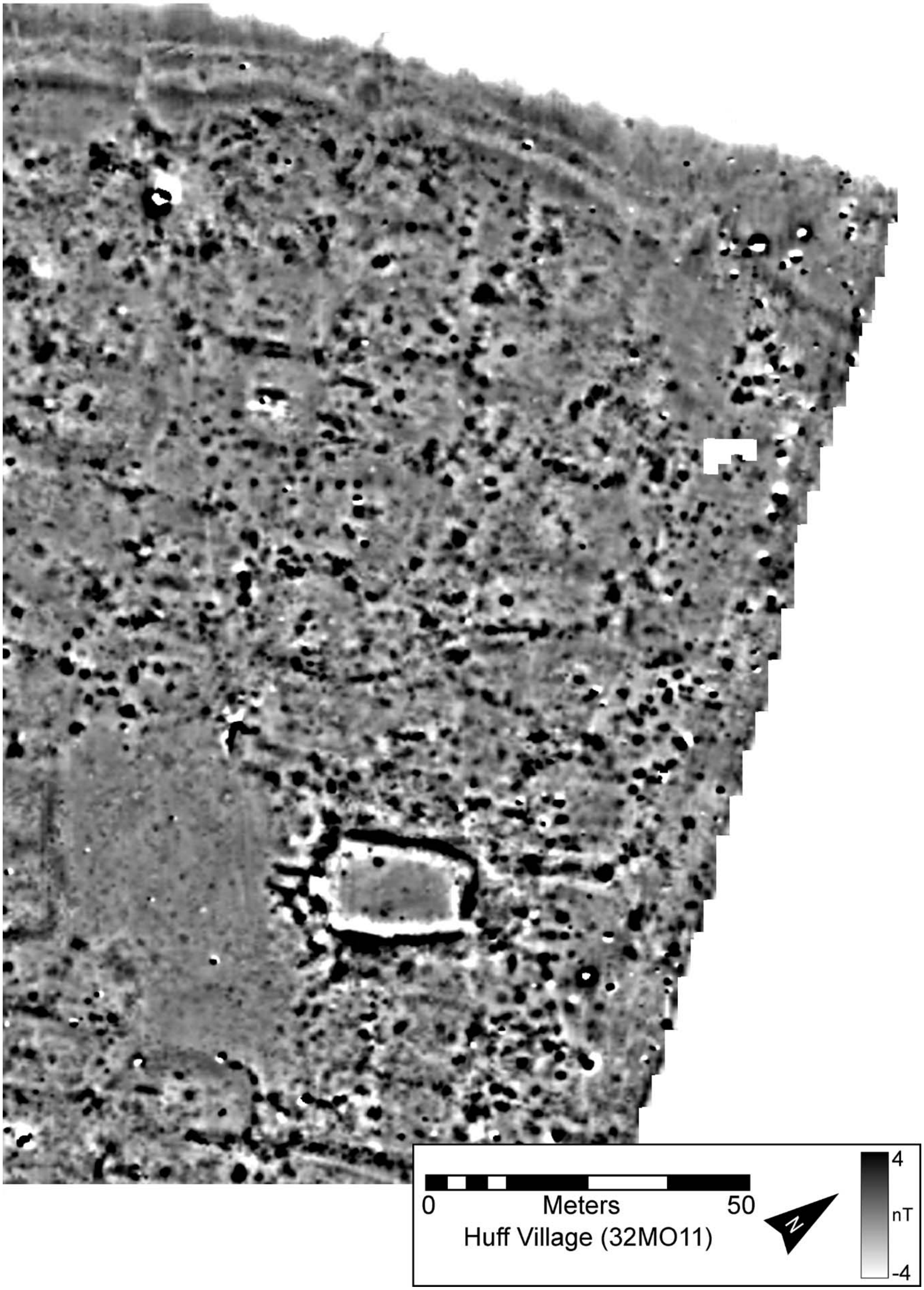

Figure A2.3. Magnetic gradiometry results at Huff Village (north section).

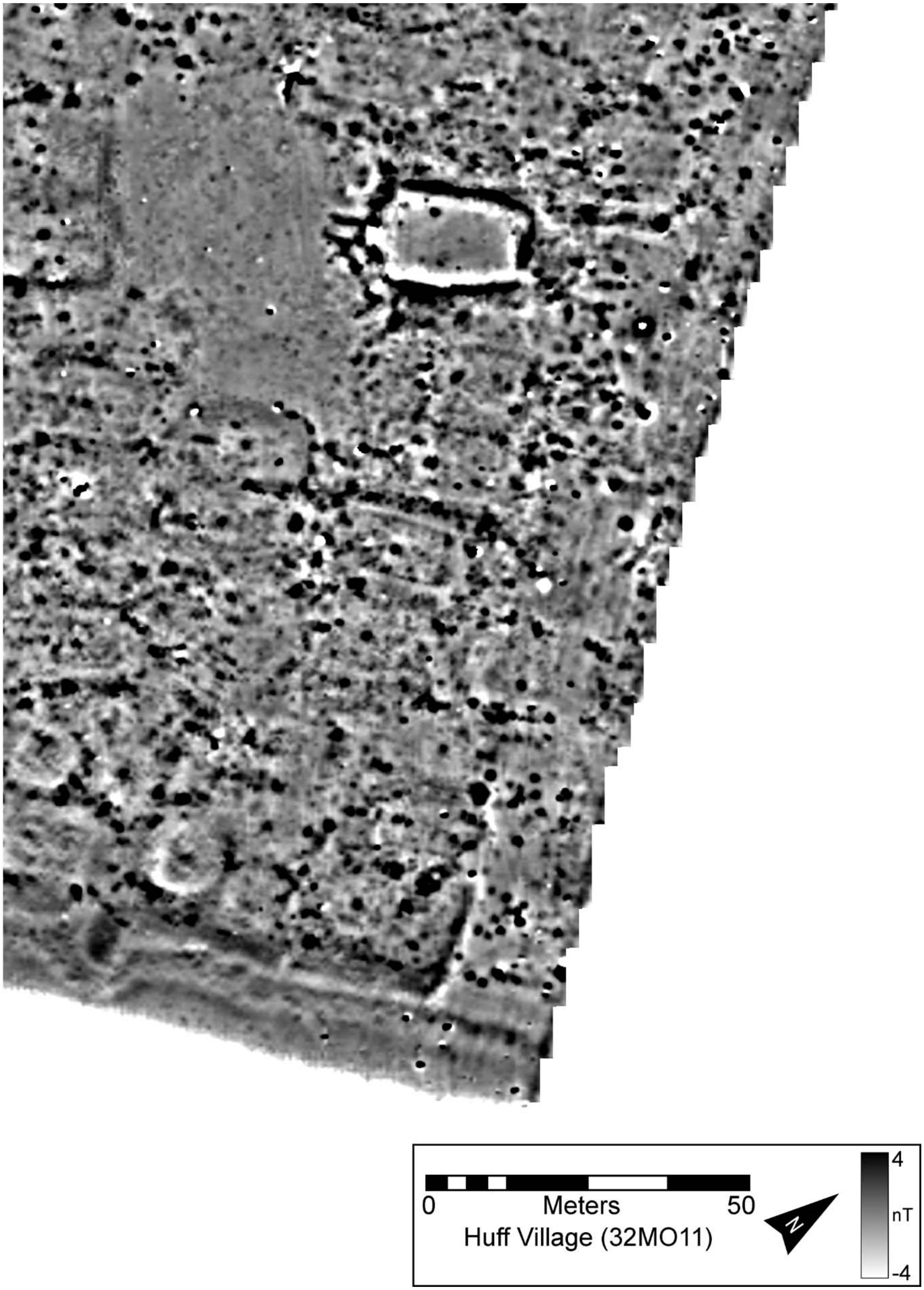

Figure A2.4. Magnetic gradiometry results at Huff Village (east section).

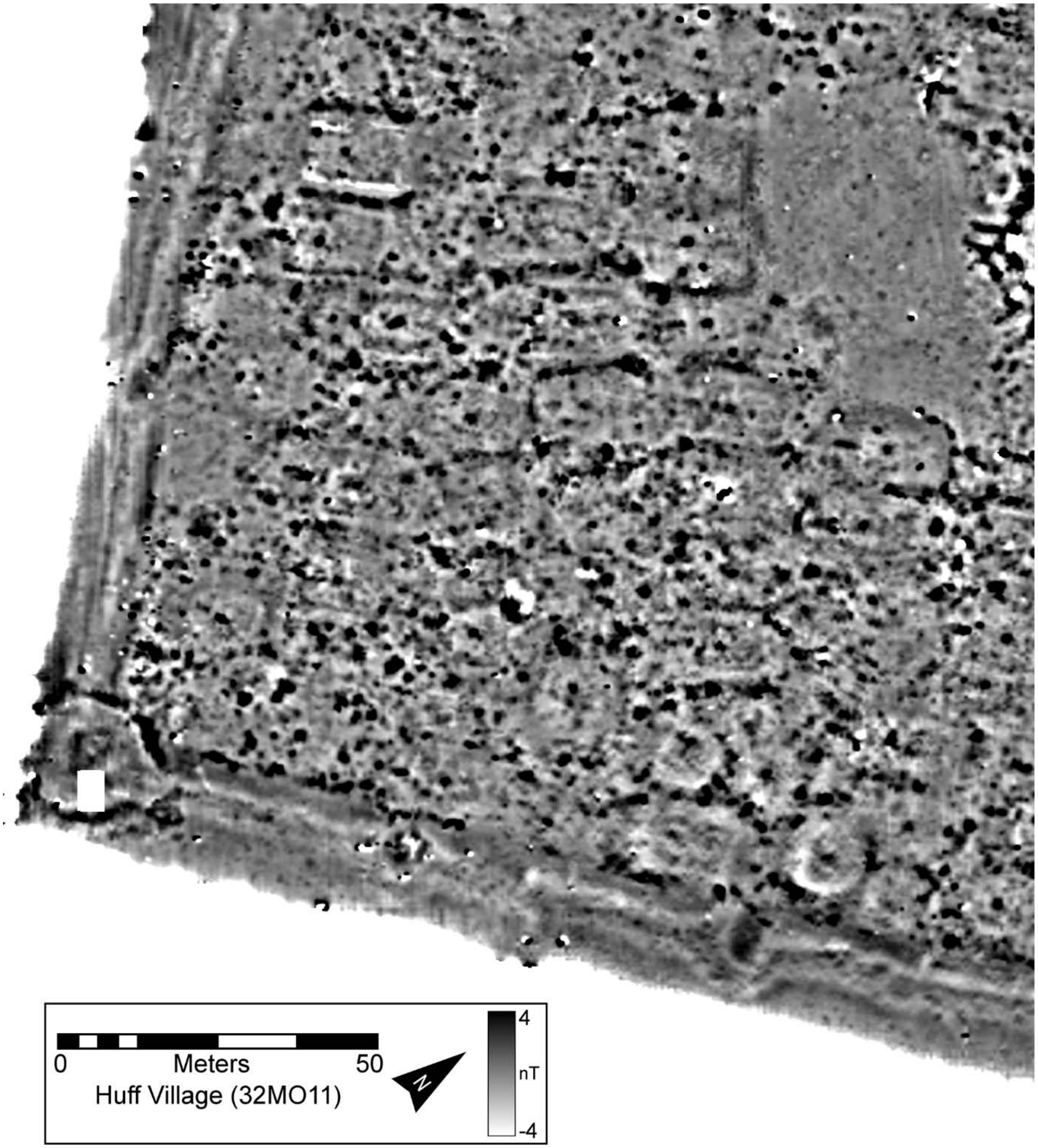

Figure A2.5. Magnetic gradiometry results at Huff Village (south section).

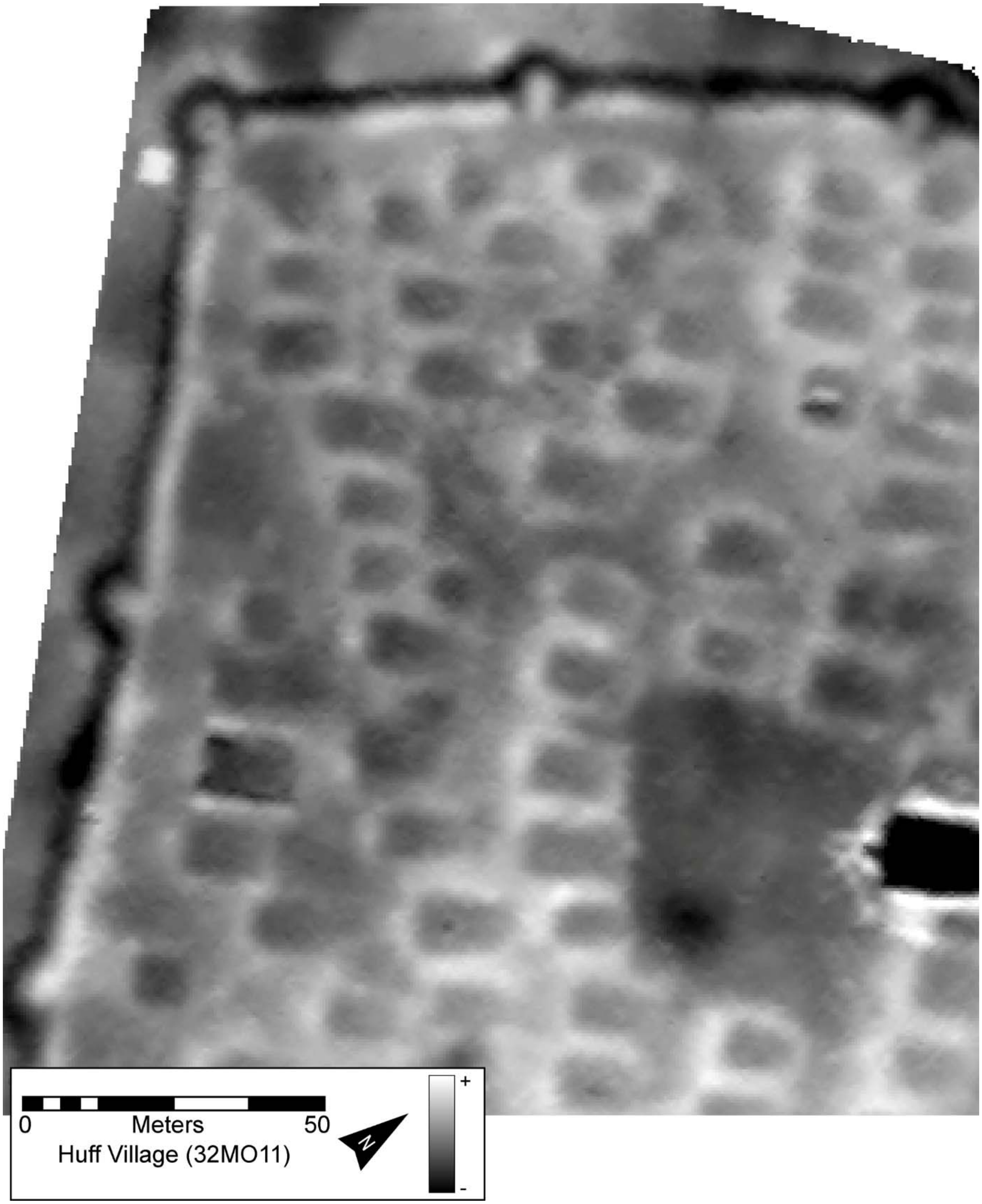

Figure A2.6. Local relief model of the west section of Huff Village.

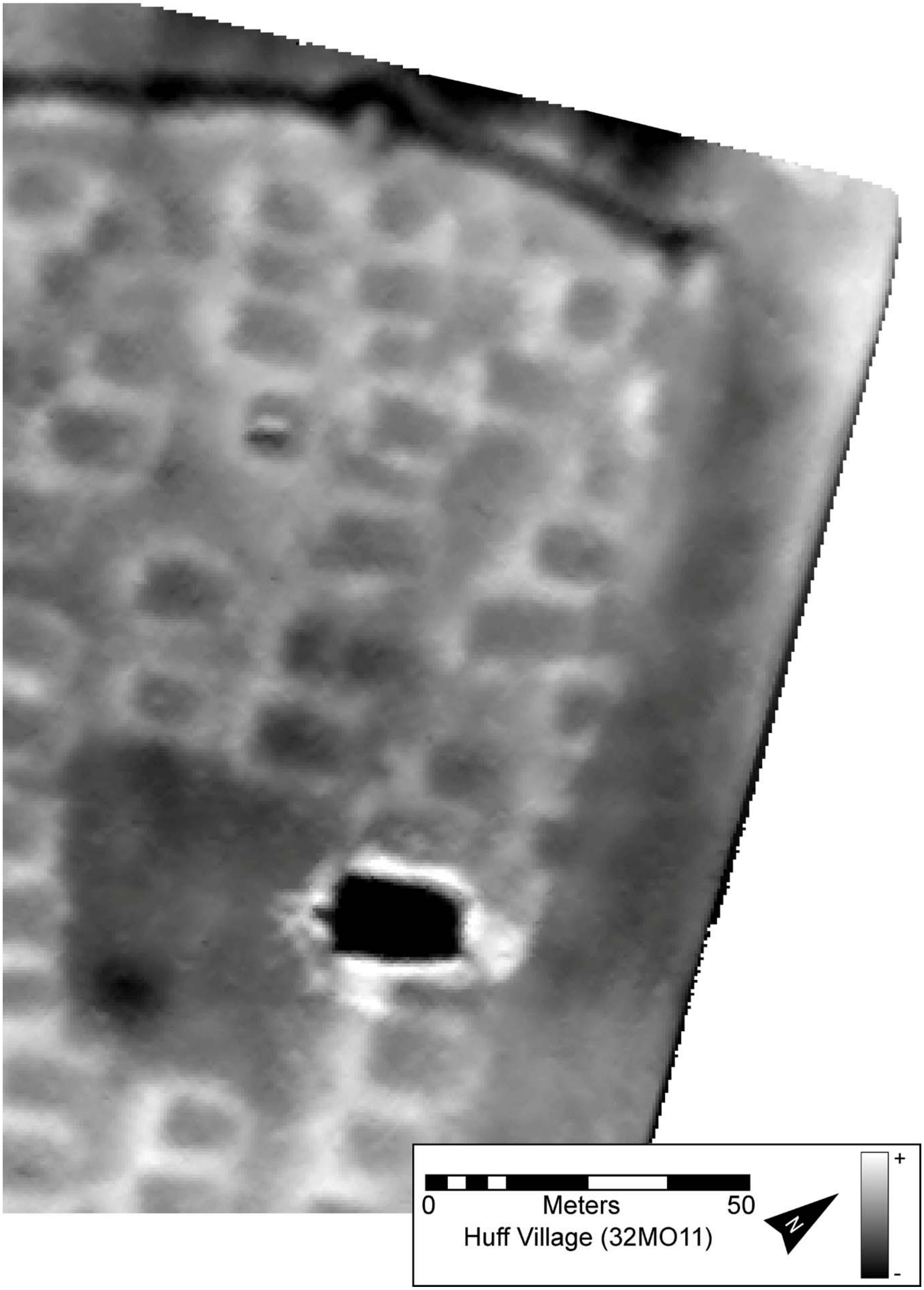

Figure A2.7. Local relief model of the north section of Huff Village.

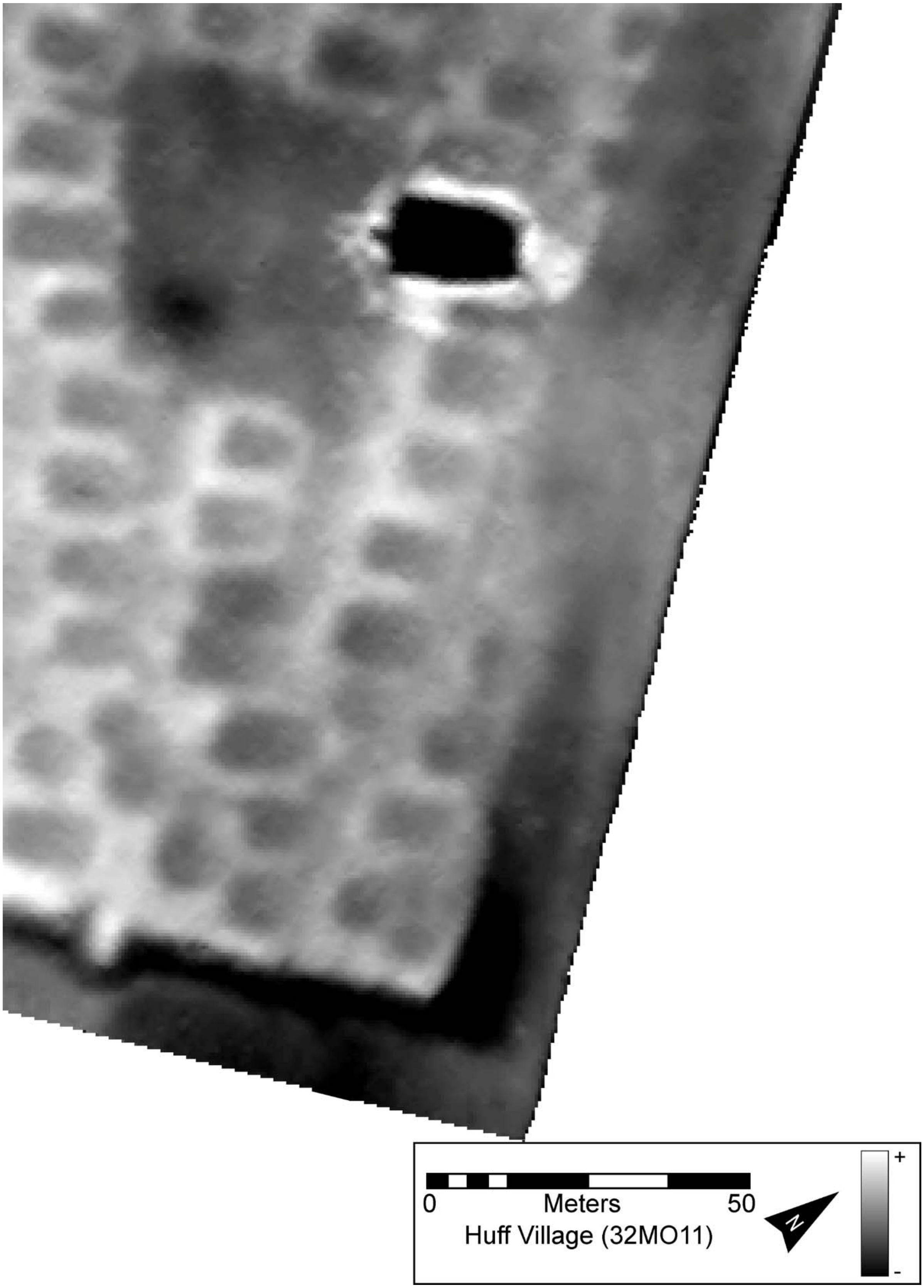

Figure A2.8. Local relief model of the east section of Huff Village.

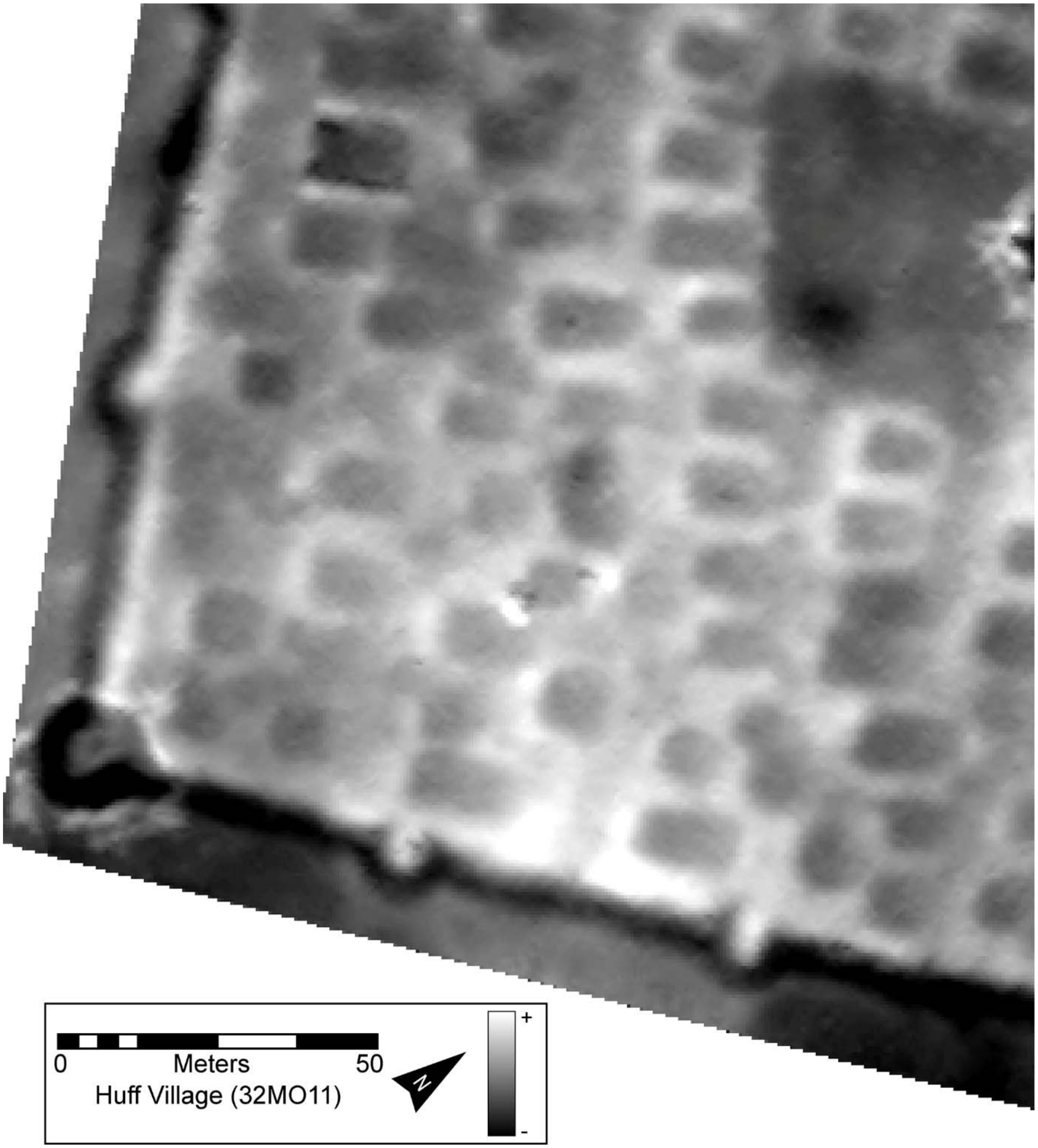

Figure A2.9. Local relief model of the south section of Huff Village.

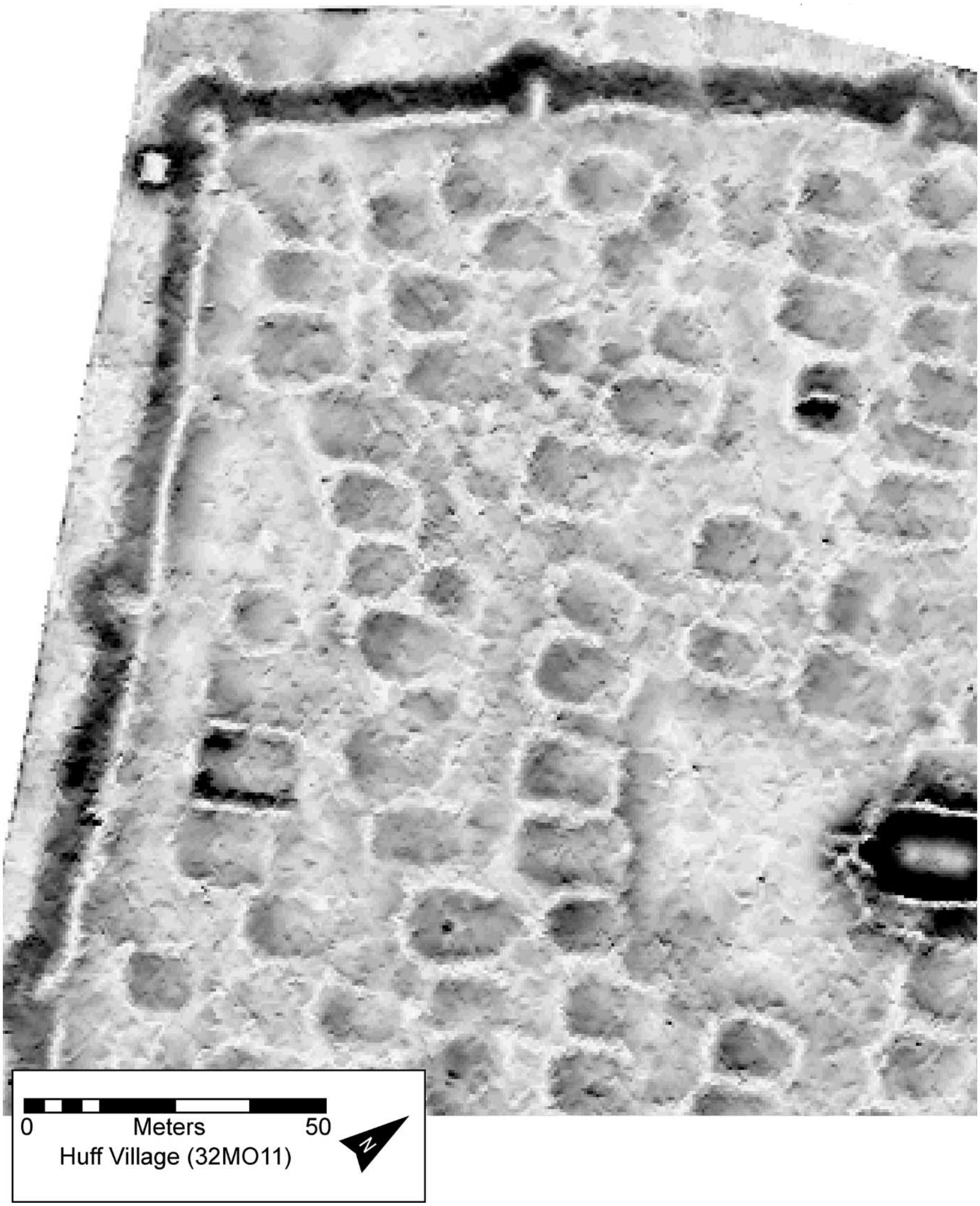

Figure A2.10. Sky view factor visualization of the west section of Huff Village.

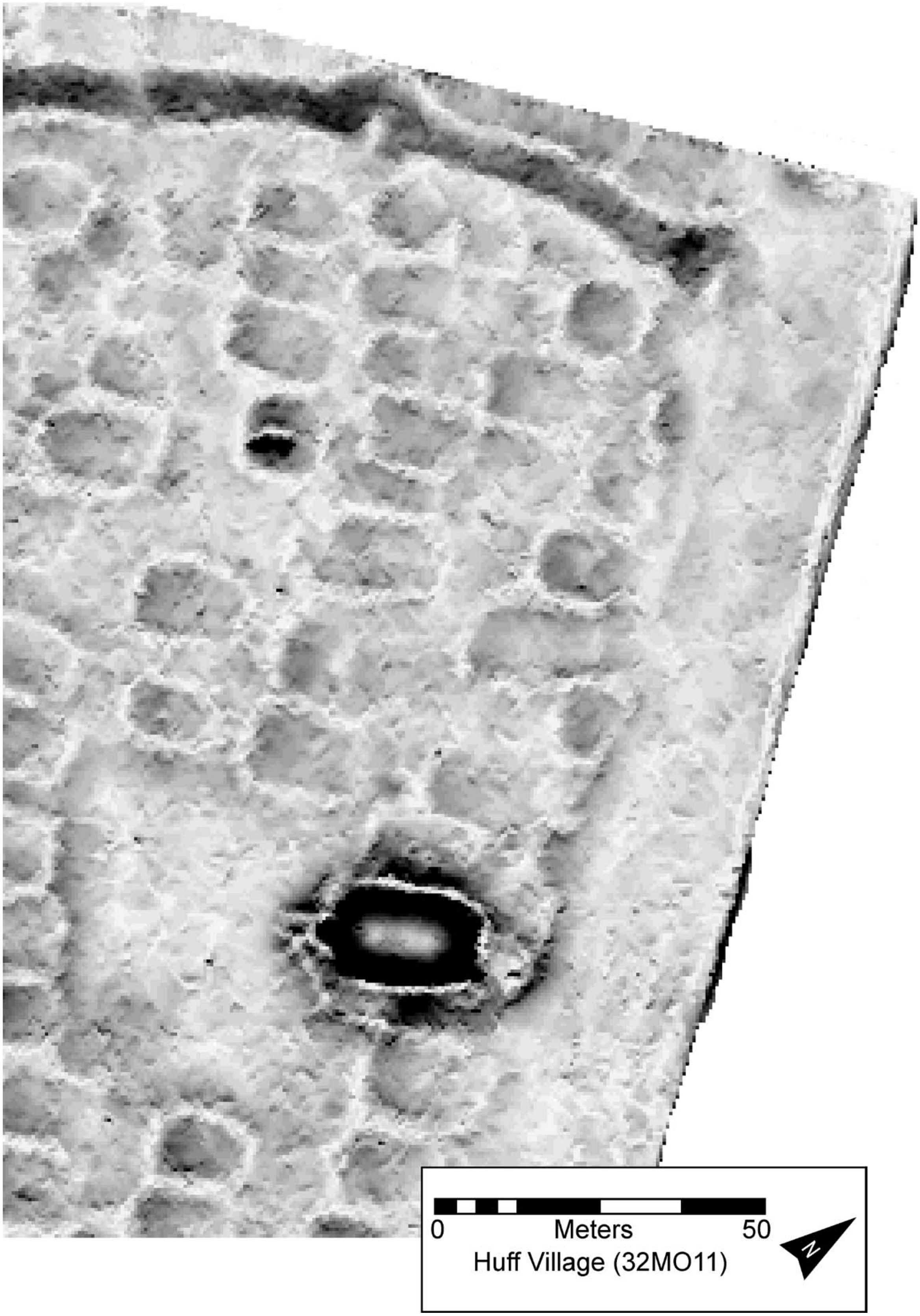

Figure A2.11. Sky view factor visualization of the north section of Huff Village.

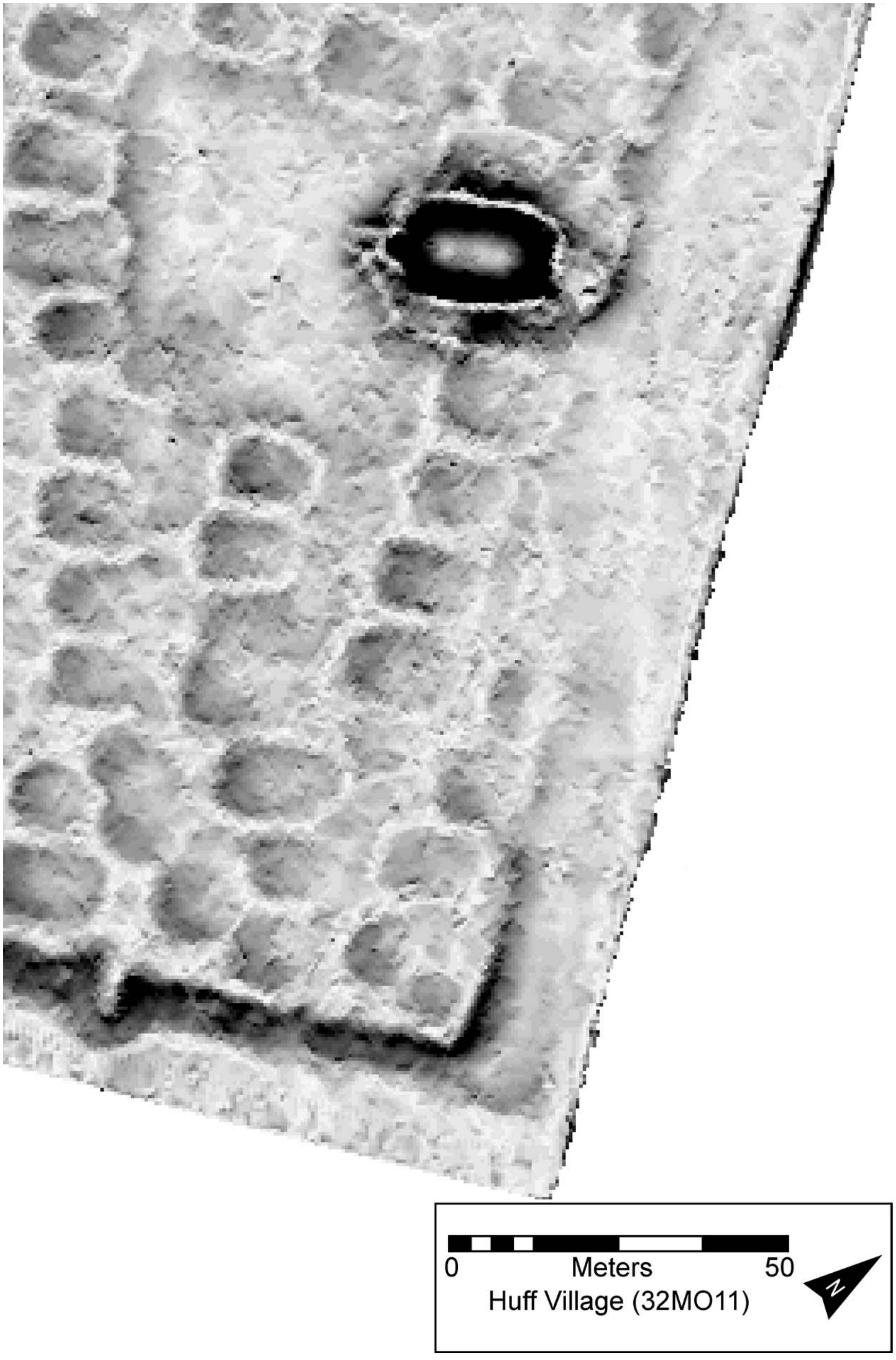

Figure A2.12. Sky view factor visualization of the east section of Huff Village.

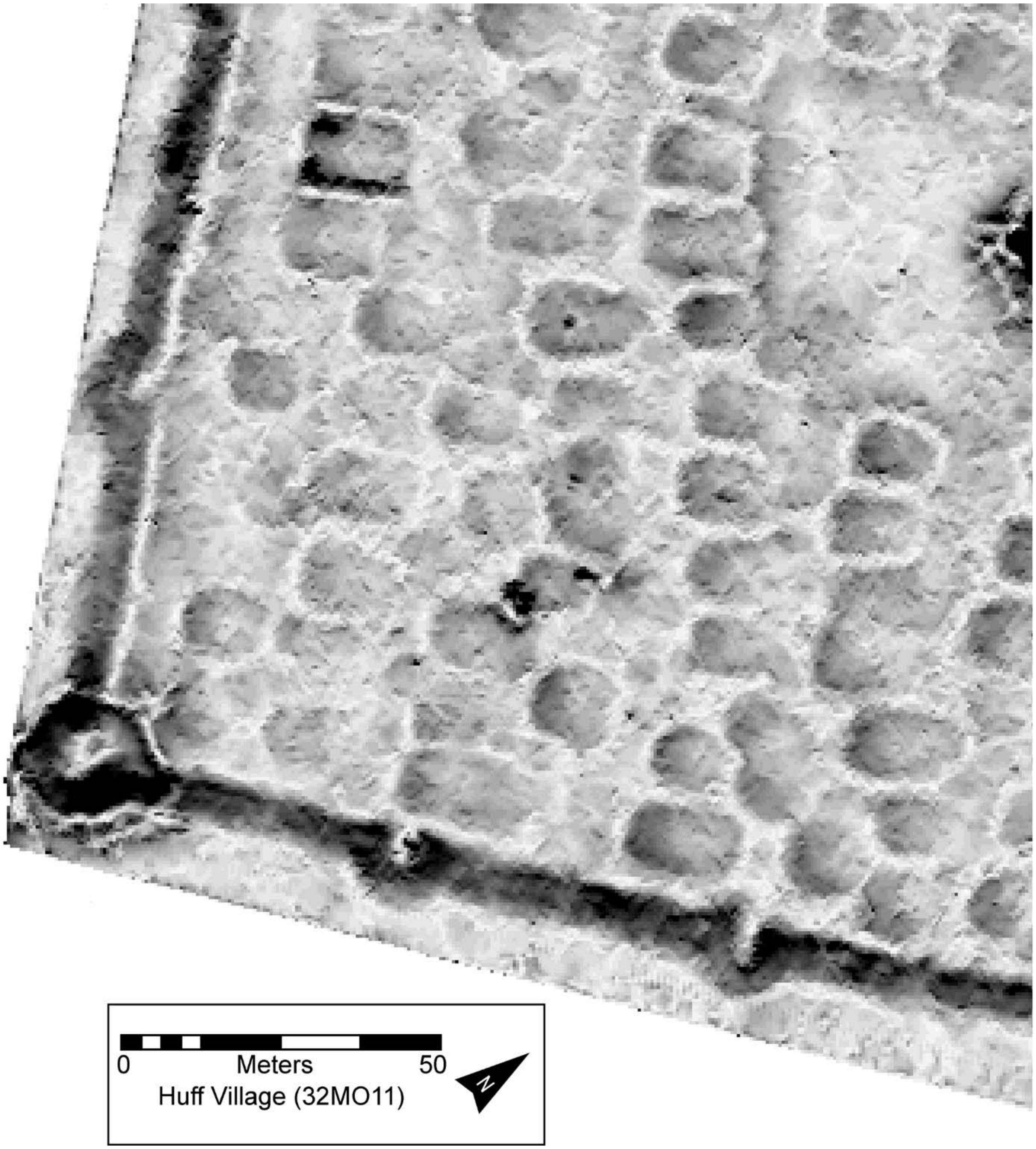

Figure A2.13. Sky view factor visualization of the south section of Huff Village.

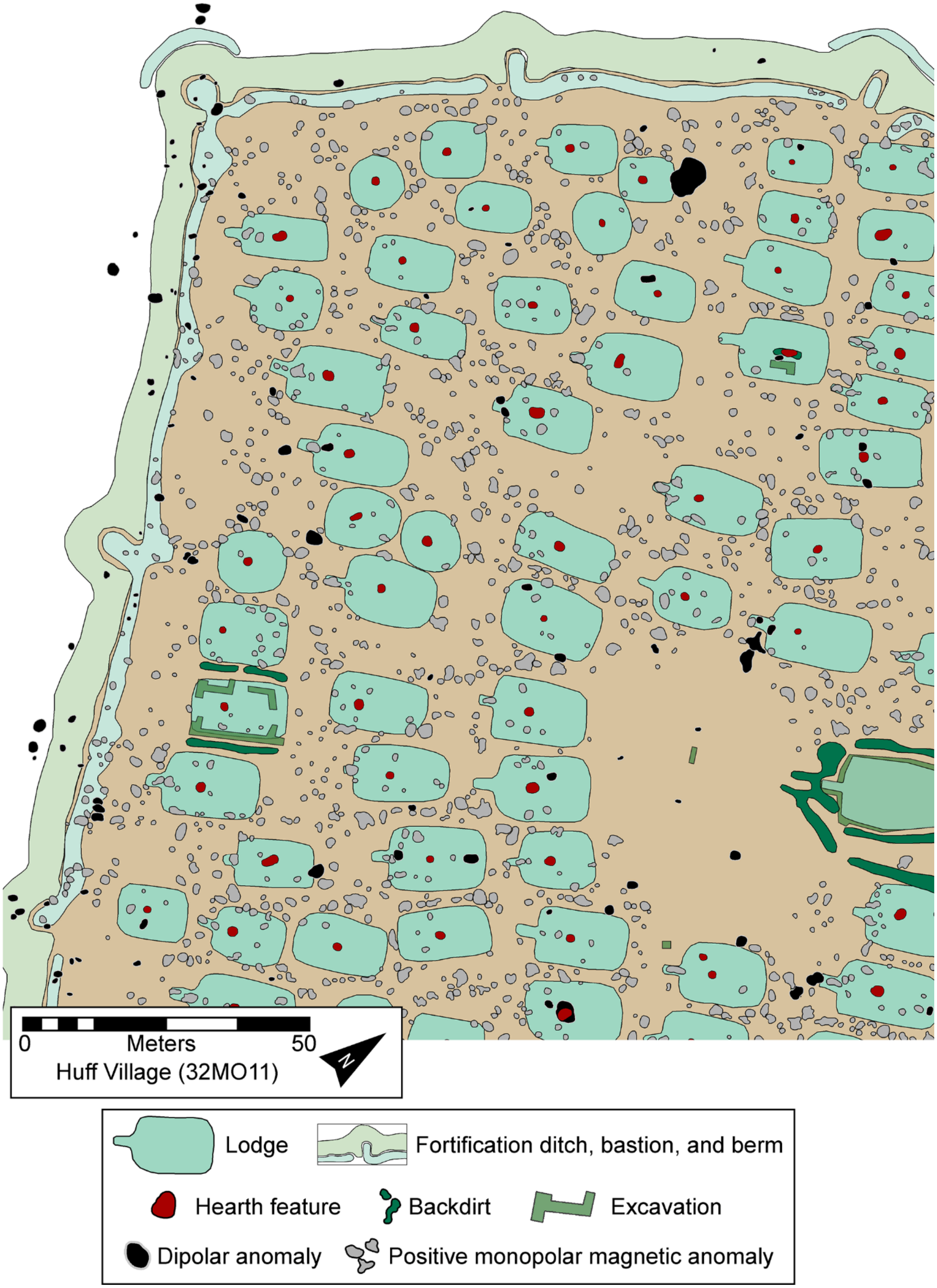

Figure A2.14. Interpretive map of the west section of Huff Village.

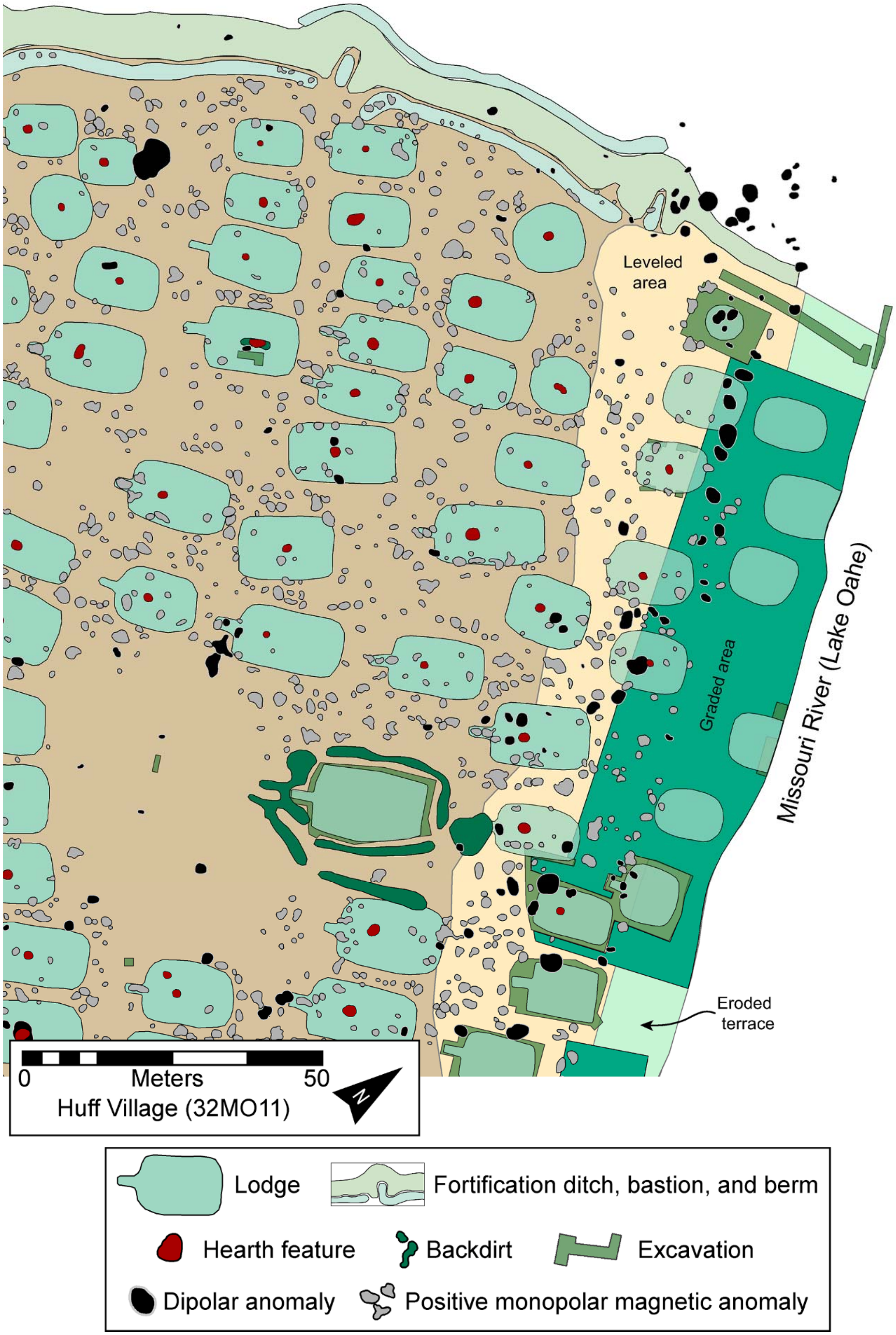

Figure A2.15. Interpretive map of the north section of Huff Village.

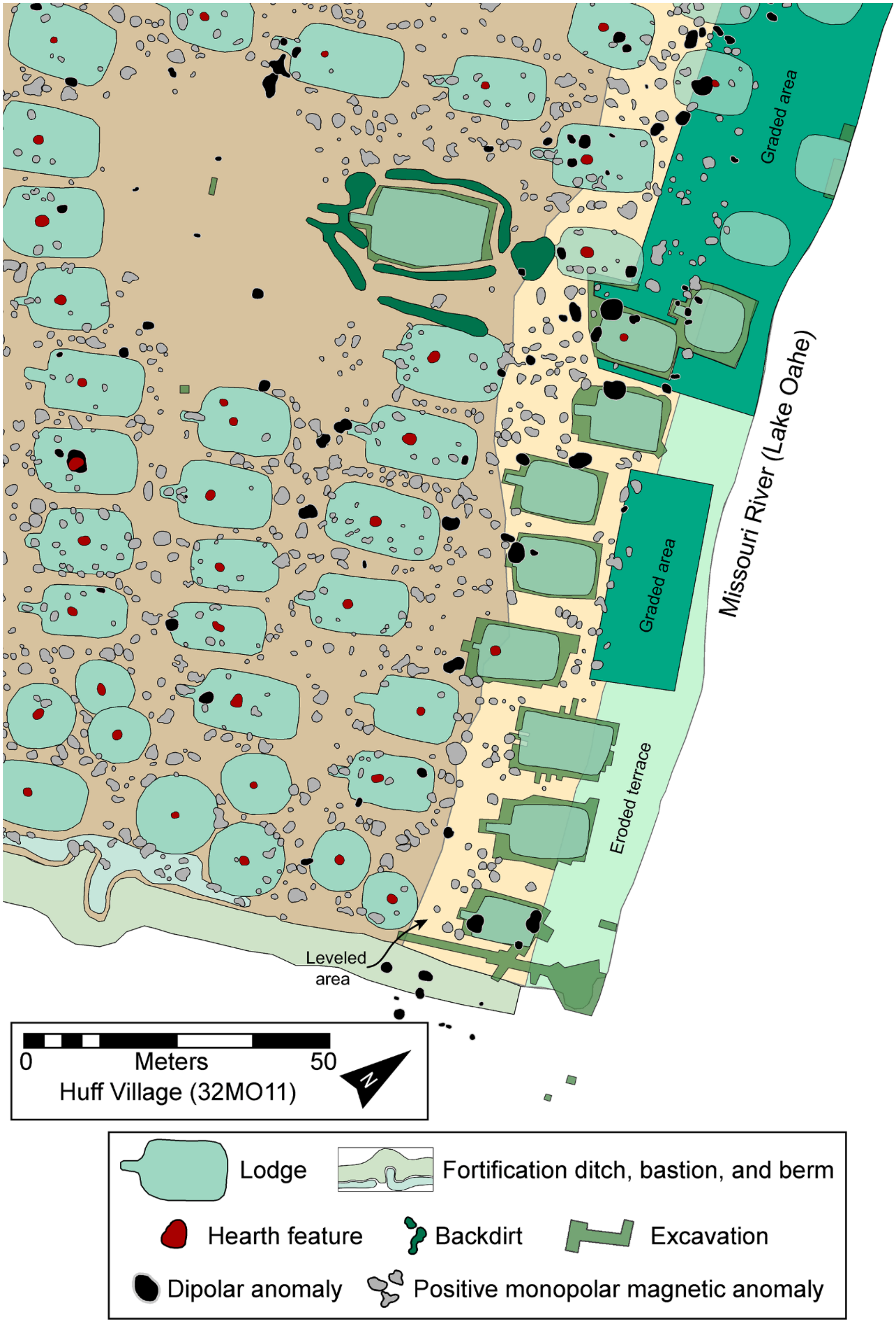

Figure A2.16. Interpretive map of the east section of Huff Village.

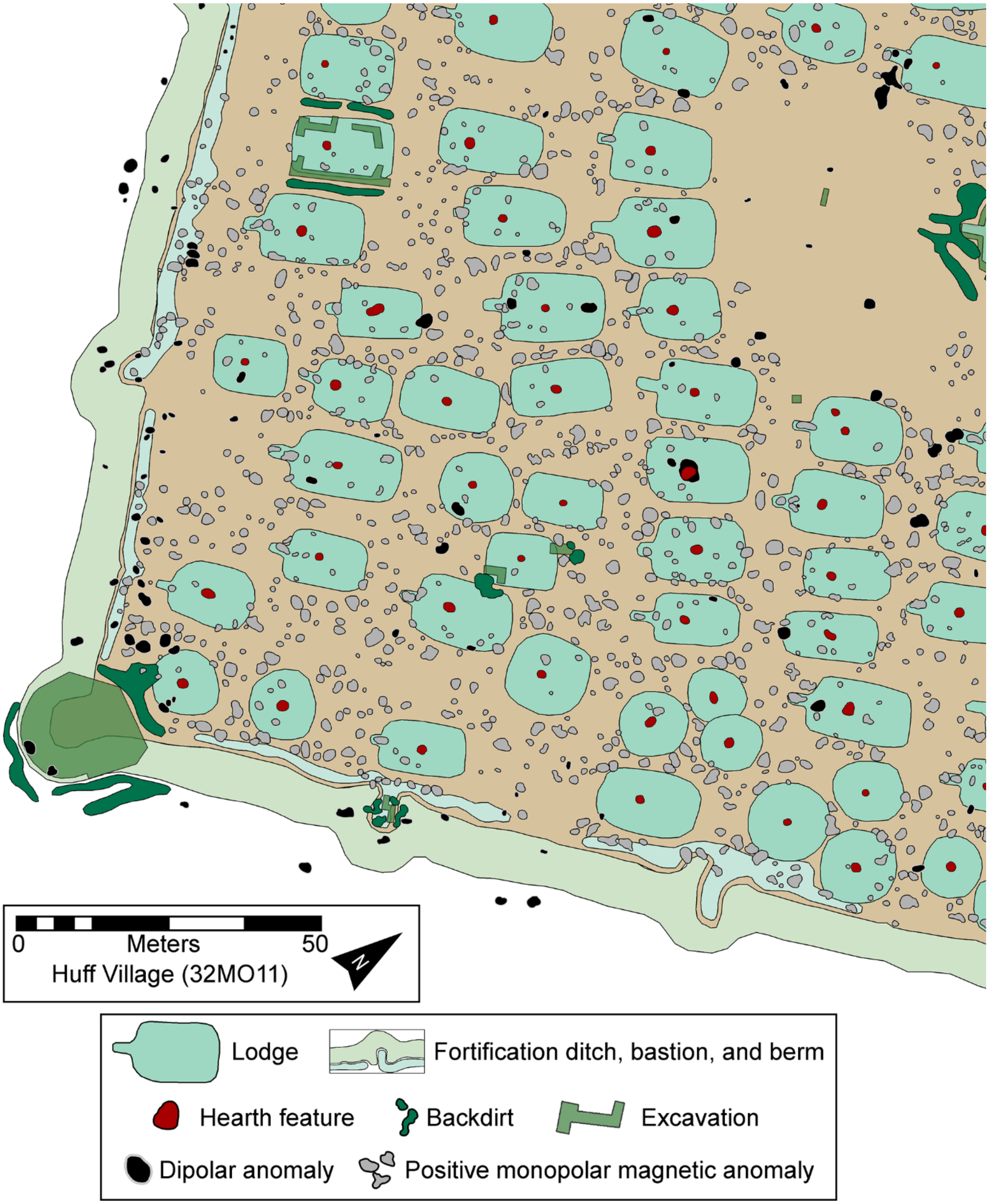

Figure A2.17. Interpretive map of the south section of Huff Village.

APPENDIX 3: NORTHERN PLAINS VILLAGE SITE SUMMARIES AND EXCAVATION DATA

In Chapter 4 I discussed temporal trends in subterranean storage pit volumes among Northern Plains Village sites that date from approximately 1200 to 1886. Pit volumes were estimated using excavation data—the depths, mouth diameters, and base diameters of hundreds of straight-sided and undercut pits —from 20 archaeological sites located along the Missouri River in North Dakota and the northern part of South Dakota (Figure 1.3). These data are listed below. Moreover, I provide site-specific synopses, which include information about settlement size, village layout, house count, occupation length, chronology, and the history of fieldwork.

Paul Brave (32SI4)

An initial investigation of Paul Brave, an Extended Middle Missouri variant (EMMV) settlement, was undertaken by a crew from the University of North Dakota (UND) in 1947, which prompted more intensive excavations in 1955 by the State Historical Society of North Dakota (SHSND) (Wood and Woolworth 1964:2-4). The site is located on the west bank of the Missouri River about 8 km southeast of the present-day town of Fort Yates, North Dakota. At the time of the fieldwork in 1955, at least 14 oval depressions indicating the locations of potential lodges were evident on the ground surface (Wood and Woolworth 1964:2) (Figure A3.1). The depressions were clustered in an area of about 1.6 ha. Although the houses were covered by more than 1 m of overburden, three complete structures were excavated during the latter investigation (Wood and Woolworth 1964:4-11) (Table A3.1). Additional tests in other areas revealed no evidence of an earlier occupation, a finding supported by the general lack of superimposed or overlapping features associated with the three lodges. Numerous relatively small straight-sided and undercut pits were excavated within and adjacent to the structures (Wood and Woolworth 1964:13-14) (Table A3.2). Three accepted radiocarbon dates from materials recovered in separate undercut pits indicate an occupation during the thirteenth century (Johnson 2007:76, Table 7, and Tables C.1-C.3).

Figure A3.1. Aerial photograph from September 24, 1938, which shows many circular and oval-shaped depressions at the Paul Brave site (32SI4). U.S. Department of Agriculture, National Archives and Records Administration (BAA-51-30).

Table A3.1. The area, number of excavated storage pits, and total storage volume for houses excavated at the Paul Brave site.

House No.	Area (m^2)[a]	Interior Storage Pit No.	Total Vol. (m^3)
House 1	137.2	10	1.969
House 2	90.8	8	2.418
House 3	133.2	8	2.361

[a] House area data from Johnson (1979:Table 20).

Table A3.2. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Paul Brave site.

Feature or Coring No.	**Pit Type**	**Total Depth (cmsd)[a]**	**Pit Depth (cm)**	**Mouth Diam. (cm)**	**Base Diam. (cm)**	**Exc. Vol. (m^3)**	**Est. Vol. (m^3)**	**Structure Context**	**Period(s)**	**Comments**
F15	undercut		116	122	183		2.147	2	3	Outside known houses
F46	undercut		79	137	198		1.760	2	3	
F31	undercut	189	61	79	98		0.377	1	3	In F12 (house)
F32	undercut		119	61	171		1.352		3	
F16	undercut	153	43	55	67		0.126	1	3	House 1
F73	undercut	180	70	85	98		0.461	1	3	
F76	undercut	153	43	55	64		0.120	1	3	
F78	undercut	162	52	55	61		0.138	1	3	
F79	undercut	165	55	61	73		0.194	1	3	
F80	undercut	150	40	73	79		0.182	1	3	
F84	straight-sided	159	49		55		0.116	1	3	
F85	undercut	177	67	79	91		0.381	1	3	
F86	undercut	153	43	61	73		0.152	1	3	
F91	undercut		70	128	183		1.343	2	3	
F97	undercut	144	34	55	67		0.100	1	3	
F21	undercut		79	73	98		0.457	2	3	House 2
F27	undercut	119	34	55	67		0.100	1	3	
F33	undercut	146	61	55	101		0.300	1	3	
F34	straight-sided	167	82		85		0.465	1	3	
F35	straight-sided	149	64		101		0.513	1	3	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F36	straight-sided	140	55		58		0.145	1	3	
F37	undercut	164	79	76	107		0.524	1	3	
F38	undercut	134	49	76	85		0.250	1	3	
F39	undercut		61	37	67		0.133	2	3	
F40	undercut	115	30	64	79		0.121	1	3	
F42	undercut		82	91	152		0.971	2	3	
F88	undercut		67	131	189		1.362	2	3	
F90	undercut		61	98	122		0.582	2	3	
F54	undercut	137	52	61	79		0.201	1	3	House 3
F55	undercut	131	46	61	79		0.178	1	3	
F57	undercut	149	64	67	85		0.292	1	3	
F58	undercut	146	61	82	91		0.359	1	3	
F59	undercut	164	79	91	104		0.591	1	3	
F60	undercut	161	76	76	91		0.417	1	3	
F61	undercut	146	61	49	61		0.146	1	3	
F62	undercut	140	55	55	73		0.178	1	3	

[a] Total depth determined by summing the pit depth and the depth of house floors from the ground surface as reported by Wood and Woolworth (1964).

Jake White Bull (39CO6)

Jake White Bull is located in South Dakota along the west bank of the Missouri River approximately 14 km south of the state's border with North Dakota. When the village was initially identified during an examination of aerial photographs in 1952, it contained approximately 30 oval lodge depressions (Ahler 1977:10-12). During a site visit in 1966, John J. Hoffman and Donald J. Lehmer confirmed the presence of about 30 oval depressions, with their long axes oriented northeast to southwest, in three or four parallel rows located within a fortification ditch surrounding an area of about 4.7 ha. Much of site was impacted by erosion and inundation during subsequent years. Thus, a fraction of the site remained intact (Mitchell [2011:Table A3] estimates a site area of 1.6 ha) at the time of Ahler's (1977:19) investigation in 1976. A total of 11 depressions marked the locations of potential earthlodges, eight of which exhibited clear oval-shaped perimeters (Ahler 1977:19). A cutbank profile in which the floor of a probable long rectangular lodge was exposed, and limited test excavations within the structure revealed several storage pits (Ahler 1977:23-38) (Table A3.3). Seven conventional radiocarbon dates were obtained during Ahler's (1977:127, 129-130) investigation, although given questions concerning their reliability, three more recent conventional and AMS dates are favored (Johnson 2007:68-70, Table 7, and Tables C.1-C.3). The three dates suggest a thirteenth-century occupation of the village, a finding supported by the site's EMMV ceramic assemblage (Ahler 1977:144-145; Johnson 2007:68-70).

Table A3.3. Dimensions, excavated volume, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Jake White Bull site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[a]	Structure Context	Period(s)	Comments
F2	undercut		75	60	105		0.411	2	3	House 4
F7	undercut		60		70	0.102	**0.231**	1	3	
F11	undercut		57	105	130	0.466	0.620	1	3	
F16	straight-sided		63		100		0.495	2	3	

[a] The volume of F7, an undercut pit, is calculated with the equation for the volume of a cylinder.

Fire Heart Creek (32SI2)

The Fire Heart Creek site is situated at the confluence of Fire Heart Creek and the Missouri River, on the north terrace of the creek and west side of the river, approximately 5 km north of the North Dakota-South Dakota border. At the time of its investigation by Donald J. Lehmer (1966:4) in 1964, the site was bisected by a gravel road, with several shallow depressions indicating lodge features visible in the eastern section (Figure A3.2). Extensive test excavations revealed two long rectangular structures, which were completely excavated, in the cultivated area west of the road (Lehmer 1966:5, 12-15). To the east, a more complex occupation was revealed with both long rectangular and superimposed circular house forms (Lehmer 1966:8-9). Importantly, the structures and associated features such as storage pits were easily differentiated between the two components. The latter appeared to have been the consequence of a semi-permanent eighteenth- or nineteenth-century hunting camp and the former a permanent village with distinguishable diagnostic ceramics. A total of three long rectangular lodges from the early component were excavated along with many associated intramural and extramural storage pits (Tables A3.4 and A3.5). Each structure was oriented northeast to southwest along their long axes, with the entrances toward the southwest (Lehmer 1966:8-15). One rectangular lodge yielded a radiocarbon date with a calibration curve intercept of 1286 (Johnson 2007:84, Table C.3; Lehmer 1966:52). Although one circular structure was superimposed atop of a rectangular lodge, the lack of midden deposits and evidence of rebuilding episodes suggests the early occupation was likely short in length.

Figure A3.2. An aerial view of the Fire Heart Creek site (32SI2) from September 24, 1938, with a small number of house depressions evident on the east and west sides of a road. U.S. Department of Agriculture, National Archives and Records Administration (BAA-51-15).

Table A3.4. The area, number of excavated storage pits, and total storage volume for houses excavated at the Fire Heart Creek site.

House No.	Area (m^2)[a]	Interior Storage Pit No.	Total Vol. (m^3)
House 2	98.2	2	0.402
House 51	86.4	7	2.501
House 59	72.2	4	1.749

[a] House area data from Johnson (1979:Table 20).

Table A3.5. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Fire Heart Creek site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature 17	straight-sided	122	40		88		0.243	1	3	House 2 (early rectangular)
F20	straight-sided	112	30		82		0.158	1	3	
F52	undercut	131	70	34	58		0.119	1	3	House 51 (early rectangular)
F53	straight-sided	137	76		49		0.143	1	3	
F54	undercut	152	91	61	116		0.578	1	3	
F55	undercut	116	55	61	88		0.242	1	3	
F56	undercut	177	116	79	137		1.088	1	3	
F57	straight-sided	110	49		64		0.158	1	3	
F58	straight-sided	110	49		67		0.173	1	3	
F62	straight-sided	116	55		98		0.415	2	3	
F63	undercut	162	101	137	162		1.777	2	3	
F60	straight-sided	122	46		73		0.193	1	3	House 59 (early rectangular)
F61	straight-sided	131	55		107		0.495	1	3	
F64	straight-sided	155	79		104		0.671	1	3	
F65	undercut	158	82	64	91		0.391	1	3	
F23	straight-sided		61		91		0.132	2	3	Exterior pits (early)

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F26	undercut		104	94	119		0.931	2	3	

[a] Total depth determined by summing the pit depth and the average floor depth of each structure as noted by Lehmer (1966).

Bendish (32MO2)

Bendish is located about 2.5 km south of the present-day town of Fort Rice, North Dakota on the west bank of the Missouri River. The unfortified settlement has been the subject of multiple investigations (Thiessen 1995:114-115). The most extensive work occurred in 1969 when the National Park Service conducted test excavations and completely excavated two long rectangular lodges (Thiessen 1995:115-120) (Table A3.6). When the site was visited in 1969, vegetation cover and regular cultivation had obscured evidence of structures, although 18 shallow depressions were identified (Thiessen 1995:112, 115). However, subsequent use of aerial photographs led to the discovery of at least 45 probable lodges (Thiessen 1995:113, 115) (Figure A3.3). The long rectangular structures, with their long-axes oriented northeast to southwest, form several irregular rows covering an area of about 6.2 ha (Mitchell 2011:Table A3; Thiessen 1995:113, 164-165). Both excavated houses contained several straight-sided and undercut storage pits but little evidence of rebuilding or superimposed features, indicating the occupation was likely of short duration (Thiessen 1995:115-120, 164, and 167) (Table A3.7). Although four radiocarbon dates exist for the site, Johnson (2007:84, Tables C.2 and C.3) eliminated three from consideration; the remaining date indicates the village was occupied during the thirteenth century.

Table A3.6. The area, number of excavated storage pits, and total storage volume for houses excavated at the Bendish site.

House No.	Area (m^2)[a]	Interior Storage Pit No.	Total Vol. (m^3)
House 3	114.1	10	2.213
House 6	104.2	2	0.620

[a] House area data from Mitchell (2011:402). Calculated from Thiessen's (1995) published maps.

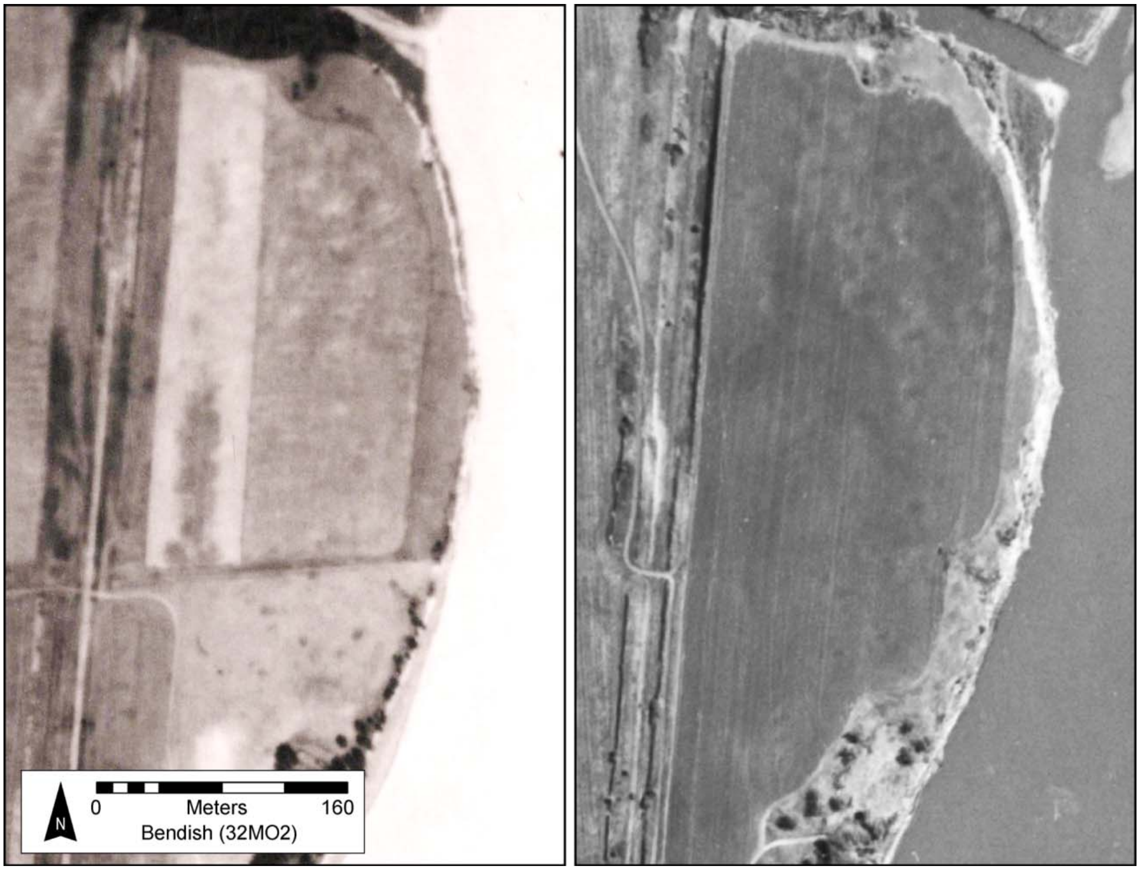

Figure A3.3. Subtle indications of oval-shaped lodges along the east side of the Missouri River at the Bendish site (32MO2) in aerial photographs from August 25, 1938 (left) and May 29, 1967 (right). Left photograph: U.S. Department of Agriculture, National Archives and Records Administration (AZY-23-57). Right photograph: Data available from the U.S. Geological Survey (AR1VBRE00010006).

Table A3.7. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Bendish site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature 25	straight-sided		30		122		0.351	1	3	House 6
F27	straight-sided		30		107		0.270	1	3	
F39	undercut		46		99		0.354	2	3	
Feature 1	straight-sided		30		84		0.166	1	3	House 3
F2	undercut		70		76		0.318	1	3	
F4a	straight-sided		37		91		0.241	1	3	
F4b	straight-sided		43		73		0.180	1	3	
F5	undercut		70		69		0.262	1	3	
F6	undercut		49		55		0.116	1	3	
F10	straight-sided		37		64		0.119	1	3	
F12	straight-sided		46		66		0.157	1	3	
F15	straight-sided		61		201		1.936	2	3	
F18	undercut		70		46		0.116	1	3	
F19	undercut		46		122		0.538	1	3	

[a] A minimum diameter (or orifice diameter) was not provided for undercut pits. Calculation of estimated volumes is based on the equation for a cylinder.

Havens (32EM1)

The Havens site, which is located on the east bank of the Missouri River opposite of Paul Brave, was initially investigated in the late 1960s (Sperry 1995:10). The unfortified settlement had not been impacted by cultivation and consisted of 56 depressions in an area of about 6 ha. The depressions indicated the locations of long rectangular houses with southwest-facing entryways. Moreover, the structures were arranged irregularly in rows that paralleled the bank of the Missouri River. A total of four houses were completely excavated, revealing many straight-sided and undercut storage pits within and surrounding the houses (Sperry 1995:13-31) (Tables A3.8 and A3.9). Importantly, one house exhibited evidence of rebuilding (Sperry 1995:29). The structure's centerposts had either been replaced or supported with a secondary post and it contained multiple secondary hearths. Another house with multiple overlapping primary hearths and intersecting storage pits appeared to have been occupied for an extended period (Sperry 1995:20-21). A total of four radiocarbon dates have been run for the site, although two are problematic and have been disregarded by Johnson (2007:75-76; see also Sperry 1995:71). The two most recent radiocarbon dates indicate a fourteenth-century occupation of the settlement (Johnson 2007:75-76 and Tables C.1-C.3).

Table A3.8. The area, number of excavated storage pits, and total storage volume for houses excavated at the Havens site.

House No.	Area (m^2)[a]	Interior Storage Pit No.[b]	Total Vol. (m^3)
House 1	101.0	9	7.915
House 2	115.9	20	6.888
House 3	126.6	6	1.376
House 4	94.8	8	3.534

[a] House area data from Mitchell (2011:402). Calculated from Sperry's (1995) published maps.

[b] Figure does not include storage pits thought by Sperry (1968) to predate a house.

Table A3.9. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Havens site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Pit 4	undercut	146	88	90	110		0.693	1	3	House 1
P5	undercut	152	94	85	143		0.980	1	3	
P7	undercut	107	49	55	64		0.137	1	3	
P8	undercut	162	104	116	157		1.533	1	3	
P9	undercut	143	85	88	116		0.699	1	3	
P10	undercut	134	76	79	85		0.402	1	3	
P12	undercut	131	73	94	131		0.732	1	3	
P13	undercut	177	119	120	137		1.546	1	3	
P16	undercut	177	119	94	131		1.194	1	3	
Pit 3	straight-sided	108	73		143		1.172	2	3	House 2; intruded into P4; intersecting pits and hearths indicate rebuilding and long period of occupation
P4	undercut	114	79	128	162		1.311	2	3	
P5	straight-sided	148	113		210		3.914	2	3	
P6	undercut	91	56	113	128		0.639	2	3	intrusive into corner of house
P7	undercut	102	67	110	143		0.847	2	3	postdates house
P9	undercut	85	50	114	119		0.533	2	3	intersected by P11

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
P15	undercut	111	76	116	152		1.078	2	3	intersected by P13 and P14
P17	undercut	130	76	76	88		0.402	1	3	
P19	undercut	139	85	91	125		0.785	1	3	
P21	undercut	97	43	61	73		0.152	1	3	
P24	undercut	127	73	78	99		0.451	1	3	
P25	undercut	160	125		140		**1.924**	2	3	predates house; truncated
P26	undercut	133	98	79	104		0.648	2	3	predates house; truncated
P27	undercut	118	64	73	104		0.398	1	3	
P29	undercut	121	67	75	88		0.350	1	3	
P33	undercut	103	49	58	82		0.190	1	3	intersects P32
P35	undercut	130	76	91	119		0.662	1	3	
P39	undercut	127	73	91	107		0.563	1	3	
P40	undercut	103	49	64	67		0.165	1	3	intersects P41
P42	straight-sided	130	76	75	27		0.167	1	3	straight-sided with tapered walls
P43	straight-sided	109	55	94	67		0.283	1	3	intersects P44; straight-sided with tapered walls
P44	straight-sided	97	43		66		0.147	1	3	intersects P43
P45	straight-sided	138	84		94		0.583	1	3	predates house

Feature or Coring No.	Pit Type	Total Depth (cmsd)^a	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
P46	undercut	130	76	90	110		0.599	1	3	
P47	undercut	118	64	67	91		0.316	1	3	
P48	straight-sided	100	46	107	64		0.270	1	3	straight-sided with tapered walls
P50	undercut	115	61	76	82		0.299	1	3	intruded into P49
P51	undercut	100	46	52	61		0.116	1	3	
P52	undercut	109	55	90	104		0.407	1	3	
P54	straight-sided	119	84		104		0.714	2	3	postdates house
P55	undercut	97	43	61	79		0.166	1	3	
P57	straight-sided	96	61		107		0.549	2	3	incompletely excavated
Pit 1	undercut	139	104		168		**2.305**	2	3	House 3; intrusive into P3
P2	undercut	158	123	134	183		2.446	2	3	looted
P3	undercut	114	79	122	143		1.092	2	3	pit merged with others
P4	undercut	87	52	101	125		0.523	2	3	pit merged with others
P7	undercut	99	64		244		**2.993**	2	3	pit merged with others
P9	undercut	111	76	134	165		1.339	2	3	intrusive into P8
P12	pit	108	73		165		1.561	2	3	
P13	undercut	85	50	98	104		0.401	2	3	
P15	undercut	96	61	105	133		0.682	2	3	intersects P16

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
P17	undercut	111	76	113	137		0.936	2	3	possibly post- or predates house
P34	undercut	105	44	79	85		0.232	1	3	
P37	undercut	104	43	49	67		0.115	1	3	
P39	undercut	113	52	52	70		0.153	1	3	
P44	undercut	117	56	73	104		0.348	1	3	
P49	undercut	105	44	91	107		0.339	1	3	
P50	undercut	101	40	77	78		0.189	1	3	
Pit 1	undercut	213	178	166	197		4.617	2	3	House 4; extensive evidence of rebuilding
P12	undercut	129	88	116	125		1.004	1	3	
P21	undercut	117	76	67	98		0.411	1	3	
P24	undercut	102	61	62	88		0.272	1	3	
P28	straight-sided	90	49		94		0.340	1	3	intruded into by hearth
P29	straight-sided	100	59	64	35		0.117	1	3	straight-sided with tapered walls
P33	undercut	97	56	81	95		0.341	1	3	
P34	straight-sided	120	79		99		0.608	1	3	
P36	straight-sided	96	55		101		0.441	1	3	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Pit 1	undercut	142	98	146	177		2.014	2	3	test excavation 1
Pit 1	undercut	109	88	122	137		1.160	2	3	test excavation 2

[a] Total depth determined by summing the pit depth and the average depth to the occupation surface or house floor reported by Sperry (1995).

[b] The volumes of three undercut pits are calculated with the equation for the volume of a cylinder.

South Cannonball (32SI19)

South Cannonball is located at the Cannonball-Missouri River confluence in southern North Dakota. The unfortified village, approximately 6.5 ha in area (Mitchell 2011:Table A3), includes 35 elongated depressions indicating long rectangular houses oriented approximately northeast to southwest with southwest-facing entrances (Griffin 1984:5, 8-10, and 108-111) (Figure A3.4). Moreover, the dwellings are aligned in irregular rows parallel to the terrace. Johnson (2007:85, Tables C.2-C.3) suggests one radiocarbon date for the site is problematic, but thirteen other dates show the village was occupied during the fourteenth century. Additionally, the site's ceramic assemblage supports its EMMV assignment (Griffin 1984:21-31). From 1966 to 1968 Smithsonian Institution River Basin Surveys archaeologists completely excavated six houses and partially excavated a seventh, extensive work that revealed numerous features (Griffin 1984:5-20) (Tables A3.10 and A3.11). Subterranean storage pits were common both within and outside the structures. In fact, the density of intersecting pits, particularly in Houses 5 and 6, led Griffin (1984:10) to suggest that the two were occupied longer than other houses. Furthermore, Griffin (1984:108-111) argued that houses were occupied in a sequence, or the site was abandoned and reoccupied over a long period, although neither the ceramic assemblage nor excavation data support this assertion (e.g., there is little evidence of overlapping or rebuilt structures).

Figure A3.4. An aerial photograph from August 25, 1938, which shows rows of oval-shaped lodge depressions at the South Cannonball site (32SI19). U.S. Department of Agriculture, National Archives and Records Administration (AZY-23-65).

Table A3.10. The area, number of excavated storage pits, and total storage volume for houses excavated at the South Cannonball site.

House No.	Area (m^2)[a]	Interior Storage Pit No.[b]	Total Vol. (m^3)
House 1	103.5	2	2.130
House 2	141.8	7	1.128
House 3	71.2	1	0.163
House 4	152.7	5	1.749
House 5	99.6	5	2.305
House 7	88.9	4	1.852

[a] House area data from Johnson (1979:Table 20). After Mitchell (2011:405), House 6 is excluded since its width could not be determined based on the published map.

[b] Count does not include storage pits thought by Griffin (1984) to predate a house.

Table A3.11. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the South Cannonball site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)[b]	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F34	straight-sided	149	104		137		1.533	1	4	House 1
F38	straight-sided	118	73		102		0.597	1	4	
F55	straight-sided	60	30		125		0.368	2	4	
Feature 40	straight-sided	67	37		82		0.195	2	4	House 2
F48	straight-sided	60	30		94		0.208	2	4	
F53	undercut	112	82		125		1.006	2	4	
F56	straight-sided	76	46		117		0.495	2	4	
F69	undercut	103	73		134		1.029	2	4	
F107	undercut	97	52		64		0.167	1	4	
F111	undercut	109	64		50		0.126	1	4	
F114	straight-sided	91	46		70		0.177	1	4	
F115	straight-sided	82	52		98		0.392	2	4	
F119	undercut	109	64		47		0.111	1	4	
F120	undercut	94	49		79		0.240	1	4	
F123	undercut	103	58		66		0.198	1	4	
F134	undercut	94	49		53		0.108	1	4	
Feature 80	undercut	88	58		88		0.353	2	4	House 3
F84	straight-sided	64	34		120		0.385	2	4	
F85	straight-sided	67	37		101		0.296	2	4	intersects with F87
F87	undercut	73	43		177		1.058	2	4	
F88	undercut	103	73		96		0.528	2	4	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)[b]	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F95	undercut	85	40		72		0.163	1	4	
F102	undercut	115	85		93		0.577	2	4	
F103	straight-sided	91	61		110		0.580	2	4	
Feature 142	undercut	136	91		76		0.413	1	4	House 4
F146	undercut	85	40		119		0.445	1	4	contains post; intersects F148
F147	undercut	82	52		111		0.503	2	4	
F149	straight-sided	112	67		88		0.408	1	4	
F151	pit	115	70		81		0.361	1	4	pocket cache
F153	pit	103	58		52		0.123	1	4	pocket cache
F156	undercut	73	43		107		0.387	2	4	
F167	undercut	70	40		99		0.308	2	4	
F169	undercut	103	73		102		0.597	2	4	
F172	straight-sided	76	46		128		0.592	2	4	
Feature 176	straight-sided	94	49		130		0.650	1	4	House 5; contains post
F180	straight-sided	106	61		91		0.397	1	4	
F184	straight-sided	91	61		81		0.314	2	4	
F192	undercut	94	49		85		0.278	1	4	
F199	straight-sided	109	64		111		0.619	1	4	
F205	undercut	97	52		94		0.361	1	4	
Feature 215	undercut	106	76		91		0.494	2	4	House 6
F225	undercut	76	46		94		0.319	2	4	intersects F224

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)[b]	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F228	pit	106	61		56		0.150	1	4	pocket cache; intersects house wall
Feature 261	straight-sided	82	37		160		0.744	1	4	House 7; intersects F273 and house wall
F269	undercut	115	70		93		0.476	1	4	
F271	undercut	82	37		131		0.499	1	4	intersects F270
F273	undercut	94	49		59		0.134	1	4	intersects F261
Feature 58	undercut	103	73		88		0.444	2	4	Interhouse 2-3 area
F65	undercut	131	101		113		1.013	2	4	
F66	undercut	97	67		175		1.612	2	4	
F76	straight-sided	85	55		113		0.552	2	4	
F86	undercut	115	85		128		1.094	2	4	intersects walls and F89
F89	undercut	103	73		213		2.601	2	4	intersects F86

[a] Total depth determined by summing the pit depth and the approximate depth to the occupation surface or house floor (Griffin [1984] noted that houses were excavated between 30-60 cm below the occupation surface).

[b] A minimum diameter (or orifice diameter) was not provided for undercut pits. Calculation of estimated volumes is based on the equation for a cylinder.

Cross Ranch (32OL14)

Cross Ranch is located on the west bank of the Missouri River approximately 2 km north of the town of Sanger, North Dakota. Excavations were undertaken at the site in 1969, during which two long rectangular lodges were excavated (Calabrese 1972:6-13) (Table A3.12). The two structures are oriented northeast to southwest along their long axes and have southwest-facing entryways like dwellings at other Extended variant sites. They are among a row of nine structures visible on the ground surface as oval-shaped depressions that parallel the river's edge (Calabrese 1972:6) (Figure A3.5). Erosion, cultivation, and road construction have destroyed an unknown portion of the larger site. At the time of the investigation, the extant portion was only 1.3 ha (Mitchell 2011:Table A3). Six radiocarbon dates have been acquired for the site, although Johnson (2007:84, Tables C.2-C.3) considers only three. The three accepted dates indicate the site was occupied during the fourteenth century. Additionally, a lack of thick midden deposits and overlapping or superimposed structures suggest the occupation was short in duration (Calabrese 1972:6-13). Among numerous features, several straight-sided and undercut pits were excavated within and outside the two houses (Table A3.13). None of the pit features overlap, which supports the idea of a short occupation length.

Table A3.12. The area, number of excavated storage pits, and total storage volume for houses excavated at the Cross Ranch site.

House No.	Area (m^2)[a]	Interior Storage Pit No.	Total Vol. (m^3)
House 3	76.8	0	0
House 7	59.4	1	0.142

[a] House area from Mitchell (2011:401). Calculated from Calabrese's (1972) published maps.

Figure A3.5. A row of oval-shaped lodge depressions between railroad tracks and the Missouri River at Cross Ranch (32OL14) in an aerial photograph from July 27, 1938. U.S. Department of Agriculture, National Archives and Records Administration (BAQ-47-52).

Table A3.13. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Cross Ranch site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature 105	undercut	113	67	116	113		0.690	2	4	House 3
F106	undercut	104	61	91	116		0.516	2	4	
F107	straight-sided	76	30	76	67		0.121	2	4	straight-sided with tapered walls
F1T1	undercut	121	91	137	149		1.462	2	4	Between Houses 5 and 6
F63	undercut	159	116	101	134		1.266	2	4	House 7
F53	undercut	125	98	116	137		1.235	2	4	
F54	straight-sided	80	37		70		0.142	1	4	
F52	straight-sided	73	30		67		0.106	2	4	slightly undercut

[a] Total depth determined by summing the pit depth and the depth at which features were encountered (Calabrese 1972:8).

White Buffalo Robe (32ME7)

White Buffalo Robe is located approximately 4 km southeast of present-day Stanton, North Dakota on the west side of the Missouri River. Extensive excavations were carried out in 1978 by the UND, by which time railroad construction, highway construction, and cultivation had destroyed much of the site (Lee and Ahler 1980:1). Although limited work had been carried out at the site previously, the 1978 excavations revealed the complexity of the settlement (Lee and Ahler 1980:4). That is, radiocarbon dates and artifacts provide evidence of multiple components, indicating an intermittent site occupation over hundreds of years (Hetland 1980:43). Among the components is a short-term, fourteenth-century Extended variant occupation, as evidenced by five radiocarbon dates obtained from five features in three probable houses (Johnson 2007:84, Tables C.2-C.3). At least one long rectangular house associated with the EMMV occupation is indicated by the locations of postmolds and pits while clusters of additional features point to other possible structures (Lee and Hetland 1980:114). Many pit features were excavated as part of the undertaking (Lee and Hetland 1980:87- 131), but I consider only the earlier Nailati phase features (Table A3.14).

Table A3.14. Excavated volume for storage pits at the White Buffalo Robe site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)[a]	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature 4	undercut					0.866				Heart
F11	undercut					0.703				Heart
F105	undercut					0.420				Heart
F210	undercut					0.302				Heart
F220	undercut					0.104				Heart
F230	undercut					0.128				Heart
F232	undercut					0.180				Heart
F236	undercut					0.305				Heart
F195	undercut					0.177				Knife
F215	undercut					0.138				Knife
F242	undercut					0.197				Knife
F91	undercut					0.138				Knife
F112	pit					0.174				Knife; cache
F38	undercut					0.234			4	Nailati; House 6
F61	undercut					0.354			4	Nailati; House 5
F96	undercut					0.191			4	Nailati; House 4
F100	undercut					0.485			4	Nailati; House 4
F121	undercut					0.294			4	Nailati; House 1
F124	undercut					0.501			4	Nailati; House 1
F144	undercut					0.268			4	Nailati; House 1

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. $(m^3)^a$	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F151	pit					0.122			4	Nailati; House 1, undercut
F172	undercut					0.292			4	Nailati; House 1
F176	undercut					0.928			4	Nailati; House 4
F226	undercut					0.327			4	Nailati; House 5
F240	undercut					1.038			4	Nailati; House 8
F255	undercut					0.227			4	Nailati; House 7

[a] Excavated volumes reported by Lee (1980) for each completely excavated storage pit.

Shermer (32EM10)

The Shermer site is located on the east bank of the Missouri River, nearly opposite of Huff Village, a short distance upstream from the mouth of the Cannonball River (Sperry 1968). Although it has generally been recognized as a Terminal Middle Missouri variant (TMMV) site like Huff Village (Lehmer 1971:120-121; Sperry 1968), its mid- to late fourteenth-century date is nearly a century earlier (Johnson 2007:77-78). Moreover, Shermer's ceramic assemblage includes EMMV types and justifies its Extended variant designation (Mitchell 2013:220-221). The site, approximately 4.2 ha in size, is located in an area that has been cultivated for many decades. Yet, at the time of Sperry's (1968:2, Plate 1A) work in the mid-1960s, numerous house locations and a fortification ditch, which includes multiple bastions, were visible as crop markings or surface depressions. The rectangular houses were constructed so that their long axes were oriented northeast to southwest, like those at Huff Village, and they were likewise aligned in approximate rows (Sperry 1968:2). Sperry (1968:2, Figure 3) relied on an early twentieth century map of the site to determine a house count of 79. However, Mitchell (2013:220-221) notes that Sperry's (1968:Figure 2) own map and an aerial view (Sperry 1968:Plate 1A) of the site support a lower house count. Sperry (1968:8-9) completely excavated four long rectangular houses as well as one portion of the fortification ditch and palisade (Table A3.15). Several factors indicate the occupation may have extended over multiple decades, including midden up to approximately .5 m in depth in one area, superimposed and intersecting subterranean storage pits within some houses, and the rebuilding of some houses (Mitchell 2011:398-399; Sperry 1968) (Table A3.16). Shermer's mid- to late fourteenth century date and perhaps its long-term occupation are evidenced by multiple radiocarbon samples (Johnson 2007:77-78, Table C.3).

Table A3.15. The area, number of excavated storage pits, and total storage volume for houses excavated at the Shermer site.

House No.	Area (m^2)[a]	Interior Storage Pit No.[b]	Total Vol. (m^3)
House 1	109.5	6	4.398
House 4[c]	138.7	10	12.723
House 6[c]	104.8	7	6.072
House 7	279.1	4	7.457

[a] House area data from Mitchell (2011:403-404). Calculated from Sperry's (1968) published maps.

[b] Count does not include storage pits thought by Sperry (1968) to predate a house.

[c] Houses exhibit evidence of rebuilding.

Table A3.16. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Shermer site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
Pit 1	undercut	113	73	146	180		1.529	1	4	House 1; pit predates house
P7	straight-sided	93	53	64	37		0.109	1	4	straight-sided with tapered walls
P9	straight-sided	92	52	61	38		0.102	1	4	straight-sided with tapered walls
P10	undercut	113	73	101	119		0.695	1	4	
P11	undercut	113	73	113	128		0.834	1	4	
P18	undercut	122	82	110	128		0.914	1	4	
P21	undercut	138	98	143	158		1.745	1	4	
P1	undercut	180	128	131	165		2.212	1	4	House 4
P6	undercut	101	49	79	88		0.269	1	4	
P8	undercut	134	82		128		**1.055**	1	4	intersected by P9
P9	straight-sided	153	101	151	131		1.580	1	4	straight-sided with tapered walls
P11	undercut	131	79	98	122		0.754	1	4	
P12	straight-sided	113	61		91		0.397	1	4	intersected by P11 and P13
P13	undercut	140	88	113	134		1.057	1	4	
P19	straight-sided	150	98	163	113		1.482	1	4	straight-sided with tapered walls
P21	undercut	146	94	189	223		3.140	1	4	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
P22	undercut	122	70	125	113		0.779	1	4	
P26	undercut	189	137	149	165		2.655	2	4	
P27	undercut	107	55	104	119		0.538	2	4	
P1	undercut	125	82	171	174		1.916	2	4	House 6
P2	undercut	83	40	55	70		0.123	1	4	
P3	straight-sided	92	49		116		0.518	2	4	pit predates house (cut by house wall)
P4	straight-sided	73	30		93		0.204	2	4	truncated by P3 and P5
P5	undercut	107	64	122	128		0.786	2	4	truncated by P4 and P6
P6	undercut	101	58	88	94		0.377	2	4	pit predates house (cut by house wall)
P7	undercut	177	134	128	146		1.978	1	4	
P11	straight-sided	107	64		186		1.739	1	4	
P12	undercut	73	30	64	67		0.101	1	4	
P13	straight-sided	101	58		119		0.215	1	4	
P19	undercut	116	73	117	146		0.995	1	4	
P20	undercut	110	67	76	128		0.559	1	4	predates house
P21	undercut	83	40	91	125		0.369	1	4	predates house
P22	undercut	116	73	116	137		0.920	1	4	
P6	straight-sided	75	52		81		0.268	1	4	House 7; ceremonial lodge

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
P8	straight-sided	157	134	218	160		3.789	1	4	straight-sided with tapered walls
P9	undercut	128	105	152	171		2.153	1	4	
P11	undercut	127	104	119	128		1.246	1	4	
P1	undercut		85	131	134		1.172	2	4	Midden excavations

[a] Total depth determined by summing the pit depth and the house floor depth (Sperry 1968:Table 1).

[b] The volume of P8, an undercut pit, is calculated with the equation for the volume of a cylinder.

Huff Village State Historic Site (32MO11)

Huff Village, the subject of Chapter 3, is located on the west bank of the Missouri River a short distance south of the Heart and Missouri River confluence. The site is a short-term TMMV occupation that was occupied around 1440-1460 as shown by six AMS dates (Ahler 2000; Wood 1967). The well-preserved 4.4 ha site is roughly rectangular in shape, with its perimeter defined by a fortification ditch that includes ten bastions. Within the fortification, 115 houses, most with long rectangular floor plans, are aligned roughly in rows that parallel the Missouri River. Like earlier Extended variant houses, their long axes are oriented northeast to southwest. In 1960, W. Raymond Wood (1967:31-52) excavated eight houses and fully documented the previous investigations of three others, revealing a large number of subterranean storage pits (Tables A3.17 and A3.18). Although the density of storage pits is quite high within houses, these excavations revealed little evidence of a long-term occupation (e.g., extensive rebuilding of houses). The results of a systematic coring program undertaken in 1999 as part of an intensive geophysical investigation, which are reported by Kvamme and Ahler (2000), are included below.

Table A3.17. The area, number of excavated storage pits, and total storage volume for houses excavated at Huff Village.

House No.	Area (m^2)[a]	Interior Storage Pit No.[b]	Total Vol. (m^3)
House 1	109.4	6	4.848
House 2	199.3	6	8.490
House 3	55.6	7	7.063
House 4	107.6	2	6.033
House 5	127.2	0	0
House 6	120.8	5	3.164
House 7	145.2	5	2.970
House 8	131.9	7	6.699
House 10	135.4	2	3.626
House 12	95.4	3	1.845

[a] House area data from Mitchell (2011:415). Calculated from Wood's (1967:Map 4) published maps.

[b] Count does not include storage pits thought by Wood (1967) to predate a house.

Table A3.18. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at Huff Village.

Feature or Coring No.	Pit Type	Total Depth (cmsd)^a	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature A	undercut	114	76	85	110		0.571	1	5	House 1
B	undercut	99	61	76	91		0.335	1	5	
C	undercut	175	137	91	137		1.417	1	5	
D	undercut	145	107	91	122		0.960	1	5	
E	undercut	99	61	91	107		0.471	1	5	located in wall line; predates house?
F	undercut	117	79	116	149		1.095	1	5	
Feature A	undercut	166	128	125	137		1.726	1	5	House 2; ceremonial lodge
B	undercut	175	137	146	165		2.605	1	5	
C	undercut	114	76	122	137		1.002	1	5	
D	straight-sided	84	46		73		0.193	1	5	intersects C
E	undercut	145	107	107	122		1.103	1	5	
G	undercut	132	94	143	174		1.861	1	5	
Feature 2	undercut	145	107	76	107		0.710	1	5	House 3; intersects with F6 and F7
F3	undercut	160	122	91	122		1.094	1	5	
F4	undercut	121	91	98	107		0.751	2	5	
F6	undercut	129	91	91	122		0.816	1	5	intersects with F2 and F8
F7	undercut	163	125	113	146		1.655	1	5	intersects with F2

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F8	undercut	129	91	98	128		0.918	1	5	intersects with F6 and F23
F20	undercut	136	98	104	146		1.214	1	5	
F21	undercut	111	73	91	122		0.655	1	5	
Feature 42	undercut	227	189	171	189		4.813	1	5	House 4
F43	undercut	163	125	94	128		1.219	1	5	
Feature 87	undercut	123	85	110	116		0.853	1	5	House 6
F88	straight-sided	87	49		61		0.143	1	5	
F101	undercut	123	85	107	119		0.853	1	5	
F102	undercut	97	67	107	131		0.748	2	5	
F104	straight-sided	123	85		116		0.898	1	5	intersects other pits
F110	straight-sided	102	64		91		0.416	1	5	
Feature 55	undercut	160	122	88	122		1.066	1	5	House 7
F59	undercut	90	52	88	122		0.454	1	5	
F67	straight-sided	99	61		102		0.498	1	5	
F79	undercut	90	52	98	113		0.455	1	5	
F111	straight-sided	160	122		72		0.497	1	5	
F113	undercut	93	55	88	94		0.358	1	5	House 8; predates house
F118	undercut	187	149	128	149		2.249	1	5	
F119	undercut	145	107	73	91		0.567	1	5	
F123	straight-sided	81	43		55		0.102	1	5	
F129	straight-sided	114	76		123		0.903	1	5	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F136	undercut	114	76	107	122		0.784	1	5	
F142	straight-sided	81	43		67		0.152	1	5	
F143	undercut	166	128	104	152		1.666	1	5	located in wall line; predates house
F145	undercut	184	146	107	152		1.942	1	5	
Feature 147	undercut	136	98	122	140		1.323	1	5	House 9
Feature 152	undercut	129	91	101	110		0.796	1	5	House 10
F154	undercut	181	143	143	174		2.831	1	5	
Feature 158	undercut	136	98	107	122		1.011	1	5	House 12 (subrectangular)
F167	undercut	114	76	76	91		0.417	1	5	
F169	undercut	123	85	73	85		0.417	1	5	
Core F	pit	105						2	5	Targeted coring and limited excavation
H	pit	74						2	5	
I	pit	75						2	5	
K	pit	75						2	5	
L	pit	108						2	5	
M	pit	90						2	5	
N,F501	undercut	152	112	100	150		1.393	2	5	excavated feature
O	pit	150						2	5	
P	pit	73						2	5	
Q	pit	120						2	5	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
R	pit	85						2	5	
S	pit	120						2	5	
T	pit	80						2	5	
U	pit	80						2	5	
V	pit	75						2	5	
W	pit	75						2	5	
Y,F502	undercut	160	125					2	5	excavation and probing to determine depth
Z	pit	84						2	5	
AA	pit	92						2	5	
CC	pit	110						2	5	
DD	pit	120						2	5	
EE	pit	68						2	5	
FF	pit	82						2	5	
GG	pit	113						2	5	
E	pit	112						1	5	
J	pit	60						1	5	
LL	pit	78						1	5	

[a] Total depth determined by summing the pit depth and the approximate depth to the occupation surface or house floor (Wood 1967:31-32).

Demery (39CO1)

Demery is unique among the sample of sites as it is the only example of an Extended Coalescent variant (ECV) settlement. The site is located on the west bank of the Missouri River approximately .5 km south of the border between North Dakota and South Dakota. When the village was investigated in 1956 by members of the SHSND, the main settlement area was visible due to thick vegetation in an area of about .8 ha (Woolworth and Wood 1964:73-74) (Figure A3.6). Overburden was stripped from six areas, and further excavation revealed five definite and two possible circular earthlodges (Woolworth and Wood 1964:75-85). Given the distribution of the houses, Woolworth and Wood (1964:74) suggest that the settlement likely contained about 30 houses, and excavation results indicated the village was unfortified. Four of the houses located by stripping were excavated completely, which led to the discovery of many associated storage pits (Woolworth and Wood 1964:86-88) (Tables A3.19 and A3.20). Furthermore, multiple central hearths and support posts within the perimeters of two dwellings suggested the possibility of overlapping or superimposed lodges. However, few features intersected, meaning the evidence for long-term occupation was minimal (Johnson 2007:78-79; Woolworth and Wood 1964:78-85). The weighted mean of three conventional radiocarbon dates indicate a calibrated date of occupation during the early fifteenth century (Johnson 2007:78-79, Table 7, and Tables C.1-C.3).

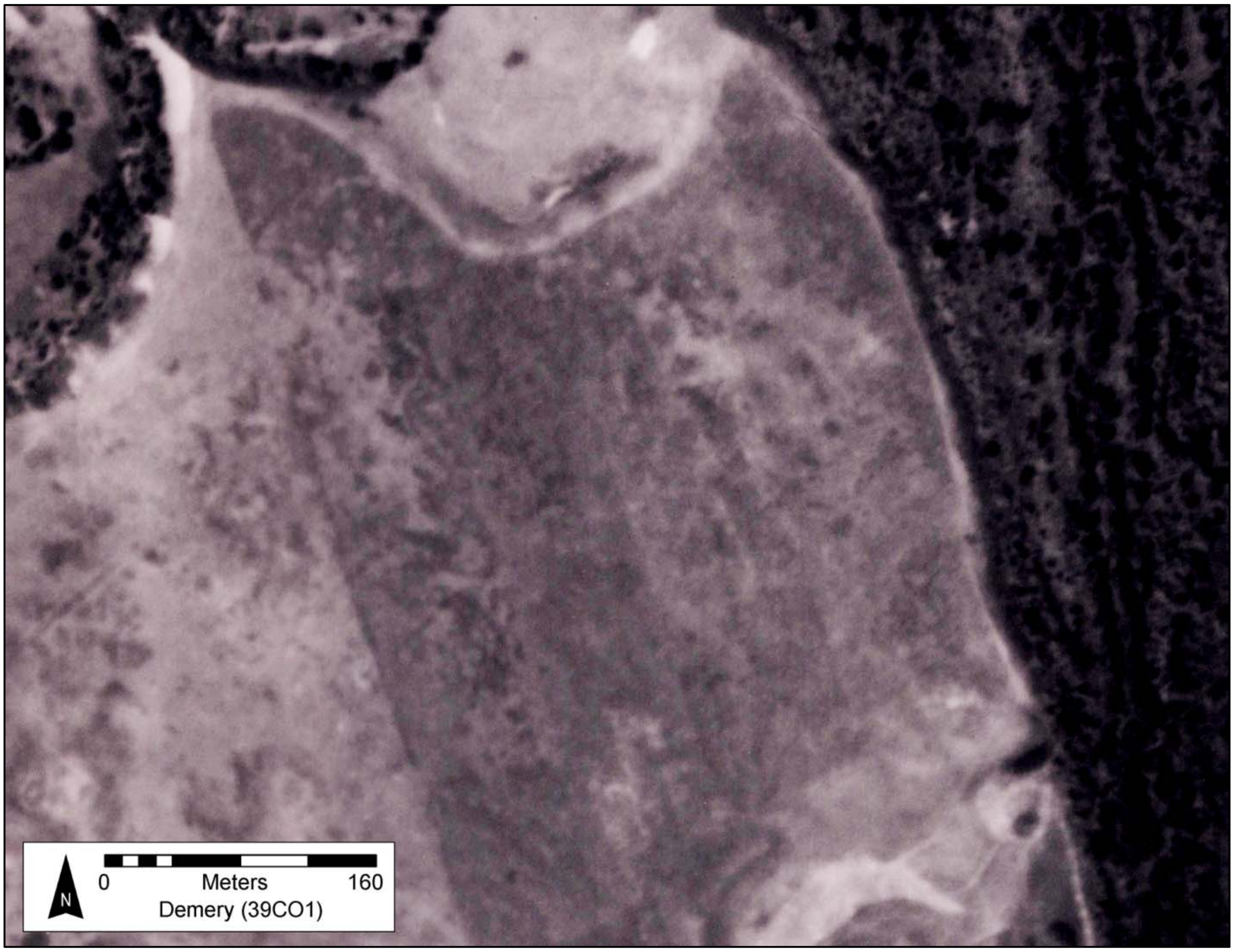

Figure A3.6. Subtle circular depressions, which indicate the locations of lodges at the Demery site (39CO1), visible in an aerial photograph from August 22, 1938. U.S. Department of Agriculture, National Archives and Records Administration (BNV-119-31).

Table A3.19. The area, number of excavated storage pits, and total storage volume for houses excavated at the Demery site.

House No.	Area (m^2)[a]	Interior Storage Pit No.	Total Vol. (m^3)
House 1	43.9	5	1.941
House 2	36.7	4	0.802
House 3	69.1	4	2.478
House 4	44.7	4	2.386

[a] House area calculated from digitized published maps (Woolworth and Wood 1964).

Table A3.20. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Demery site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature 8	undercut		61	55	98		0.288	1	5	House 1; possible evidence of rebuilding
F9	undercut		61	55	107		0.325	1	5	
F10	undercut		64	85	110		0.480	1	5	intersects F11
F11	undercut		37	67	85		0.169	1	5	
F15	undercut		107	61	116		0.679	1	5	in house wall line
F16	undercut		67	37	67		0.146	2	5	in entryway
F34	straight-sided		30		85		0.170	2	5	
F36	undercut		149	70	143		1.379	2	5	
F71	undercut		116	58	134		0.883	2	5	
F101	undercut		49	46	76		0.146	2	5	in entryway
F20	undercut		58	61	76		0.215	1	5	House 2; possible evidence of rebuilding
F21	undercut		58	55	73		0.188	1	5	in house wall line
F23A	undercut		58	73	82		0.274	1	5	
F23B	undercut		40	46	79		0.126	1	5	in base of F23A
F26	undercut		140	73	168		1.679	2	5	House 3
F65	undercut		116	73	122		0.884	1	5	in house wall line
F66	undercut		49	43	61		0.105	1	5	

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F67	undercut		91	98	128		0.918	1	5	
F68	undercut		91	67	110		0.571	1	5	
F113	undercut		67	61	134		0.524	2	5	
F93	undercut		49	55	85		0.191	2	5	House 4
F94	undercut		82	49	91		0.325	1	5	intersects F96
F95	undercut		76	67	116		0.512	1	5	
F96	undercut		79	85	140		0.801	1	5	in house wall line
F106	undercut		91	67	134		0.749	1	5	
F52	undercut		88	85	116		0.704	2	5	House 5
F54	undercut		91	82	122		0.753	2	5	
F82	undercut		46	55	73		0.149	1	5	
F28	undercut		82	79	137		0.769	2	5	Outside known houses
F43	undercut		94	73	168		1.128	2	5	
F48	undercut		91	76	137		0.833	2	5	
F49	undercut		64	79	113		0.468	2	5	
F72	undercut		76	85	107		0.553	2	5	
F78	undercut		101	113	119		1.068	2	5	
F111	undercut		91	67	122		0.656	2	5	

Double Ditch State Historic Site (32BL8)

Double Ditch is a prominent traditional Mandan village located on the east side of the Missouri River about 15 km north of present-day Bismarck, North Dakota. The site has been the subject of numerous investigations over the last century, although the most extensive and intensive geophysical surveys and corresponding excavations occurred during a four-year period from 2001 to 2004 (Ahler, ed. 2003b, 2004, 2005; Kvamme and Ahler 2007). The expansive site covers nearly 9.7 ha and is well known for its impressive midden mounds and two fortification ditches (Kvamme and Ahler 2007; Swenson 2007). However, geophysical surveys and excavations found that the site has two additional fortification ditches, neither of which is visible on the ground surface (Crawford and Ahler 2003; Kvamme and Ahler 2007). More importantly, based on a large number of AMS radiocarbon dates and trade artifact densities, the village appears to have contracted through time (Ahler 2005a; Swenson 2007). At the time of its founding (i.e., the late fifteenth century) the village perhaps contained as many as 160 lodges, although by the time of its abandonment around 1785, just after the 1780-1781 smallpox epidemic, the settlement consisted of about 32 earthlodges (Swenson 2007). During the course of the four-year program, a considerable number of storage pits, which date to various periods of the occupation, were positively identified by geophysical investigations and subsequently cored or excavated (Ahler 2005b; Ahler and Crawford 2003; Geib 2004) (Table A3.21). These features yielded crucial information concerning storage pit volumes during multiple centuries in the Heart River region.

Table A3.21. Dimensions, excavated volume, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at the Double Ditch site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)	Exc. Vol. (m^3)[b]	Est. Vol. (m^3)[b, c]	Structure Context	Period(s)	Comments
Anomaly A,1,F706	undercut	193	138	120	170	1.009	2.301	2	8	Cored in multiple years and later excavated; village exterior; truncated
B	pit	73						2		
D,2,F701	undercut	160	100	130	175	0.698	1.840	2	6/7	village exterior; truncated
E	pit	157						2		
F	pit	170						2		
G	pit	160						2		
J	pit	162						2		
K	pit	144						2		depth greater than max depth
L&M,3,F702	undercut	87	42	**135**	150	0.182	0.670	2	6/7	village exterior; greatly truncated
L&M,3,F703	undercut	117	72	95	160	0.497	0.939	2	6/7	village exterior; greatly truncated
N	pit	85						2		
P	pit	98						2		
Q	pit	78						2		
R,4,F201	straight-sided	70	30	**113**	100		0.268	2		village exterior; greatly truncated

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)	Exc. Vol. (m^3)[b]	Est. Vol. (m^3)[b, c]	Structure Context	Period(s)	Comments
T	pit	82						2		
U,5,F707	globular-shaped	130	75	110	135	0.442	0.887	2	8	village exterior; greatly truncated
V,6,F704	globular-shaped	121	76	105	120	0.469	0.757	2	6/7	village exterior; greatly truncated
V,6,F705	undercut	100	55	115	130	0.23	0.649	2	8	village exterior; greatly truncated
W	pit	99						2		
X	pit	64						2		
Y,9,F204	undercut	94	64	**105**	120		0.637	2		excavation not completed (60 cmsd); depth greater than max depth; village exterior; truncated
Z,7	pit	93						2		
AA	pit	144						2		
Core,F604	undercut	200	163	**85**	177	**2.419**	**2.287**	1	11	House 23 coring in village interior (Block 10/12); later excavated
F602	undercut	189	163	**74**	165	2.042	1.916	1	9	House 23
Core		200						2		

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)	Exc. Vol. (m^3)[b]	Est. Vol. (m^3)[b, c]	Structure Context	Period(s)	Comments
Core		180						2		House coring in village interior (Block 17); 180+ cm
Anomaly 12,F202	undercut	194	144	**105**	160		2.014	2	6/7	excavation not completed (161 cmsd); depth greater than max depth; village exterior; truncated
Anomaly 14	pit	62						2		
Feature 314	straight-sided	120	70	145	160		1.280		9	partial excavations of six truncated pit features; village exterior; greatly truncated
Feature 319	undercut	110	80	145	180		1.666		6/7	partial excavations of six truncated pit features; village exterior; greatly truncated

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)	Exc. Vol. (m^3)[b]	Est. Vol. (m^3)[b, c]	Structure Context	Period(s)	Comments
Feature 320	undercut	120	90	175	300		4.079		6/7	partial excavations of six truncated pit features; village exterior; greatly truncated
Feature 332	undercut	160	115	150	180		2.466		6/7	partial excavations of six truncated pit features; village exterior; greatly truncated
Feature 333	undercut	120	100	150	240		3.039		8	partial excavations of six truncated pit features; village exterior; greatly truncated
Feature 708	jar-shaped	121	83	88	160		1.030	2	8	village exterior; truncated

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)^a	Base Diam. (cm)	Exc. Vol. (m^3)^b	Est. Vol. (m^3)$^{b, c}$	Structure Context	Period(s)	Comments
F605	undercut	150	120	**116**	160		1.810	1	9	House 30; village interior; initial base at 150 cm w/ bilobed pit feature beneath; excavated to 225 cmsd (cored to 270 cmsd); five episodes of infilling
F605sub	undercut	270	120	100	120		1.144	1	6/7	bilobed undercut
F621sub	undercut	260	110	100	110		0.953	1	6/7	bilobed undercut
F616	straight-sided	130	100		130	1.003	1.327	1	6/7	House 24; intersects w/ F623; truncated
F623	undercut	171	131	**67**	170	0.463	1.536	1	9	House 24; intersects w/F616
F620	undercut	120	80	**115**	125	0.624	0.905	1	8	House 24; truncated
F614	pit	115	85	110	125	0.613	0.923	1	9	House 24; multiple intersecting pits; F614 and F618; truncated

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)	Exc. Vol. (m^3)[b]	Est. Vol. (m^3)[b, c]	Structure Context	Period(s)	Comments
F618	undercut	115	85	100	160	0.297	1.148	1	6/7	House 24; multiple intersecting pits; F614 and F618; truncated
F426	undercut		110	**89**	125		0.998		6/7	below mound; truncated

[a] Measurements in bold are calculated from published plan view and profile maps (Ahler 2005b; Ahler and Crawford 2003; Geib 2004).

[b] Measurements in bold are used in comparison of excavated and estimated volumes.

[c] Calculation of estimated volumes based on the equations for the volume of a conical frustum and cylinder. Estimated volumes based on Ahler's (2005b) approximation of the remaining unexcavated portion of each pit lower, although most of these are noted as underestimates.

Larson Village (32BL9)

Larson Village shares several similarities with Double Ditch, including the presence of multiple midden mounds and fortification ditches (Mitchell, ed. 2007, 2008; Swenson 2007) (Figure A3.7). The extant portion of the village covers an area of about 3 ha, although an unknown part of the site has been destroyed by erosion (Swenson 2007). The traditional Mandan settlement is located on the east bank of the Missouri River a short distance north of Double Ditch. It too has been the focus of several archaeological investigations during the last century, although geophysical surveys and excavations undertaken in 2006 and 2007 provided the most thorough information to date about the contents and organization of the site (Kvamme 2007b, 2008c; Mitchell 2007b, 2008). Like Double Ditch, Larson Village was founded around the turn of the sixteenth century, and it apparently contracted through time as well before its eventual abandonment during the 1780s (Mitchell, ed. 2007, 2008). Moreover, two previously undocumented fortification ditches outside the two visible on the ground surface were revealed by magnetic gradiometry (Kvamme 2007b, 2008c). Relatively few storage pits were excavated as part of the fieldwork during the 2000s, although over 35 magnetic anomalies were cored and confirmed as storage pits (Kvamme 2007b; Mitchell 2007b, 2008) (Table A3.22).

Figure A3.7. Circular earthlodge depressions, two fortification ditches, and midden mounds visible at Larson Village (32BL9) in an aerial photograph from June 11, 1938. U.S. Department of Agriculture, National Archives and Records Administration (BAP-4-46).

Table A3.22. Dimensions, excavated volume, and estimated volume for storage pits excavated at the Larson site.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)^a	Base Diam. (cm)^a	Exc. Vol. (m^3)	Est. Vol. (m^3)^b	Structure Context	Period(s)	Comments
Anomaly A,F109	undercut	112	72	**108**	**115**	0.505	0.703		8	Inside ditch 3
D	pit	132								
E	pit	120								
F,F107	undercut	218	178	50	125	0.901	1.136		8	cored to 218 cmsd (78 cm cored)
F104	straight-sided	62	37		100		0.291			
I	pit	95								Between ditch 3 & 4
L	pit	119								
Core 19,20		107								Outside (outside ditch 4)
Core 21,22,23		134								
Core 25		112								
Core 45		117								
Core 49		92								
Core 121		152								Mid-zone (between ditches 1 & 2)
Core 122		108								
Core 126		126								
Core 127		185								
Core 128		102								
Core 129		113								

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)[a]	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
Core 134		162								
Core 135		155								
Core 137		134								
Core 236,237		126								
Core 238		190								
Core 50		139								Village interior
Core 52		170								
Core 102		111								
Core 103		168								
Core 104		124								
Core 107		170								
Core 111		142								
Core 113		134								
Core 114		91								
Core 117		148								
Core 118		111								
Core 119		203								
Core 138		205								
Core 204		210								
Core 205		85								
Core 215		133								
Core 216		172								

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)[a]	Base Diam. (cm)[a]	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
Core 217		115								
Core 220		147								
Core 51		171								hearth overlying feature
Core 214		140								hearth overlying feature
Core 219		163								hearth overlying feature

[a] The mouth and base diameters for F109 are measured from published plan view and profile drawings (Mitchell 2007b).

[b] The volume of F109, an undercut pit, is calculated with the equation for the volume of a cylinder.

Scattered Village (32MO31)

Scattered Village was discovered in 1998 during street renovations in Mandan, North Dakota, opposite Bismarck on the west side of the Missouri River (Ahler 2002). Due to the nature of the project, extensive excavations were undertaken to salvage intact portions of the site, including parts of three earthlodges and deposits outside houses (Feiler et al. 2002). During the course of the excavations, a large number of features were revealed, including numerous straight-sided and undercut storage pits (Feiler et al. 2002) (Table A3.23). The presence or absence of specific trade items and their relative frequencies as well as a considerable number of radiocarbon dates indicate an occupation that was initiated during the latter part of the sixteenth century and which lasted about one century (Ahler and Haas 2002). More importantly, the establishment of a relative chronology proved vital for assigning the large number of pit features to different periods of the occupation.

Table A3.23. Dimensions, excavated volume, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at Scattered Village.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)[b]	Mouth Diam. (cm)[b]	Base Diam. (cm)[b]	Exc. Vol. (m^3)[c]	Est. Vol. (m^3)[c, d]	Structure Context	Period(s)	Comments
Feature 67	undercut	145	85			0.112		2	9	later period of occupation; two pits overtop of F178
F68	undercut	193	73	80	105	0.196	0.494	2	6/7	early village (originate at previllage soil); partially excavated
F178	undercut	266	121		**154**	0.958	**2.254**	2	8	early village (originate at previllage soil); partially excavated
F57	undercut	200	90	60	75	0.153	0.323	2	6/7	early village (originate at previllage soil); partially excavated
F14	undercut	135	65	**124**	130	**0.838**	**0.824**	2	9	later period of occupation; truncated
F4	undercut	85	50	80	115	0.227	0.377	2	6/7	truncated by curb trench
F26	undercut		75	80	130	1.02	0.662	1	9	truncated by curb trench

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)[b]	Mouth Diam. (cm)[b]	Base Diam. (cm)[b]	Exc. Vol. (m^3)[c]	Est. Vol. (m^3)[c, d]	Structure Context	Period(s)	Comments
F47	undercut	105	80	120	140	0.748	1.064	1	8	truncated by F55 (burial)
F73	undercut	73	43	115	125	0.341	0.487	1	8	partially excavated
F101	undercut		71	80	110	**0.509**	**0.507**	1	6/7	
F104	undercut	115	75	55	70	**0.479**	**0.231**	1	6/7	
F106	undercut	95	40	90	110	**0.183**	**0.315**	1	9	truncated
F108	straight-sided		234	115	160	**3.383**	**3.506**	2	8	interment chamber; undercut
F111	straight-sided		53		58	**0.138**	**0.140**	1	6/7	
F99	undercut		100	80	120		1.131	2	6/7	
F115	undercut	70	25	90	98	0.104	0.174	2	6/7	truncated?; partially excavated
F119	undercut	180	100	90	140	0.503	1.055	2	6/7	early village (originate at previllage soil); below lodge; partially excavated
F163	undercut	107	40	45	68	**0.085**	**0.102**		8	early village (originate at previllage soil); below lodge
F140	undercut	88	**43**	44	70	**0.118**	**0.112**	1	8	associated with lodge

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)[b]	Mouth Diam. (cm)[b]	Base Diam. (cm)[b]	Exc. Vol. (m^3)[c]	Est. Vol. (m^3)[c, d]	Structure Context	Period(s)	Comments
F127	undercut		195	144	160		3.542	1	9	partially excavated (excavated to 165 cm; 30 cm core to base)
F120	undercut		120	70	165	**1.109**	**1.372**		9	truncated
F124	pit		49	130	140	**0.437**	**0.702**		9	
F130	undercut		81	100	128	**0.704**	**0.831**		9	
F132	undercut		150	120	150	**1.486**	**2.156**		9	
F133	undercut		75	75	100	**0.405**	**0.454**		6/7	
F175	undercut		120	90	105	**0.803**	**0.898**		9	

[a] Total depth (datum depth rather than surface depth) determined by summing the pit depth and the depth at which the pit's orifice was encountered as described by Feiler and colleagues (2002). Each was checked against the published profile maps whenever possible.

[b] Measurements in bold are calculated from published plan view and profile maps (Feiler et al. 2002).

[c] Measurements in bold are used in comparison of excavated and estimated volumes.

[d] The volume of F178, an undercut pit, is calculated with the equation for the volume of a cylinder.

On-A-Slant Village (32MO26)

On-A-Slant Village, which has been impacted by road and railroad construction as well as Civilian Conservation Corps work (i.e., construction of earthlodges, a fortification ditch, and a vertical timber palisade), is located on the west bank of the Missouri River at its confluence with the Heart River (Swenson 2007) (Figure A3.8). Based on early maps and aerial photographs of the site, the traditional Mandan village once contained numerous large midden mounds adjacent to a fortification ditch along its western edge and a large number of earthlodge depressions, some of which encircled an open plaza (Swenson 2007). Test excavations were undertaken by the UND in 1980 in several areas across the village and located both disturbed and intact archaeological deposits (Ahler 1997; Ahler et al. 1997). Among the findings were a relatively small number of undercut storage pits (Table A3.24). Like contemporaneous Heart River sites, the occurrence of particular types of trade items and their relative amounts were useful for determining the approximate date of each storage pit. The relative chronology suggests different components date from about 1575 to the settlement's abandonment around 1785.

Figure A3.8. On-A-Slant Village (32MO26) in an aerial photograph from August 17, 1938, which shows circular lodge depressions and reconstructed lodges. U.S. Department of Agriculture, National Archives and Records Administration (AZY-13-109).

Table A3.24. Dimensions, excavated volume, and estimated volume for storage pits excavated at On-A-Slant Village.

Feature or Coring No.	**Pit Type**	**Total Depth (cmsd)^a**	**Pit Depth (cm)**	**Mouth Diam. (cm)^b**	**Base Diam. (cm)**	**Exc. Vol. (m^3)**	**Est. Vol. (m^3)^c**	**Structure Context**	**Period(s)**	**Comments**
Feature 2	undercut	47	39	**121**	138	0.151	0.514		11	truncated; 40% excavated
F5	undercut	171	159	58	131	0.248	1.171		10	truncated; 40% excavated
F6	undercut	149	121	94	128	0.151	1.180		10	40% excavated
F21	undercut	121	109	90	110	0.183	0.859		10	30% excavated
F24	undercut	231	224	26	68	0.065	0.414		11	truncated; 30% excavated
F48	undercut	86	76	84	100	0.275	0.506		11	truncated; 60% excavated
F10	undercut	95	64	120	150	0.168	0.920		8	truncated; 60% excavated
F11	undercut	87	57	45	85	0.061	0.195		8	truncated; 50% excavated
F8	straight-sided	150	120		76	0.152	0.544		8	30% excavated
F92	straight-sided		116		110	0.371	1.102		8	40% excavated
F51	undercut	97	52	65	160	0.37	0.548		8	60% excavated
F54	undercut	147	102	60	90	0.045	0.457		8	20% excavated
F41	undercut	210	198	145	180	1.234	4.122		10	truncated; 60% excavated

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)[b]	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[c]	Structure Context	Period(s)	Comments
F81	undercut	122	77	120	140	0.206	1.024		11	30% excavated

[a] Total depth determined by summing the pit depth and the depth at which the pit's orifice was encountered or mapped in the wall profile (Ahler et al. 1997).

[b] Measurements in bold are calculated from published profile maps (Ahler et al. 1997).

[c] Calculation of estimated volumes based on the equation for the volume of a conical frustum or cylinder. Estimated volumes reported by Ahler and colleague's (1997) (based on the approximate remaining unexcavated portion of each pit) are lower.

Boley Village (32MO37)

Boley Village is a traditional Mandan settlement located on the west bank of the Missouri River just upstream from present-day Bismarck, North Dakota and the Heart River confluence (Ahler, ed. 2006; Swenson 2007). The site was once at least 4.5 ha in size, although it has been altered significantly by river bank erosion, railroad and road construction, a housing development, and cultivation (Figure A3.9). Early twentieth-century mapping projects documented at least one fortification ditch, perhaps a second ditch, and over 100 supposed earthlodge depressions (Swenson 2006, 2007). Among several investigations of the site, Donald J. Lehmer excavated one house in 1964, revealing its central hearth and associated pit features, including two undercut storage pits (Swenson 2006). Further investigation of the site in 2005 involved geophysical surveys, excavations, and coring (Kvamme 2006d; Mitchell and Ahler 2006). Two overlapping fortification ditches, suggesting different episodes of occupation, were identified in addition to many probable storage pit features, several of which were confirmed through coring or excavation (Table A3.25). Six AMS radiocarbon dates as well as trade artifact composition and density were used to develop a site chronology (Ahler 2006). These data suggest that Boley Village dates as early as 1440, although Ahler (2006:74) argues that a late sixteenth-century or possibly a seventeenth-century date is more probable for the initiation of the occupation. The sampled contexts suggest the settlement was occupied as late as 1725 by the Mandans.

Figure A3.9. Circular earthlodge depressions and a fortification ditch at Boley Village (32MO37) are noticeable in an aerial photograph from June 16, 1938. U.S. Department of Agriculture, National Archives and Records Administration (BAB-2-50).

Table A3.25. Dimensions, excavated volume, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at Boley Village.

Feature or Coring No.	**Pit Type**	**Total Depth (cmsd)[a]**	**Pit Depth (cm)[b]**	**Mouth Diam. (cm)**	**Base Diam. (cm)[c]**	**Exc. Vol. (m^3)**	**Est. Vol. (m^3)[d]**	**Structure Context**	**Period(s)**	**Comments**
F101	undercut	202	168	100	169	1.599	2.439	2	10	pit depth (162 cmsd); core depth (40 cm); 40-50% excavated; truncated orifice at 34 cmsd
F102	undercut	165	140	100	165	0.828	1.969	2	8	pit depth (115 cmsd); core depth (50 cm); 50% excavated; truncated orifice at 25 cmsd; late precontact
F103	undercut	114	82	60	158	0.579	0.817	2	8	pit depth (114 cmsd); 70% excavated; orifice at 32 cmsd; late precontact-early postcontact (trade artifacts present)
F104	undercut	107	72	125	132	0.861	0.934	2	9	pit depth (107 cmsd); over 50% excavated; truncated orifice at 35 cmsd
Feature 6	undercut		130	76	160		1.482		11	Lehmer house excavation[e]

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)[b]	Mouth Diam. (cm)	Base Diam. (cm)[c]	Exc. Vol. (m^3)	Est. Vol. (m^3)[d]	Structure Context	Period(s)	Comments
Feature 10	undercut		58	91	120		0.510		11	Lehmer house excavation[e]

[a] Total depth (F101-F102) determined by summing the reported pit depth noted in comments and the core depth of the remaining unexcavated portion of the pit.

[b] Pit depth (F101-F104) based on differencing the total depth and the depth at which the orifice was encountered.

[c] Base diameter (F101-F104) measured from published plan and profile drawings (Mitchell and Ahler 2006). A general projected base diameter of 1.5-1.75 m is reported for the pits.

[d] Calculation of estimated volumes based on the equation for the volume of a conical frustum. Estimated volumes based on Mitchell and Ahler's (2006) approximation of the remaining unexcavated portion of each pit are roughly similar.

[e] Period assignment is based on the location of the lodge within the village core (Mitchell 2011:415-416).

Amahami (32ME8)

Based on a map made by A. B. Stout in 1909, Amahami (32ME8) once had as many as 30 circular earthlodges, although a fortification ditch surrounded 21 dwellings in an area of about 1.3 ha (Lehmer et al. 1978:Figure 7.2; Mitchell 2011:Table A7). However, around 1938 a large portion of the site was impacted by gravel pit operations (Lehmer et al. 1978:144) (Figure A3.10). The village, which is located on the northwest corner of the present-day town of Stanton, North Dakota, was occupied by one subgroup of the Hidatsas from about 1787 to 1834 when it was destroyed and abandoned (Stewart 2001:329-330; Wood 1986:20, 1993a:17). Plans to construct a courthouse in an area of the village led to salvage excavations by the SHSND from 1970 to 1972 (Lehmer et al. 1978:148-152). Although the excavations revealed the presence of an earlier component in the form of a likely long rectangular lodge and distinctive ceramics, three circular earthlodges associated with the Hidatsa occupation were identified (Lehmer et al. 1978:152-160). Many straight-sided and undercut pits were excavated, and those with ceramics associated with the early component were noted (Lehmer et al. 1978:152-160) (Table A3.26). However, due to the possibility of superimposed structures and overlapping storage pits from the two components, pit volume data from Amahami should be viewed cautiously.

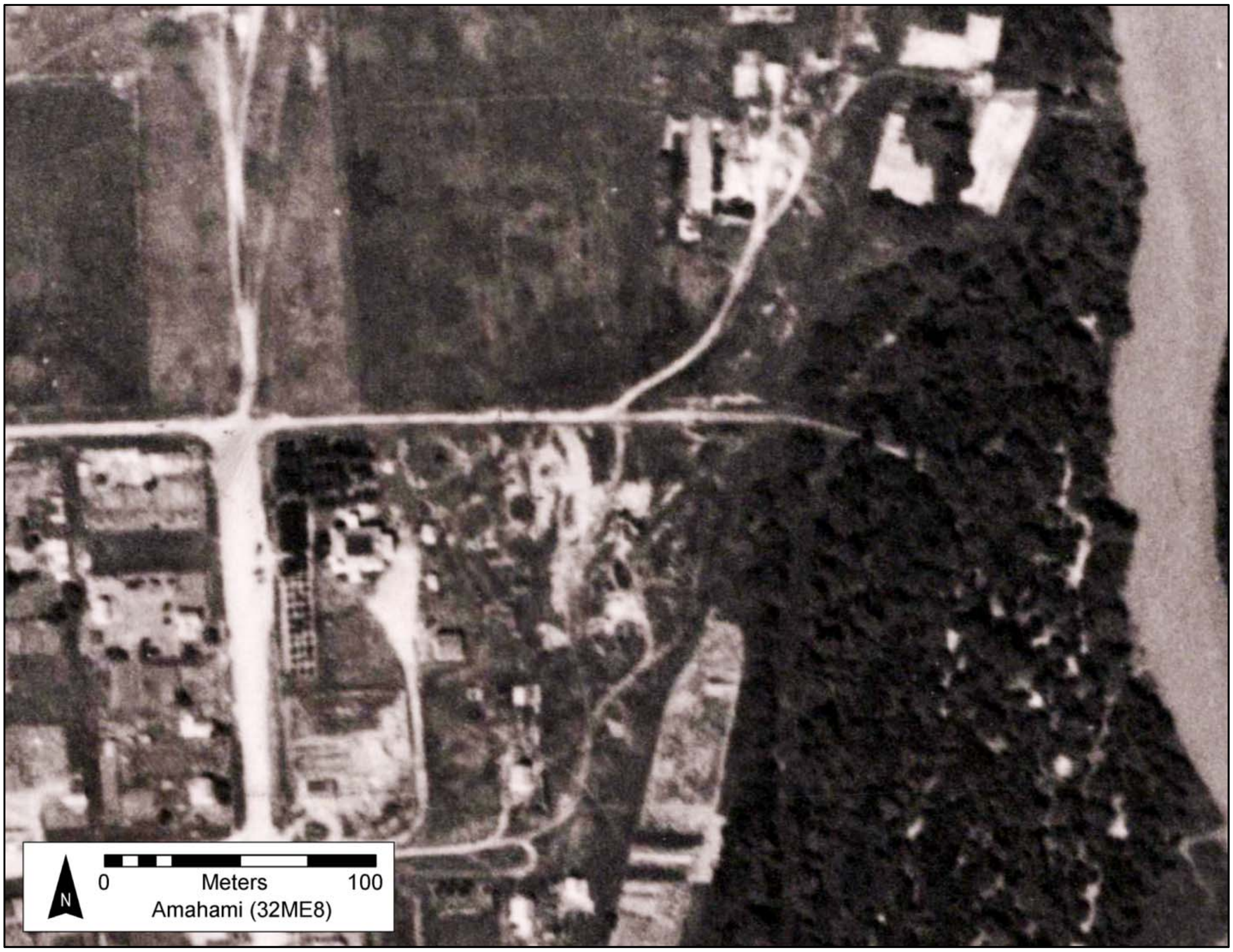

Figure A3.10. An aerial photograph from July 9, 1938, which shows a few circular earthlodge depressions at Amahami (32ME8) on the northeast side of Stanton, North Dakota. U.S. Department of Agriculture, National Archives and Records Administration (BAO-23-97).

Table A3.26. Dimensions and estimated volume for storage pits excavated at Amahami.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[a]	Structure Context	Period(s)	Comments
F342	undercut		37	76	82		0.180			early component
F345	undercut		43	128	143		0.617			early component
F344	undercut		91	91	119		0.799			early component
F340	straight-sided		27		98		0.205			early component
F349	straight-sided		30		73		0.128		12	late component
F302	undercut		49	62	94		0.239		12	late component
F306	undercut		107	137	122		1.408		12	late component
F309	undercut		73	82	91		0.434		12	late component
F310	undercut		61	43	55		0.114		12	late component
F312	undercut		46	73	82		0.217		12	late component
F316	undercut		43		99		**0.329**		12	late component
F319	straight-sided		40		73		0.167		12	late component
F325	undercut		79	101	110		0.689		12	late component
F326	undercut		52	73	104		0.321		12	late component
F327	undercut		91	79	116		0.691		12	late component
F328	undercut		73	61	76		0.271		12	late component
F330	undercut		43	61	73		0.151		12	late component
F337	straight-sided		40		79		0.195		12	late component
F341	undercut		43	98	104		0.339		12	late component
F343	undercut		37	70	76		0.154		12	late component

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[a]	Structure Context	Period(s)	Comments
F348	undercut		46	64	88		0.210		12	late component

[a] The volume of F316, an undercut pit, is calculated with the equation for the volume of a cylinder.

Rock Village (32ME15)

Prior to the creation of Lake Sakakawea in North Dakota in the 1950s, Rock Village was located on the south bank of the Missouri River and was the focus of several archaeological investigations (Hartle 1960:25-26; Lehmer et al. 1978:11). The settlement, a fortified Hidatsa village that dates to the late eighteenth and early nineteenth centuries, contained shallow depressions indicating the locations of 35 circular earthlodges in an area of about 1.3 ha (Hartle 1960:30; Johnson 2007:199, 202; Lehmer et al. 1978:Figure 3.1, 13; Mitchell 2011:Table A7). However, at the time of its investigation by Donald Hartle in 1951, lodge floors, hearths, and storage pits were exposed in the cut bank of the Missouri River, meaning an unknown portion of the village had already been destroyed. Like the Mandan villages of Double Ditch and Larson, multiple fortification ditches were located at Rock (Hartle 1960: 93-97; Lehmer et al. 1978:43-45). The fortification was thought to have been expanded during the occupation to include ten additional earthlodges since at least one structure was superimposed over the inner ditch. Moreover, post molds indicate a palisade was located outside the ditch similar to fortification systems of later villages like Fort Clark (Hartle 1960:97). Thirteen earthlodges, some of which are superimposed, were excavated in 1950 and 1951 (Lehmer et al. 1978:11, 18-40) (Table A3.27). Quantitative data for most of the excavated storage pits are listed below (Table A3.28).

Table A3.27. The area, number of excavated storage pits, and total storage volume for houses excavated at Rock Village.

House No.[a]	Area (m^2)[b]	Interior Storage Pit No.	Total Vol. (m^3)
House 1	85.8	3	1.276
House 2	90.4	3	1.167
House 3	98.3	0	0
House 4	72.8	1	0.427
House 6	93.0	0	0
House 7	74.7	0	0
House 10	84.8	2	0.822
House 11	78.5	3	1.788
House 13	53.2	2	0.576

[a] Houses 5, 8, 9, and 12 are excluded because they are superimposed and their association with particular storage pits is unclear.

[b] House area data from Mitchell (2011:416). Calculated from published maps (Lehmer et al. 1978).

Table A3.28. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at Rock Village.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
Feature 121	straight-sided	106	85	119	88		0.720	1	12	House 1
F116a	undercut	64	43	91	91		0.280	1	12	
F116b	straight-sided	73	52	91	73		0.276	1	12	
F103	undercut	67	37	82	82		0.195	1	12	House 2
F106	undercut	60	30	76	82		0.147	1	12	
F145	straight-sided	97	67	137	113		0.825	1	12	
F70	undercut	85	55	64	73		0.203	2	12	House 3
F28	undercut	82	52	91	113		0.427	1	12	House 4
F118	undercut	61	40	61	67		0.129	1	12	House 5/House 12 superimposed
F124	undercut	70	49	82	110		0.357	1	12	
F125	undercut	109	88	79	122		0.709	1	12	
F126	undercut	85	64	46	104		0.297	1	12	
F129	undercut	146	125	58	128		0.889	1	12	
F130	undercut	94	73	55	94		0.325	1	12	
F134	straight-sided	143	122	134	122		1.571	1	12	
F123	straight-sided	128	107	104	116		1.018	2	12	
F37	undercut		88	61	107		0.500	1	12	House 8/House 9 superimposed
F41	straight-sided		67		137		0.988	1	12	
F61	undercut		79	70	82		0.359	1	12	House 10

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F63	undercut		58	79	88		0.318	2	12	
F66	undercut		70	79	104		0.463	1	12	
F136	straight-sided		134	94	110		1.097	1	12	House 11
F138	straight-sided		94	76	85		0.479	1	12	
F144	undercut		79	46	70		0.212	1	12	
F147	straight-sided		146	113	131		1.710	2	12	
F149	undercut		64	64	85		0.281	2	12	
F80	undercut		82	58	88		0.348	1	12	House 13
F82	undercut		64	55	79		0.228	1	12	
F15	undercut		119		107		1.070		12	provenience unclear
F16	undercut		101		116		1.067	1	12	
F24a	straight-sided		168		158		3.294		12	
F24b	undercut		91		101		0.729		12	
F26	undercut		122	49	104		0.585		12	
F31	undercut		58	119	137		0.748		12	
F32	straight-sided		119		146		1.992		12	
F38	straight-sided		162		137		2.388		12	
F40	undercut		107	49	104		0.513		12	
F51	undercut		101	116	131		1.211		12	
F56	undercut		131	91	107		1.011		12	
F84	undercut		107	58	85		0.435		12	
F85	undercut		152	61	104		0.831		12	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)	Structure Context	Period(s)	Comments
F89	undercut		94	88	107		0.704		12	
F90	straight-sided		88	101	116		0.815		12	
F94	undercut		131	98	119		1.215		12	
F95	undercut		98	46	98		0.416		12	
F96	straight-sided		125	128	131		1.646		12	
F98	straight-sided		168	107	122		1.732		12	
F105	straight-sided		158	104	113		1.462		12	
F107	undercut		189	152	155		3.498		12	
F114	straight-sided		119	116	116		1.258		12	
F133	straight-sided		128	122	128		1.571		12	

[a] Total depth determined by summing the pit depth and the depth of each house below the surface (Hartle 1960; Lehmer et al. 1978).

Leavenworth (39CO9)

The Leavenworth site is located on the west bank of the Missouri River about 11 km northeast of the Grand River confluence in South Dakota. The site is well known as the location of an Arikara attack upon fur traders led by William Henry Ashley in June 1823 and the subsequent retaliation by U.S. Army Colonel Henry Leavenworth (after whom archaeologists have named the site) in August of the same year (Krause 1972:15). Although Leavenworth made an attempt to broker peace with the Arikaras, many or all lodges within the settlement were burned, likely by Missouri Fur Company traders who were among the military forces (Krause 1972:15; Nichols 1982:88). The site was characterized by two adjacent villages, both with 60-80 lodge depressions, separated by a small drainage or creek (Krause 1972:16). The settlements were constructed around the turn of the nineteenth century (Krause 1972:15). After the villages were destroyed, the Arikaras migrated northward and settled near the Mandans in North Dakota before reoccupying the settlements in 1824 (Krause 1972:15; Parks 2001:367). Prince Maximilian (Witte and Gallagher 2010:179) observed that the villages had been abandoned when he traveled up the Missouri River in 1833, although George Catlin's (1973 [1844]:Plate 80, 204) painting of the villages shows they were still occupied the previous year. Leavenworth and its associated cemeteries have been the focus of several archaeological investigations during the twentieth century, including excavations by William Duncan Strong and the Smithsonian Institution in 1932 (Billeck 2007:229-234; Krause 1972:21-22). The most intensive excavations of the villages were undertaken by the University of Nebraska in 1960 and 1961 (Krause 1972). Seven earthlodges were completely excavated (Krause 1972:24-40) (Table A3.29). Additionally, many straight-sided and undercut storage pits were excavated, although only a small number were clearly associated with the lodges (Krause 1972:41-46) (Table A3.30).

Table A3.29. The area, number of excavated storage pits, and total storage volume for houses excavated at Leavenworth.

House No.	Area (m^2)[b]	Interior Storage Pit No.	Total Vol. (m^3)
Lodge 2	106.6	1	0.245
Lodge 7	55.2	0	0
Lodge 20[a]	118.4	2	1.744
Lodge 23	108.4	0	0
Lodge 34	167.8	1	0.952
Lodge 40	114.3	2	1.794
Lodge 47	88.6	2	0.982

[a] Additional pits were excavated in Lodge 20, but their specific dimensions were not included in Krause's (1972) report.

[b] House area calculated from digitized published maps (Krause 1972).

Table A3.30. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at Leavenworth.

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)^a	Structure Context	Period(s)	Comments
F1	undercut		152	107	128		1.653	1	12	Lodge 40; early structure
F2	undercut		30	61	91		0.141	1	12	
F3	straight-sided		61		91		0.400	1	12	postdates house
F4a	straight-sided		98		107		0.872	1	12	Lodge 20; double pit
F4b	straight-sided		98		107		0.872	1	12	double pit
F5	undercut		119	85	116		0.952	1	12	Lodge 34
F6	straight-sided		84		61		0.245	1	12	Lodge 2
F7	straight-sided		58		72		0.238	1	12	Lodge 47
F8	undercut		116	73	107		0.744	1	12	
Pit 3	undercut		125	88	119		1.062	2	12	exterior pits
P4	undercut		76		122		**0.890**	2	12	
P5	undercut		98	76	131		0.842	2	12	
P6	undercut		91	94	110		0.750	2	12	
P7	undercut		146	91	168		1.984	2	12	
P8	straight-sided		122		146		2.050	2	12	
P9	straight-sided		59		137		0.878	2	12	
P10	undercut		79	104	125		0.816	2	12	
P11	undercut		110	98	149		1.333	2	12	
P14	undercut		110	76	91		0.607	2	12	

Feature or Coring No.	Pit Type	Total Depth (cmsd)	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[a]	Structure Context	Period(s)	Comments
P15	undercut		73	79	88		0.404	2	12	
P16	undercut		73	107	122		0.752	2	12	
P17	undercut		104	107	143		1.280	2	12	
P18	undercut		104	107	122		1.065	2	12	
P19	undercut		40	70	85		0.189	2	12	
P20	undercut		116	101	122		1.129	2	12	
P21	undercut		91	94	119		0.821	2	12	
P22	straight-sided		55		122		0.641	2	12	
P23	undercut		79	76	104		0.507	2	12	
P26	straight-sided		58		128		0.745	2	12	
P27	straight-sided		64		134		0.904	2	12	
P28	straight-sided		128		152		2.335	2	12	
P29	undercut		91	52	125		0.593	2	12	
P31	undercut		94	91	82		0.561	2	12	
P32	undercut		91	43	134		0.611	2	12	
P34	undercut		61	49	76		0.190	2	12	

[a] The volume of one undercut pit is calculated with the equation for the volume of a cylinder.

Like-A-Fishhook (32ML2)

Like-A-Fishhook Village, located over 40 km northwest of the Knife and Missouri River confluence, was initially constructed by the Hidatsas and some Mandans in 1845 (Smith 1972:4-9). Soon after the establishment of the settlement, a trading post referred to as Fort James but later renamed Fort Berthold was constructed, perhaps by James Kipp and Francis Chardon, for the American Fur Company (Upper Missouri Outfit) (Smith 1972:4-9; Wood 2011:14). The plan of the original village mimicked earlier Mandan settlements, including an open ceremonial area and a palisade fortification (Smith 1972:4-9). Approximately 70 earthlodges and log cabins were constructed around the plaza by 1861, the year the Arikaras constructed Star Village on the opposite bank of the Missouri River (Metcalf 1963; Smith 1972:4-9). An opposition post operated by the St. Louis Fur Company (or Union Fur Company), which also managed Fort Primeau adjacent to Fort Clark, was established near the village in 1851 (Smith 1972:9). Then, in 1858, another opposition post, named Fort Atkinson, was constructed (Smith 1972:9). When the original Fort Berthold was destroyed by fire, the newer opposition post was purchased by Pierre Chouteau, Jr., & Company and renamed Fort Berthold. After 1862, the Arikaras would occupy a section of the village distinct from that of the Hidatsas and Mandans with their own ceremonial plaza (Smith 1972:9-11, 25-30). A count of earthlodges and log cabins in 1872 indicated that the Arikaras occupied 71 structures while the Hidatsas and Mandans combined inhabited 104 (Smith 1972:29). Among the Arikaras, nearly 40 percent of the dwellings were log cabins while nearly two-thirds of the Mandan-Hidatsa structures were cabins. In the mid-1860s, the U.S. Army was briefly garrisoned at Fort Berthold, just prior to the establishment of an agency in the trading post by the Office of Indian Affairs (Smith 1972:17-18). The village was ultimately abandoned in the late 1880s when U.S. policy changed and reservation lands were allotted to individual families. During the first half of the 1950s, personnel with the SHSND, National Park Service, and Smithsonian Institution River Basin Surveys carried out extensive excavations at Like-A-Fishhook given that the settlement would be inundated by construction of Garrison Dam and flooding of Lake Sakakawea. Besides the remains of the original and second Fort Berthold, at least 20 Native dwellings, primarily circular earthlodges, were completely excavated (Smith 1972:31-53) (Table A3.31). Some excavations revealed evidence of superimposed lodges, which were indicated by the patterning of post holes, hearths, and entryways. Following Mitchell (2011:414), floor areas are not considered for superimposed dwellings. Finally, this undertaking led to the excavation of many large straight-sided and undercut storage pits, most of which are associated with houses (Smith 1972:33-53) (Table A3.32).

Table A3.31. The area, number of excavated storage pits, and total storage volume for houses excavated at Like-A-Fishhook.

House No.[a]	Area (m^2)[b]	Interior Storage Pit No.	Total Vol. (m^3)
House 1	421.4	0	0
House 2	111.0	3	1.913
House 4	147.7	0	0
House 5	220.7	2	1.228
House 7	168.2	0	0
House 8	220.7	1	1.436
House 9	175.2	3	4.469
House 10	122.6	1	1.063
House 12	182.4	0	0
House 13	237.1	5	19.562
House 14	237.1	1	1.506
House 15	228.8	1	1.251
House 18	212.7	4	3.843

[a] House 6 is excluded because it is likely a log cabin with an unclear floor plan. Areas for houses 3, 11, 16, 17, 19, and 20 are not included because their floor plans are also ambiguous. They were remodeled and have unclear post configurations (after Mitchell 2011:414-415).

[b] House area from Mitchell (2011:414-415). Calculated from Smith's (1972) published maps.

Figure A3.32. Dimensions, estimated volume, and context for storage pits (1 = intramural or 2 = extramural) excavated at Leavenworth.

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
Pit 1	undercut	149	119	53	110		0.646	2	13	Arikara ceremonial lodge (House 1)
Pit 1	undercut	94	76	64	128		0.570	1	13	Arikara area (House 2)
Pit 2	undercut	117	99	70	137		0.862	1	13	
Pit 3	undercut	82	64	85	110		0.480	1	13	
Pit 4	straight-sided	97	79		165		1.689	2	13	
Pit 1	straight-sided		130		180		3.308		13	Mandan-Hidatsa area (House 3); penetrated undisturbed gravel
Pit 2	straight-sided		73		110		0.694		13	
Pit 3	straight-sided		67		94		0.465		13	
Pit 4	undercut		82	18	70		0.139		13	
Pit 6	undercut		101	101	146		1.223		13	
Pit 7	undercut		125	64	152		1.208		13	
Pit 8	undercut			130	146				13	
Pit 1	undercut	176	152	168	198		4.007	2	13	Mandan-Hidatsa area (House 4)
Pit 1	straight-sided	99	76		130		1.009	1	13	Mandan-Hidatsa area (House 5)
Pit 2	undercut	114	91	43	67		0.220	1	13	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
Pit 1	pit	48	30		131		0.404		13	Mandan-Hidatsa area (House 6)
									13	Mandan-Hidatsa area (House 7)
Pit 1	undercut	176	152	61	152		1.436	1	13	Mandan-Hidatsa area (House 8)
Pit 2	undercut	161	137	122	152		2.028	2	13	
Pit 3	undercut	183	158	213	274		7.396	2	13	base excavated to undisturbed gravel
Pit 1	undercut	170	152	61	152		1.436	1	13	Arikara area (House 9)
Pit 2	undercut	149	131	61	122		0.893	1	13	
Pit 3	straight-sided	201	183		122		2.139	1	13	penetrated undisturbed gravel
Pit 4	undercut	201	183	98	143		2.111	2	13	
Pit 1	undercut	148	130	70	131		1.063	1	13	Arikara area (House 10)
Pit 2	undercut	122	104	99	125		1.029	2	13	
									13	House 12
Pit 1	undercut	207	183	107	168		2.762	1	13	Hidatsa ceremonial lodge (House 13)
Pit 2	pit	199	175	305	244		10.399	1	13	straight-sided with tapered walls
Pit 3	undercut	230	206	91	137		2.131	1	13	

Feature or Coring No.	Pit Type	Total Depth (cmsd)[a]	Pit Depth (cm)	Mouth Diam. (cm)	Base Diam. (cm)	Exc. Vol. (m^3)	Est. Vol. (m^3)[b]	Structure Context	Period(s)	Comments
Pit 4	undercut	164	140	61	134		1.094	1	13	
Pit 5	undercut	207	183	137	160		3.176	1	13	
Pit 6	straight-sided	176	152		244		7.107	2	13	
Pit 1	undercut		116	69	180		1.506	1	13	House 14
Pit 1	straight-sided	134	107		122		1.251	1	13	House 15
Pit 2	undercut	210	183	146	183		3.906	2	13	
Pit 3	undercut	150	122	122	165		1.988	2	13	
Pit 4	undercut	131	104	121	183		1.913	2	13	
Pit 5	undercut	198	171	122	152		2.531	2	13	
Pit 1	straight-sided		162		91		1.054	1	13	House 16; evidence of multiple lodges, late
Pit 2	undercut		152	107	168		2.294	1	13	early
Pit 3	undercut		38	99	114		0.339	1	13	early
Pit 1	undercut		122		168		**2.704**	1	13	House 17; evidence of multiple lodges, late
Pit 2	straight-sided		152		143		2.441	1	13	late
Pit 3	undercut		91	101	122		0.891	1	13	early
Pit 1	undercut	118	94	113	152		1.305	1	13	Arikara area (House 18)
Pit 2	undercut	121	98	84	128		0.877	1	13	
Pit 3	straight-sided	107	84		99		0.647	1	13	

Feature or Coring No.	**Pit Type**	**Total Depth (cmsd)**[a]	**Pit Depth (cm)**	**Mouth Diam. (cm)**	**Base Diam. (cm)**	**Exc. Vol. (m^3)**	**Est. Vol. (m^3)**[b]	**Structure Context**	**Period(s)**	**Comments**
Pit 4	undercut	136	113	91	122		1.014	1	13	
Pit 1	undercut		91	70	104		0.548	1	13	House 19; evidence of multiple lodges, early
Pit 2	undercut		91	64	64		0.293	1	13	early
Pit 3	undercut		131	107	152		1.743	1	13	early
Pit 4	pit		177	183	122		3.276	2	13	
Pit 1	undercut		122	91	137		1.262	1	13	Arikara area (House 20); evidence of multiple lodges
Pit 2	undercut		128	91	122		1.148	1	13	

[a] Total depth determined by summing the pit depth and the average floor depth of each structure as noted by Smith (1972).

[b] The volume of House 17 Pit 1, an undercut pit, is calculated with the equation for the volume of a cylinder.

APPENDIX 4: FORT CLARK STATE HISTORIC SITE (32ME2) REMOTE SENSING DATA AND INTERPRETATIONS

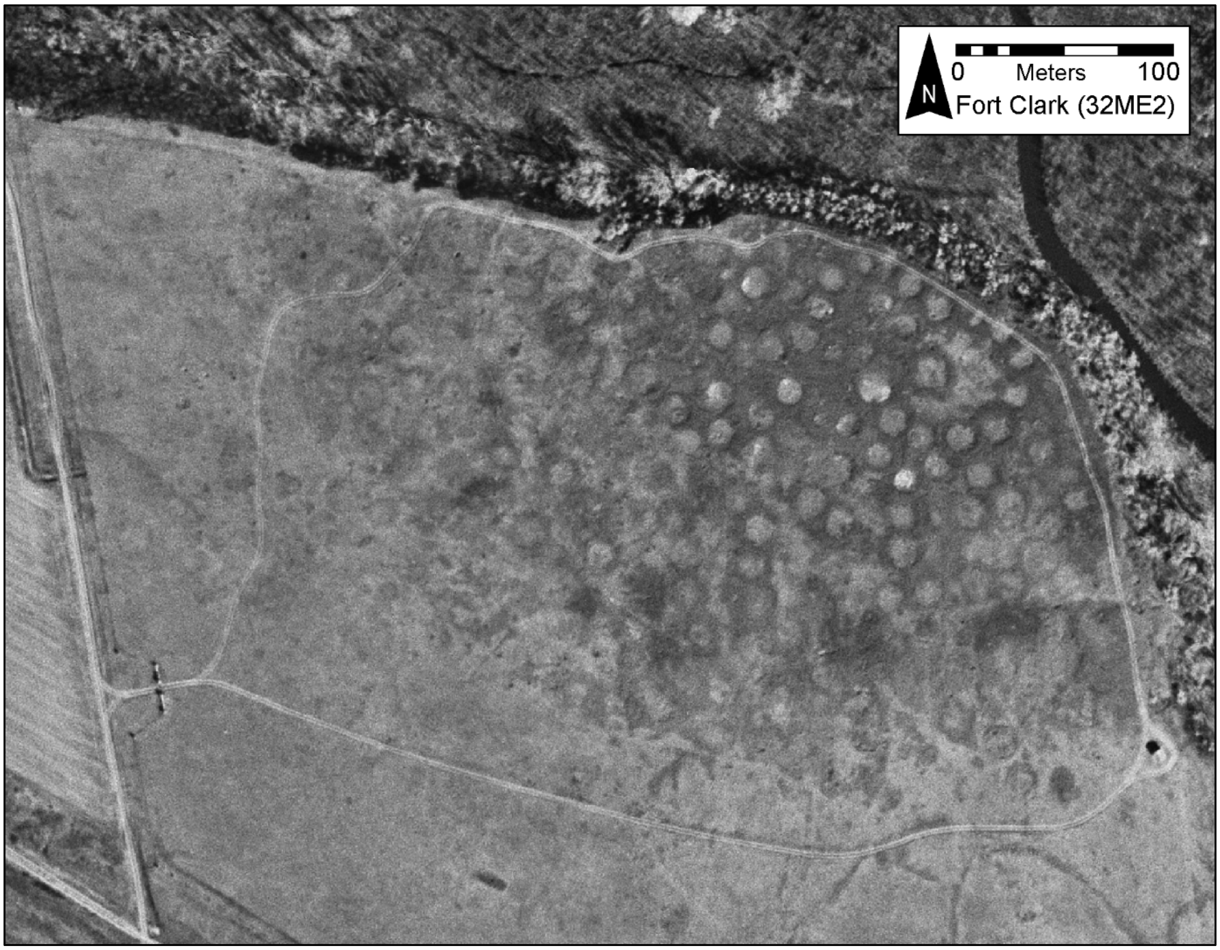

Figure A4.1. Black-and-white orthophotograph from October 8, 1965 showing the Mandan/Arikara village at Fort Clark. Data available from the U.S. Geological Survey.

Figure A4.2. Black-and-white orthophotograph from June 26, 1967 showing the Mandan/Arikara village at Fort Clark. Data available from the U.S. Geological Survey.

Figure A4.3. Black-and-white photograph from August 5, 1985 showing the Mandan/Arikara village at Fort Clark. Photograph courtesy of the State Historical Society of North Dakota. Used with permission.

Figure A4.4. Black-and-white photograph from August 5, 1985 showing the west section of the Mandan/Arikara village at Fort Clark. Photograph courtesy of the State Historical Society of North Dakota. Used with permission.

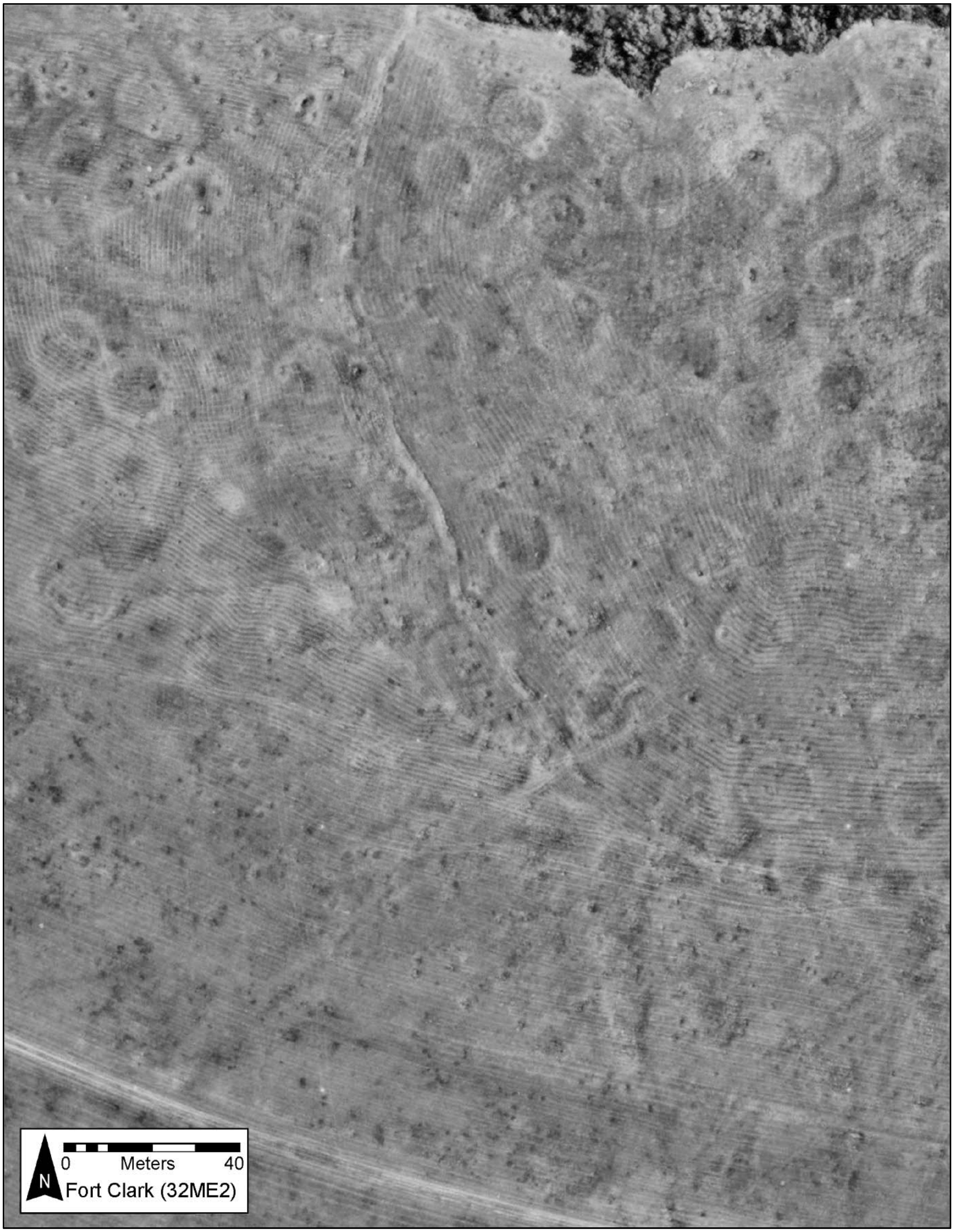

Figure A4.5. Black-and-white photograph from August 5, 1985 showing the central section of the Mandan/Arikara village at Fort Clark. Photograph courtesy of the State Historical Society of North Dakota. Used with permission.

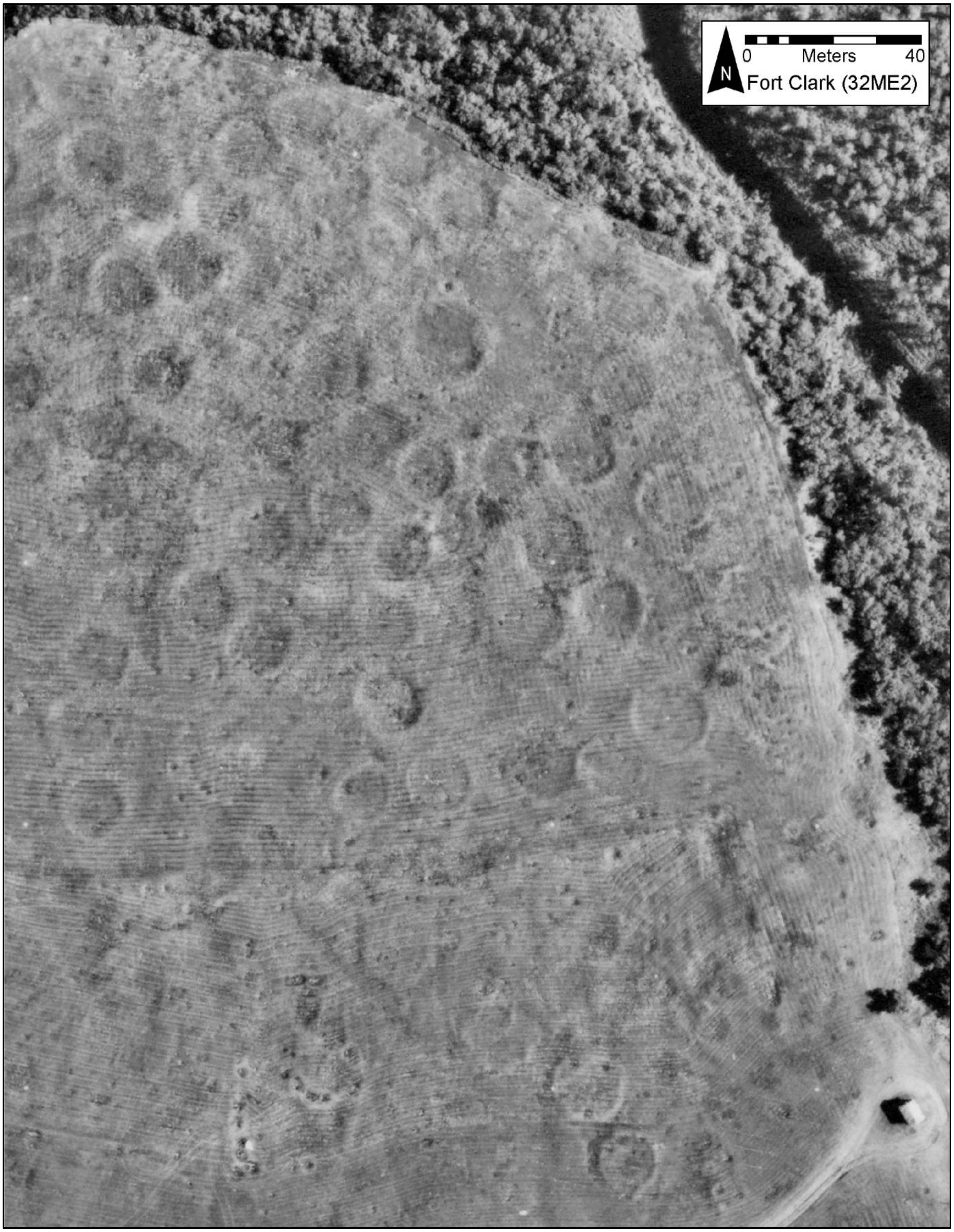

Figure A4.6. Black-and-white photograph from August 5, 1985 showing the east section of the Mandan/Arikara village at Fort Clark. Photograph courtesy of the State Historical Society of North Dakota. Used with permission.

Figure A4.7. Color orthophotograph produced from July 9, 2004 photographs showing the Mandan/Arikara village at Fort Clark. Adapted from photographs by Tommy Hailey. Used with permission.

Figure A4.8. Color orthophotograph produced from July 9, 2004 photographs showing the west section of the Mandan/Arikara village at Fort Clark. Adapted from photographs by Tommy Hailey. Used with permission.

Figure A4.9. Color orthophotograph produced from July 9, 2004 photographs showing the central section of the Mandan/Arikara village at Fort Clark. Adapted from photographs by Tommy Hailey. Used with permission.

Figure A4.10. Color orthophotograph produced from July 9, 2004 photographs showing the east section of the Mandan/Arikara village at Fort Clark. Adapted from photographs by Tommy Hailey. Used with permission.

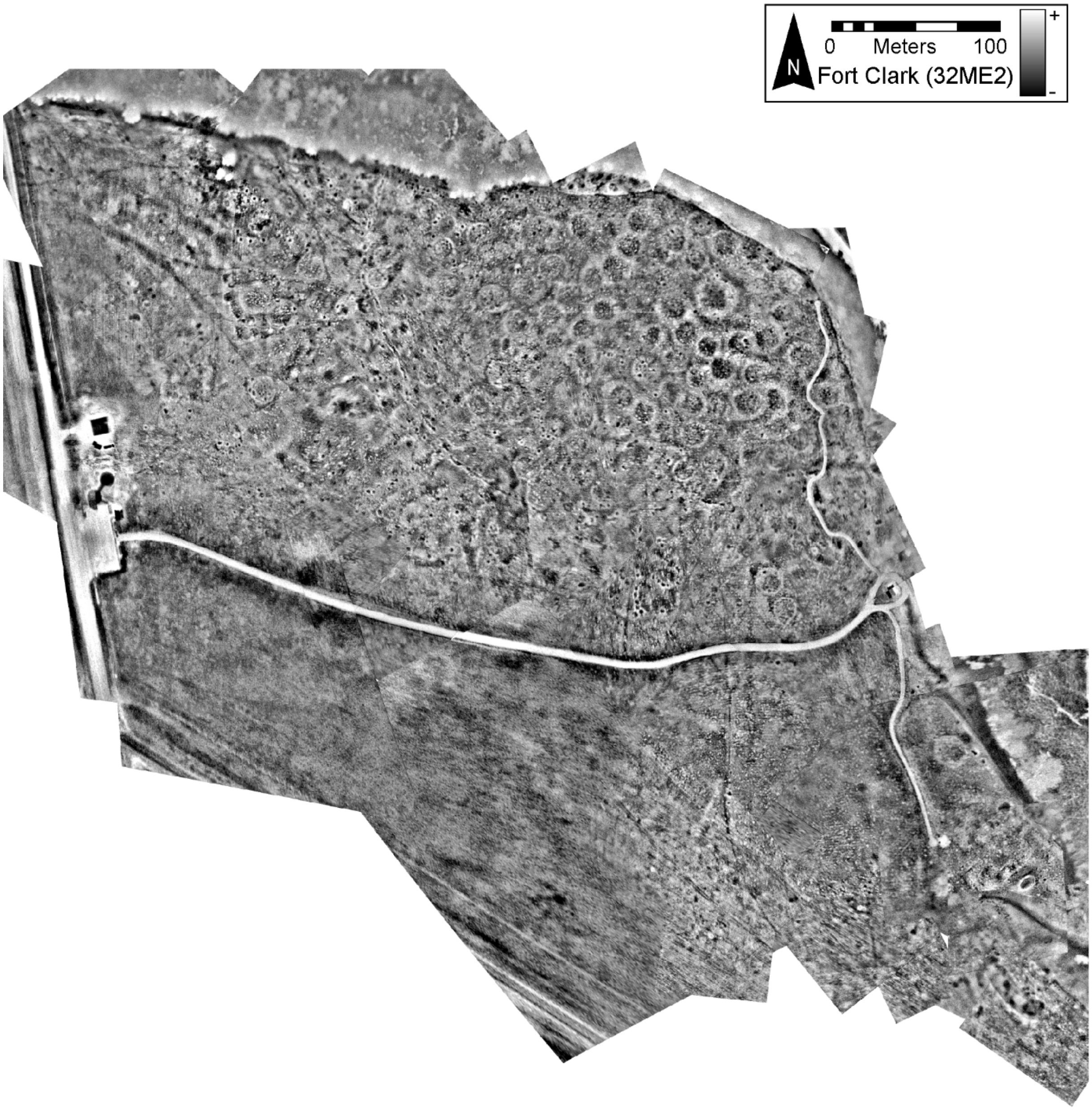

Figure A4.11. Mosaicked thermal infrared imagery from July 9, 2004 showing the Mandan/Arikara village at Fort Clark. Adapted from frames by Kenneth L. Kvamme. Used with permission.

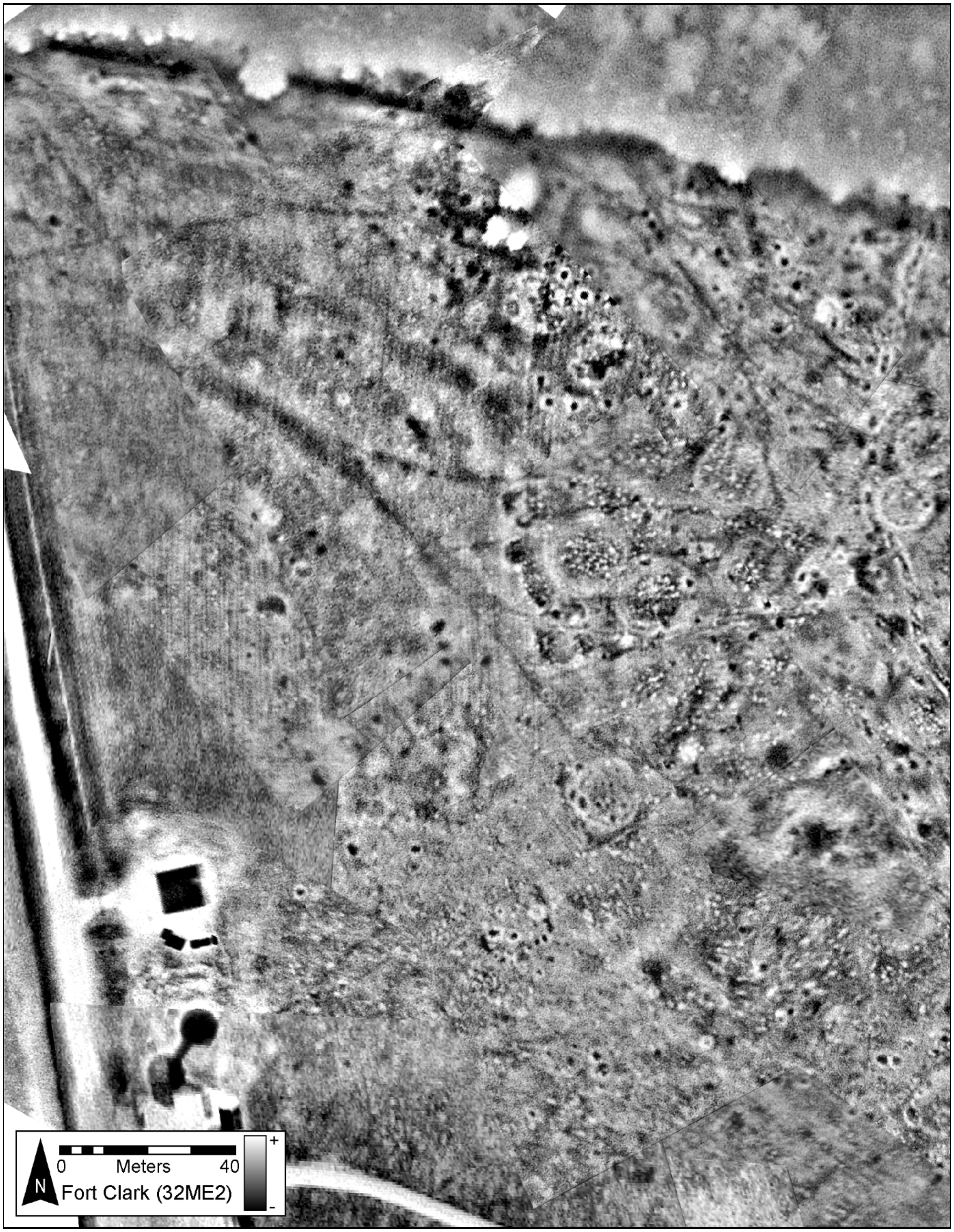

Figure A4.12. Mosaicked thermal infrared imagery from July 9, 2004 showing the west section of the Mandan/Arikara village at Fort Clark. Adapted from frames by Kenneth L. Kvamme. Used with permission.

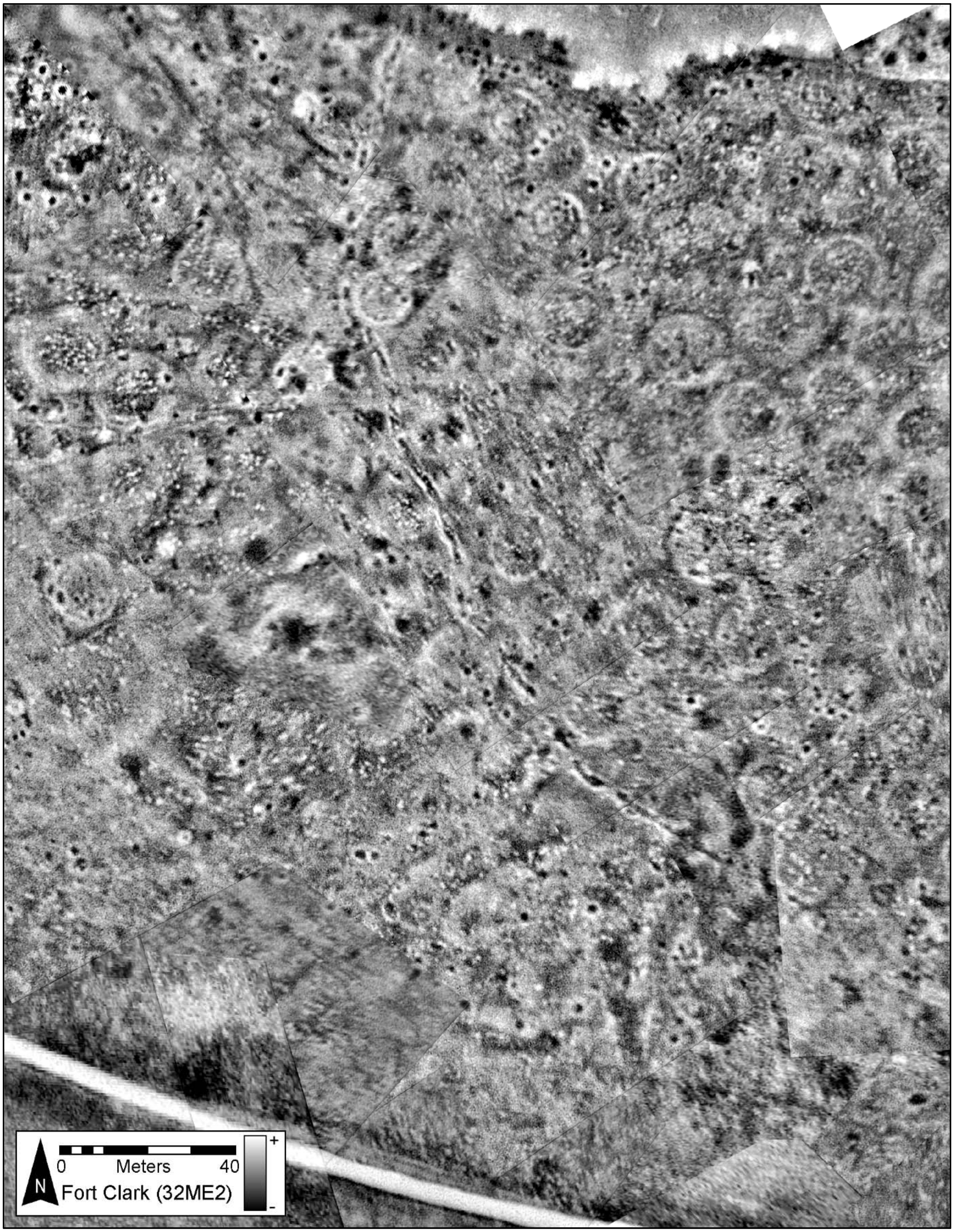

Figure A4.13. Mosaicked thermal infrared imagery from July 9, 2004 showing the central section of the Mandan/Arikara village at Fort Clark. Adapted from frames by Kenneth L. Kvamme. Used with permission.

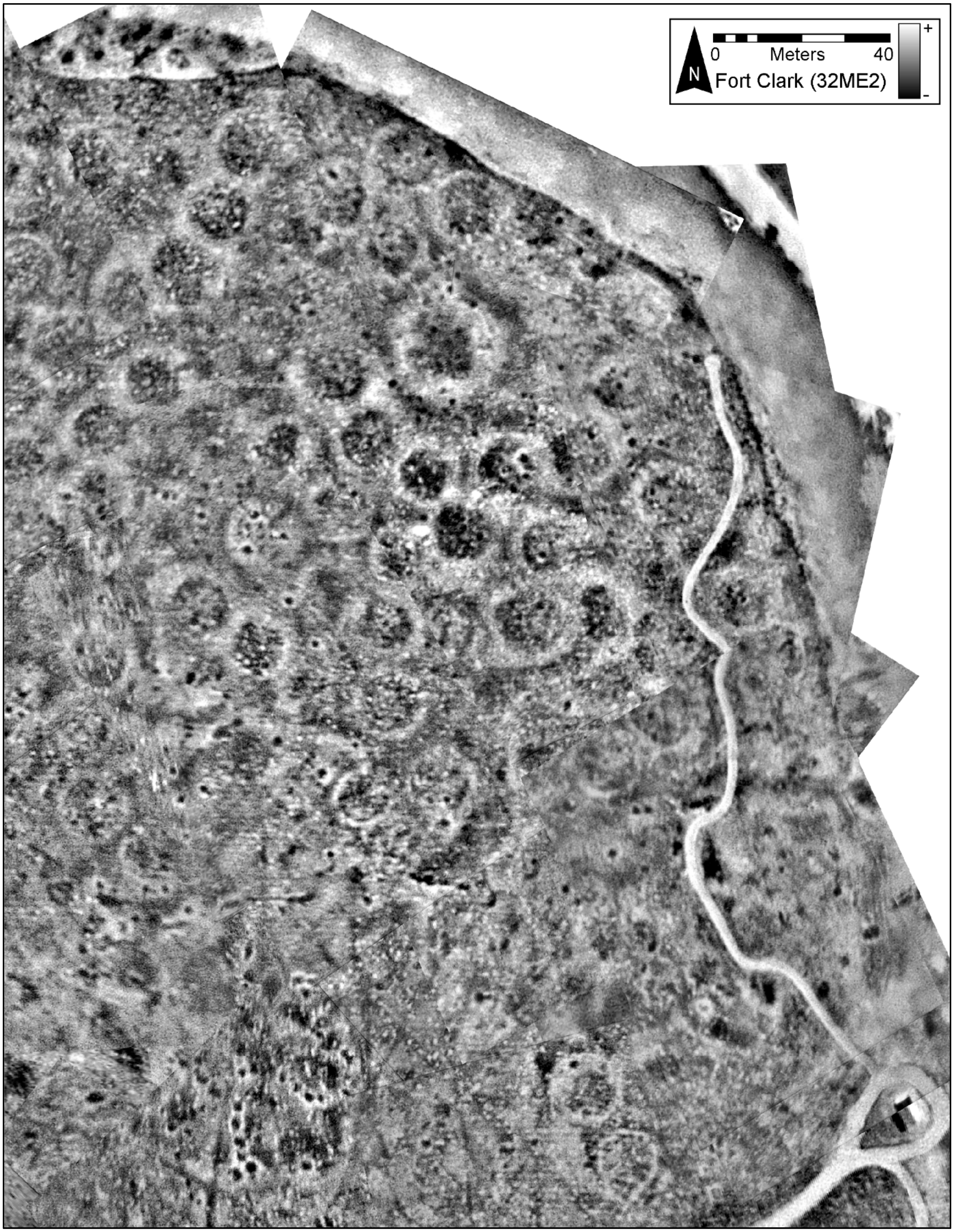

Figure A4.14. Mosaicked thermal infrared imagery from July 9, 2004 showing the east section of the Mandan/Arikara village at Fort Clark. Adapted from frames by Kenneth L. Kvamme. Used with permission.

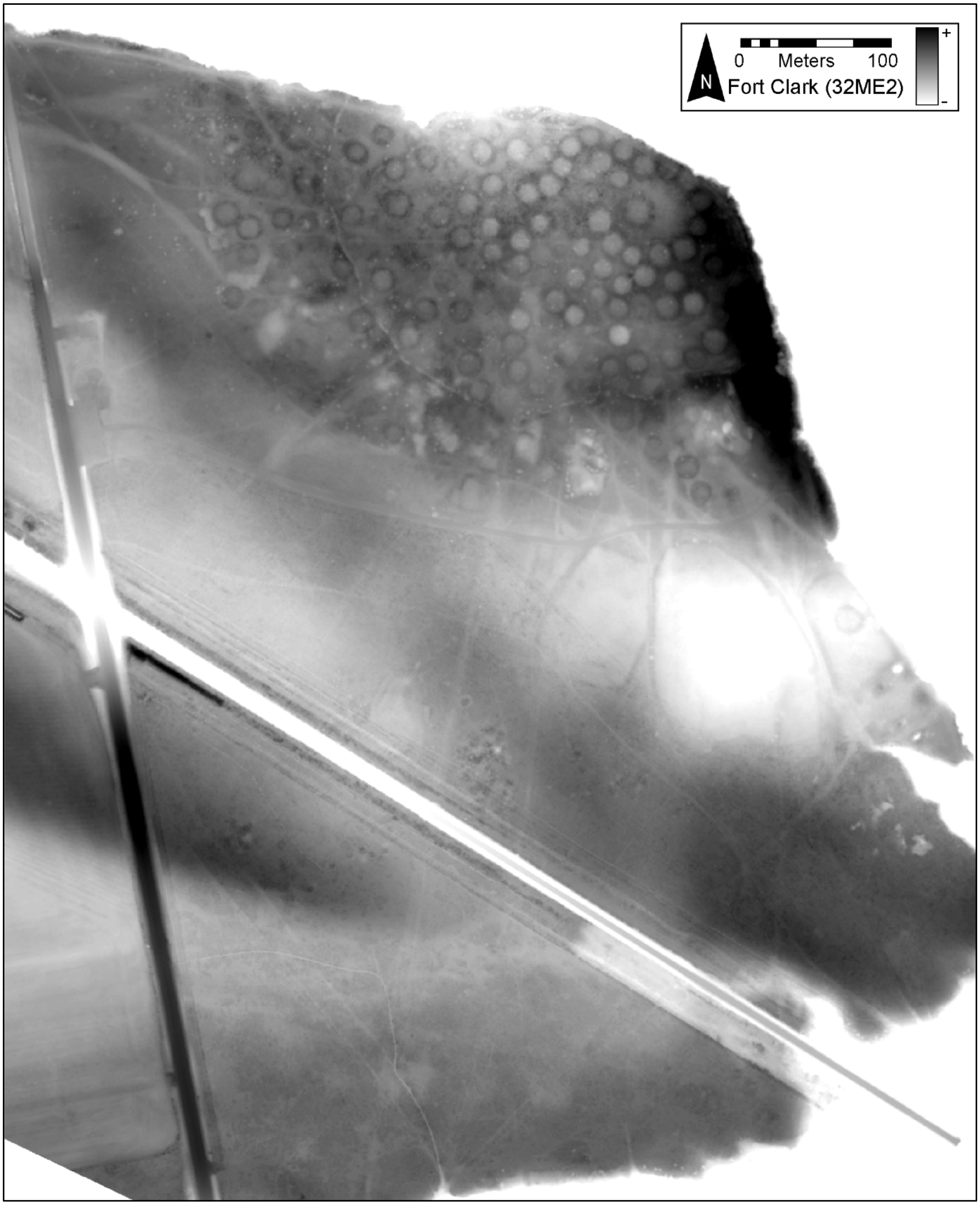

Figure A4.15. Local relief model showing the Mandan/Arikara village at Fort Clark.

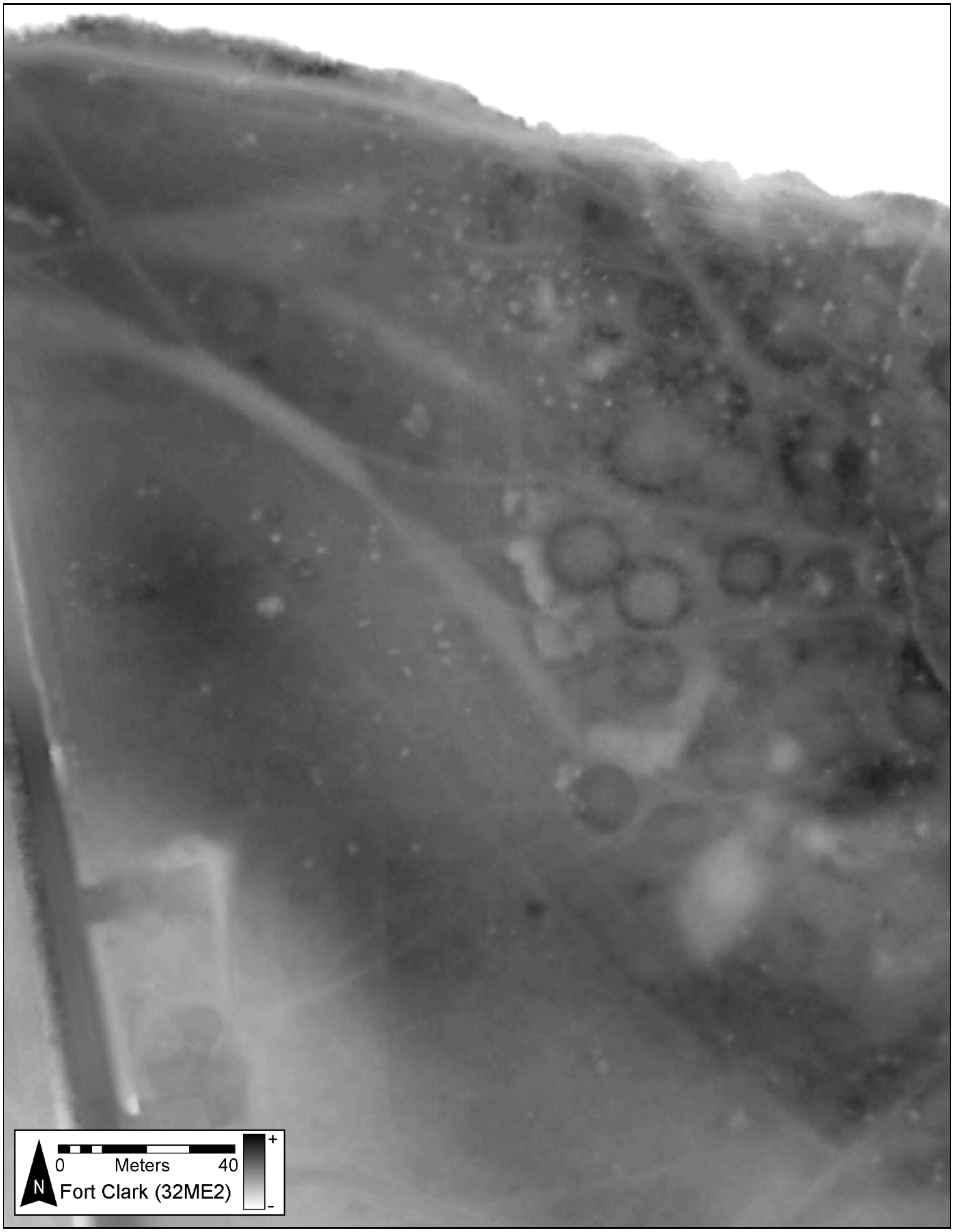

Figure A4.16. Local relief model showing the west section of the Mandan/Arikara village at Fort Clark.

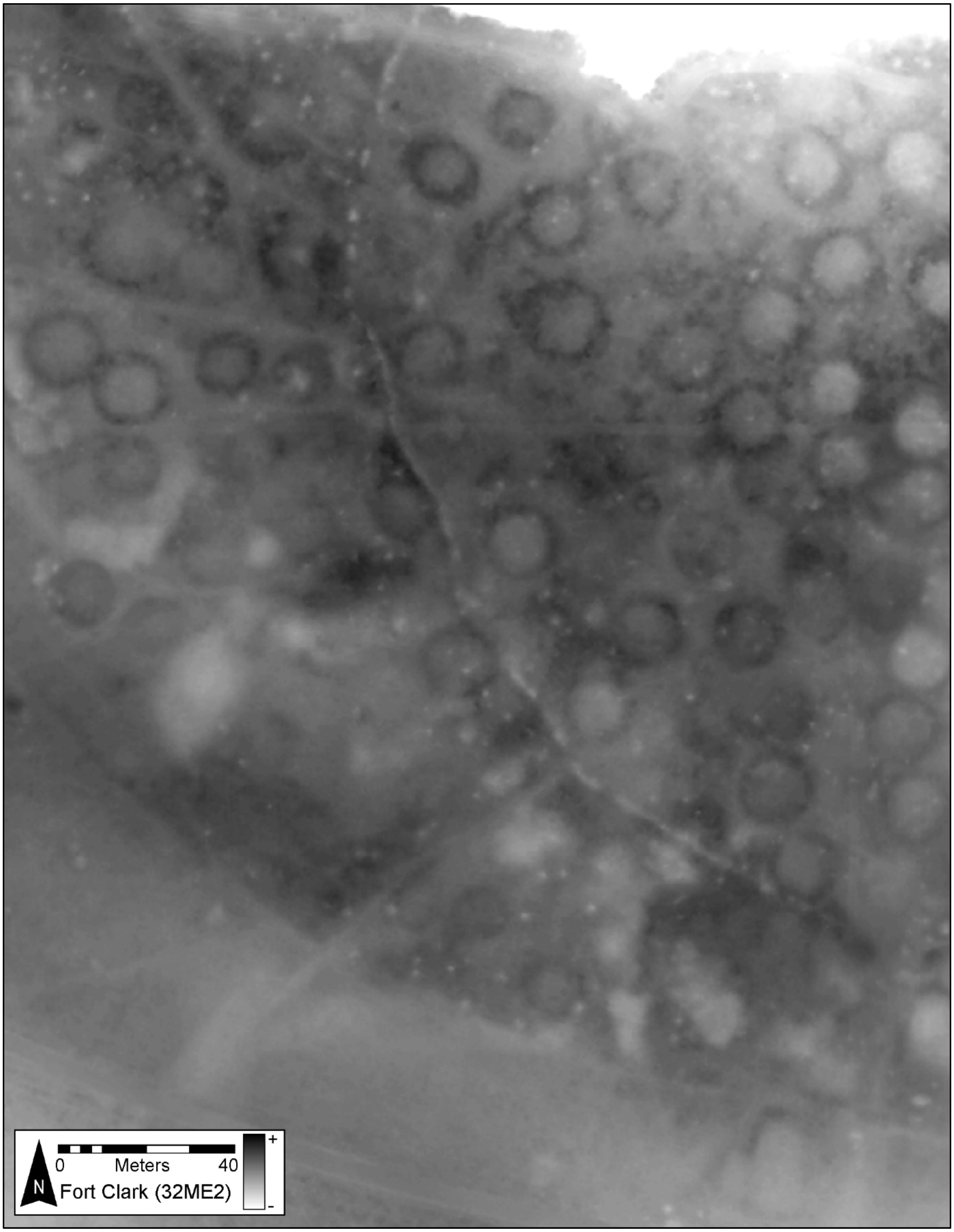

Figure A4.17. Local relief model showing the central section of the Mandan/Arikara village at Fort Clark.

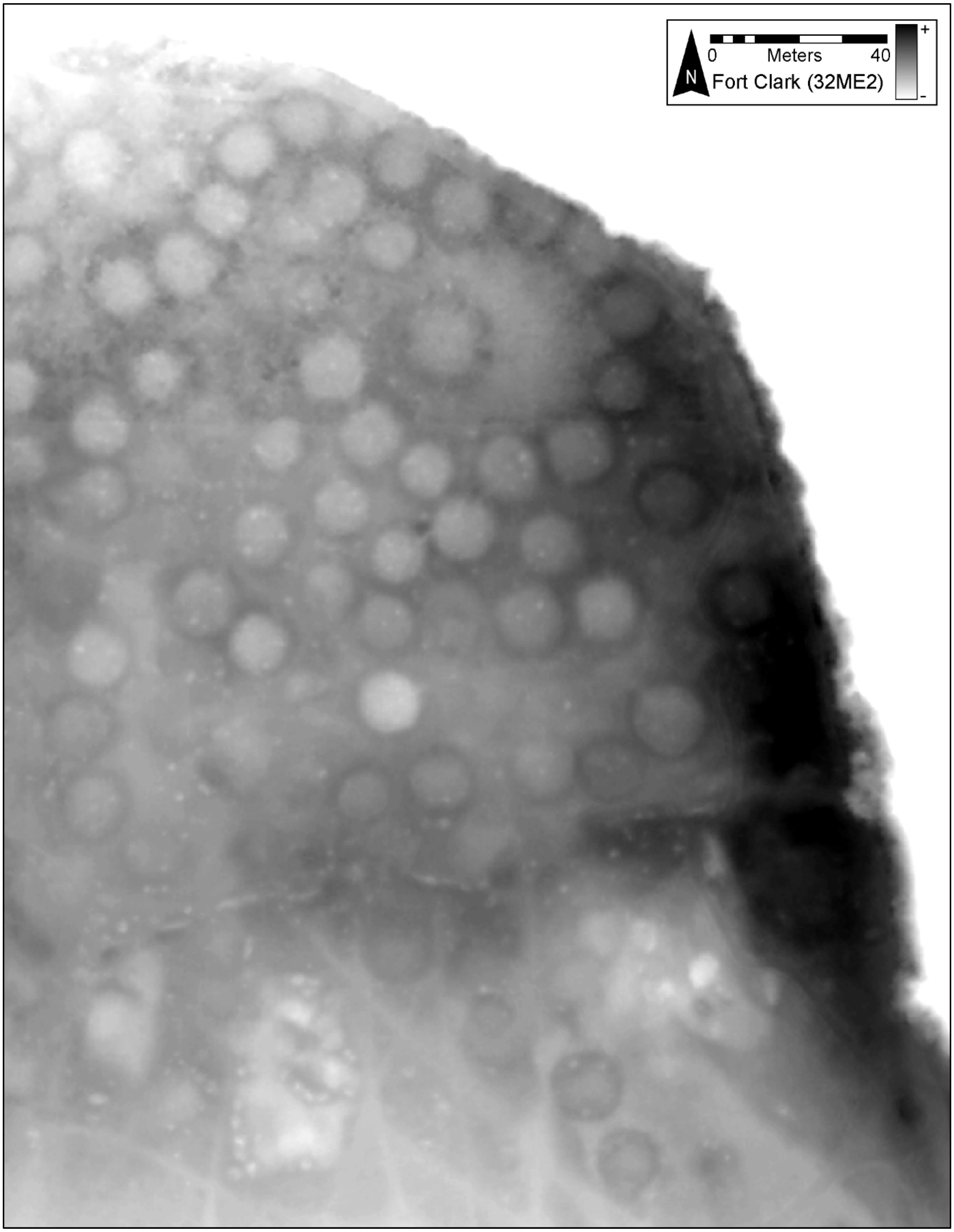

Figure A4.18. Local relief model showing the east section of the Mandan/Arikara village at Fort Clark.

Figure A4.19. Sky view factor visualization showing the Mandan/Arikara village at Fort Clark.

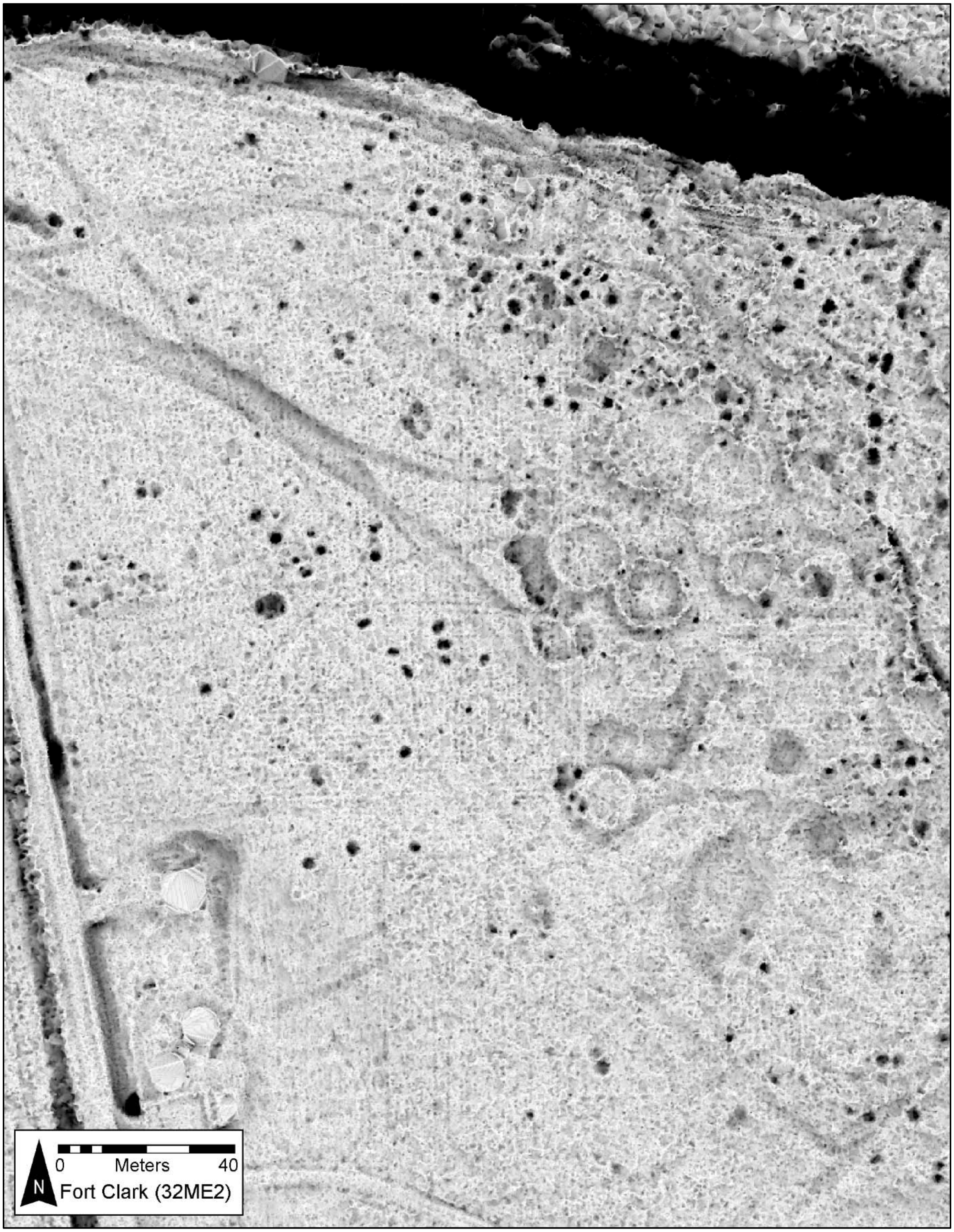

Figure A4.20. Sky view factor visualization showing the west section of the Mandan/Arikara village at Fort Clark.

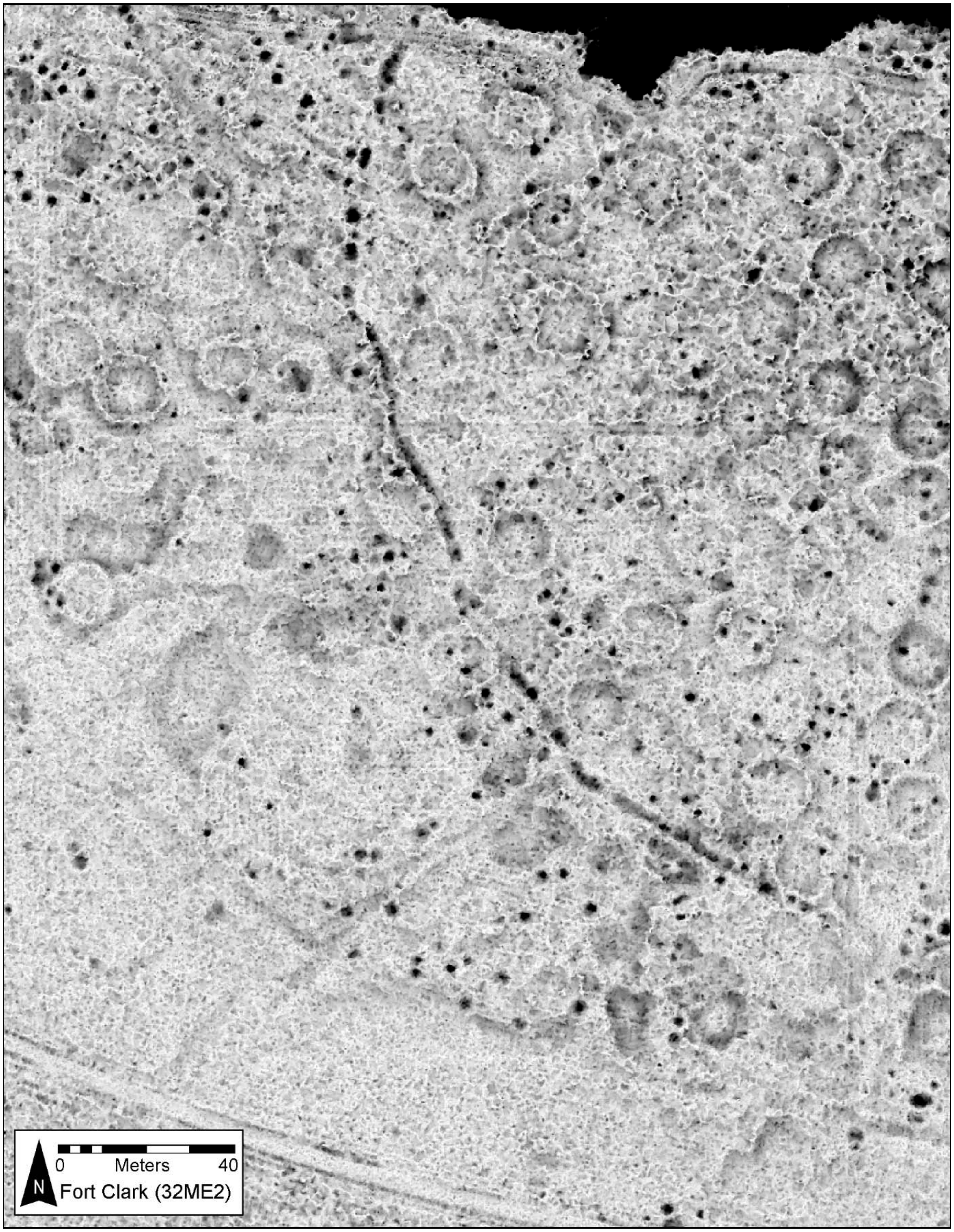

Figure A4.21. Sky view factor visualization showing the central section of the Mandan/Arikara village at Fort Clark.

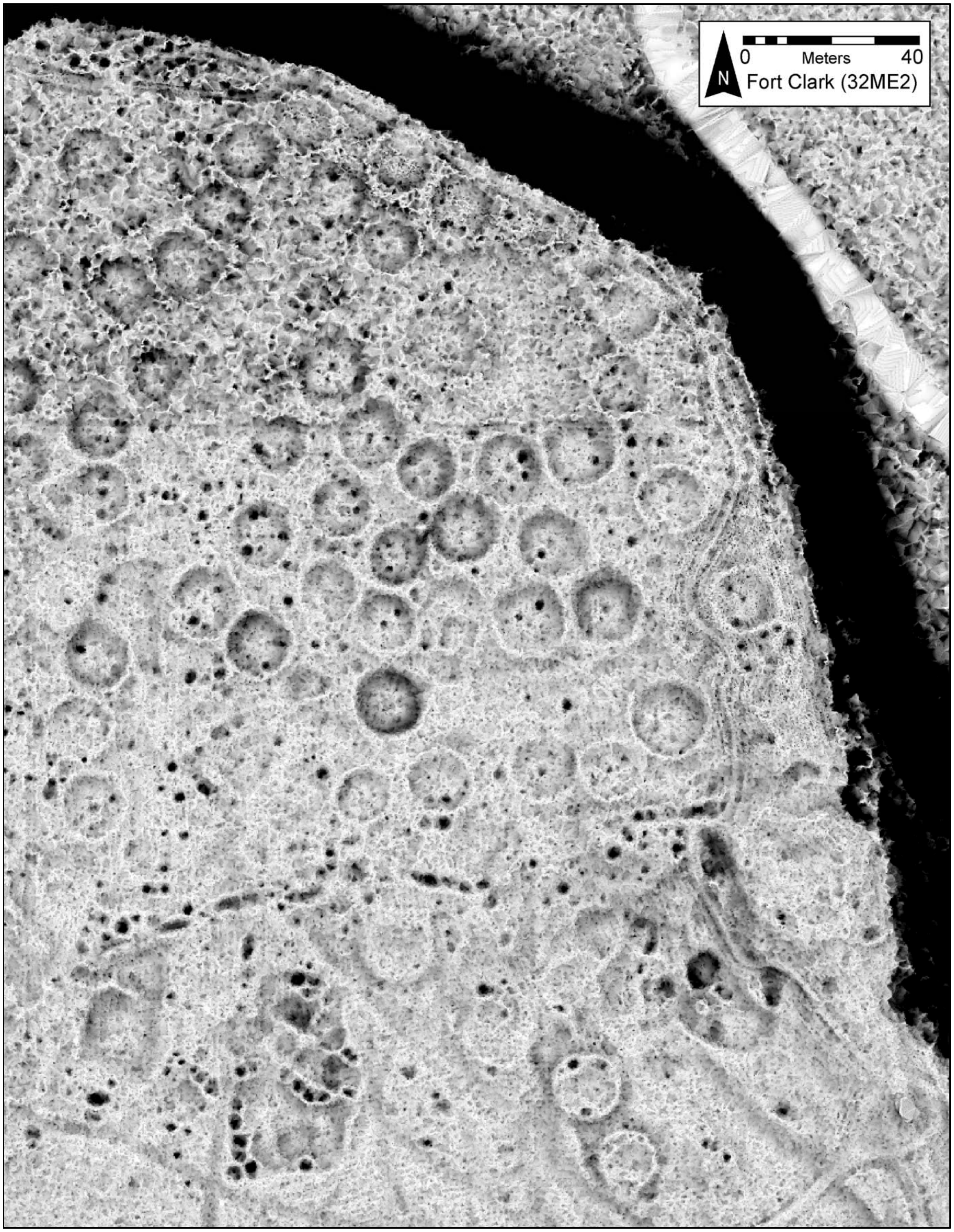

Figure A4.22. Sky view factor visualization showing the east section of the Mandan/Arikara village at Fort Clark.

Figure A4.23. Multi-directional hillshade showing the Mandan/Arikara village at Fort Clark.

Figure A4.24. Multi-directional hillshade showing the west section of the Mandan/Arikara village at Fort Clark.

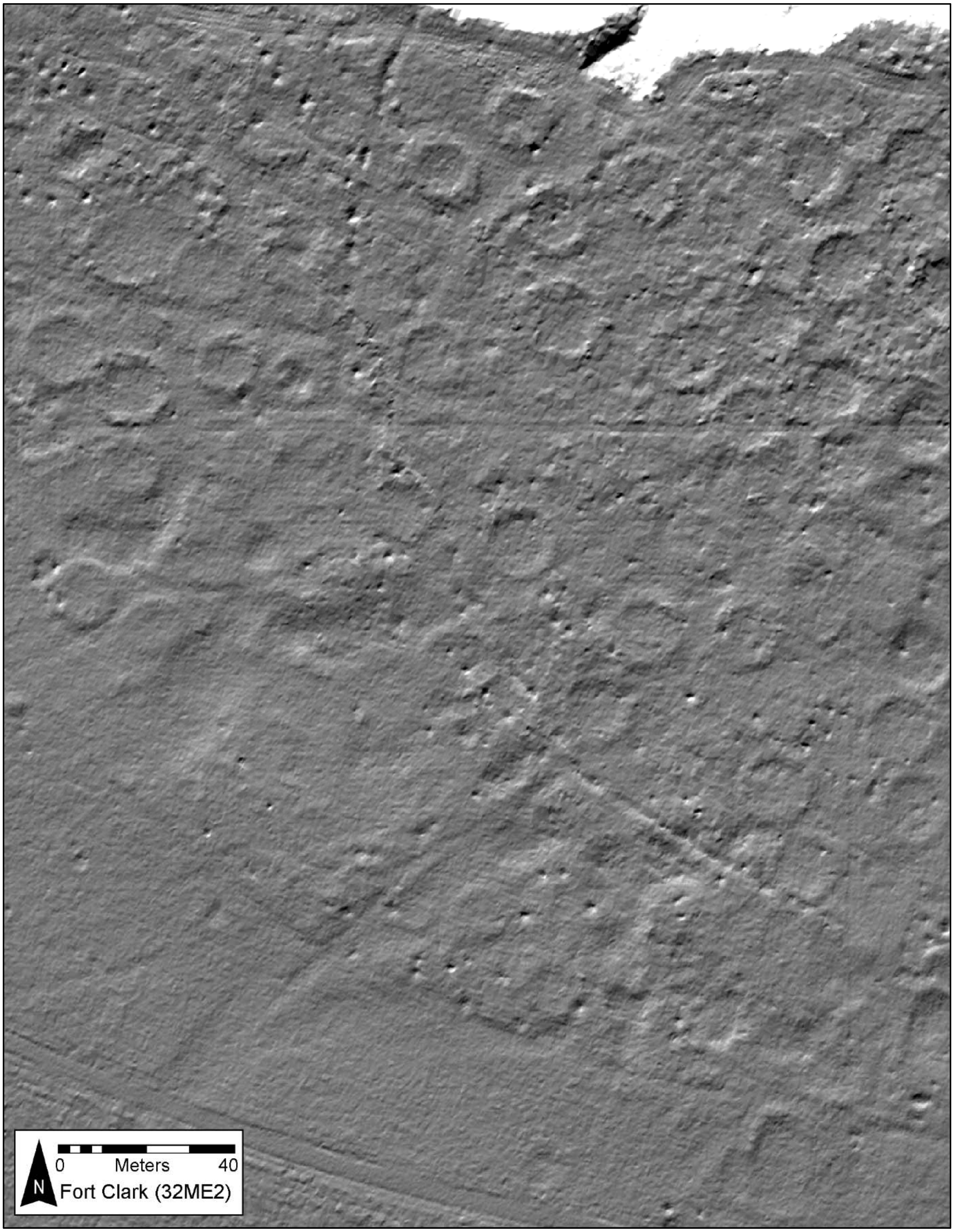

Figure A4.25. Multi-directional hillshade showing the central section of the Mandan/Arikara village at Fort Clark.

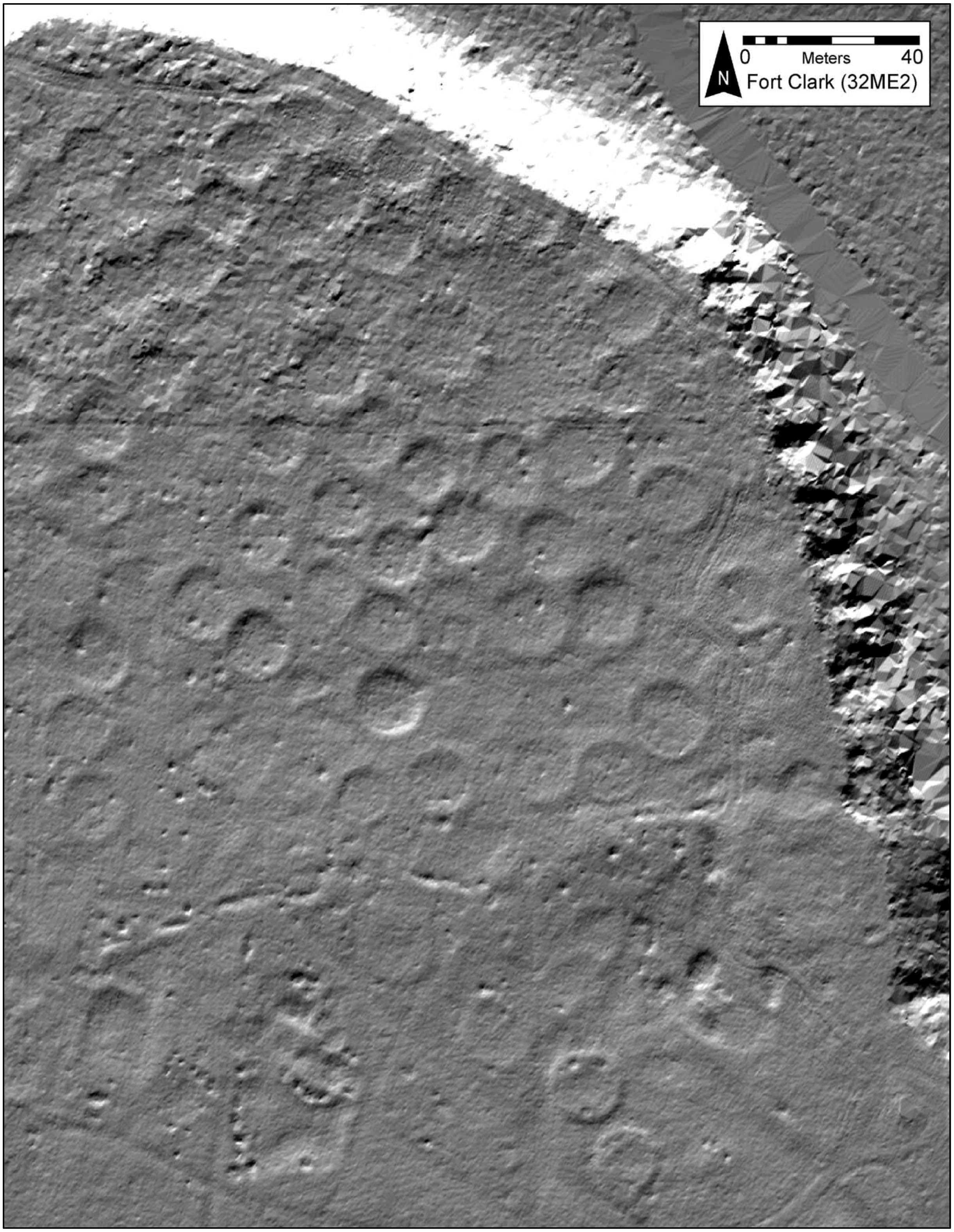

Figure A4.26. Multi-directional hillshade showing the east section of the Mandan/Arikara village at Fort Clark.

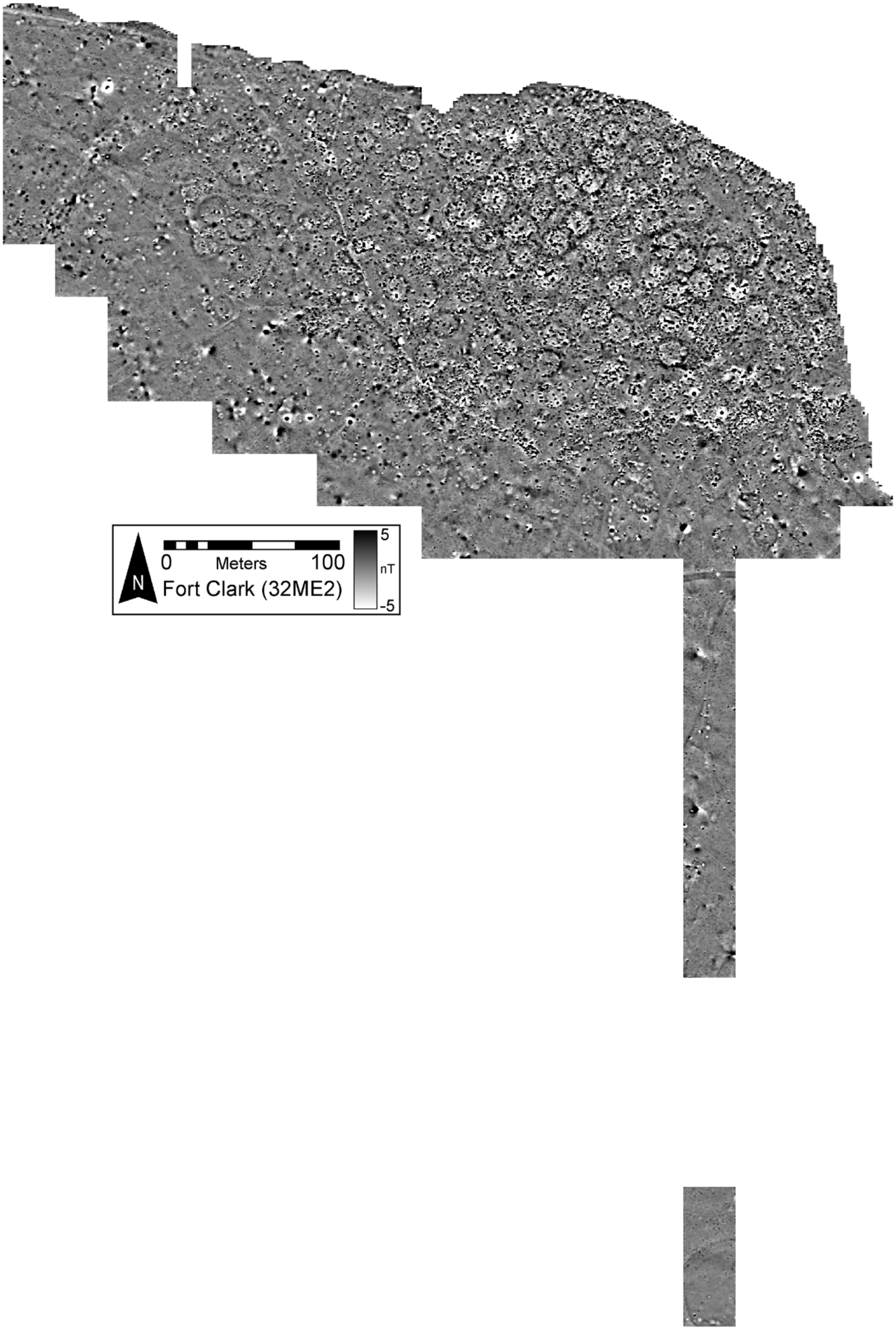

Figure A4.27. Village-wide magnetic gradiometry survey results at Fort Clark.

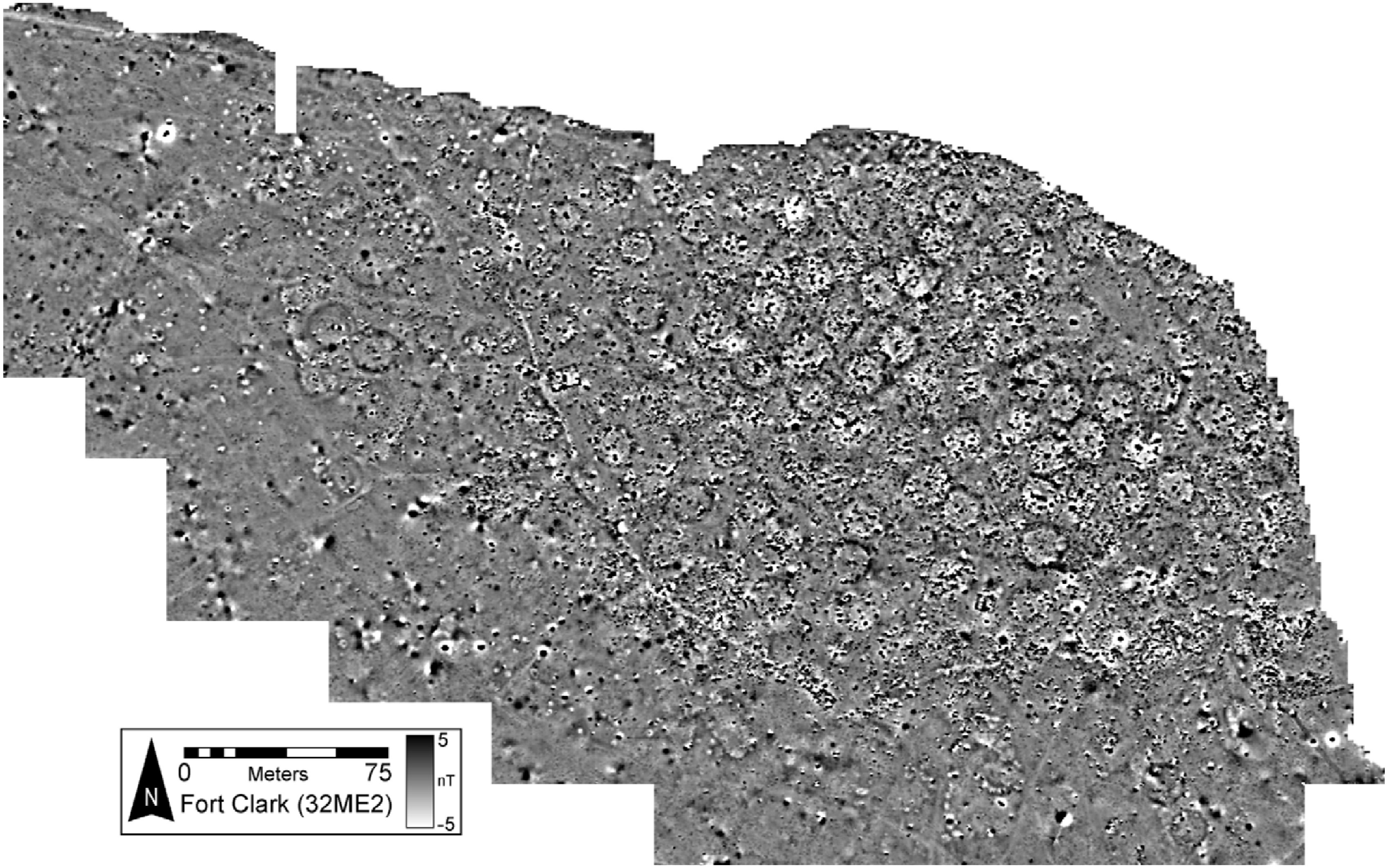

Figure A4.28. Magnetic gradiometry survey results from the Mandan/Arikara village at Fort Clark.

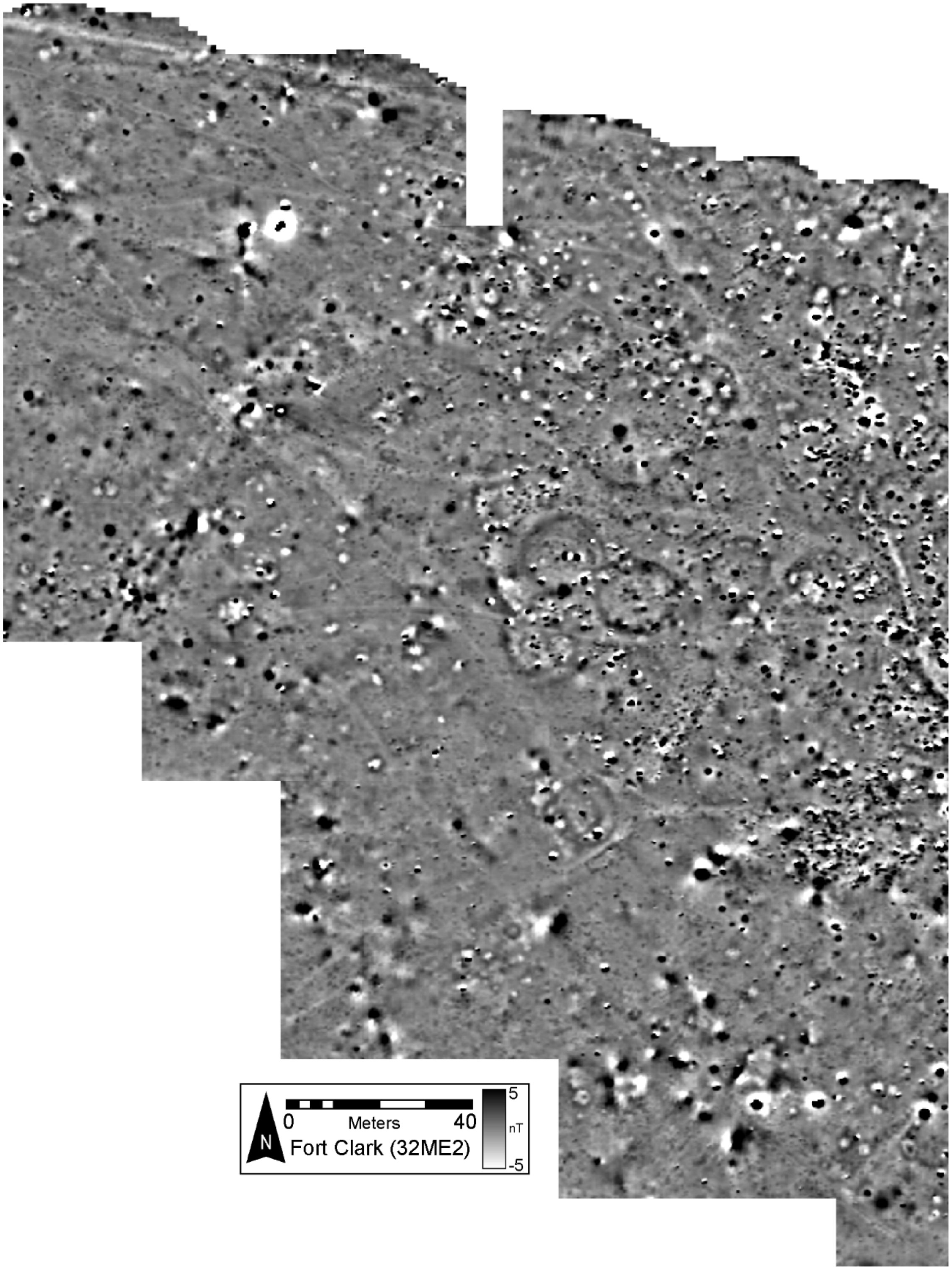

Figure A4.29. Magnetic gradiometry survey results from the west section of the Mandan/Arikara village at Fort Clark.

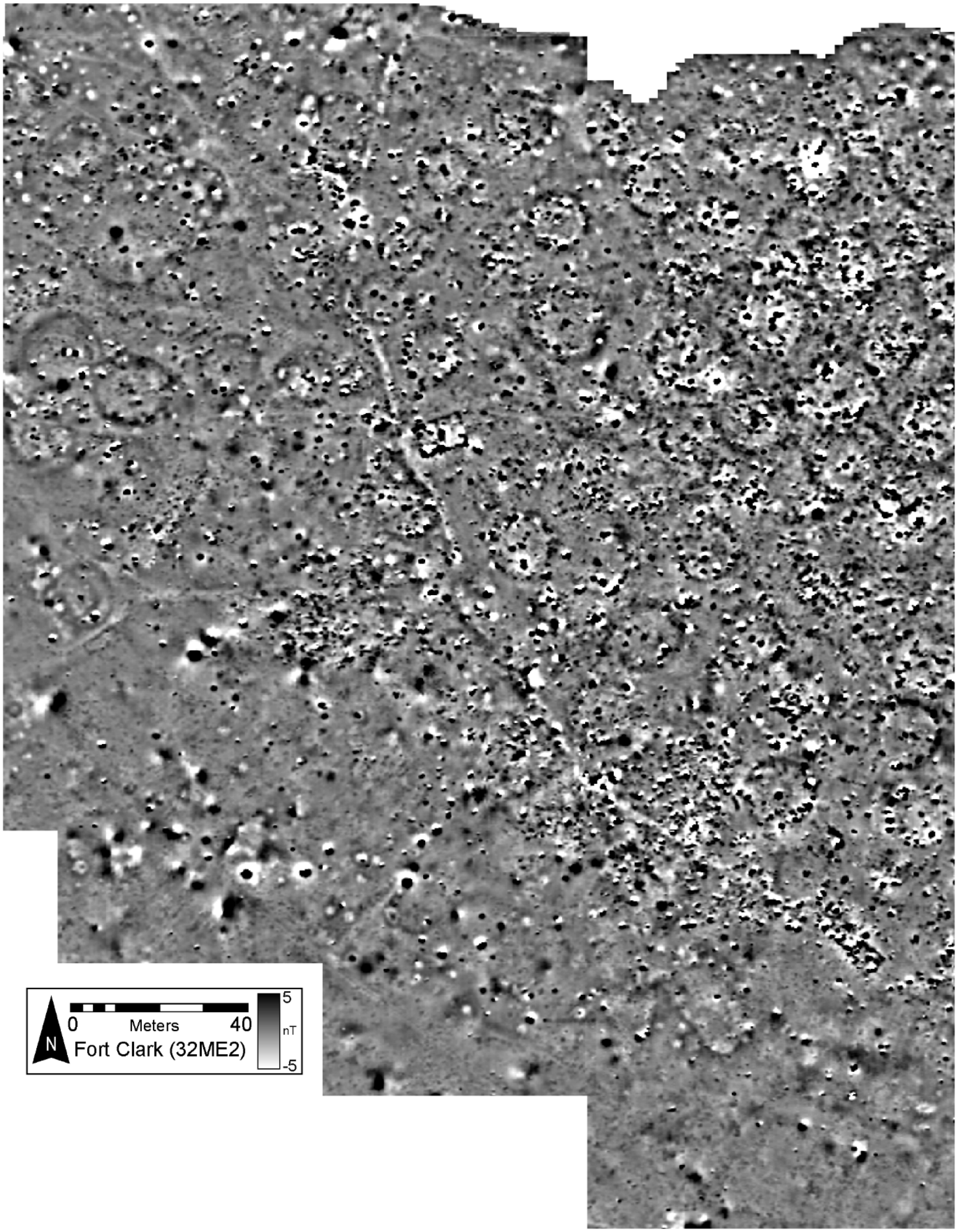

Figure A4.30. Magnetic gradiometry survey results from central section of the Mandan/Arikara village at Fort Clark.

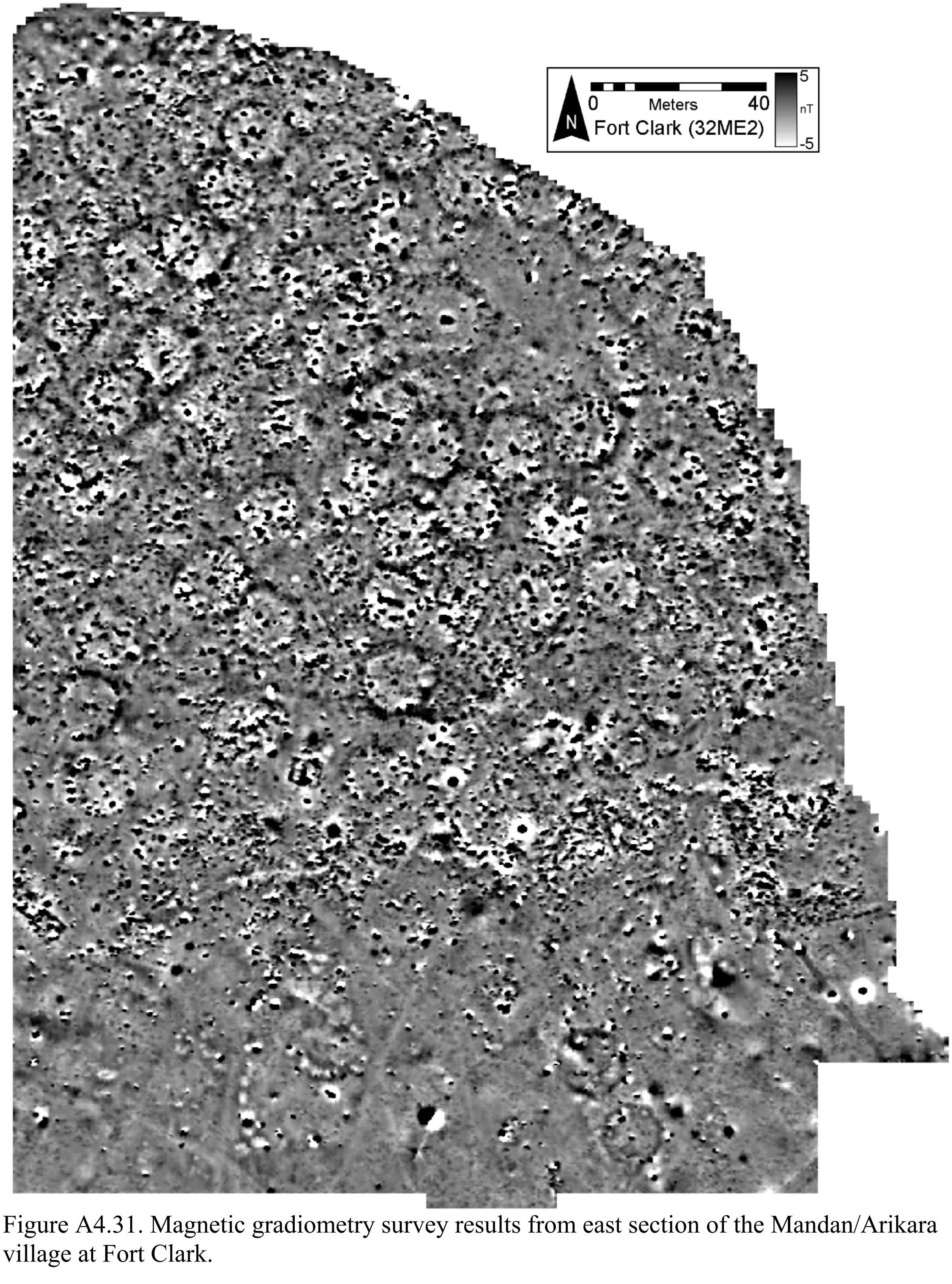

Figure A4.31. Magnetic gradiometry survey results from east section of the Mandan/Arikara village at Fort Clark.

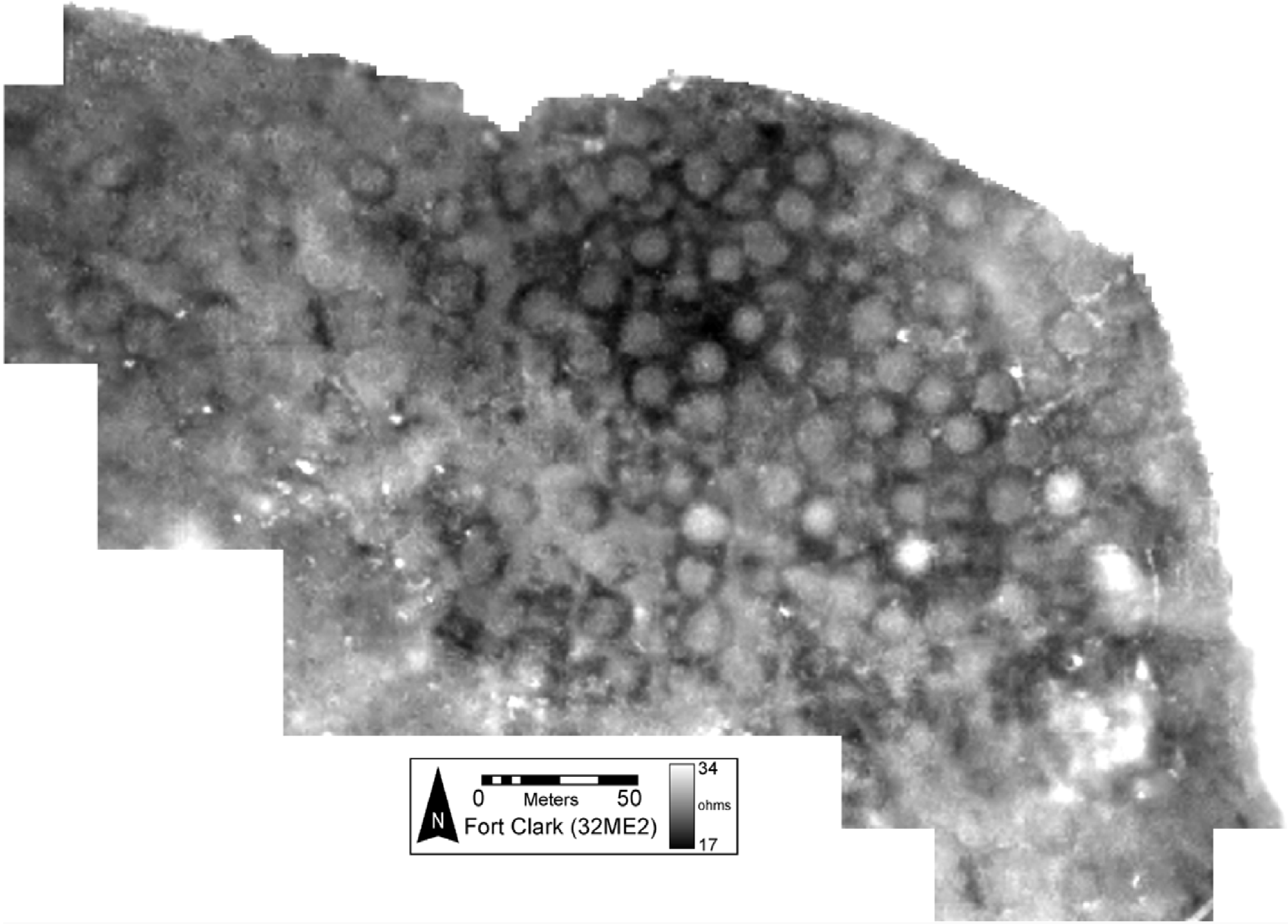

Figure A4.32. Earth resistance survey results from the Mandan/Arikara village at Fort Clark.

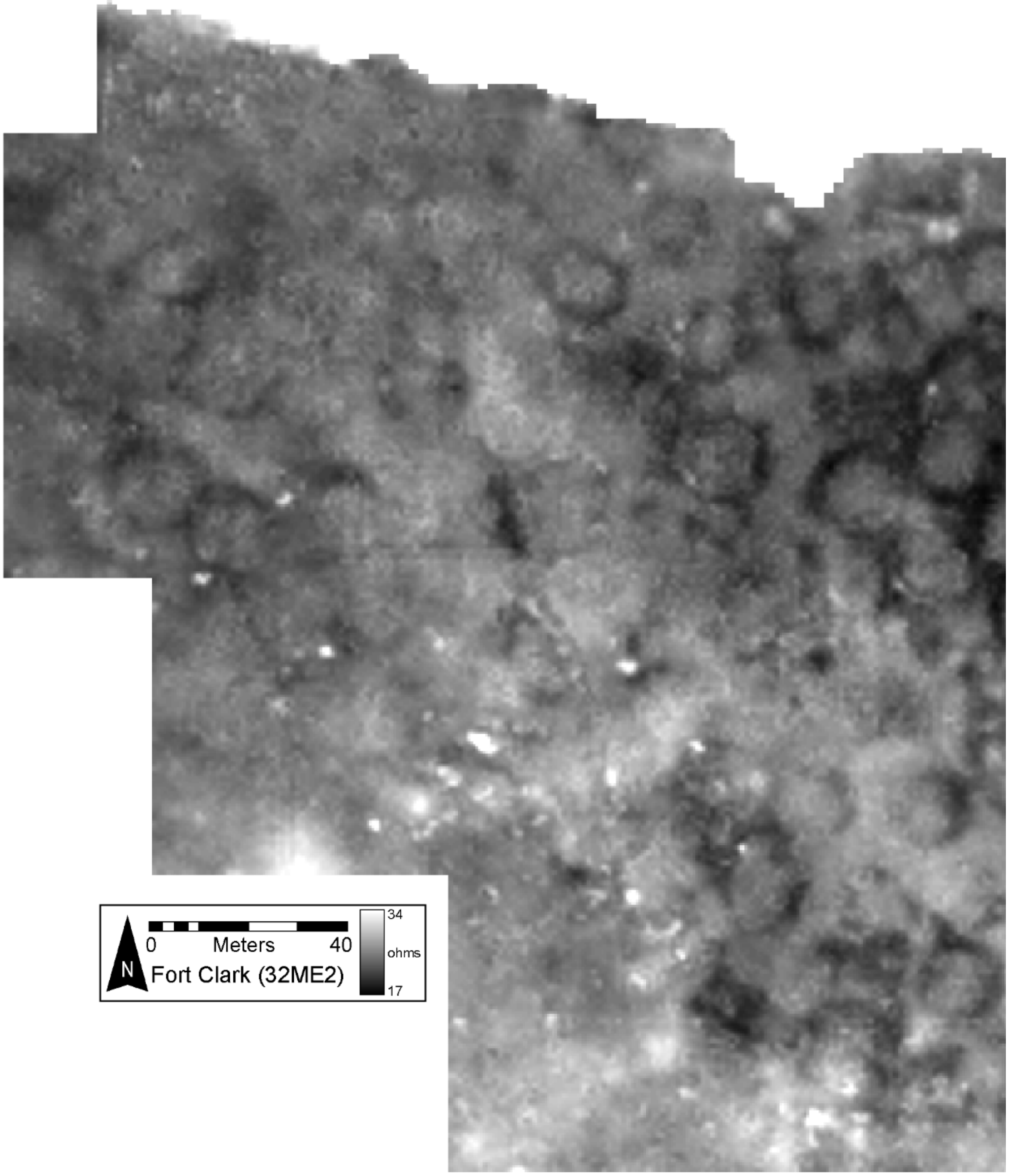

Figure A4.33. Earth resistance survey results from the west section of the Mandan/Arikara village at Fort Clark.

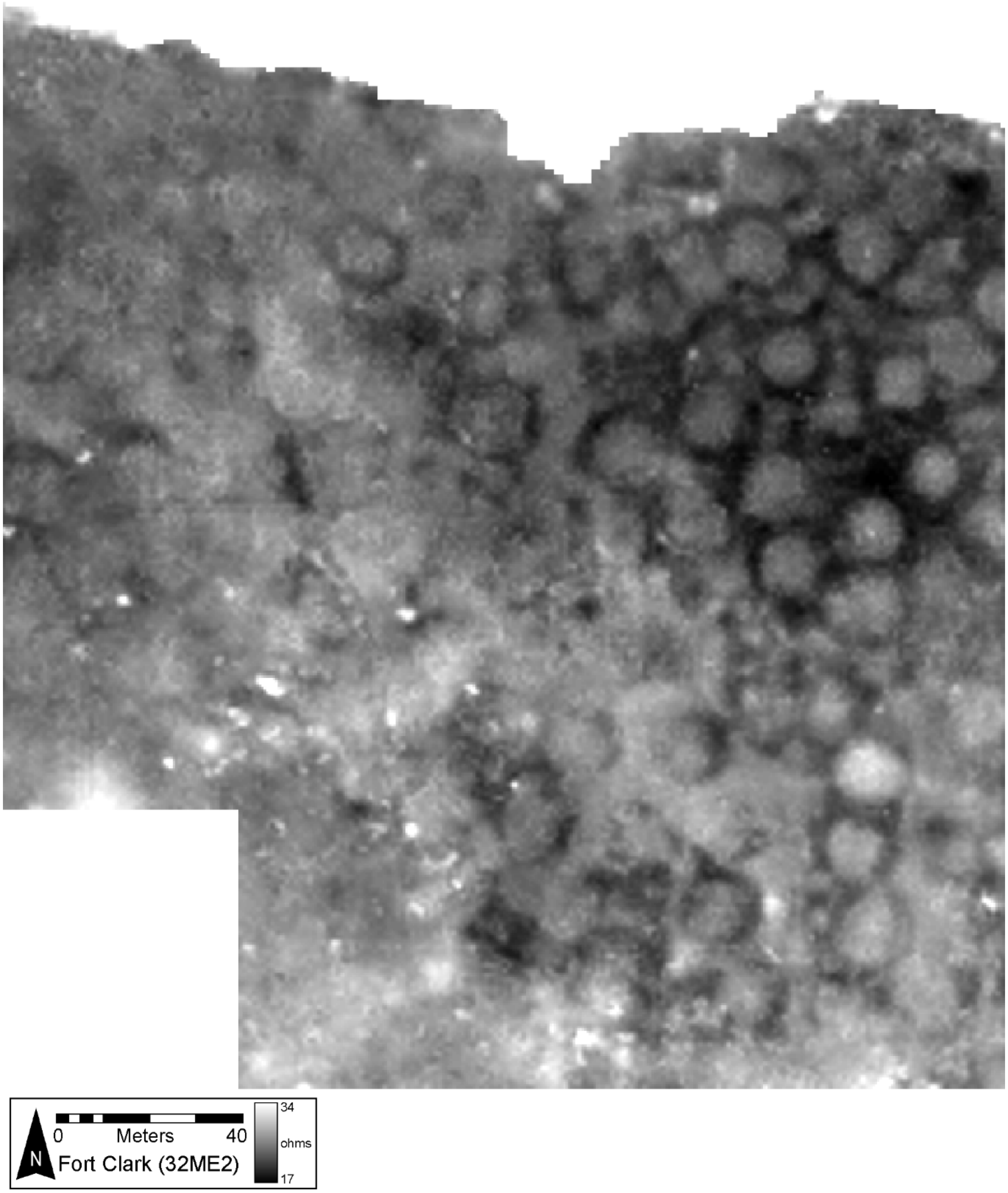

Figure A4.34. Earth resistance survey results from the central section of the Mandan/Arikara village at Fort Clark.

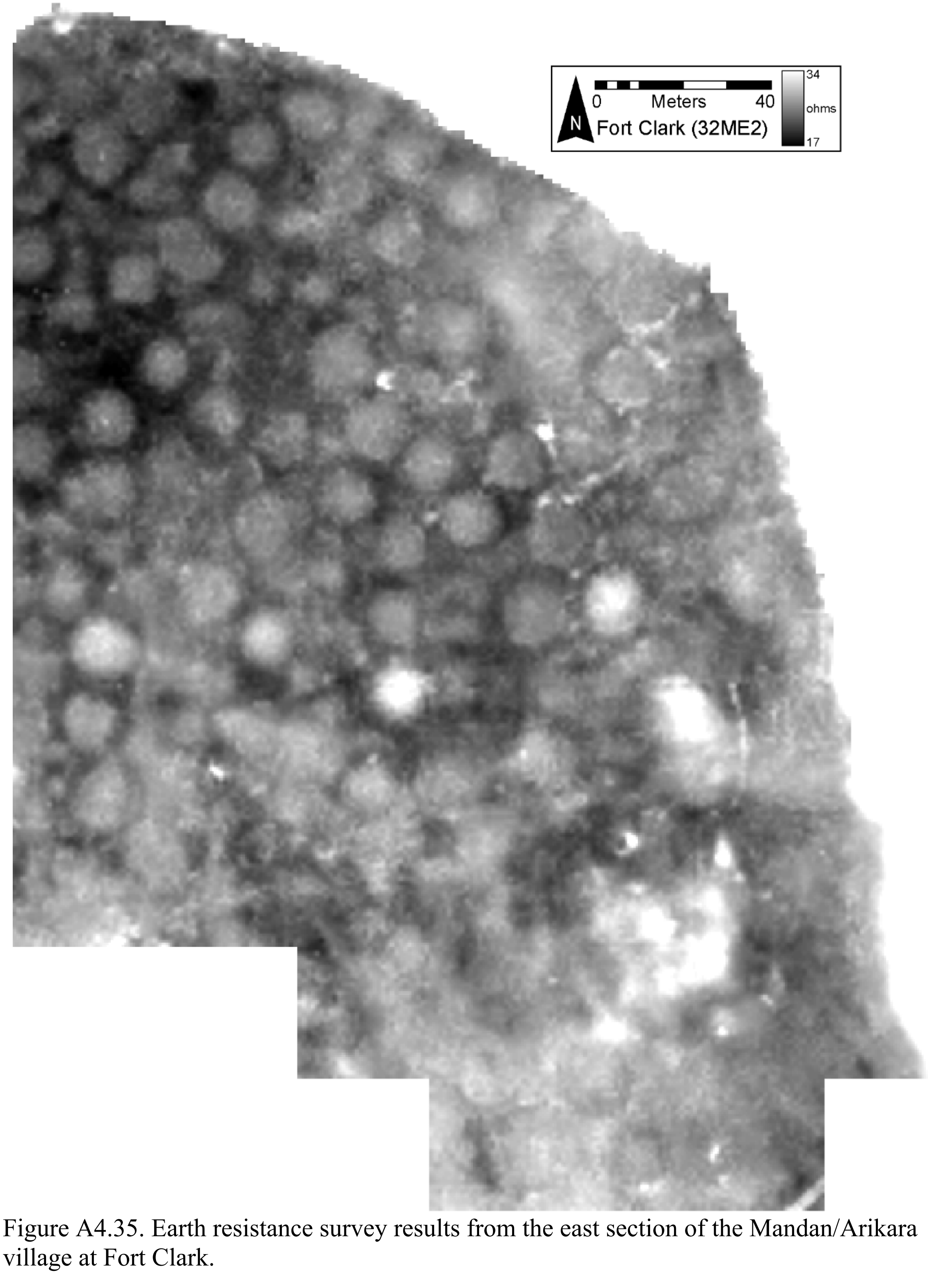

Figure A4.35. Earth resistance survey results from the east section of the Mandan/Arikara village at Fort Clark.

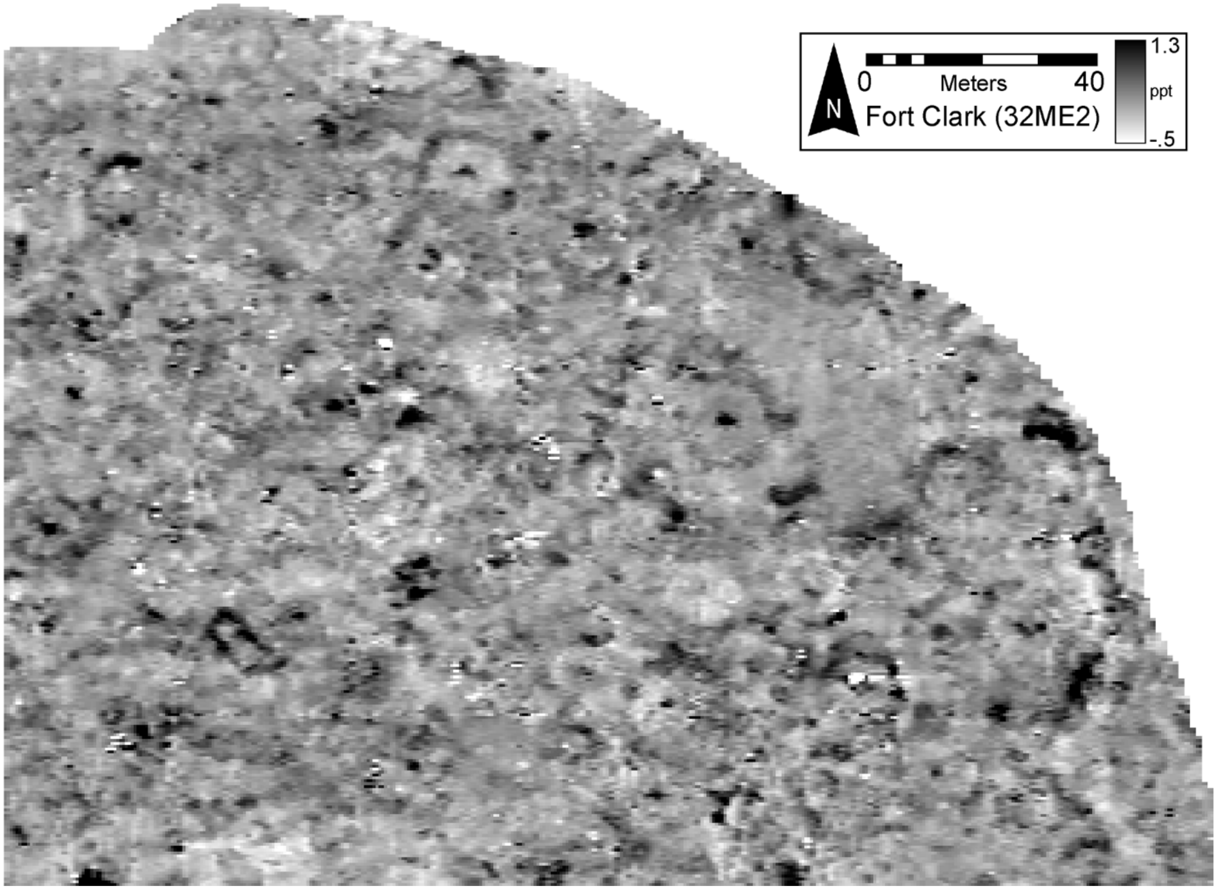

Figure A4.36. Magnetic susceptibility survey results from the Mandan/Arikara village at Fort Clark.

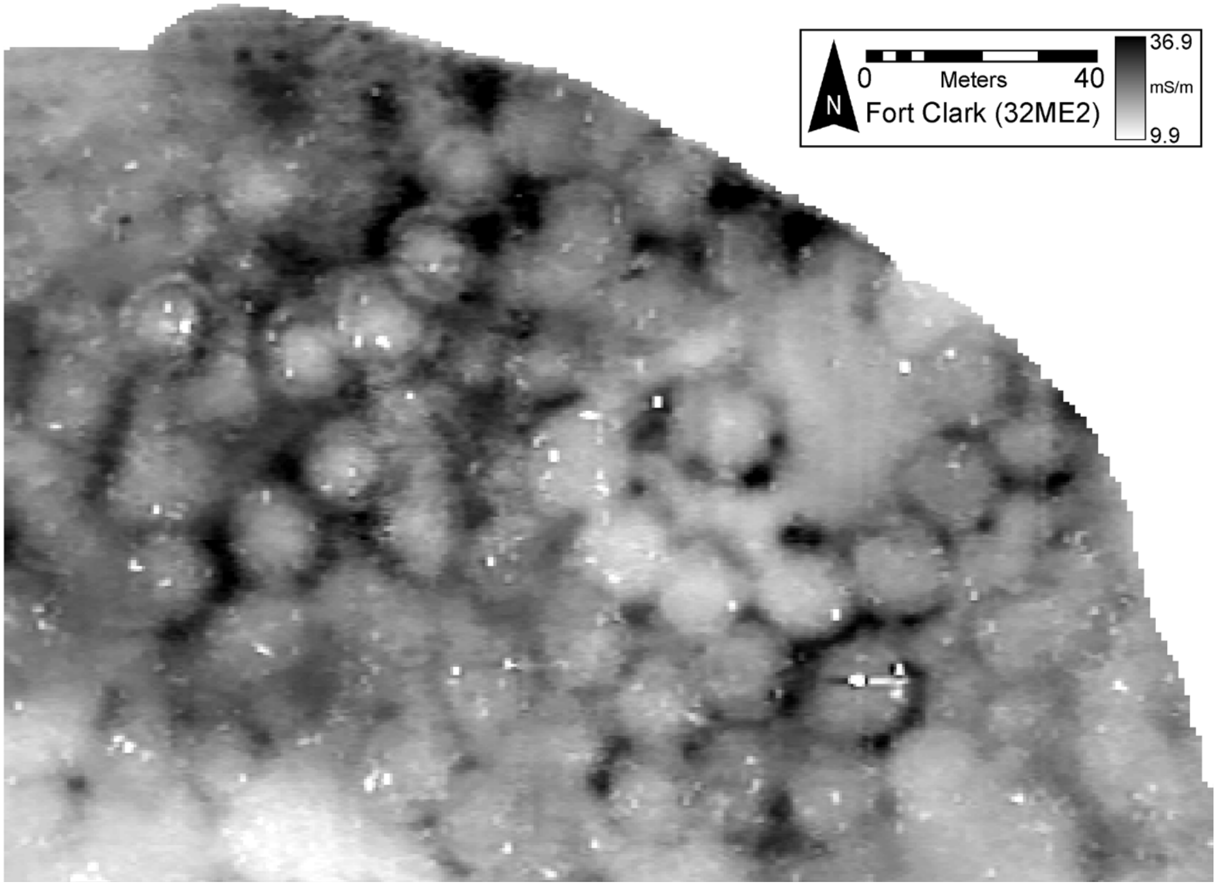

Figure A4.37. Conductivity survey results from the Mandan/Arikara village at Fort Clark.

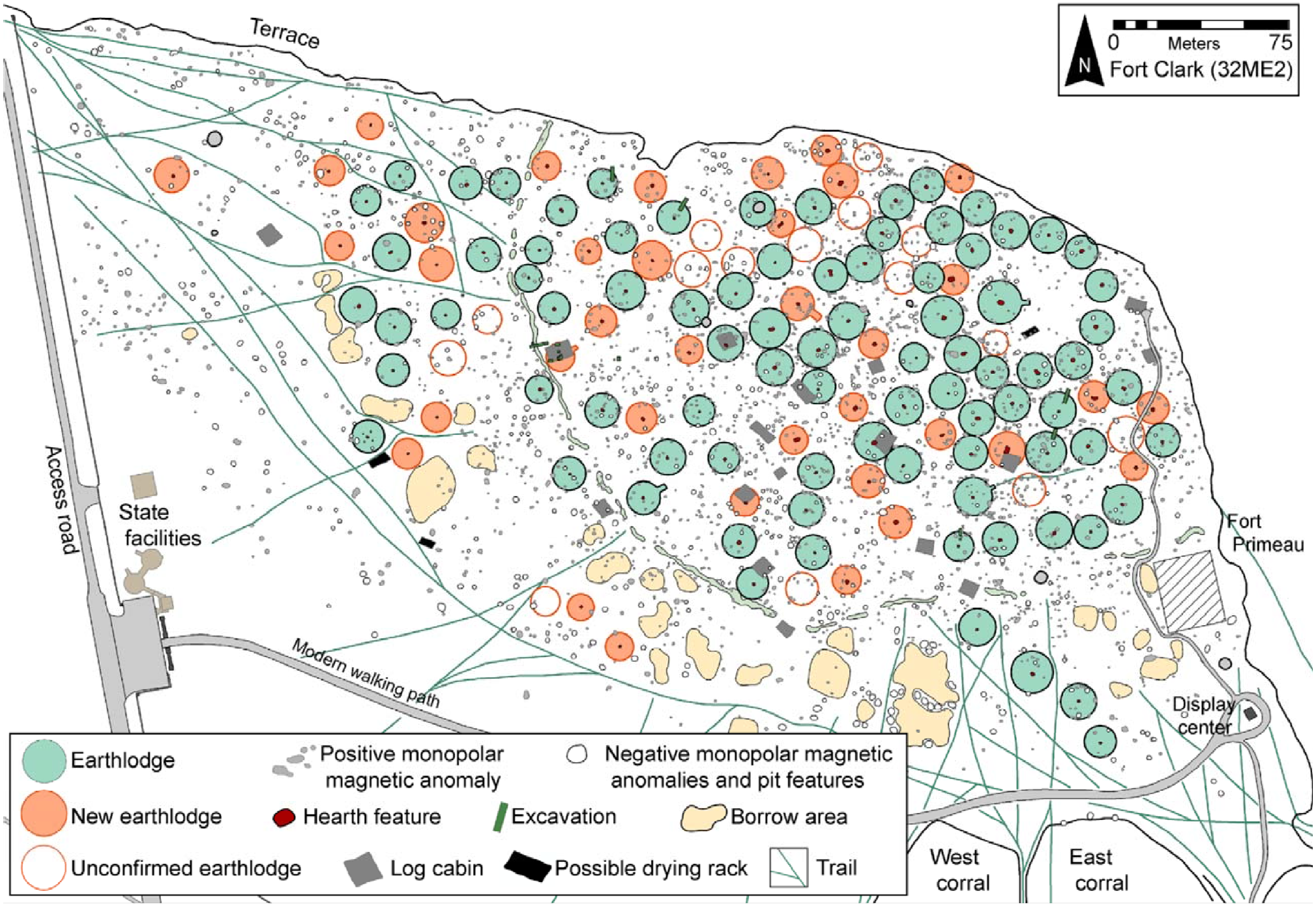

Figure A4.38. Interpretive map of the Mandan/Arikara village at Fort Clark.

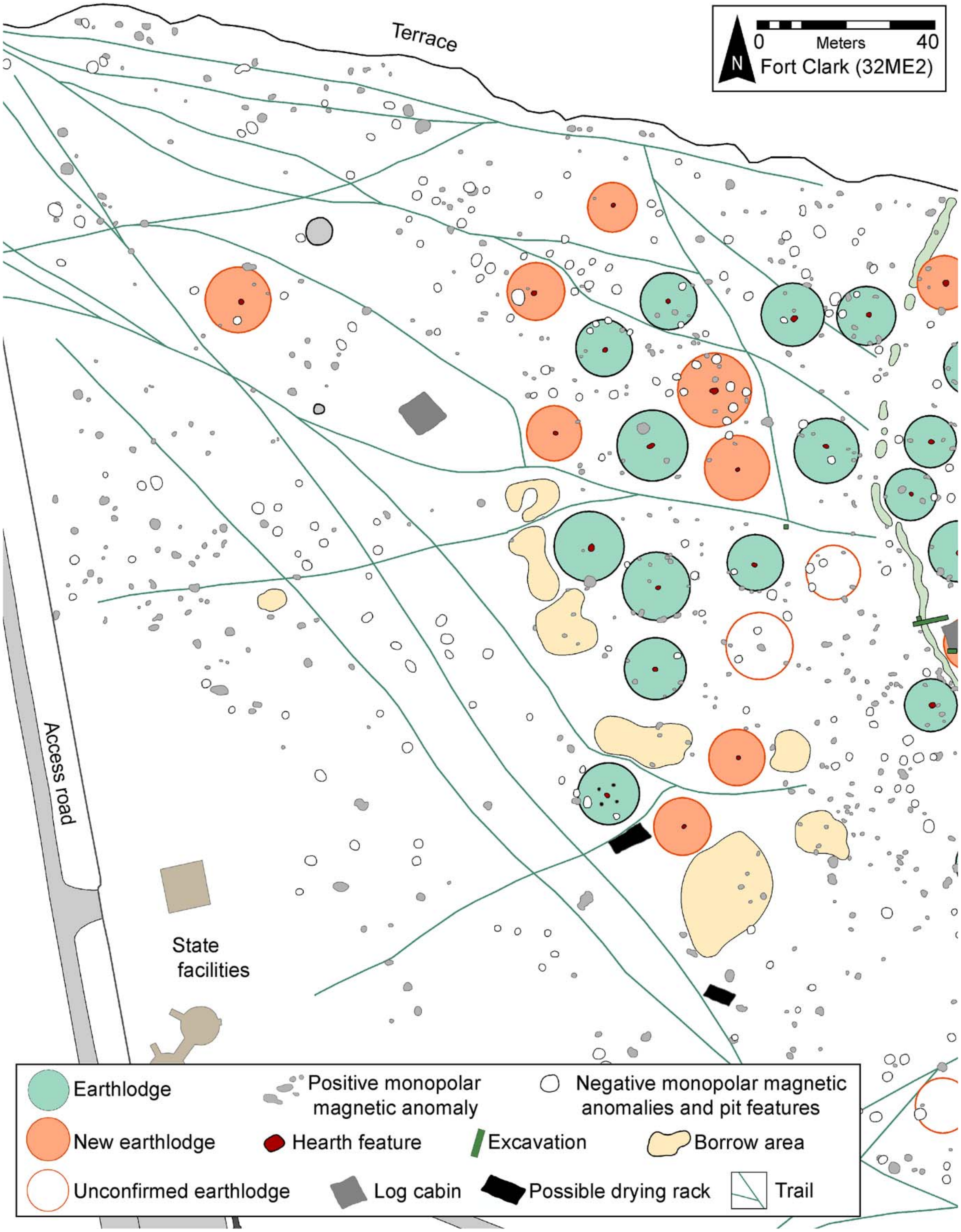

Figure A4.39. Interpretive map of the west section of the Mandan/Arikara village at Fort Clark.

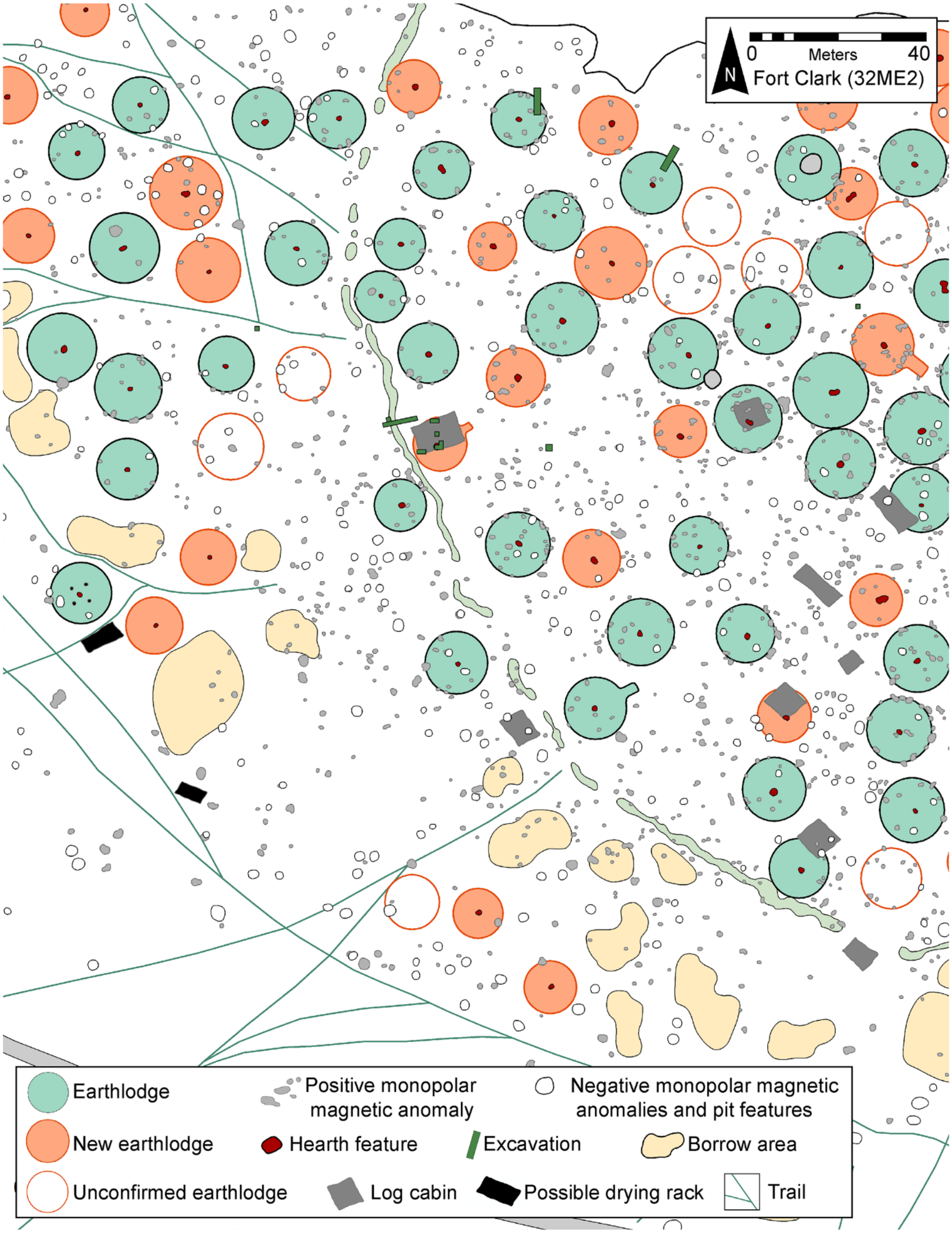

Figure A4.40. Interpretive map of the central section of the Mandan/Arikara village at Fort Clark.

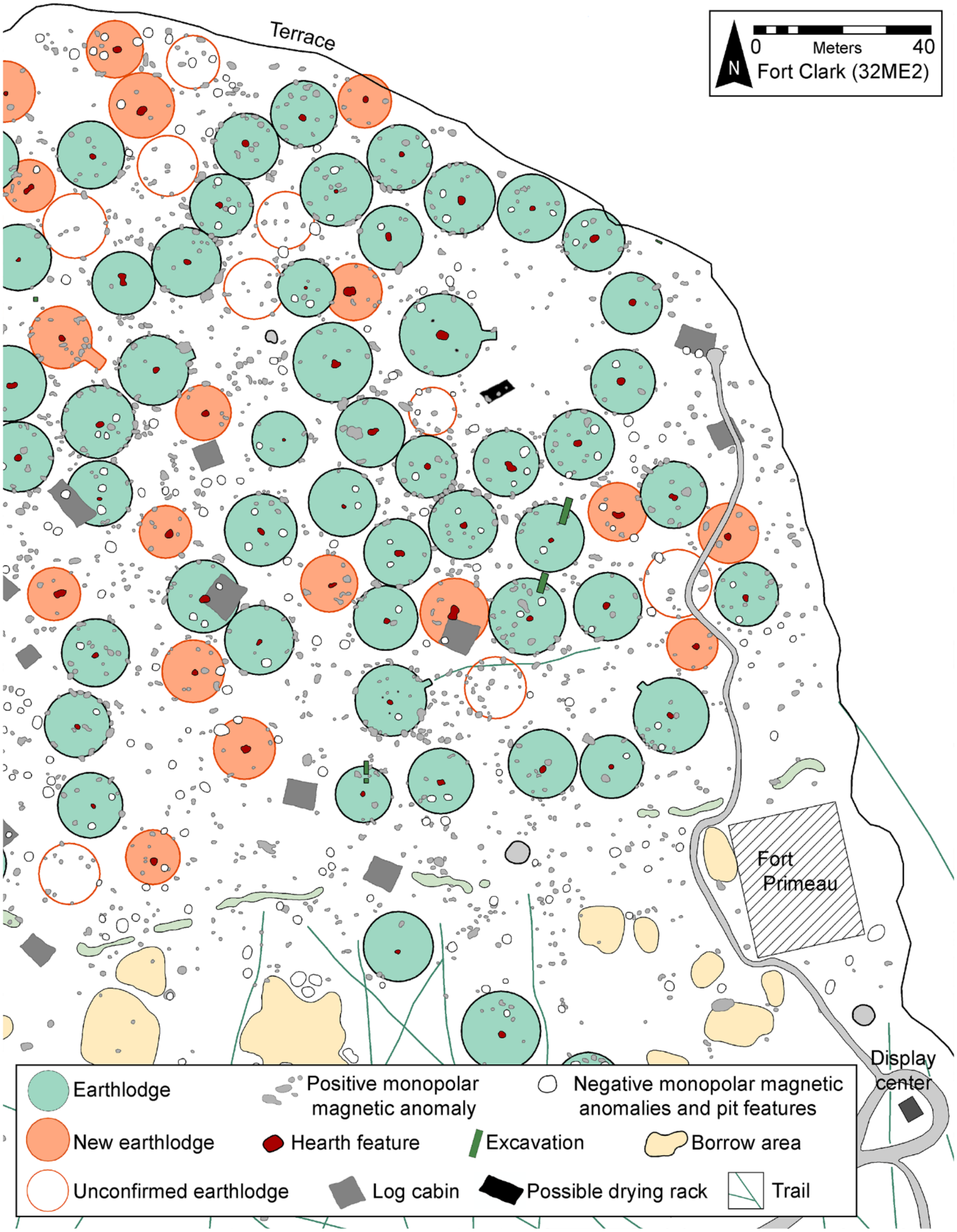

Figure A4.41. Interpretive map of the east section of the Mandan/Arikara village at Fort Clark.