New Interpretations of the Fort Clark State Historic Site Based on Aerial Color and Thermal Infrared Imagery

New Interpretations of the Fort Clark State Historic Site Based on Aerial Color and Thermal Infrared Imagery

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Master of Arts in Anthropology

By

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ABSTRACT

The Fort Clark State Historic Site (32ME2) is a well known site on the upper Missouri River, North Dakota. The site was the location of two Euroamerican trading posts and a large Mandan-Arikara earthlodge village. In 2004, Dr. Kenneth L. Kvamme and Dr. Tommy Hailey surveyed the site using aerial color and thermal infrared imagery collected from a powered parachute. Individual images were stitched together into large image mosaics and registered to Wood's 1993 interpretive map of the site using Adobe Photoshop. The analysis of those image mosaics resulted in the identification of more than 1,500 archaeological features, including as many as 124 earthlodges.

This thesis is approved for
Recommendation to the
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While I have attempted to be exhaustive in my gratitude, I am certain that there are individuals that I have failed to adequately acknowledge. I can only hope that they will accept my thanks anyway.

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CHAPTER 1: INTRODUCTION

Fort Clark State Historic Site (32ME2) is located on a terrace overlooking the west bank of a derelict course of the Missouri River in Mercer County, North Dakota. It is the site of a large Mandan and Arikara village and two important fur trading posts: Fort Clark and Primeau's Post (Figure 1). The Mandan village was established in 1822. Shortly thereafter, the American Fur Company began attempts at establishing trade with the Mandan at the site. After two marginally successful attempts, the Company established Fort Clark in 1831. The Mandan abandoned their village in 1838 following a devastating smallpox epidemic and an Arikara takeover of the village. In 1850, Harvey, Primeau and Company, a competitor of the American Fur Company, established Primeau's Post only a few hundred feet away. The entire site was abandoned in 1861 after Fort Clark burned and the Arikara moved to establish Star Village (32ME16) (Wood 1993:545).

As the site was the location of one of the last Mandan villages, and two major fur trading posts, the site has been the subject of numerous examinations beginning as early as 1862 (Morgan 1959) and continuing through this study. The site was purchased by the State Historical Society of North Dakota in 1931 and exhibits remarkable preservation. The current research project examines the remains of the Fort Clark State Historic Site through a program of aerial remote sensing. High resolution color and thermal infrared imagery were collected during the summer of 2004 from a low flying powered parachute. This thesis examines the results of that survey. To this end, images collected during the survey were stitched together into two image mosaics covering much of the northern half of the site. The mosaics were made in Adobe Photoshop 6.0 by manually rectifying the imagery and registering them to an accurate base map of the entire site prepared by Wood (1993). Finally, interpretation were made from the color and thermal infrared datasets and combined into a master interpretive map of the site.

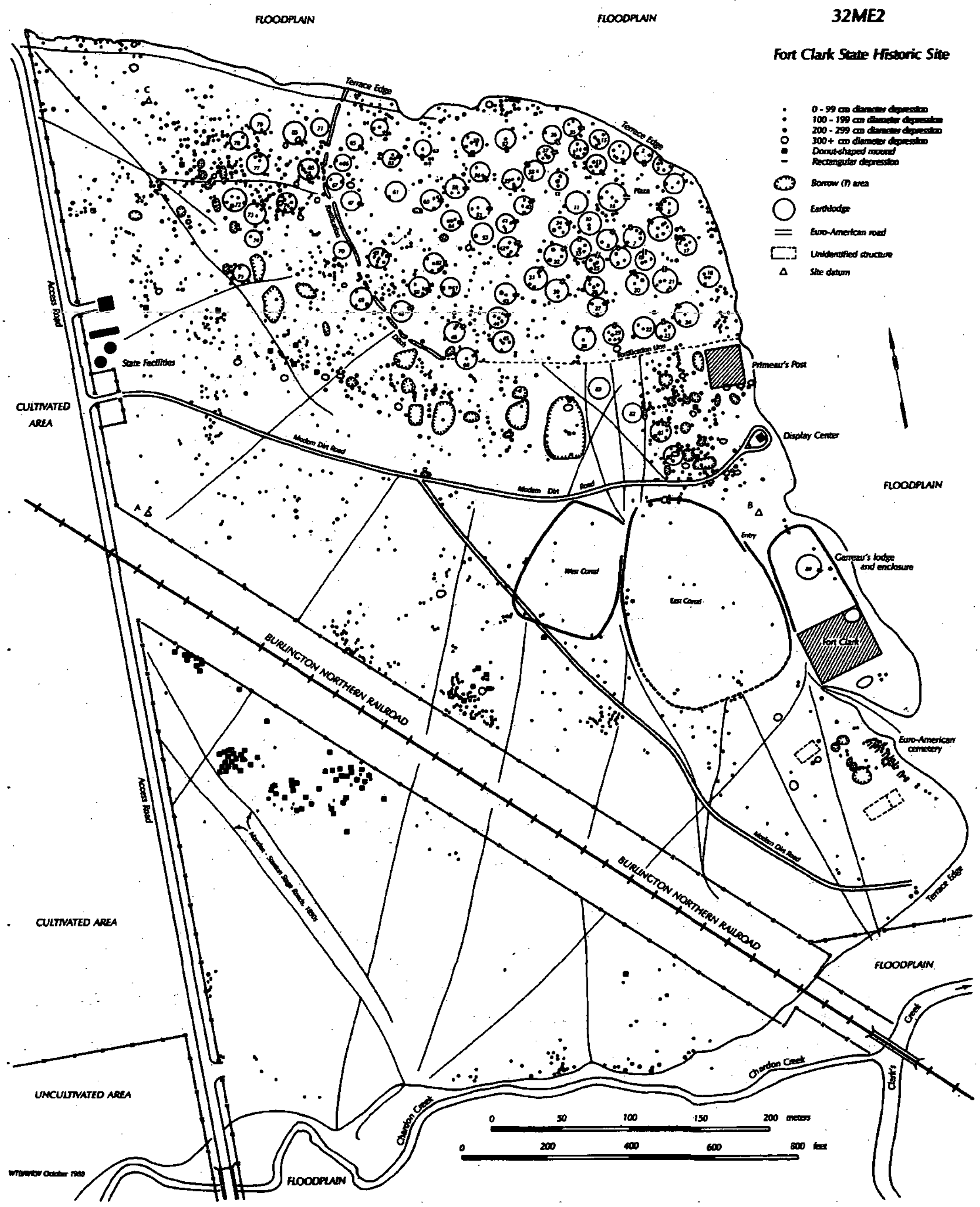

Figure 1: Interpretive map of the Fort Clark State Historic Site prepared by Wood (1993). (Image courtesy of the State Historical Society of North Dakota)

Site History

Fort Clark opened in 1831 and became one of the most important and famous trading posts on the upper Missouri River. It was located adjacent to Mitu'tahakto, a large Mandan and later Arikara village. As such, the fort witnessed many of the events that affected the local Native Americans, including a smallpox epidemic in 1837 that nearly wiped out the Mandan population. Additionally, the fort hosted many famous individuals in whose notes and paintings are recorded information about the fort, those who worked there, and the Native Americans who lived nearby. The record of the site began in 1822 when the Mandan founded Mitu'tahakto and continued until the final destruction of Fort Clark in 1861.

Mitu'tahakto:

Prior to the smallpox epidemic of 1781, both the Mandan and Arikara lived on the Missouri River near the mouth of the Heart River. Additionally, as Europeans settled the eastern seaboard, Native American tribes were displaced and forced to move west. The stress caused by the introduction of new populations into the Mandan territory lead to intertribal warfare. Conflict with the Sioux and other nomadic groups was especially violent and bitter (Ahler 2003:1).

The smallpox epidemic of 1781 decimated the Mandan and Arikara populations along the Missouri River. The devastation caused the Mandan to consolidate into two major villages along the Missouri River at the mouth of the Knife River, near the Hidatsa. Shortly afterward, the Arikara also moved to the area, potentially seeking the safety of larger numbers against predatory nomadic tribes. When Lewis and Clark encountered the Mandan in 1804, they estimated that their total population was between 1,500 and 2,000

(Chittenden 1933: 846). The Arikara did not fare much better with an estimated population of 2,600 (Denig 1961:43).

In 1822, the Mandan established Mitu'tahakto on the west bank of the Missouri River. By 1829, Mitu'tahakto was the larger of the two remaining Mandan villages. By 1833, the village was composed of 65 earthlodges. That village was fortified against attack with a shallow ditch and palisade that together surrounded the village. Additionally, Prince Maximilian of Wied suggests that the fur traders at Fort Clark constructed earthen bastions along the edges of the village (Wood 2003:7). According to Catlin, a cemetery of scaffolds upon which the bodies of the dead were laid out, visible in at least one of his paintings, was located south of the village (Catlin 1973:89-90). The scaffolds were intended as temporary structures and as such were not maintained. When a scaffold collapsed, the bones of the individual were taken and the skulls were arranged in circles near where the scaffold had stood (Bowers 2004:100).

Early Trading Attempts:

To take advantage of the trade opportunities created by the newly established Mandan village, James Kipp constructed Fort Tilton in May 1823 for Tilton and Company- commonly referred to as the Columbia Fur Company (Chittenden 1933:326). The fort did not last long and was abandoned in the spring of 1824. This was largely the result of the constant threat posed by the local Arikara (Wood 2003:8) who were aggravated by the military campaign lead by Colonel Leavenworth during the so-called Arikara Wars in August of 1823 (Chittenden 1933:587-600).

Though his initial attempt at establishing a trading post at Mitu'tahakto failed almost as quickly as it began, Kipp established a new trading post in the summer of 1824, possibly within the Mandan village (Chittenden 1933:327; Wood 2003:8). While the name of this post is not definitively known, it is usually referred to as Kipp's Post (Ahler 2003:6), a name it shares with another trading post constructed by Kipp during the fall and winter of 1826-27 at the confluence of the White Earth River and Missouri River (Woolworth and Wood 1960:247). Williams has suggested that based on an American Fur Company document, the name of the trading post at Mitu'tahakto may have been Fort Clark (Williams 1998:71). Although Kipp left to establish Kipp's Post in the fall of 1826, American fur Company employment records show that a post was in use at the site as late as 1829 (Williams 1998:265).

In July 1827, the American Fur Company purchased Tilton and Company. The American Fur Company was the largest and most powerful fur trading company in the country at the time. It is often referred to simply as "the company," while nearly all other fur trading outfits were termed "the opposition." Tilton and Company was incorporated into the Western Division of the American Fur Company and renamed the Upper Missouri Outfit (Chittenden 1933:328).

Fort Clark:

Now an employee of the Upper Missouri Outfit, Kipp and David D. Mitchell of the American Fur Company began construction of a third trading post at Mitu'tahakto during the winter of 1830-31 (Wood 1993:545). Fort Clark became an important trading posts on the upper Missouri River, serving as a major trading post for the Mandan, Arikara, Crow, Yankton, Yanktonai, and Saone (Wood 2003:11). The trading fort was located approximately "300 paces" south of Mitu'tahakto on the western edge of the Missouri river according to Maximilian (Williams 1998:80). Fort Clark was built in a style similar to many other American Fur Company trading posts. The fort's defensive structures included a wooden palisade as well as two blockhouses set at opposite corners of the main structure. While the blockhouses have been documented by numerous visitors to the fort, there is some discrepancy in the accounts of their location and construction. However, according to the archaeological evidence it would appear likely that the blockhouses were built of wood and located on the northwest and southeast corners of the fort (Williams 1998:80-1). During its 30 years of use, however, it was subject to many alterations and construction, which probably accounts for variations in descriptions (Hunt 2003:154-161)

The first steamboat, the *Yellow Stone*, arrived in 1832. Along with provisions for the fort, the *Yellow Stone*, also brought George Catlin, a painter, ethnographer, and documenter of many Native peoples (Wood 2003:13). Catlin stayed at Fort Clark to observe the Mandan, whom he depicted in numerous portraits and paintings, and authored more than a dozen letters in which he describes Mitu'tahakto and its inhabitants (Catlin 1973:79-184). Others in the long line of prestigious visitors include Prince Maximilian of Weid and his expedition artist Karl Bodmer who visited the fort in the summer of 1833 and again during the winter of 1833-34. Maximilian kept extensive notes on his time at the fort, recorded its history from the director of the fort, James Kipp, and acquired information on the Mandan from village leaders. Bodmer made detailed watercolors of the Mandan, Mitu'tahakto, and Fort Clark, as well as several species of local animals. Among other visitors to the fort were John Audubon, Carl Wimar, and Lewis Henry Morgan (but only after the fort had closed) (Wood 2003:13-4).

In 1834 Francis A. Chardon became the director at Fort Clark. Chardon kept a journal of the daily occurrences at the fort between 1834 and 1839. These entries chronicle life at the fort as well as many of the events at Mitu'tahakto (Chardon 1997). Among these entries is the arrival of the steamboat *St. Peters* on June 18, 1837: "The Steam Boat St. Peters hove in sight at 2 P. M. – Capt. Pratte, with Mess. Papin & Halsey on board (Chardon 1997: 118)." The *St. Peters* offloaded at Fort Clark on the 19th. Aboard the *St. Peters*, several crewmen were infected with smallpox (Chittenden 1933:613). Chardon recorded the first deaths from smallpox on July 14, 1837: "A young Mandan died today of the Small Pox – several others has caught it (Chardon1997:121)." As he describes in gruesome detail the effects of the disease on the infected, Chardon records several instances of individuals committing suicide to escape the painful death that smallpox promised (Chardon 1997:121). Several of the trading post's employees and their families were infected, including Chardon. While Chardon recovered, many of the others, particularly children, did not (Williams 1998:174). According to Chardon, the disease destroyed 7/8ths of the Mandan population. Wishart (1979:68) suggests that the remaining Mandan population consisted of "twenty-three adult males, forty adult women, and sixty to seventy children." The epidemic spread, in part because the *St. Peters* continued upriver to Fort Union where the Assiniboine contracted the disease and infected trade goods were also transported to Fort McKenzie. Additionally, warfare among the Native Americans further exacerbated the spread of the epidemic. In total, an estimated 17,200 people died among the six most affected tribes, including the Mandan, Arikara, and Hidatsa (Wishart 1979:68).

As the epidemic raged, the relationship between the employees of the fort and the Mandan became increasingly strained. On July 28th a nearly successful attempt on Chardon's life was made by a young Mandan man. Chardon suggested that the Mandan blamed him personally for the epidemic. On July 30th, 1837 he recorded a speech by Four Bears, a Mandan chief, to the Mandan and Arikara demanding the destruction of Fort Clark and the death of all of the fort's employees (Chardon 1997:123-5). The Mandan and Arikara were far too weak to carry out their threats, however, and the Hidatsa refused to aid them in their plot for revenge. While no general attack was ever attempted, individual efforts were commonplace. The inhabitants of the fort were constantly in fear of attack: "We are beset by enemies on all sides – expecting to be shot every Minute (Chardon 1997:128)." In the end, only one of the employees of the trading post, John Cliver, was successfully killed by an Arikara man on August 17, 1837 (Chardon 1997:128).

In August of 1837, the Mandan left Mitu'tahakto for their winter village (Wood 1993:544). When the Mandan returned the next spring, they found that the Arikara, seizing upon the weakness of the Mandan, had taken control of their village. While a few of the Mandan remained with the Arikara there, the majority of their population moved in with the Hidatsa at their village on the Knife River. It is likely that though the Arikara population had been diminished by the epidemic, they constructed an additional 20 earthlodges (Ahler 2003:6-8). In 1845, the Mandan and Hidatsa population left the Knife River village to establish Like-A-Fishhook village (Ahler 2003:8) sixty miles upriver from Fort Clark (Wood 2003:15). According to Chardon, a Sioux raiding party burned Mitu'tahakto on January 9, 1839: "I got up [...] and went out to see what was going on, when I beheld the Mandan village all in flames (Chardon 1997:181)." Undeterred the Mandan and Arikara population rebuilt the village, renaming it NuuneeswatuuNu in the process (Wood 2003:1).

Sometime between 1838 and 1839 a compound was constructed adjacent to the north end of Fort Clark by Pierre Garreau, a French-Arikara trader at the post. The compound consisted of a large U-shaped palisade that enclosed a single earthlodge along with two scaffolds and several storage pits. Garreau had been an employee of the fort as a hunter and trader during much of the 1830's; by the end of the decade, however, he had become the fort's interpreter (Wood 2003:12).

In the 1840's, the volume of trade at Fort Clark began a serious decline that would eventually lead to its closing. The smallpox epidemic had irrevocably injured trade at the post. Not only had the epidemic killed thousands of individuals upon whom the fort depended on for furs and buffalo robes, many of the survivors eventually left the area serviced by Fort Clark. In 1845, when the Mandan and Hidatsa survivors established Like-A-Fishhook village the American Fur Company established Fort Berthold nearby-further limiting Fort Clark's trading potential. Additionally, in 1851 the Arikara at NuuneeswatuuNuu were afflicted by a cholera epidemic that killed an additional 300 (Williams 1998:248).

In 1850, Harvey, Primeau and Company, an opposition fur trading company established in 1845 by dissatisfied former employees of the American Fur Compay, founded Fort Primeau (named for Charles Primeau, a founding partner) at NuuneeswatuuNuu to establish trade with the local Mandan, Hidatsa, and Arikara in direct competition with American's Fort Clark (Sunder 1965:87). Little is known about the trading post though it was recorded in a sketch by William Hays in July 1860 (Wood 2003:13). In 1858, Fort Primeau was one of three forts operated by Clark, Primeau and Company- the direct descendant of Harvey, Primeau and Company- the others were Fort Atkinson and Fort William (Williams 1998:222).

While Fort Primeau was operated by the same general group of individuals, the corporate structure that managed the trading post went through numerous transformations. Between 1850 and 1860, Fort Primeau changed hands at least four times. Due to a lack of financial backing, Clark, Primeau and Company, was consolidated into the P. Chouteau, Jr. & Co. - the descendant of the Western Division of the American Fur Company in the spring of 1860.

Fort Clark's closure was announced on June 10, 1860. This was a result of the declining trade and the American Fur Company's desire to consolidate their stake in the region, having little or no competition from so-called opposition companies. The fort's remaining employees and goods were transported to Fort Berthold aboard the steamboats *Spread Eagle, Chippewa,* and *Key West* (Wood 2003:15). On June 3, 1862 the *Spread Eagle,* and with it Lewis Henry Morgan, stopped at the site of Fort Clark and NuuneeswatuuNuu to find both abandoned: "We reached the site of Fort Clark [...] to wood from the timber of the abandoned Fort and Arickaree village by its side (Morgan 1959:161)." The practice of taking wood from the abandoned fort and village for fuel was commonplace (Wood 2003:16), as the remains presented an ideal source of prepared lumber.

After the consolidation, Fort Primeau went disused until1861 when a fire that destroyed the southern portion of Fort Clark forced the Catholic missionaries that had taken up residence there to move operations (Hunt 2003:200; Williams 1998:245). In the end, Fort Primeau was abandoned when the inhabitants of NuuneeswatuuNuu left to join the remaining Mandan and Hidatsa at Fort Buford later that year taking any remaining trade opportunity with them.

History of the Archaeology at Fort Clark

The Fort Clark State Historic Site has been the subject of several investigations over the last century and a half. Successive investigations at the site have continued to yield more detailed information about the site.

The first investigation at the site was conducted by Lewis Henry Morgan on June 3rd and 4th of 1862, just a year following the site's final abandonment. Morgan's visit to the site was primarily intended as a refueling stop on the way to Fort Berthold as it was common practice to scavenge timber from abandoned structures for fuel on steamboat trips. During his brief stay at the site he made notes on the remains of the village, especially the size, construction, and layout of the remaining structures of Mandan-Arikara village. He suggests that at the time there were approximately 40 earthlodges still visible at the site, many more scaffolds, as well as numerous open cache pits, and other artifacts. He describes the construction of the earthlodges in detail, suggesting that they are approximately 40 feet (12.2 meters) in diameter, round with an opening at the apex of the roof, constructed on a wooden frame overlaid with mats and soil, with a large, central hearth. He suggests that each structure was divided into apartments that would be capable of accommodating several families – housing as many 2,400 inhabitants (Morgan 1862:161-2). While it is likely that other travelers visited the site after Morgan, little information is available in this regard. In 1881, Goran Alderin, a Swedish immigrant, built a small cabin near the site of Fort Clark as part of his family's homestead. Though the 1885 Dakota Territory Census suggests he was a farmer, the Fort Clark State Historic Site shows no evidence of ever being plowed or intensively cultivated. (North Dakota State University Institute for Regional Studies)

In 1906, Frank Kiebert surveyed the site on behalf of the State Historical Society of North Dakota. His survey resulted in the identification of 96 earthlodges, Fort Primeau, Fort Clark and Pierre Garreau's enclosure, a fortification ditch, two earthen dikes, and several trails (Dill 1990:26).

In 1931, the State Historical Society of North Dakota, recognizing the importance of the site, began a program of protection and preservation of the property. In 1938, the Civilian Conservation Corp constructed a pavilion at the site, between the remains of Fort Clark and Fort Primeau (Dill 1990:27).

Aside from Bower's work in 1929, which has been described as "incidental" (Dill 1990:27), and Will and Heceker's survey of sites in the region, which consisted primarily of surface collection (Wood 2003:15), the next archaeological endeavor at Fort Clark occurred in 1968.

In 1968, Wood and Lehmer conducted a survey of sixteen sites in the vicinity of the Knife River, including Fort Clark. The survey strategy included targeted excavation guided by coring in an effort to produce a large collection of diagnostic ceramics. To achieve this goal, excavation was conducted in areas interpreted as middens based on the results of the coring. Three 5-foot square units and one 11.5-foot by 3-foot trench were excavated. These excavations resulted in the identification of a large stone-lined hearth, one postmold, an unexcavated pit feature, and the burned remains of an earthlodge roof (Wood 2003:16-18).

Following Wood and Lehmer's work at the site, the State Historical Society of North Dakota began developing the site in an effort to make it more accessible to the public and researchers. Development involved creating facilities to house a site supervisor, a parking lot, fencing, and the drilling of a well (Dill 1990:27). At the same time it hired Dill as the site first supervisor to manage the site's archaeological remains (Ahler 2003:21).

During his brief tenure at the site (1973-5), Dill conducted two seasons of archaeological investigation between 1973-4. Dill excavated a total of 51 trenches on the remains of Fort Clark. The trenches were each three feet wide with varying lengths set at right angles to each other. Additionally, sixteen trenches were opened over the remains of Primeau's Post. These units were similarly designed as those at Fort Clark (Dill 1990:29-32). Finally, six excavation units were sited within the village: three 5 x 20 foot trenches, one 5 x 15 foot trench, one 5 x 5 foot square, and one 5 foot profile on an exposed bank (Ahler 2003:21).

Dill's excavations uncovered a wealth of evidence about the construction and layout of the Fort Clark trading post. Fort Clark was likely built upon a substantial stone foundation and consisted of at least seventeen interior rooms and structures. Additionally, Dill encountered several trenches associated with the construction of the fort. Information about the structure of Primeau's Post is somewhat limited as the excavations were terminated at a depth of about ten centimeters and backfilled due to concerns about preserving ceiling and floor boards that were uncovered (Dill 1990:31). Excavation within the village produced "leaners," structural support posts associated with earthlodge construction, in two units. These were left unexcavated and in one instance were covered with plastic prior to backfilling. Additionally, two postmolds and three pit features were uncovered (Ahler 2003:22).

During the 1985-6 field seasons, Wood returned to the site with O'Brien to conduct a surface survey of the site. The survey program involved collecting a series of aerial photographs during the1985 field season. Black and white, color, near-infrared, and color near-infrared photography of the site was collected. The aerial photography program resulted in the generation of a fifteen centimeters contour map of the northern half of the site, the area principally occupied by the village remains. The survey also involved the installation of three permanent benchmarks at the site. The benchmarks consist of a cylinder of concrete twenty centimeters in diameter and 1.3m in depth inlayed with a brass disc marking its coordinates relative to the site grid.

During the 1986 field season the aerial photography was augmented by an intensive surface survey conducted using a laser transit. The result of this survey and an analysis of the color-infrared, black and white, and infrared photographs was a detailed planimetric map of the entire site. This aspect of the survey identified more than 2,200 potential archaeological remains. These remains include: Fort Clark, Primeau's Post, 86 earthlodges, a fortification ditch, trails, two corrals, and more than 1,800 surface depressions of various sizes interpreted as cache pits, graves, and looters' pits (Wood 1993:550; Wood 2003:26-7).

Excavation of three areas was also carried out by Wood during the 1986 field season. Partial excavation of an earthlodge resulted in the identification of numerous postmolds, pits, middens, and earthlodge remains – including: wooden beams, a collapsed earthen roof, and a compacted, prepared floor. Excavation of a section of the fortification ditch resulted in the characterization of the ditch as a convex feature approximately 60 centimeters deep. A postmold, possibly associated with a palisade, was also uncovered during the excavation approximately three meters west of the ditch. In both excavations features appeared at a depth of twenty centimeters suggesting significant deposition in the intervening 120 years. Additional excavation at Primeau's Post revealed a burial and was abandoned. Wood and O'Brien also conducted a small-scale soil chemistry analysis of the two features usually identified as corrals, which revealed elevated levels of phosphates and organic carbon. The results of this investigation seem to support that interpretation for the west corral but are not as convincing for the east corral (Wood 2003:25–40).

In 2000, Paleo-Cultural Research Group (PCRG) and the State Historical Society of North Dakota undertook a program of remote sensing, coring, and limited excavation at the site. Kvamme conducted an extensive geophysical investigation of Fort Clark, Primeau's Post, Garreau's lodge and enclosure, the Euroamerican cemetery, and the village. Kvamme used a wide range of geophysical methods to investigate the presence of subsurface archaeological remains including: electrical resistivity (at both single and multiple depths), magnetic gradiometry, ground penetrating radar, electromagnetic conductivity, and magnetic susceptibility (Kvamme 2002:1). The results of these surveys indicated a wealth of archaeological features present within the study areas. Multiple surveys indicated the presence of structural remains of both trading posts, Garreau's lodge and enclosure, as well as numerous pits, middens, and other anomalies likely resulting from both modern and historic metal debris. Additionally, the magnetic and electrical resistivity surveys strongly suggest the presence of graves within the area of the Euroamerican cemetery defined by Wood (1993) (Kvamme 2002:36, 41).

Coring was conducted using a 1-inch Oakfield hand corer in an effort to investigate the results of Kvamme's (2002) geophysical survey. Based on the results of the geophysical survey, four twenty meter by twenty meter survey blocks were selected for detailed study. Three of the four were investigated using a systematic strategy of coring at one meter intervals. In the fourth block, coring was relegated only to locations identified as a result of the geophysical survey as likely locations of archaeological features. Coring resulted in the identification of a midden, sixteen pits, seven hearths, and four wooden posts. Additionally, twelve one meter by one meter test units were excavated; three within the village, two within Primeau's Post, and seven within Fort Clark. These excavations identified two middens, the roof and floor remains of one earthlodge, five trenches, and five postmolds. Additionally, a gravel layer was observed in one of the units (Ahler 2003:57).

Hunt conducted further excavation based on Kvamme's geophysical examination of the site in 2001. Excavation included numerous test pits located in and around Fort Clark as well as a large, 28 square meter unit at the western bastion of the fort. Excavation revealed numerous pit features, the remains of a wooden flagpole, large trenches associated with three episode of palisade building, and a stone foundation associated with the fort's western bastion (Kvamme 2002:5).

In 2004, Kvamme returned to Fort Clark with Tommy Hailey to conduct an aerial survey of the site. Survey was conducted from Hailey's powered parachute, a low and slow-flying aerial platform frequently used for aerial imaging (Hailey 2005). Two datasets were collected during this survey: digital color images and thermal infrared. The latter acquires data on heat energy, which is to be distinguished from the near-infrared imagery acquired by Wood (1993), which portrays plant health. Both datasets were collected at high resolution, producing a survey of the site with an effective resolution of ten to twenty centimeters per pixel. In the course of the survey, over 100 digital color still images and 74,000 thermal infrared images of the site were produced. Interpretation of these datasets had not been completed prior to this research, the results of which will be discussed in the following pages.

Although the Fort Clark State Historic Site has been preserved since 1931, it is by no means a static landscape. Numerous endeavors to improve access to the site and conduct research have inalterably changed it. Construction projects and excavations have likely had a significant impact on the archaeological remains at the site and may impact future attempts to conduct research as well. As the following research involves an examination of remotely sensed data, modern intrusions, such as pathways and roads, must be taken into account so they are not confused with potential archaeological data. It is important to recognize that excavation units made during the 1970s and cache pits excavated in the 1820s can be similar in character and an attempt to differentiate between the two should be made.

Discussion:

Historic accounts suggest that there may have been anywhere from 40 to 140 earthlodges at the village occupied at the same time (Morgan 1959:151; Denig 1961:59). To date, archaeological evidence suggests that the total number of earthlodges at the site is somewhat less than 100 (Dill 1990:26, 28; Wood 1993:550). However, it is likely that early earthlodges, particularly those built by the Mandan, are difficult to detect without a more comprehensive program of subsurface examination. Therefore, it is possible that over the course of the village's occupation there were more than 100 earthlodges constructed at the site. Yet, it is also possible that due to the labor and resource intensive nature of construction, early earthlodges were maintained and reused, limiting the necessity of new construction, except in cases of population expansion.

Previously conducted archaeological endeavors suggest a broad range of remains at the Fort Clark State Historic Site. Remains of earthlodges including timbers, burned earth, earthen berm rings, and postmolds appear to typify much of the northern half of the site. Additionally, numerous types of pit features, ranging from twenty centimeters to three meters in diameter appear commonly throughout the site, although they are most concentrated in the north half of it (Wood 2003:27). The southern half of the site is dominated by the remains of the Fort Clark trading post, Garreau's lodge and enclosure, a cemetery, and two corrals.

CHAPTER 2: THEORECTICAL BACKGROUND: COLOR AND THERMAL AERIAL IMAGERY

Many of the features in the Fort Clark State Historic Site uncovered by excavation are characterized by significant changes in the subsoil. Pit features, trails, and prepared earthen floors represent significant changes in soil density, as do berms resultant from roof sloughing surrounding earthlodges. The use of stone for foundations and wood for structural support suggest discrete changes in subsurface material type. The presence of organic matter such as manure in the corrals, or higher water retention rates due to densely packed earth, suggest the possibility of variation in vegetative growth. All of these factors point to significant disconformities within the soil that archaeological remote sensing may be able to detect though color and thermal infrared imagery.

The appearance of *in situ* features and artifacts as well as perishables indicates a high degree of preservation. That the site appears to have never been intensively cultivated and has been under the protection of the State Historical Society of North Dakota since the early 1930s, suggests a likelihood that archaeological remains have retained a significant degree of integrity. This assumption is clearly borne out by previous archaeological investigations. It is therefore reasonable to assume that some anomalies detected during an archaeological remote sensing project may be related to subsurface discontinuities associated with previous cultural activity.

As excavation is inherently limited by cost, time, and preservation concerns, remote sensing is an ideal mechanism for the examination of an entire site. Additionally, as the majority of the archaeological remains appear to be near-surface they are ideally situated to be detected by high resolution archaeological geophysics. Aerial remote sensing generally involves total site coverage that can be produced rapidly. The current research resulted in two datasets that cover the entirety of the Fort Clark State Historic Site at a resolution far in excess of what might reasonably be expected from a program of excavation within the space of a few hours and without impacting any of the archaeological remains.

Elements Detectable in Color Imagery

Archaeological work conducted at the site suggests that most of the archaeological remains at Fort Clark are situated within one to one and half meters of the surface. The original living surface, and therefore the upper terminus of most features, appears only twenty centimeters below ground level (Wood 2003:34–40). Many of the archaeological features at the site are substantial enough that they have significant enough surface expression to be recognizable. These surface expressions can be highly visible in color imagery under low sunlight angles, which produce shadows marks. Shadow marks form a primary means of archaeological detection from the air (Scollar et al. 1990:33-5). At Fort Clark, flights were timed for early morning, which enabled strong shadows to be cast over surface expressions of site features. However, geophysical investigations suggest there are a significant number of archaeological remains that have otherwise gone undetected and may be more deeply buried. Changes in soil type, compaction, and moisture content affect vegetation growth and variations in vegetation density and type are readily detectable in color imagery.

Shadow marks are generated by oblique light striking areas of slightly different elevation. Either light is obscured from an area on the side opposite from the sun of an elevation or cannot reach the bottom of a steep-sided or deep depression. The appearance of shadow marks is most clearly visible when light is most oblique – in the early morning or late evening. Changes in soil color can result from several conditions. Moisture tends to darken soil, so it might stand out in cases where soil is denser and more able to capture moisture than the surrounding matrix. Human activity may alter soil color for a number of reasons: soil mixture associated with digging through multiple strata, adding to the soil – human activity tends to add organic compounds to the soil, stripping away topsoil, burning, or the remains of structures. Additionally, changes in soil texture may affect the soil's appearance. Soil density, moisture retention, or inclusions in the soil may all affect the growth of vegetation. Dense soils, such as prepared floors, tend to retard the growth of plants, while moist soils promote growth. The presence of remains near the surface may also affect the growth of vegetation – for example, a kitchen midden rich in organic material may positively affect growth while an inclusion of structural remains such as brick would likely retard growth. Finally, snow or frost marks resultant from variation in either incidental solar radiation or soil temperature may indicate the presence of archaeological remains. In cases of incidental solar variation, snow/frost marks are analogous to shadow marks when the ground is obscured by snow. Otherwise, variation in the structure of the soil related to its thermal properties may indicate archaeological remains (Giardino and Haley 2006:57–60).

For the purposes of this research shadow marks and vegetation marks are the most useful means of identified anomalies. As the data were collected during the summer, snow/frost marks were not available for analysis. Additionally, as there is little, if any, exposed soil at the site, variations in soil color were not visible. As the data were collected during the morning and the site is, as a rule, flat, shadow marks were pronounced in the color still images. The thermal data were collected pre-dawn and therefore, shadow marks are not visible. Vegetation marks are useful in both data sets. Changes in the type and robustness of the vegetation are visible, and therefore useful, in the color imagery while the thermal effect of vegetation may comprise the fundamental aspect of thermal variation at the site.

Thermal Properties of Soil and Thermal Remote Sensing

All bodies with a temperature above absolute zero emit thermal radiation. As such, thermal radiation can be used to remotely detect temperatures of surface materials. Thermal radiation is detectable within two primary windows in the electromagnetic spectrum: 3-5 μm and 8-14 μm, both of which fall within the infrared bands (Scollar et al. 1990:610-1). Archaeological thermography measures variations in the soil's emission of thermal radiation in an effort to define discontinuities in the soil related to past cultural activity.

The transfer of heat through soil involves a complex system of interactions between solar radiation and variables in the soil. Factors such as moisture content, grain size, and compaction, among others, can drastically alter the flow and speed of heat energy. The affect of these factors on heat transfer can be characterized in terms of a few basic properties of soil: thermal conductivity, heat capacity, thermal diffusivity, and thermal inertia (Avery and Berlin 1992:123).

<u>Thermal Conductivity</u>:

Thermal conductivity is a measure of the speed at which heat moves through a material. It is formally defined in terms of calories transferred over one cubic centimeter in one second at a temperature gradient of one degree (Avery and Berlin 1992:122). The thermal conductivity of soil is largely dependent upon water content, porosity, grain size, and the inter-facial contact between particles (Lal and Shukla 2004:538-9; Jury and Horton 2004:181).

In most cases, the thermal conductivity of solids is greater than liquids, which have a greater conductivity than gases. This is largely the result of the degree of contact between the individual molecules. As the molecules of solids are the most tightly packed and "intimately" in contact with one another, solids have the greatest thermal conductivity (Jury and Horton 2004:181). However, in a granular material such as soil, the degree of contact between the individual grains is equally important. In this case, greater grain size, due to the increased surface contact, results in greater thermal conductivity. Inversely, decreased surface contact results in greater porosity, and likely air content. As air has an extremely low thermal conductivity, greater porosity generally results in lower conductivity. However, if the soil has access to water, greater porosity may result in a greater concentration of water, which has a lower thermal conductivity than solids and greater conductivity than air, and would result in an increases in overall thermal conductivity (Lal and Shukla 2004:539).

Heat Capacity:

Heat capacity is defined as the amount of energy required to increase the temperature of a quantity of material by one degree (Jury and Horton 2004:180). There are two types of heat capacity: gravimetric and volumetric heat capacity. Gravimetric heat capacity is a measure of the energy necessary to raise 1 Kg of soil by 1°, whereas volumetric heat capacity measures temperature change per cubic meter (Lal and Shukla 2004:523). As such, the primary difference between the two is the density of the material. Therefore gravimetric heat capacity can be converted to volumetric when multiplied by density (Kirkham and Powers 1972:463).

The heat capacity of a material is largely dependent upon the particle density of a material and its specific heat (Lal and Shukla 2004:538). Specific heat is defined as the ratio of a material's heat capacity to that of pure water (Kirkham and Powers 1972:463), which is effectively one (Lal and Shukla 2004:538). As soil is generally a mixture of numerous materials including water, air, organic compounds and minerals, its heat capacity is an average of its constituent components relative to their fraction of the whole (Jury and Horton 2004: 180). As the density of air is so small, its contribution is generally considered negligible (Lal and Shukla 2004:538). Due to the high heat capacity of water (Avery and Berlin 1992:122), heat capacity of soil increases almost linearly with water content (Jury and Horton 2004:184). Additionally, heat capacity can be used to define the ability of a material to retain heat, known as thermal storage. Thermal storage is defined as the density of a material multiplied by its heat capacity (Avery and Berlin 1992:122-3).

Heat capacity may influence the thermal remote sensing at Fort Clark. The site is characterized by numerous earthlodge depressions, which tend to accrue and hold moisture. As such, they should be expected to warm slowly throughout the day – likely remaining cool throughout much of the morning. The drier berms surrounding lodge depressions, on the other hand, will likely warm up quickly early in the day. Denser materials, such as stone and brick, require significantly more heat to raise their temperature significantly. However, because of their increased thermal storage, they are able to maintain that change in temperature longer. At Fort Clark, this suggests that stone foundations, once heated, should appear warmer throughout much of the day and night.

Thermal Diffusivity:

Thermal diffusivity is a measure of the speed at which a material transfers heat. As such, it is determined by the heat capacity and thermal conductivity of the material (Kirkham and Powers 1972:463). Thermal diffusivity is calculated by dividing the thermal conductivity of a material by its volumetric heat capacity. As both heat capacity and thermal conductivity are affected by water content, so, by necessity, is thermal diffusivity. Diffusivity increases with water content up to a critical level at which it decreases. This is due to the relationship that heat capacity and thermal conductivity has with water. While heat capacity increases with water content, thermal conductivity rises most quickly at low moisture content (Jury and Horton 2004:184). In other words, as the water content of a material increases the change in thermal conductivity becomes less significant.

Thermal Inertia:

Thermal inertia is a measure of a material's resistance to changes in temperature. A material that resists changes in temperature is said to exhibit greater thermal inertia. As such, materials that exhibit greater thermal inertia also exhibit low thermal conductivity and heat capacity (Avery and Berlin 1992:123). The thermal inertia of a material is calculated by dividing the thermal conductivity by the half-power of the thermal diffusivity (Scollar et. al. 1990:595). Due to the nature of air, dry and porous soils exhibit low thermal inertia (Avery and Berlin 1992:123-4). Additionally, because of a decrease in surface contact, fine-grained soils exhibit decreased thermal conductivity and therefore thermal inertia (Dabas and Tabbagh 2000:628). Soils with greater thermal inertia are less affected by short-term changes in thermal energy, such as the changes in incident radiation associated with the diurnal cycle (Avery and Berlin 1992:124; Jury and Horton 2004:528).

Thermal inertia is particularly relevant to thermal remote sensing at Fort Clark. As dense materials exhibit high thermal inertias, they can be expected to maintain a steady temperature throughout the day and night. This indicates that material such as stone and brick, materials used during construction of both trading posts, would likely appear warm regardless of the time of survey. Additionally, densely packed earthlodge floors, though made of soil, may also appear significantly warmer.

Other Factors:

Latitude, topography, and vegetation have an important role in determining the observable surface temperature of soil. Latitudinal variation, and therefore the angle of solar radiation, affects the amount of incidental solar radiation, though this is relevant only in very broad surveys. Variation in vegetation and topography, however, may result in greater temperature variation than could be produced by changes in the basic thermal properties discussed above. Topographic variation affects the soil's access to incidental solar radiation. East facing slopes warm up quickly in the morning and cool faster in evening. It can also affect the drainage of water as higher areas tend to drain moisture quickly, while depressions tend to capture it. While changes in moisture content have a dramatic effect on all of the thermal properties of soil, its greatest impact on thermal remote sensing is likely its promotion of vegetation. Evapotranspiration is the process by which vegetation transports moisture up its body where it is vaporized and released into the air. Therefore, areas of dense vegetation exhibit greater concentrations of moisture near the ground surface and generally appear cooler.

Fort Clark is characterized by earthlodge depressions surrounded by elevated berms. As moisture drains from the berms and is concentrated in the depressions, vegetative growth is accelerated in the depressions and retarded on the berms. Therefore, because of evaporative cooling and evapotranspiration, the densely vegetated depressions should appear cool while the elevated berms, characterized by a relative lack of vegetation, should appear warmer.

Discussion:

In an archaeological context, thermal variation is most valuable when measured across an area. However, due to the diurnal cycle of solar radiation, variation in surface temperature is strongly correlated with the time of day. As such, thermal variation across an area must be measured very quickly, simultaneously if possible, to avoid confusing temporal (diurnal) variation with spatial variation due to disconformities in the soil. As surface temperature can be measured remotely, an ideal solution to this obstacle is the adoption of an aerial platform.

Aerial thermography allows for the collection of large areas either simultaneously (from high altitude) or very quickly (from low altitude). However, there is a trade-off between altitude and spatial resolution. While high altitude data collection may result in greater spatial coverage, it likely also results in poorer spatial resolution. Low altitude data collection can produce data with greater spatial resolution but can only collect data on a small scale, and therefore is vulnerable to temporal variation, and may require greater data processing. An effective thermal investigation must balance concerns of resolution with collection speed.

Variation in soil properties directly related to past cultural interaction with the soil have a measurable effect on the soil's thermal properties and therefore surface temperature. In most archaeological contexts, however, thermal conductivity and diffusivity is largely irrelevant, as they relate specifically to the process of heat transfer. Thermal conductivity may only be pertinent in cases where a survey is conducted during a period of rapid temperature change, the morning after sunrise for example. As the air temperature increases, soils with increased thermal conductivity and diffusivity will likely heat up faster as the heat energy is transferred quickly to the soil. However, most archaeological surveys are conducted in either the late evening after sunset or early morning before sunrise to limit the impact of rapidly changing soil temperature and artificially cool anomalies produced by shadows. Variation in thermal inertia, thermal storage, topography, and vegetation account for the majority of observable thermal deviations associated with past cultural activity.

In 2004, Kvamme (2008) conducted a thermal investigation at Double Ditch, an earthlodge village similar to the Mandan-Arikara village at Fort Clark. Interpretation of the results of that survey provides a template for understanding the results of the current research. That survey was conducted in the evening. As expected, the prepared floors of earthlodges, which exhibit significantly more robust vegetation, appeared cool while the associated berms, with their lack of moisture and vegetation, appeared significantly warmer.

CHAPTER 3: METHODS

Project Goals

The project is designed to answer two primary questions: (1) Are there significant archaeological features at the Fort Clark State Historic Site that have not yet been detected; and (2) is thermal infrared an effective tool for archaeological remote sensing? To achieve these goals an aerial survey using color and thermal infrared imaging was undertaken at Fort Clark during the summer of 2004. The results of that survey are described and interpreted in the following chapters.

Background

Aerial photography became a tool of the archaeologist at least as early as 1880, although these early results were less than spectacular. The earliest successful aerial photographs taken for the purpose of archaeological interpretation were collected at Stonehenge from a hot-air balloon in 1906. During the 1920s, O. G. S. Crawford and Charles Lindberg popularized the method by taking pictures of archaeological sites in Britain and Mesoamerica. The earliest aerial remote sensing in the United State of America was conducted at Cahokia in 1921 (Reeves 1936:102; Giardino and Haley 2006:48). Archaeological remote sensing has since become a means for site identification and analysis. It offers the observer an opportunity to view an entire archaeological landscape simultaneously. While many archaeological features may be visible from the ground, relationships between them are best understood from an aerial vantage point. In a 1923 address, Crawford suggested aerial remote sensing had the ability to transform the "confused tangle" of archaeological features, if they are even visible at the surface, into a recognizable "orderly system" (Crawford 1923:342).

Methods

Dr. Kenneth Kvamme and JoAnn Kvamme of the University of Arkansas, and Dr. Tommy Hailey of Northwestern State University collected aerial imagery at the Fort Clark State Historic Site during the summer of 2004. Data collection was conducted using a powered parachute (PPC) (Figure 2).

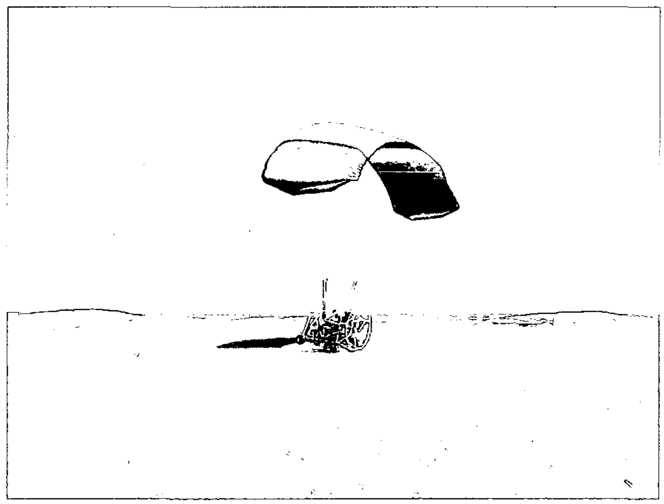

Figure 2: Dr. Tommy Hailey and JoAnn Kvamme conducting an aerial survey using a powered parachute (PPC) at the Double Ditch State Historic Site.

Aerial remote sensing requires a platform that can fly slowly and at low altitude to maximize the efficacy of the survey. Flying too quickly yields images with a significant amount of blurring while flying too high yields imagery with insufficient detail. As the PPC meets these requirements, it is ideally suited to archaeological remote sensing. Average cruising speed is approximately 50 kilometers per hour, but can be reduced to nearly a standstill by flying into the wind, which was done during the survey of Fort Clark. The PPC can fly at altitudes ranging from one meter above the ground to a maximum of 3,000 meters. Additionally, the PPC has the advantage of being a flexible platform. The PPC requires a short runway for landing and take-off, it is highly portable, easy to fly, and relatively inexpensive to operate (Hailey 2005). Aerial survey resulted in the collection of both digital color still images and thermal infrared digital video of the entire site.

Digital color still images were collected with a Minolta Dimage A2 eight megapixel camera. A total of 112 high resolution images were collected. Digital thermal infrared video was collected using a Raytheon Palm IR-250 thermal imager. The Palm IR-250 can record spectral variation in the seven to fourteen micron band with a sensitivity of 0.1° C. The data were recorded at a resolution of 320 x 240 pixels in eight-bit grayscale yielding 256 potential levels of thermal variation. The thermal data were ~~collected in the seven to fourteen micron band to maximize ground luminance without~~ direct measurement of air temperature (Scollar et. al 1990:610). A total of 28 minutes and 43 seconds of data were collected at a rate of 30 frames per second. The survey yielded a total of 51,690 frames of thermal infrared data.

Aerial survey was conducted over the course of a single morning. Flights were conducted at altitudes between 500 and 1,000 meters. Low altitude data collection yielded an average effective spatial resolution of about ten centimeters for the digital color still images and fifteen centimeters for the thermal infrared data. The thermal infrared data were collected before dawn in an effort to limit the impacts of rapid ground heating of eastern facing slopes after sunrise and cooler shadows that might create false anomalies. As such, the thermal data reflect only thermal variation related to physical variation at or near the ground surface. The color still images were collected throughout the morning after sunrise. Images collected during the low angle sunlight of early morning are sensitive to microtopographic variation highlighted by shadow, or shadow marks. While shadows are useful to indicate microterrain variation, large shadows from nearby trees can obscure important features. Images collected during the late morning are subject to fewer, shorter shadows potentially obscuring less of the ground surface.

Computer Methods

To accomplish the goals of the project, two image mosaics were created (see Appendix A and Appendix B). They entailed establishing a base map. To this end, Wood's (1993) interpretive map, published in *American Antiquity* and available at large scale from the State Historical Society of North Dakota, was scanned and resampled to an effective resolution of twenty centimeters per pixel (five pixels per meter). All subsequent data were resampled to this resolution. This was done in an effort to standardize the data as well as make the data manageable given computer data handling difficulties with large files, given the vast area of the state park.

The first stage in creating the image mosaics involved selecting imagery that was suitable for the project. Color still images were selected based on the degree of image distortion (obliqueness) and resolution (dependant on altitude). As the images were collected somewhat off-vertical, they all exhibit a degree of distortion. Additionally, color imagery was inevitably collected at multiple altitudes in order to cover the entire site. As the resolution of the camera is fixed, ground resolution is determined by altitude such that lower altitude yields greater detail. In general, color images were selected for greatest clarity at the highest resolution. Thermal infrared imagery was also selected based on the degree of image blurring as well as resolution, however. In these data image blurring affected a large portion of the data because video capture is much slower than the shutter speed of the digital camera, and even with the slow speed of the PPC blurring did occur. As such, thermal infrared imagery was selected by examining the digital video at ultra-low speed in an effort to capture individual frames that exhibited a minimum of blurring.

The first image mosaic of the site was constructed based on Wood's (1993) interpretive site map using the color still images. In other words, Wood base map was the foundation against which all imagery was rectified and registered. To accomplish this goal a comparison between GIS methods of rectification and registration – the standard approach – was made against Adobe Photoshop, which offers many tools that are quicker and easier to use. A color still image was manually rectified and registered using Adobe Photoshop. The same image was then also rectified and registered to the base map in ESRI ArcGIS using a second-order polynomial orthorectification algorithm with 22 registration points.

Registration conducted with Photoshop was completed in approximately 30 minutes while in ArcGIS it took just over an hour. The results of the two endeavors were nearly identical (Figure 3). While there is a significant decrease in the efficiency of the GIS-based image registration process, there may be several advantages to this approach. The GIS-based fit is determined by polynomial functions that are mathematically consistent and replicable with quantifiable error. As such, it may be less vulnerable to user error, while in Photoshop an image is warped and distorted manually until a good "fit" is subjectively judged. Additionally, a GIS allows for easy geo-registration and offers an array of analytical tools. However, while a GIS-based algorithm may be more internally consistent, it still relies on a subjective process of establishing ground control points (GCP). The distribution of GCP has a profound effect on the quality of high-order polynomial rubber sheeting. Poor fits are distinctly likely which requires an iterative process that reevaluates each GCP. Additionally, determining the quality of the fit is still largely a visual and subjective process. As such, it can be as subjective as registering imagery based on manual manipulation and distortion. As any image file can easily be imported into a GIS, its analytical tools are easily accessible to Photoshop generated imagery. Additionally, Adobe Photoshop offers a range of image editing tools and filters that facilitate color and contrast manipulation and cropping. For the purposes of this research, the efficiency and rapidity of Adobe Photoshop made it the system of choice for registering the imagery.

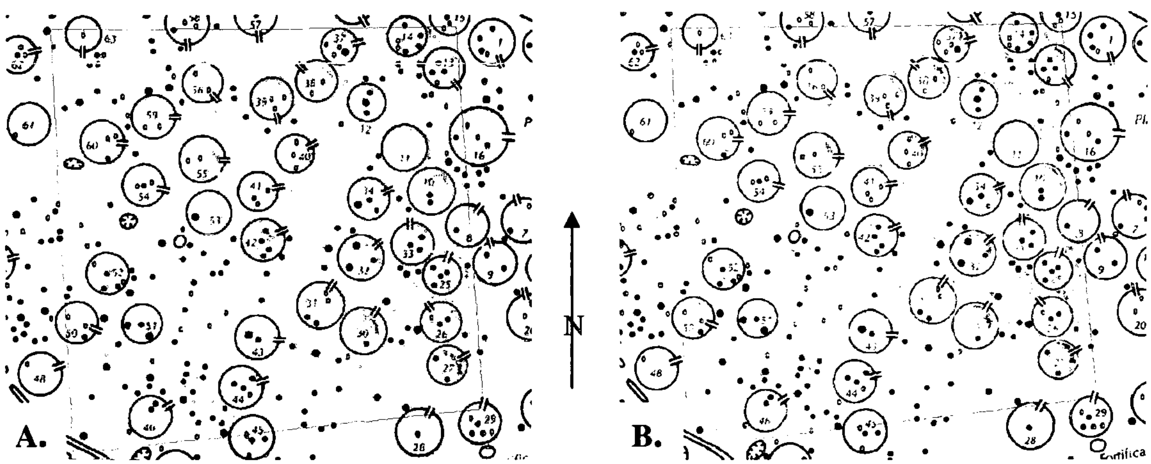

Figure 3: A) Image registered and rectified to Wood's interpretive map using ArcGIS. B) Image registered manually using Adobe Photoshop. Images are nearly identical. (Interpretive map courtesy of the State Historical Society of North Dakota)

Individual images were imported into Adobe Photoshop and manually manipulated to fit the base map (Figure 4). Manipulation consisted of resizing the images as well as warping or stretching the image. This was accomplished by "pulling" or "pushing" image corners and sides until image features closely matched map elements. With each push or pull Adobe performs a linear contraction or expansion of the data. Images were thus rectified and registered based on the perceived match between anomalies apparent in the imagery and the features recorded on Wood's map. Due to the lack of imagery of sufficient resolution or clarity in the southern portion of the site, only the area of the site north of the railroad was completed. The thermal infrared imagery was registered to a combination of features in Wood's base map and the color still image mosaic in the same fashion.

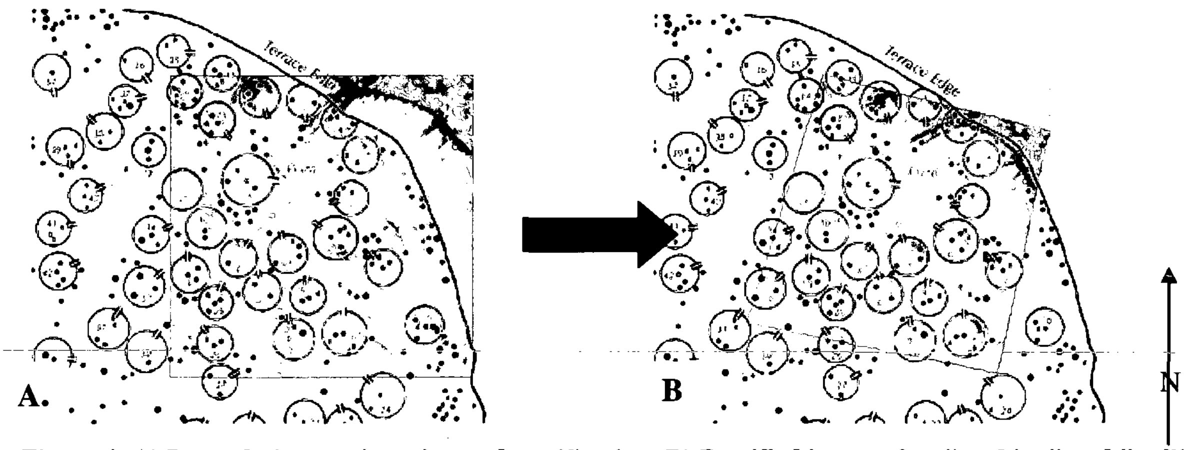

Figure 4: A) Image before registration and rectification; B) Rectified image after "pushing" and "pulling" in Adobe Photoshop registered to Wood's interpretive site map (Interpretive map courtesy of the State Historical Society of North Dakota)

Following registration, both mosaics were manipulated in an effort to emphasize contrasts associated with potential archaeological features. Adjustments were made to the color mosaic to increase contrast, the difference between the lightest and darkest color value, saturation, the intensity of the color, and brightness. These procedures were chosen to amplify existing variations in the data while modifying the actual data as little as possible. Again, a similar procedure was conducted for the thermal infrared data except that saturation was not necessary as the images are in grayscale.

Interpretation

As with any remote sensing project, the archaeological value of the research is wholly dependent on the interpretation of the results. A method for interpreting remotely sensed data relies on an understanding of apparent phenomena associated with archaeological remains. As such, aerial imagery can be interpreted by an examination of shadow, variation in soil color, crop/vegetation marks, and snow/frost marks, as discussed in an earlier section (Giardino and Haley 2006:57), of which only some are applicable at Fort Clark.

Fundamental to interpretation is the understanding that the remains of human existence are generally different than those that exist in a nature. Human construction exhibits numerous characteristics that can be used to distinguish it from naturally occurring phenomena. These phenomena can be examined by employing the long standing principles of pattern recognition used in aerial photo interpretation: shape, systematic repetition, size, association, and context (Kvamme 2006:3-9).

As a rule, geometric shapes are the product of human construction. Additionally, human construction possesses discrete boundaries while natural phenomena rarely posses these characteristics. Naturally occurring phenomena generally exhibit irregular shapes with gradated boundaries. Therefore, it is reasonable to assume that when a regular shape (e. g. squares or circles) with discrete boundaries appears on a landscape it is likely the result of human interaction (Kvamme 2006:3-5).

While natural phenomena exhibit irregular distribution, human construction is often systematically distributed. As such, cultural interaction with the landscape may be visible as repetition of features in an organized pattern. City streets, for example, are visible as lineations repeated at regular intervals while no such analogue exists in nature. Therefore, anomalies that appear repeatedly across a landscape in an apparently organized manner are likely of human rather than natural origin.

The size of an anomaly may also provide a means for interpretation. An understanding of the likely size of structures may be useful when attempting to ascribe an anomaly to an archaeological feature class. For example, a structure that is ten meters in width may be a dwelling while one that is only two meters across probably is not. Examining the relative size of these features may also prove a profitable means of analysis. The function or importance of buildings whose size is well outside of what is typical may be inferred by this discrepancy. A building that is conspicuously larger than other dwellings may have communal, rather than individual, function.

Association, or the relationship between anomalies, may suggest potential interpretations. For example, hearths usually appear inside dwellings, while dwellings usually appear within fortifications. As such, the specific relationships between apparent anomalies may provide a means for discerning any archaeological provenance. Additionally, the context of anomalies may be beneficial. The relationship between archaeological sites and the environment, or context, may prove a beneficial avenue for identifying potential archaeological remains. For example, archaeological sites generally do not occur on steep slopes or at the bottom of contemporary river beds (Kvamme 2006:7-9).

Additionally, the wealth of ethnographic and pictorial data on the site and its inhabitants provides an excellent source for the interpretation by detailing the types of construction that were present during the occupation of the site. However, this record, like all archaeological records, should be viewed as incomplete and not influence the interpretation to the exclusion of interpretations not included in the written record. This record, discussed in chapter one, should instead be used to inform the interpretation of anomalies identified as likely archaeological features based on the previously discussed criteria.

Interpretive maps of each dataset were generated using Adobe Photoshop. Maps indicate the plan of archaeological features visible in the data. Finally, each interpretive map was merged in to a master interpretive map showing all of the features identified in each dataset registered onto the master coordinate grid for the site.

CHAPTER 4: INTERPREATION OF COLOR AERIAL IMAGERY

The color aerial imagery was assembled into a mosaic covering the northern half of the site using the methods described in the previous chapter. This mosaic includes 72 images, covers approximately 25 hectares, and required nearly 50 hours to complete. The mosaic was examined almost pixel-by-pixel for any evidence of possible cultural features utilizing methods discussed in the previous chapter. Interpretations were "drawn" or digitized in Adobe Photoshop in multiple layers according to specific types of cultural features. The following sections describe each feature type and the evidence for it in the color imagery.

Earthlodges

The primary feature indicative of an earthlodge village is, not entirely surprisingly, the earthlodge. Earthlodges dominate the northern and western portions of the site. They were the primary structure type used by both the Mandan and Arikara for habitation, social, and religious functions. Typical earthlodges constructed during the occupation of the site were circular structures measuring approximately ten to fifteen meters across and upwards of three meters tall (Figure 5). Lodges were circular dwellings separated into smaller living areas radiating outward from the central hearth (Morgan1965: 135). Ethnohistoric evidence suggests that these structures were intended for multiple families and that as many as nineteen individuals occupied a single earthlodge at a similar village (Smith 1972:28). They consisted of a large wooden frame, covered with a layer of woven mats and an exterior layer of soil (Morgan 1965:134).

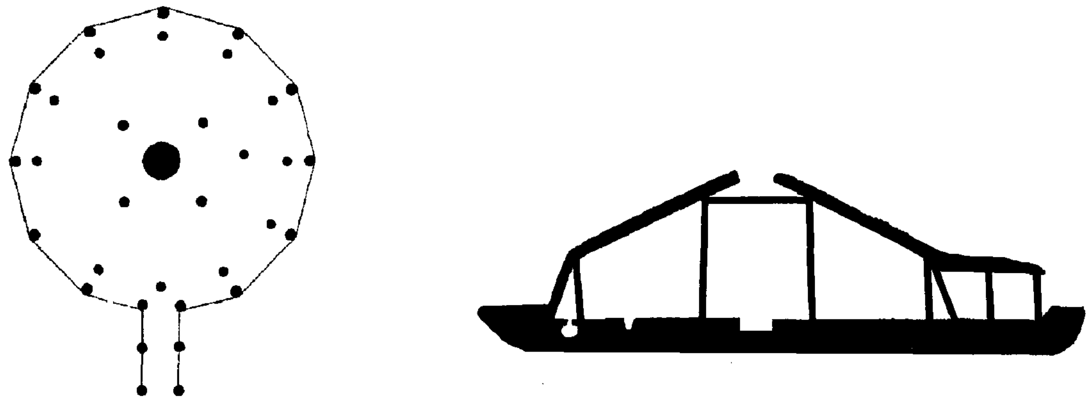

Figure 5: Plan and profile view of an earthlodge at Fort Clark drawn my Lewis Henry Morgan after his visit to the abandoned village in 1862 (after Morgan 1965)

A thorough examination of earthlodge distributions at Fort Clark provides evidence potentially important for further study of demography and social organization. The number of earthlodges at the site provides a measure of the number of occupants at the site. As the site was occupied for a short period of time (38 years), the number of lodges may provide a highly accurate indicator of population. Additionally, the distribution of earthlodges may provide insight into social organization of the village. For example, at the northeast edge of the village several earthlodges are arranged around an open plaza with a large earthlodge at its center. The odd configuration reflects social and religious circumstances. The central lodge is identified as a ceremonial lodge constructed by the Arikara sometime after the Mandan abandoned the site in 1837 as a result of the decimating smallpox epidemic (Ahler 2003:8). The lodge was placed in the center of what had been the Mandan ceremonial plaza. Additionally, the residents of the lodges immediately adjacent to the plaza were likely members of the highest levels of the Mandan political, religious, and social hierarchy.

Previous archaeological surveys at the site indicate the presence of numerous earthlodges at the site. During the 1985 – 1986 field seasons, Wood (1993) mapped 86 earthlodges, including Pierre Garreau's. The majority of these lodges (69) appear within the fortification ditch. Kvamme's (2002) geophysical survey of an east-west transect across the central portion of the village indicates the presence 27 earthlodges, including some not mapped by Wood.

Visibility of earthlodge evidence in the color imagery is attributable to two primary lines of evidence: shadow marks and differential vegetative growth (Figure 6). As discussed in an earlier section, changes in elevation can cause shadows cast by oblique light. As the data were collected during the early morning, oblique light causing shadows on the western edge of the features indicate elevated berms surrounding most lodges and surface depressions within the lodges. Additionally, changes in vegetative growth also appear to indicate the presence of elevated berms. Elevated, loose soils – such as those that could be reasonably expected to be resultant from soil falling or washing into a pile at the base of a structure – tend to drain moisture quickly. Additionally, the dense soil associated with an earthlodge's prepared floor provides a moisture trap. Therefore, vegetation is likely to be robust in the moist depressions at the center of the features while vegetation growing on the berms is likely to be stunted. Differential vegetative growth appears in the imagery as changes in color such that the central depressions exhibit a verdant green while the associated berms appear browner in color.

An examination of the color imagery indicates the presence of as many as 104 earthlodges. Eighty-six of them are clearly apparent in the data and can be identified with a reasonable level of confidence. Eighty-one of these lodges correspond with the 86 mapped by Wood (1993). The remaining eighteen earthlodges are suggested in the data but their expression in the data is not clear enough to be considered definitive. Shadows from tall trees along the edge of the site obscure much of the potential data within approximately ten to fifteen meters along the site's eastern periphery. In these areas some lodges are suggested by small areas that appear to exhibit surface expression consistent with a section of an earthlodge. Other possible lodges lie in an area on the western edge of the village where the data are not as clear as other areas of the site, due in large part to longer, unmowed vegetation.

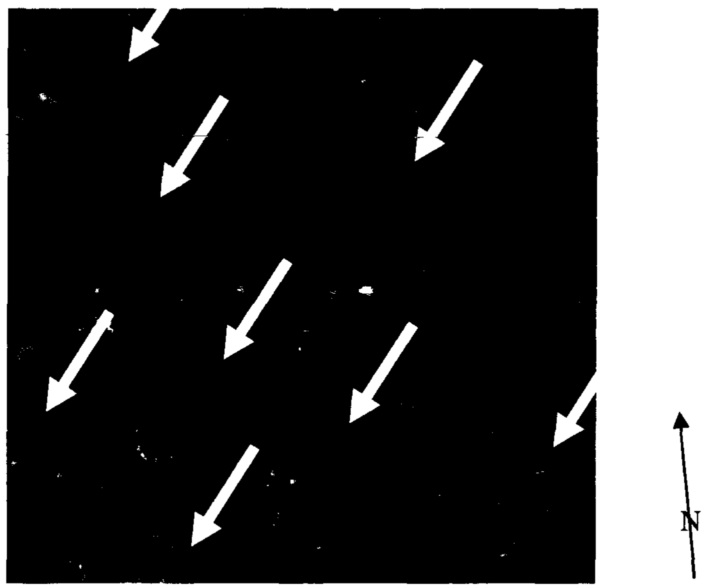

Figure 6: Arrows indicate earthlodge depressions visible in the aerial color imagery (Appendix A). The larger earthlodge in the upper right is the Arikara ceremonial lodge constructed sometime after 1838. The arrows follow the direction of sunlight. (Image is approximately 60 meters across)

Earthlodge Features

Anomalies associated with earthlodges may be more thoroughly analyzed and confidently interpreted based on ethnohistoric and ethnographic accounts. Descriptions of earthlodges include a number of associated feature types including storage pits and hearths. Storage pits were used to store goods and food, particularly corn. While many were located outside of earthlodges, some – probably those that held items of particular value – were located within dwellings near the perimeter. Though storage pits varied in size, ethnohistoric evidence suggests that large pits may have been nearly two meters in diameter and two meters deep. During Wood's (1993) mapping survey he identified more than 1,800 surface depressions that indicate the presence of pit features. Additionally, Wood mapped the entrances to 44 earthlodges. Entrances to earthlodges were built like corridors extending outward from the structure approximately three meters. Wood's interpretive map (1993) suggests that entrances typically faced the central ceremonial plaza.

An analysis of color aerial anomalies associated with earthlodges suggests that the vast majority of pit features are likely storage pits, which appear in the data as surface depressions visible as shadow marks. As oblique light interacts with the change in elevation, areas of low elevation, such as the bottom of depressions, is obscured by shadow. Curiously, a number of pit features are located at the centers of apparent earthlodges, which are known to be the locus of hearths. Of the more than 600 pit features identified, at least fifteen occur at the centers of lodges. Although hearths were basin shaped pits excavated to a depth of up to thirty centimeters (Morgan 1965:135), they are typically filled with ash and charcoal and probably do not form surface depressions. It is possible that some of these depressions may represent hearths; however it is more likely that they represent the loci of looters' holes, which are often placed preferentially in the center of earthlodges (Figure 7).

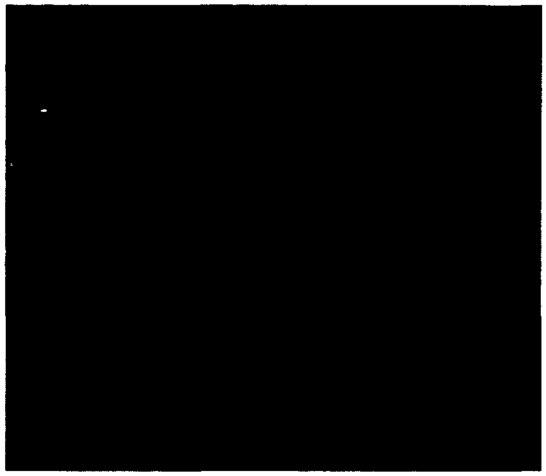

Figure 7: Arrow indicates a surface depression located in the center of an earthlodge. Depression likely indicates the locus of a looters' hole. (Image is approximately 30 meters across)

Entrances to earthlodges appear in the data as gaps in the elevated earthen berms that surround most earthlodges. These gaps are evident as shadow marks and, in some cases, variations in vegetation. Gaps in earthen berms were probably created as soil fell off of the roofs and was deflected by the entrance structure, leaving these areas subject to significantly less deposition. Additionally, entrances were likely somewhat compacted - if not by design then by continued usage. As such, they may exhibit surface depressions. Changes in vegetation are likely the result of differential drainage that characterizes earthlodges in general. Moisture drains quickly from higher elevations and tends to collect in depressions. An examination of the data suggests that 30 entryways may be indicated in the data (Figure 8). Twenty of them are clearly evident and may be interpreted confidently. The expression of the remaining ten anomalies is somewhat less clear. The orientation of entryways appears to generally agree with Wood's (1993) observation.

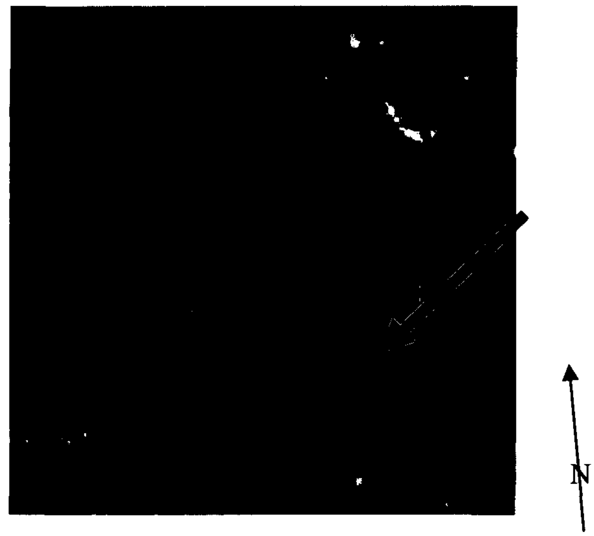

Figure 8: Arrow indicates an entryway visible as a gap in the berm surrounding the earthlodge depression. (Image is approximately 25 meters across)

Fortifications

The fortification system at the village consisted of a wooden palisade outside of a shallow ditch, a somewhat unique configuration when compared to similar fortified villages where palisades uniformly occur along the inside edges of fortification ditches (Wood 2003:38). The stockade, of course, provided a wall between aggressors and the village. The ditch would have been used as a place for defenders to crouch, thus limiting their exposure to aggressor attacks, while firing. Ethnohistoric evidence suggests that the fortifications surrounded the village and had several bastions constructed by the Euroamerican fur traders in an effort to help the village occupants protect themselves from the Sioux, with whom they were in near constant conflict (Ahler 2003:6).

Wood (1993) mapped the western section of the fortification ditch. He suggests that there was insufficient visible surface expression of the feature to map the entirety of the ditch. Instead he suggests the course that the ditch may be expected to follow east around the "bottom" of the village.

The remains of the stockade are either invisible in the data or indistinguishable from the associated ditch. The ditch appears in the imagery as the product of shadow marking (Figure 9). It appears as though the sides of the fortification ditch are simply too steep to allow the oblique morning light to reach the bottom, producing a thin line of shadow that effectively traces the center line of the ditch. Additionally, the west side of the ditch (that which directly faces the direction of sunlight) appears significantly brighter than the surrounding area due to the increased amount of light striking the surface. The ditch is therefore delineated as a band of shadow bounded on the western edge by a band of brighter soil and vegetation.

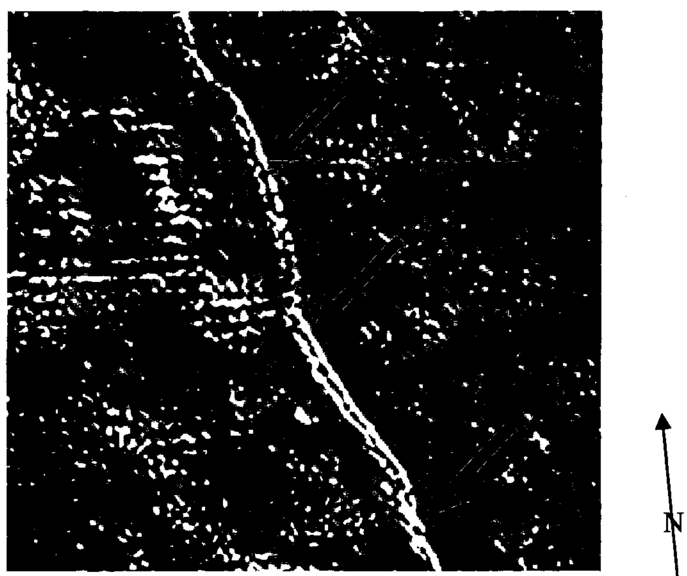

Figure 9: Arrows indicate a section of the defensive ditch on the western periphery of the village core. (Image is approximately 55 meters across)

The village's fortification system apparently consists of a long, shallow ditch that borders the village on the southern and western sides. The ditch appears to enter the site near the northwest corner of the village, encircle the majority of the village core and exits just north of Primeau's Post. It is logical that a fortification would surround the area that it was designed to protect. As such, we would expect the remains of the fortification ditch to surround the remains of the village as defined by the extent of the earthlodge distribution. However, there are nineteen earthlodges outside of the ditch. These have been interpreted as being the product of the later Arikara occupation of the site (Ahler 2003:6-8). The ditch was originally built by the Mandan when the site was founded in 1822 and likely protected the entire village as it stood at that time. When the Arikara took control of the village in winter of 1837-8, it is possible that the village was too small to accommodate their population. Although the village expanded, the majority of it was still protected by the fortification ditch and palisade. This circumstance together with the presence of the nearby trading post probably made a new fortification system unnecessary.

That the ditch is only present on the southern and western sides of the village is easily understood. The course of the Missouri River in the nineteenth century bordered the village on the north and east. The river and the steep bluff edge formed a natural defense. This defensive set-up is common throughout the entire Middle Missouri sub-area of the Plains Village Tradition. The river and associated terrace formed one leg of a defensive network that was continued by palisades and ditches on the sides facing the surrounding plains.

A section of the ditch at the southern edge of the village is not identifiable in the color imagery (Figure 10). Although this could mark a potential entrance to the village it is unlikely as other features commonly associated with an entrance point are not present. Trails should be expected to be associated with an entrance. While there are significant remains of trails at the site, none appear to lead to this section of ditch. It is therefore more likely that some other process is likely responsible for obscuring this feature. As the ditch's visibility largely owes to shadow marks it is possible that the orientation of the feature parallel to the direction of the sunlight creates a condition where there is insufficient surface expression to create the necessary shadow. If the sunlight is simply running down the center of the ditch it would not meet with a change in elevation necessary to create a shadow mark, essentially rendering the feature invisible. However, other areas of the ditch appear to exhibit the same basic orientation but are visible in the data. These other areas are, by and large, more subtly reflected in the data and likely only exhibit shadow marks due to their curving more obliquely to the path of sunlight.

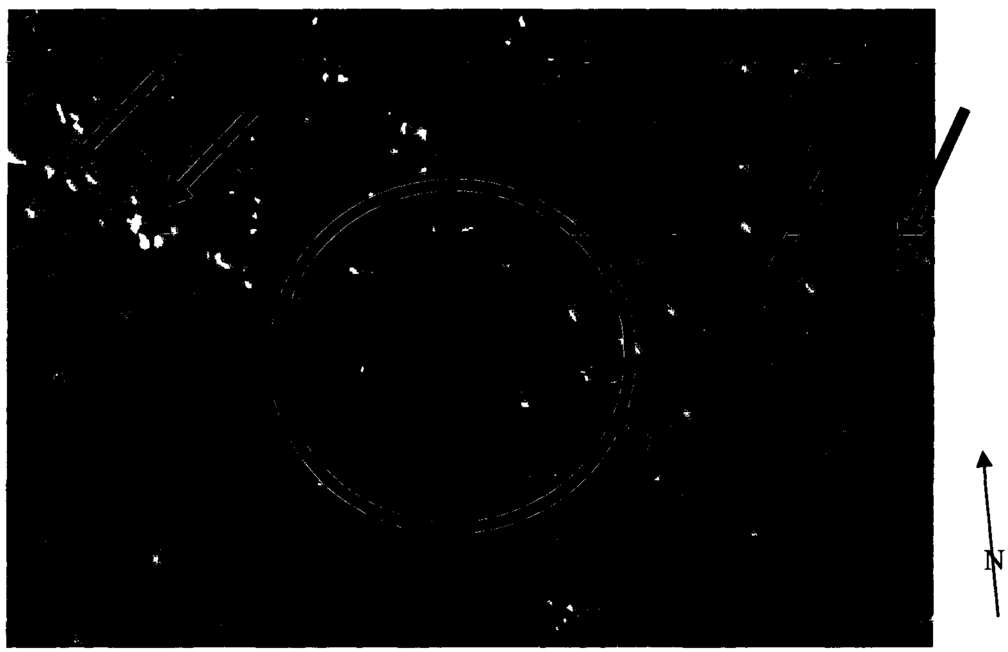

Figure 10: Arrows indicate apparent sections of the fortification ditch. "Missing" section (circle) may be the result of the angle of the ditch being parallel to the direction of sunlight. (Image is approximately 80 meters across)

There are, of course, alternate explanations to this phenomenon. It is possible that modern activity disturbed the soil at this location effectively destroying the feature's remains. However, as the site has never been used for intensive agricultural purposes and has been under the ownership and protection of the State Historical Society of North Dakota since 1931, this explanation appears somewhat unlikely (Dill 1990:27).

Borrow Pits

Borrow pits are the remains of areas where earth is removed for another use. For example, excavated soil was necessary for the construction of earthlodges. As there appear to be nearly 100 earthlodges at the site, numerous borrow pits were likely necessary. However, borrow pits may be ephemeral features depending on the duration of their use and the amount of soil removed. Borrow pits at the site appear most concentrated at the southern edge of the site, on the outside edge of the fortification ditch – likely because open pits inside of the primary village would be hazardous or simply use valuable space behind the fortifications. Wood (1993) mapped 39 borrow pits, all of which exist outside of the fortification ditch. An alternative explanation is that some of the depression interpreted as earthlodges may, indeed, have been borrows. Kvamme and Ahler (2007) give much evidence of this phenomenon at the Double Ditch site, also in North Dakota.

The depressed center of any pit forms a moisture trap, as water tends to travel downhill. Therefore, borrow pits are identifiable by stronger vegetative growth indicated by changes in color: lush green centers bounded by brown areas outside of the pits. Shadow marks are not strongly apparent in this instance as borrow pits are too shallow to produce enough of an impediment to sunlight (Figure 11).

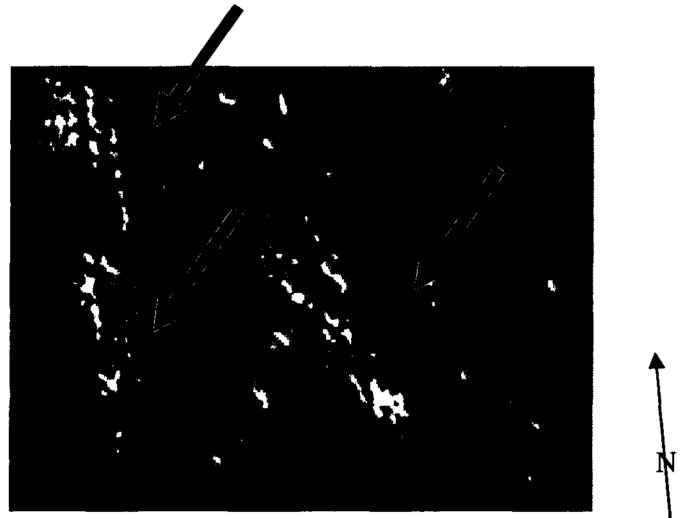

Figure 11: Arrows indicate borrow pits identifiable by their lush vegetation and lack of uniform borders. (Image is approximately 40 meters across)

Fifteen borrows are clearly identifiable in the color imagery, all of which are located outside of the fortification ditch. A potential sixteenth borrow pit is visible inside the fortification ditch. This pit is approximately the same size and shape of an earthlodge. While it is possible that this anomaly may be the remains of an earthlodge, it lacks the discrete elevated berm indicative of earthlodges.

Trails

Trails dominate the landscape south and northwest of the village outside of its fortifications. Wood's (1993) interpretive map suggests the presence of nine separate trails. Trails are formed as individuals traverse the same paths repeatedly. As a result, soil becomes increasingly compacted with use. As soils become more compact they take up less space, forming depressions. As such, trails are often visible in the data as shadow marks. However, it is unlikely that all pathways were used extensively enough that they exhibit sufficient variation in soil density to have an appreciable effect. As such, major trails are likely the only ones that appear in the data (Figure 12).

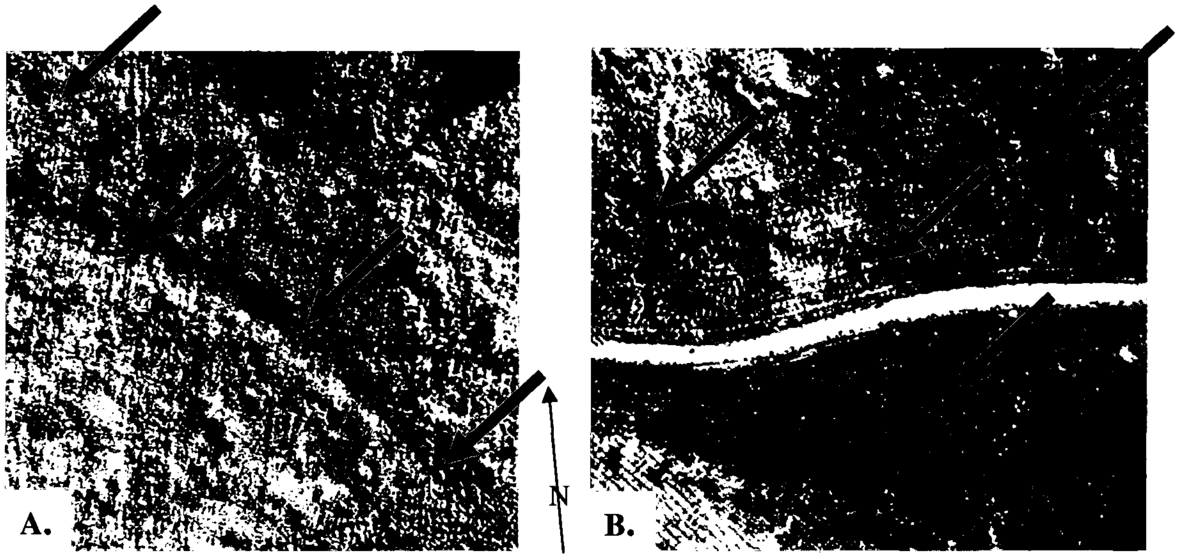

Figure 12: Arrows indicate potential trails. A) A major trail connecting the Mandan/Arikara village at Fort Clark with Deapolis (32ME5), another nearby Mandan village. B) Smaller trails south of the village core likely lead to Fort Clark and nearby activity areas. (Images are approximately 120 meters and 85 meters across, respectively)

Two major trail networks are visible in the data with one trail connecting the two networks. The western trail network consolidates into a broad trail that leads to Deapolis, a Mandan village that formerly existed a few miles north of Fort Clark. The southern trail network remains largely dispersed and likely leads to local activity areas – river access, pony corrals, and the Euroamerican, Mandan, and Arikara cemeteries. These trails also probably lead to Fort Clark and the fort's mooring site.

All of the trails terminate at or near the fortification ditch. That the trails terminate at two regions of the fortification ditch may suggest that there were at least two major entry points. The trails however, spread out as they reach the ditch suggesting that, if each trail indicates an individual entry point into the village, the fortifications at the site were extremely permeable.

Storage Pits, Post Molds, Hearths, Graves, and Looters' Holes

Small depressions are the most common feature at the site. Many of these features can be interpreted as storage pits. The surface expression of these features as depressions results from the slow infill of soil over time from pit collapse and deposition of sediment. As such, there is less soil in these areas than the surrounding matrix and the fill becomes compacted during precipitation events. The soil within may be less densely compacted than the surrounding matrix. Pits are visible in the data as small circular shadow marks (Figure 13). The change in density and elevation likely results in more robust growth of vegetation; however, shadows cover the areas that would be expected to exhibit this phenomenon making the changes in vegetation difficult to detect.

Figure 13: Arrows indicate potential pit features visible as small depressions on the surface. Pits were likely excavated for storing goods, particularly maize, or by modern looters looking for artifacts. (Image is approximately 35 meters across)

Wood (1993) mapped more than 1,800 depressions he interpreted as pit features. Wood does not attempt to determine the function of the pit features nor does he attempt to differentiate between the different types of pits (apart from borrow pits). Kvamme's (2000) partial geophysical survey indicates numerous potential pit features in the earthlodge village.

A total of 616 potential pit features were identified during the analysis of the color imagery. The majority of these features are likely indications of storage pits or looters' holes. Storage pits are common features of the cultural landscape. Storage pits were located in all areas of the village and were probably used to store many different types of goods, though maize was by far the most common. Other feature types that may be indicated by apparent pit features include post molds, hearths, and graves. Post molds may be evident as small pit features; however, most post molds were likely too small to impact the soil enough to produce pronounced depressions visible in the imagery. Hearths, as has already been discussed, although excavated into earthlodge floors, are unlikely to exhibit surface expressions. The fifteen surface depressions centrally located within earthlodges probably represent looters' holes. Fifty depressions are visible in an area that ethnohistoric data indicate was used as a cemetery for the Euroamerican fur traders and it has been mapped as such by Wood (1993). Most of these depressions likely result from burials (Figure 14).

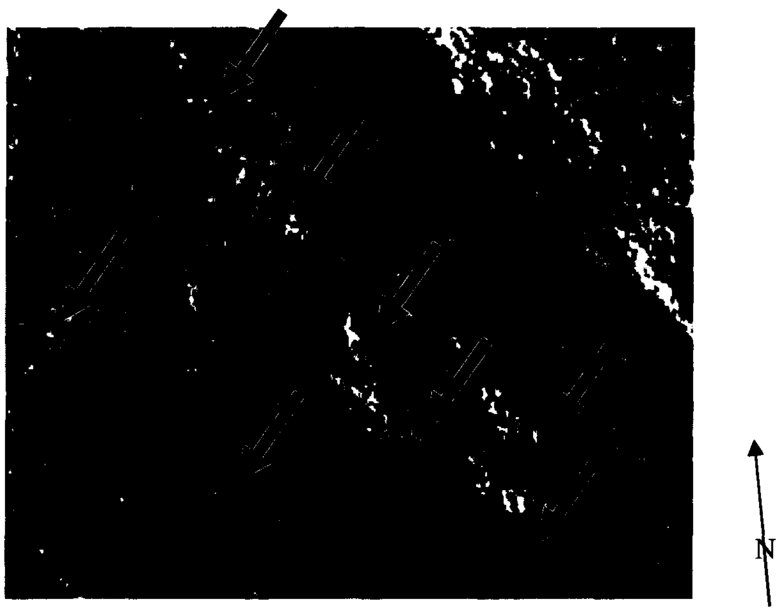

Figure 14: Arrows indicate surface depressions south of Fort Clark. As this area is known to have been the location of the Euroamerican cemetery, these depressions likely represent graves. (Image is approximately 60 meters across)

Corrals

Two large structures dominate the color imagery from the southern periphery of the site (Appendix A). These structures are characterized by slightly elevated earthen berms that encircle a flat, featureless area (Figure 15). According to Wood (1993), the berms are likely not intentional constructions. The areas were likely surrounded by a wooden fence or piled brush instead of a low earthen border. The berms are probably the result of aeolian soil deposition. As wind blew across the landscape, any soil grains carried in the wind were deposited when it struck the barrier. Over time, soil deposits grew, creating an elevated area at the base of the "fence."

Corrals are manifested as variations in elevation and are visible in the data as shadow marks delineating the base of the original construction. The southern portion of each of these features is not visible in the data, probably a result of the mowing pattern at the site when the data were collected. There is also a broad change in vegetation that covers the southern half of the site that begins at the location of the southern termination of these features which may also help to obscure their full extent.

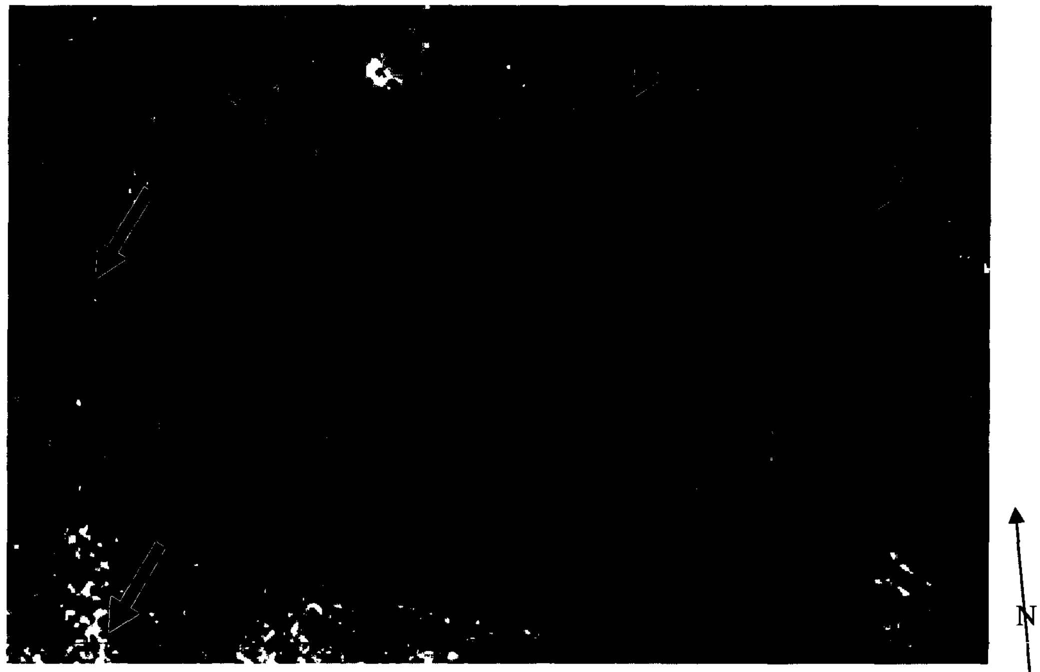

Figure 15: Arrows indicate the berm of the eastern corral. The berm is likely the result of soil being deposited by the wind as it ran into some type of standing barrier, probably used to fence in ponies. (Image is approximately 80 meters across)

Ethnohistoric data from Fort Clark do not indicate what the original use of these structures may have been. However, a similar structure was constructed by the Arikara at Like-A-Fishhook Village for use as a pony corral. Additionally, during Wood's (1993:552) mapping survey, he conducted soil chemistry tests of these features. Tests indicated that extremely elevated levels of phosphorus and organic carbon were present in the eastern enclosure indicating animal waste. The western enclosure did not show significant variation in its chemical profile. As Native Americans did not fertilize their gardens, this supports the interpretation of the eastern feature as an Arikara pony corral while the data relevant to the western structure is inconclusive.

Garreau's Enclosure

In the winter of 1838 – 1839 the interpreter and sometimes trader at Fort Clark, Pierre Garreau, constructed an earthlodge and fenced-in enclosure for personal use. The enclosure consisted of a large earthlodge, a garden, several storage pits, and two scaffolds surrounded by a U-shaped wooden fence. The enclosure was constructed with the open end of the U adjacent to the northern edge of Fort Clark (Wood 2003:12). While the lodge was significantly larger than most of the earthlodges at the site, its construction and style were identical to those in the village. Scaffolds were built as temporary wooden structures for the purpose of drying food. Garreau also excavated several storage pits at the site identical to those in the village in both size and shape.

Many of the features associated with Garreau are evident in Wood's (1993) map. Wood indicates the remains of the fence, consisting of a raised earthen berm – again, likely the result of aeolian deposition – four pits, each of which were manifested as slight depressions, and Garreau's earthlodge, whose remains mirrored those within the village. Kvamme's 2000 - 2001 magnetic gradiometer survey confirmed the location and layout of the enclosure, identifying the extent of the palisade, the earthlodge and central hearth, and several storage pits. Additionally, Kvamme suggests that evidence of the scaffolds may be visible in the data; however, the associated anomalies are too subtle to make definitive interpretations (Kvamme 2001:28 - 30).

Several of the features associated with Garreau's enclosure are evident in the color imagery by means of shadow marks. The elevated earthen berms that indicate the location of the base of the palisade and the perimeter of the earthlodge produce shadows that appear clearly in the data. The elevated earthen berm surrounding the enclosure is likely a product of the same aeolian depositional processes that created the earthen berm that indicates the presence of the corral features. Additionally, as the construction of the earthlodge was identical in most respects to those in the village, the same processes are likely responsible for surface expression of that feature (Figure 16).

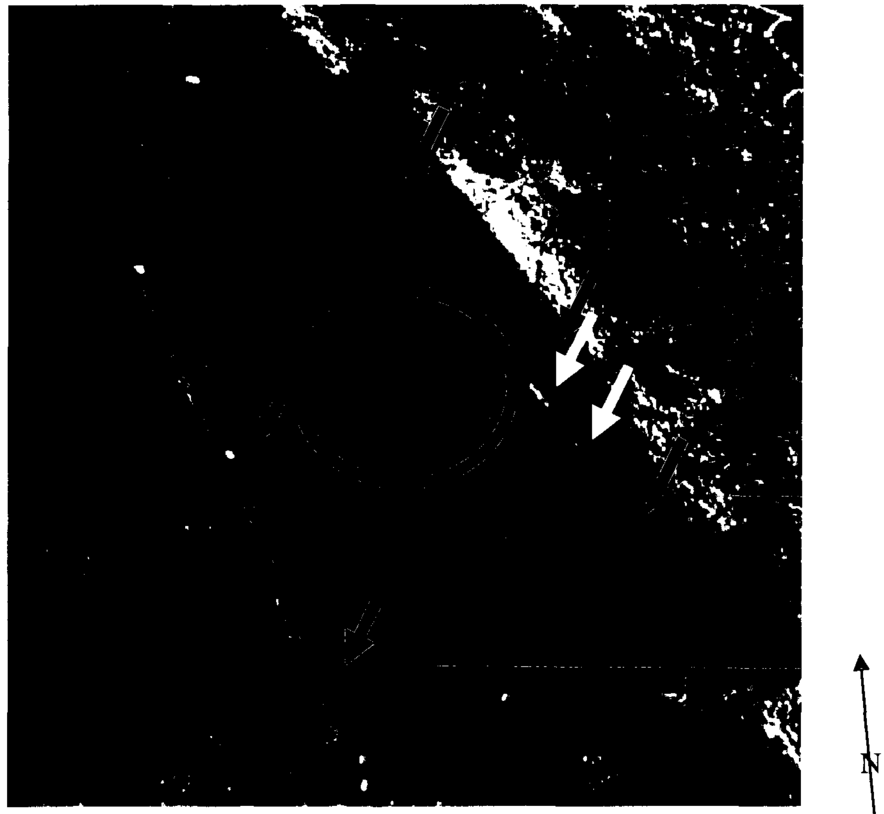

Figure 16: Garreau's Enclosure consisted of a large earthlodge (circle) surrounded by a tall wooden fence, the remains of which are evident as an earthen berm (indicated by black arrows). Several pits (indicated by white arrows are also evident within the enclosure just to the right of the earthlodge and were probably used for storage. (Image is approximately 95 meters across)

Aerial imagery confirms the location and interpretations of the anomalies previously identified. The location and orientation of Garreau's earthlodge and the location and structure of the palisade are clearly evident in the data. Six depressions here interpreted as storage pits are also evident in the data. These appear as shadow marks, as light cannot reach the bottom of depressions evident on the surface. Of these features, four depressions are verified by Wood's map, while two of the pit features, both of which appear inside the earthlodge, were not identified prior to this research. Indications of numerous other depressions are evident in the data, however, these features are too subtle for confident interpretation No evidence of the scaffolds is apparent in the color imagery data. This is likely due to the ephemeral nature of the features' interaction with the soil – only a few small post molds are all that likely remain of these structures.

Subtle shadow and vegetation marks indicate the presence of a semi-circular, donut-shaped depression at the southern end of the enclosure. Unfortunately, the southern portion of the apparent feature is obscured by the shadow of a large tree (Figure 17), so a full accounting of the feature's surface expression is impossible with the current data. This feature is not indicated in any of the prior archaeological research nor does anything fitting its description appear in the ethnohistoric record. As such, its function remains somewhat mysterious. It is possible that it is connected in some way to the fort immediately south of the anomaly. However, maps of the fort made during its occupation suggest that all of the associated structures exhibited rectilinear rather than curvilinear boundaries. One possible interpretation of this feature is the location of a structure built prior to either the fort or Garreau's enclosure. However, the feature does not exhibit many of the characteristics of other structures at the site – although this may be explained by disturbance of the surface due to intensive activity during the construction and occupation of the trading post and enclosure. This feature may reflect a pattern of gardening activity in the enclosure or a wagon track segment in use prior to the enclosure's construction.

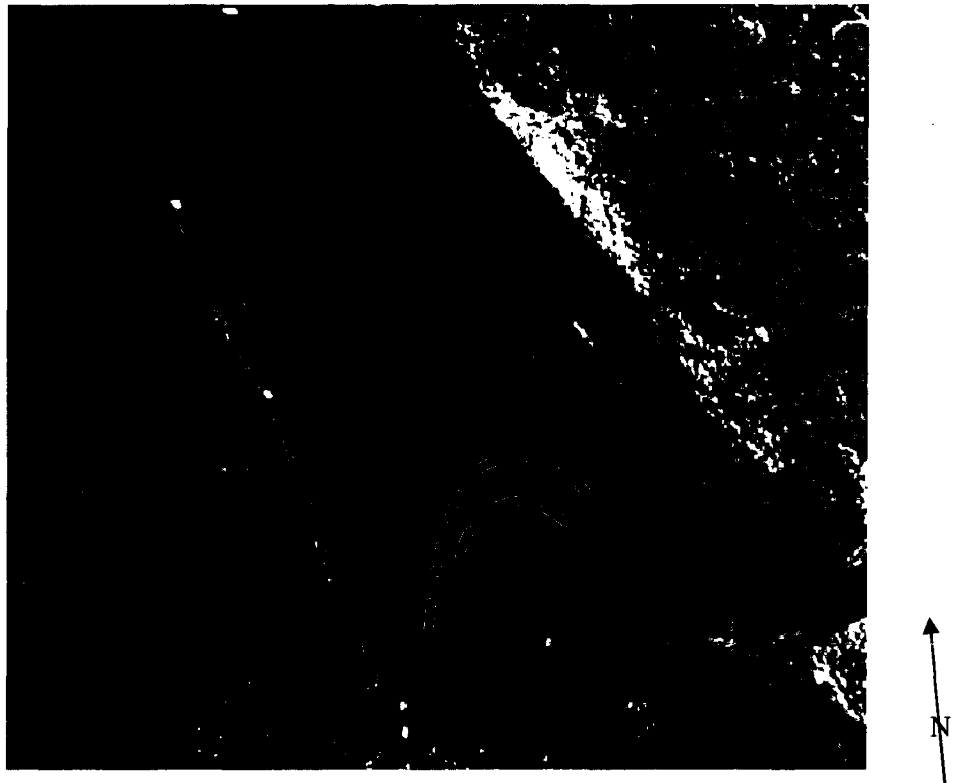

Figure 17: Dashed lines indicate a subtle depression evident at the southern end of Garreau's Enclosure. Whether this depression is associated with the enclosure of with Fort Clark (immediately adjacent to the south) is unknown. (Image is approximately 95 meters across)

Fort Clark Trading Post

The construction of the Fort Clark trading post began during the winter of 1830 and was completed during the early months of 1831. As described earlier, the fort was established as a means of conducting fur trading activities in the area.

Ethnohistoric sources as well as archaeological data suggest that the fort was constructed of wood built on a stone foundation. The fort consisted of a large rectangular palisade with two wooden blockhouses – one on both the northeast and southwest corners. Two entrances were located roughly in the middle of the east and west walls of the palisade. Inside the palisade, were several structures that were likely used for housing of the fort's occupants and storage of trade goods, provisions, and munitions, and various other buildings necessary to the fort's operations including at least one workshop. The internal structures were situated adjacent to the north and south walls of the palisade. Few buildings were located along the east and west walls of the palisade and these were all north of the fort's two entrances. Hunt (2003), based on archaeological and geophysical evidence, shows the post grew significantly through time, with at least three palisade lines to the west.

Wood's (1993) map indicates the basic footprint of the fort. However, Wood's map does not provide any significant detail with respect to any of the internal structures indicated by contemporary maps. His map does suggest the present of a large depression in the northeast corner of the fort. This depression has been interpreted as the potential location of an ice house, powder armory, or root cellar (Williams 1998:80–85). Kvamme's geophysical examination of the fort suggests significant details of internal structures. However, due to the intensive nature of previous excavation at the fort's location (Ahler 2003), several of the apparent walls seen in the geophysical data are likely attributable to the remains of previously excavated trenches (Kvamme 2001:18).

Indications of the remains of Fort Clark appear in the data as both shadow and vegetation marks (Figure 18). Apparent walls are indicated by brown vegetation, potentially caused by dense inclusions near the surface, such as the remains of a stone foundation, impeding the growth of vegetation. Additionally, shadow marks resulting from depressions may indicate the location of building remains.

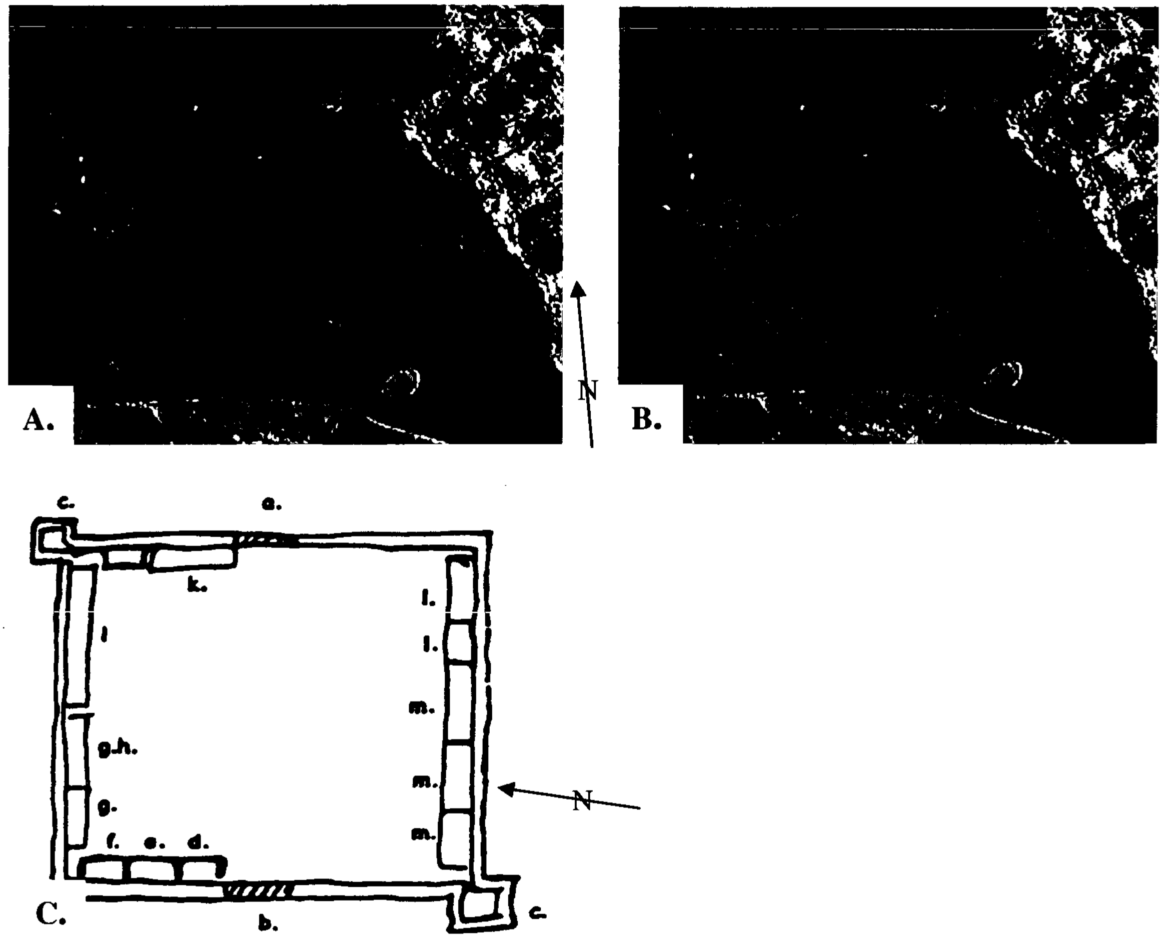

Figure 18: A) Remains of Fort Clark apparent in the color aerial imagery (Appendix A); B) Black lines indicate the location of apparent structural remains of the fort. C) Drawing of Fort Clark made by Prince Maximilian von Weid in the early 1830s confirms the locations of structures along the north and south wall of the fort (Thwaites 1906). (Images are approximately 85 meters across)

The basic shape and orientation of the trading post is verified by Wood's interpretive map of the site. However, a large portion of the northern half of the fort as indicated by prior archaeological work, including much of the large depression indicated in Wood's map, is completely obscured by a large tree shadow. Even so, several interior walls are apparent. These walls roughly agree with a map made of the fort by Prince Maximilian von Wied during his stay at the fort in 1833-1834 (Figure 18). These interior walls suggest several structures present along the northern interior wall of the palisade and along the southern interior wall. However, Kvamme's (2002) data suggests that excavations conducted at the site may be the cause of some of the apparent anomalies. As such, these interpretations are inherently somewhat suspect. Interpretations based on vegetation marks may be more accurate as depressions are likely the result of excavation while vegetation would be expected to grow more robustly due to the slightly depressed, loose soils they typically leave behind.

Primeau's Post

In 1850 opposition fur traders constructed Primeau's Post north of Fort Clark with the intent of challenging the American Fur Company's monopoly in the region. As the post was constructed late and only survived a few years, little information can be found in the historic record. The best source of information on the fort's construction and layout exists in the form of a small sketch drawn by William Hays in 1860. His sketch suggests that the post was surrounded by a wooden palisade with what appears to be an east-facing entrance. At least one large wooden building occupied the post and formed a large part of the eastern exterior wall. Additionally, there are indications that a blockhouse or some other structure occupied the southeast corner of the post (Wood 2003:14).

Wood's (1993) interpretive map suggests the location and general footprint of the post. According to Wood, Primeau's Post was a square structure that was significantly smaller than Fort Clark situated about two hundred meters north of the fort. Kvamme's (2002) geophysical survey of the post suggests a significant amount of internal structure is present at the post. His survey appears to suggest the presence of several internal buildings surrounded by a palisade line consistent with the Hays' sketch.

Evidence of Primeau's Post in the color imagery appears primarily as shadow and vegetation marks. Significant changes in the types of vegetation indicate that there is a significant change in the subsurface along the northern and southwestern border of the post promoting the growth of robust vegetation. However, vegetation marks in this area are somewhat amorphous and do not provide an ideal indicator of structural detail. Rather, it is the change in vegetation type and density that suggests anthropogenic variation in the near surface soils. Shadow marks indicate the presence of several depressions that potentially delineate the remains of walls within the post or borrow pits. Unfortunately, few internal details are evident. One internal wall is apparent in the southeastern area of the post as a shadow mark. Broad changes in vegetation coupled with an apparent gap in the eastern wall of the post suggest that primary entrance to the post was located in the eastern wall of the post (Figure 19).

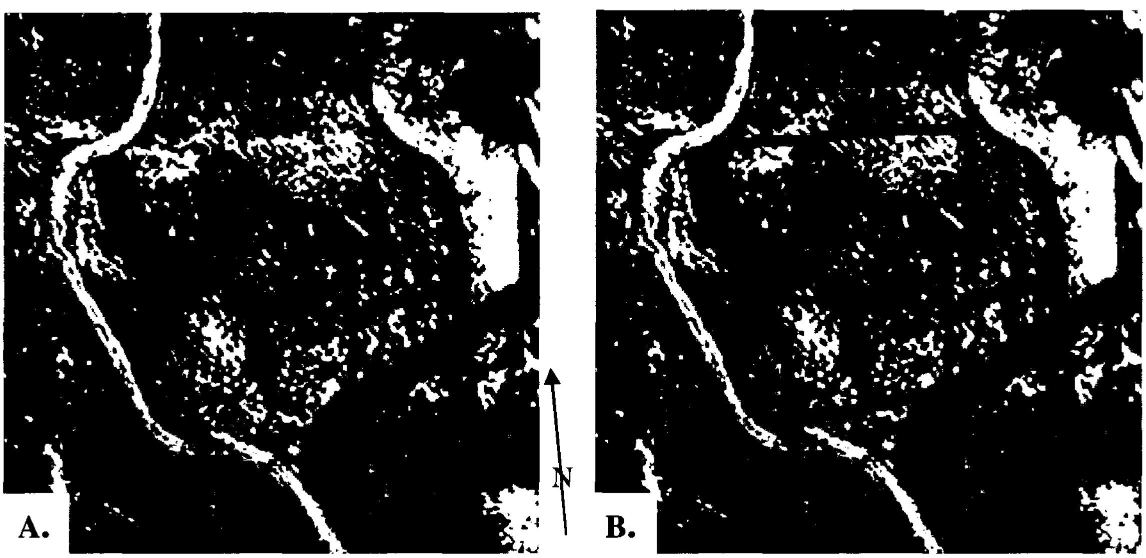

Figure 19: A) Remains of Primeau's Post apparent in the aerial color imagery (Appendix A); B) Black lines indicate the location of apparent structural remains of the fort. Gap in the east (left) wall of the post indicates an apparent entryway. (Images are approximately 60 meters across)

Discussion

Analysis of the high resolution color imagery yielded the identification of more than 800 archaeological features (Figure 20). One hundred-three earthlodges were potentially identified indicating that the population of the site was probably greater than has previously been suggested. A fortification ditch is evident at the site. Instead of surrounding the entire village, as is indicated in certain ethnohistoric resources, the ditch is evident only on the western and southern borders of the site. Two major trail networks were identified in the data – one that leads to Deapolis, another Mandan village several miles northwest of Fort Clark, and one that probably leads to local activity areas. The remains of more than 600 pit features are indicated. Of these features, at least fifteen have been identified as central to earthlodges at the loci of hearths and may represent looters' holes or actual hearth depressions. The remainder is likely the remains of storage pits. In addition to these features, the remains of two large structures were identified at the southern periphery of the site that previous work suggests are the remains of pony corrals.

Evidence of both trading posts and Garreau's enclosure at the site are clearly indicated in the data. Subtle evidence of interior structure of both trading posts is apparent. The layout of the interior structures at Fort Clark appears to generally agree with a map made by Maximilian in the mid-1830s. Some of the apparent interior structures at the fort indicate that the layout of the fort changed during the years after Maximilian's visit, as suggested by Hunt's (2003) interpretations, that his map is incomplete or inaccurate, or that some surface features are actually the result of trenches excavated in the 1970s. While the first two options must be considered, the last is a likely cause of many features. As excavation creates disconformities in the soil, it is reasonable to assume that these disconformities caused by archaeological excavation would produce similar, if not identical, disconformities as excavation related to construction.

Pierre Garreau's enclosure and earthlodge are also clearly evident in the data. While ethnohistoric information provides an indication of the types of structures associated with the fort interpreter's home, the semi-circular anomaly at the southern end of the enclosure seems to indicate that other activities occurred in the enclosure. What these activities may have been are still subject to speculation. It may predate the construction of either the fort or the enclosure or have been an effect of their construction.

Fifty surface depressions were identified as the likely remains of graves at the Euroamerican cemetery. Unfortunately, death records at Fort Clark are not available to determine whether this interpretation is borne out by the number of deaths during the occupation of the fort. However, it is not entirely unlikely that that many graves were necessitated by a frontier lifestyle, devastating epidemics of smallpox and cholera, and tension between the traders and the local Native Americans.

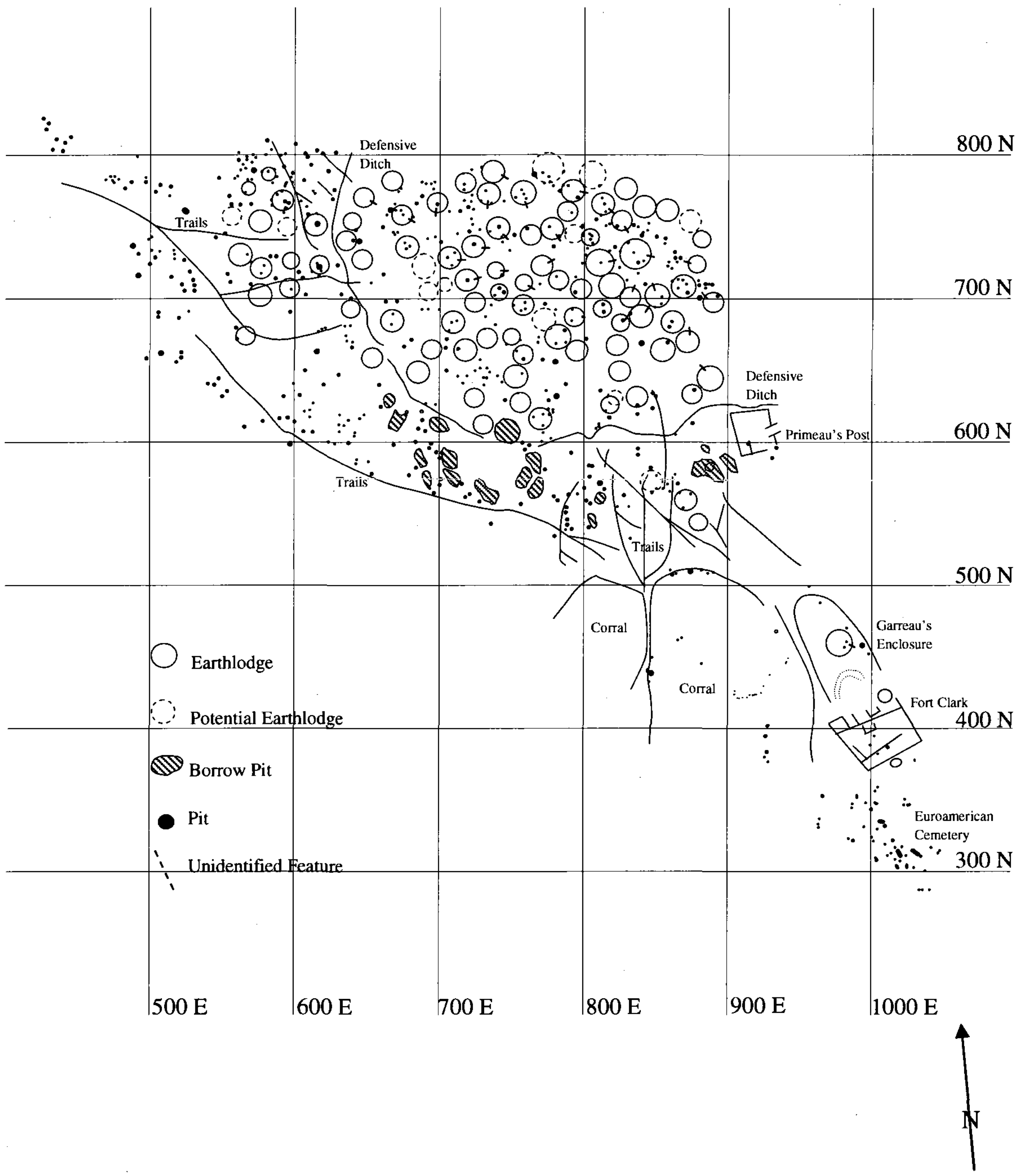

Figure 20: Interpretive map based on the aerial color imagery (see Appendix A for large scale version)

CHAPTER 5: INTERPRETATIONS OF THERMAL INFRARED IMAGERY

The previous chapter described and defined key cultural features that exist in the Fort Clark State Historic Site as revealed by color aerial imagery. This chapter reexamines these features in the face of evidence from thermal infrared imaging using the same archaeological feature types. In doing so, numerous new insights are gained. In the following thermal infrared imagery, relatively warm areas appear light gray to white while cool places are dark gray to black.

Earthlodges

Earthlodges tend to appear in the data as warm (light) circles surrounding a cool (dark) central area (Figure 21). This variation in observed temperature probably results from changes in soil density and moisture. This variation agrees with expected thermal properties associated with changes in the physical attributes of earthlodges. The earthen berms surrounding earthlodges are created by soil falling or washing off their roofs. They are somewhat elevated and tend to drain moisture quickly. As a result, the remains of earthlodge floors are generally significantly wetter than the immediately surrounding soil. The increased moisture content of the soil promotes the growth of vegetation such that areas interpreted as earthlodge floors exhibit much denser and healthier vegetation – an assumption verified by the color imagery data. Vegetation tends to appear cool in thermal infrared imagery because of evapotranspiration, in which moisture is transported up the body of vegetation where it is released into the air as water vapor (Jury and Horton 2004:119). Consequently, earthlodges appear thermally as a ring of warmth associated with the raised berm surrounding a cooler floor area, forming a clear and repetitive pattern.

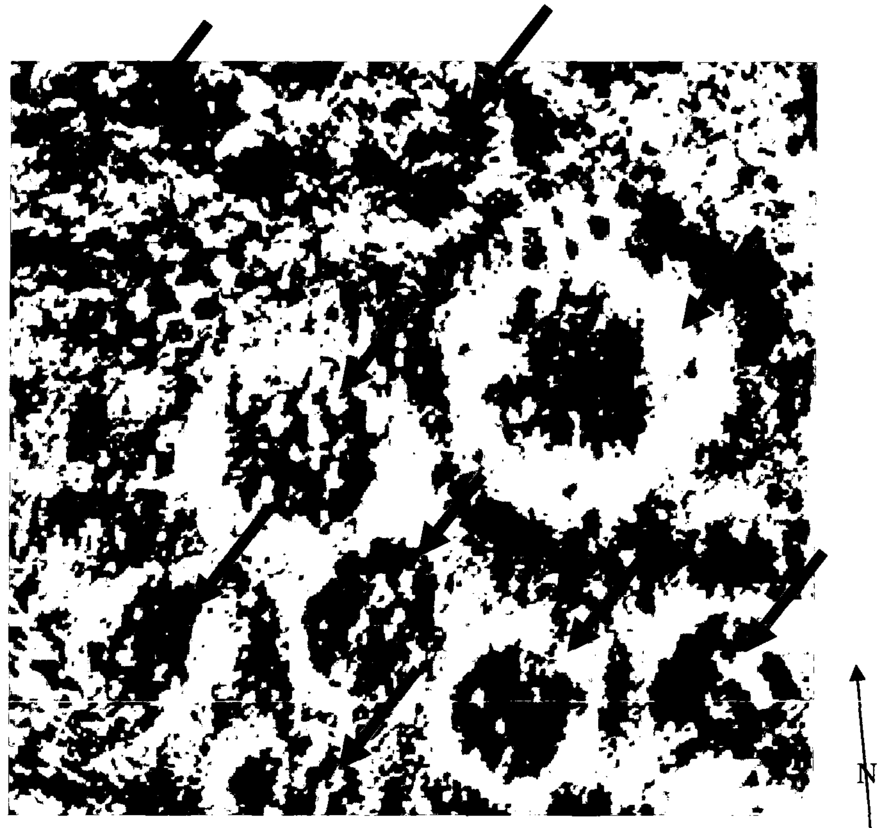

Figure 21: Arrows indicate potential earthlodges. Lodges are characterized in the data as warm (light) rings surrounding cool (dark) areas. The large lodge in the upper right (northeast) is the Arikara ceremonial lodge. (Image is approximately 75 meters across)

Careful analysis of the thermal data suggests the presence of at total of 112 earthlodges, excluding the earthlodge constructed by Pierre Garreau adjacent to Fort Clark. The interpretation of 105 of these features should be considered probable, while the remaining seven earthlodges should be considered, at best, possible. Thermal variation exhibited by these seven features is not great enough to be confidently interpreted; however, indications of the general shape and character of the features are consistent with other earthlodges. These features may be the remains of early earthlodges that, for some reason, did not last the occupation of the site and were disturbed by typical processes related to human occupation: trampling, scavenging useful materials, excavation of storage pits, etc.

Earthlodge Features

As earthlodges are most readily identified by their basic structural remains, anomalies associated with these remains can be interpreted based on their location relative to these remains. Ethnographic and ethnohistoric sources suggest that pits excavated within earthlodges were spatially segregated. In other words, pit features were restricted to specific, non-overlapping areas within the earthlodge. In this manner, an analysis of the association of pit features relative to earthlodge remains may yield interpretations as to their specific function.

A careful examination of the association of apparent pit features, many of which are also apparent in the color imagery and have previously been identified by Wood (1993), and earthlodges reveals 23 centrally located pits (Figure 22). In earthlodge construction, hearths were always placed in the center of lodges. However, as has already been discussed, hearths likely do not leave depressions as they are filled with ash and charcoal. Therefore, depressions located in the center of earthlodges are likely the product of looting where individuals would excavate pits in the village in an attempt to find artifacts. These looters' holes are often preferentially placed in the center of apparent earthlodge depressions. It is also possible, however, that vegetative growth, which appears cool in thermal imagery, may be stimulated in areas richer in organic matter near hearths. Unfortunately, there is no evidence of earthlodge entryways apparent in the thermal infrared data.

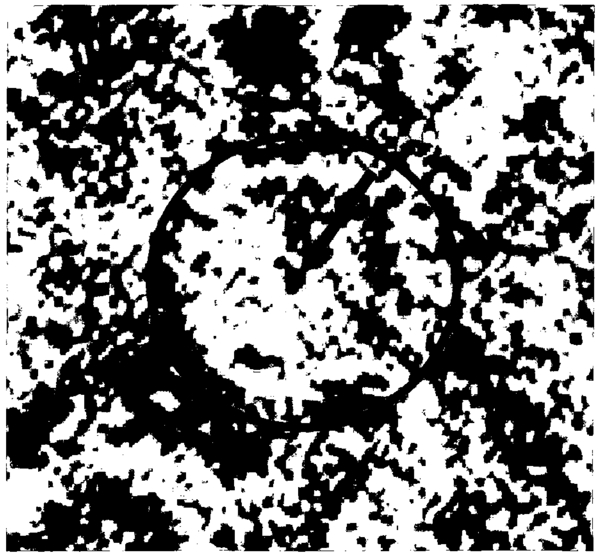

Figure 22: Arrow indicates a large pit feature centrally located in an apparent earthlodge (indicated by a circle). The pit is likely the result of looting at the site rather than any activity associated with the site's inhabitants. (Image is approximately 30 meters across)

Fortifications

The fortification ditch appears in the data principally as a cool feature with warm edges. The cool center line of the anomaly represents the bottom of the ditch. The ditch likely collects and holds moisture more than the surrounding soils. As has previously been discussed, increased moisture content promotes the growth of vegetation, which, due to evaporative cooling and evapotranspiration, tends to appear in thermal imagery as cool anomalies. The warmer edges of the feature are probably due to a lack of moisture, owing to their elevated positions, natural drainage of moisture and greater exposure to wind, which carries moisture away. The relative lack of moisture in the soil indicates a similar lack of vegetation causing the soil to appear warmer (Figure 23).

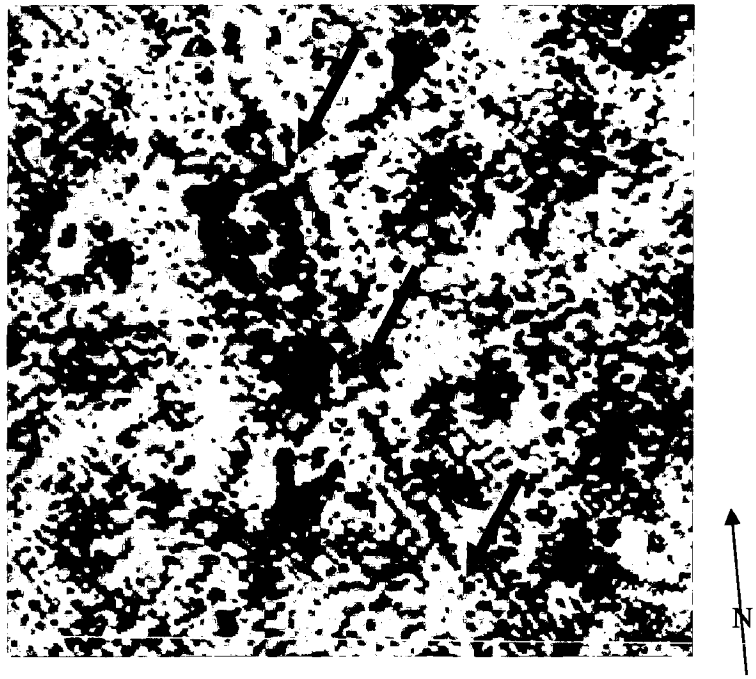

Figure 23: Arrows indicate the defensive ditch. The ditch is visible in the data as a cool line with warm edges. (Image is approximately 60 meters across)

The fortification ditch enters the site at the northern edge of the village, follows the southern edge of the site and exits north of Fort Primeau, at the eastern bluff edge overlooking the Missouri River. Significantly, the southern path of the ditch is difficult to follow on the ground or in the color imagery (Appendix A), but can be seen in its entirety thermally (Appendix B). Although ethnohistoric records and paintings indicate the presence of a wooden stockade at the village, and nearly all villages of earlier periods were fortified with one, no evidence of it can be found in the data.

Bastions

The fortification ditch appears to exhibit two structures that are interpreted as bastions. Bastions are common defensive structures built into a fortification system to allow defenders to fire projectiles at the flanks of attackers facing the intervening walls of the stockade. They are a common feature of earthlodge village fortifications in the

Northern Plains. In a geophysical survey at Double Ditch (32BL8), Kvamme documented numerous bastions built into the site's four defensive ditches (Kvamme 2008:68).

An eastern bastion exhibits the protruding semi-circular structure typical of bastions present at other fortified earthlodge villages (Figure 24). A western bastion however, exhibits a triangular shape where the ditch juts outward to a sharp point (Figure 25). This form is unknown in Northern Plains villages and represents a significant finding. It is intriguing as a contemporary map drawn by Maximilian von Wied between 1833 and 1834 indicates four similarly shaped bastions were present at the ditch (Figure 25). Additionally, he suggests that the Euroamerican fur traders at Fort Clark constructed earthen bastions into the village's fortifications (Ahler 2003:6). They were probably constructed for protection against the Sioux, with whom the residents of the village were in near constant conflict (Ahler 2003: 1). Known bastions at other Mandan and Arikara villages are C-shaped in earlier periods (Kvamme 2008), lending credence to the inference that this clearly triangular bastion is likely the work of the Euroamerican traders.

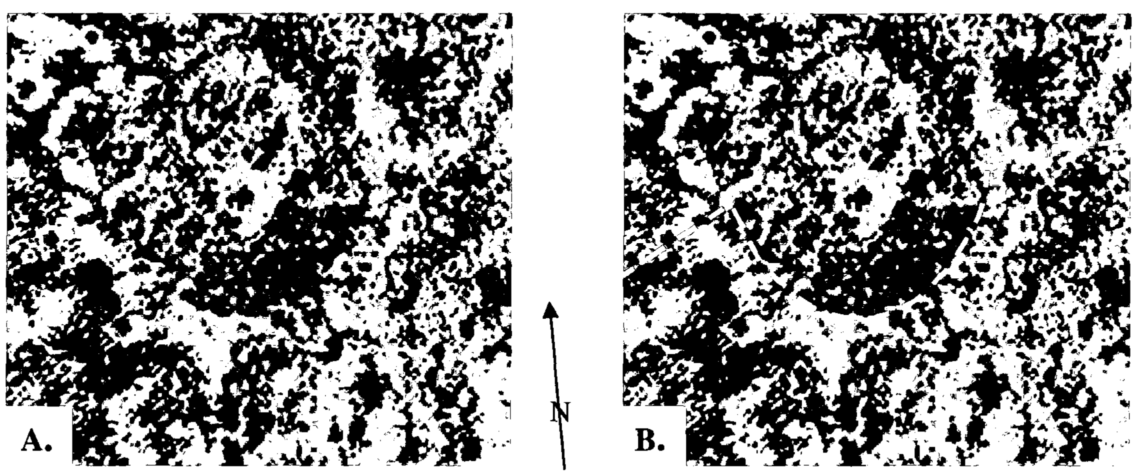

Figure 24: A) Anomalies interpreted as the fortification ditch and a bastion apparent in the thermal infrared imagery. B) Dashed line indicates the interpreted fortification ditch and bastion. (Image is approximately 65 meters across)

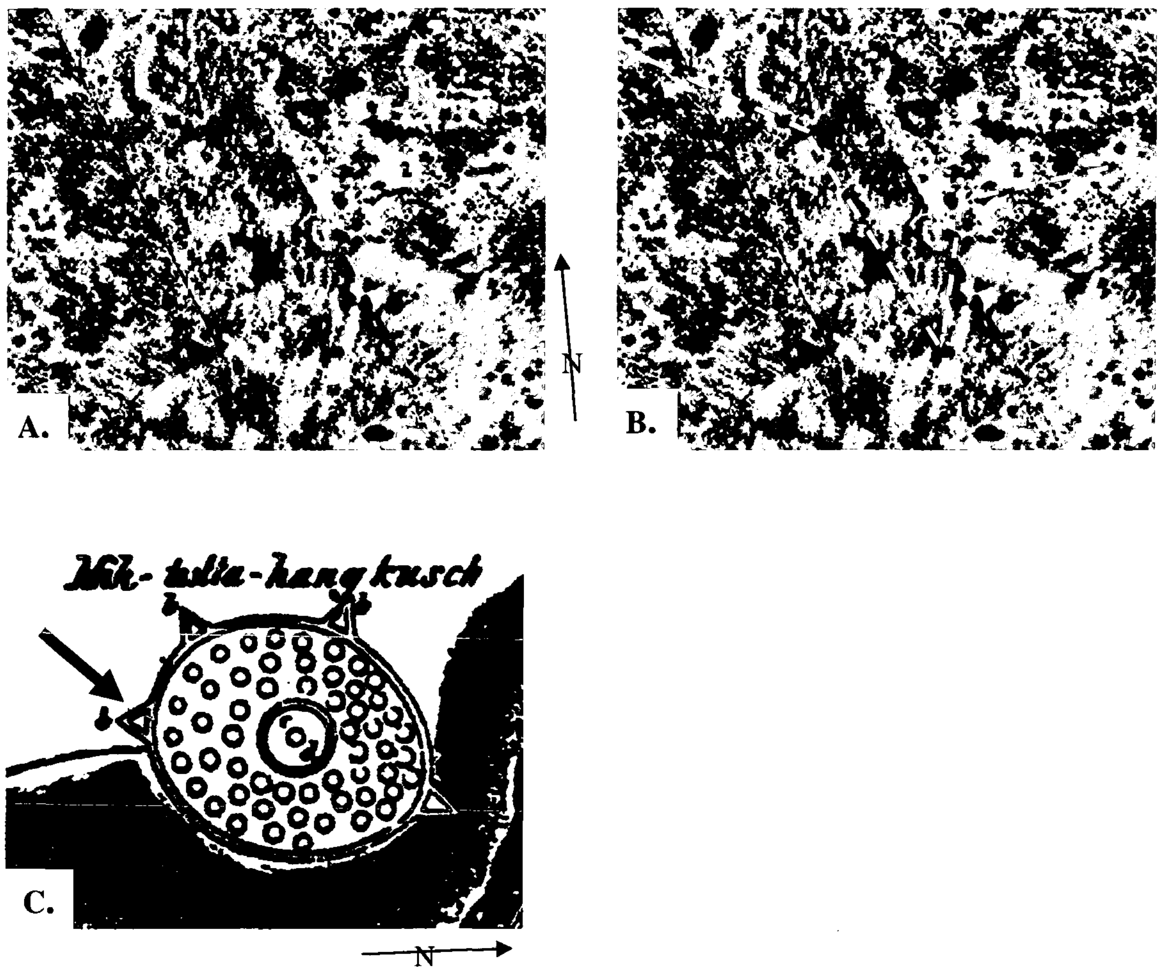

Figure 25: A) Anomalies interpreted as the defensive ditch and a triangular bastion apparent in the thermal infrared data. B) Dashed line indicates the interpreted fortification ditch and bastion. C) Arrow indicates a similar structure in a map of the village drawn by Prince Maximilian von Wied in the early 1830s (Thwaites 1906). (Images are approximately 85 meters across)

Borrow Pits

Borrow pits are indicated in the thermal imagery data as cool features with slightly warmer edges. The basic circular shape exhibited by some of these features make them somewhat difficult to distinguish from earthlodges. However, earthlodges generally exhibit more discrete boundaries and a generally more circular shape. Borrow pits are characterized as depressions on the surface resulting from excavation of topsoil. As such, they likely exhibit a thinner layer of top soil than the surrounding area. Depressions, as has already been discussed, tend to appear cooler due to greater moisture accumulation and retention and associated vegetative growth (Figure 26).

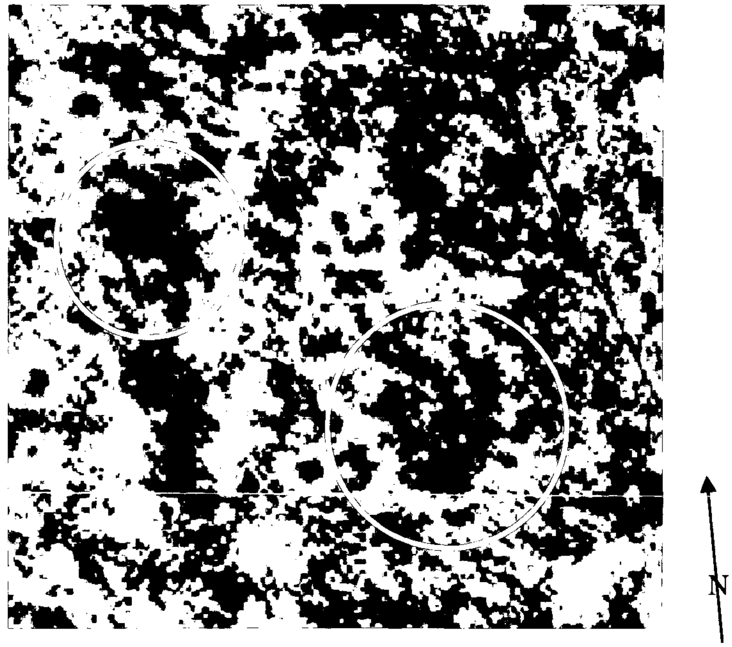

Figure 26: Circles indicate potential borrow pits evident in the thermal infrared imagery. Borrow pits are characterized in the data as somewhat amorphous cool anomalies. (Image is approximately 45 meters across)

An examination of the data indicates at minimum thirteen borrow pits. As the size of the village and the necessity of excavated soil for lodge construction indicates the need for many borrow pits, this may only represent a small percentage of the total borrow pits present at the site. It is possible; however, that soil for lodge coverings was recovered off-site from the bluff edges adjacent to the river bank. As discussed in the previous section, the expression of borrow pits in the data may be largely related to the tenure and intensity of their use. The borrow pits indicated by the data may be more established borrow pits that were used continuously over a long time period. However, it may be more likely that these were among the last ones excavated or were located in areas that were not as intensively disturbed as others. Several of the borrow pits appear to be directly associated with the construction of a modern access road and therefore may not be part of the archaeological assemblage of the site.

Trails

Trails are apparent in the data as a series of cool, linear features. As trails can be characterized by increased compactness associated with continuous use, their thermal signature is likely the result of increased soil moisture and vegetation lying along the subtle surface depressions that define their courses. As has previously been discussed, denser materials may retain moisture longer and therefore appear cooler. Although trails are a compacted feature and are therefore visible on the surface (and in the aerial color imagery data) as a depression, they lack the warm borders indicative of other depressed features. This is likely due to the feature's poorly defined boundaries and the lack of adjacent raised berms. As individuals use a trail, not everyone will maintain exactly the same heading – walking along the edge of a path instead of its center line, for example. As this process continues to happen, any discrete border will become somewhat indistinct or shallowly gradated to the surrounding surface level. This process reduces the likelihood of a raised berm that is principally responsible for the warm-edge phenomenon. At Double Ditch, Kvamme (2008) identified a linear warm feature apparent in thermal infrared imagery as a trail. However, as the apparent temperature of soil is the product of a complex of interacting factors, this difference may owe to any number of differences including soil grain size, compaction, recent availability of moisture (i. e. rain), local topography, and ambient temperature. Additionally, and perhaps significantly, this feature showed no corresponding surface evidence.

Three trail networks are evident in the thermal infrared data (Figure 27). Two of the trail networks are significantly larger with a greater number of trails. Each of the two primary trail systems, one heading west away from the village and one heading south toward Fort Clark and possibly beyond, consist of one or two main trails with multiple smaller trails branching off as they approach the village. The third, smaller trail network appears between the primary trail networks and consists of fewer, less well defined trails. A fourth trail appears to connect the three trail systems. Instead of leading away from the village, this trail follows a path parallel to the fortification ditch. All trails terminate at or near the fortification ditch, again suggesting that there were no defined pathways for maneuvering about the village. Numerous trails are indicated in the data to have ended at the fortification ditch, suggesting that there were at least three broad openings in the defenses or that there were numerous narrow ones.

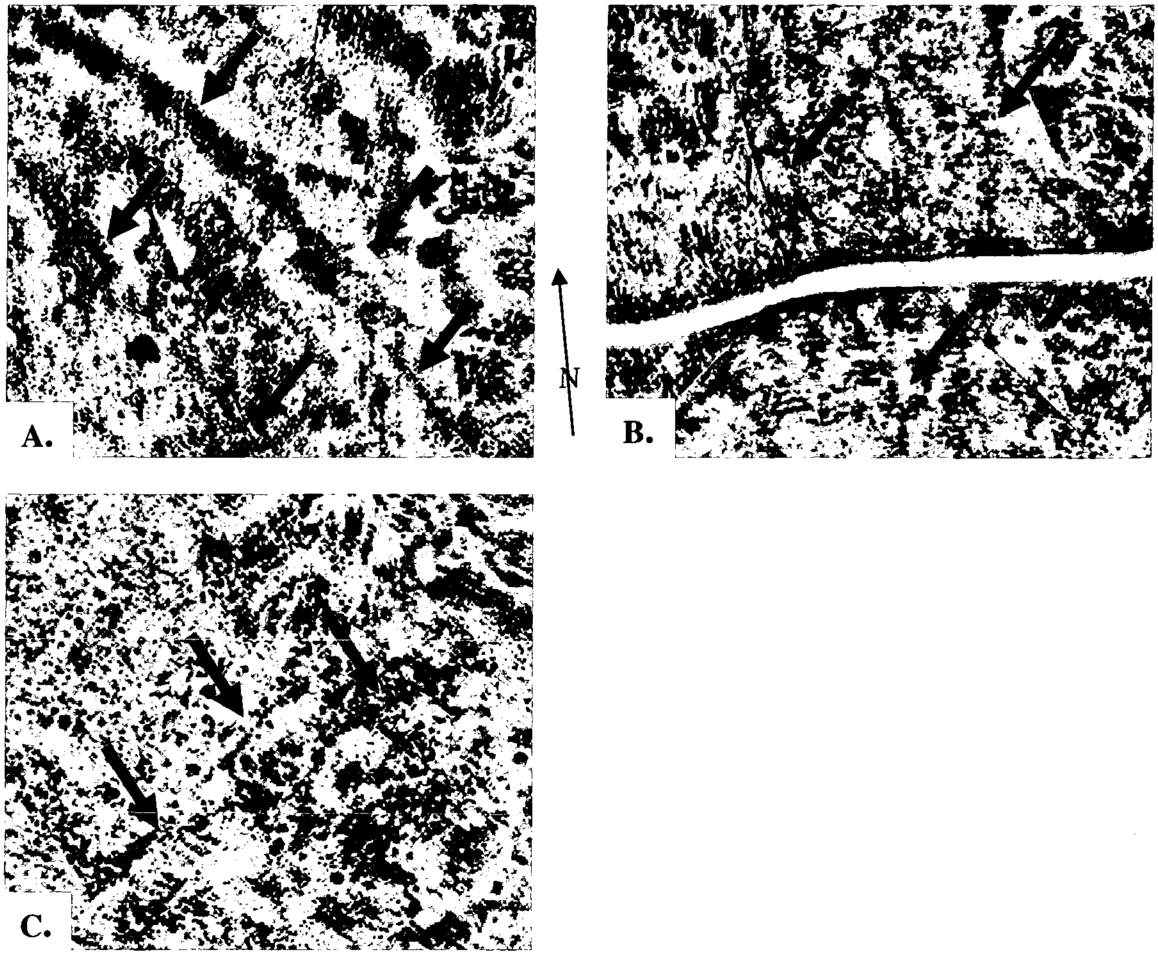

Figure 27: A) Arrows indicate a major trail northwest of the village core that leads to Deapolis (32ME5). The small trail apparent in the bottom right (southwest) connects the three trail systems. B) Arrows indicate a system of small trails south of the village that likely lead to Fort Clark and local activity areas. C) Arrows indicate a minor system of small trails southwest of the village core. (Images are approximately 90 meters, 85 meters, and 70 meters across, respectively)

Storage Pits, Hearths, Graves, and Looters' Holes

Evidence of small depressions is apparent throughout the site. These features dominate the northern half of the site throughout and around the village. Depressions are evident as small cool features with slightly warm borders (Figure 28). That these features appear cool in the data is likely a product of moisture capture, rich vegetation, and soil density. As previously discussed, depressed features likely receive a significant amount of runoff moisture from nearby areas of higher elevation. This preferential drainage pattern likely accounts for the warm edges of the features and at least partially accounts for the cool nature of the central portion of the feature. Again, this is largely due to the association of soil moisture and vegetative growth, where moisture promotes the growth of vegetation and dry areas retard it. Additionally, as pit features generally exhibit loose soils as a product of infilling by collapse, natural deposition, or human directed backfilling, they further promote vegetative growth. A plant's roots are better able to expand through loose soils and absorb moisture and nutrients. Increased vegetative growth, as previously discussed, produces cooler anomalies due to evapotranspiration.

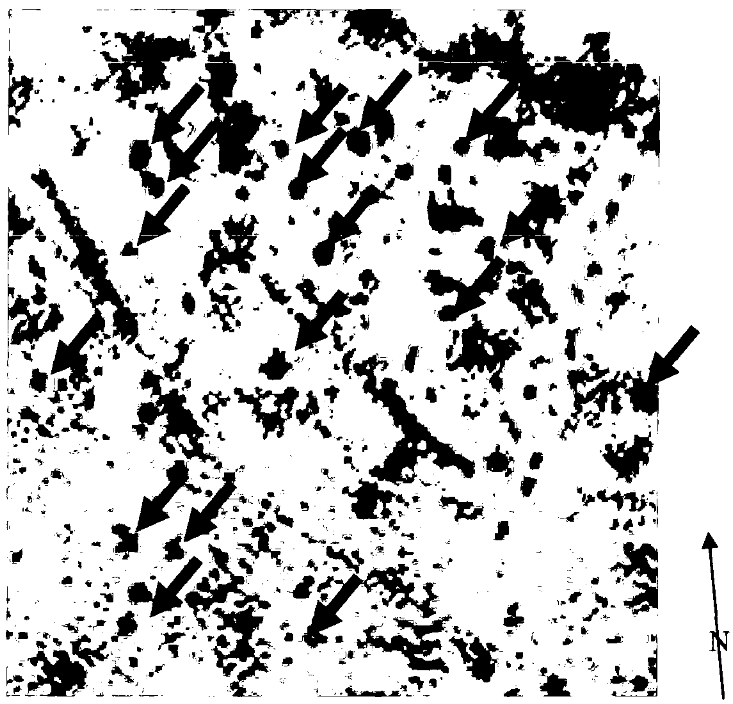

Figure 28: Arrows indicate potential pit features. Pit features are characterized as small, cool anomalies with slightly warmer edges. The majority of these features likely indicate storage pits and looters' holes, though some may be the result of hearths and graves. The defensive ditch is apparent in the right (east) side of the image. Note: the apparent linear anomaly crossing the image from left to right is the product of a seam between two images and is not related to any condition at the site. (Image is approximately 55 meters across)

A thorough analysis of the data yields the identification of 960 potential pit features. While these features may have held numerous functions, it is difficult to determine which features should be assigned to each class – except in the case of the

Euroamerican cemetery. Thirty-four graves are interpreted as a separate feature class from other depressions primarily due to their association with an ethnohistorically documented Euroamerican cemetery (Figure 29). Apparent pit features may also represent looters' holes or badger and coyote dens. Alternatively, small pits may be the result of a mowing pattern. As robust vegetation appears cool, it is possible that some pit features are merely clumps of grass that were missed when the site was last mowed or pockets of thicker and taller vegetation.

Figure 29: Arrows indicate anomalies interpreted as graves. They appear similar to all other interpreted pit features in the data; however, they are located in a known Euroamerican cemetery making their interpretation as graves probable. (Image is approximately 50 meters across)

Corrals

The corrals at the southern periphery of the village, as seen in the color imagery, are revealed as large, curvilinear warm features. These features are characterized as elevated earthen berms partially surrounding a central area. The central area exhibits a temperature signature typical of areas outside of the village core (Figure 30). The earthen berms, as discussed with regard to earthlodges, produce a warm thermal signature due to differential draining and a lack of vegetation. The earthen berms' southern terminus appears to be the product of a mowing pattern. Evident in the color imagery data is a change in mowing pattern at the southern terminus of the corral features. Mowing appears to have been conducted with preference given to the village core area. As such, the area south of the village was not mowed as intensively and the remaining vegetation obscures any further remains of these features.

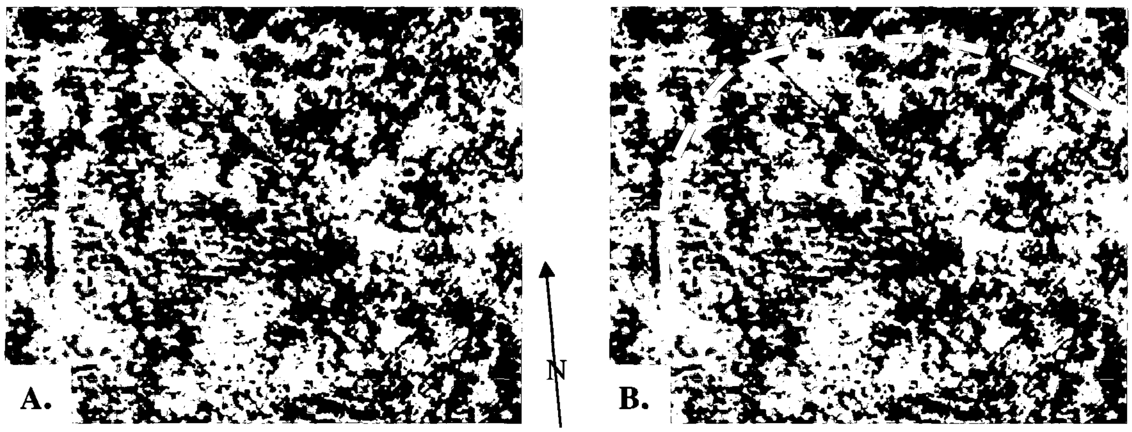

Figure 30: A) A portion of the warm anomaly apparent in the thermal infrared imagery (Appendix B) interpreted as the east corral. B) Dashed line indicates the interpretation of the corral feature. Note: The apparent linear anomaly in the upper left of the image is an image seam and does not reflect any condition at the site. (Images are approximately 100 meters across)

As discussed in the color imagery data interpretation, these features are likely the result of aeolian soil deposits related to a standing fence or wall of brush. The apparent thermal signature of these features is consistent with this assertion. Additionally, the presence of a brush fence or similar structure is supported by an associated trail that runs between them. Had the original enclosures consisted only of a low earthen berm, one might expect individuals to simply step over the berm instead of repeatedly navigating around the feature. As the central area does not exhibit thermal variation significantly different from what appears to be the natural average of the site, it is likely that the area was not used in a manner that involved significant interaction with the soil. As such, this may seem to support their interpretation as pony corrals, though one might expect robust vegetative growth as a product of fertilization, which is not present.

Garreau's Enclosure

Garreau's Enclosure consists of several different archaeological feature classes. As such, it is represented in the thermal infrared imagery as a combination of cool and warm features (Figure 31). The earthen berm surrounding the enclosure and Garreau's earthlodge appears as a warm feature in the data while six possible pit features appear cool. The berm exhibits an increased apparent temperature as a result of preferential drainage, lack of moisture, and poor vegetative growth associated with aeolian soil deposits at the base of a standing palisade. Garreau's earthlodge appears identical in the thermal infrared imagery to other earthlodges in the primary village, likely for the same reasons. Additionally, pit features associated with the enclosure are identical to those associated with other areas of the site. Finally, a single large, amorphous depression is visible in the data on the east side of Garreau's earthlodge that appears as a cool feature. This may be the remains of the borrow pit used in the construction of Garreau's earthlodge.

Figure 31: Dashed line indicates the locus of the fence that enclosed Garreau's garden area. Garreau's earthlodge (indicated by a circle), several pits (indicated with arrows), and an apparent borrow pit (indicated by a dashed line circle) are apparent within the enclosure. (Image is approximately 95 meters across)

The function of Garreau's enclosure is well known from ethnohistoric sources. It was constructed as a personal residence for Fort Clark's interpreter. It consisted of a tall wooden fence, an earthlodge, storage pits, drying scaffolds, and a garden. The loci of the palisade, earthlodge, and perhaps six storage pits are evident in the data. Indications of the drying scaffolds are not visible in the data likely because they were ephemeral structures that did not impact the soil in a significant manner. Additionally, the gardens likely only impacted the topsoil and did not entail the removal or addition of soil that could alter their thermal properties.

Fort Clark

Fort Clark is indicated in the data as a complex of warm and cool features. The warm features likely represent collapsed remains of the trading post. While the fort was primarily constructed of wood, it was constructed on a stone foundation. Inclusions of stone near the surface of the soil likely account for the largely indistinct, warm features. That stone inclusions are significantly warmer than the surrounding soil is likely the result of increased thermal storage and thermal inertia. As convective heat is transferred through the ground, the stone, due to its incredible density, has the ability to retain heat much longer than the granular soils. Additionally, because of its increased thermal inertia, stone is less susceptible to diurnal changes in temperature. Therefore, stone appears warm even at the coldest time of night. Additionally, as stone is a solid, it cannot retain moisture at nearly the level of porous soils. Therefore, while variation in thermal storage and inertia may contribute to the warm nature of the anomaly, the relative lack of moisture may also be a significant factor.

The area of the trading post is also marked by a series of linear cool anomalies (Figure 32). These anomalies are potentially the remains of two-meter deep builder's trenches used to secure the large posts of the palisade (Hunt 2003). A decrease in soil density and increased moisture content accounts for the cooler features associated with wall construction. Additionally, two large cool features are indicated, one at the northeast corner and one south of the fort, that represent depressed features filled with robust vegetation, as confirmed by the color imagery. These features probably represent the fort's magazine, root cellar, or ice house.

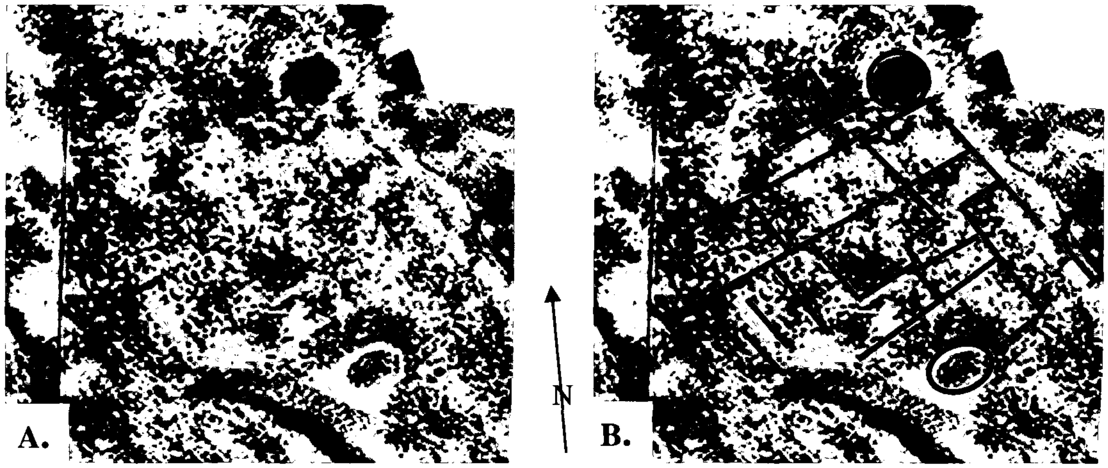

Figure 32: A) Anomalies associated with the location of the Fort Clark Trading Post visible in the thermal infrared imagery (Appendix B). B) Black lines indicate interpreted structural remains of Fort Clark. The two areas indicated by black circles are the probably remains of the fort's magazine, root cellar, ice house, or other subterranean structure. (Images are approximately 85 meters across)

The warm features provide the most reliable means of delineating the remains of the fort as they are the most distinct features with a readily identifiable cause. As such, a basic outline of the fort can be constructed by mapping the extent of these warm anomalies. However, these anomalies do not provide a detailed view of the fort. The cool linear features may be the remains of builder's trenches, all of which were identified by Hunt (2003) and revealed by Kvamme's (2002) electrical resistivity survey. As such, they may provide a more detailed picture as to the extant remains of the fort. However, the cool linear features may also be the result of Dill's 1973-4 excavations. As excavation and backfilling of trenches for archaeology and construction produce similar thermal effects, it is impossible to state with certainty the nature of the cool linear features. A comparison of these features with the plans of Dill's excavations reveals a correlation between them and several thermal anomalies.

Primeau's Post

Primeau's Post appears in the data as a series of subtle cool and warm linear anomalies. The feature is principally characterized by cool linear anomalies bounded by warm edges. Several distinct cool anomalies are present along the southern and western edge of the feature. The cool linear anomalies are likely the result of builder's trenches with warm edges potentially resulting from a collapsed stone foundation. A comparison of the thermal infrared data and Kvamme's (2002) electrical resistivity survey confirm significant variation in ground moisture is present in the feature and therefore likely contributes significantly to the apparent thermal variation.

While the exterior boundary of the stockade is apparent in the thermal data, little detail about the interior structure of Primeau's Post is evident in the thermal infrared data (Figure 33). The stockade surrounding the post appears as a warm linear anomaly with a cool center line. The cool aspect of the anomaly is potentially the result of excavated trenches associated with setting in the stockade. The warm aspect of this anomaly may be the remains of the stone foundation or mounded soil that was placed at the base of the stockade pickets as support. Several additional cool anomalies are present in the feature. These may be the result subterranean structures such as a magazine or a root cellar. However, many of these anomalies are also likely attributable to the remains of Dill's excavation trenches.

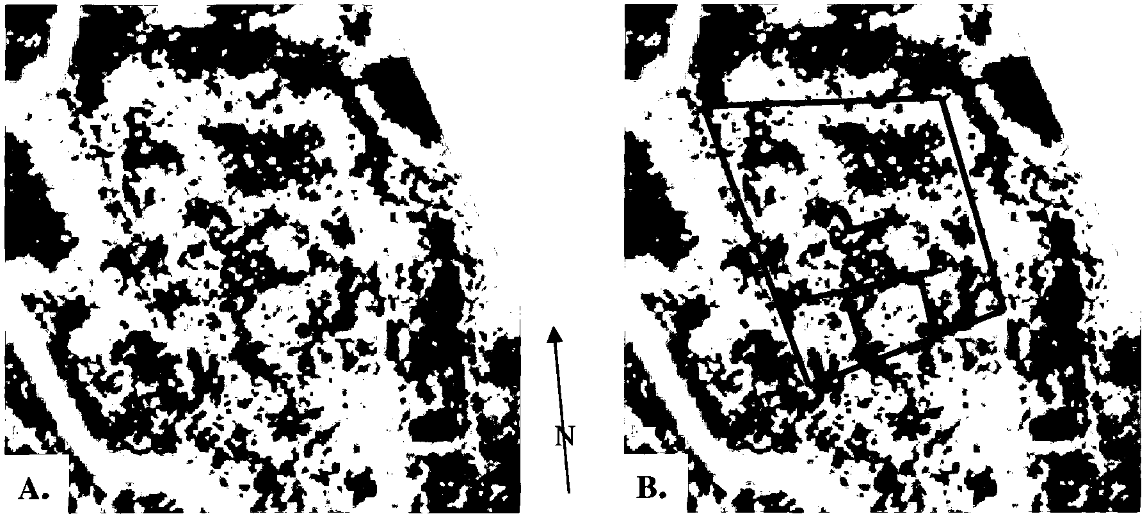

Figure 33: A) Anomalies associated with the location of the Primeau's Post visible in the thermal infrared imagery (Appendix B). B) Black lines indicate interpreted structural remains of Primeau's Post. (Images are approximately 40 meters across)

Other Anomalies

Several anomalies are present in the data that do not yield evident explanations. The first of these anomalies is a slightly cool, linear anomaly just north of Primeau's Post. The cool nature of the anomaly suggests that it may have been a path (Figure 34). The river was the only means of transporting goods and people to and from trading posts. As the post was situated on a bluff above the river, all materials that were either being sent to St. Louis for sale or offloaded at the post as provisions had to be hauled up to the post. Doing so would likely create a pathway that after continuous use would become compacted and manifest on the surface as a depression. As was already discussed, depressions tend to appear in the thermal data as cool anomalies. That the anomaly is subtle may reflect the relatively brief tenure of the trading post.

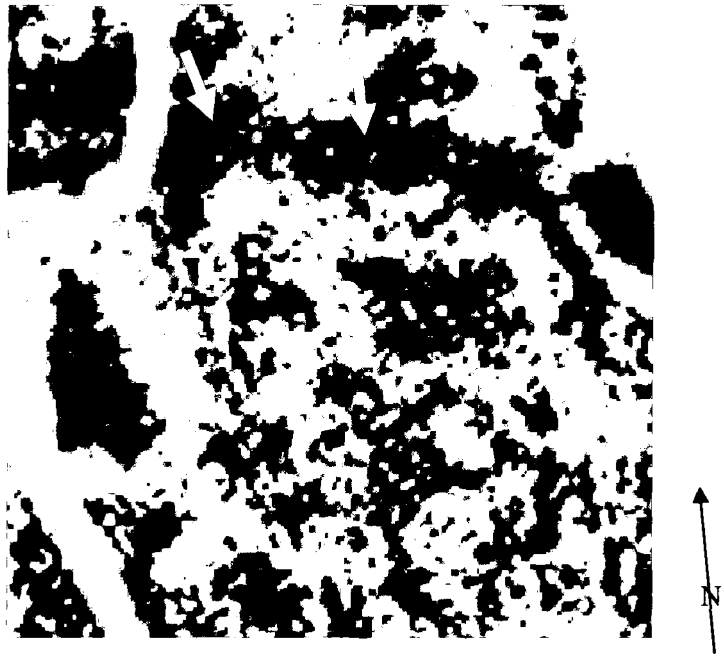

Figure 34: White arrows indicate a cool linear anomaly apparent in the thermal infrared imagery (Appendix B). This anomaly is potentially a path used by the employees Primeau's Post to transport goods to and from steamboats on the river. (Image is approximately 50 meters across)

Two anomalies southeast of Primeau's Post are also evident in the data as cool, linear anomalies (Figure 35). These features are characterized by linear anomalies that intersect at right angles. This suggests the potential that these anomalies are the remains of Euroamerican structures constructed outside of the trading post. An 1860 sketch by William Hays (Hunt 2003) of Primeau's Post, indicates that several small buildings were constructed northeast of Primeau's Post. While the sketch clearly does not reflect the source of the anomalies, it does confirm that small out-buildings were constructed outside of the trading posts' stockades. Therefore, these anomalies potentially indicate small outbuildings constructed during the occupation of Primeau's Post.

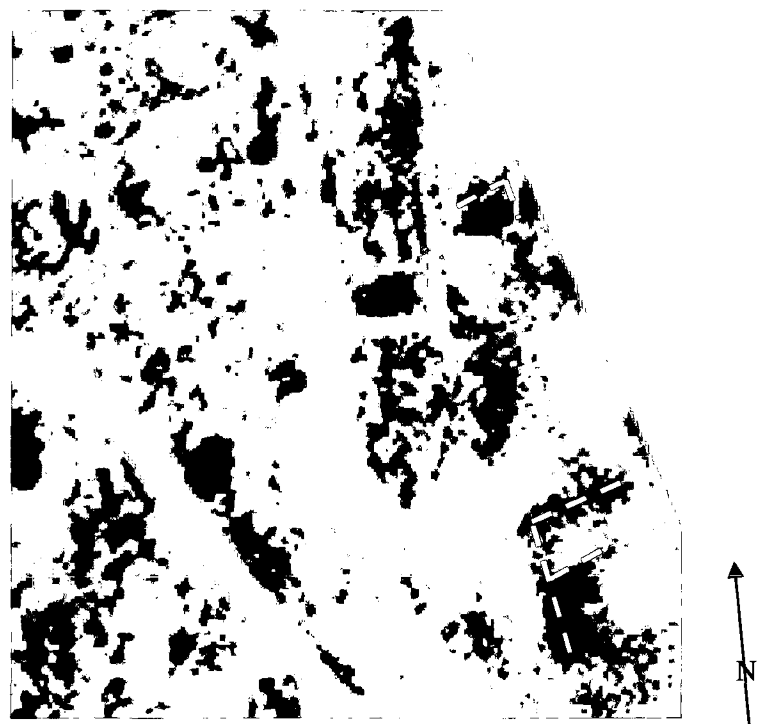

Figure 35: White dashed line indicates two cool anomalies that may represent the remains of out-buildings constructed near Primeau's Post. (Image is approximately 45 meters across)

Finally, a subtly warm feature is evident across the middle of the village. As the anomaly appears to cross-cut other features without any apparent effect on their structure or layout, it is probably not the result of any activity during the sites occupation. Additionally, this warm feature directly corresponds with the geophysical transect surveyed by Kvamme in 2000 (Figure 36). The anomaly is therefore probably the result of being traversed repeatedly during that survey. Surveyors walking across the site repeatedly disturbed the vegetation. The brevity of the survey did not allow for great compaction, but stressed the vegetation, possibly decreasing its density or healthy growth, causing a subtle warm signature.

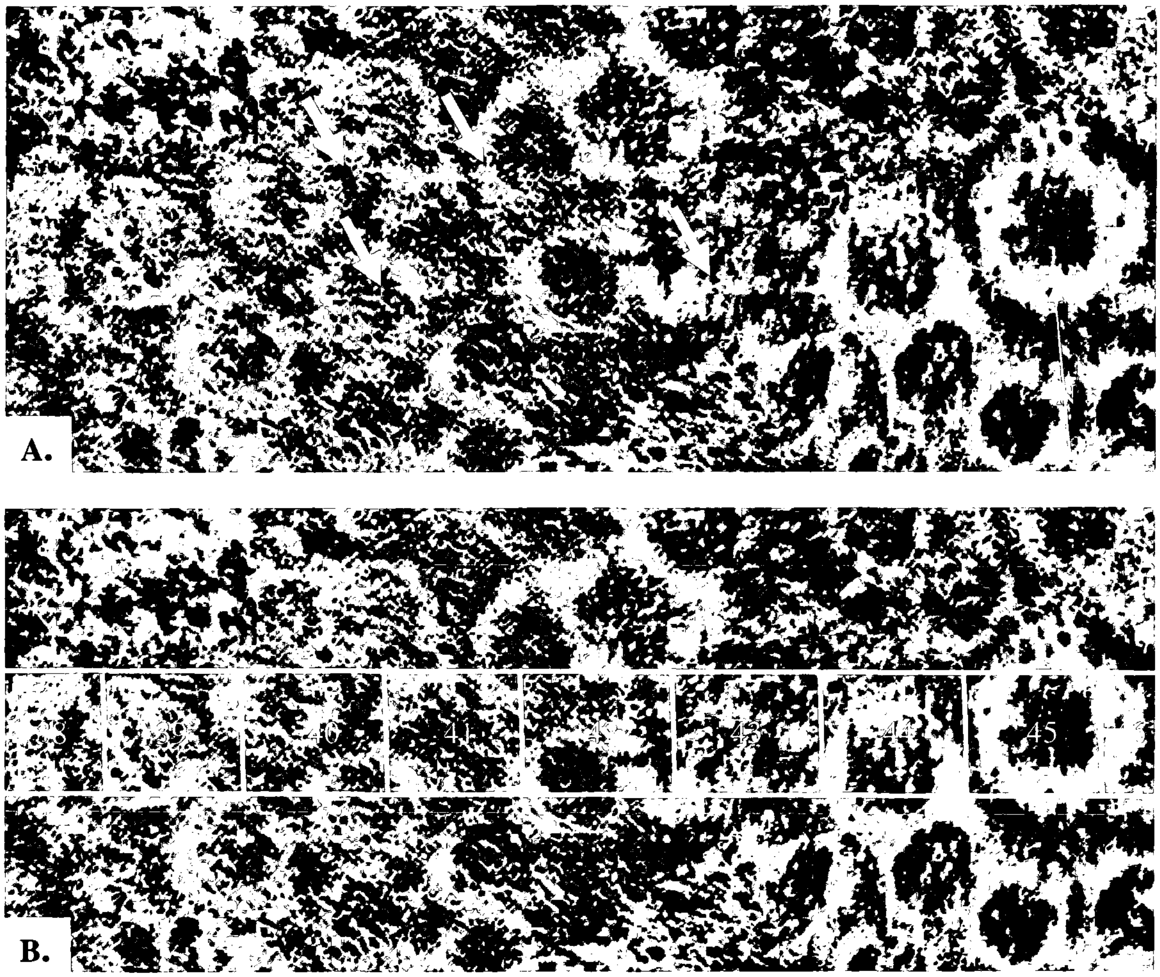

Figure 36: A) Arrows indicate subtle warm anomaly visible in the thermal infrared imagery. B) Kvamme's geophysical transect overlaid on the thermal infrared imagery, numbers correspond to twenty meter by twenty meter survey blocks. (Images are approximately 165 meters across)

Correlation of Ground-Based and Aerial-Based Geophysics

Kvamme's (2002) geophysical survey of the site can be used to inform the interpretation of the thermal infrared imagery. Ground-based geophysical survey methods measure variation in the soil's physical properties, some of which are directly correlated with the soil's thermal properties. Electrical resistivity is largely responsive to variation in moisture – areas of low moisture are highly resistive while areas of high moisture and highly conductive. Additionally, other geophysical methods measure variation in properties of soil that may be the expression of other phenomena. Magnetic gradiometry measures variation in soil magnetism. As topsoil exhibits greater magnetism than subsoil, areas of concentrated topsoil often exhibit greater magnetism making correlation between magnetism and apparent thermal response possible in areas of mounded soil, such as the many berms through the site.

Apparent correlations exist between the results of the magnetic gradiometry survey, the electrical resistivity survey, and the thermal infrared indications of earthlodges. The resistivity survey indicates that earthlodges appear as areas of low resistivity surrounded by rings of high resistance. This validates the assumption that earthlodges are characterized by variation in moisture content principally related to topographic changes. Additionally, the magnetic gradiometry indicates that earthlodges are characterized by rings of increased magnetism. These rings of increased magnetism correspond with the berms surrounding lodges and the rings of warm anomalies in the thermal data. These anomalies result from the elevated earthen berms characteristic of earthlodge collapse. Similar correlations are apparent with respect to the berm surrounding Garreau's Enclosure.

Discussion

Analysis of the thermal infrared imagery yielded the identification of more than 1,200 archaeological features (Figure 37). As many as112 earthlodges were identified. A fortification ditch is evident at the site, as well as two bastions. The west bastion appears to agree with a map of the site made by Prince Maximilian von Wied during his visit in the early 1830s. This is intriguing as none of these bastions had been previously identified. Three trail networks were identified in the data. A major trail network leads to the nearby village of Deapolis and another major trail system appears to lead to local activity areas including Fort Clark. The remains of more than 960 possible pit features are indicated. Approximately 23 of these pits are located at the center of earthlodges that may indicate likely looters' holes or, perhaps, hearths. Thirty-four depressions indicated in the data were identified as the likely remains of graves at the Euroamerican cemetery. Additionally, two large enclosures are apparent at the southern periphery of the site. As discussed previously, due to prior archaeological work as well as their similarities to a structure known from another Arikara village, these features probably represent pony corrals constructed by the Arikara.

The remains of both trading posts and Garreau's enclosure at the site are clearly indicated in the data. Garreau's enclosure is clearly evident in the data. The remains of an earthlodge, a large fence, several storage pits, and a potential borrow pit are all visible in the thermal data. Extensive evidence of interior structure of Fort Clark is apparent. The interior structure apparent at Primeau's Post is somewhat less clear in the data. As previously discussed, it is possible that some of the apparent structure visible in the thermal data related to the trading posts may be the result of archaeological trenches excavated in the 1970s.

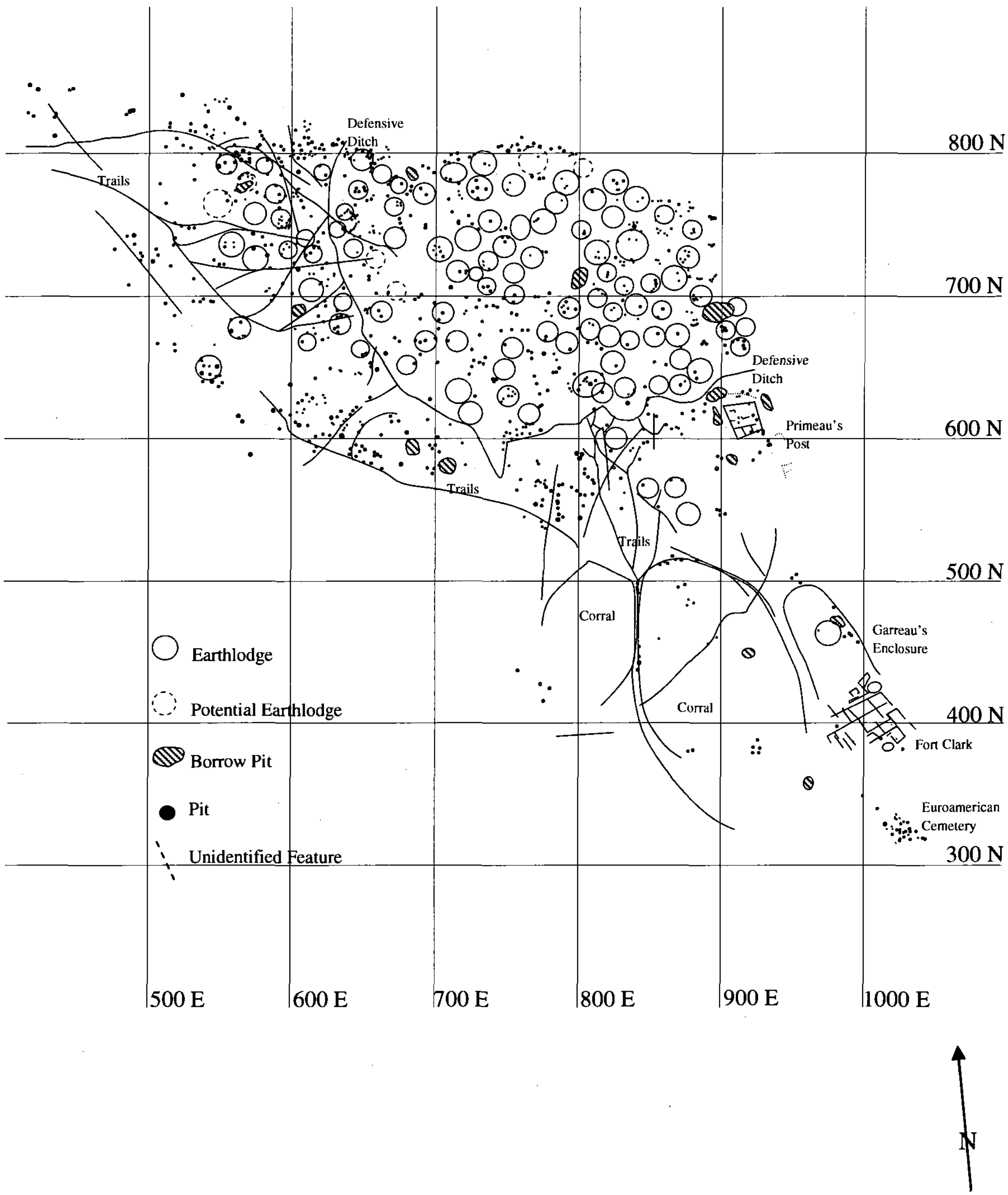

Figure 37: Interpretive map based on the aerial thermal infrared imagery (see Appendix B for large-scale version).

CHAPTER 6: INTERPRETATIONS BASED ON COMBINED COLOR AND THERMAL INFRARED IMAGERY

While each dataset provides a wealth of information about the site, new insight may be gained when the datasets are combined. Interpretations from each dataset are obtained based on a single line of evidence. The color data represents only those features that affect sufficient change on the surface to be seen. Therefore, any features that do not exhibit distinctive surface expression are effectively invisible. On the other hand, the thermal infrared data indicate only features whose character produces significant change in their apparent temperature. As such, each set of data can be used to inform the other, the result of which is a fuller interpretation of the site's remains. To this end, information from both the color and thermal infrared datasets are synthesized into a one master interpretive map (Figure 38). The combined datasets yield significant new information about the site from which new inferences may be based.

The combined datasets indicate the presence of 124 earthlodges. Of these 112 are confidently interpreted in at least one of the component datasets. The remaining twelve are indicated in at least one dataset; however the evidence for these lodges is not sufficient for confident interpretation. Associated with these earthlodges are at least 26 entryways, all of which were identified in the color imagery.

The interpretation of the two datasets differs somewhat in their representation of the defensive ditch. The western half of the ditch appears almost identically in each dataset. The southern portion of the ditch, on the other hand, indicates two different trajectories of the ditch. The color imagery suggests that the ditch maintains a straighter path across the southern edge of the village core and exits the site immediately adjacent to the north end of Primeau's Post. The thermal infrared imagery suggests that the ditch curves slightly north and exits the site several meters north of Primeau's Post. The discrepancy is likely the result of a misinterpretation of the color imagery in this regard. What had originally been interpreted as a section of the defensive ditch is more likely a vestige of a trail. The indication of the defensive ditch is relatively clear in the thermal infrared imagery (Figure 36). Additionally, the thermal imagery indicates another anomaly consistent with would be expected to be a trail at the same location. As the ditch is clear in the thermal imagery and an alternative interpretation is possible for the feature present in the color imagery, the course of the ditch shown by the thermal imagery is certainly more probable.

The combined data indicate at least 27 borrow pits, the majority of which were identified in the color imagery, at the site. Of these features, one appears in the color imagery to overlap with a potential earthlodge indicated in the thermal imagery. While the borrow pit is confidently interpreted in the color imagery and the earthlodge can only be considered a possibility based on the thermal imagery, these interpretations should not be considered mutually exclusive. It is entirely possible that after abandonment an earthlodge would have been "mined" for soil and other useable materials, especially wood. The remains of that activity would manifest itself in a similar manner to any other borrow pit.

The trail systems apparent in both datasets generally agree with each other rather strongly. Numerous trails are apparent in both sets of data although few are evident within the village. The result of combining the data indicates two primary trail systems and a minor one leading away from the site or to activity areas and one trail following a course parallel to the defensive ditch connecting the three exit trail networks. The two major trail networks each consist of at least fifteen individual trails, many of which consolidate into larger trails. The trails northwest of the village merge to form two major trails, the larger of which leads to Deapolis (32ME5), a smaller Mandan village north of Fort Clark. The second, smaller trail probably either leads to a local activity area – potentially an access point to the Missouri River or some other resource – or merges with the other major trail somewhere out of the study area.

The trail system south of the village appears somewhat less organized, probably indicating that they lead to immediately available resources or activity areas. These trails likely were used as travel routes to gardens, corn crops, cemeteries, and other local areas. Interestingly, a trail appears to cross through an opening in one of the corrals validating the location of an interpreted entryway.

Pit features are by far the most common feature in the landscape. The combination of the two datasets indicates at least 1,370 features that can be variously interpreted as storage pits, looters' holes, hearths, and other pit feature types. Any interpretation beyond the identification of pit is difficult. In addition, 75 surface depressions identified in both datasets are probably the result graves excavated in the Euroamerican cemetery. This interpretation largely relies on their association with the cemetery and does not reflect any difference in the character of the visible anomalies.

The two features interpreted as corrals are apparent in both datasets. Each dataset is consistent in their representation of these features. However, the color imagery indicates the corral features far more clearly than the thermal imagery. An opening in the feature's boundaries indicates an entryway into the west corral that is clearly visible in the color imagery. This probably shows the location of an entryway into the corral. As previously mentioned, this interpretation is potentially verified by a trail feature indicated by the thermal infrared imagery.

The remains of Garreau's Enclosure are again clearly indicated in both datasets. Both datasets indicate similar features suggesting little information is gained from combining the data in this instance. This is probably due to substantial nature of the remains associated with Garreau's Enclosure. The data point toward a confirmation of the use of the space as a living compound with a lodge, several storage pits, scaffolds, and a garden. The large, semi-circular feature at the southern periphery is evident only in the color imagery. The interpretation of this feature remains speculative and may actually be associated with Fort Clark, which is immediately adjacent to the southern edge of the enclosure.

Indications of Fort Clark are visible in both datasets, although to differing degrees. The color imagery indicates the location of the palisade that surrounded the fort, while the thermal data denotes significant remains of interior structures. Some of the apparent remains in the data appear to correlate significantly with excavations carried out during the 1970s. However, it is also clear that many of the apparent remains also correlate with features indicated in Kvamme's (2002) electrical resistance survey.

Primeau's Post is similarly represented in the data. The color imagery suggests little beyond the exterior palisade, while the thermal data indicate some interior structure. It appears from the combined datasets that the majority of the interior structures were located along the southern wall of the palisade. A gap in the eastern palisade wall, indicated in the color imagery, suggest the location of a gate into the post, which is seen in a historical sketch.

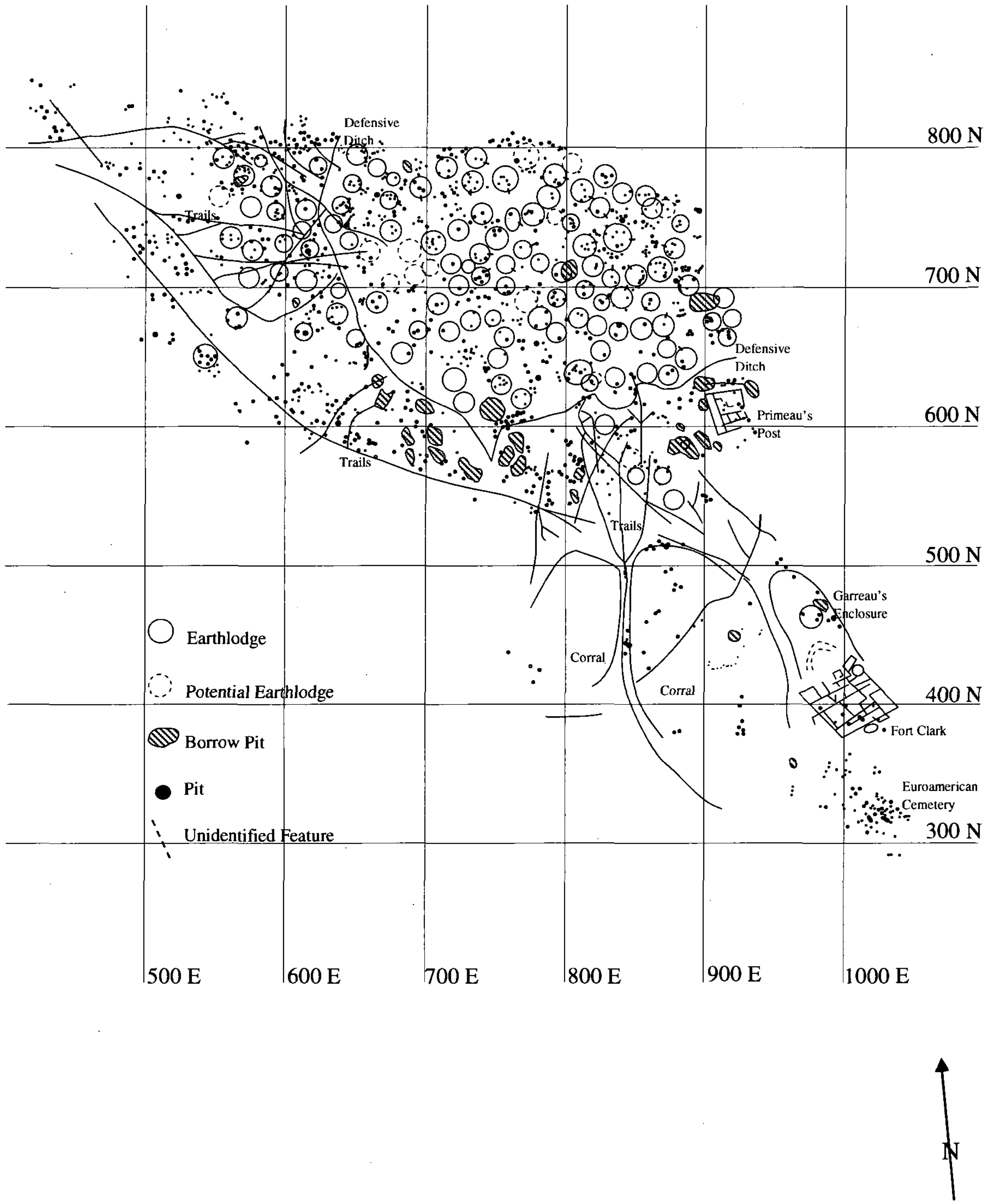

Figure 38: Interpretive map based on both the aerial color and thermal infrared imagery

CHAPTER 7: CONCLUSIONS

The Fort Clark State Historic Site is a complex characterized by a large, fortified earthlodge village and two trading posts. Although the site has been the subject of intensive archaeological inquiry for more than a century, there is much left at the site that has previously gone undetected. A careful examination of high resolution color imagery and thermal infrared imagery collected from a low-flying powered parachute yielded a wealth of new information about the site as well as confirming much of what was already known.

The application of a high-resolution digital camera and the powered parachute provided an ideal medium for examining the surface expression of features at the site. While the increased resolution is, of course, a boon to image analysis, particularly when attempting to discern minute variations in the ground surface, digital image processing potentially proves the greater advantage of collecting digital imagery.

Digital image processing encompasses numerous techniques not available in chemical photo processing and allows multiple processes to be "stacked" and reordered to produce an ideal image. Additionally, digital image processing can be accomplished quickly, without special facilities, and can be done repeatedly allowing for the examination of the ground surface for evidence of archaeological remains along numerous lines of evidence. The ability to adjust contrast, saturation, and brightness proved to be the most useful tools for enhancing the visual contrast of anomalies apparent on the surface indicative of cultural phenomena. To this end, Adobe Photoshop provided an ideal means of image manipulation and analysis.

Adobe Photoshop additionally proved ideal for image registration and rectification. GISs have proven the usefulness and flexibility of using layers to manage and manipulate data. Adobe Photoshop not only incorporates the layer concept, it also provides a means for greater interaction with the data. The ability to manually stretch and warp the data provided an easy means for registering and rectifying the imagery to Wood's (1993) base map compared to more cumbersome GIS methods.

Thermal infrared thermography is clearly a method of archaeological remote sensing with great potential. Archaeologists have long recognized that cultural activity tends to alter the basic character of the soil. Basic archaeological excavation techniques involve the identification of archaeological remains by changes in soil texture, composition, color, and moisture content. The processes that affect these variations in the appearance and texture of the soil also affect variations in the soil's thermal response. As such, a thermal infrared survey can detect the same types of disconformities uncovered during traditional archaeological endeavors. Interpretation of the disconformities detected by a thermal infrared survey should not be limited to the mere identification of variation but should attempt to explore the type and cause of that variation. Fortunately, the basic properties of soil heat flux are relatively simple and accessible as a massive corpus of literature has been devoted to the subject as it pertains to the soil sciences.

Changes in the thermal response appear to be primarily related to available moisture in the soil. While this may appear quite limiting, it should be seen as an accessible indicator of numerous variations in the soil – density, surface topography, moisture content, and vegetation. In turn, from these apparent variations inferences into the cultural processes that produced them can be made using traditional methods of pattern recognition. In this instance, thermal infrared imagery yielded the identification of more than 1,000 anomalies that have been interpreted as having a cultural origin.

As the basis for this research project was provided by Wood's (1993) interpretive map of the site, the results of each effort should be viewed as complementary. When examined side-to-side each dataset adds significant information to the other. While the data generated in this research project indicate as many as 40 previously unknown earthlodges, several mapped by Wood are not apparent in the data. Additionally, Wood's (1993) survey indicated over 1,800 small surface depressions that are likely the remains of storage pits, looters' holes, hearths, or graves. The current research indicated less than 1,450 such features. As such, it is clear that neither endeavor has yielded a complete inventory of the site.

While the research program identified nearly 1,500 archaeological features, Wood's (1993) survey of the site identified more than 2,200. The bulk of these features are indicated by small surface depressions identified as probably being the result of storage pits, looters' holes, graves, or hearths. This indicates aerial remote sensing may not be an ideal method for identifying small features. As all of the data used in the research was resampled to a spatial resolution of twenty centimeters per pixel, a feature would have to be at least that size to be detected, though small features may be made more indistinct by the resampling process. It would seem, therefore, that ground-based survey methods may be better suited to the identification of small, ephemeral features. However, if the spatial resolution of the data were greater smaller features may be identifiable. Additionally, many features may have been obscured by longer vegetation in the southern half of the site. Had the grass been mowed shorter, more features would likely have been visible in the datasets.

Archaeological aerial-based remote sensing has several advantages over traditional archaeological prospecting methods – test excavation, surface walking/collecting, plow zone removal, etc – including speed, coverage, cost, and destructiveness. While traditional archaeological survey may take weeks to conduct and weeks to analyze, aerial remote sensing can be conducted in a few hours and analyzed within a few days – depending on the scope of the project, of course. Additionally, a remote sensing endeavor can easily survey an entire study region, while traditional excavation methods generally only examine an extremely small percentage of a site. Total site coverage means that a greater percentage of the archaeological material at the site will be detected. Potentially the most beneficial aspect of remote sensing is the lack of impact to the site. Traditional archaeological methods, particularly those that involve excavation, destroy much of what they observe. While aerial remote sensing is not applicable to every research program, its utility is apparent.

Avenues for Further Research:

Clearly, there is more to the Fort Clark State Historic Site than had previously been known. Both the color and thermal infrared imagery data yielded information about previously undetected archaeological remains. However, a large portion of the site was not adequately surveyed as part of this project. Additional survey is required to include the entire southern half of the site. Ethnohistoric records suggest that the Native American cemetery was located south of the site. Unfortunately, little evidence is evident in the data to suggest where those remains may be located. Further, to date, all archaeological work at the site has been limited to the area between the modern road and the derelict shoreline. As the modern road did not exist during the site's occupation there is no reason to assume that the site ended there. The destinations of the south-leading trails are, as yet, unknown. Perhaps an examination of the surrounding area may lead to the identification of these locations.

As has already been briefly mentioned, the number and density of earthlodges provides a means to study population dynamics. In this case, an understanding of the distribution of the dwellings may provide insight into social organizational principles. Additionally, a better estimate of the population should be generated from a more complete record of the number of lodges at the site. As such, a fuller examination into these issues than is available here may be warranted.

The project clearly indicates the benefit of combining multiple data sets from numerous sources. While the color and thermal infrared surveys independently produced significant amounts of data useful for the identification of cultural phenomena, coupling those datasets provides a far more holistic view of the site. Additionally, comparing the new interpretations with what is known about the site from aerial photographs, traditional ground-based survey, and ground-based geophysical survey provides additional information. Consequently, research at the site should continue using as many techniques as are available.

However, much data on the site has already been collected and may benefit from reexamination. Digital color imagery is processed as a three layers of data - a green layer, a blue layer, and a red layer – which, when blended by the computer, produce an image that reflects the visual experience of humans. Each of these bands of data may reflect different aspects of conditions present on the ground surface. During the comparison of a GIS and Adobe Photoshop, imagery had to be split into its constituent layers. A passing examination of the individual layers revealed that a single layer may provide a clearer image of the specific aspects of the ground surface. For example, vegetation absorbs a far greater percentage of red light than other wavelengths. An examination of the red band may provide a clearer picture of differential vegetative growth, which has been shown to be an effective indicator of cultural phenomena. An examination of these layers individually may provide an alternate means for using digital color imagery for identifying surface variation. This paper did not explore digital image classification methods. Color and thermal layers with multivariate digital classification techniques have unrealized and large potential. It will be up to future researchers to follow this path.

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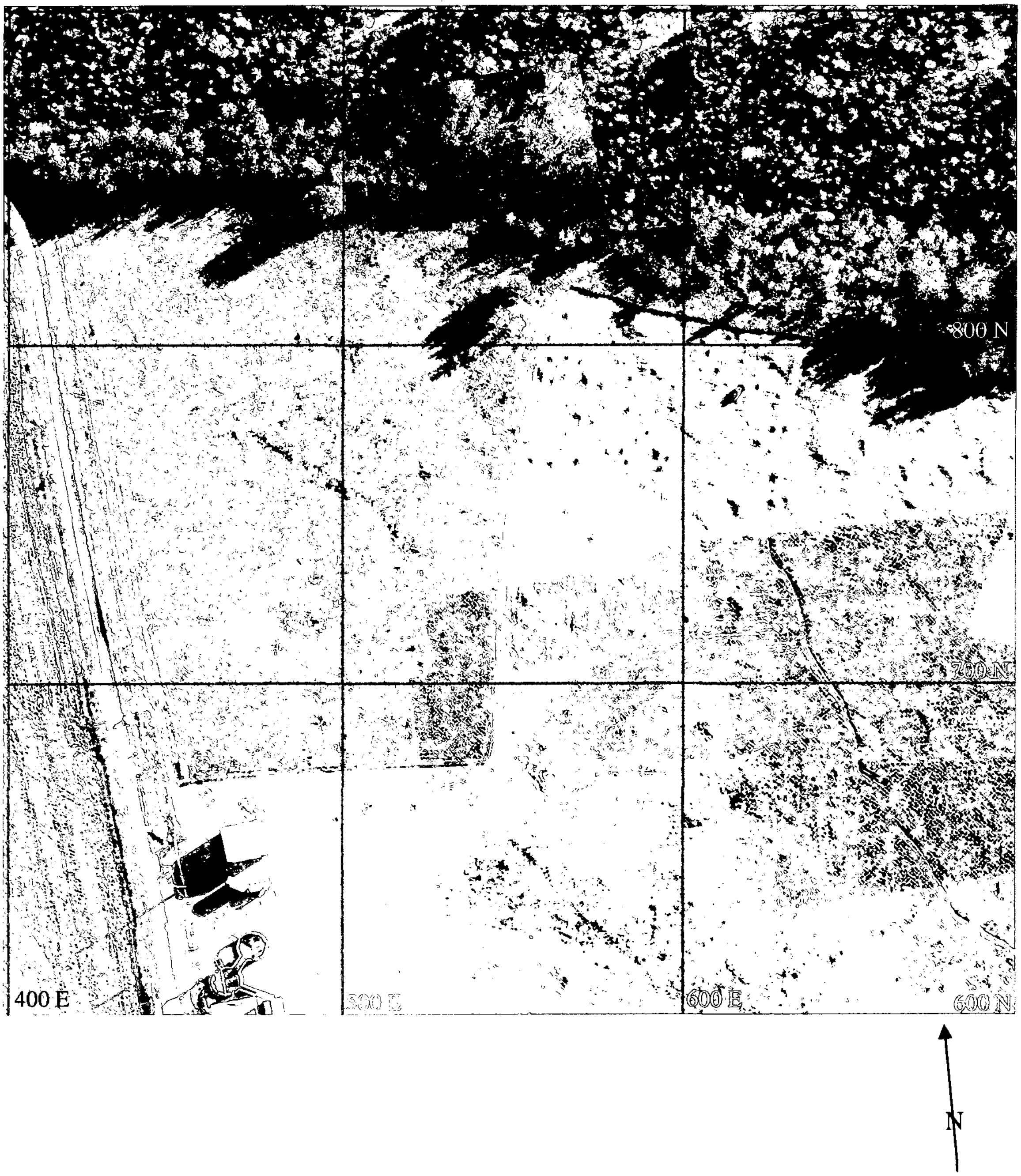
APPENDIX A: AERIAL COLOR IMAGERY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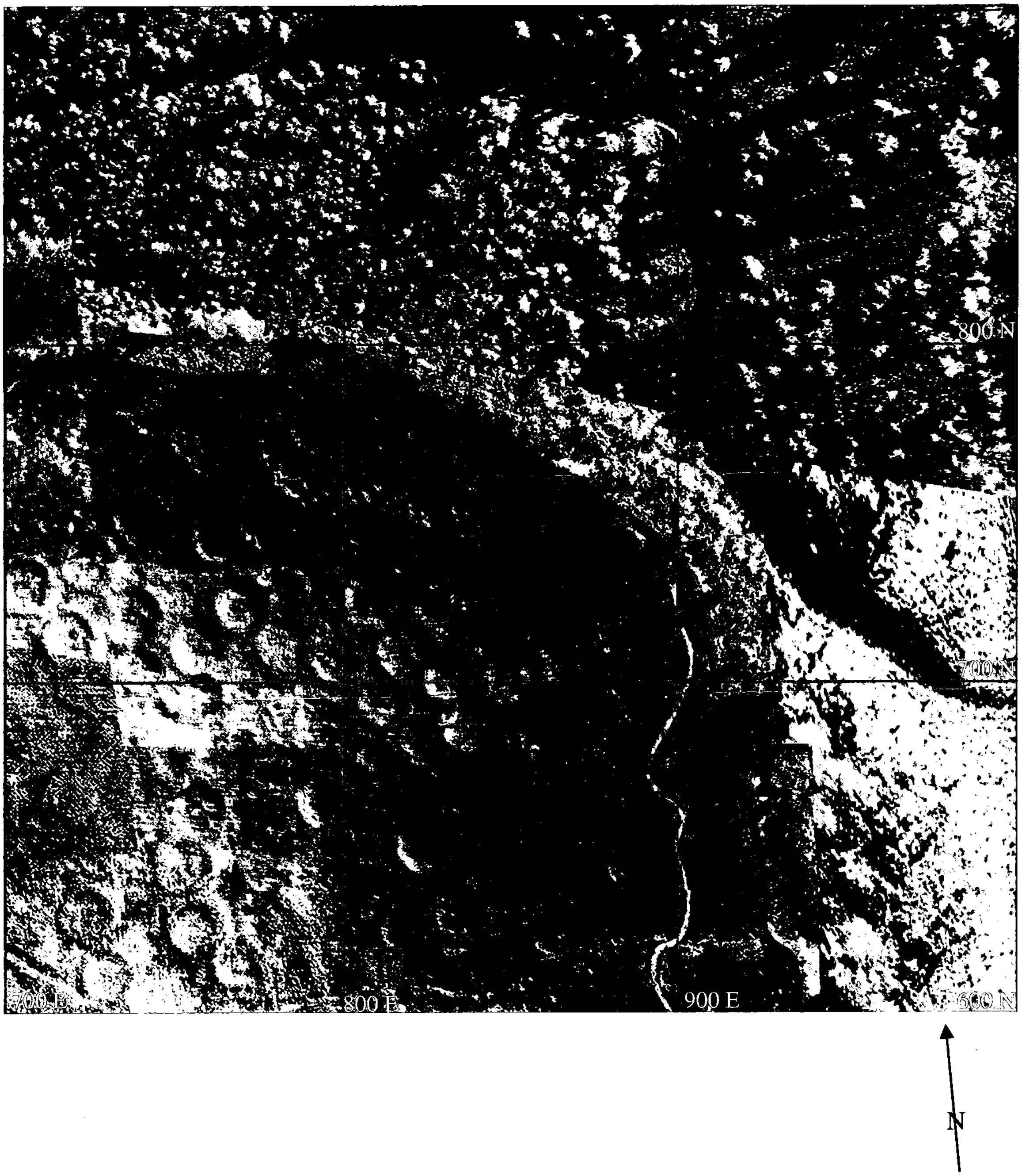

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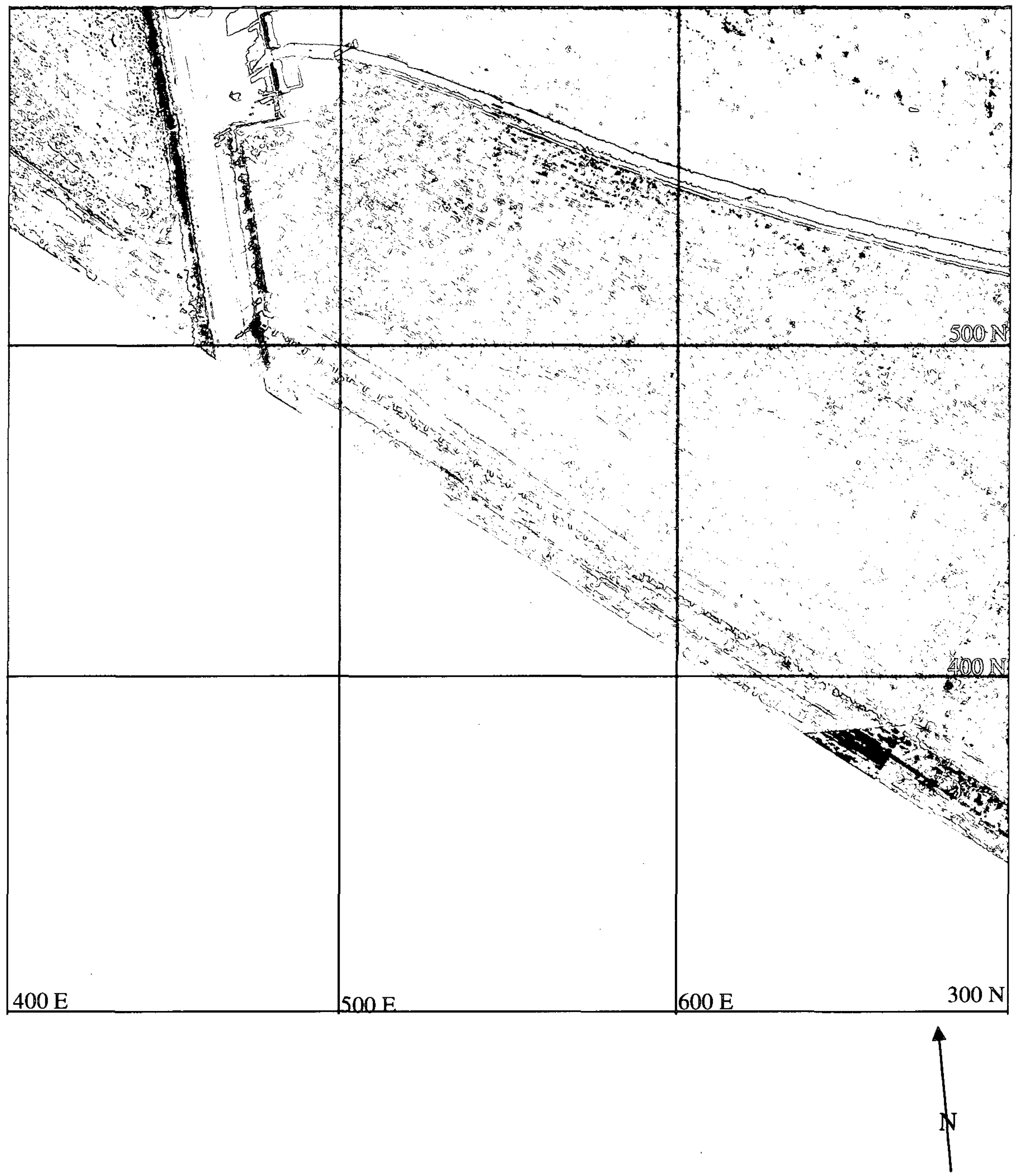
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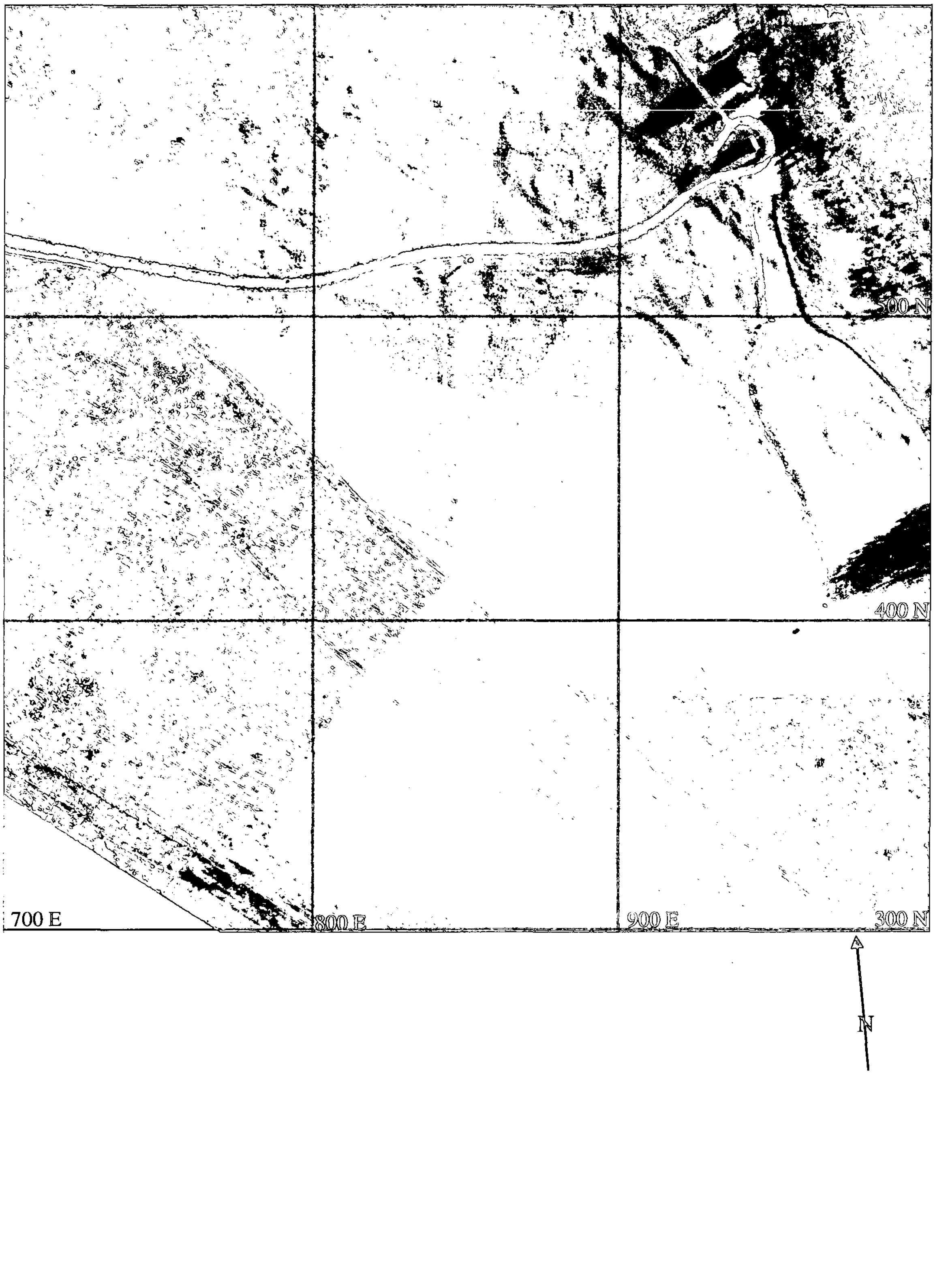
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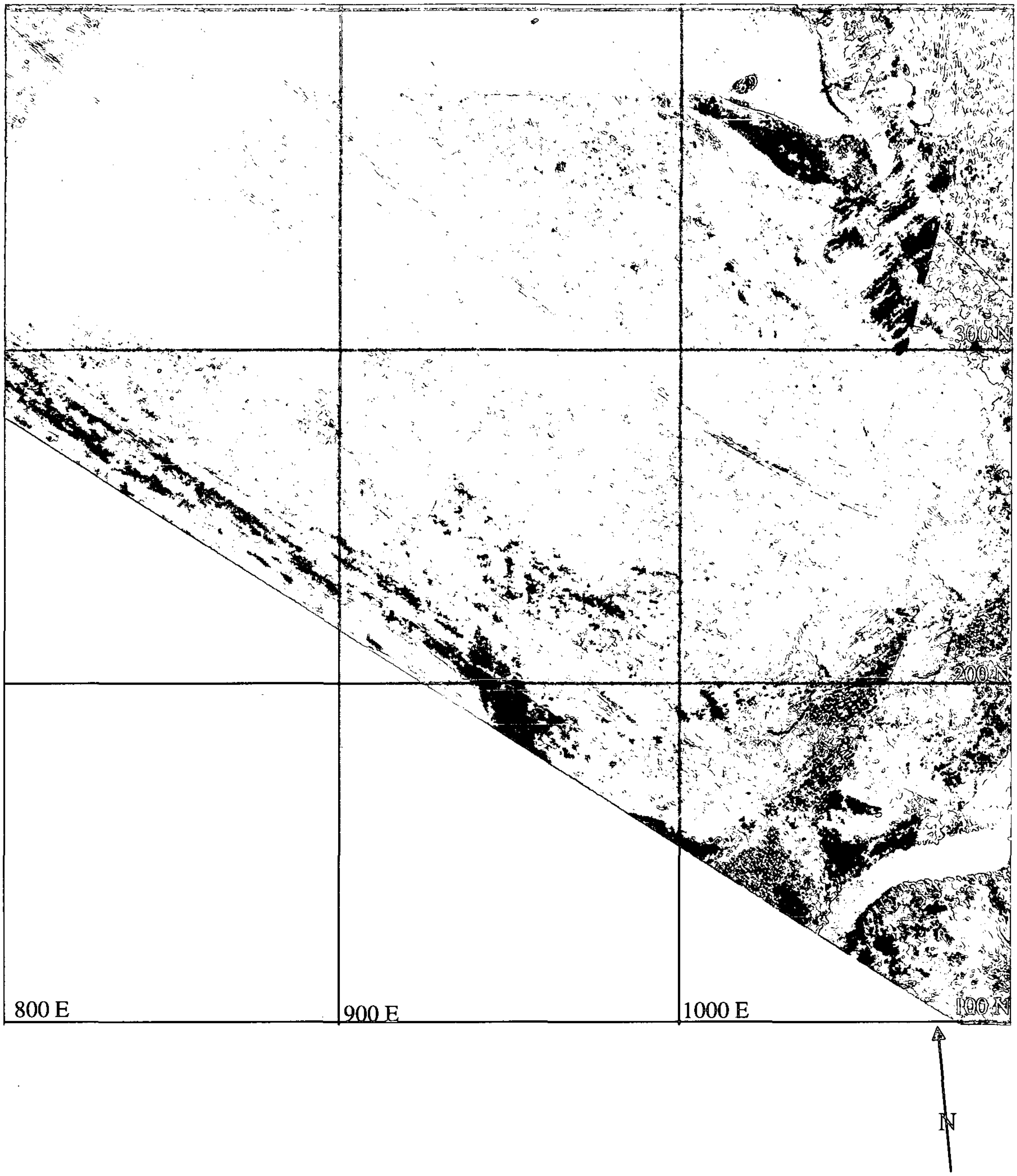

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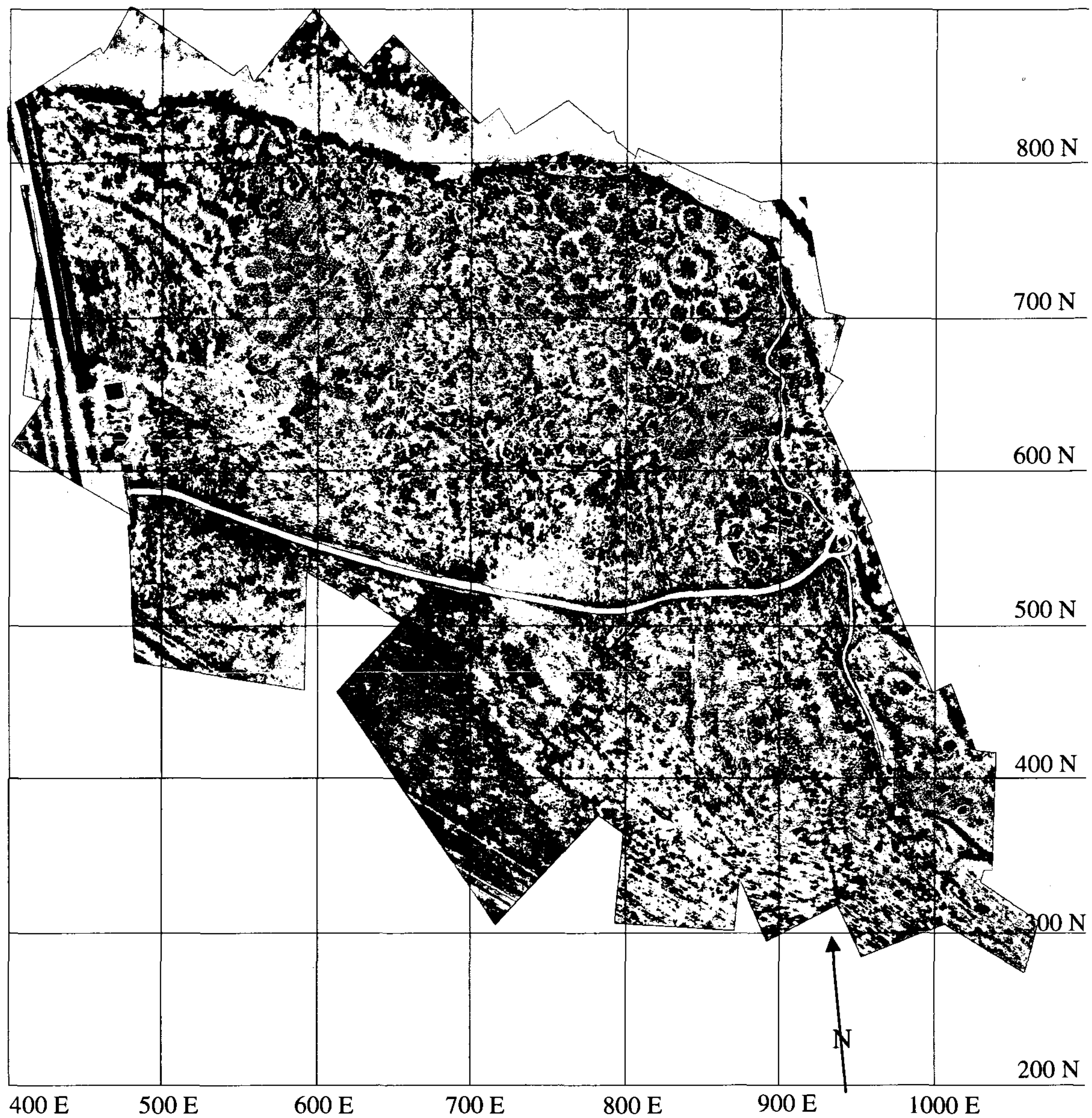

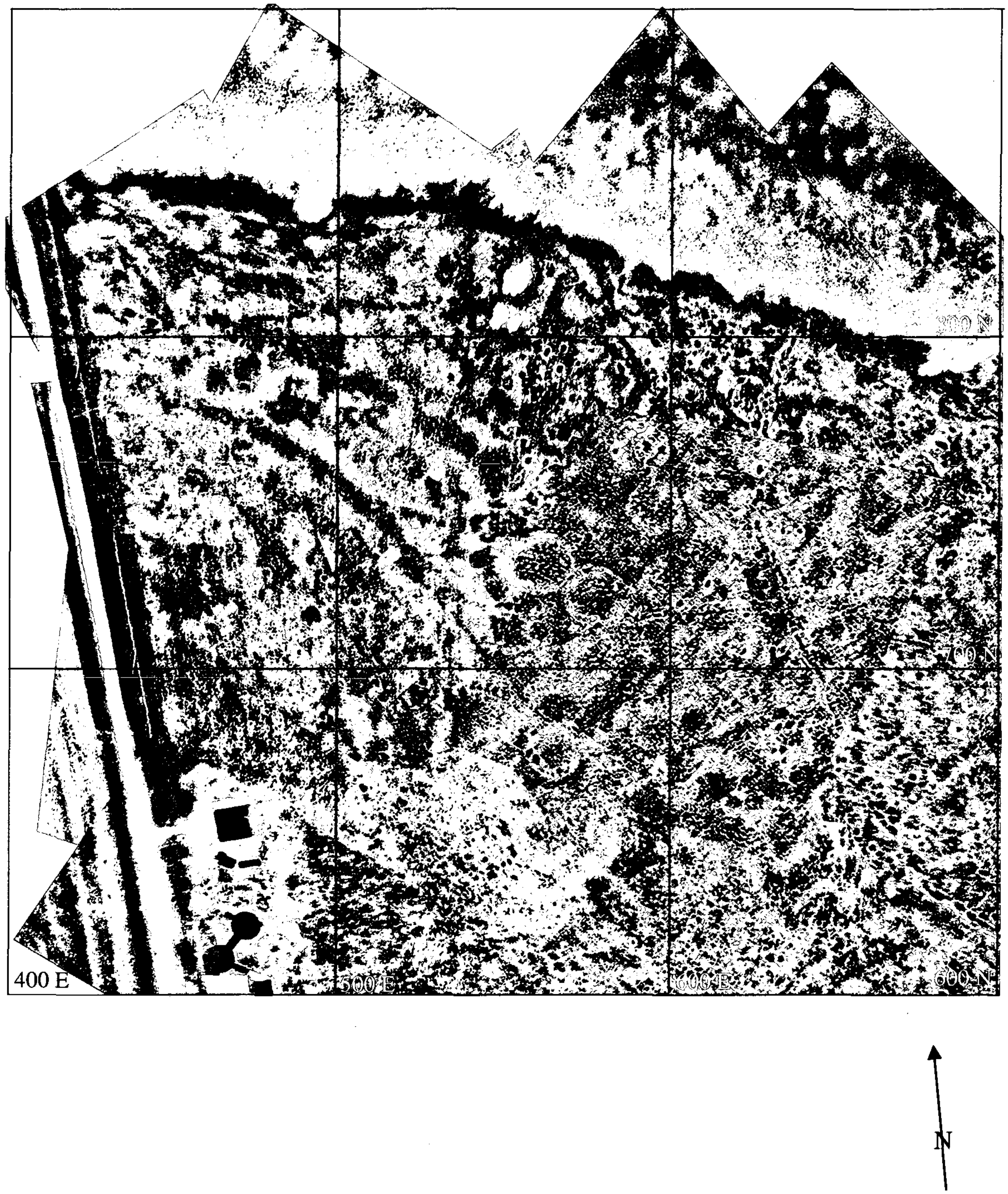
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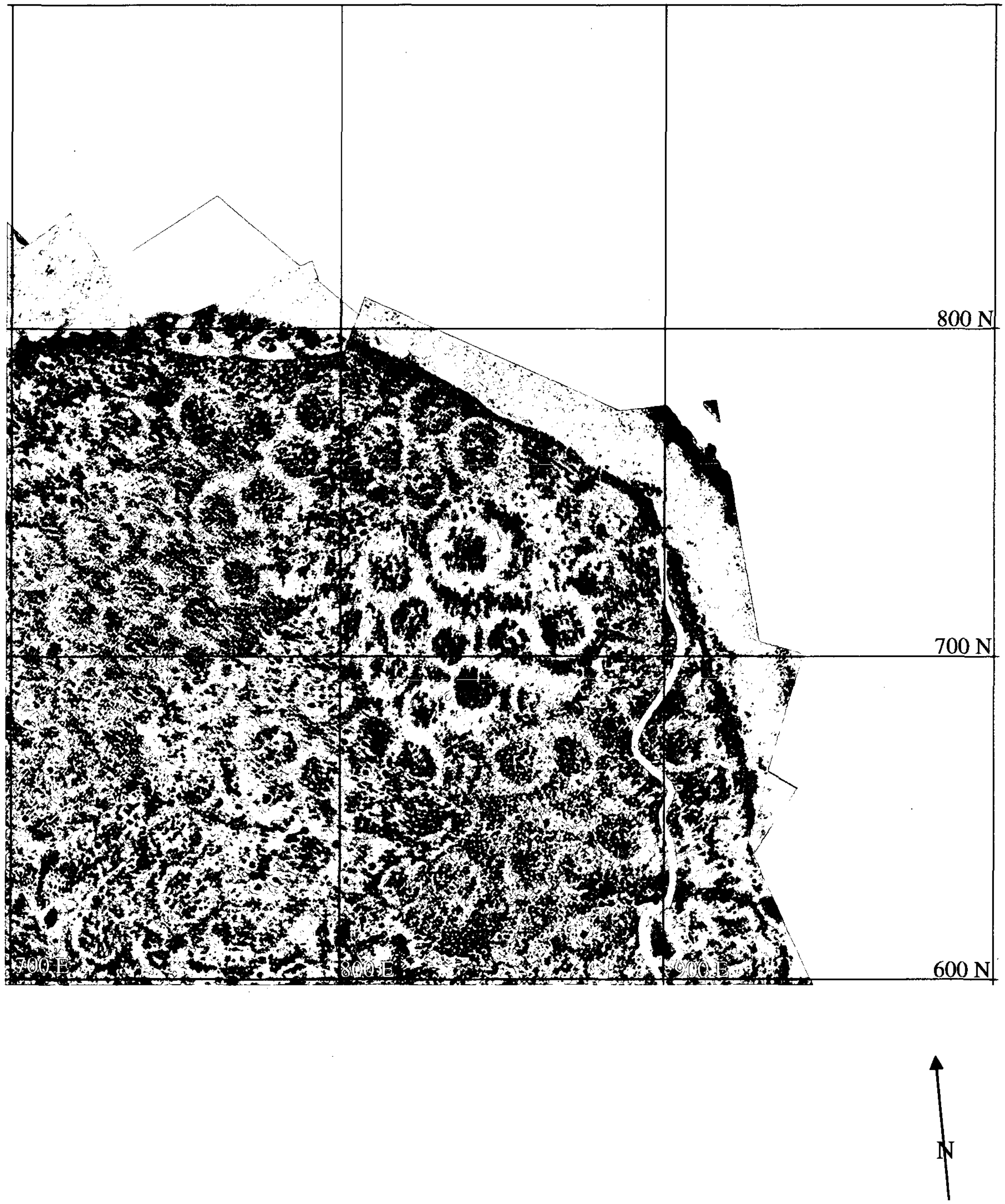
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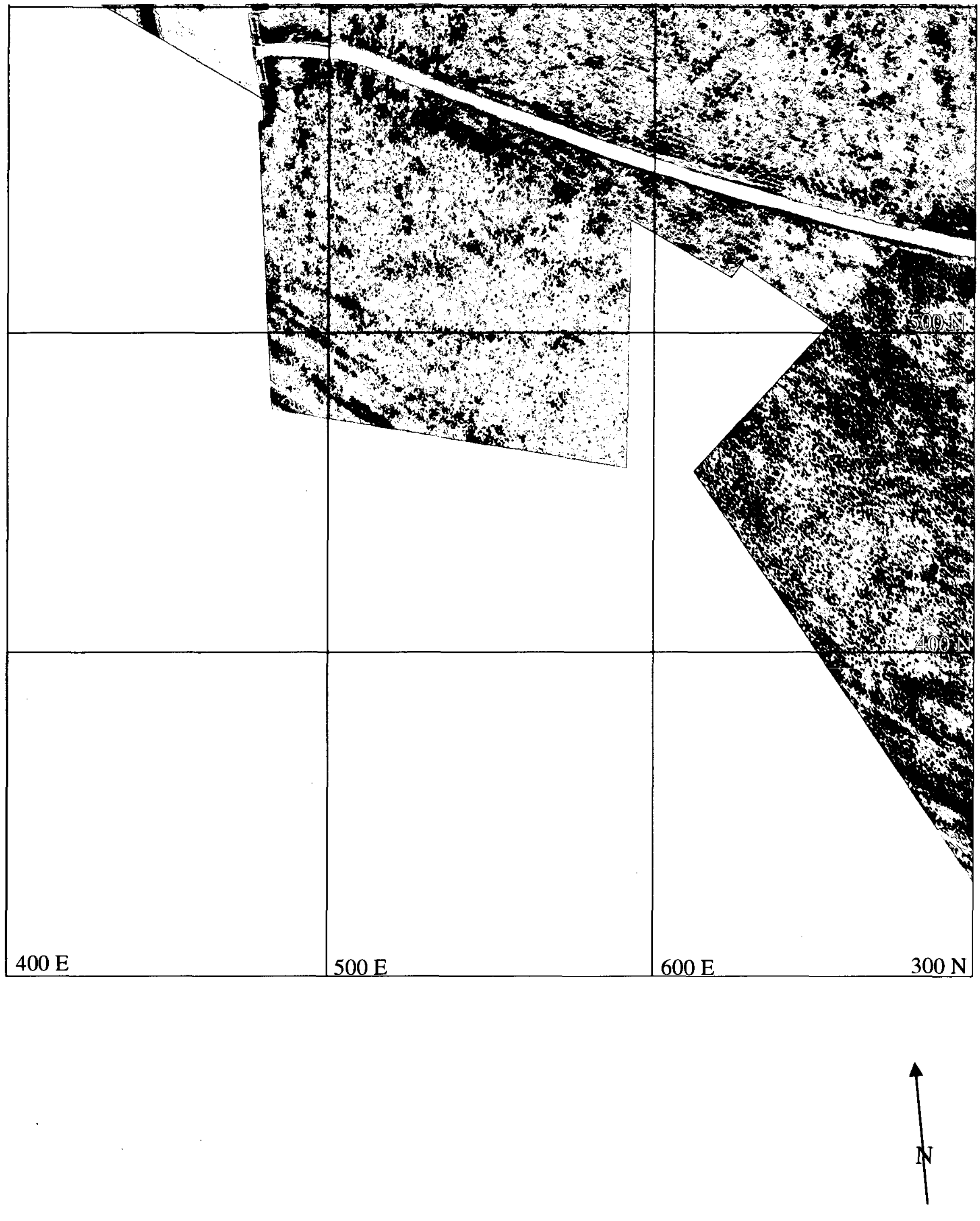

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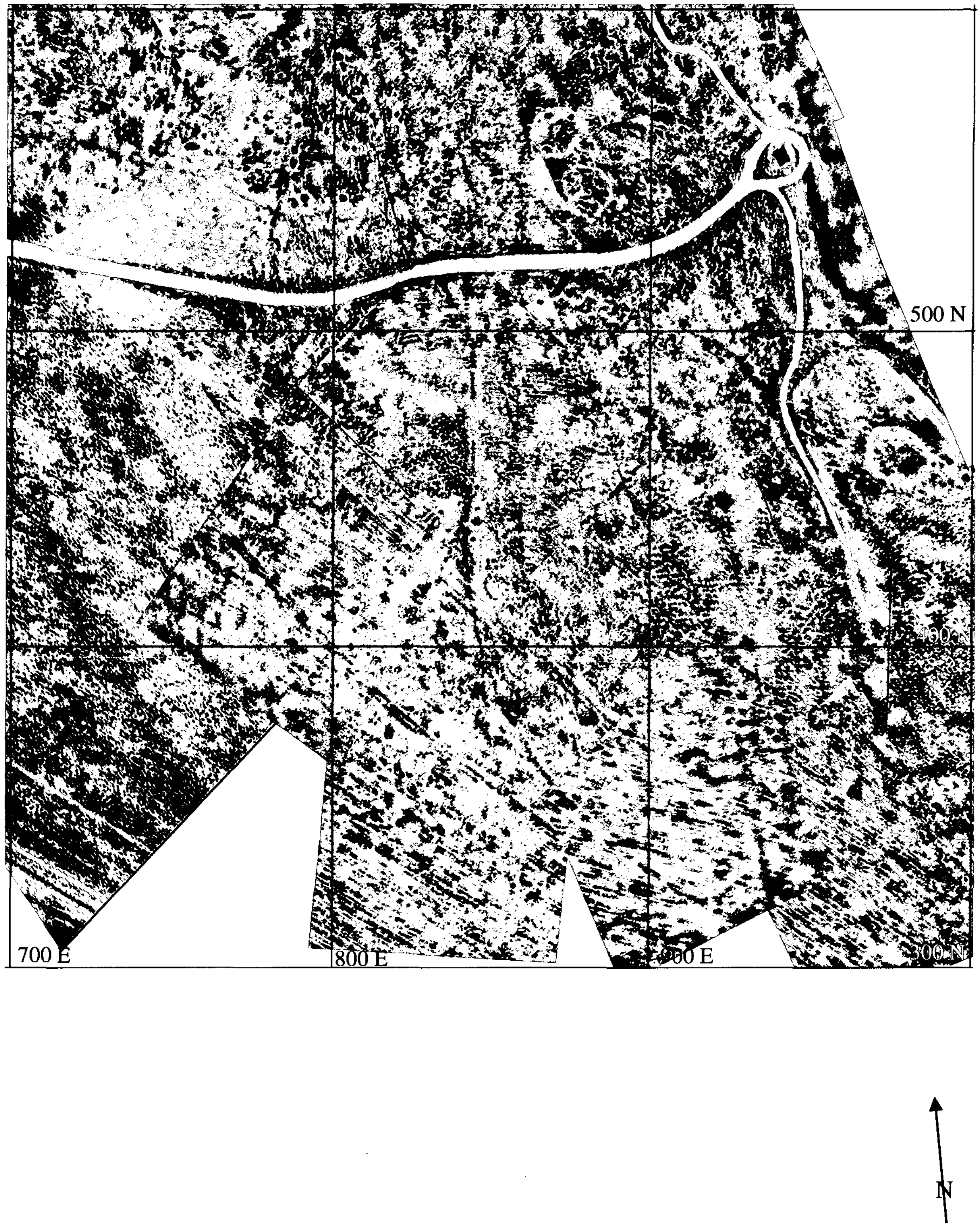
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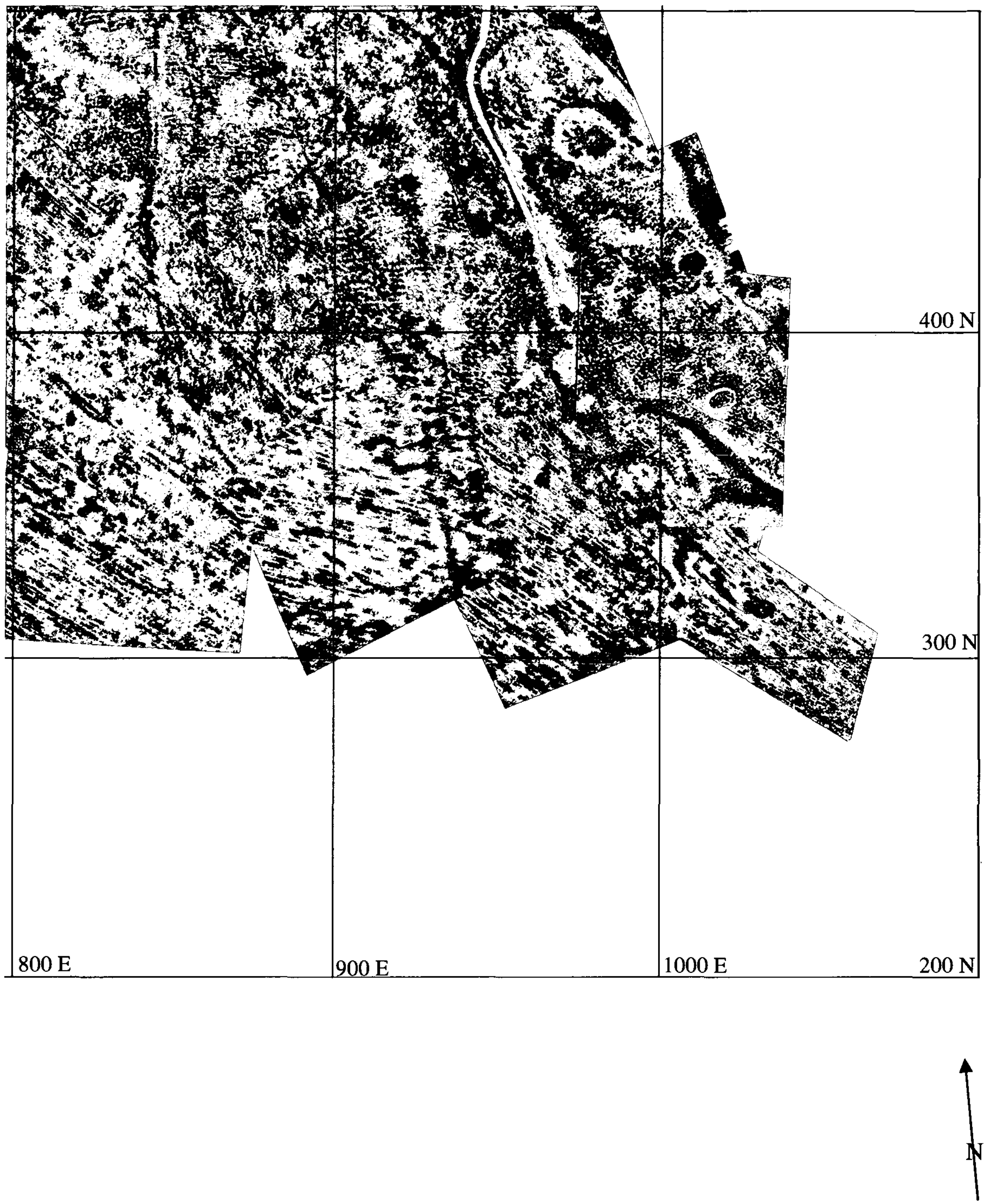
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