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A new approach to population: Using multiple measures to estimate the population of a protohistoric village in the western Great Lakes region, USA

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ABSTRACT

Prehistoric population sizes are difficult to determine, even with very well documented archaeological contexts. Within the Western Great Lakes, USA region, village population size is poorly understood due to poor preservation of village structures, excavations that did not capture the full extents of villages, and widespread destruction of archaeological sites. We combine data from geophysical surveys, historical aerial and drone-based image analyses, as well as excavation to determine the distribution of archaeological features at the protohistoric Middle Grant Creek site (11WI2739), Illinois, USA. Estimates of village population are calculated and compared using multiple measures, including structure floor area, maize storage volume, cultivation area, and maize consumption. The different estimates vary, yet they converge to indicate a population of 100 and 180 people at this agricultural village. The use of converging multiple estimates of population provides a more convincing estimate than any single source and shows how various assumptions affect different estimates. The measures employed provide a new approach to determining village size beyond traditional methods of using floor area and historic comparison, and can be used in locations where traditional measures are not available, as well as for large, dispersed sites that cannot be fully excavated.

1. Introduction

Population size and density are essential to understanding key aspects of past communities. Many different methods have been used to estimate population distributions from the level of the settlement to large regions (Chamberlain, 2009). Within the North American Midwest, prehistoric population estimates are most famously employed in debates surrounding whether Cahokia was a true urban center with a state-level organization or a collection of smaller communities organized as a complex chiefdom; debates that have been difficult to resolve because of the wide range of Cahokian population estimates (Milner, 1998). Pre-Columbian population estimates also have been used to determine the severity of epidemics and impacts of colonialism within the Americas (Koch et al., 2019). Yet, few studies have sought to estimate population size among smaller-scale late pre-Columbian communities, especially within the Great Lakes region, USA, leaving critical gaps in our understanding of the dynamics of village lifeways as well as impacts of colonialism.

In the western Great Lakes, limited early historical records of the first European-Indigenous encounters provide glimpses into population sizes of seasonally mobile, largely egalitarian, agricultural Indigenous communities of this time (de Liette, 1934; White, 1991). Yet, wide-ranging changes associated with colonialism likely occurred in advance of direct contact in the late 17th century, as European trade goods are regularly found at early 17th century, protohistoric sites (Brown and Sasso, 2001; Erdhardt, 2010; Mazrim and Esarey, 2007; McLeester and Schurr, 2020a). In particular, historical accounts in the midcontinent, which often include village population counts, were written as refugees fled villages and aggregated in larger centers as a defense against Iroquoian attacks and expansionist efforts to control the fur trade and to avoid epidemics (White, 1991). Thus, historical accounts offer only possibilities of protohistoric village lifeways and direct investigations are needed to better understand how communities changed, responded to, and incorporated indirect colonialism into their lifeways.

Archaeological investigations have not yet been able to answer fundamental questions about this era, in particular the size of villages and their layout, due to preservation issues and archaeological methods used in the region. These challenges are especially stark within the

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Chicago region, where understandings of the protohistoric era are limited by extensive development in the metropolitan area and its suburbs, accompanied by surrounding agricultural and industrial activities, which have destroyed the vast majority of archaeological sites and large portions of others. Further compounding these preservation issues, our existing understandings of protohistory are based on excavations that were either conducted as mitigation projects or occurred over fifty years ago (Bluhm and Fenner, 1961; Bluhm and Liss, 1961; Brown and O'Brien, 1990; Herold et al., 1990; Jackson, 2014; 2017a). While mitigation projects provide excellent information about the types of features present and their distributions in excavated areas, they typically sampled relatively small portions of a site, with locations that were often determined by expediency or high impact. The destructive activities of artifact collectors have also been significant despite attempts to salvage information (Dausman, 1990; Hargrave et al., 2017; Jackson, 2010).

The most significant limitation of the past investigations is that they occurred prior to the development of geophysical survey methods that allow archaeologists to determine the distribution of subsurface features across sites that are too large or dispersed to be completely excavated. While geophysical surveys (or archaeological prospection) have been used successfully in many areas of the USA and across the globe, they have rarely been used in the Chicago region, in large part because many excavations were conducted before the geophysical instruments and methods were available. While existing accounts of protohistoric communities expertly address questions about protohistoric subsistence and material culture, they are nonetheless limited in their ability to address broader-scale village-level dynamics, because they have relied primarily on excavation to sample relatively small portions of sites.

Here we use multiple lines of evidence to provide a range of village population estimates based on the village-scale layout of storage and potential housing at a protohistoric, early 17th century Huber phase village, Middle Grant Creek (11Wi2739), near Chicago, Illinois. Geophysical surveys (specifically magnetometry and soil resistivity) and ground truthing excavations conducted between 2016 and 2020, supplemented by historical aerial photographs and drone-based thermal images, provide essential data to create estimates of the village population using three different methods. These multiple approaches illustrate the variation inherent in population estimates, such that no one estimate is sufficient. Yet, despite the variation, our results ultimately indicate that this early 17th century community significantly invested in storage and may have had a population of between 100 and 180 individuals.

2. Huber phase at Middle Grant Creek (11 Wi 2739)

Middle Grant Creek (MGC) offers a unique opportunity to explore protohistoric village population size. Located at Midewin National Tallgrass Prairie in Will County, Illinois, it is approximately 65 km from Chicago and situated on the former TNT storage bunker field of the now decommissioned WWII Joliet Arsenal, whose construction in 1940 prevented the most severe impacts of farming and development, leaving much of the site intact.

MGC is a single component, Huber phase village that corresponds to the local, eastern Oneota archaeological tradition from approximately CE 1500 until European contact. Many Huber sites are classified as protohistoric because European trade goods indicative of down-the-line trade through Indigenous trade networks are often uncovered. Thus, investigations into late Huber sites are uniquely positioned to expand our understanding of Indigenous lifeways prior to direct European contact, at a time when Indigenous groups were likely aware of impending European encounters and perhaps already experiencing significant changes within their communities.

Huber communities are typically interpreted as semi-sedentary agriculturalists whose settlement types include large agricultural villages, winter hunting camps, and wide range of resource extraction camps (McLeester, 2017). However, recent excavations at MGC suggest that at least some Huber villages may be occupied by some of the community year-round (McLeester and Schurr, 2020a). Primarily maize-intensive agriculturalists, Huber sites were occupied during the Little Ice Age, an unusually cold climatic period (Matthews and Briffa, 2005) that may have stressed agricultural systems by shortening growing seasons and changing precipitation patterns (Degroot, 2018; McLeester and Schurr, 2020b).

The majority of Huber sites are located in a small cluster north of MGC in the Cal-Sag Channel and Calumet River drainage area in northern Illinois (Fig. 1). Additional Huber sites, interpreted as warm season marsh resource procurement and processing sites (Faulkner, 1972; Schurr, 2017), are found along the former Grand Kankakee Marsh in northwest Indiana, including the well-known Griesmer site (Faulkner, 1972) and other less well-known sites such as Rader (Faulkner, 1964), Wilson (Bellis et al., 1979), and possibly Davidson (Jeske, 1998). Huber sites geographically distant from the core area include Zimmerman near Peoria, Illinois to the west (Brown, 1961) and Berrien phase sites (Cremin, 1992; O'Gorman and Lovis, 2006) on the lower St. Joseph River valley in southwestern lower Michigan to the east. Huber agricultural villages, similar to MGC, include Palos, Oak Forest, Huber, New Lenox, and the Huber component at the Hoxie site. Each of these sites has been excavated to varying degrees as part of salvage operations, mitigation projects, and/or field schools. While recent excavations have been conducted at multiple sites, the last excavation of an effectively single component Huber site prior to MGC was the 1979 excavation of Oak Forest (Brown and O'Brien, 1990), and since then significant advances have been made in archaeological approaches and methods, as exemplified by the recent work at the Fisher/Huber Hoxie Farm Site (Jackson, 2014; 2017a).

2.1. Previous work at Middle Grant Creek

The Middle Grant Creek archaeological site was first reported in 2002 when a Phase I survey found shell tempered ceramic sherds in a disturbed area and in a shovel probe, indicative of a probable late prehistoric occupation. Based on the recommendation for a Phase II investigation, the site was evaluated using intensive shovel probing at 10 m intervals and ten test units (Haas et al., 2012). Positive shovel probes from the Phase II survey established the current site boundary (site polygon) of 3.4 ha, with maximum dimensions of 445 m north–south by 190 m east–west, located along a low ridge or outwash terrace edge overlooking Grant Creek. (Fig. 2). Two of the test units contained prehistoric features, including one large refuse filled pit and a smaller, shallower feature, interpreted as a possible hearth (Haas et al., 2012).

The report of the Phase II investigations (Haas et al., 2012:74) concludes that MGC was likely an agricultural village, largely based on its location in an environmental setting suitable for Oneota agricultural activities, the presence of maize cob fragments, and a deep refuse-filled storage pit. However, without a better understanding of feature distribution and density, the function of the site remained speculative until recent investigations, initiated in 2016 (described below) undertook extensive geophysics and excavation of the site.

3. Geophysical surveys

Geophysical surveys have become well established in the discipline as an alternative to destructive exploratory excavations as well as a means to guide excavation (Clark, 1962; Gaffney and Gater, 2003; McKinnon and Haley, 2017). While many different survey methods are available, two types of geophysical surveys were undertaken at MGC, magnetic and soil resistivity. Magnetic survey (magnetometry) is probably the most frequently used method for covering large areas quickly and for identifying concentrations of metallic artifacts associated with historic activities or building foundations. It can also identify prehistoric features such as large postmolds, houses (especially when burned), hearths and fire-cracked rock (FCR) concentrations, and

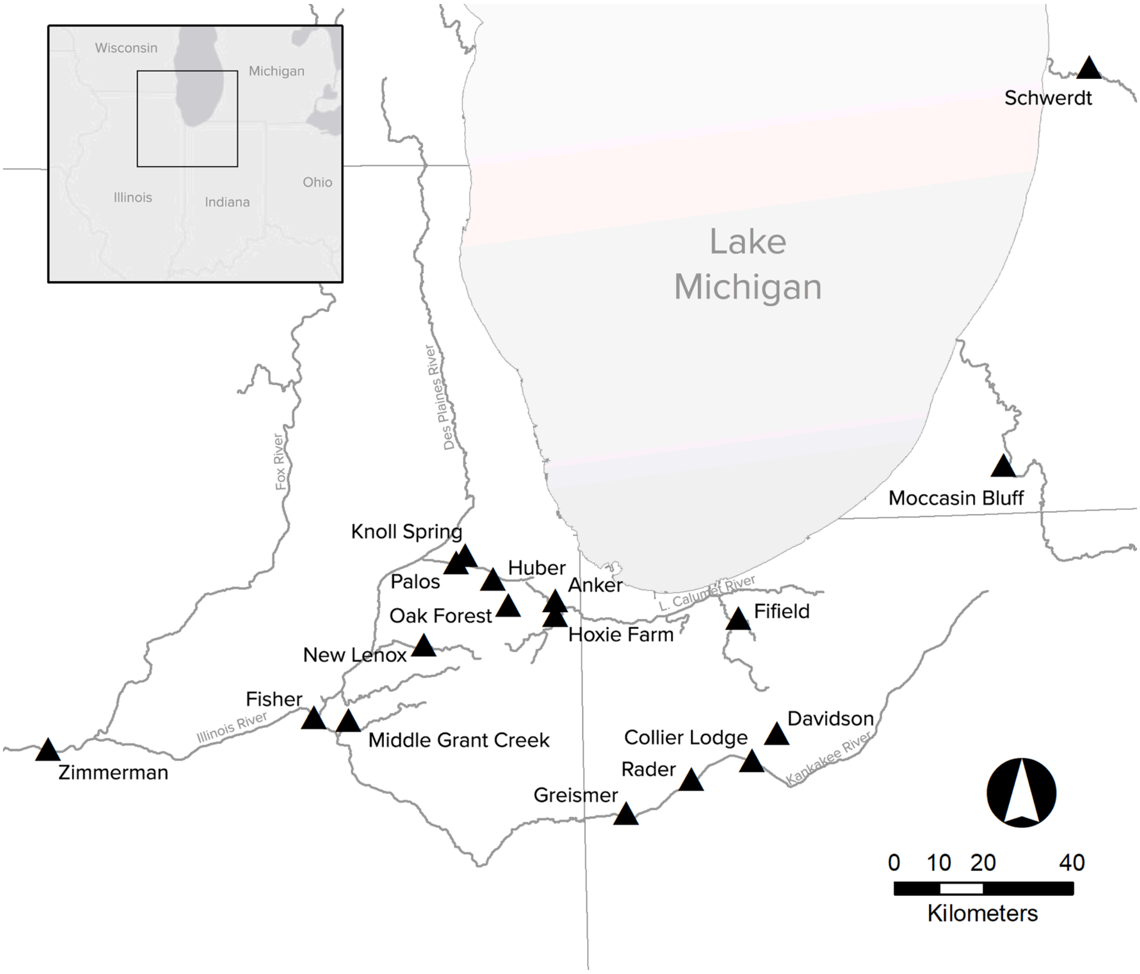

Fig. 1. Site location and other Huber phase sites mentioned in the text.

anthropomorphically modified soils. Soil resistivity surveys, while less commonly used than magnetic surveys and slower to perform, are useful for identifying areas of historically disturbed or compacted soils and patches of prehistoric midden. Thus, magnetic and soil resistivity surveys are time-effective ways to quickly inventory geophysical anomalies that may be associated with significant archaeological features near the surface at Native American villages.

However, a site such as MGC, which is situated on a former Arsenal during the twentieth century, presents some special challenges for geophysical survey. Historic period features tend to be more diverse than prehistoric ones in the Midwest, and typically produce more intense anomalies, therefore masking earlier features. However, historic period anomalies are typically easily identified because of their well-defined geometric shapes and our familiarity with the types of features that produce them. Precontact features produce weaker anomalies with less well-defined shapes and often require verification by ground truthing excavations.

As most excavations at Huber sites were conducted before the era of practical magnetic survey, there is little prior information on the expected results of magnetic surveys on Huber phase sites. To date, geophysical surveys have only been reported from 14th to 15th century habitation sites in the region categorized as Late Fisher phase (the phase preceding Huber) where they have detected defensive ditches (Jackson, 2014; Hill and Murray, 2012), possible housing structures (Hargave and Jackson, 2014), a midden (Schurr, 2017), and other features (Hill and Murray, 2012). At Collier Lodge (Schurr, 2017), a site with prehistoric Late Fisher and historic features, the historic features were most pronounced in the magnetic, soil resistivity, and ground penetrating radar surveys, and these strong anomalies masked the Late Fisher component, including roasting pits which were quickly refilled after use and not detectable. While similar surveys have not been conducted at other Huber phase sites, the results from surveys at earlier Late Fisher sites show that prehistoric features can be detected.

3.1. *Magnetic survey*

At MGC, magnetic surveys covering 9,700 m^2 (approximately 29% of the 2006 site polygon area) were conducted within the existing site boundaries, except in areas that were disturbed (e.g. areas adjacent to Arsenal-era TNT storage bunkers and rail lines), the historic farmstead on the southern end of the site, and where dense brush precluded access (mainly on the western edge of the site). An additional area of 1,485 m^2 to the east of the existing site polygon was also surveyed (Fig. 2). Surveys were conducted with a Geoscan FM36 gradiometer at transect intervals of 1 m and sample intervals of 0.25 m in parallel traverse mode. Magnetic data were processed to remove within-grid drift, normalized to eliminate grid-edge defects, and georeferenced.

The surveys were conducted in four blocks. The largest block (Block A, 4,184 m^2) is located on the northern end of the site, a portion of the site that was found to contain the most abundant evidence of prehistoric occupation during the Phase II investigation. It was supplemented with a single 400 m^2 gridded block (Block B) placed on the ridge at the northern end of the site in an undisturbed area west of the night bunker (an Arsenal-era bunker used for the temporary overnight storage of explosives) separated from Block A by a former rail bed. The southern block (Block C, 3,600 m^2) runs south along the ridge that contains the

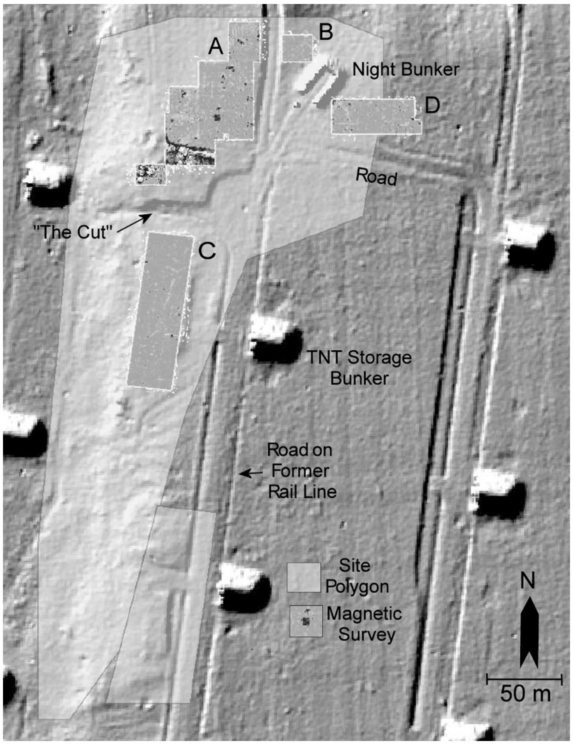

Fig. 2. Site polygon defined by the distribution of artifacts in shovel probes and geophysical survey Blocks A through D on LiDAR image of the site vicinity.

site and is separated from the northern block by what is believed to be a historic-period drainage channel running east–west through the ridge known as "the cut." Last, an area of 1,485 m^2 (Block D) was surveyed to the east of the night bunker. This block contains part of the eastern edge of the site polygon and two dark features identified in pre-Arsenal aerial photographs and interpreted as possible house basins (McLeester et al., 2018; McLeester and Schurr, 2020a).

3.2. Soil resistivity survey

A soil resistivity survey covering 1,494 m^2 was also conducted in the Block D east of the night bunker in the same grid covered by the magnetic survey. This area was chosen for survey because it contains two possible house locations. The survey used a Geoscan RM15 soil resistivity meter with a twin probe array. The probe spacing, transect, and sample intervals were all 1 m. The resistivity data were despiked, bias corrected, and georeferenced.

4. Results

4.1. Blocks A and B

In Blocks A and B, intense magnetic anomalies, including a prominent linear one running east–west, dominate the results on the southern end of the survey grid (Fig. 3). These strong anomalies correlate with water lines that were installed for fire suppression during the Arsenal period. To the north of the water lines, anomalies consist mainly of small, scattered dipoles (paired light and dark spots) caused by scattered iron objects dating to the Farming and Arsenal eras. Small weak (ca. 5 to 15 nT maximum intensity) positive monopolar anomalies (light spots) are scattered across the grid. They are densely distributed in the southwest corner of the survey area and are also relatively abundant along the top of the ridge toward the northeast. Weak positive anomalies are also present in the single survey grid to the west of the night bunker but are much less abundant. A prominent square negative anomaly with some positive interior anomalies is an excavation unit (the magnetic surveys were conducted over several years and some areas were already undergoing excavation before they were surveyed). Weak positive linear anomalies running north–south appear to represent remnant plow lines. These are especially visible on the northern end of the survey grid. The prominent pair of linear anomalies running north–south across the eastern side of the survey block is probably from a farm road that appears in pre-Arsenal aerial photographs. The northern end of the survey area covered the area from the top of the ridge to its base. There is no evidence of a linear feature that could represent a stockade ditch like those found at the Late Fisher phase Fortified Village component at Hoxie (Hargrave and Jackson, 2014) and at the Late Fisher phase Taylor Village in east central Indiana (Hill and Murray, 2012).

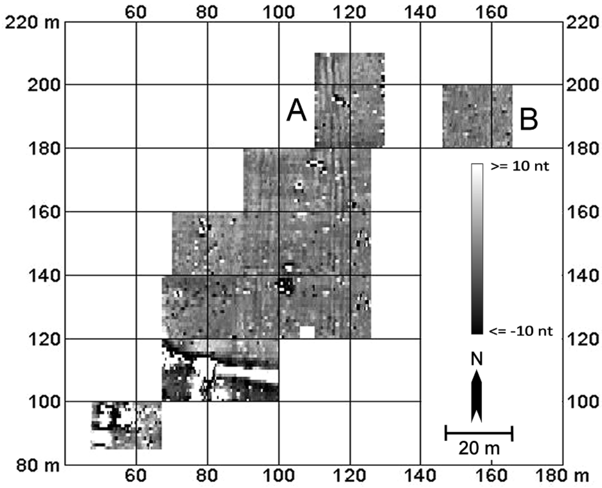

Fig. 3. Magnetic survey of Blocks A and B.

4.2. Block C

The southern survey block (Block C) also contains scattered dipoles and weak positive anomalies but they are much sparser compared to the northern survey grid (Fig. 4). A weak positive linear anomaly approximately 1 m wide extends from Grid N 11 to S 10 with another segment from Grid S 30 to S 55. These correlate with the upper edge of a sharp break in the terrain that was probably created when soil was removed from the eastern side of the ridge during construction of the Arsenal railways and bunkers. The linear anomaly is probably produced by exposed topsoil or midden on the edge of the earth-moving excavation. Weak magnetic anomalies are more abundant in the southern end of the survey grid and are largely confined to the highest area of the ridge, as was the case in the northern grid.

4.3. Block D

The magnetic survey grid east of the night bunker (Block D) depicts a large intense positive magnetic anomaly in its northwest corner which is part of the eastern edge of the fill covering the night bunker (Fig. 5). The remainder of the grid contains mainly scattered dipoles with a few weak magnetic anomalies. The weak anomalies are very sparse compared to the other grids, except perhaps in the northeast corner of the survey area. Scattered positive pixels in the southeast corner of the grid are data collection errors. This portion of the survey grid had been cultivated and was difficult to survey because of abundant corn stubble, which introduced noise from tilting the gradiometer to avoid the stalks.

The soil resistivity survey of the same block (Block D) was conducted over an area where two dark spots, interpreted as house basins, appear on the pre-Arsenal era, 1939 aerial imagery (McLeester et al., 2018). The ground locations of the dark spots were determined by Joseph Wheeler

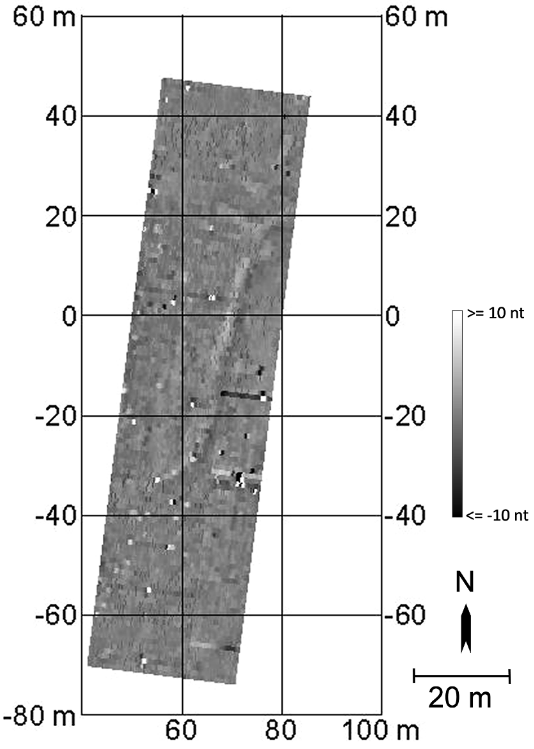

Fig. 4. Magnetic survey of Block C.

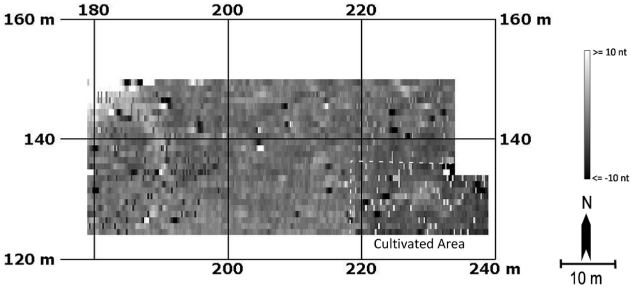

Fig. 5. Magnetic survey of Block D. Previously cultivated area indicated with dotted line.

III, who georeferenced the centers of the spots so they could be located in the field with GPS.

Results display a prominent oval low resistivity anomaly approximately 12.5 m long and 6 m wide in the northwest corner of the survey area (Fig. 6). This anomaly correlates well with the position of one of the identified dark spots (McLeester et al., 2018), is consistent with the retention of water, and is the size and shape of a typical Huber phase house, though may be caused by an unknown natural source or be the result of other anthropogenically modified soil. The second dark spot located on the pre-arsenal aerial photograph is not clearly associated with a well-defined resistivity anomaly; however, the area around the georeferenced location does have slightly lower resistivity than the surrounding soil, indicating a possible second house basin or other anthropogenically modified soil. The area of low resistivity in the southeastern part of the survey correlates with the cultivated area with corn stubble (see above) where the recently tilled soil is more conductive than the compact undisturbed sod in the rest of the grid.

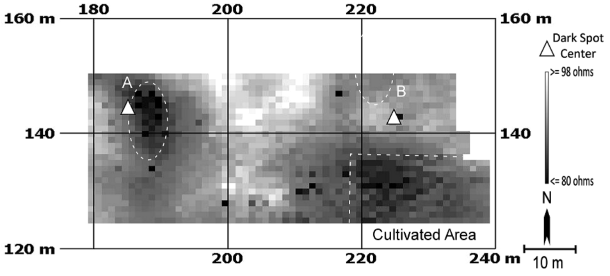

Fig. 6. Soil resistivity survey of Block D. (A) and (B) low resistivity anomalies. Triangles indicate estimated locations of dark spots on pre-arsenal aerial photograph. Previously cultivated area indicated with dotted line.

5. Ground truthing the anomalies

To ground truth the magnetic anomalies, 2 × 2 m square units were placed over selected magnetic anomalies in Block A. Several units were expanded to search for features that were not detected by magnetic survey. To date, excavations have opened a total area of 47.5 m^2 along the northern part of the ridge which contained the densest weak magnetic anomalies and a 71 m^2 area east of the night bunker. Most of the excavations were conducted by hand, except an area of 66 m^2 east of the Night Bunker that was stripped to a depth of 35 cm below surface (cmbs) with a mechanical excavator.

The excavations to date have defined 21 subterranean features, comprised primarily of refused-filled storage pits and also a few pits of unknown use. Fifteen features were ground-truthed through excavation in Block A and two features were excavated in Block D (east of the night bunker). Four artifact scatters in dark soil stains identified in the mechanically stripped area are interpreted as features and remain unexcavated. In Block A, features were easily recognized as circular stains containing abundant artifacts contrasting against the lighter sterile subsoil once a depth of approximately 35 cmbs was reached. The darker soils in Block D make features much more difficult to recognize, although they appear at similar depths.

5.1. *Description of pit features*

All features located to date are discreet pit features with no overlap or intrusions. Each displays varying, multiple episodes of refill, evident in the stratigraphy, with the exception of Feature NBE 1 in the eastern Block D area which appears to have been refilled in a single episode. Pits do not show any clear evidence of reuse, as has been described by Buffalo Bird Woman (Wilson, 1987 [1917]: 95) and seen archaeologically, for example at the Petitt site (11Ax253) (Grooms, 1999). While it is possible MGC pits were reused, experimental data shows that reused pits are more likely to have spoilage by mold, and specific conditions, like time between refill episodes (Grooms, 1999), had to be met for effective reuse. The majority of the excavated pits are very deep storage pits that were dug to depths where a stratum of sand was found (approximately 125 cmbs) (Features 3, 4, 5, 6, 11, 12, and 13). This deeply buried sand would have ensured excellent drainage, central to preventing spoilage (Howey and Frederick, 2016). In some of the pits, the walls flared outward at the base, potentially caused by the soft sand walls collapsing as the pit was excavated or emptied. The deep pits were likely first used for the storage of maize and other agricultural products. After being emptied of foodstuffs, they were refilled relatively rapidly with refuse and soil. Typical of Midwestern sites, other pits with unknown uses were also found, and pits F7, F8, and F14 were not excavated, so their potential uses remain unknown.

5.2. *Correlating anomalies with pit features*

Fig. 7 shows the location of units and features superimposed on the magnetic data for the northern portion of the site (magnetic survey Block A), and Table 1 shows which features were detected by magnetometry. Blue values indicate values below −10 nT, red values indicate values above 10 nt, and other colors are intermediate, with green around

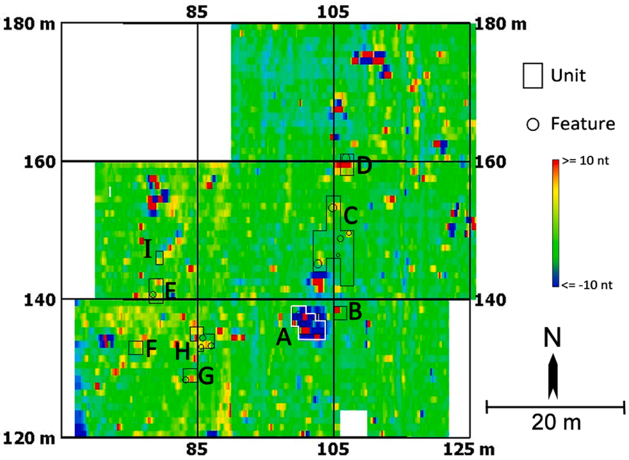

Fig. 7. Excavation units and feature locations on Block A magnetic survey.

0 nT. The unit labelled A was excavated before the magnetic survey. The negative values (blue) are characteristic of disturbed soil while the positive ones (red) are probably due to areas of gravel discarded during screening. In the other three eastern units (labelled B through D), there is good correspondence between monopolar positive magnetic anomalies (yellow to red spots) and storage pit features (Table 1) and pit features in these units were confirmed by excavation (McLeester and Schurr, 2020a, Fig. 3A). The magnetometer detected the organically rich soils of the pit fill and paramagnetic artifacts such as sherds and FCR.

Two features (7 and 9 in Unit C) are not associated with detected anomalies. Feature 9 was a small pit that was not a storage pit (Table 1). The reason for Feature 7's lack of magnetic visibility is unknown as it has not been excavated. Unit B contained a positive magnetic anomaly, but did not contain a feature. The anomaly in this unit is different from the anomalies located over pits. The anomalies over pits show varying intensities whereas the anomaly in Unit B consists only of consistent positive values (of 10.1 and 11.6 nt) and was probably produced by a small piece of iron in the plowzone.

The correspondence of features with positive anomalies in the western five units is less clear, probably due to small indexing errors in this part of the survey. Still, every feature but one is within 0.5 m of a monopolar positive anomaly in units G and H, realistic accuracy for a survey using 1 m transects and 0.25 m sample intervals. Unit G contains a positive anomaly at its northern end and a feature at its southern end. The anomaly and feature were separated by a distance of 2 m, so there was a poor correlation between anomaly and feature in this unit. Two units (F and I) did not contain features. The magnetic data over Unit I contains a faint bipolar anomaly (paired red and blue pixels) which can be seen trending away from the unit to the northeast. Excavation produced pieces of iron fence wire, which probably accounts for the anomaly. Unit F contains a monopolar positive anomaly that appears to represent a feature but the unit did not contain a feature. The topsoil in this unit contained a nail and an iron snap. Either of these items may have produced the anomaly as small rusted iron artifacts sometimes fail to produce a dipolar signal typical of iron objects. This shows that some features are not associated with detectable anomalies and confirms that all anomalies as defined here do not represent features.

In summary, storage pit features in Block A were correlated with relatively weak positive (+5 to +10 nT) monopolar anomalies of variable intensity in seven out of eight cases. However, two pit features in Block A were not detected by magnetometry, and two units were found to contain false positives. Magnetic survey is clearly an efficient but not perfect method for identifying storage pit features at MGC.

6. Estimating the number of pits present at the site

Based on the success of the magnetic data for locating storage pit features, we are able to estimate the number of storage pits at MGC. To do this, the magnetic data were reclassified to select data pixels (0.25 × 1 m) with intensities of +5 to +10 nT. The positive side of dipolar anomalies probably caused by iron were also selected by this algorithm. Those were manually deleted by inspection. The classification produced 87 anomalies in Block A (Fig. 8), eight anomalies in the single 20 × 20 m grid west of the Night Bunker (Block B, Fig. 8), and 30 in the southern survey block (Block C, Fig. 9) with magnetic signatures consistent with those found to be associated with storage pits; totaling 125 anomalies. Based on the 73% association of magnetic anomalies with pits (eight out of nine identified correctly by ground truthing with two false positives), we estimate there are approximately 63 storage pits within Block A, six in Block B, and 22 in Block C; totaling 91 features. In addition to the 11 storage pits identified during excavation, three pits invisible to magnetometry were also identified by excavation (Table 1). If the same ratio pertains across the site, there could easily be an additional 17 pits in Block A, one or two in Block B, and six in Block C (24 or 25 total) that are invisible to magnetometry. The total number of pits originally at the site was certainly larger as the distribution of pit anomalies extends to the edge of the magnetic survey in some areas, indicating the distribution of

Table 1
Pit dimensions and characteristics.

Feature	Length (cm)	Width (cm)	Depth (cmbs)	Base Shape	Wall Shape	Possible Use	Detected in Magnetic Survey
2006, F1	110	90	143	flat bottomed	slightly inverted	storage	excavation pre-dates survey
2006, F2	59	57	5	basin	slightly inverted	hearth	excavation pre-dates survey
F1	80	72	98	basin	slightly inverted	unknown	excavation pre-dates survey
F2	67.5	44[a]	56	flat	straight walled	plant processing?	excavation pre-dates survey
F3	90	81	143	rounded	unknown	storage	excavation pre-dates survey
F4	121	104	155	flat	slightly flared	storage	yes
F5	125	110	170	rounded	smaller base	storage	yes
F6	110	109	173	flat	slightly flared	storage	yes
F7	85[b]	60[d]	—	—	—	—	no
F8	95[b]	70[b]	—	—	—	—	yes
F9	55	50	45	rounded	slightly inverted	unknown	no
F10	80	70	89	rounded	slightly flared	unknown	yes
F11	98	97	160	rounded	slightly flared	storage, cooking?	no
F12	82	80	153	rounded	v. slightly flared	storage, cooking?	yes
F13	108	90	148.5	rounded	slightly flared	storage	yes
NBE, F1	90	95	185	flat	straight walled	unknown	no
F14	80[b]	70[b]	—	—	—	—	no
Mean	90.3	81.6	123.8				
Storage Mean	105.5	95.1	155.7				

[a] Estimate of dimensions.

[b] Based on dimensions at surface of definition.

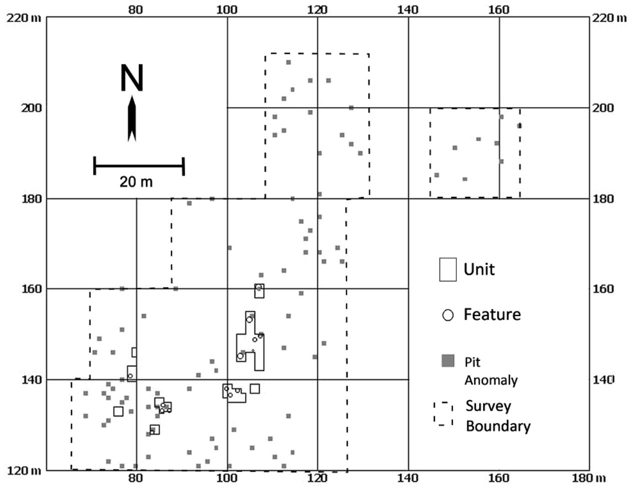

Fig. 8. Magnetic anomalies classified as possible features in Blocks A and B.

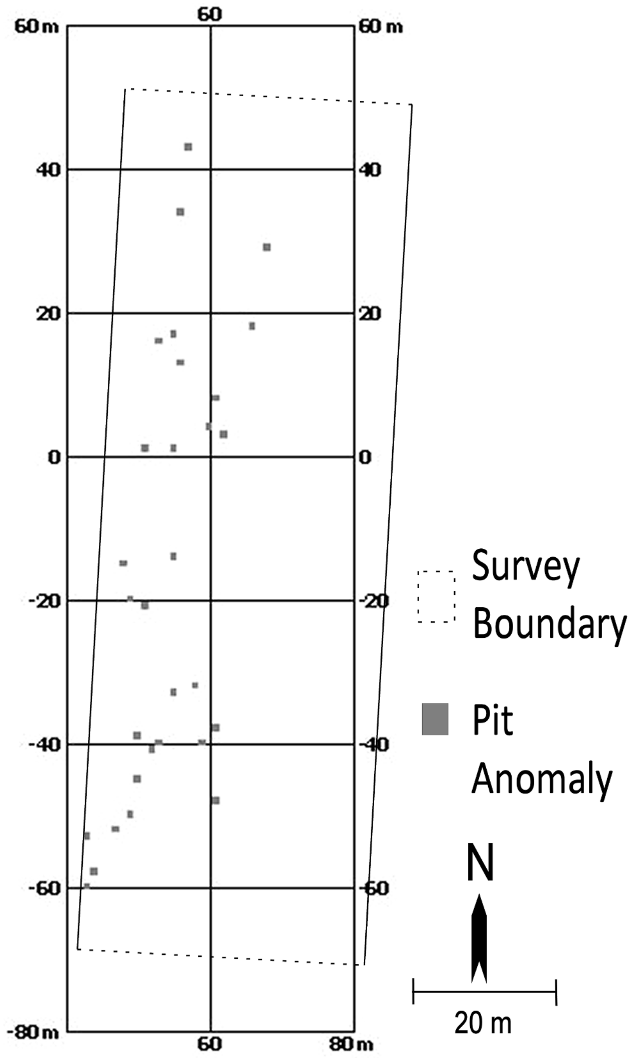

Fig. 9. Magnetic anomalies classified as possible features in Block C.

pits probably extends beyond the limits of the magnetic survey. Pits were probably also destroyed by grading for the rail line and the “cut” across the ridge, and by the water lines, whose magnetic signals also overwhelm that of any pit that might be near them. The anomaly densities, and presumably the pit densities as well, are variable in the three magnetic survey blocks. The anomaly density in the main north Block A (0.028 anomalies/m^2) is about twice that of the 400 m^2 Block B to its east (0.018 anomalies/m^2), and the density in Block C (the southern block) is much lower than the pit densities in either of the northern survey blocks (0.008 anomalies/m^2).

The magnetic survey sampled 29% of the site polygon. Assuming that the average anomaly density (0.013 anomalies/m^2) for the entire survey provides a representative sample, and based on the ground truthing percent positive detection rate of 73%, the 3.4 ha of the site polygon could have contained at least 315 storage pits. As the anomalies (and presumably pits) were densest along the top of the ridge in the northern part of the site, the part most extensively sampled by magnetic survey, this is probably an upper estimate.

6.1. *Storage capacity at MGC*

The estimate of the number of pits can be combined with pit volumes to estimate the potential total storage capacity at the site. The average pit volume is 1.23 m^3, so the total storage volume of the pits at the site is 387 m^3 based on the 315 storage pits inferred from the magnetic survey. Part of this volume would have been filled with materials used to line the pits, likely a grass lining, which was used at Oak Forest, though bark was also used (McLeester, 2018). Dunham (2000) suggests that up to 50% of the pit volume consisted of liners or fillers, but does not explain how that estimate was derived. Grooms (1999), in his experimental replication of Fort Ancient maize storage pits, lined pits with 6 cm thick bundles of Big Blue Stem grass followed by an interior layer of corn cobs. The cob layer molded but the interior contents of shelled corn were protected. A 6 cm thick grass lining would have reduced the average storage pit volume of 1.23 m^3 (Table 2) to 0.88 m^3, a 28% reduction, with the spoilage of the cob lining included in our spoilage estimates (see below). A reasonable estimate for liner volume is the midpoint of the two estimates, 40%, indicating approximately 232 m^3 of storage volume.

Ethnographic evidence indicates that various dried foods were stored alongside maize in storage pits. Buffalo Bird Woman (Wilson, 1987 [1917]) lists the contents of four cache pits. Two contained only maize, a third contained maize, squash and other vegetables, and a fourth smaller one in the lodge contained dried wild turnips, dried choke-cherries, dried June berries, and any valuables that could not be taken to the winter village. Dunham (2000) lists maize, wild rice, squash, dried berries, and maple sugar as being stored in pits. It is clear that storage pits could contain more than maize, but as we have no ethnographic or direct evidence of relative volumes of different foodstuffs, and since maize is the primary stored grain in all ethnographic examples, we do not include additional foods in our storage calculations, which are upper estimates.

Pits interpreted as storage pits at MGC are much larger than those found at other Huber villages, suggesting a different storage tradition at MGC than other Huber phase sites. The storage pits at MGC most closely resemble those found at Greismer and Zimmerman’s Huber occupation; however, the MGC pits are still over 50 cm deeper than the deepest storage pits at these locations. And, we assume that NBE F1 might not have been used for storage because of the poorly draining clay at its base, but if we include this feature, with a depth of 189 cm, it further emphasizes the difference in depths at this versus other Huber sites. As shown in Table 2, which describes the deepest pits from other Huber sites, the differences in means is even starker. For instance, Huber pits at Hoxie have a mean depth of 19 cm, and Oak Forest have a mean depth of 17.9 cm (Jackson, 2017b:75), both about one meter less than MGC’s average pit depth. Though some differences in depth may be due to mechanical stripping, no excavation report describes removing over a meter of soil at the sites listed in Table 2, and several sites used only hand excavation. At Palos (Munson and Munson, 1969:184), 10.2 to 20.3 cm (4 to 18 in) of plowzone humus was removed by hand before the features were defined. At Huber, hand excavation by troweling in 15.6

Table 2
Maximum pit depth at other Huber sites.

Site	Feature	Length (cm)	Width (cm)	Depth (cm)	Volume (m^3)	Notes	Citation
MGC	F6	115	113	158	1.61		
Palos	n/a	100*	100*	100*	0.79	Based on summary data	Munson and Munson, 1969: 184
Huber	F15	76	61	64	0.23	incomplete; Feature only 1/4 excavated	Herold et al., 1990: 16
Hoxie Farm	F459	84	82	39	0.21	Based on Huber pits	Jackson, 2017b: Table A3
Anker	2XP	122	94	49	0.44		Bluhm and Liss, 1961: 101
Oak Forest	F107	80	80	47	0.24		Brown ,1991: 188
Greismer	F67	183	91	99	1.30	Based on Type B, non-roasting pits	Faulkner, 1972: 187
Zimmerman	F121	91	–	107	0.70	Type B, flat-bottomed cylinder	Emerson and Evans, 2015

cm (0.5 ft) levels was used to uncover features and no mention was made of surface disturbance in the detailed procedure description (Herold et al., 1990:12). At Griesmer, the excavated portion of the site was unplowed and excavation was also conducted by hand using 15.6 cm (0.5 ft) levels (Faulkner, 1972:40-44). A figure of a pit profile indicates that the topsoil was about 10.2 cm (4 in) thick (Faulkner, 1972:51, Fig. 5). Other sites were subject to mechanical excavation. At Oak Forest, some portions of the site had been disturbed by earthmoving activities. Hand excavation was used to identify undisturbed portions of the site below a layer of overburden and to determine the depth of the topsoil. The 30.5 cm (0.75 ft) of overburden was carefully stripped off and then floors were shovel scraped to reach the base of the topsoil (Brown, 1990:178). A profile of a trench shows 25 cm of plowzone with only about 15 cm maximum mechanically stripped from the south end of the excavation (Brown, 1990:173, Fig. 7.3). At Zimmerman, 25.4 cm (10 in) of plowzone was stripped by machinery, followed by hand excavation with shovels (Brown, 1975). A similar procedure was used at Anker, where about 38.1 cm (15 in) of topsoil was stripped from the work area and floors were shovel skimmed to define features (Bluhm and Liss, 1961:92). Mechanical stripping was used most extensively at Hoxie. Once again, overburden from the construction of an adjacent highway was carefully stripped to leave remnant plow zone, followed by shovel scraping and hand excavation to expose features (Jackson, 2014:50). It is clear that when mechanical excavation was used, the archaeologists were very careful to control and record the depths of the stripped soil. Thus, the depths of MGC pits do seem unique.

While tuber roasting pits at Greismer are deeper and some pits at MGC have some possible in situ burn episodes, there is no evidence that MGC pits were roasting pits, as in situ burning, when it occurred, was mid-pit and not at the base. Roasting pits at Griesmer (Faulkner, 1972), Collier Lodge (Schurr, 2017), and Rader (Faulkner, 1964) exhibit a pronounced layer of oxidized sand and large charcoal fragments at the base.

One explanation for depth may be that the deep storage pits were dug to well-drained sand to ensure drainage, and such depths were not required at other sites. However, not all deep pits at MGC are dug to sand, as the deepest pit at the site was dug to clay. While pit size differs from those at other Huber sites, they are of similar depths to many deeper storage pits found at other Oneota sites, including some pit features at the Grant Village in eastern Iowa (McKusick, 1973) and at least one feature from the Lower Sand Lake site in western Wisconsin (Boszhardt et al., 1985).

The pits identified as storage pits at MGC appear to more closely resemble the shape and depth of storage pits described in the early 20th century, including those described by Buffalo Bird Woman in North Dakota (Wilson, 1987 [1917]) as well as those detailed by Densmore (1974 [1928]) among the Ojibwa [Chippewa, Anishanaabe] in Wisconsin, though we are not proposing any ancestral ties at MGC to either these communities. Instead, it may be that the increased reliance on maize agriculture (McLeester and Schurr, 2020a) was tied to this particular type of storage or the depth was related to drainage, and it should also be noted that storage pits and methods vary significantly based on location, including among maize intensive communities. Whatever the reason, for Huber communities, these deep pits at MGC do appear to be atypical, and the MGC community exhibits a much greater investment in storage than other Huber phase sites excavated to date.

7. Village population estimates

In the Midwestern USA, village population sizes have typically been estimated based on house floor areas and ethnographic information correlating structure floor area with the number of inhabitants (e.g. Brose, 1970; Milner, 1986) or historically recorded populations (e.g. Milner and Chaplin, 2010). We compare population estimates for MGC based on house floor area to two alternative measures: the area that must have been cultivated to produce the amount of maize stored in the features (cultivated area); and the number of people who could have been supported by the stored maize (maize consumption). Each approach has its own set of assumptions and limitations. If the different approaches converge on similar estimates, we can have more confidence in the village population size estimate.

7.1. Based on structure floor area

Evidence indicating an extensive habitation area at Middle Grant Creek suggests a sizeable village comprising over a dozen households dispersed over a large area (McLeester et al., 2018). The probable habitation area was identified through analysis of 1939 aerial imagery which shows a scatter of at least fourteen dark, sub-rounded or oval features approximately 10 m in diameter, spread over an area of 20 ha, mostly east of the current site boundaries (McLeester et al., 2018). Further analysis with a thermal imaging drone survey found that at least two of these features, located in the night bunker east area (geophysical survey Block D) under low vegetation cover, could be resolved in the thermal data, suggesting that these may be the remains of infilled shallow house basins or organic-rich soils from house occupations (McLeester et al., 2018; McLeester and Schurr, 2020a).

While our excavations at MGC in this area have thus far proved inconclusive, promising evidence supports our interpretation of these anomalies as remains of habitation structures. As described above, the resistivity survey identified one well defined low resistivity anomaly and a second possible weaker one corresponding with the two Block D dark spots. The westernmost Block D anomaly was especially well defined, appearing as a large oval feature of approximately 12 m by 5 m (Fig. 6), compatible with a structure of similar dimensions to the longhouses excavated at the Huber sites Oak Forest, Hoxie Farm, Anker, and New Lenox (Table 3). Although five cultural features were defined during excavations in 2018 and 2019, no postmolds were identified, but they may be obscured by the dark soil that is on that portion of the site, or may have been destroyed by later Euro-American agricultural or Arsenal-era activities.

Documented late prehistoric housing structures show a great deal of variation across Upper Mississippian sites, from small, single-family pit houses to large extended or multi-family lodges and longhouses (Schroeder, 2004). Some localities, such as Koshkonong in Wisconsin have shown a mix of housing types and construction styles within the same site and time period (Jeske et al., 2020). Large longhouses associated with summer agricultural occupations have been especially well-

Table 3

Documented Huber longhouses and population estimates.

Huber Longhouse Dimensions							Occupancy Estimates		
Site	Structure	Length (m)	Width (m)	Hearths	Area (m^2)[a]	Source	Cook, 1972 formula	Casselberry, 1974 formula	Brose, 1970 formula
Middle Grant Creek	NBE anomaly	12	5	1[b]	54.6	Mcleester and Schurr, 2020	10.4	9.1	16.5–21
Oak Forest	House 1	14.5	4.1	2	55.8	Bluhm and Fenner, 1961	10.5	9.3	16.9–21.5
	House 3	8.8[b]	4.6	1	–	Bluhm and Fenner, 1961	–	–	–
	House 5	9.7	3.8	1	33.8	Bluhm and Fenner, 1961	8.1	5.6	10.2–13
	House 7	7.6	3.7	2	25.2	Bluhm and Fenner, 1961	7.2	4.2	7.6–9.7
Hoxie Farm	F415	10.7	3.4	2	33.9	Jackson, 2017b	8.2	5.6	10.3–13
	F791	6b	4.5	3	–	Jackson, 2017b	–	–	–
	F2136	11[b]	3.8	1	–	Jackson, 2017b	–	–	–
Anker	House 1	16.8	4	3	63.8	Bluhm and Liss, 1961	11.4	10.6	19.3–24.5
Average		10.8	4.1		44.5		9.3	7.4	13.5–17.2

[a] The typical form of extant Huber longhouses is a roughly obround or stadium floor plan with straight, parallel sides on the long axis and rounded, semi-circular ends. Floor area (A) of these structures is estimated by: A = (Length-Width) × Width + π(Width/2)2.

[b] Indicates incomplete data, due to preservation conditions or partial excavation.

documented at Tremaine in Wisconsin (O'Gorman, 1995; O'Gorman, 2010) and the Grant site in Iowa (McKusick, 1973; 1974). Both of these sites show closely-spaced clusters of large, multi-family dwellings varying from 6 to 9 m wide and 20 to 65 m long, with evidence of periodic rebuilding and/or expansion. O'Gorman (2010:583, Table 1) suggested the Tremaine structures would house three to four families, a potential occupancy ranging from 14 to 92 persons depending on the size of the house. McKusick (1974:206) estimated the likely size of the Grant village as 200 individuals at any given time, with a household capacity of 50 people per longhouse.

The mean areas of Oneota houses change over time (Hollinger, 1995, 2005:14). The earliest Emergent horizon (A.D. 900–1150) Oneota houses were the smallest (22.4 m^2). Houses increased to a maximum size of 186.2 m^2 during the Classic Horizon (CE 1400–1650). It is generally believed that large dwellings of the type known from Grant and Tremaine may have been maintained seasonally during times of planting, cultivation, and harvest (Hollinger, 1995:156). House sizes then declined to a mean area of 62.3 m^2 during the Historic period (CE 1650 to 1800).

The estimated house area at MGC and other Huber houses (Table 3) is more similar to those of the Historic than the Classic horizon. MGC dates to the time of the transition between the two horizons and the large longhouses of the Classic horizon have never been recorded at Huber sites or within the broader study region.

Household sizes among Huber communities were likely on the smaller side compared to other contemporary Oneota sites: the known Huber longhouse-type structures average about 4 m wide by 12 m long (Table 3). The Huber phase Oak Forest site in northern Illinois shows smaller longhouses with eight structures of similar form and dimensions loosely clustered within a 1 ha area (Brown, 1990:168, Fig. 7.1). The MGC housing area is not clustered, and it is possible that this represents a different village layout, or that only a small sample of houses are captured in the aerial photography.

Estimates of prehistoric population at archaeological sites have typically used the floor area of dwellings to calculate potential occupancy (e.g. Brose, 1970; Milner, 1986). Various formulas have been proposed using contemporary ethnographic data on house size and occupancy among non-Western populations; however, the accuracy, reliability, and cross-cultural applicability of these models and the data they are derived from has long been debated (Naroll, 1962; LeBlanc, 1971; Schacht, 1981; Weissner, 1974). We experiment here with three published floor-area-population models that were developed using North American data, as a preliminary assessment of the potential residential capacity of Huber longhouses and assume concurrent occupation of all houses. Cook's (1972) formula gives 25 ft^2 (2.3 m^2) per person for the first six individuals in a house and 100 ft^2 (9.3 m^2) per each additional person. This formula attempts to account for the nonlinear relationship between population and floor area, in which floor area per person changes as population increases. Casselberry's (1974) formula, which is tailored specifically for multi-family dwellings, estimates the number of occupants as approximately one-sixth of the floor area as measured in square meters. Casselberry notes, however, that this tends to underestimate actual population densities observed ethnographically. Brose (1970), examining a narrower range of ethnographic documentation of upper Great Lakes Indigenous communities during the early 20th century, derives an average range of 28 ft^2 (2.6 m^2) to 35.4 ft^2 (3.3 m^2) per person.

Table 3 shows population estimates for known Huber longhouses for which we have sufficiently complete dimensions to calculate floor area. Comparison of the three floor-area formulas shows considerable discrepancies, with the lower estimates of the Brose formula almost double the estimates of the Casselberry formula. Some of the more conservative estimates may be improbably low (e.g. less than 5 individuals for House 7 at Oak Forest), but the upper estimates from the Brose formula of 20 to 25 individuals for the larger excavated longhouses would be consistent with the estimates of Classic horizon longhouses, which have more than double the floor area of Huber examples. If we assume that the fourteen soil stains identified in aerial imagery at MGC indicate longhouses of similar dimensions to those found at other Huber sites and our own resistivity data, with a typical average floor area of 46.5 m^2, and take the various floor area estimates as indexes of the potential range of population for the site (considering that individual households probably varied in size, occupancy may have fluctuated from year to year, and not all houses may have been occupied simultaneously), this indicates that the MGC village likely comprised at least 108 individuals and may have housed as many as 252 people.

7.2. *Based on cultivated area*

If we combine the estimated storage volume (232 m^3/6,590 bu) with estimates of the area cultivated, we can obtain an idea of how many people would have produced these pits. Riedhead (1981:205) estimates the average yield of maize was around 1681 kg/ha (25 bu/acre). Using Hidatsa, Mandan, and Arikara cultivation methods, Munson-Scullin and Scullin (2005) determined 2690 kg/ha (40 bu/acre) during the first year of cultivation decreasing to 1681 kg/ha (25 bu/acre) by year three within an experimental plot. Mt. Pleasant and Burt (2010) calculated 1480 to 1511 kg/ha (22 to 76 bu/acre) of maize from experimental plots in New York and found results to be dependent on soils, climate, and intercropping. Nineteenth century records of Native Americans in the Midwest and Central Plains not using plows produced average yields of 1271 m^3 (18.9 bu/acre) although Schroeder (1999) argues that yields of 627.2 kg/ha (10 bu/acre) might be more representative of prehistoric subsistence production because of wider plant spacing and more intercropping compared to the nineteenth century (Schroeder, 1999), though her low estimates and methodology have been critiqued (Baden and Beekman, 2001).

Maize yields per acre were clearly quite variable, perhaps ranging from about 627 to 1511 kg/ha (10 to 76 bu/ acre). Here, we use the most conservative estimate (10 bu/acre) in our calculations, but note that higher yields would have supported a larger population or less land to be cultivated. Using this conservative estimate of 627 kg/ha (10 bu/acre) alongside the estimate of the maximum volume of maize that was stored at MGC (232 m^3, which would have weighed 167,504 kg [from Schroeder, 1999:516], at least 276 ha (112 acres) would be needed to produce that amount of maize. Historically recorded Native American field sizes also varied, from fractions of an acre up to as high as 2 to 2.4 ha (5 to 6 acres) per household, with a mean of 0.23 ha (0.59 acres) for 19th century Native Americans not using plows (Schroeder, 1999). If each plot was cultivated for three years, and each family typically cultivated 1.21 ha (3 acres) (the median of the historically recorded range), the number of families that produced the pits would be approximately 74 families, perhaps numbering around 370 people (assuming an average family size of five, based on family sizes implied by recipes in Buffalo Bird Woman's account [Wilson, 1987[1917]). This rough estimate is likely high, because it assumes that MGC was only occupied for three years. If MGC was occupied for 8 years, this number drops to 138 people. And of course, as mentioned above, higher yields would increase the population that could be supported or require less land to be cultivated.

7.3. *Based on maize consumption*

We also estimate the number of people that could be supported by the amount of maize stored at MGC using stable carbon isotope ratios, expressed as δ^{13}C values. It has long been recognized that human stable carbon isotope ratios reflect maize consumption in prehistoric eastern North America, as most edible plants in this ecosystem utilize the C_3 pathway, whereas maize utilizes the C_4 (Hatch-Slack) photosynthetic pathway, and the two pathways produce plants with different δ^{13}C values.

The δ^{13}C values of C_3 plants average around −26‰, and humans who consume an exclusively C_3 diet typically have bone collagen δ^{13}C values around −20.5‰ (Schoeninger, 2011; Vogel and van der Merwe, 1977). When compared to C_3 plants, maize (a C_4 plant) is enriched in ^{13}C, resulting in less negative values (Ehleringer and Osmond, 1994). We measured the δ^{13}C value of eight maize kernels from MGC after mild acid/base/acid pretreatment (Fraser et al., 2013) and found a mean value of –11.3‰ (s.d. = 0.46). Assuming a 5.5‰ enrichment between diet and bone collagen (Schoeninger, 2011), a nutritionally improbable diet of 100% maize from MGC would produce human bone collagen with a δ^{13}C value of −5.7‰.

The percent maize in the diet can be estimated using the equation,

$$\%\ \text{Maize} = \left(\delta^{13}\text{C}_{\text{col}} - \delta^{13}\text{C}_{\text{C3}}\right) / \left(\delta^{13}\text{C}_{\text{C4}} - \delta^{13}\text{C}_{\text{C3}}\right) \times 100 \tag{1}$$

where observed δ^{13}C values in bone collagen ($\delta^{13}C_{col}$) are compared to collagen δ^{13}C values produced by hypothetical diets composed solely of C_3 ($\delta^{13}C_{C3}$) or C_4 plants ($\delta^{13}C_{C4}$). Here, as defined above, a pure $\delta^{13}C_{C3}$ diet produces a value of −20.5‰ and a pure maize diet ($\delta^{13}C_{C4}$) produces a value of –5.7‰.

If we had human collagen carbon stable isotope ratios from MGC, we would know the value of $\delta^{13}C_{col}$; however, we do not have such isotope ratios or stable carbon isotope measurements from MGC or any Huber phase burials. Nonetheless, $\delta^{13}C_{col}$ values reported from three Oneota sites (OT, King Hill, and Norris Farms #36) range from −13.4 to −11.9‰ (Tubbs, 2013:270) with an overall mean of –12.6‰, comparable to values from the maize intensive Langford phase sites of Material Services Quarry (mean = –12.5‰, n = 10) and Gentlemen Farm (mean = –11.7‰, n = 26) closer to the study region (Emerson et al., 2005). These $\delta^{13}C_{col}$ values correspond to a maize-intensive diet supplemented by other crops, wild plants, and animal proteins. Other cultivated and wild plants, and all wild animals would have C_3 δ^{13}C values. The importance of these C_3 foods in Oneota diets is indicated by plant and animal remains found at MGC and other Oneota sites (Brown, 1991; Emerson et al., 2005; McLeester and Schurr, 2020a). However, local variability in diets may exist, since values from these Langford (CE 1100–1350) and Oneota (CE 1450–1650) burials are more positive than the $\delta^{13}C_{col}$ values determined from the Late Fisher phase (CE 1300–1375) burials from the Hoxie Main Occupation Area (mean = –15.7‰, n = 17), indicative of less maize consumption (Hargrave et al., 2017). Assuming Huber phase diets were similar to those at other Oneota, Langford, and Late Fisher sites, human $\delta^{13}C_{col}$ values would range from −15.7 to −11.7‰. Using these values for $\delta^{13}C_{col}$ in Eq. (1), the MGC diet likely was composed of 30 to 60% maize (Fig. 10). Given the abundance of maize and similarities to other Oneota sites, the higher estimate seems likely.

Because bone collagen isotope ratios reflect the protein component of the diet (Ambrose and Norr, 1993), it is necessary to consider the protein content of maize. Other attempts to calculate how many pits a household would need (Grooms, 1999) or the total food value of maize stored at a site (McConaughy, 1991) have used total calories, overestimating the food value of maize. Maize contains approximately 10% protein (FAO, 1992) so the estimated 137,367 kg (6,590 bu) of maize stored at MGC contained 16,737 kg of protein. We can estimate how many people could have been supported by the stored maize assuming: (1) the village inhabitants each required of 42 g of protein per day (Reidhead, 1981); (2) an MGC diet contained 60% maize; (3) that the spoilage rate ranged from 20 to 35% (Kuijt, 2015); and (4) at least 35% of the unspoiled grain was needed for seed corn (Wilson, 1987 [1917]). Using these figures to create minimum and maximum estimates, the grain stored at MGC contained enough protein to support approximately 768 (35% spoilage) to 946 (20% spoilage) people for one year, 256 to 315 persons for three years, or 96 to 118 individuals for eight years. Less reliance on maize would increase these estimates.

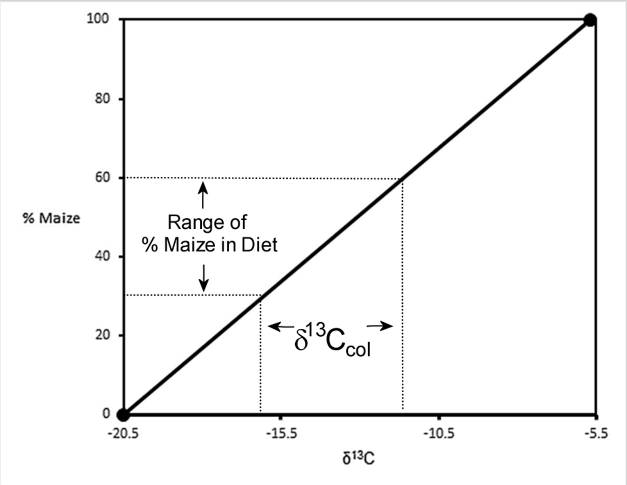

Fig. 10. Estimated Percent of Maize in the Diet as a Function of δ13Ccol.

8. Discussion

Table 4 summarizes the village population estimates derived by the different methods. Population estimates based on area cultivated and maize consumption are similar for the three and eight year estimates. The estimates based on house floor area is much larger. This may indicate that not all houses were occupied simultaneously, or that maize was less than 60% of the diet. However, the estimates are of similar magnitude, ranging between approximately 100 to 180 people. The estimates based on cultivated area and maize consumption are sensitive to assumptions about the time span of the occupation, and an occupation span of five years matches the average estimate based on floor area. The eight-year estimate based on maize consumption is the lowest estimate, suggesting that maize productivity could have been higher than 627 kg/ha (10 bu/acre) or that a larger area was cultivated.

While estimates are largely unavailable for other Huber sites, due to the reasons detailed above, the storage and housing data described herein does point to the ability to support a relatively large population. The MGC village size estimates are still significantly smaller than some late 17th century villages locally recorded, such as at the Grand Village of the Kaskaskia, where approximately 1,000 individuals lived in 1673, as well as de Liette's own accounts of the Illinois in 1688, where he recorded approximately 800 occupants in the summer agricultural village (de Liette, 1934). The smaller size for MGC, which we argue is still relatively large for a Huber phase protohistoric village, is consistent with population estimates for the Huber region at CE 1500 (about a century before MGC was occupied) based on archaeological data. MGC pre-dates the rise of Algonquin refugee centers (White, 1991) and the estimated village population indicates a relatively low population density compared to historic records (Milner and Chaplin, 2010).

9. Conclusion

Findings described here provide the first estimates of storage capacity and population size of a Huber phase village from multiple estimators of village population. Magnetic surveys covering 9,700 m^2 detected 123 magnetic anomalies that ground truthing excavations showed were likely maize storage pits refilled with refuse after they were emptied. The magnetic survey was very effective for obtaining an estimate of storage pit feature numbers at the site without the need for extensive excavations. The estimated number of pits ranges from 109 for the survey area to 315 if the average pit density per m^2 is extrapolated across the entire existing site polygon.

If the village contained 180 people based on estimated house floor area and possible house patterns derived from aerial photographs and resistivity survey, and all the houses were used simultaneously, we can then estimate an occupation span of about five years from estimates of maize consumption. This estimate is consistent with the single component nature of the occupation and the lack of overlapping features. Thus, while the possible amount of maize stored at the site seems very large, when the storage estimates are combined with village population and consumption estimates, the storage volume is very reasonable for a population of 100 to 180 individuals. This demonstrates how geophysical surveys of sites with subsurface storage pits can be used to estimate storage volumes when combined with ground truthing excavations. The storage volume can then be combined with other estimators of population size, providing key insights into protohistoric village life in the American Midwest. This approach can be applied on any site with features that are detectable by geophysical survey and distributed over a large area that cannot be fully investigated with excavation.

Table 4
Summary of village population estimates.

Method	Low Estimate	High Estimate	Average Estimate	Timeframe
Structure Floor Area	108	252	180	All houses concurrently occupied
Cultivated Area			370	3 years
			138	8 years
Maize Consumption	768	946	857	1 year
	256	315	286	3 years
	96	118	107	8 years

CRediT authorship contribution statement

Mark R. Schurr: Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Madeleine McLeester:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Jamie Countryman:** Investigation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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