APPENDIX A

MAGNETOMETER STUDY OF THE DALE SITE

Dale Historic Site, US Route 113 Corridor, New Castle County, Delaware.

Report on Geophysical Surveys, August 2011

for

The Louis Berger Group, Inc.

T.J. Horsley

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Horsley Archaeological Prospection, LLC
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Summary

A non-invasive geophysical survey has been conducted at the Dale site near Middletown in New Castle County, Delaware. A 7 acre, (2.8 hectare), high resolution magnetometer survey has helped to map areas of historic activity, including the sites of two probable brick-built structures, a well, and two smaller outbuildings. The results better define the shape and extent of two clusters of historic material identified during the Phase I survey, and suggest that a third concentration has no substantial buried remains associated with it. These results have been used to target subsequent excavation by the Louis Berger Group.

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1. Introduction

1.1 Geophysical surveys have been undertaken over the Dale historic site in response to a request from the Louis Berger Group, Inc. for DelDOT. Three distinct surface clusters of historic material had been identified during the Phase I investigations, suggesting the locations of 19th-20th century buildings. These are believed to be related to the Samuel/William Dale site dating from 1854 to 1915 (Liebeknecht & Burrows 2010). It was decided to employ a non-invasive geophysical survey to locate and map any surviving sub-plowzone features and to identify targets for subsequent excavation.

1.2 The geophysical survey grid was centered on 569980E, 541450N (NAD 1983, State Plane Delaware (feet)); 437920E, 4370990N (Universal Transverse Mercator coordinates, zone 18S). In total, an area of 7.00 acres or 2.83 hectares was surveyed, encompassing the three clusters of surface material identified during the Phase I survey. The location of the survey grid is shown in Figure 1, with the three previously discovered sites labeled A, B and C.

1.3 The central portion of the geophysical survey is situated on the Woodstown loam, a deep, (> 80 inches/2m), moderately well drained loam and sandy loam that has formed on loamy fluviomarine sediments (USDA-NRCS 2011). Along the eastern side of the survey area the soil is described as the Reybold silt loam, another deep, well drained soil that is described as becoming more gravelly and sandy below 30 inches (0.76m). These soils are formed on high silt loamy eolian deposits over fluvioumarine sediments. The northwestern edge of the survey area is situated on the Othello silt loam, a poorly drained soil that is formed on silty eolian deposits and/or fluviomarine sediments. This is also described as being more than 80 inches, (2m), before restrictive features are encountered (Ibid. 2011).

1.4 These soils have formed on a middle Pleistocene glacial outwash sediment known as the Columbia Formation. Ramsey (2005) describes this as being composed of a fine to coarse feldspathic quartz sand with varying amounts of gravel. Within this gravel, clasts of cobble to small boulder size are found that may be sandstone, siltstone, shale, pegmatite, micaceous schist, and amphibolite. Such mixed material will have a variable chemical composition and can therefore be expected to have a range of magnetic properties. This is an important consideration for magnetometer surveys as shallow deposits of such material can be expected to produce random background magnetic 'noise' against which anomalies of archaeological origin will be set. The relatively deep soils present at the Dale site should help minimize the geological input.

1.5 Geophysical surveys were undertaken between August 22-25, 2011. During this period the weather was generally dry and conducive for survey, but with stormy weather on the August 25 as the fieldwork was being completed.

1.6 At the time of fieldwork the survey area was being farmed. As the cover photo shows, soy bean was being grown, but with variable success across the field. Survey conditions were therefore reasonable as the magnetometer employed for this survey generally had good clearance over the top of these low plants.

1.7 The objectives of this investigation were to identify the presence of sub-plowzone archaeological remains relating to the known historic remains, and to provide a map of any such features for subsequent excavation in order to determine the significance of these sites.

1.8 Based on the type of features and natural conditions expected at this site, and following the success of an earlier magnetometer survey by the author over the nearby Bird-Houston sites (Horsley 2011), it was decided to conduct a high resolution magnetometer survey to answer the survey objectives.

1.9 Before the field methodologies are described in some detail, a brief introduction to geophysical techniques and the methods employed is provided in Section 2; this introduces some fundamental principles and explains why this method was chosen. More specific details regarding magnetometry and the methodology employed is presented in Annex 1.

2 Geophysical prospection methods

2.1 Geophysical methods include a range of non-destructive techniques for detecting subsurface disturbances associated with buried remains. It is important to note that these techniques do not detect the features themselves, but rather physical variations – or *anomalies* – that require interpretation. For a buried feature to be detected there must therefore be some physical contrast between it and the background soil and subsoil; if no such contrast exists, that feature will be effectively be invisible.

2.2 Many archaeological features exhibit physical contrasts to the natural soils and sediments, either through the addition of foreign material into the soil (e.g. building materials such as bricks and rocks), or by altering the soils and subsoils (e.g. conversion of magnetic properties through heating, or the silting up of cut features such as pits and ditches).

2.3 A selection of geophysical techniques is available for archaeological prospection, including magnetometry, earth resistance and ground-penetrating radar (GPR). Each method measures a different physical property and therefore a particular method or

combination of methods may be chosen that will be best suited to the conditions at a given site.

2.4 Magnetometry is the most rapid geophysical method and can detect a broad range of both prehistoric and historic archaeological features. In addition to pits, ditches, and many burnt remains, it is often possible to identify areas of occupation using a magnetometer. Historic sites are usually more easily identified on account of the higher concentration of magnetic material in the form of brick, tile and ceramics, in addition to iron objects. Due to the speed with which measurements can be made this method is well suited to characterize magnetic anomalies over large areas at high resolution. Further information on this technique may be found in Annex 1.

3 Methodology

3.1 In order to collect an even coverage of data and to accurately locate any resulting anomalies, geophysical surveys are undertaken over a regular grid. For these surveys a baseline was established along the straight wooden fence to the east of the site using a total station instrument. Orienting the survey grid to this particular field boundary allowed magnetometer data to be collected along traverses running parallel with the predominant direction of plowing across the survey area; this approach can aid later removal of plowscar anomalies that may appear in the data. A grid comprising 31 30m x 30m squares was set out to encompass the three clusters of historic material identified in the Phase I survey (See Figure 1). During the course of the geophysical survey it was decided to extend the grid an additional 30m south in the southeastern corner in order to map the extent of an area of magnetic noise that was seen to continue beyond the original grid edge. The locations of the survey grid points were later recorded by Louis Berger personnel using a Trimble GeoXH.

3.2 The magnetometer survey was undertaken using a Bartington *Grad601-2* dual fluxgate gradiometer. Data were collected at a sample interval of 0.125m along traverses spaced 0.5m apart. Each line was walked in opposite directions, in the so-called zig-zag fashion. Before and during the course of each day's measurements the electronic and mechanical setup of the instrument was adjusted to correct for electronic drift and variations in coil orientation. The magnetometer was set to a recording sensitivity of 0.1nT.

3.3 Magnetometer data were downloaded using *ArcheoSurveyor* for initial treatment, and then processed using *Geoplot 3.00*. For this data set, treatment was restricted to *clipping* of the data to reduce the influence of extreme readings, followed by *sensor destripe* to reduce or remove any striping in the data due to sensor mismatch and/or plow scars. Finally, the data were *interpolated*, (i.e. from a resolution of 0.5m x 0.125m to 0.25m x 0.125m), in order to produce a smoother appearance and aid interpretation. After processing, the data have been imported into *ArcView*, a Geographical Information

System (GIS) package that has allowed the results to be integrated with other maps and images. The GIS was also used to produce the interpretation.

4. Results

4.1 A grayscale of the raw magnetometer data is presented in Figure 2, (after treatment to reduce striping – see Section 3.3). In Figure 3, the smoothed, interpolated image is shown. Finally, an interpretation of the magnetometer data is presented in Figure 4.

4.2 In contrast to the magnetometer results from the nearby Bird-Houston sites, these results from the Dale site reveal that the soils are generally deeper, suppressing much of the magnetic interference associated with the underlying Columbia Formation. As a consequence, magnetic anomalies of cultural origin are more easily identifiable in Figures 2 and 3. Geological responses are still visible, especially in the southeastern corner of the survey area; however, their form and character makes them easy to distinguish from more shallow archaeological anomalies. These areas of geological responses are highlighted in the interpretation in Figure 4.

4.3 As at other historic sites, areas of previous anthropogenic activity can be identified on account of localized concentrations of small-scale bipolar magnetic responses. Pieces of brick, tile, ceramic, and iron produce discrete positive and negative responses on account of their intense remanent magnetization. While it is not uncommon to see a background scatter of intense anomalies in magnetometer data due to iron trash or broken farm equipment on or in the topsoil, concentrations of this magnetic 'noise' can indicate sites of former structures and other areas of historic activity. At the Dale site, a number of distinct clusters of magnetic noise have been detected. These are highlighted in the interpretation map in Figure 4 and discussed below.

4.4 The concentration of bipolar anomalies at [1] coincides with a cluster of cultural material identified in the Phase I survey, ('A' in Figure 1). The range of anomaly intensities suggests both iron and magnetic material such as brick fragments are present and, since red brickbats were reported in this area (Liebeknecht & Burrows 2010, 3-65), it is likely that these results indicate the site of a historic structure. Area [1] measures approximately 120 feet x 70 feet, (36m x 20m), and very subtle linear trends within this were tentatively interpreted as indicating surviving foundation remains. However, subsequent excavation did not find any intact deposits below the plowzone in this area (Bedell, *pers. comm.*).

4.5 At [2] is a broader area of magnetic noise, more diffuse than those at [1], but surrounding area [1] and extending some 110 feet, (35m), south from it. This may indicate a former yard or some other activity area. Within this area, a discrete positive anomaly is visible at [3]. It measures 6 x 5 feet, (2.0m x 1.4m), and is around 15-20nT in strength. Such a response could be produced by a large pit or localized area of

burning. Subsequent excavation by the Louis Berger Group revealed this to be a well, 1.5m across and 2.0m deep (Bedell, *pers. comm.*).

4.6 The area of magnetic noise at [4] is less dense than [1] and measures approximately 83 feet x 56 feet (26m x 18m). This area lies at the center of a previously identified concentration of cultural material, labeled 'B' in Figure 1 (Liebeknecht & Burrows 2010). From the geophysical data, it appears to be comprised of a combination of intense bipolar ferrous anomalies and other strong responses due to fired material such as bricks, and is therefore interpreted as indicating the site of a second structure, although somewhat smaller than that detected at [1]. These magnetometer results better define the shape and extent of the cultural material and also suggest that few intact sub-plowzone deposits survive in this area.

4.7 Some 75 feet, (20m), north of [4] is a small group of bipolar magnetic anomalies, labeled [5] in Figure 4. Some of these form a linear NE-SW trend, running towards the concentration of cultural material at [1]. From the magnetometer data alone it was unclear whether this represented a portion of former field boundary or part of a structure, but excavation has indicated that this was in fact due to a spread of cultural material alongside a former driveway (Bedell *pers. comm*.).

4.8 At [6], roughly 50 feet, (18m), southwest of the responses at [4], is an alignment of at least five strongly magnetic anomalies, in excess of 25nT in strength. While these may all be ferrous in origin, (e.g. due to buried iron such as loops of barb wire), these responses are consistent with magnetic enhancement through burning, and features related to high temperature industrial processes could not be ruled out. Subsequent investigations here indicated that this was actually part of an old fenceline (Bedell *pers. comm*.), and it is now possible to draw a line from these responses through a number of other intense ferrous anomalies to the modern fence to the south.

4.9 Interestingly, the third cluster of cultural material identified in the Phase I survey, ('C' in Figure 1), is not accompanied by a cluster of magnetic noise, (it would be centered on [7] in Figure 4). These results therefore suggest that this was not the site of a building and it may instead represent a plowed-out trash deposit. Given the quantity of material observed in the Phase I investigation, it is curious that this area does not have a noticeable concentration of bipolar ferrous anomalies, implying that little iron is present.

4.10 Along the western side of the field, and at the corresponding edge of the magnetometer survey area, two additional areas of small-scale magnetic noise have been identified at [8]. These indicate locations of concentrations of cultural material, again probably largely comprised of brick fragments. While they could therefore indicate the sites of former structures, it is more likely that they represent material cleared from [1] and [2] to the edge of the field to improve the soils for farming.

4.11 In the southeast of the survey area, two small concentrations of magnetic responses can be seen at [9] and [10] that were not identified in the Phase I survey. The cluster of bipolar responses at [9] measures around 40 x 16 feet, (11.5m x 4.5m), and could indicate the site of a small outbuilding or possibly a trash deposit. The responses at [10] cover an area just 14 x 7 feet, (4m x 2m), and likely represent another small outbuilding. Investigations by the Louis Berger Group noted concentrations or iron nails at these locations. These artifacts would produce the results seen here and support the interpretation that these both represent the locations of outbuildings.

4.12 The subtle but distinctive pattern of magnetic anomalies due to a surviving portion of fired clay land drain is visible in northeastern portion of the survey area at [11].

4.13 Contrasting with the numerous bipolar magnetic anomalies visible throughout these data, a few discrete positive responses have been identified. These are highlighted in Figure 4 as 'pit-like responses', and some are labeled [12]. Such anomalies may be indeed due to pits, or alternatively localized areas of burning (e.g. hearths); however, they may also be natural in origin, being produced by larger magnetic rocks in the soil. In each case, excavation would be required to correctly identify the source of these anomalies and provide dating evidence. If archaeological in origin, these responses could represent prehistoric features, although no other indication for prehistoric activity has been identified in this survey.

4.14 At [13], the magnetometer survey has provided evidence for a vertical iron pole or pipe. This could indicate a well pipe sunk at this position.

5. Conclusions

5.1 The magnetometer survey over the Dale site has helped to map and define areas of historic cultural activity, and locate a number of features for subsequent investigation through excavation. Two of the three clusters of anthropogenic material identified in the earlier Phase I survey appear to indicate the former sites of buildings, while no clear evidence for cultural remains was found associated with a third cluster.

5.2 The largest concentration of magnetic anomalies suggests cultural material associated with a brick-built structure. A spread of more diffuse anomalies to the south of this may indicate a yard area, and a distinct positive magnetic anomaly within this area was subsequently revealed through excavation to be due to a well.

5.3 The sites of two smaller outbuildings are also suggested by localized clusters of magnetic material. Two similar concentrations of magnetic anomalies along the western field boundary more likely represent cultural material that has been cleared to the edge of the field.

5.4 The geophysical results also provided evidence for a former field boundary and a driveway and, although the correct identification of these was only possible following their excavation, this survey was able locate anomalies that indicated the locations of intact features for further investigation.

5.5 Other than a few isolated positive anomalies that could represent historic or prehistoric pits or localized areas of burning - or naturally occurring magnetic rocks – no evidence for prehistoric activity has been detected.

5.6 This survey has continued to demonstrate the successful application of magnetometer surveys for locating and mapping historic sites in similar situations in Delaware. The underlying Columbia Formation can produce spurious magnetic effects that, in areas of shallow soils, may make the interpretation of data difficult. However, where deeper soils are present, such as the Dale site, this geological effect is markedly reduced. Ground-penetrating radar has been shown to be beneficial on historic sites and could be useful in detecting the presence or absence of intact structural foundations, especially over near-surface fluvioglacial deposits like the Columbia Formation, but was not necessary in this instance.

The results and subsequent interpretation of geophysical surveys should not be treated as an absolute representation of the underlying features. It is normally only possible to prove the nature of anomalies through intrusive means, such as trial excavations.

Acknowledgements

Fieldwork:	**T.J. Horsley**	**Dates of survey:**	**08/22/11 – 08/25/11**
Report:	**T.J. Horsley**	**Date of report:**	**11/30/11**

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Annex 1. Magnetometry

It can be possible to detect subtle anomalies in the Earth's magnetic field caused by buried archaeological remains using a magnetometer. Variations in the magnetism, (the *magnetic susceptibility*), between a feature and the surrounding soil can arise owing to weakly magnetic oxides present in the soil. Past human activities may have redistributed these minerals or converted them into more magnetic forms so that buried features may be detected and identified by their resulting magnetic anomalies. In this way, it is possible to identify and map buried pits, ditches, hearths and, depending on their size and degree of magnetic contrast, postholes. Based on patterns and alignments of pits it may be possible to identify structural remains.

Features associated with high temperature processes can also be detected on account of a permanent, so-called *thermoremanent* magnetization that is retained when a material containing iron oxides is heated to above around 600-800°C (1000-1400°F) and then cooled. In this way, kilns, furnaces, pit ovens and often deposits containing bricks, tiles and fire-cracked rocks can be identified from the more intense magnetic anomalies associated with them.

Burials are not usually identified using a magnetometer since neither the cutting and backfilling of the grave shaft, nor the inhumation itself, creates a magnetic contrast that can be measured at the ground surface. Bones are too small to be detected with any geophysical technique and, despite digging of the grave and interment of a body or human remains, the grave is usually immediately backfilled with the same material that was removed and so there may be no difference between the grave fill and the surrounding soil. In some instances, notably historic graves where coffins were used, an air-filled void may be left after the body has decayed; however, this feature is often only detectable using GPR.

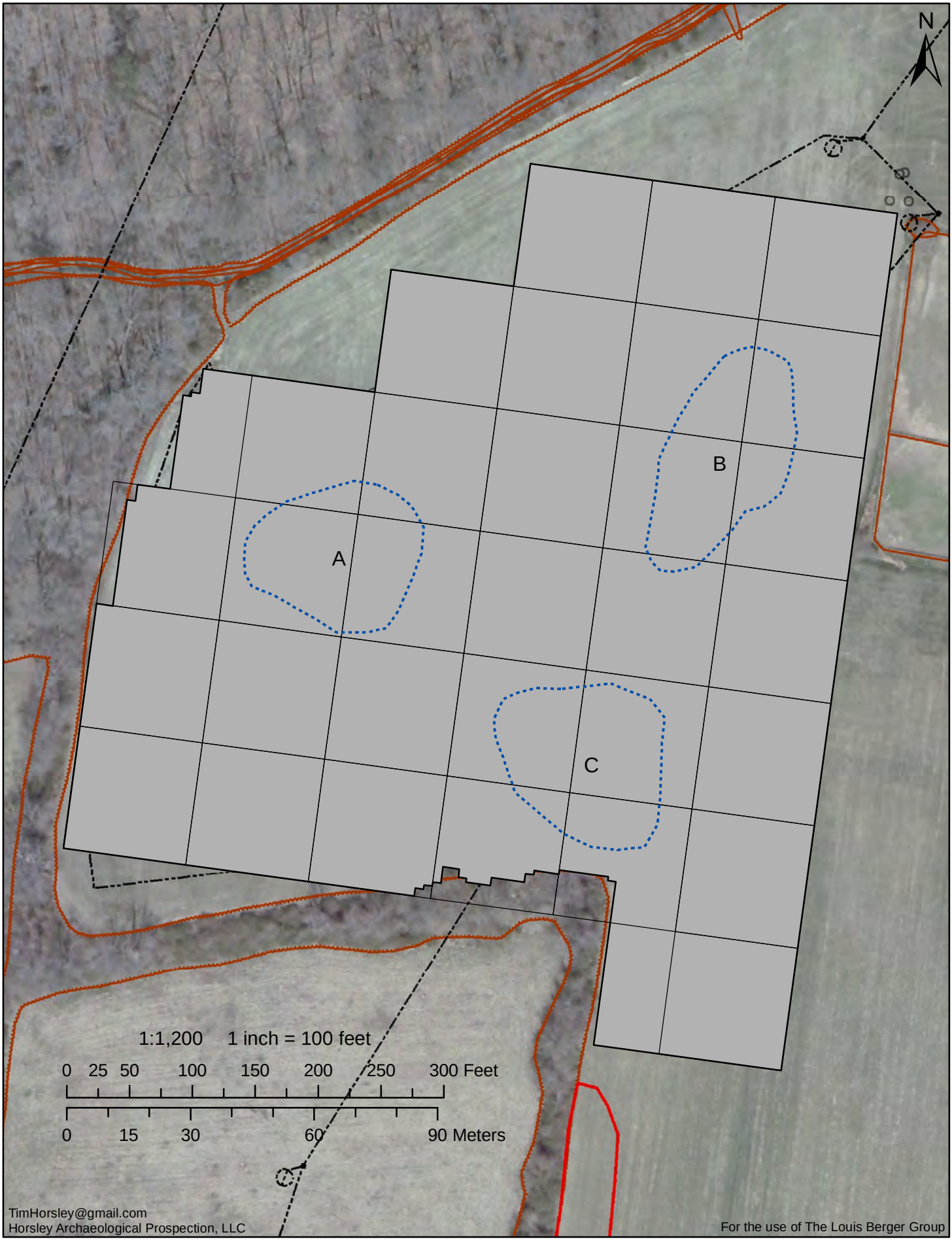
Magnetometers are highly sensitive to iron metal and consequently surface or buried iron objects can be detected as very intense responses. While this iron may be archaeological in origin it is often from modern fences, farm machinery and trash, and it is impossible to distinguish between different sources.

Many magnetometers allow readings to be collected at regular and closely-spaced time intervals, (defined by the operator), such that data may be recorded at regular distance intervals by walking along a marked guide rope at a constant pace guided by a beep. The quality and accuracy of the data is therefore dependent on the operator's ability to walk smoothly and at a constant speed throughout the survey area. Standard practice for such data collection is to establish a grid of 20m or 30m squares that are each surveyed in turn. Within each grid, data may be collected at 0.125m or 0.25m intervals along traverses spaced either 0.5m or 1.0m apart. Decisions about the resolution at which to collect geophysical data are based on factors including the size and nature of expected archaeological features and the time available for survey.

For more information on this technique, see Aspinall *et al*. (2008), Clark (1990: 64-98), Gaffney and Gater (2003: 36-42) and Kvamme (2006).

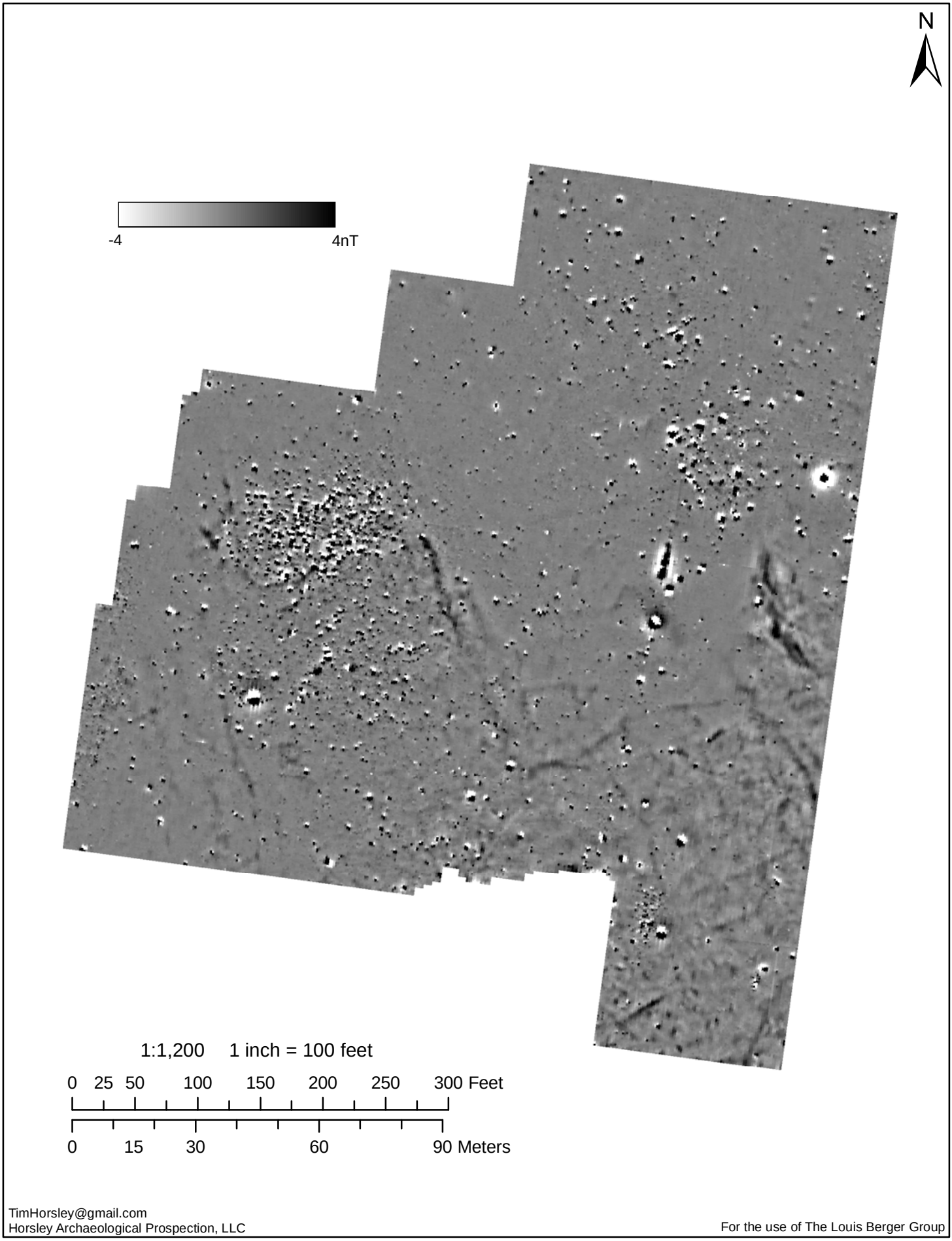
US Route 301 Phase II, Newcastle County, Dale Historic Site. August 22-25, 2011.

Figure 1. Location of the geophysical survey grid relative to the surface concentrations of historic material



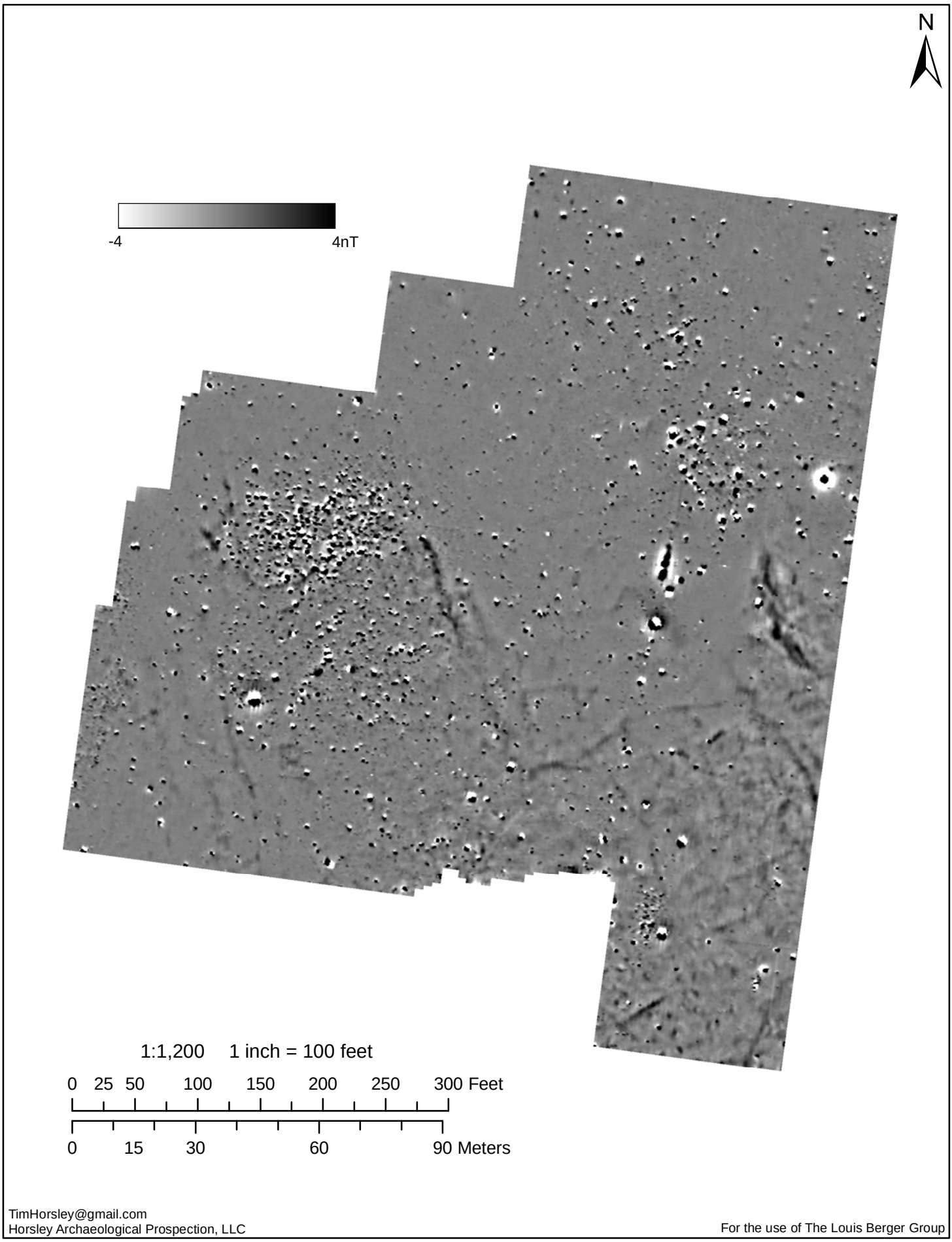
US Route 301 Phase II, Newcastle County, Dale Historic Site. August 22-25, 2011.

Figure 2. Raw magnetometer data (after treatment to match adjacent sensors)



US Route 301 Phase II, Newcastle County, Dale Historic Site. August 22-25, 2011.

Figure 3. Processed magnetometer data (after interpolation)



US Route 301 Phase II, Newcastle County, Dale Historic Site. August 22-25, 2011.

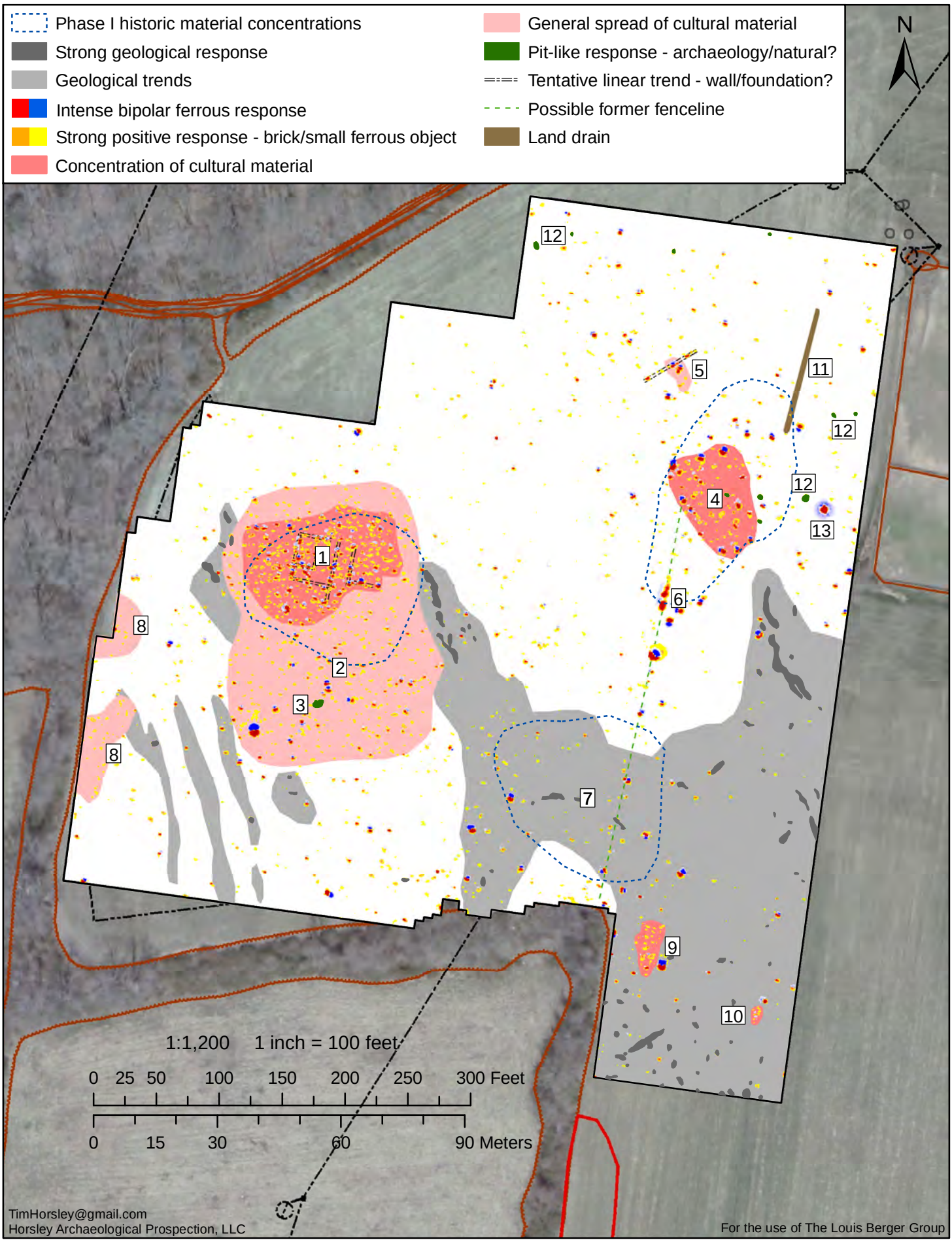



Figure 4. Interpretation of the magnetometer data (see text for details)