Centre for Archaeological Fieldwork

Geophysical Survey Report No. 31

Magnetometry survey, Tullaghoge Fort, Co. Tyrone

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Summary of results

An evaluation resolution (1m x 0.125m) magnetic gradiometery survey was carried out over a total 3.5 Ha in the immediate environs of Tullaghoge Fort (TYR 038:016). Rapid processing and interpretation of this data identified two areas, covering 0.72 Ha in total, for higher characterisation resolution (0.5m x 0.125m) survey. In general the magnetic survey data was quite noisy returning a notable amount of high magnetic spotting and dipolar readings. These are mainly due to magnetic contamination and geological factors.

The current survey identified a number of key anomalies with significant archaeological potential. A dipolar feature, m8, was interpreted, using information gathered during the previous electrical resistance survey, as a possible stone built, keyhole kiln aligned north – south. This was confirmed through excavation (Sloan 2014b). A similar dipolar anomaly is noted further to the west. This may mark the location of a second kiln, perhaps different in form, which may be associated with some form of enclosing activity. The excavated kiln appears to be inserted into the southern portion of a circular enclosure (m11), *c.* 33m diameter, which appears to be comprised of a series of pits. Plough marks were recorded truncating the enclosure in the higher resolution survey of Area A2. A series of higher magnetic features, m7, appear to trace the path of a high resistance curvilinear anomaly, l3, identified in the 2006 survey (Trick 2006, 7). This appears to correspond with a depression identified during GIS analysis of the LiDAR data (McDermott 2013, 35).

Site Specific Information

Site Name: Tullaghoge Fort

Townland: Ballymully Glebe

SMR No: TYR 038:016

Grid Ref: H 82342 74177

County: Tyrone

Dates of Survey: 21st August – 5th September 2014

Surveyors Present: Siobhán McDermott, Brian Sloane, Ruth Logue, Harry Walsh, Stuart Alexander

Size of area surveyed: 3.5 Ha

Weather conditions: Overcast to sunny and clear

Solid Geology: Rockdale Limestone Formation – interbedded limestone & argillaceous rocks

Drift Geology: Diamicton Till

Current Land Use: Heritage landscape with low intensity grazing

Intended Land Use: No change intended

Survey methodology overview

Survey type
Magnetic gradiometery
Instrumentation:
Bartington Grad601-2 magnetic gradiometer
Probe spacing:
1m
Grid size:
30m x 30m
Traverse interval:
1m (0.5m higher resolution as required)
Sample Interval:
0.125m
Traverse Pattern:
Zig-zag

Lecia TS06-plus total station
Station setup:
Tied into Irish National Grid using differential GPS
Map Accuracy:
Survey grade accuracy (<3cm)
Georeferencing:
The EDM data will be used to georeference the geophysical survey datasets exported from Geolplot v.3 into ArcMap 10.2.

Data processing:
The geophysical data was processed in Geoplot v. 3 software. The primary processes applied included Zero Mean Traverse to remove traverse stripping and Low Pass Filter to remove high frequency, small scale spatial detail. The data was interpolated to smooth its appearance and account for traverse to sample interval ratio differences.

Visualisations:
The datasets will be visualised in Geoplot v.3 using shade, trace, dot density and relief plots. The raster datasets were imported into ArcMap 10.2. Cluster analysis was applied to aid the discovery of patterns (Ogden *et al.* 2009). The resulting rasters were analysed in relation to the historical Ordnance Survey map series, available orthorectified aerial photographs and the previous seasons of electrical resistance surveys.

Digital archive:
The geophysical datasets were collected, processed and archived in accordance with Archaeological Data Services best practice.[1]

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[1] Schmidt, A. & E. Ernenwein, 2011, Guide to good practice: Geophysical data in Archaeology [Online] http://guides.archaeologydataservice.ac.uk/g2gp/Geophysics_Toc

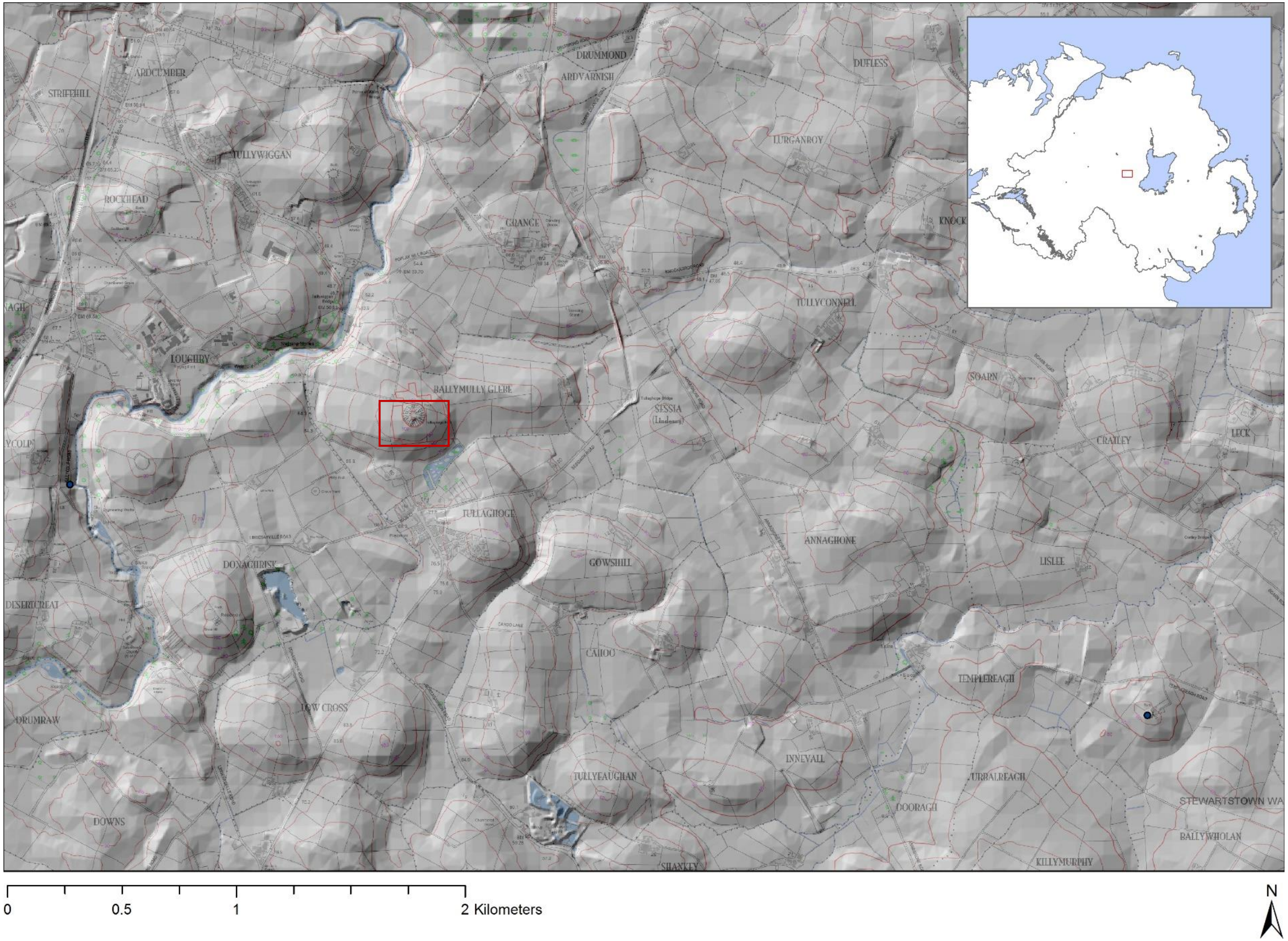

Figure 1
Location and landscape setting of the geophysical survey grid marked in red (OSNI 10km vector data layered over 5km DEM Hillshade)

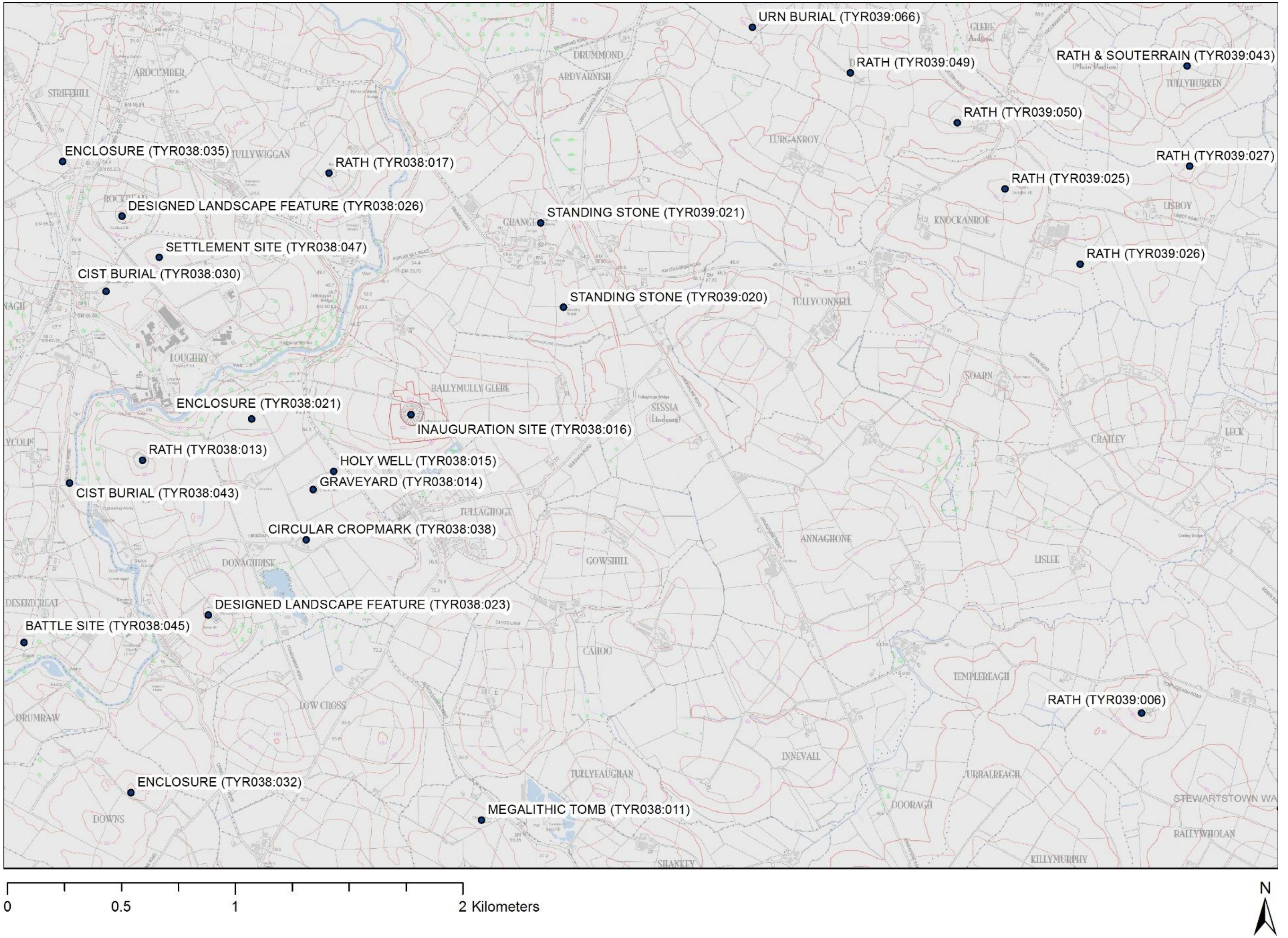

Figure 2 Wider recorded archaeological landscape setting. Geophysical survey area in red with Key NISMR locations noted.

Figure 3 Location of earlier seasons of electrical resistance geophysical surveys.

Figure 4 Extent of 2014 magnetometry survey in relation to Scheduled Area Zone.

Introduction

The survey area is located *c.* 300m north of Tullaghoge village mid-way between Cookstown and Stewartstown, Co. Tyrone. An area of 3.5 ha was surveyed immediately surrounding Tullaghogue Fort (TYR038:016) to the centre of Ballymully Glebe townland, Desertcreat Civil Parish. The landscape is dominated by low-lying drumlins which stretch from the richer soils of the Lough Neagh basin westwards towards the water-logged Sperrin uplands and southwards into counties Armagh and Monaghan. At only *c.* 95m OD the drumlin affords an excellent aspect over the surrounding countryside. Standing on the drumlins eastern slopes you can look north towards Magherfelt and the pass through which the A29 travels to link Moneymore with Desertmarin. Turning clockwise onto the shores of Lough Neagh in the west, southwards onto north Armagh and finally south to Dungannon. The drumlin height obscures views from the eastern slopes onto Cookstown in the north-north-west and the Sperrin uplands to the west.

In general the magnetic survey data was quite busy returning a notable amount of high magnetic spotting and dipolar readings. The geology of the area probably accounts for a sizable proportion of these signals. The limestone bedrock geology of the survey area is generally suitable for magnetometry. Although the carboniferous limestone that dominates Ireland has a lower magnetic contrast then other limestone geologies (Bonsall *et al.* 2014, 7). It is more likely that the drumlin geomorphology and superficial till geology which has the greater influence on the magnetometry data. The drumlin landscape of mid-Ulster was produced by receding glaciers leaving a distinct 'basket of eggs' topography (Geraghty 1997, 4). It remains a relatively water-logged landscape dominated by a diamicton till which prohibits water percolation. Soils are consequently wetter and difficult to drain with lakes, rivers and streams occupying the lowlands between the drumlins (Geraghty ibid; Mitchell and Ryan 1997, 352). Waterlogging further impedes the magnetic enhancement of soils (Bonsall *et al.* 2014, 8). The soil pedon is dominated by an narrow A-horizon of sandy clay and a B-horizon of orange boulder clay near the drumlin apex (Sloan 2014b) moving to a gravel & bedrock B-horizon at the western base of the drumlin where the 2013 excavations occurred (Sloan 2014a). The current magnetometry data was gathered over the boulder clay B-horizon which generally produces a poor response (David *et al.* 2008, 15).

The data also displayed evidence for magnetic contamination. This occurred near lengths of the wire boundary fencing and over a buried metal water pipe. Dipolar readings are also noted in the vicinity of entrances and corners which may be related to parts being lost from machinery as they gain access or turn. Even allowing for dipolar responses associated with this magnetic contamination there were still a large number of higher magnetic anomalies. Cluster analysis, similar to dot-density plots, of the raster dataset was used to try to identify patterns which may indicate human-made structures such as possible pit alignments. Magnetic geophysical survey was not applied at the same time as the electrical resistance due to concerns that igneous geology may cause interference (Trick 2006, 4). An initial testing phase demonstrated that magnetic gradiometery could be implemented successfully and it identified a number of anomalies not recorded by the resistivity survey. Further, the additional dataset supplemented that captured during the electrical resistance surveys and aided its interpretation.

The landscape use is predominately agricultural and mainly pastoral. With evidence of significant changes since it was first recorded by the First Edition Ordnance survey, *c.* 1832 – 34 (Figure 22). Landholdings have been amalgamated, earlier field boundaries and settlements removed or eroded, trackways and entrances widened to allow access for heavier farm machinery and increase productivity. This is not a recent development with agricultural improvement occurring in the area for at least the last 230 years (McDermott

2013, 4). The detrimental effects of this activity in relation to topographically extant archaeology, as evident in the Tullaghoge LiDAR survey, has been discussed by McDermott (2013). Settlement patterns are typical of Irish rural dispersed settlement with the accompanying web of narrow roads.

The survey was situated in the area immediately surrounding the fort with an emphasis on the fields to the south and east. The total survey area was divided into two (Figure 9): Area A occupies a large field to the south and Area B a portion of the northern field. In Area A the ground surface drops away steeply to the east clockwise through to the south before following a gentler gradient to the west of the fort. A gate is located in the northern boundary of Area A affording access. Access to Area B is situated in the same location. The gradient of the ground surface in Area B increases as you move from the west clockwise through to the east. The ground surface to the east of Area B drops away sharply at a 20% gradient. The land is currently farmed for pasture having been freshly cut for silage just before the area was surveyed. Both areas are enclosed with wire fencing.

The form of Tullaghoge fort itself is evident in the Digital Terrain Model (DTM) produced from LiDAR survey data (Figure 26). It consists of a central, raised hexagonal platform with a pronounced lip forming a bank around the perimeter. This is encircled by a broad, flat-bottomed fosse and a high outer bank, which is overgrown with trees along much of its surface.

Historical context and previous archaeological enquiries (after McDermott 2013)

Tullaghoge fort is situated in the townland of Ballymully, which translates as the ‘farmstead of the summit’. In the early 17th-century a land parcel called Ballymully was one of fifteen which formed the ballybetagh of Ballehagan. These were the sept lands of the O’Hagans who had a key role in the inauguration of the O’Neill (FitzPatrick 2004, 142). The O’Hagan’s claim their lineage from the Clann Feargusa, a sept of the Cenel Eoghain. In ODubhagain’s 13th-century topographical poem the O’Hagan’s are described as: “A stout chief over Tulach Og, OhOgain, chief of the white roads, the plough has passed through every wood for it, another O'hOgain is near it." (O’Donovan 1862, 17).

The origin of the earthwork itself is uncertain. FitzPatrick (2004, 144) has speculated that it was originally a prehistoric hilltop enclosure or residential rath. The integration of the 2008 geophysical survey data with a LiDAR survey of the site would support this conjecture (McDermott 2013, 24-5). The site rose to prominence in the 11th century, when it was the dynastic centre and inauguration place of the Cenel Eoghain, who were later to become the O’Neill lordship (Donnelly 1997, 74). The earliest reference to Tullaghoge identifies it as the location of a peace pact between the Aileach and Ulidia in the 914AD (*AU*). By the 13th-century Tullaghoge was the epicentre of O’Neill rule. From the 11th- down to the early 17th-century the fort appears to have had a residential function albeit one that warranted numerous annalistic references.

Bartlett’s famous depiction of the site illustrates a two storey, hip-gabled house and a single storey dwelling, within the interior of Tullaghoge fort (Figure 4). When this image was produced, *c.*1602, the site was the chief residence of the O’Hagans who were stewards of O’Neill’s household on the *lucht tighe* lands of Tír Eoghain (FitzPatrick 2004, 200). The monument drawn by Bartlett is very different than that one that now tops Tullaghoge hill: It is enclosed by a single, tree-topped bank. Two entrances marked by posts which form lintel gateways appear to oppose each other. A path runs to the north of the fort from the foot of the hill. The area to the south and east is wooded. The aforementioned houses seem to cluster to the south-east of the interior. A small roofed church is shown to the south-west of the hill. The inauguration seat is located further downhill on the eastern slope of Tullaghoge drumlin and a routeway is depicted running over the drumlin to the west of the fort. Such was the importance of the inaugural chair at Tullaghoge, to Tudor expansion, that it was illustrated on a number of occasions. Jobson's maps from *c.* 1590 and *c.* 1598 (FitzPatrick 2004, 151) both note the location of 'the stone where Oneale is named'.

The residential focus of Tullaghoge fort continued on into the early Plantation period. The proportion known as Tullaghoge, which comprised 'the old Irish territory of *Ballhagan*' (Hill 1877, 288), was granted to a Robert Lindsey in 1611. In 1619 a Mrs Lindsey held 1,000 acres with 'a good strong bawne of earth, with a quick-set hedge upon it, and a ditch, a timber house within, in which she and her family dwell' (*Cal. Carew MSS.*1619, 413). The adoption of Gaelic settlement foci and forms by the Planter community in the early 17th-century occurred throughout the escheated counties (*Cal. Carew MSS.* 1611, 94, Harris 1757, 84-5). However by 1622 the family had moved to a new residence at the foot of the hill eventually founding Loughry House in the 1630s. Without its residential component Tullaghoge fort was now, 'a Bawne of Sodds on the topp of the hill where the Great O'Neal was wont to be chosen, but noe gate to it, nor Inhabitants neerer than the foot of the hill, being half a quarter of a mile from thence. Onely there is a smale frame of timber erected within the Bawne for a litle dwelling house, but without Walls or covering' (Treadwell 1964, 148; FitzPatrick 2004, 147). It is noteworthy that this makes reference to a timber frame structure in the forts interior.

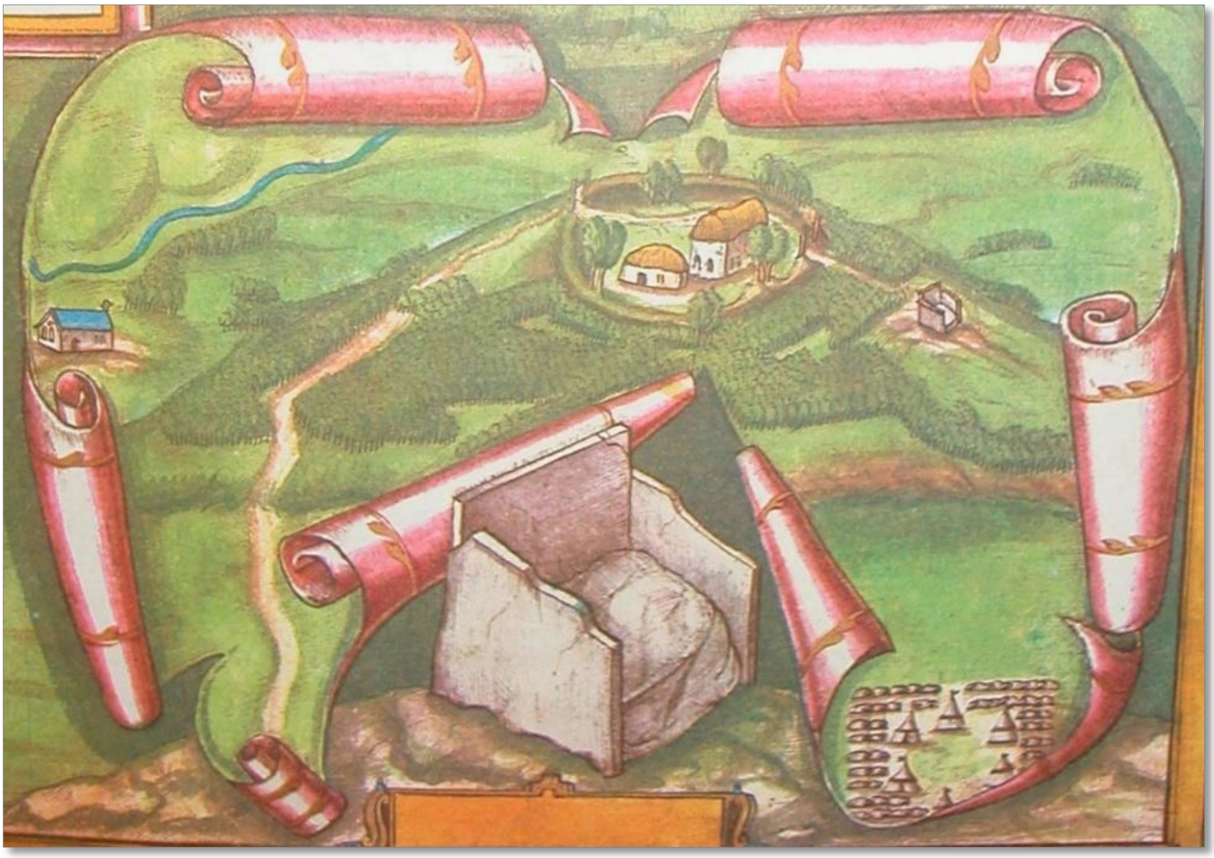

Figure 5 Extract from Bartlett map of Tullaghoge, Dungannon and an attack on a crannog. After Hayes-McCoy 1964, 8-10, Plate V.

Tullaghoge fort and its environs has recently been the focussed of a number of archaeological investigations implemented by the Centre for Archaeological Fieldwork, QUB, on behalf of the NIEA and Cookstown District Council. Several seasons of electrical resistance geophysical survey (Trick 2008, McHugh 2008 & 2013) covered an area of *c.* 16.5 hectares immediately surrounding the fort, within its interior and in two large fields to the west. In 2013 GIS analysis was carried out incorporating this early geophysical survey with data captured during a LiDAR survey of the fort and its wider landscape (McDermott 2013). The GIS analysis recommended that magnetic gradiometery be trailed with a view that the area previously surveyed with electrical resistance be also covered with this method. In the summer of 2014 this magnetometry was successfully applied the details of which are covered in this report. The data gathered was fully integrated into the project GIS.

Thus far two episodes of excavation have occurred within the catchment area previously covered by the electrical resistance survey. In the winter of 2013 an excavation (AE/14/01E) took place in advance of the proposed development of public amenities in the fields to the east of the current carpark, *c.* 350m west of the fort (Sloan 2014a). The excavation was carried out by staff from CAF on behalf of the NIEA. A total of thirty-three trenches were excavated, manually and mechanically, in two areas to the north and south of the laneway that gives access to the monument. A simple bowl cereal-drying kiln, radiocarbon dated to the 7th century, was excavated in the southern area. To the north of the laneway a notable Mesolithic flint scatter was identified, the presence of which mitigated against the mechanical excavation of any further trenches in this area (ibid, 2).

A programme of excavation (AE/14/124) in summer 2014 incorporated a wider community aspect involving local schools and adult volunteers. This season targeted possible 19th-century remains identified during the previous excavation and recommended for further investigation (Sloan 2014a, 2). A number of anomalies identified in the electrical resistance surveys were also investigated but revealed nothing of archaeological significance. Trenches were opened near both the boulders on the east face of the drumlin, again nothing of archaeological significance was revealed. Finally, the anomaly m8 identified during magnetic gradiometery survey (see discussion below) was excavated. This revealed it to be a stone-lined, key-hole shaped, cereal-drying kiln. A quantity of charcoal and charred grains were recovered which were radiocarbon dated, to the late 8th- to the end of the 10th-centuries, roughly coterminous with the previously excavated kiln (B.Sloane *per comms*).

Description and interpretation of anomalies (Figure 4)

General comments:

In general the magnetic survey data was quite busy with limited correlation between the magnetic anomalies and features recorded during the previous electrical resistance surveys (Trick 2006; McHugh 2008, 2013). The data returned a notable level of magnetic spotting and dipolar readings. The busy magnetic readings are primarily a consequence of a clay rich till which tends to return poorer results for magnetometry survey. A number of dipolar returns are probably associated with magnetic contamination which can mask archaeological anomalies.

The entire area was surveyed at an evaluation resolution (1m x 0.125m) along N – S zig-zag traverses. This data was used to targeted smaller areas for characterisation resolution (0.5m x 0.125m) survey: Area A2 and Area B2. These higher resolution surveys were walked along E – W zig-zag traverses. This change in traverse direction meant that a greater sampling density occurred along the x-axis in the later surveys as opposed to the y-axis in the initial evaluation survey. This affects the visualisation of anomalies but when all datasets are incorporated into a GIS, for comparative analysis, it provides an efficient method to interpolate high density resolution data within limited resources. Notably Bonsall *et al.* (2014, 13) have questioned the usefulness of evaluation resolution magnetometry surveys over some Irish soils. The greater clarity and larger number of anomalies captured in the higher resolution survey, specifically in Area A2, compared with the evaluation resolution survey would appear to support this conclusion.

Caution must be applied when overlaying the electrical resistance data with other survey datasets such as the gradiometery and LiDAR surveys. The latter datasets were gathered using GPS/GNSS geographical location systems whereas the electrical resistance surveys were carried out on floating grids 'best fitted' onto OSNI basemaps. More recently the electrical resistance data has been imported into ArcGIS as raster datasets and further georeferenced using information contained within the LiDAR dataset. Although this facilitates some degree of comparative analysis between the resistance and magnetometry datasets, it is still important to note that 'best fit' is not a very satisfactory solution to maintaining accuracy in GIS systems (English Heritage 2003, 8).

Table 1 Description and interpretation of archaeological anomalies in Area A

Code	**Description**	**Interpretation**
m1 (m1a & m1b)	The anomaly m1a is a subtly higher magnetic linear, *c.* 1.5m wide, running north-south to in the western half of Area A. The anomaly can be traced for a distance of *c.* 25.5m and may be associated with the anomalies which form m1b.	This area was targeted for higher resolution (0.5m traverse x 0.125m sample interval) survey, Area B2. The higher resolution traverses were walked in a perpendicular direction (E – W) to the previous evaluation resolution (N-S, 1m traverse x 0.125m sample interval) survey. The definition on some of the features, especially those running E – W, was lost in the higher resolution survey. This may

	A series of very subtle magnetic linear features, m1b, which appear to enclose a trapezoid area *c.* 28.5m N – S, *c.* 18m E – W.	be because the change in traverse direction meant these features were not adequately sampled or that interpolation of the lower resolution dataset gave a false sense of the extent of these anomalies initially. A 1970s edition of the six inch Ordnance Survey records a number of small, regular rectangular enclosures in the large field to the north of the fort. This land was owned by the department of agriculture during this period and the enclosures may relate to experimental farming activity. The trapezoid linear features, m1a & m1b, identified by the gradiometery survey may be related to this anomaly.
m2	Subtle magnetic linear which can be traced for a distance of *c.*15m to the north of Area B. It appears to run from the southern limit of m2a extending beyond the survey limit.	Because m2 extends beyond the survey limit it is difficult to interpret. If the series of possible pits associated with m18 are archaeological then it is possible that together both sets of features may enclose the area surrounding m3.
m3	Regular high magnetic feature (*c.* 2.5m N-S, E – W) situated at the very northern limit of Area B.	The anomaly m3 could be a large pit, perhaps of midden or refuse material. It is possible that m2 and m5 are also related to this activity if it is archaeological. However caution must be used the dataset in general was magnetically busy. Although the size of this feature does make it stand out.
m4	Regular high magnetic feature (*c.* 2m N-S, E-W) situated *c.* 44m north of the modern entrance to Tullaghoge fort.	Like m3 above the feature m4 could be a large pit, perhaps of midden or refuse material. However caution must be used the dataset in general was magnetically busy. This feature stood out because it appears to be enclosed by the linear anomalies associated with m1 within an area that was magnetically quieter and more uniform than that to the immediate west and east. If it is associated with m1 then if may be related to late 20th-century experimental agricultural practises.
m5	The anomaly m2a is a series of four higher magnetic pits (*c.* 1.5m wide) which form a neat semi-circle (*c.* 10m diameter SW – NE). The group	Best visualised using cluster analysis of the processed gradiometery data. It may be related to the linear anomaly m2 and the possible pit m3.

	of features is *c.* 90m north of the modern entrance to Tullaghoge fort in Area B.	It is difficult to interpret this data as it extends beyond the survey limit. The dataset in general is magnetically busy. However given the proximity to Tullaghoge fort, and the probability of it being a multi-period site (McDermott 2013), the possibility that this is archaeological cannot be ruled out.
m6	Irregular dipolar response (*c.* 4m E – W, 3.5m N – S) *c.* 1m west of a large bolder on the east facing drumlin slope to the east of Area A.	It is commonly believed that the late medieval inauguration chair of the O'Neills was on the east face of Tullaghoge drumlin before it was destroyed by Mountjoy's forces. The chair is depicted in this position by Bartlett (Figure 5b). Two large boulders are situated on the east face of the drumlin with a third at the bottom of the slope in the south-east corner of the survey area. It is not possible to say if any of these boulders were associated with the chair prior to its destruction. The returns, m6, do suggest that the area immediately surrounding and to the west of the northernmost boulder is magnetically volatile. It displays the type of dipolar responses one would associate with magnetic contamination or an episode of prolonged burning. The association of the anomaly so near a boulder which could be the remnants of the inauguration seat mean that it must be considered as having archaeological potential. An excavation trench (Sloan 2014) to the immediate east of the boulder did not reveal anything of archaeological significance.
m7	Three irregular high magnetic anomalies (*c.* 2.5m E – W, 3m N – S) in the eastern half of the field to the south of Tullaghoge fort. They appear to occur along the path of an anomaly noted during the 2006 electrical resistance survey.	The 2006 electrical resistance survey identified a curvilinear high resistance anomaly l3 running north-east to south-west *c.* 50m south-east of the fort. GIS analysis of data captured by LiDAR survey identified a very subtle, negative curvilinear feature following the same course (McDermott 2013, 35). The gradiometery data is magnetically noisy in general. Cluster analysis on the dataset did not initially aid pattern identification in this area. However when the features which comprise m7 were overlaid with the earlier electrical resistance data there does appear to be a correlation with the high resistance linear l3. The anomaly l3 was interpreted as a possible "boundary of a former field or other enclosure" (Trick 2006, 6).

		This could suggest that m7 are archaeological in nature as well perhaps associated with an enclosing element which appears to focus on the fort.
m8	A dipolar anomaly (*c.* 10m N – S, *c.* 2m E – W) running north – south to the south of Area A. It is situated *c.* 60m south of Tullaghoge fort.	The anomaly comprises of a keyhole-shaped core (*c.* 7m N-S) of high magnetic anomalies with a distinctive halo of negative readings to the west, north and east. In the higher resolution survey, Area A2, the feature appears to merge with a cluster of higher magnetic readings immediately to the north. This is due to the rotation of the traverse direction (E – W) by 90^{o} in the later survey and the effects of interpolation. It roughly corresponds with a high resistance feature evident in the 2006 electrical resistance survey. The high resistance anomaly was not identified has having archaeological potential at the time as the data was interpreted without access to the later gradiometery survey. The feature m8 displayed the characteristic signature of a kiln aligned north – south to take full advantage of the air flow generated by the south-facing slope. The halo of negative readings is not evident around the southern tip of the possible kiln suggesting this is where the kiln was fired. The presence of high resistance readings indicated that the anomaly was made of stone. The feature was targeted for excavation (Sloan 2014b). The excavation confirmed that it was a stone-lined, keyhole-shaped, cereal drying kiln aligned north-south with the flue to the south drawing heat into the bowl. Charred cereal remains have been dated to the late 8^{th} to the end of the 10^{th} centuries (B.Sloan *per comms*). Another cereal-drying kiln was excavated *c.* 350m west of the fort in early 2014. Only the bowl of the kiln was uncovered along with charcoal and charred grains, predominately oats and barely. It was radiocarbon dated to the mid-7^{th} century (Sloan 2014a, 81).
m9	A subtle curvilinear feature traceable for a distance of *c.* 16m to the west of m8. It comprises of a series of higher magnetic returns which are evident in cluster analysis patterns.	The magnetic anomaly m9 is very subtle. It would not have been identified without the use of cluster analysis and its relationship to a high resistance linear noted in the 2006 dataset. The higher resistance linear feature can be traced for a distance *c.* 23m running south to north before curving roundly to the east. It is no wider then *c.* 1m. The anomaly is situated *c.* 2m to the west of m8 appearing to encompass the kiln and

		a small open area to the north, *c.* 6m in diameter. The subtle magnetic anomaly m9 traces part of this path too. The returns are very modest but they could trace structural elements associated with the kiln perhaps a break against the north-westerly wind which also served to annex a sheltered area for other agricultural activities. The association of higher resistance and magnetic returns suggests the presence of stone, perhaps as packing material, and also decomposition *in situ*. Screens or windbreaks have been found associated with kilns elsewhere on the island (Monk & Kelleher 2005, 84).
m10	A series of four parallel, linear (ranging in length from *c.* 23.5m – 32m, *c.* 0.5 wide) features running north to south in the higher resolution survey of Area A2.	The anomalies are evident on the higher resolution Area A2 survey because of the change in traverse direction. The N – S alignment of the earlier survey, with 1m traverse interval sampling most likely meant these narrow features were not captured. The anomalies are most likely plough marks. The area has been heavily cultivated for at least the last 230 years (McDermott 2013). They appear to truncate the anomaly m11.
m11 (m11a & m11b)	The anomaly m11a is a series of irregular, higher magnetic anomalies (ranging from *c.* 1 – 4m N – S to *c.* 1 – 2m E – W) which traced three quarters of a large circular enclosure (*c.* 33m diameter). The enclosure is situated *c.* 35m due south of Tullaghoge fort. The kiln associated with m8 is located in the northern quarter of the enclosures interior. The feature m11b is a cluster of very subtle magnetic returns which may be an extension of m11a. It can be traced for a distance of *c.* 20m, width of *c.* 1m, extending from the southern limit of m11a.	The enclosure is situated along the 90m contour mark on a south-facing drumlin rise with a 12% gradient. It can be traced from the north-northeast anticlockwise through to the south, and possibly the south-west. There is the possibility that m11b may be an extension of m11a. In which case it would make the enclosures more plectrum-shaped. In the evaluation grade survey of Area A the anomaly appears to be a continuous linear feature. This would suggest a ditch *c.* 33.5m internal diameter. The anomalies landscape position on the higher slopes of a drumlin and the wider early medieval archaeological distribution of raths suggest that this could be a ploughed-out ringfort. Although the gradient of the slope does would mean the interior would be quite uneven. The higher resolution data gathered in Area A2 suggests it is composed of a series of pits. The anomaly could therefore relate to an earlier phase of activity such as a

		hengeiform structure or pit circle. An argument (McDermott 2013) has already been made that the fort itself and anomalies present in the 2008 (McHugh) electrical resistance survey indicate a prehistoric, possible Iron Age, antecedent for the hill top monument. In either scenario the cereal-drying kiln associated with m10 would be a later insertion. Phases of rath settlement activity followed by the construction of cereal-drying kilns are known from elsewhere in the county (McCormick *et al* 2014, 202).
m12	A series of higher magnetic, irregular pits (ranging from *c.* 1.5 – 3m N – S, 1 – 2m E – W) enclosed by m11.	Given that these occur within the possible interior of m11 these anomalies must be considered as possible refuse pits with archaeological potential. The magnetic signature of soil can be enhanced by the natural decaying process (Aspinall 2009, 24 – 5).
m13	A dipolar anomaly (*c.* 7m N – S, *c.* 2.5m E – W) running southwest – northeast to the southwest of Area A. It is situated *c.* 60m south-southwest of Tullaghoge fort and *c.* 72 west of the cereal-drying kiln associated with m8.	Displaying a similar distinctive cluster of positive values with a negative halo as m8. The anomaly m13 has an oblong core (*c.* 7m N-S) of high magnetic anomalies which narrows towards the middle. It is accompanied by a halo of negative readings to the west and east. As with m8 it also corresponds with a high resistance feature evident in the 2006 electrical resistance survey (Figure 9). The high resistance anomaly associated with m13 was interpreted as part of a linear high resistance feature, l17 which was thought to relating to the modern use of the area as an orchard (Trick 2006, 7). The anomaly l17 can be traced running E – W for a distance of *c.* 17m before turning sharply towards the north-northwest where is continues for another *c.* 22m. The presence of a possible kiln, and the relationship between it and l17, suggest that l17 may relate to an enclosure associated with the possible kiln itself.
m14	A straight, high resistance linear which can be traced for a distance of *c.* 53m along the north-western limit of Area A. It runs parallel, at a distance of *c.* 4m, to the modern field boundary.	This is the eastern limit of a roadway linking Tullaghoge village with the fort mapped by the 1st Edition Ordnance Survey, *c.* 1832 – 4. During data capture a narrow, stone-lined holloway was noted running N – S in this location to the west of the fort (Figure 22).

m15	A series of large dipolar anomalies associated with areas of magnetic contamination.	Of particular interest is the area of magnetic contamination which follows the path of the low resistance anomaly r1 identified during the 2008 (McHugh 2008, 18) electrical resistance survey. The presence of the distinctive magnetic signature confirmed that this was a metal water pipe. The other areas or magnetic contamination occur because of wire fencing and near field entrances or relict modern field entrances.
m16	Linear feature (*c.* 66m) running N – S. Defined by a series of dipolar anomalies.	This pattern became evident during cluster analysis. The anomaly m17 follows the path of a field boundary mapped in the modern Ordnance Survey data.
m17	Irregular, anomalous area (*c.* 7.5m N – S, 10m E – W) of dipolar readings situated *c.* 73m southwest of Tullaghoge fort.	The feature m18 is roughly coterminous with an area of high resistance, a5, noted during the 2006 survey (Trick 2006, 5). It was initially interpreted as relating to drainage activity. The dipolar magnetic response would strengthen that interpretation.

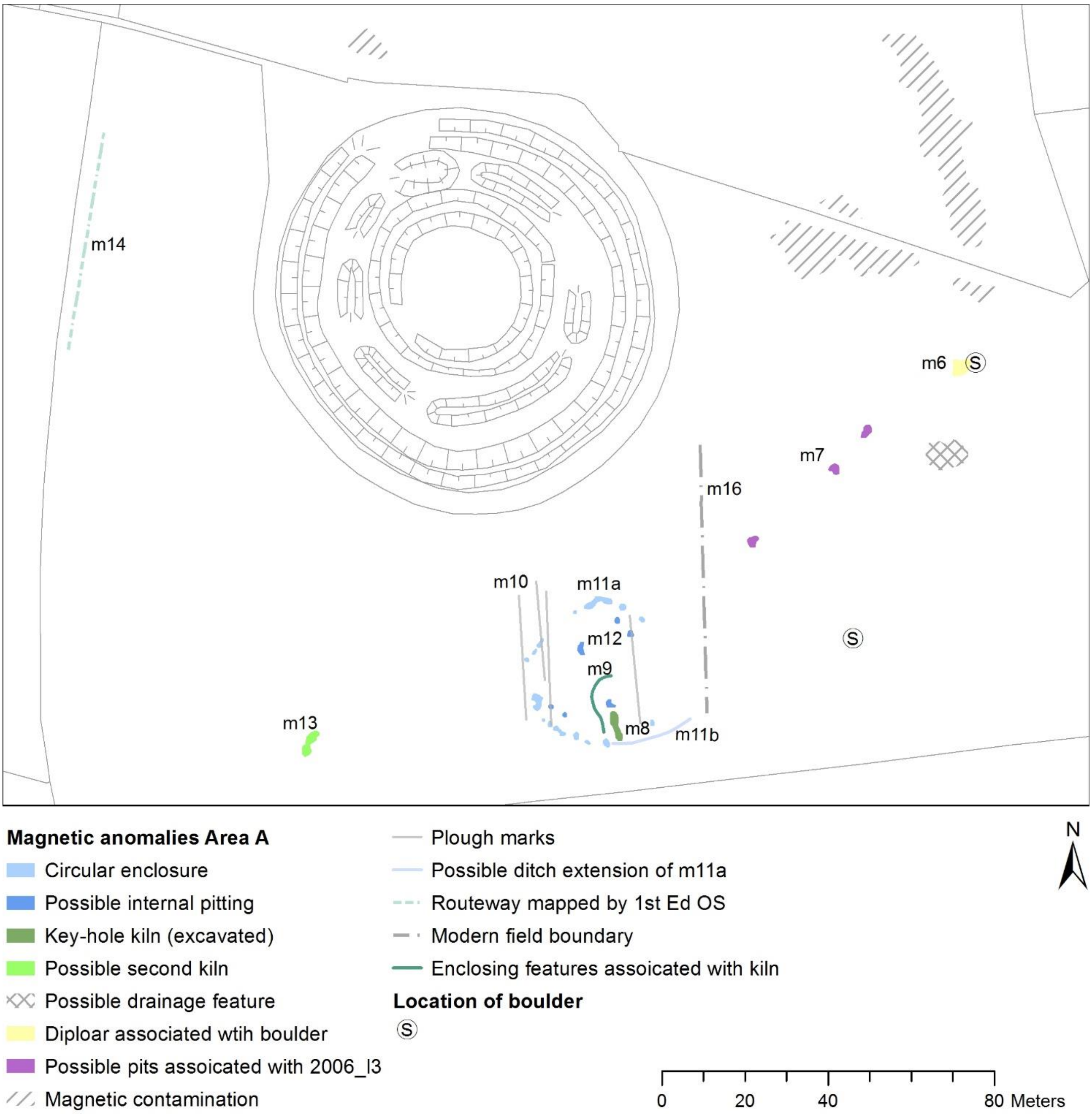

Figure 6 Interpretation diagram of Area A.

Figure 7 Interpretation diagram of Area B.

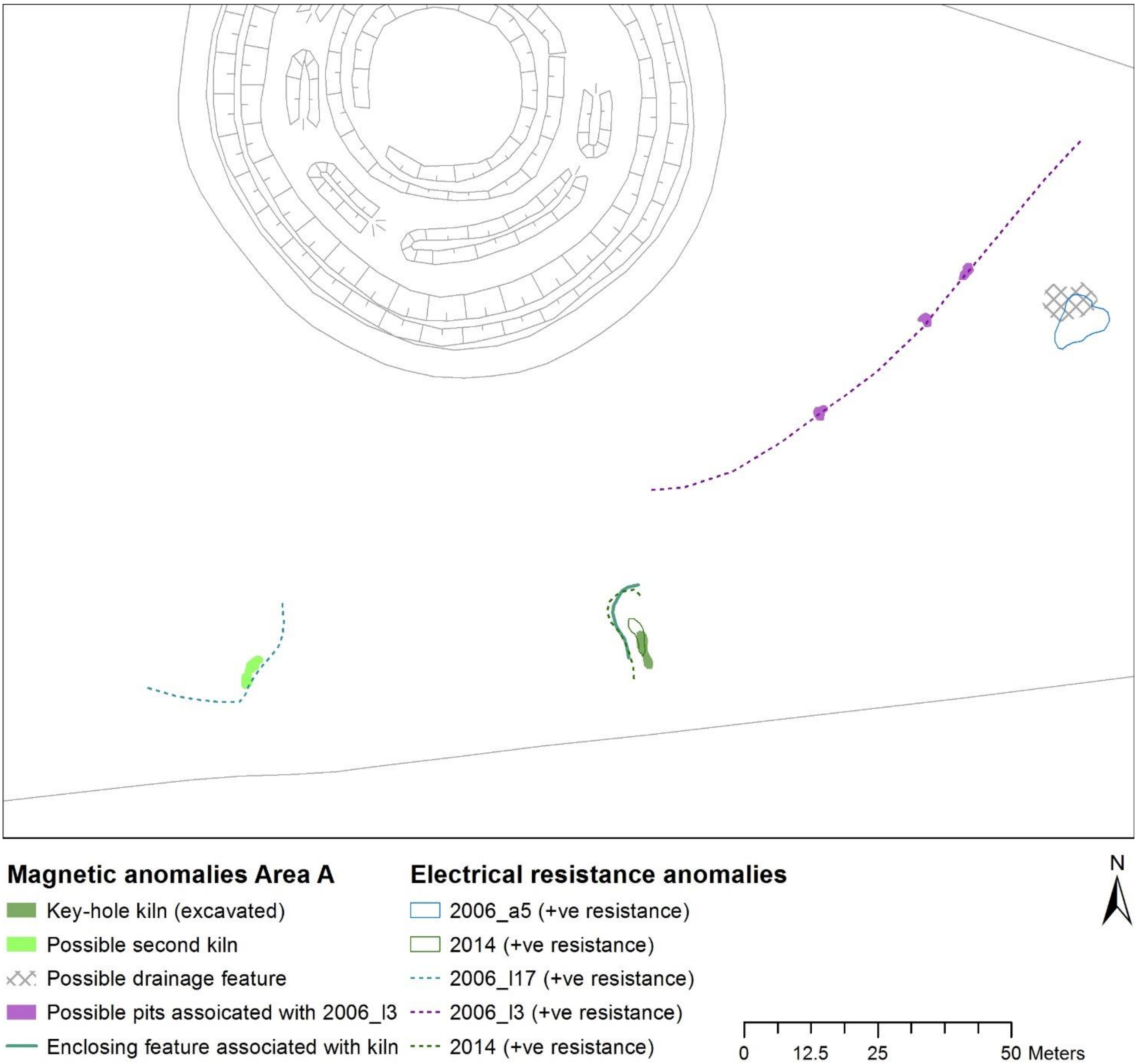

Figure 8 Interpretation diagram of Area A with key electrical resistance anomalies included.

Discussion

The magnetic gradiometery survey of the area immediately surrounding Tullaghoge fort demonstrated the usefulness of this form of geophysical survey technique even with challenging geology. The dataset it generated aided the further interpretation of information captured by previous seasons of electrical resistance survey. Georeferencing the geophysical survey grid with survey grade GPS provided the level of spatial accuracy necessary for trusted integration into GIS. It also facilitated the targeting of a potential archaeological anomaly (m8) with keyhole trenches (Sloan 2014b).

The magnetic anomaly m8 displayed the text book characteristics of a kiln. The keyhole-shaped core (*c.* 7m N-S) of high magnetic anomalies with a distinctive halo of negative readings displayed the characteristic signature of a kiln aligned north – south to take full advantage of the air flow generated by the south-facing slope. The halo of negative readings was not evident around the southern tip indicating this is where the kiln was fired. A re-evaluation of the electrical resistance data (Trick 2006) identified an oblong high resistance anomaly coterminous with m8 (Figure 9) indicating that the kiln was stone lined. Excavation confirmed that it was a stone-lined, keyhole-shaped, cereal drying kiln aligned north-south with the flue to the south drawing heat into the bowl (Sloan 2014b). It has been dated to between the end of the 8^{th}- to the end of the 10^{th}-centuries.

The higher resolution survey of Area A2 captures a subtle curvilinear feature traceable for a distance of *c.* 16m to the west of m8. It would not have been identified without the use of cluster analysis and its relationship to a high resistance linear noted in the 2006 dataset (Figure 9). The higher resistance linear feature can be traced for a distance *c.* 23m running south to north before curving round to the east. It is no wider then *c.* 1m. The anomaly is situated *c.* 2m to the west of m8 appearing to encompass the kiln and a small open area to the north, *c.* 6m in diameter. The subtle magnetic anomaly m9 traces part of this path too. The returns are very modest but they could trace structural elements associated with the kiln perhaps a break against the north-westerly wind which also served to annex a sheltered area for other agricultural activities. The association of higher resistance and magnetic returns suggests the presence of stone, perhaps as packing material, and also decomposition *in situ*. Screens, windbreaks and other enclosing elements have been found associated with kilns elsewhere on the island (Monk & Kelleher 2005, 84; McCormick *et al* 2014, 203). The 2014 trench which excavated the kiln did not extend far enough west to include m9.

Interpolation along the y-axis in the higher resolution survey of Area A2 somewhat obscures the kiln's plan but the later survey captures a series of plough marks, m10, not visible in the lower resolution data. It also supplies further information about the circular enclosure, m11a, within which m8 would appear to be set. The circular enclosure is situated just above the 90m contour mark on a south-facing drumlin rise. In the evaluation grade survey of Area A the anomaly appears to be a continuous linear feature traceable for about ¾ of its path. This would suggest a ditch *c.* 33.5m internal diameter. The anomalies landscape position on the higher slopes of a drumlin and the wider early medieval archaeological distribution of raths (Figure 2) suggest that this could be a ploughed-out rath. The presence of plough marks truncating the anomaly supports this interpretation. However the gradient of the slope would mean the interior would have been notably uneven. The 2014 excavations did not reveal evidence for buried soil horizons or a significant change in the surface gradient.

The higher resolution survey suggests the m11a is composed of a series of pits rather than a continual ditch. The anomaly could therefore relate to an earlier phase of activity such as a hengeiform structure or pit circle. An argument (McDermott 2013) has already been made that the fort itself and anomalies present in the 2008 (McHugh 2008) electrical resistance survey indicate a prehistoric, possible Iron Age, antecedent for the hill top monument. There is the possibility that m11b may be an extension of m11a. In which case it would make the enclosures more plectrum-shaped. In either scenario the cereal-drying kiln associated with m11 would be a later insertion. Phases of rath settlement activity followed by the construction of cereal-drying kilns are known from elsewhere in the county (McCormick *et al* 2014, 202).

Seventy-two meters to the west of the cereal-drying kiln associated with m8 is another interesting dipolar anomaly, m13. Displaying a similar distinctive cluster of positive values with a negative halo as m8. The anomaly m13 has an oblong less well-defined core (*c.* 7m N-S) which appears to narrow towards the centre. Plots of dipolar anomalies should not be taken as true representations of the form of sub-surface features and a number of other factors need to be considered (Aspinall 2009, 64). However the noted difference in form between m13 and the excavated kiln represented by m8 does suggest, that if this is a kiln, it may have a different form. Another cereal-drying kiln was excavated *c.* 350m west of the fort in early 2014. Only the bowl of the kiln was uncovered which the excavator interpreted as indicating a rudimentary kiln type. Charcoal and charred grains, predominately oats and barley, were recovered which were radiocarbon dated to the mid-7^{th} century (Sloan 2014a, 81).

As with m8 it, the anomaly m13, also corresponds with a high resistance, kidney-shaped feature evident in the 2006 electrical resistance survey (Figure 9). Without the additional information captured by the magnetometry survey the high resistance anomaly was interpreted as part of a linear feature, l17 which was thought to relate to the modern use of the area as an orchard (Trick 2006, 7). The presence of a possible kiln, and the relationship between it and l17, suggest that l17 may relate to enclosing activity perhaps associated with the possible kiln itself or into which the kiln was later incorporated.

Kilns were obvious fire hazards, in a society dominated by wood and thatch, and thus often situated away from the settlement core (McCormick *et al* 2014, 203). Thus, the identification of several excavated kilns, and possible kilns, near Tullaghoge fort could be argued to reinforce its domestic role during the early, and possibly later, medieval periods. It is especially exciting given the O'Hagan's boastful ploughing recounted in ODubhagain's topographical poem (O'Donovan 1862, 17) – however thus far both excavated examples have been dated to the period before the O'Hagan's forefathers came to the area so for the moment we must conclude the praise poems' claims are just coincidental bluster.

Although successful on a number of fronts the dataset did not shed further light on the late medieval inaugural landscape of Tullaghoge. There were no enclosing features evident on the east face of Ballymully drumlin in the area commonly associated with the O'Neills inauguration seat or focusing on either of the lone boulders located there. The dipolar, m6, to the west of the northernmost boulder may represent an episode of intense burning or buried metal object which could be archaeological in nature – perhaps relating to the destruction of the seat. Excavations to the east of the stone revealed nothing of archaeological significance (Sloan 2014b). A series of magnetic pits, m7, may be associated with a high resistance linear, l3 (Trick 2006), indicating a curvilinear ditch with evidence of decay *in situ*. GIS analysis of data captured by LiDAR survey identified a very subtle, negatively expressed topographical feature following the same route (McDermott 2013, 35). This reinforces the interpretation that this could be a ditch but it appears to focus on the fort rather than the boulders.

To the north of the fort there was little correlation between the geophysical anomalies identified using electrical resistance and magnetometry. A band of dipolar readings confirmed that the low resistance anomaly, r1 identified in 2008 (McHugh 2008, 18 – 9), was a buried metal water-pipe. None of the possible archaeological features (r3, r4 & r5) to the north of the fort identified in the electrical resistance were evident in the magnetometry data suggesting they are not associated with conditions that would have led to changes in the soils magnetic signature. The high resistance anomaly, r3, was targeted for excavation in the summer of 2014. The excavation trench, trench 4, revealed nothing of archaeological significance (Sloan 2014b). This should not be interpreted as evidence of absence since the older dataset was georeferenced to 'best fit' whereas the magnetometry survey was tied in using survey grade GPS. It is likely that the location for trench 4 missed the feature. A trapezoid anomaly defined by m1, and possible associated with m4 may related to modern agricultural practices. A collection of anomalies (m2, m3 & m5) to the very north of the survey area display subtle changes in their magnetic response, when coupled with the resolution at which they were surveyed it makes them difficult to interpret. Surveying a wider area beyond that covered by the current survey may further aid their interpretation.

Recommendations

It is recommended that the area previously covered by electrical resistance (Trick 2006; McHugh 2008, 2013) also be surveyed with magnetometry. As well as creating a new and valuable dataset it will aid the further interpretation of the electrical resistance data.

The circular enclosure associated with m11 is an obvious target for excavation. As is the second possible kiln site, m13.

It is recommended that the high resistance curvilinear anomaly originally targeted by trench 4 (Sloan 2014b) be reinvestigated. The electrical resistance datasets have now been incorporated in ArcGIS as digital rasters and more tightly georeferenced to spatial data contained with the LiDAR survey.

A large number of dipolar anomalies dot the site. It is suggested that a program to auger for archaeologically important samples be developed. Samples such as charcoal, grains and slag may provide a cost effective way to gather dating evidence, identify targets for further excavation and complement the excavation record. Auger targets can be located with great precision (<0.1m) using the GPS base points already established over the survey area. This would limit the potential for damage to archaeological importance deposits.

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Appendix one: Georeferenced geophysical survey grid

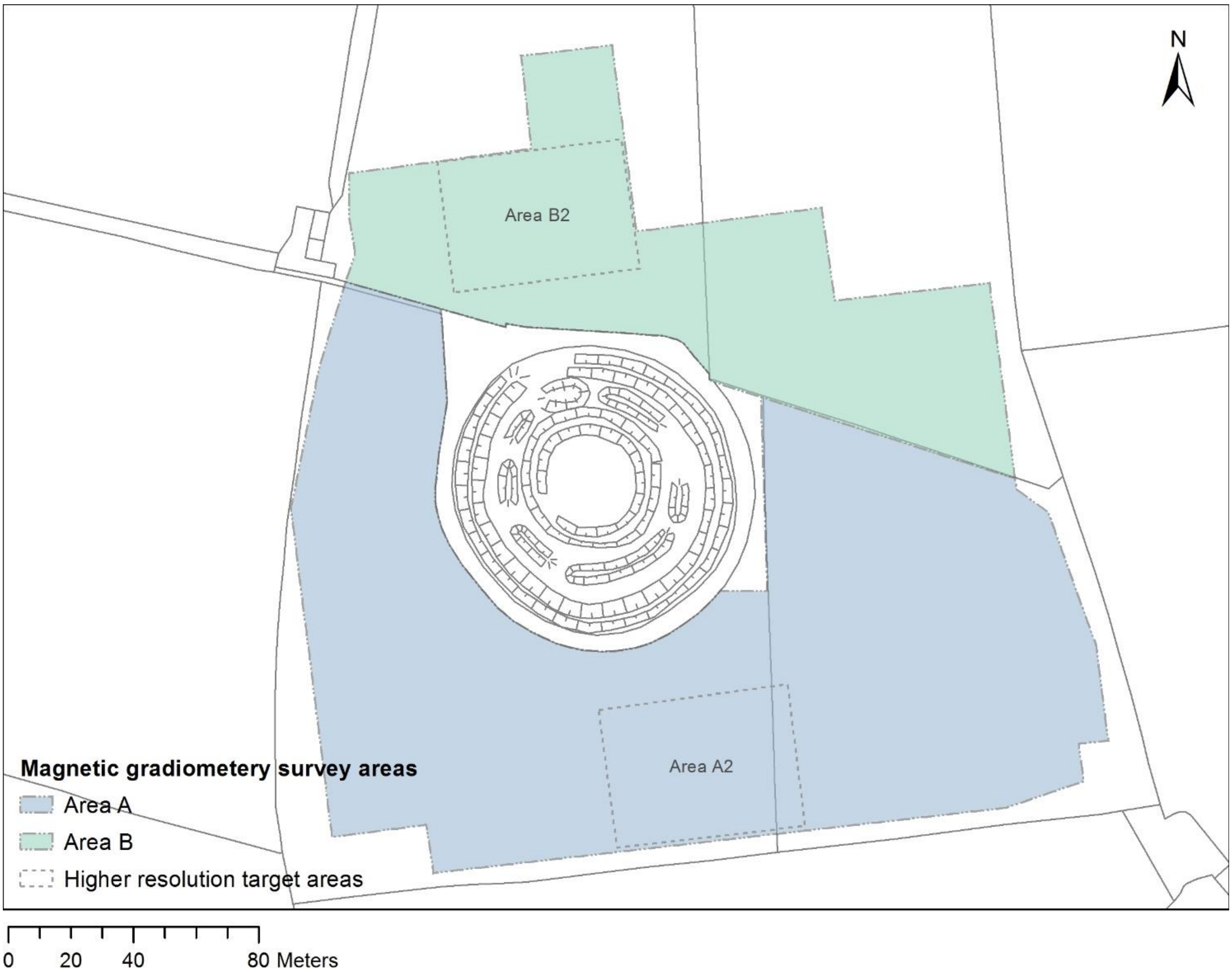

Figure 9 Magnetic gradiometery survey areas with higher resolution targets identified.

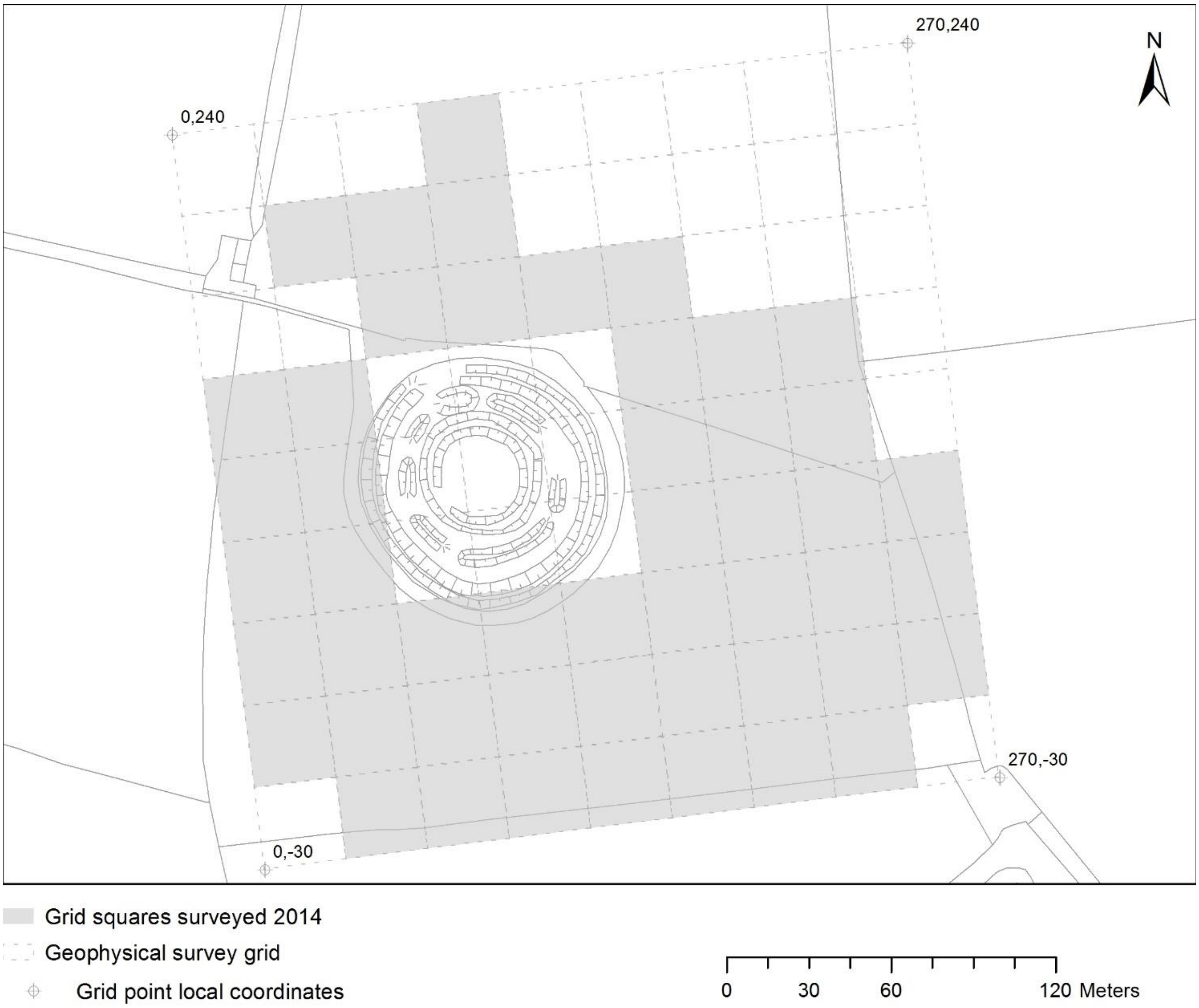

Figure 10 Geophysical survey grid with local coordinate system.

Table 2 ING coordinates for local grid points

Local grid coordiante	**ING coordiantes**
0, -30	E 282423.22, N 374161.47
0, 240	E 282389.56, N 374429.36
270, -30	E 282691.19 N 374195.07
270, 240	E 282657.53 N 374462.86

Appendix two: Raw data plots

Figure 11 Greyscale plot of Area A & Area B raw data. Clipped +/-20 nT and dipolar over metal pipe in Area A (+/-100 nT) replaced with dummy value.
Statistics:
Mean: -0.46
Std Dev.: 4.42

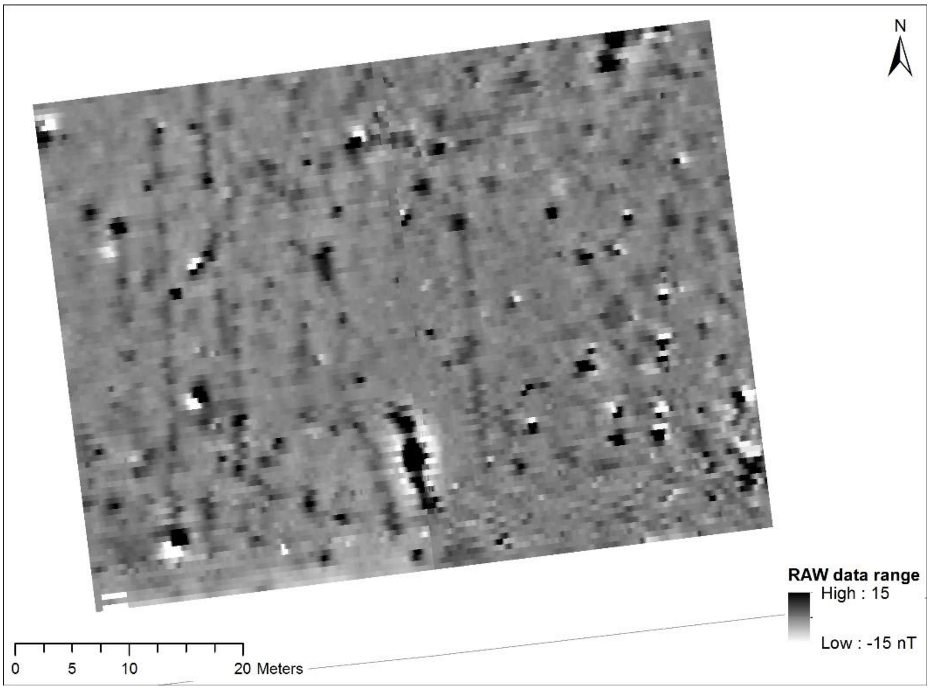

Figure 12 Greyscale plot of Area A2 higher resolution data (0.5m traverse x 0.125m sample interval) surveyed with a west to east zig-zag traverse. Raw data clipped +/- 15 nT, ZMT, destaggered.
Statistics:
Mean: -0.04
Std Dev.: 3.46

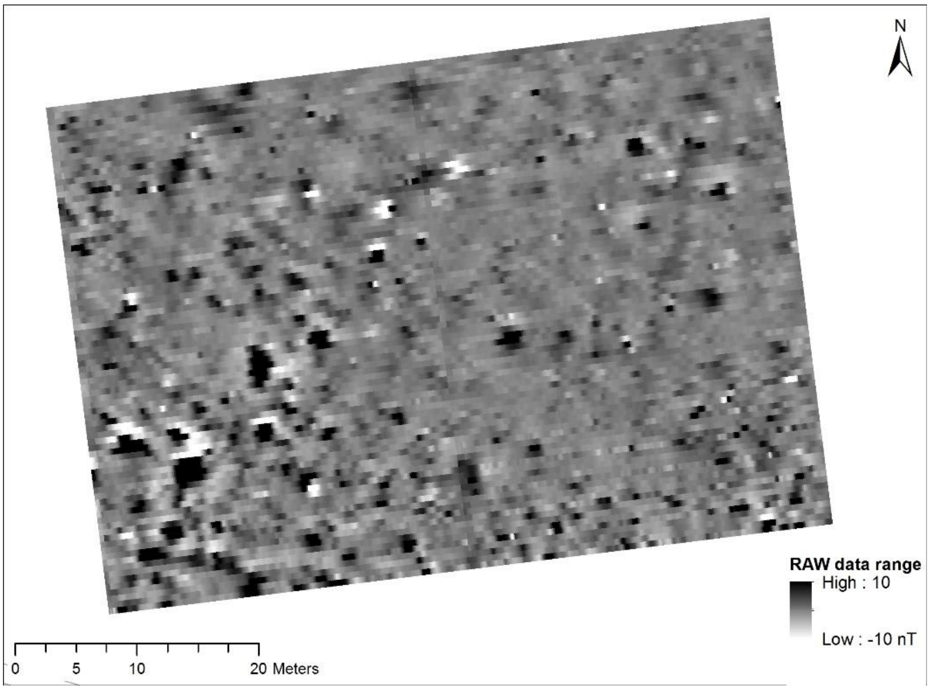

Figure 13 Greyscale plot of Area B2 higher resolution data (0.5m traverse x 0.125m sample interval) surveyed with a west to east zig-zag traverse. Raw data clipped +/- 15 nT, ZMT, destaggered.
Statistics:
Mean: 0.34
Std Dev.: 3.00

Appendix three: Processed data plots

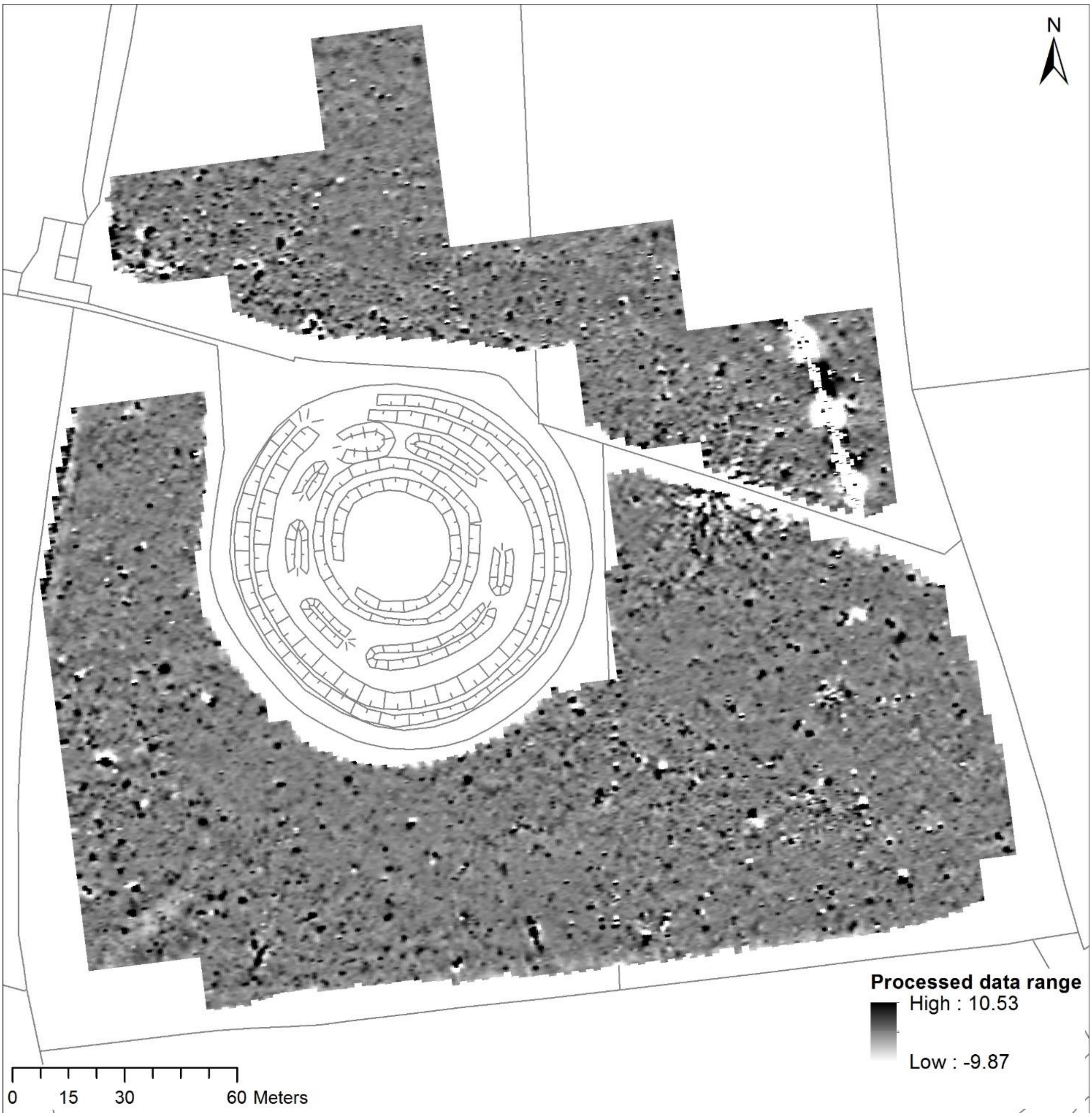

Figure 14 Greyscale plot of Area A & Area B clipped +/- 3 Std. Dev, dipolar (+/-100 nT) replaced with dummy value, ZMT, LPF Gaussian weighting applied on the y-axis, and sin(x)/x interpolation along the y-axis.
Statistics:
Mean: -0.34
Std Dev.: 3.40

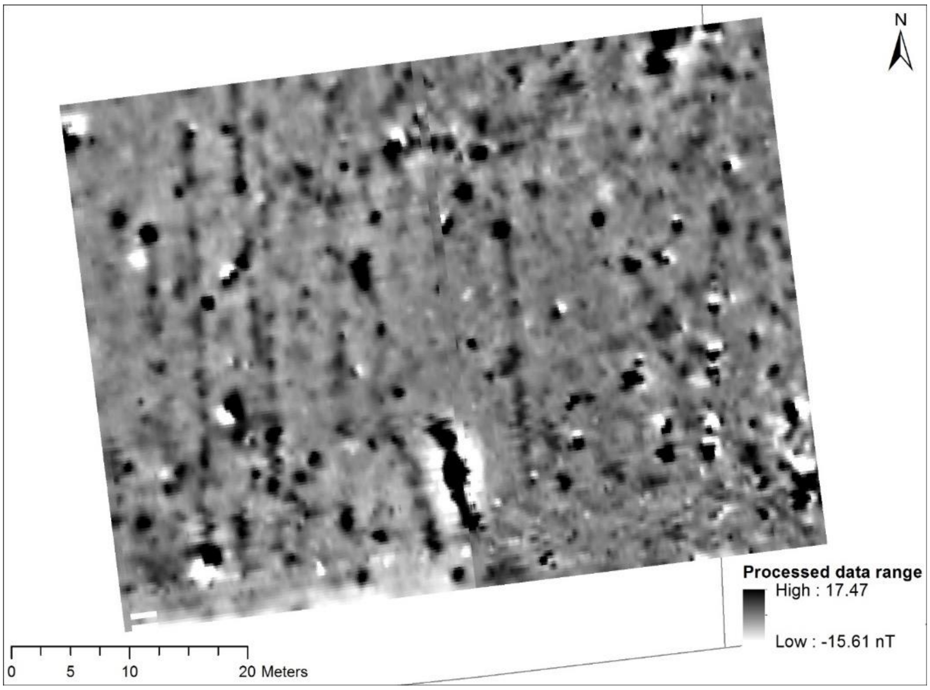

Figure 15 Greyscale plot of Area A2 higher resolution data (0.5m traverse x 0.125m sample interval) surveyed with a west to east zig-zag traverse. Raw data clipped +/- 3 Std. Dev, ZMT, destaggered, LPF Gaussian weighting applied on the y-axis, and sin(x)/x interpolation along the y-axis.
Statistics:
Mean: -0.03; Std Dev.: 3.14

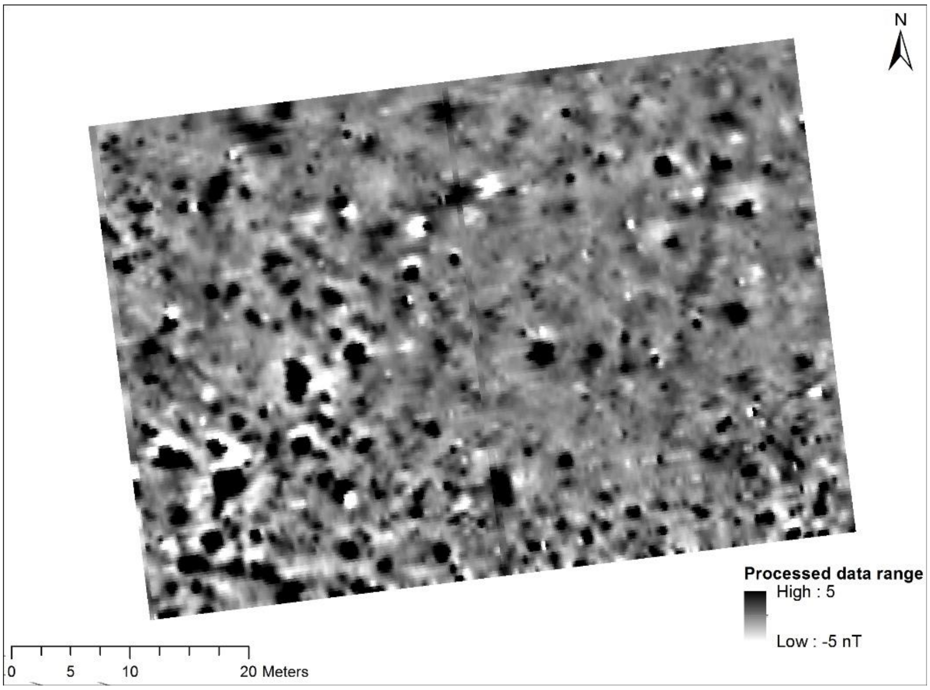

Figure 16 Greyscale plot of Area B2 higher resolution data (0.5m traverse x 0.125m sample interval) surveyed with a west to east zig-zag traverse. Raw data clipped +/- 3 Std. Dev, ZMT, destaggered, LPF Gaussian weighting applied on the y-axis, and sin(x)/x interpolation along the y-axis.
Statistics:
Mean: -0.34; Std Dev.: 2.64

Appendix four: Trace diagrams

Figure 17 Trace diagram of Area A. Data clipped (+/-15nT) and ZMT (no thresholds).

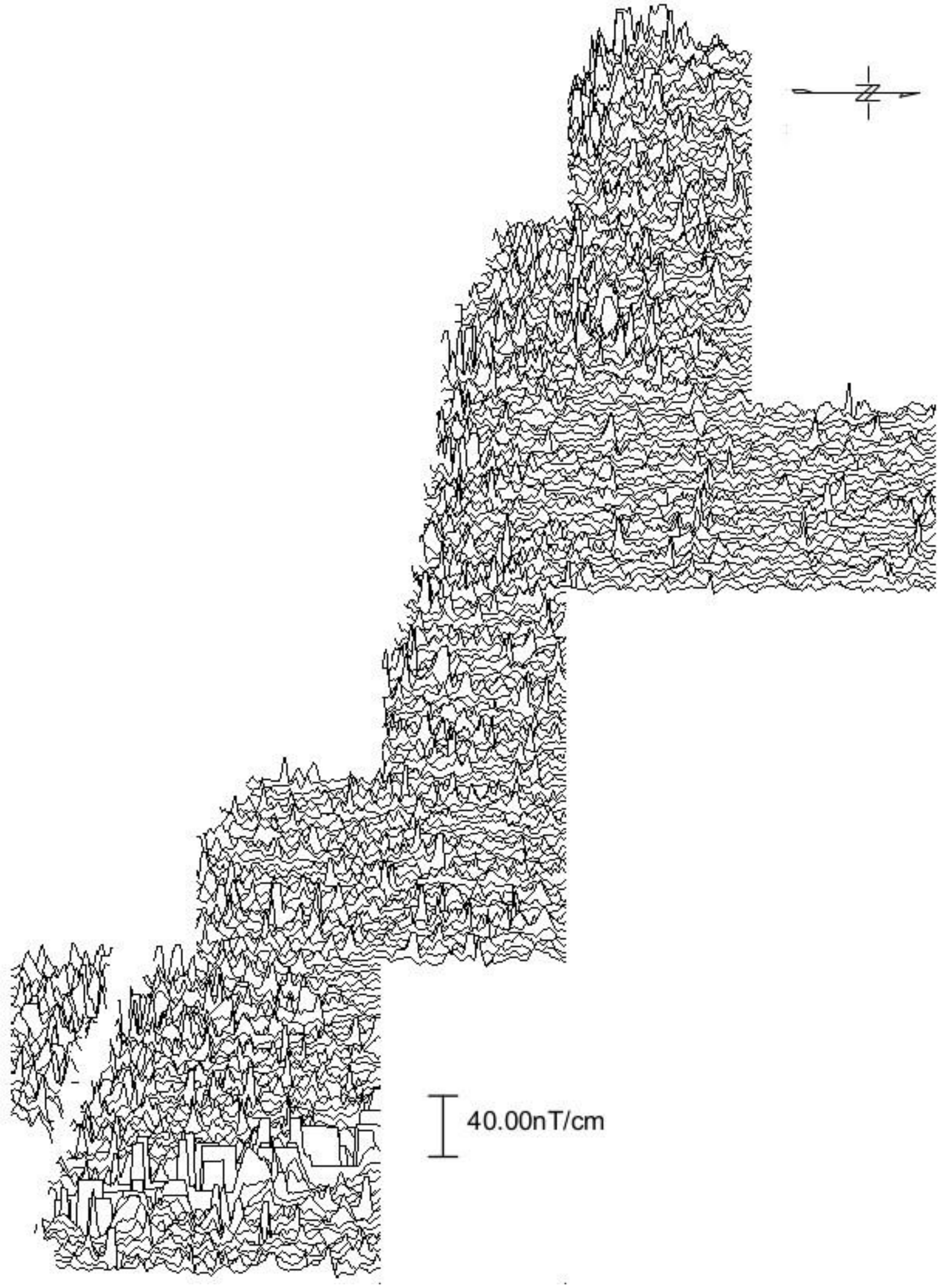

Figure 18 Trace diagram of Area B. Data clipped (+/-15nT) and ZMT (no thresholds).

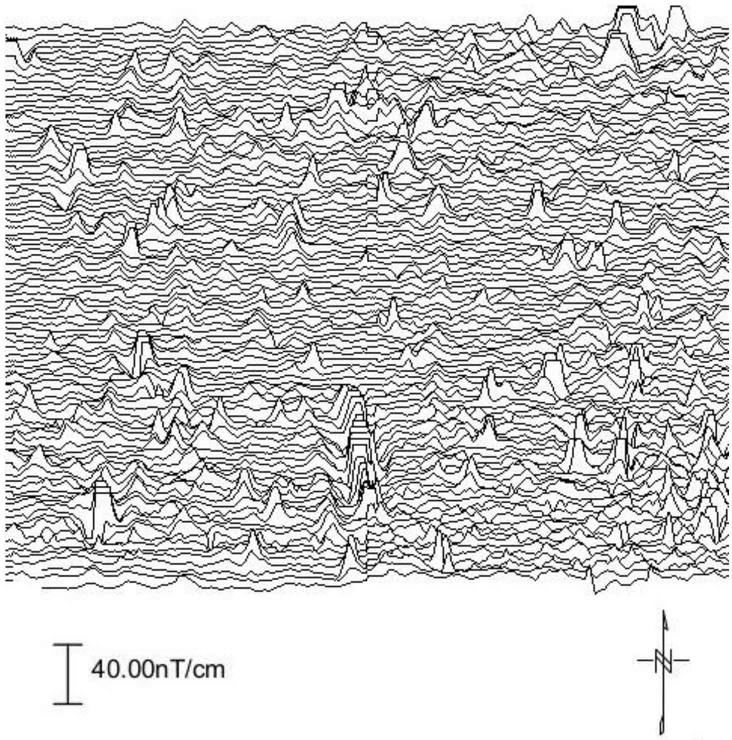

Figure 19 Trace diagram of Area A2. Data clipped (+/-15nT) and ZMT (no thresholds).

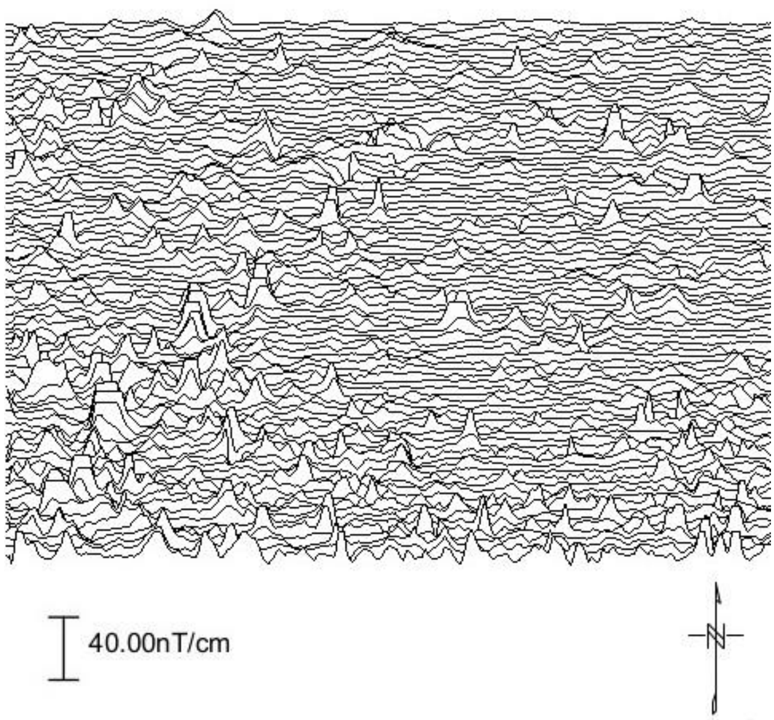

Figure 20 Trace diagram of Area B2. Data clipped (+/-15nT) and ZMT (no thresholds).

Appendix five: Supporting visualisations

Figure 21 Compilation of the 2006 (Trick) and 2008 (McHugh) electrical resistance surveys which occurred in the same survey area as the 2014 magnetic gradiometery survey.

Appendix six: Historical mapping & vertical views

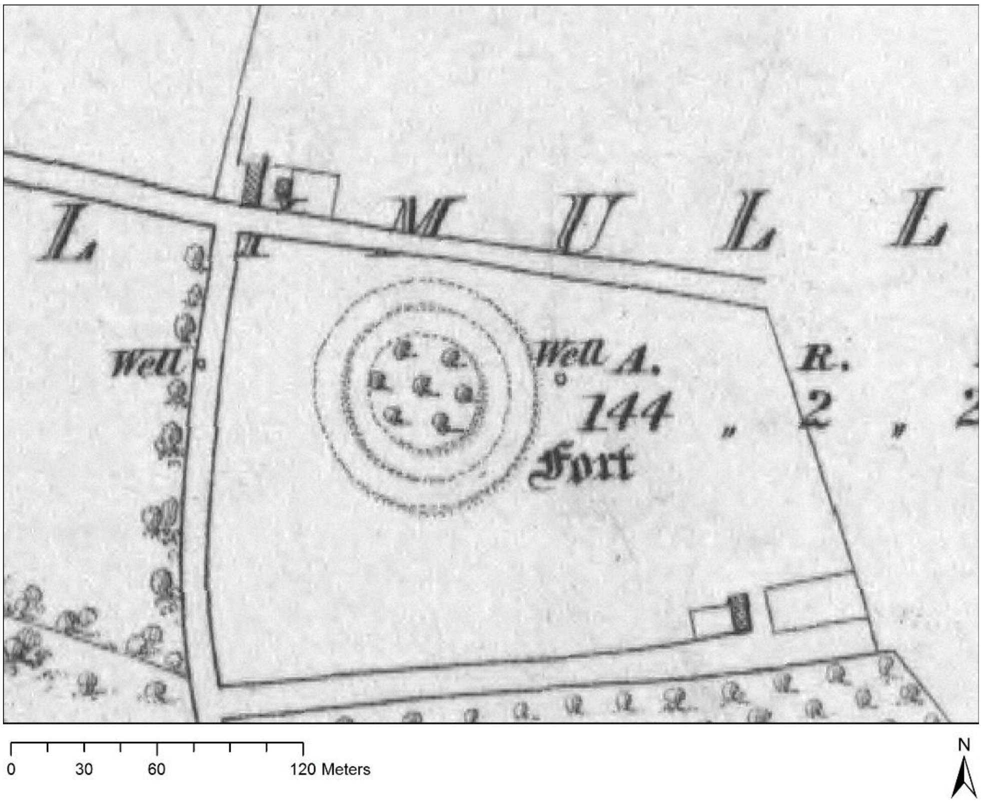

Figure 22 Area surveyed by magnetometry as depicted by the First Edition Ordnance Survey map series, *c.* 1832 – 4.

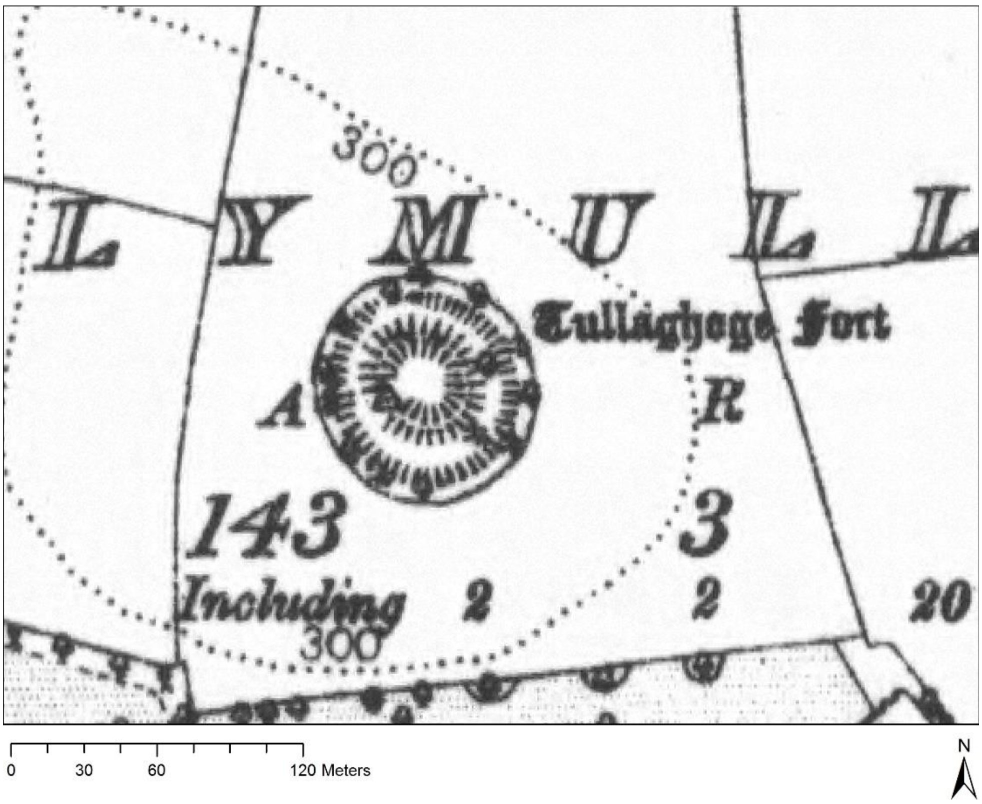

Figure 23 Area surveyed by magnetometry as depicted by the Third Edition Ordnance Survey map series, *c.* 1905-6.

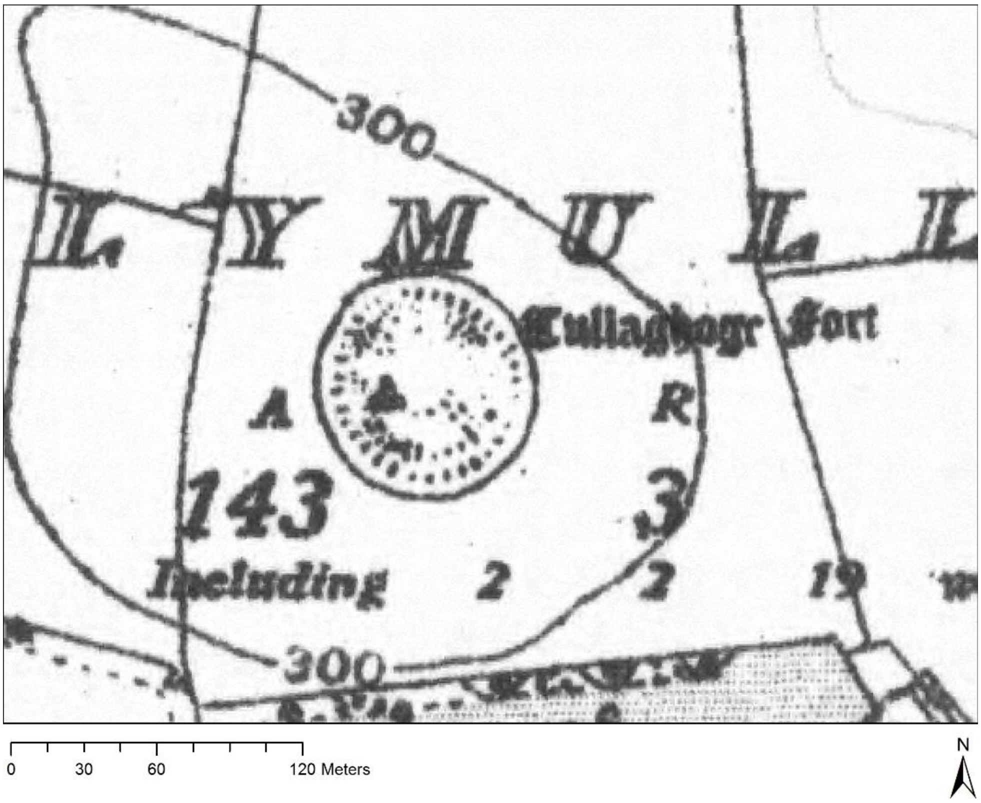

Figure 24 Area surveyed by magnetometry as depicted by the Fifth Edition Ordnance Survey map series, *c.* 1950 – 3.

Figure 25 Area surveyed by magnetometry as captured in orthorectified aerial photographs, 2006.

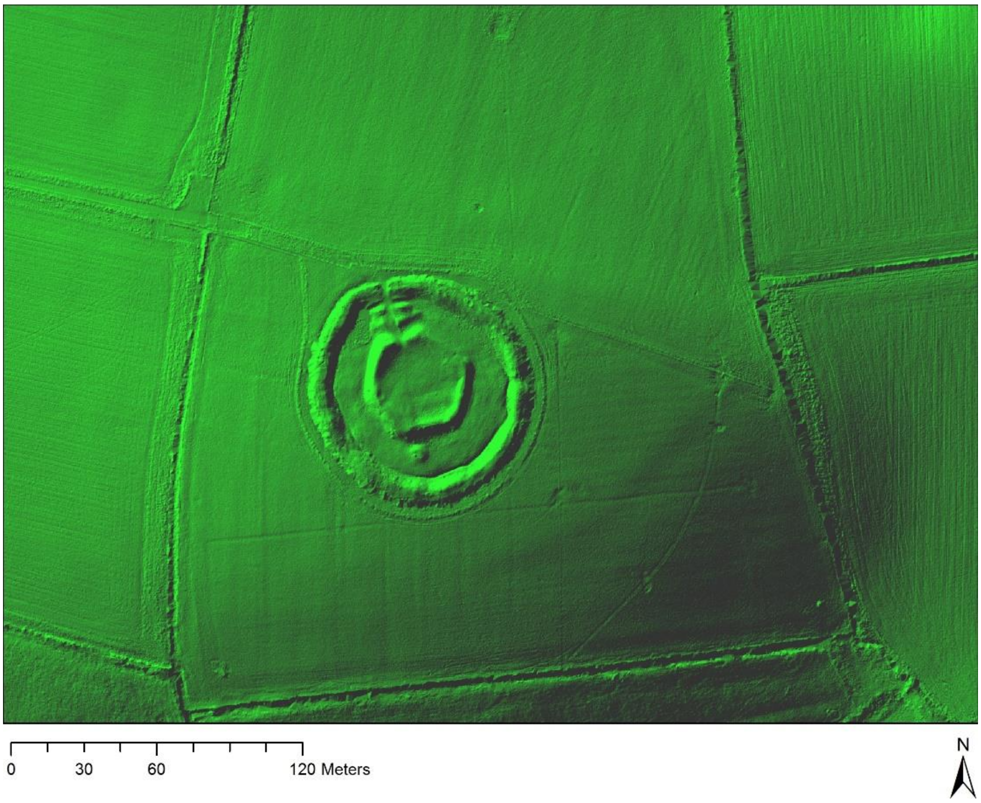

Figure 26 Area surveyed by magnetometry as captured by LiDAR survey. LiDAR data visualised using Principle Component Analysis of 16 hillshades at regularly varying azimuths and a fixed zenith, 11°, 2nd band displayed.