ARCHAEOLOGICAL SERVICES
DURHAM UNIVERSITY

on behalf of
Altogether Archaeology

NORTH PENNINES
Area of Outstanding Natural Beauty
GLOBAL GEOPARKS NETWORK

Long Meg and Her Daughters
Little Salkeld
Cumbria

geophysical and topographic surveys

report 3132
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Durham University

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1. Summary

The project

1.1 This report presents the results of geophysical and topographic surveys conducted as part of the 'Altogether Archaeology' community project at the site of Long Meg and Her Daughters stone circle and adjacent enclosure near Penrith, Cumbria. The works comprised approximately 5.8ha of earth resistance, geomagnetic and topographic surveys.

1.2 The works were commissioned by the North Pennines AONB, through Durham County Council, and supervised by Archaeological Services Durham University.

Results

1.3 The topographic survey has enabled the production of detailed contour maps and digital terrain models for the site. Many subtle features have been recorded by the survey, including the large enclosure ditch in the north which has previously only been recorded from the air. The survey highlights the fact that both the stone circle and enclosure occupy gentle slopes within the very head of the valley. Although the springs that feed the valley stream now rise just to the north of the enclosure, there may have been earlier springs within the enclosure or stone circle, which influenced the location of the monuments.

1.4 The enclosure ditch has also been detected as a low resistance anomaly in parts of each field. The ditch appears to lie to the immediate north of the stone circle, with no sub-surface relationship between the two. Some of the smaller geomagnetic and resistance anomalies within the enclosure could possibly have archaeological origins.

1.5 The topographic and resistance surveys support the possibility that the stones may have been set within a bank. Evidence for as bank survives in places where stones are not present. The bank, and the possible presence of parts of former stones, might only be confirmed by excavation.

1.6 Some of the stones do appear to have a different composition to others. Further work may determine if their locations are significant.

1.7 Within the stone circle some areas of high resistance could reflect the remains of cairns or barrows, as observed by Camden in the late 16th century.

1.8 Some of the resistance anomalies indicate that the monument may originally have been a henge, with an external bank and internal ditch. These possible features lie outside the stone circle but between the circle and Long Meg, and so, if real, there are implications for the phasing of the site. Lying between Long Meg and the stone circle it would suggest that Long Meg was a later addition to the monument, after the removal of the bank. If the remains of these features are indeed present, the monument would have parallels with similarly-sized henges with internal stone circles, such as Arbor Low and Stonehenge, for example. The possible bank and ditch and the possible cairn remains do not have any surface expression or corresponding air photograph soilmarks, however. Their presence or otherwise might only be determined through excavation.

1.9 The surveys have not detected any clear evidence for a second outlier or partner stone near Long Meg.

1.10 In the course of the surveys it has been possible to address each of the research aims, though some of the questions raised and the possible interpretations can only be tested through trial excavation.

1.11 In addition to ground-truthing some of the geophysical anomalies, further survey might shed some light on the possible existence of the cursus monument extending from the stone circle and could also examine the inferred location of Stukeley's 'lost' stone circle to the south-west of the main circle.

2. Project background

Location (Figures 1 & 2)

2.1 The survey area comprised 5.8ha of land at Long Meg and Her Daughters stone circle, and the adjacent enclosure, at Little Salkeld, Hunsonby parish, approximately 9km north-east of Penrith in Cumbria (NGR centre of circle: NY 57110 37210). Earth resistance, geomagnetic and topographic surveys were undertaken over the whole of the stone circle field (Area 1) and much of the field to the north (Area 2).

2.2 The stone circle and enclosure to the north are part of a Scheduled Monument: 'Long Meg and Her Daughters stone circle, associated cursus and prehistoric enclosure' (List Entry no. 1007866; Monument no. 23663; Cumbria HER no. 6154).

Objectives

2.3 The principal objectives of these surveys were threefold:

- to provide an opportunity for members of the North Pennines AONB 'Altogether Archaeology' project to receive survey training and to engage in local heritage research
- to determine the nature and extent of any sub-surface features of potential archaeological or historic significance through geophysical survey
- to collect sufficient high resolution topographic data to create accurate detailed contour maps and digital terrain models

2.4 Specific research aims of the surveys were:

- to resolve the question of whether burial mounds ever existed within the stone circle
- to determine if Long Meg formerly had a 'partner' outlier stone, forming a more elaborate approach to the south-west entrance
- to identify any buried stones or stone-holes on the line of the circle's perimeter
- to determine if the stones of the circle were set in a bank
- to identify any sub-surface relationship between the stone circle and the enclosure to the north
- to identify any features within the enclosure to the north

2.5 The wider aims of the Altogether Archaeology project at Long Meg are to further our understanding of the monument within the context of cross-Pennine transport and communications during the Neolithic and to contribute to a broader understanding of the Neolithic throughout the North Pennines.

2.6 The project also includes the production of a 3D photographic model of the site, using a camera mounted on an unmanned aerial vehicle (UAV). 3D models are also being made of each stone.

Methods statement

2.7 The surveys have been undertaken in accordance with a Project Design prepared by Paul Frodsham of the North Pennines AONB Partnership, methods statements provided by Archaeological Services Durham University (ref. DH12.444rev1 & DH13.19), and national standards and guidance (see para. 6.1 below).

2.8 Since the survey area included part of a Scheduled Monument, the geophysical surveys were also undertaken in accordance with a 'Section 42' licence granted by English Heritage under the Ancient Monuments and Archaeological Areas Act 1979 (as amended by the National Heritage Act 1983).

Dates

2.9 A project start-up meeting was held on 10th March 2013 in Hunsonby Village Hall. This was attended by about 50 project volunteers and followed by a site visit.

2.10 The geophysical and topographic surveys were undertaken over two visits: 18th-21st March and 14th-17th April 2013. This report was prepared for December 2013.

Volunteers examine long Meg

Personnel

2.11 Survey fieldwork in March 2013 was conducted by volunteers from the North Pennines AONB 'Altogether Archaeology' project (June Abbott, Jo Bird, Anne Bowyer, Phil Bowyer, Jen Callis, Denise Charlton, Linda Clarke, Lorraine Clay, Dot Coe, Pam Collins, Liz Cook, Nicola Cullens, Andrew Cullens, Andy Curtis, Ruth Ansell Davis, Carol Dougherty, Heather Edwards, Clare Finn, Jennie Garrod, Rachel Gibson, Tricia Gillespie, Martin Green, Jenny Gwynne, Derrick Gwynne, Michael Hall, Hils Hawkins, Harriet Lock, Freda Lodge, Gordon Marr, Marion Marr, Barbara Metcalfe, Tony Metcalfe, Alan Nash, Rob Pearson, Christine Powell, Michael Powell, Rachel Orange, Elaine Reedman, Ian Reedman, Joe Ridley, Helen Rowson, Graham Rowson, Margaret Thompson, Stephen Thompson, Dave Tuck, Ian Turnbull, Stuart White, Chris Wilkinson, Chris Wilson), Gemma Stewart and Kasia Litwa (Northumberland & Lake District National Park Community Archaeologists), and Beck Baker and Gearoid Murphy (AONB conservation trainees),

2.12 Volunteers were trained and supervised by Duncan Hale, Ashley Hayes and Richie Villis (Archaeological Services Durham University), and Pedro Alvim-Carvalho and Kate Sharpe (Durham University). Fieldwork was completed in April 2013 by Duncan Hale, Andy Platell, Nathan Thomas and Richie Villis (Archaeological Services).

2.13 Geophysical data processing and report preparation was by Duncan Hale (the Project Manager for Archaeological Services) with topographic data processing and illustrations by Janine Watson (Archaeological Services) .

2.14 The photogrammetry is being overseen by Jamie Quatermaine (Oxford Archaeology).

2.15 Overall project management and coordination is provided by Paul Frodsham, the Historic Environment Officer/Altogether Archaeology Project Officer for the North Pennines AONB Partnership. The academic director for the project is Professor Chris Scarre (Durham University).

Archive/OASIS

2.16 The site code is **AAL13**, for **A**ltogether **A**rchaeology **L**ong Meg 20**13**. The survey archive will be supplied on CD to the AONB for deposition with the project archive in due course. Archaeological Services Durham University is registered with the **O**nline **A**cces**S** to the **I**ndex of archaeological investigation**S** project (**OASIS**). The OASIS ID number for this project is **archaeol3-166464**.

Acknowledgements

2.17 The project team is grateful to the landowners Mr & Mrs Rowley of Glassonby Lodge, Glassonby, the tenants Mr & Mrs Morton of Long Meg Farm and to English Heritage for facilitating this research.

3. Historical and archaeological background

3.1 Much of the following information is taken from the Project Design prepared by Paul Frodsham and the English Heritage Scheduled Monument List Entry.

3.2 Long Meg and Her Daughters is one of northern England's most enigmatic ancient monuments. Although it was recorded in antiquarians' sketches and has been the subject of several surveys over many years, there has been no further investigation of the monument.

3.3 The huge stone circle, the third largest in England and fifth largest in the British Isles, measures approximately 110m by 93m, with a flattened arc to the north. It is not known how many stones may have been present originally, and some of the surviving stones are broken and partly buried, but recent work suggests a total of 69 surviving stones in the circle, of which 26 are still standing.

3.4 Long Meg herself stands 25m outside the circle's south-west entrance, which is framed by two outlying 'portal stones'. She stands 3.8m above the turf, is made of local red sandstone, presumed to be quarried from the nearby river cliffs, and is estimated to weigh about nine tonnes. She is in line with the setting sun at the winter solstice as seen from the centre of the circle. Long Meg displays incised spirals and concentric circles in her east face; she may have been quarried from an

already decorated river cliff, though there is currently no clear evidence for this. Other motifs have been recorded on some of the circle stones, but given the nature of the volcanic rock surface, it is not certain whether some of these are artificial or natural.

Long Meg and the circle, looking west

3.5 Within the circle, some of the extremely large stones appear to mark significant points around the circumference, for example in relation to sunrise at particular times of year. The largest stone is a huge block in the south-south-west, about 3.3m wide and weighing some 28 tons; it has been estimated that it would have taken 120 people to set it up. Two similarly sized massive boulders are located opposite each other in the circle's east and west arcs.

3.6 In some places, notably on the western side, it appears that the stones are set within a low bank. If original, this is an architectural feature that may suggest links with henge monuments elsewhere, though it may be a result of ploughing in more recent times.

3.7 The stones of the circle are understood to be rhyolite (a form of granite) and are usually assumed to have been deposited in the general area when the glaciers melted at the end of the Ice Age. There appears to be some variation in the geological structure of the boulders, for example some contain much more quartz than others. Those with large amounts of quartz appear to be in significant places within the circle.

3.8 The earliest known description of the site is provided by the antiquarian William Camden in 1586, who described Long Meg, the circle and some 'heapes of stones' within. Among other significant visitors was William Stukeley, who visited Long Meg in about 1725. In his sketches there are no signs of the stone mounds within the circle, but he does depict a second (now destroyed) stone circle to the south-west and a possible large mound to the west. He describes the 'lost' stone circle as a 'circle of lesser stones, in number twenty; … fifty five feet in diameter; and at some distance above it….another stone placed, regarding it as Meg does the larger circle'. There is a small disturbed area on the LiDAR image (Figure 5), immediately east of an existing barn, south-west of Long Meg, which could be the location for this smaller stone circle.

3.9 Stukeley also noted that the main circle was being damaged, with many stones having been carted away, broken up using gunpowder or sawn up for millstones.

3.10 The large enclosure to the immediate north of the stone circle was first recognised on aerial photographs in the 1980s; it is particularly clear on infra-red images. Although there is no visible trace of the enclosure on the ground, it can be discerned in the LiDAR survey (Figure 5). The relationship between the enclosure and the stone circle remains uncertain, but it seems very likely that the location of one has influenced the location of the other.

3.11 Other sites and features have also been recorded by air photography in the immediate vicinity. These include a possible cursus approaching the stone circle's south-west entrance from the west, though it is also possible that this is a much later feature, associated with field boundaries of post-medieval date.

4. Landuse, topography and geology

4.1 Both the stone circle field and adjacent field to the north are pasture for a dairy herd. The survey area is bisected by a single-track road.

4.2 The stone circle occupies a very gentle north-east-facing slope at the very head of a small valley that heads north-west to join the River Eden near Lacy's Caves. The ditched enclosure immediately north of the circle encloses the head of this valley. The northern field is predominantly level in the east but steepens in the west, down to the springs and the farm buildings. The topography is discussed in more detail below.

4.3 The underlying solid geology of the area comprises Early Triassic sandstone of the St Bees Sandstone Formation. Devensian till covers the sandstone to the east of the road that cuts through the site.

Survey in Area 1; Area 2 in left background

5. Topographic survey (Figures 3 & 4)

Field methods

5.1 A Leica GS15 global navigation satellite system (GNSS), with real-time kinematic (RTK) corrections (typically providing 10mm accuracy), was used to establish a 20m grid across each field, marked by bamboo canes. The grids served as guides for the topographic data collection and were also used for the geophysical surveys. The GNSS was also used to establish several survey stations across the site. All surveyed points are related to the Ordnance Survey National Grid.

5.2 Topographic data were collected using Leica TS15i R1000 total stations with 360° prisms.

5.3 Data were generally collected at approximately 2m intervals along parallel transects spaced approximately 2m apart, however, greater densities of points were recorded over any potential features observed on the ground and around the stones of the circle. Approximately 19,000 points were recorded during the survey, which covered 5.8ha. The survey comprises a more detailed topographic record than the existing LiDAR data.

Topographic survey training

Data processing

5.4 The topographic data were processed in AutoCAD software to create both contour maps and digital terrain models (DTM) of the site (Figures 3 & 4), as well as accurate plans on which other data can be presented.

Discussion

5.5 The survey highlights the fact that the two monuments both occupy gentle slopes within the very head of the valley, rather than the adjacent slightly higher ground. The south-western part of the stone circle sits just at the edge of a slight plateau to

the south-west and, similarly, the north-eastern part of the ditched enclosure reaches the edge of another slight plateau to the north-east.

5.6 The enclosure is bisected by the valley, aligned north-west/south-east, the end of which appears to lie within the eastern part of the stone circle. Although the springs that feed the valley stream now rise just to the north of the enclosure and Longmeg Farm, there may have been springs further south-east, within the area of the enclosure or stone circle, which influenced the location for and construction of the monuments.

5.7 The highest point in the study area is the south-western corner of the southern field, at 169.5m OD, and the lowest point in the survey is in the north-west at 160.5m OD, close to the springs.

5.8 The highest stones in the circle sit in the south-west at just over 169m OD, some 25m north of Long Meg. The lowest part of the stone circle is its eastern side, with a mean elevation of approximately 166m OD.

5.9 For the majority of the enclosure ditch's length, where it survives, it broadly follows a contour around the head of the valley, from the plateau in the north-east, southwards then west then north-west, typically staying at between 165-167m OD. In the north, the ditch descends a slope westwards from the higher ground at 166m OD in the north-east.

5.10 As well as recording the general topography across the site, the survey has also helped to identify many very subtle topographic features, some of which are not readily apparent by other means. When a light source is applied to the DTM from relatively low in the sky to the south-west the enclosure ditch becomes apparent in both fields. Although the ditch can also be traced in the contour plan, and to some extent in the geophysical surveys, it is more apparent in the DTM.

5.11 The survey confirms the visual impression that many of the stones are within slightly raised ground, possibly within a deliberately constructed bank, rather than standing slightly proud as a result of adjacent ploughing. On the west and north-west of the circle (between stones 10-17, for example), where the stones are further apart than elsewhere, the contour plan shows a continuous bank between the stones, not just raised ground around the stones. It appears that the stones are set within a bank, however, this could only be confirmed by excavation.

5.12 Other subtle features include two farm tracks across the northern field, which both contain some rubble. These features are clear in both the contour plan and DTM.

5.13 Former ploughing is evident throughout the survey area, particularly in the DTM, aligned broadly north-south to the west of the road and east-west to the east of the road.

5.14 A bank is clearly evident along the western side of the road through Area 1, in both the contour plan and DTM.

5.15 Two small topographic features recorded on the west side of the road probably indicate the locations of two former trees, one being immediately north of stone 55.

6. Geophysical survey (Figures 6-11)

Standards

6.1 The surveys and reporting were conducted in accordance with English Heritage guidelines, *Geophysical survey in archaeological field evaluation* (David, Linford & Linford 2008); the Institute for Archaeologists (IfA) *Standard and Guidance for archaeological geophysical survey* (2011); the IfA Technical Paper No.6, *The use of geophysical techniques in archaeological evaluations* (Gaffney, Gater & Ovenden 2002); and the Archaeology Data Service *Guide to Good Practice: Geophysical Data in Archaeology* (Schmidt & Ernenwein 2011).

Technique selection

6.2 Geophysical survey enables the relatively rapid and non-invasive identification of sub-surface features of potential archaeological significance and can involve a suite of complementary techniques such as magnetometry, earth electrical resistance, ground-penetrating radar, electromagnetic survey and topsoil magnetic susceptibility survey. Some techniques are more suitable than others in particular situations, depending on site-specific factors including the nature of likely targets; depth of likely targets; ground conditions; proximity of buildings, fences or services and the local geology and drift.

6.3 In this instance, it was anticipated that the remains of both cut and built features, such as stone-holes, banks, ditches, cairns, stones and pits, for example, might be present on the site, and that other types of feature such as hearths or wall-footings could also be present.

6.4 Given the anticipated depth of targets, the non-igneous geological environment and the possible presence of further, buried, stones, both electrical resistance and geomagnetic survey techniques were considered appropriate. Earth electrical resistance survey can be particularly useful for mapping stone features. When a small electrical current is injected through the earth it encounters resistance which can be measured. Since resistance is linked to moisture content and porosity, stone and brick features will give relatively high resistance values while soil-filled features, which typically retain more moisture, will provide relatively low resistance values.

6.5 A geomagnetic technique, fluxgate gradiometry, was also considered appropriate for detecting the types of feature mentioned above. This technique involves the use of hand-held magnetometers to detect and record anomalies in the vertical component of the Earth's magnetic field caused by variations in soil magnetic susceptibility or permanent magnetisation; such anomalies can reflect archaeological features.

Field methods

6.6 A 20m grid was established across each field and related to the Ordnance Survey National Grid using a Leica GS15 global navigation satellite system (GNSS) with real-time kinematic (RTK) corrections typically providing 10mm accuracy.

6.7 Measurements of earth electrical resistance were determined using Geoscan RM15D Advanced resistance meters and MPX15 multiplexers, with a mobile twin probe separation of 0.5m. A zig-zag traverse scheme was employed and data were logged in 20m grid units. The instrument sensitivity was 0.1ohm. In the stone circle field the sample interval was 0.5m and the traverse interval was 1m, thus providing 800

sample measurements per 20m grid unit. In the northern field the sample interval was 1m and the traverse interval was 1m, thus providing 400 sample measurements per 20m grid unit.

6.8 Measurements of vertical geomagnetic field gradient were determined using Bartington Grad601-2 dual fluxgate gradiometers. A zig-zag traverse scheme was employed and data were logged in 20m grid units. The instrument sensitivity was nominally 0.03nT, the sample interval was 0.25m and the traverse interval was 1m, thus providing 1,600 sample measurements per 20m grid unit.

6.9 Data were downloaded on site into a laptop computer for initial processing and storage and subsequently transferred to a desktop computer for processing, interpretation and archiving.

Resistance survey

Data processing

6.10 Geoplot v.3 software was used to process the geophysical data and to produce both continuous tone greyscale images and trace plots of the raw (minimally processed, unfiltered) data. The greyscale images and interpretations are presented in Figures 6-10; the trace plots are provided in Figure 11. In the greyscale images, high resistance and positive magnetic anomalies are displayed as dark grey, while low resistance and negative magnetic anomalies are displayed as light grey. Palette bars relate the greyscale intensities to anomaly values in nanoTesla/ohm as appropriate.

6.11 The following basic processing functions have been applied to the resistance data:

add	adds or subtracts a positive or negative constant value to defined blocks of data; used to reduce discontinuity at grid edges
despike	locates and suppresses spikes in data due to poor contact resistance

interpolate	increases the number of data points in a survey to match sample and traverse intervals; in this instance the data have been interpolated to 0.25m x 0.25m intervals

6.12 The following basic processing functions have been applied to the geomagnetic data:

clip	clips data to specified maximum or minimum values; to eliminate large noise spikes; also generally makes statistical calculations more realistic
zero mean traverse	sets the background mean of each traverse within a grid to zero; for removing striping effects in the traverse direction and removing grid edge discontinuities
destagger	corrects for displacement of geomagnetic anomalies caused by alternate zig-zag traverses
interpolate	increases the number of data points in a survey to match sample and traverse intervals; in this instance the data have been interpolated to 0.25m x 0.25m intervals

Interpretation: anomaly types

6.13 Colour-coded geophysical interpretations are provided. Two types of resistance anomaly have been distinguished in the data:

high resistance	regions of anomalously high resistance, which may reflect buried megaliths, cairns, tracks and other concentrations of stone or brick rubble
low resistance	regions of anomalously low resistance, which may be associated with soil-filled features such as stone-holes, pits and ditches

6.14 Three types of geomagnetic anomaly have been distinguished in the data:

positive magnetic	regions of anomalously high or positive magnetic field gradient, which may be associated with high magnetic susceptibility soil-filled structures such as pits and ditches
negative magnetic	regions of anomalously low or negative magnetic field gradient, which may correspond to features of low magnetic susceptibility such as wall footings and other concentrations of sedimentary rock or voids
dipolar magnetic	paired positive-negative magnetic anomalies, which typically reflect ferrous or fired materials (including fences and service pipes) and/or fired structures such as kilns or hearths

Interpretation: features

6.15 A colour-coded archaeological interpretation plan is provided. Anomaly numbers are provided on the plan and in the text below for ease of reference (eg **r1**, **r2**… for resistance anomalies and **m1**, **m2**… for magnetic anomalies).

6.16 The ditched enclosure to the north of the stone circle, observed on aerial photographs, has been detected as a very weak low resistance anomaly in parts of both fields (**r1**, **r2**). In Area 1 the ditch (**r1**) is evident entering the field in the north-west, heading south-east and then east. Its precise course north-east from the circle is less evident in the resistance data though it is anticipated to lie within the broad area of low resistance detected there.

6.17 The ditch has not been identified in the geomagnetic survey of Area 1. There appears to be insufficient contrast between the magnetic susceptibility of the sediments in the ditch and that of the surrounding soils. One explanation for this could be that the ditch was cut and then backfilled again very soon after, with the same material, before any other materials from cultural activity became incorporated into the ditch. This backfilling could be sufficient to enable slightly better water retention within the ditch fill compared with the undisturbed ground around it, giving rise to a low resistance anomaly, but insufficient to create a magnetic contrast since no different materials were present.

6.18 Alternatively, but less likely, the ditch may have remained open for longer, but subsequently become filled with materials with the same magnetic properties as the surrounding soil. If ditches are left open for some time, particularly near occupation areas or other activities, burnt materials, fired pottery, bones and other organic matter become incorporated into the fill and enhance the magnetic properties of the fill.

6.19 Infra-red photography appears to show a causewayed entrance through the ditch immediately north of a probable entrance to the stone circle, stones 17-19. However, this is not evident in the resistance survey; although the anomaly is weak it does appear to continue unbroken at this point. A possible narrow causeway may be present just to the east, north of stones 21-22.

6.20 In Area 2, a broad low resistance anomaly (**r2**) has been detected which corresponds to the location of the ditch recorded on aerial photographs. The anomaly here is well-defined over a length of about 50m but it is indistinct elsewhere. It measures 5-7m in width and almost certainly reflects the enclosure ditch. Again, the ditch is not generally present in the geomagnetic survey in this field, though a short, linear, positive magnetic anomaly (**m1**) in the north-west of this area does correspond to the enclosure's transcribed AP location and could reflect part of the ditch.

6.21 In the geophysical surveys the area enclosed by the ditch does not appear significantly different to the areas outside the ditch. However, some small resistance anomalies in Area 2 (**r3**) could possibly reflect small cut features or hard surfaces within the enclosure. There is no appreciable difference in the geomagnetic data, with a general lack of cut or built features detected either within or outside the enclosure. Small dipolar magnetic anomalies are present across both areas, but with no apparent variation in their concentration either within or outside the enclosure.

It is possible that some of these small anomalies could reflect small hearths or ovens but none is specifically interpreted as such.

6.22 Other anomalies detected by the surveys in Area 2 include some irregular areas of high resistance on the slightly higher ground to the north-east (**r4**) and a rectilinear high resistance anomaly in the north-west (**r5**). Since the latter is in the corner of the survey its full extent is not known, but the high resistance anomalies appear to define a rectangular area measuring approximately 35m by at least 55m.

6.23 Within the stone circle field, the geomagnetic survey has detected several very small anomalies (**m2**) which could possibly reflect cut, soil-filled features, possibly parts of gullies, however, these are very tentative.

6.24 Several of the standing stones appear to have magnetic anomalies associated with them, for example 13, 16, 33, 36-38, 41 and 67. These are distributed around the circle, with a possible concentration in the north-east. Some of the anomalies may be due to the presence of small ferrous items in the topsoil up against the stones, but others probably reflect the stones themselves. The stones in the circle are believed to be rhyolite, an igneous rock which would have a remnant magnetisation acquired when it cooled from its molten state. It is possible that some of the stones have a slightly different composition to others, as noted below, and that as a consequence some are more magnetic than others.

6.25 Hood (2004) notes some variation in the stones of the circle. He describes four of the stones as 'non-local quartz crystal stone' and suggests that these seem to have been positioned within the perimeter at places linked to potentially significant sunrises and sunsets, marking particular calendrical events. It would be useful to compare the locations of those stones with the results of the geomagnetic survey and with the geological analysis proposed as part of the current project, enabling the observations to be tested.

6.26 Much more variation has been recorded in the resistance survey, with some anomalies of more likely archaeological significance.

6.27 Large areas of relatively high resistance were recorded within the circle and to its immediate east. These areas could contain more stone, or more compacted ground, relative to other areas. One large anomaly (**r6**) in the approximate centre of the circle could possibly reflect the remains of one or more cairns or barrows, such as those described as 'heapes of stones' by William Camden on his visit in 1586. The cairns are apparently no longer evident by the time of William Stukeley's visit in *c.* 1725. The anomalies could reflect the remains of such cairns, after the majority of the stone had been cleared away.

6.28 Many other smaller high resistance anomalies (**r7**) can be discerned in the data within the circle, however, these are typically small and irregular with no clear structure that might suggest an interpretation other than possible areas of stone.

6.29 Many high resistance values (**r8**) were recorded immediately around the standing stones, some associated with the presence of the stones themselves, and others perhaps reflecting material used in the construction of a bank within which the stones may have been set. Some of the high resistance anomalies detected in some

of the spaces between the stones (for example to either side of stone 15 in the north-west of the circle and possibly between stones 11-12) could possibly reflect buried stones or parts of stones that once formed part of the circle. Only excavation may resolve the issue of the bank and possible additional stones.

6.30 Outside the stone circle but concentric to it, there are broad arcs of relatively high resistance (**r9**). These are most evident to the north and south-west of the stone circle but are also present elsewhere, typically between 10-15m from the stone circle. These anomalies are similar to the possible cairn remains inside the circle in that they probably reflect increased quantities of stone or compacted ground, and as such they could possibly reflect the remains of a bank or hard surface around the monument. Also in common with the possible cairn remains, there is no surface expression of these possible features. If they were once upstanding features they have been completely removed except for possible basal layers.

6.31 Another consideration in relation to the possible external bank interpretation is that the bank would have been between Long Meg and the stone circle. Indeed the resistance anomaly is particularly strong at the point between Long Meg and the other stones. If there was a bank there then that would suggest that Long Meg is not contemporary with the rest of the monument. Perhaps Long Meg is a later addition to the monument, after the removal of a bank.

6.32 In addition to the possible bank, there are slight arcs of low resistance between the bank and the stones. To some extent all the resistance anomalies reflect greater or lesser water content in the soil; the lower resistance in the south (**r10**) could reflect the natural soil moisture background relative to the more stony band, or it could reflect the remains of a ditch. Also, on north side of the circle there are the possible remains of two ditches. One of these (**r1**) corresponds to the aerial photographic evidence for the enclosure ditch, however, another overlapping anomaly (**r11**) could reflect a ditch around the stone circle; beyond this possible ditch is a broad band of higher resistance which could reflect external bank remains, as noted above.

6.33 One possible interpretation of these anomalies is that the monument began as a henge, comprising an external bank and internal ditch, with perhaps the stone circle and Long Meg being erected in later phases. This interpretation would draw parallels with other well-known monuments such as the similarly-sized henges and stone circles at Arbor Low in the Derbyshire Peak District and Stonehenge in Wiltshire.

6.34 A number of other geophysical anomalies reflect more recent activities and existing features. Former ploughing of both areas is evident as subtle, parallel, high and low resistance anomalies, aligned broadly north-south on the west side of the road and aligned broadly east-west to the east of the road; similar patterns of linear anomalies have been detected in the geomagnetic survey. These former plough features also have a very slight surface expression, which is evident in the topographic survey.

6.35 Other geophysical anomalies reflect farm equipment and two partly metalled farm tracks in Area 2, and one partly metalled track and a rutted farm access in Area 1. Two narrow, linear high resistance anomalies along the western side of the road correspond to two existing banks.

6.36 Intense magnetic anomalies along the edges of the surveys reflect the adjacent metal fences. Two large and intense dipolar magnetic anomalies in the southern corner of Area 1 reflect steel signs.

7. Conclusions

7.1 Geophysical and topographic surveys have been undertaken at Long Meg and Her Daughters scheduled monument near Penrith in Cumbria. The surveys were conducted with volunteers through the North Pennines AONB 'Altogether Archaeology' project.

7.2 5.8 ha were covered with each technique, comprising all of the stone circle field and much of the field to the north.

7.3 The topographic survey has enabled the production of detailed plans of the site, with data presented as both contour maps and digital terrain models. Many subtle features have been recorded by the survey, including the large enclosure ditch which has previously only been recorded from the air. The survey highlights the fact that the two monuments both occupy gentle slopes within the very head of the valley, rather than the adjacent slightly higher ground. The enclosure is bisected by the valley, aligned north-west/south-east, the end of which appears to lie within the eastern part of the stone circle. Although the springs that feed the valley stream now rise just to the north of the enclosure, there may have been springs further south-east, within the enclosure or stone circle, which influenced the location of the monuments.

7.4 The enclosure ditch has also been detected as a low resistance anomaly in parts of each field. In the resistance data there does not appear to be a causeway across the ditch near the north-western arc of the stone circle, although this is quite clear in the aerial images. No sub-surface relationship between the stone circle and the enclosure ditch has been detected; in the resistance data the ditch appears to lie immediately to the north of the stone circle. Although some of the smaller geomagnetic and resistance anomalies within the enclosure could possibly have archaeological origins, there appears to be no significant difference between the interior and exterior of the enclosure.

7.5 The topographic survey has confirmed the visual impression that many of the stones are within slightly raised ground, possibly within a deliberately constructed bank, rather than standing slightly proud as a result of adjacent ploughing. The resistance survey also supports the possibility of a relatively continuous bank, and the possible presence of parts of former stones, however, both of these issues could only be confirmed by excavation.

7.6 Some of the stones appear to be more magnetic than others. It would be useful to compare these with the results of further geological analysis and to investigate whether the locations of these stones are significant in terms of calendrical events.

7.7 Within the stone circle some areas of high resistance could reflect the remains of cairns or barrows, as observed by Camden in the late 16th century.

7.8 Some of the resistance anomalies indicate that the monument may originally have been a henge, with an external bank and internal ditch, outside the stone circle. Areas of relatively high resistance have been detected, concentric and external to the stone circle, which could possibly reflect the remains of a bank around the monument. These anomalies are 10-15m outside the stone circle, but between it and Long Meg. In addition, some low resistance anomalies inside the bank could indicate the remains of a ditch. If the high resistance anomalies do reflect the remains of a bank then it would have implications for the phasing of the site. Lying between Long Meg and the stone circle it would suggest that Long Meg was a later addition to the monument, after the removal of the bank. If the remains of these features are present, the monument would have parallels with similarly-sized henges with internal stone circles, such as Arbor Low and Stonehenge, for example.

7.9 The possible bank and ditch and the possible cairn remains do not have any surface expression or corresponding air photograph soilmarks. Their presence or otherwise might only be determined through excavation.

7.10 The surveys have not detected any clear evidence for a second outlier or partner stone near Long Meg. There are some very small, weak positive magnetic anomalies in the area where one might be expected, which can sometimes reflect soil-filled pits, however, each is probably too small to reflect a stone-hole. Similarly there is some variation in the resistance data but no clear evidence for either a stone-hole or buried stone remains.

7.11 In the course of the surveys it has been possible to address each of the research aims, though some of the questions raised and the possible interpretations could only be tested through trial excavation.

7.12 In addition to ground-truthing some of the geophysical anomalies, further survey might shed some light on the possible existence of the cursus monument extending from the stone circle and could also examine the inferred location of Stukeley's 'lost' stone circle to the south-west of the main circle.

8. Sources

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Schmidt, A, & Ernenwein, E, 2011 *Guide to Good Practice: Geophysical Data in Archaeology*. Archaeology Data Service

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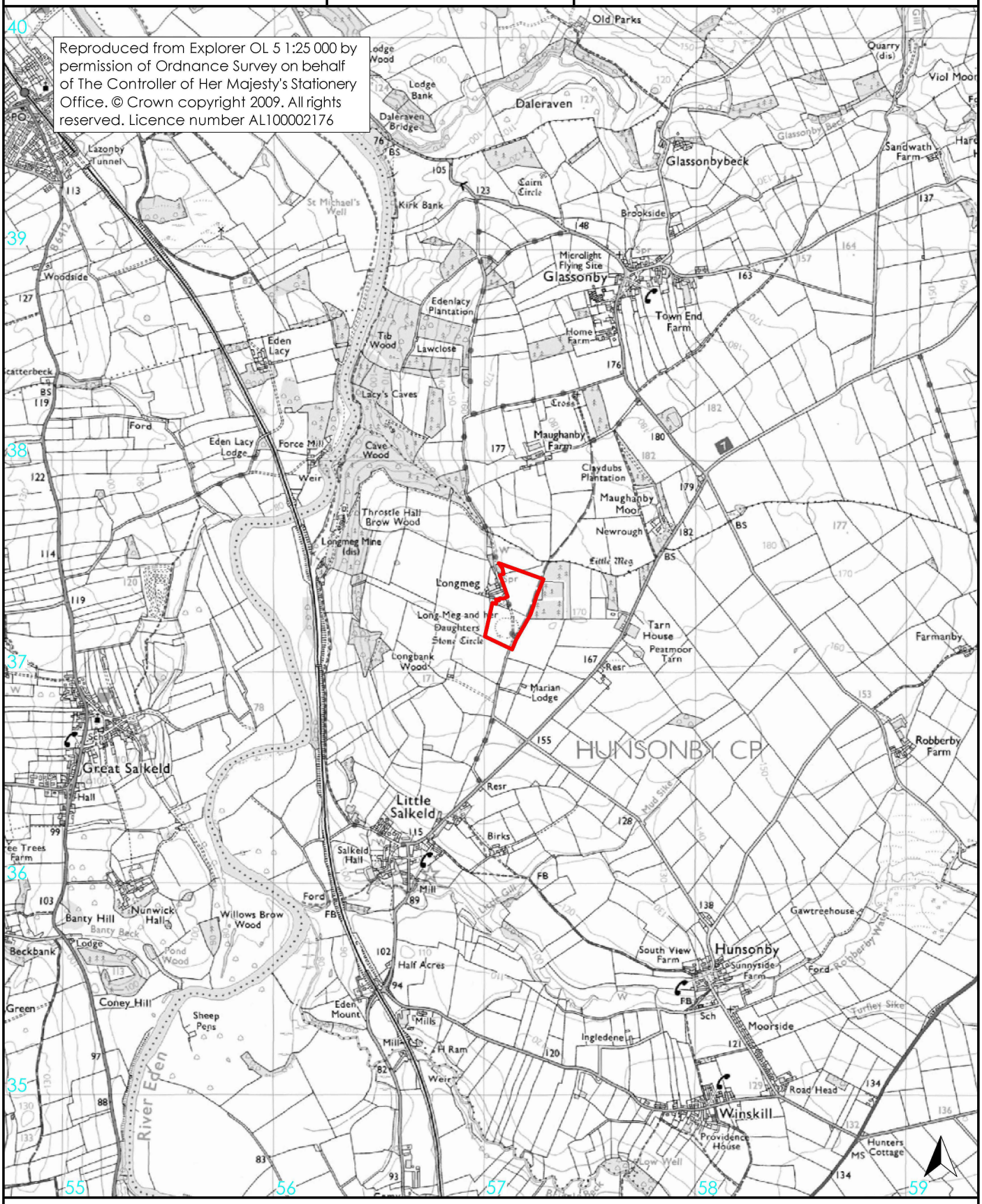
Figure 1: Site location



site boundary

0 1km
scale 1:25 000 for A4 plot

study boundary

magnetic survey

1 stones

resistance survey

375

374

373

372

570

571

572

Springs

Track

Track

Area 2

Longmeg

Area 1

Long Meg
and
Her Daughters

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0 50m
scale 1:1250 for A3 plot

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Figure 2: Survey areas

FF

Hydraulic Ram

Well

Springs

Track

Track

Area 2

Longmeg

Area 1

Long Meg
and
Her Daughters

161m
162m
163m
164m
165m
166m
167m
168m
169m

study boundary

stones

0 50m
scale 1:1000 for A2 plot

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Figure 3: Contour map

study boundary

376

375

374

373

372

371

570

571

572

FF

Hydraulic Ram

Well

Springs

Track

Track

Area 2

Longmeg

Area 1

Long Meg
and
Her Daughters

0 50m
scale 1:1000 for A2 plot

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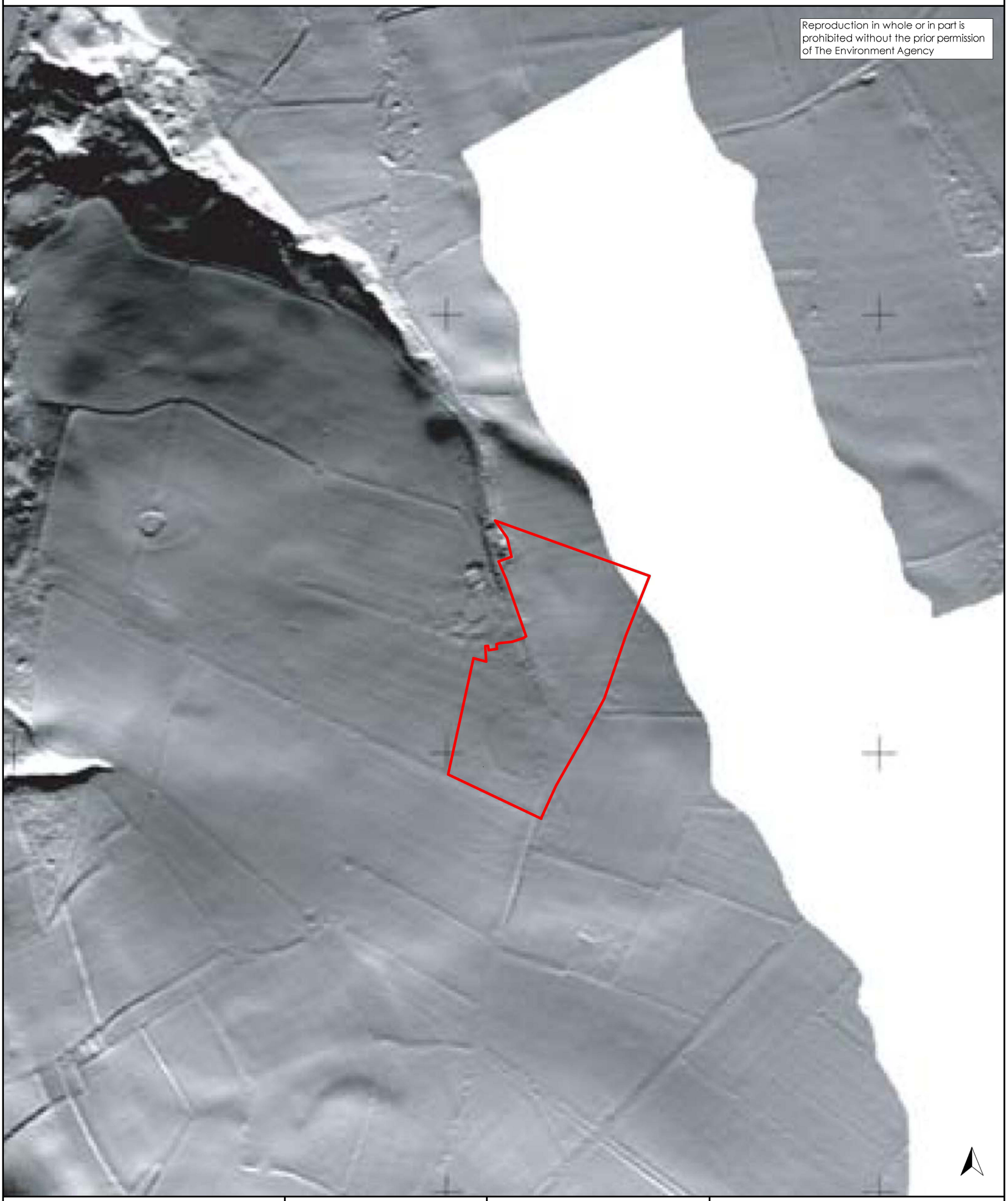
Figure 4: Digital terrain model

study boundary



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0 250m
scale 1:5000 for A3 plot

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Figure 5: LiDAR survey

study boundary

resistance survey

35 ohm 160

Area 1

20 ohm 100

Area 2

Hydraulic Ram

Well

FF

Springs

Track

Track

Longmeg

Area 2

Area 1

Long Meg
and
Her Daughters

376
375
374
373
372
371
570
571
572

0 50m

scale 1:1000 for A2 plot

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Figure 6: Resistance survey

FF

Hydraulic Ram

Well

Springs

Track

Track

Area 2

Longmeg

Area 1

Long Meg
and
Her Daughters

376
375
374
373
372
371
570
571
572

study boundary

resistance survey

stones

high resistance anomaly

low resistance anomaly

0 50m
scale 1:1000 for A2 plot

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Figure 7: Geophsyical interpretation of resistance survey

study boundary

magnetic survey

-5 nT 5

Hydraulic Ram

Well

FF

Spri

Track

Track

Area 2

Longmeg

Area 1

Long Meg
and
Her Daughters

376
375
374
373
372
371
570
571
572

0 50m
scale 1:1000 for A2 plot

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Figure 8: Geomagnetic survey

376

375

374

373

372

371

570

571

572

FF

Hydraulic Ram

Well

Springs

Track

Track

Area 2

Area 1

Longmeg

Long Meg
and
Her Daughters

study boundary

magnetic survey

stones

dipolar magnetic anomaly

positive magnetic anomaly

negative magnetic anomaly

0 50m

scale 1:1000 for A2 plot

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Figure 9: Geophysical interpretation of geomagnetic survey

376

375

374

373

372

371

570

571

572

FF

Hydraulic Ram

Well

Springs

Track

Track

farm machinery

Area 2

Area 1

Longmeg

Long Meg and Her Daughters

r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11

m1 m2

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 31a 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69

study boundary

survey area

stones

ditch transcribed from aerial photograph

soil-filled feature

possible stone / bank

former ploughing

track

bank

tree

metal sign

0 50m

scale 1:1000 for A2 plot

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Figure 10: Archaeological interpretation

Area 1 - Resistance survey

186.10ohm/cm

Area 2 - Resistance survey

111.70ohm/cm

Area 1 - Magnetic survey

28.00nT/cm

Area 2 - Magnetic survey

28.00nT/cm

0 1m

scale 1:20 for A2 plot

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Figure 11: Trace plots of geophysical data