RESEARCH DEPARTMENT REPORT SERIES no. 94-2011 ISSN 1749-8775

ARBOR LOW STONE CIRCLE, DERBYSHIRE
REPORT ON GEOPHYSICAL SURVEY, MAY 2011

Neil Linford

ARCHAEOLOGICAL SCIENCE

ENGLISH HERITAGE

Research Department Report Series 94-2011

ARBOR LOW STONE CIRCLE, DERBYSHIRE REPORT ON GEOPHYSICAL SURVEY, MAY 2011

Neil Linford

NGR SK 160 635

ISSN 1749-8775

SUMMARY

A Ground Penetrating Radar (GPR) survey was conducted over the location of a hole, measuring approximately 0.5m x 0.5m, that has opened up to the north-west of the Arbor Low henge, Derbyshire (SK 1602 6350, Monument number 11503). The full depth of the collapse is not clear and it was hoped that a GPR survey might resolve this issue and inform a suitable programme of mitigation to ensure the hole does not pose any continued hazard to visitors to the site. The GPR survey successfully imaged the immediate area of the collapse and suggests the hole may be related to a linear anomaly leading from the north-western causeway of the henge partially recorded by a previous magnetic survey.

CONTRIBUTORS

The field work was conducted by Neil Linford.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to Sarah Newsome who kindly provided preliminary copies of her own measured survey of the site used to produce the figures in this report.

ARCHIVE LOCATION

Fort Cumberland.

DATE OF FIELDWORK AND REPORT

The fieldwork was conducted on the 16th May 2011 and the report was completed on 8th December 2011. The cover photograph shows a view of the collapse at the time of the survey looking towards the north-west entrance to the henge.

CONTACT DETAILS

Dr Neil Linford, Geophysics Team, English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD.
Tel: 02392 856761. Email: neil.linford@english-heritage.org.uk

CONTENTS

INTRODUCTION

A Ground Penetrating Radar (GPR) survey was conducted over the location of a hole that appeared at Arbor Low henge, Derbyshire (SK 1602 6350, Monument number 11503). Arbor Low is a Neolithic henge comprising an external bank and internal ditch surrounding a central area with stone settings. The hole, measuring approximately 0.5m x 0.5m, that opened up is situated just outside the north-west causeway of the monument. The nature of, and reason for, the collapse is currently not clear although a natural cause due to a small solution hollow or sink hole in the underlying limestone could be one possible explanation.

The aim of the GPR survey was to further investigate the area immediately surrounding the hole in an attempt to establish the full extent of the voiding and anticipate any further collapse. Hopefully, this will inform a suitable programme of mitigation to ensure the hole does not pose any continued hazard for visitors to the site. Two previous geophysical surveys have been conducted over the site, using magnetic and earth resistance techniques, but only partially covered the area of the collapse that lies just outside the scheduled monument (Martin 2001).

The site lies on well drained silty soils of the Malham 2 association (Soil Survey of England and Wales 1983) developed over Monsal Dale Limestone (Geological Survey of Great Britain (England and Wales) 1978). At the time of the survey the field was under grass used for pasture. The weather was overcast at the time of the survey with some light rain.

METHOD

A 10m x 10m survey grid (Figure 1) was centred over the collapse using a Trimble kinematic differential global positioning system (GPS). Individual GPR traces were then collected at 0.05m intervals along parallel profiles separated by 0.5m using a Sensors and Software Pulse Ekko PE1000 console with a 450MHz centre frequency antenna recording reflections through a 70ns window (Figure 2).

Post acquisition processing involved the adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Representative profiles from the GPR survey are shown on Figure 3. An average sub-surface velocity of 0.065m/ns was assumed following constant velocity tests on the data, and was used for both the migration velocity field and the time to estimated depth conversion. In addition, owing to antenna coupling between the GPR transmitter and the ground to an approximate depth of $^{\lambda}/_{2}$, very near-surface reflection events should only be detectable below a depth of 0.072m if a centre frequency of 450MHz and a velocity of 0.065m/ns are assumed. However, the broad bandwidth of an impulse GPR signal results in a range of frequencies to either side of the centre frequency which, in practice, will record significant near-surface reflections closer to the ground surface. Such reflections are often emphasised by presenting the data as amplitude time slices. In this case, the time slices were created from the entire data set, after applying a 2D-migration algorithm, by averaging data within successive 2ns (two-way travel time) windows (Linford 2004). Each resulting time slice, illustrated as a greyscale image in Figures 4 and 5 represents the variation of reflection strength through successive 0.065m intervals from the ground surface. Figure 8 shows a subsurface relief model generated from the GPR data (*cf* Linford *et al.* 2009).

RESULTS

A graphical summary of significant GPR anomalies discussed in the following text is shown superimposed over the measured survey of the monument and a greyscale image of the previous magnetic and earth resistance data sets (Figures 6 and 7 respectively).

Significant anomalies

The response to the collapse itself appears mainly as a low amplitude anomaly [gpr1] resolved from between 10 and 42ns (0.33m to 1.37m) and demonstrates a complex response due, in part, to internal reflections within the open hole and the loss of ground coupling as the antenna passed over the void at the surface. Determining the likely maximum depth extent of the hole is confused by the nature of the response, although an apparent discontinuity in the horizontal reflector at 25ns (e.g. Figure 3; Line 10 marked by red arrows) may well be significant. Given that the reflection from the current floor of the open hole will initially have passed through the air-filled void at a much higher velocity than in the soil (a two-way travel time of approximately 5ns at a velocity of ~0.3m/ns plus 20ns at a velocity of ~0.065m/ns), the estimated depth of [gpr1] could extend up to 1.4m from the current surface. However, it is not possible to determine from the GPR data alone whether this is the maximum likely extent of the hole or whether deposits of material choke an even deeper feature.

The anomaly due to the hole at [gpr1] appears to lie over a distinct SE-NW boundary between areas of generally high [gpr2-7] and low amplitude response [gpr8]. This boundary becomes visible from 12ns (0.39m) onwards with the majority of the discrete high amplitude anomalies [gpr2-6] between 16 and 38ns (0.52 to 1.24m), although [gpr7] appears as a later reflection to the E of the boundary from 36ns (1.17m). Comparison with the previous geophysical survey data shows a strong correlation between the linear boundary marked by [gpr2-6] and an underlying positive magnetic anomaly (Figure 6). The wider area covered by the previous magnetic data suggests some additional, weaker linear anomalies are found immediately to the south-west and it is possible that these reflect striations within the underlying limestone. Unfortunately, the existing earth resistance coverage (Figure 7) does not extend far enough to allow a comparison with either the GPR or previous magnetic survey in the immediate vicinity of the collapse.

CONCLUSION

The GPR survey has successfully located the position of the collapse over a sub-surface linear boundary that correlates with a similar anomaly identified from the previous magnetic data. It is possible that this represents a striation in the underlying limestone geology and that the collapse indicates some instability at the edge of this boundary, or a sink-hole type feature that has developed on this slightly raised ridge (Figure 8). Martin (2001) postulated that the linear magnetic anomaly may be due to a track-way running towards the north-west causeway and this interpretation could well prove equally plausible with the collapse occurring on a ridge of bedding material laid underneath the track. The GPR anomaly associated with the collapse itself is complex, although it appears to be relatively discrete suggesting further lateral voiding is unlikely. The depth extent of the hole is more difficult to ascertain and may well continue to at least 1.37m, perhaps even further if the recorded reflections represent material choking the head of a more extensive sink-hole type feature. Some limited invasive intervention is recommended to confirm the proposed interpretation and inform the mitigation of the health and safety risk posed by the collapse through back-filling.

LIST OF ENCLOSED FIGURES

REFERENCES

Geological Survey of Great Britain (England and Wales) 1978 Buxton, England and Wales, Sheet 111, Drift Geology, 1:50,000 series, Ordnance Survey, Chessington, Surrey.

Linford, N 2004 'From Hypocaust to Hyperbola: Ground Penetrating Radar surveys over mainly Roman remains in the U.K.'. *Archaeological Prospection*, 11 (4), 237-246.

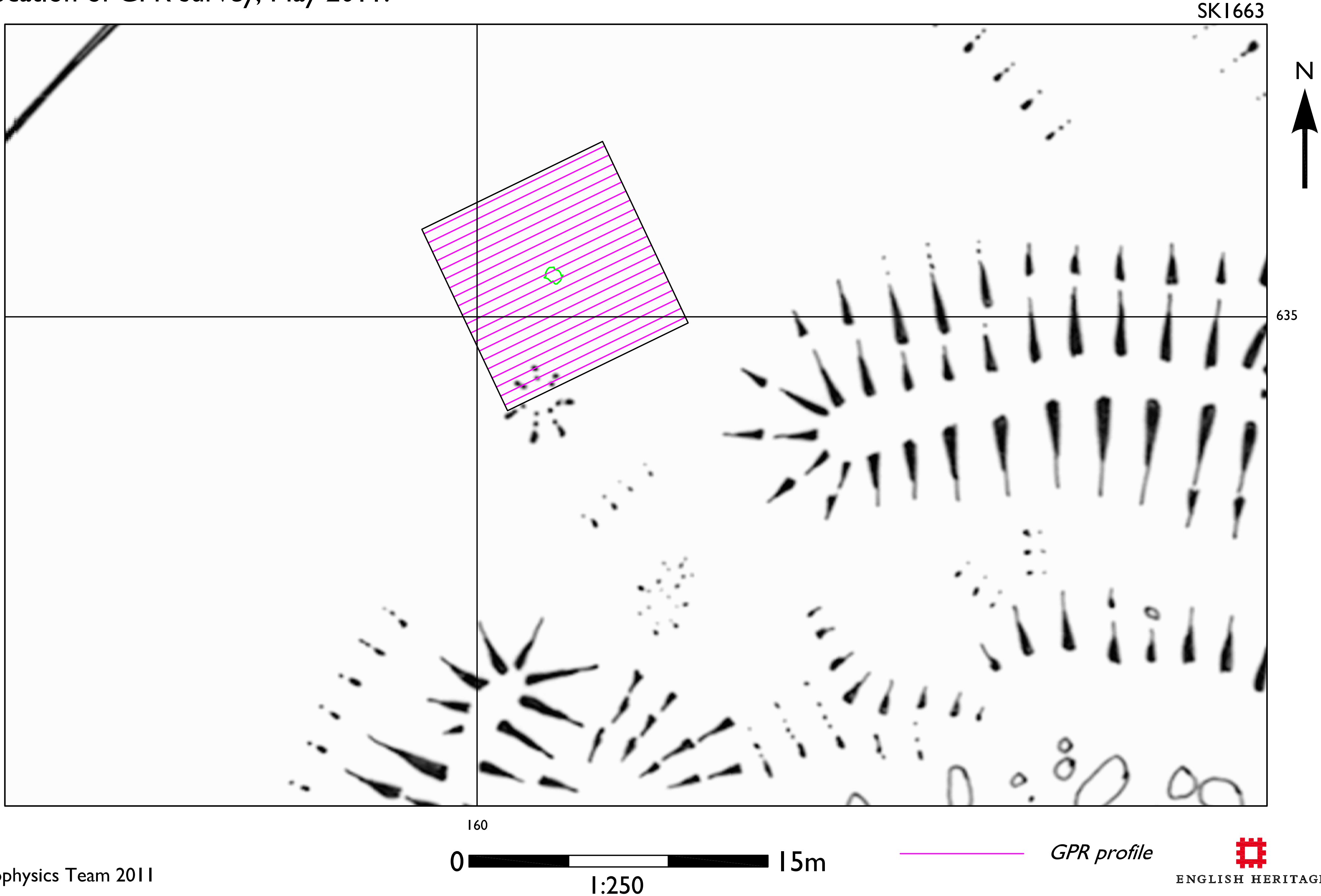
Linford, N, Martin, L and Holmes, J 2009 *'Grimes Graves, Norfolk, Report on Geophysical Survey, October 2007'*. English Heritage Research Department Reports 64/2009.

Martin, L 2001 *'Arbor Low, Derbyshire, Report on geophysical survey, August 1998.'*. English Heritage Centre for Archaeology report series 80/2001.

Soil Survey of England and Wales 1983 Soils of England and Wales: Sheet 3, Midland and Western England, 1:250,000 soil map. Harpenden, Lawes Agricultural Trust.

ARBOR LOW STONE CIRCLE, DERBYSHIRE
Location of GPR survey, May 2011.

Figure 1

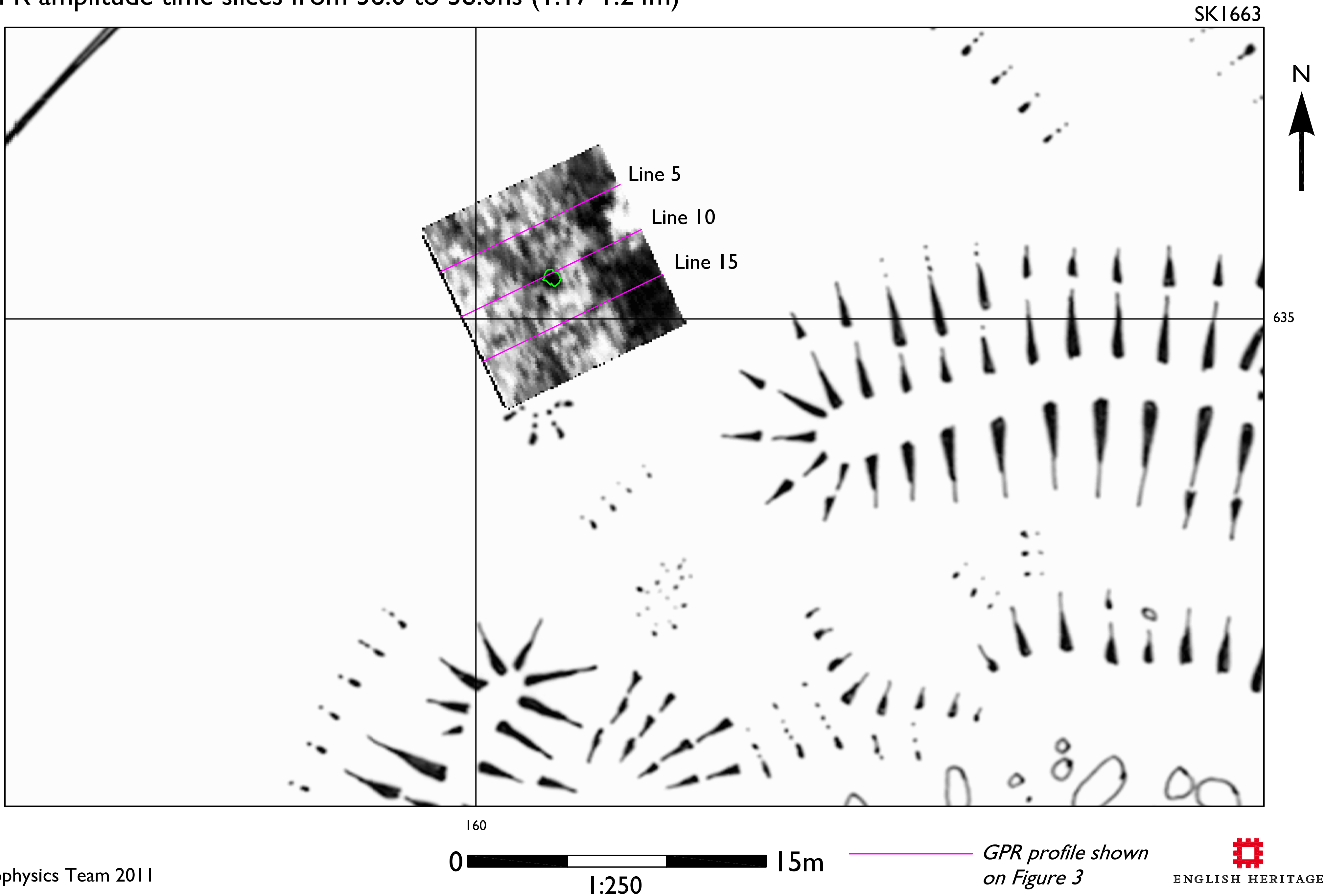


Geophysics Team 2011

ENGLISH HERITAGE

ARBOR LOW STONE CIRCLE, DERBYSHIRE
GPR amplitude time slices from 36.0 to 38.0ns (1.17-1.24m)

Figure 2

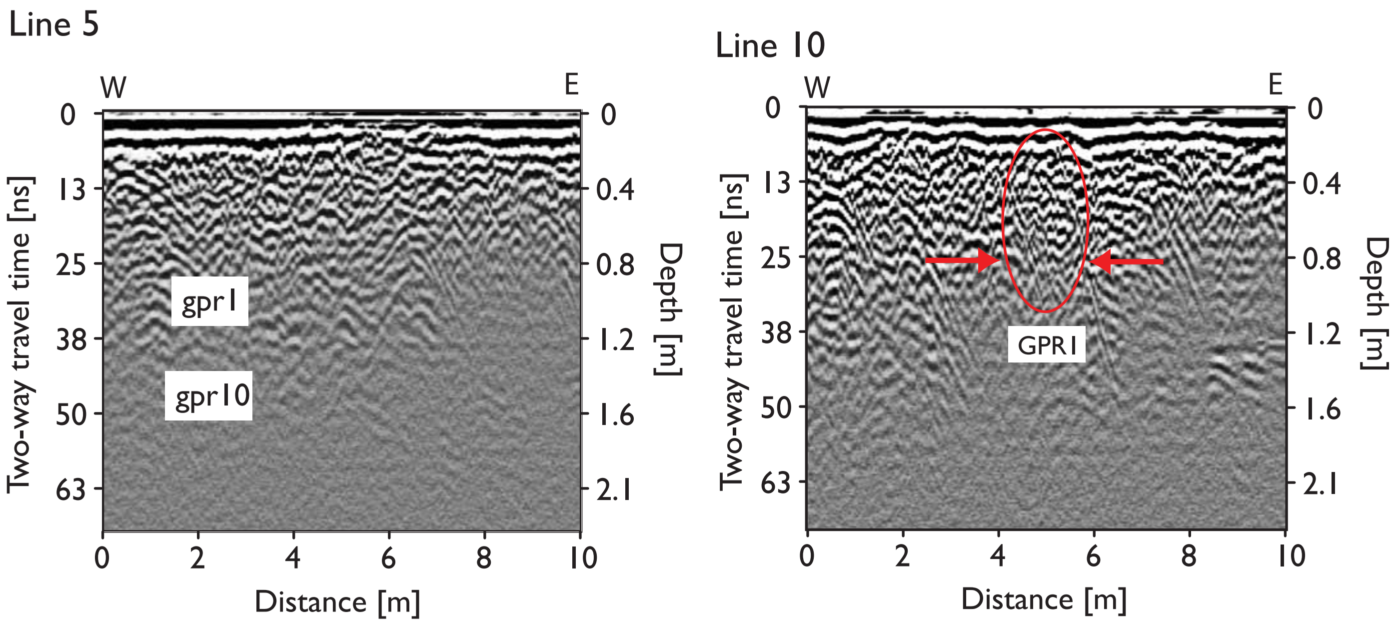


Geophysics Team 2011

ENGLISH HERITAGE

ARBOR LOW STONE CIRCLE, DERBYSHIRE.
Selected GPR profiles

Figure 3

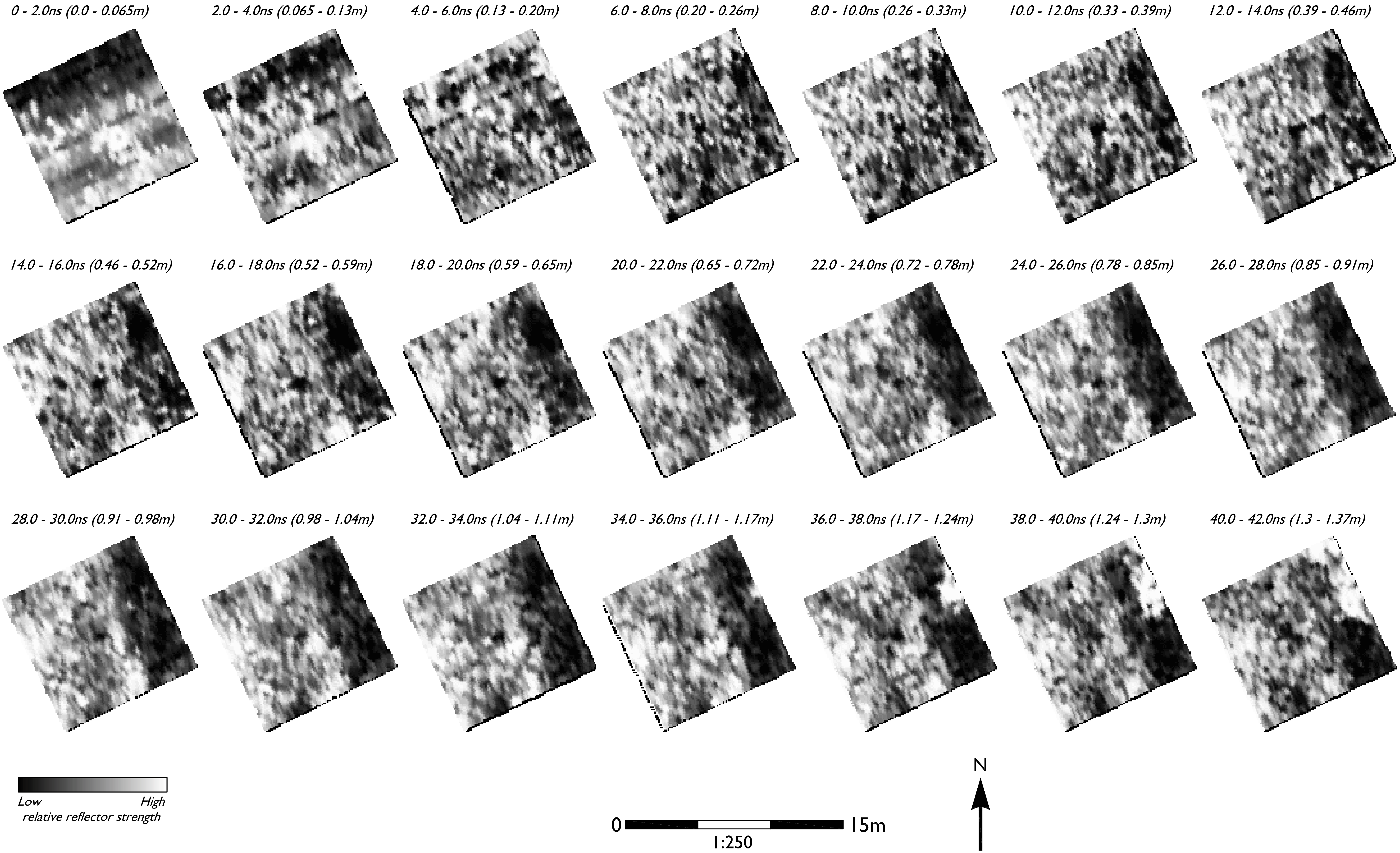


Geophysics Team 2011

ENGLISH HERITAGE

ARBOR LOW STONE CIRCLE, DERBYSHIRE
GPR amplitude time slices from 0.0 to 42.0ns, May 2011.

Figure 4



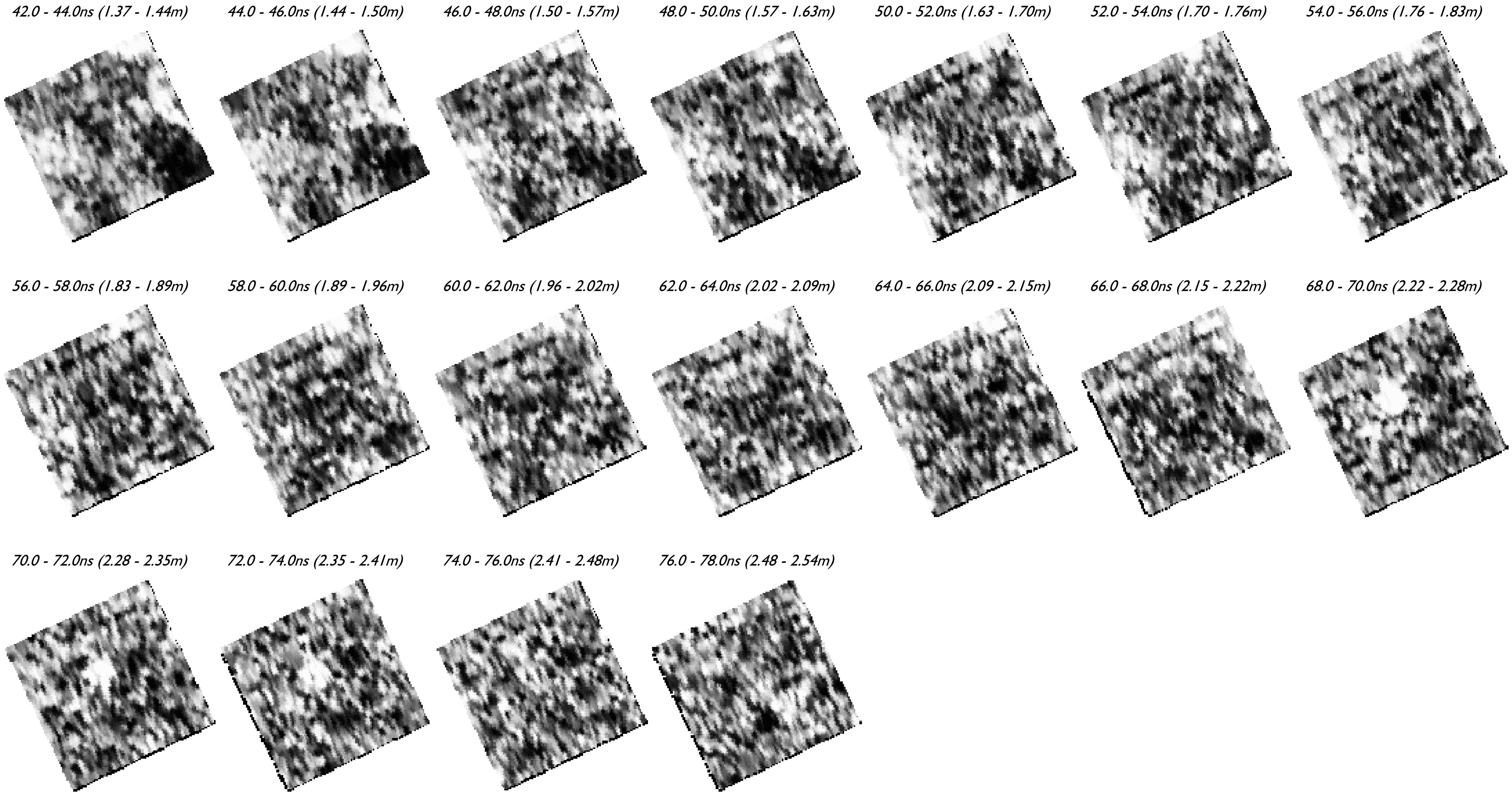
Geophysics Team 2011

ENGLISH HERITAGE

ARBOR LOW STONE CIRCLE, DERBYSHIRE

GPR amplitude time slices from 42.0 to 78.0ns, May 2011.

Figure 5



Low *High*
relative reflector strength

0 15m
1:250

N

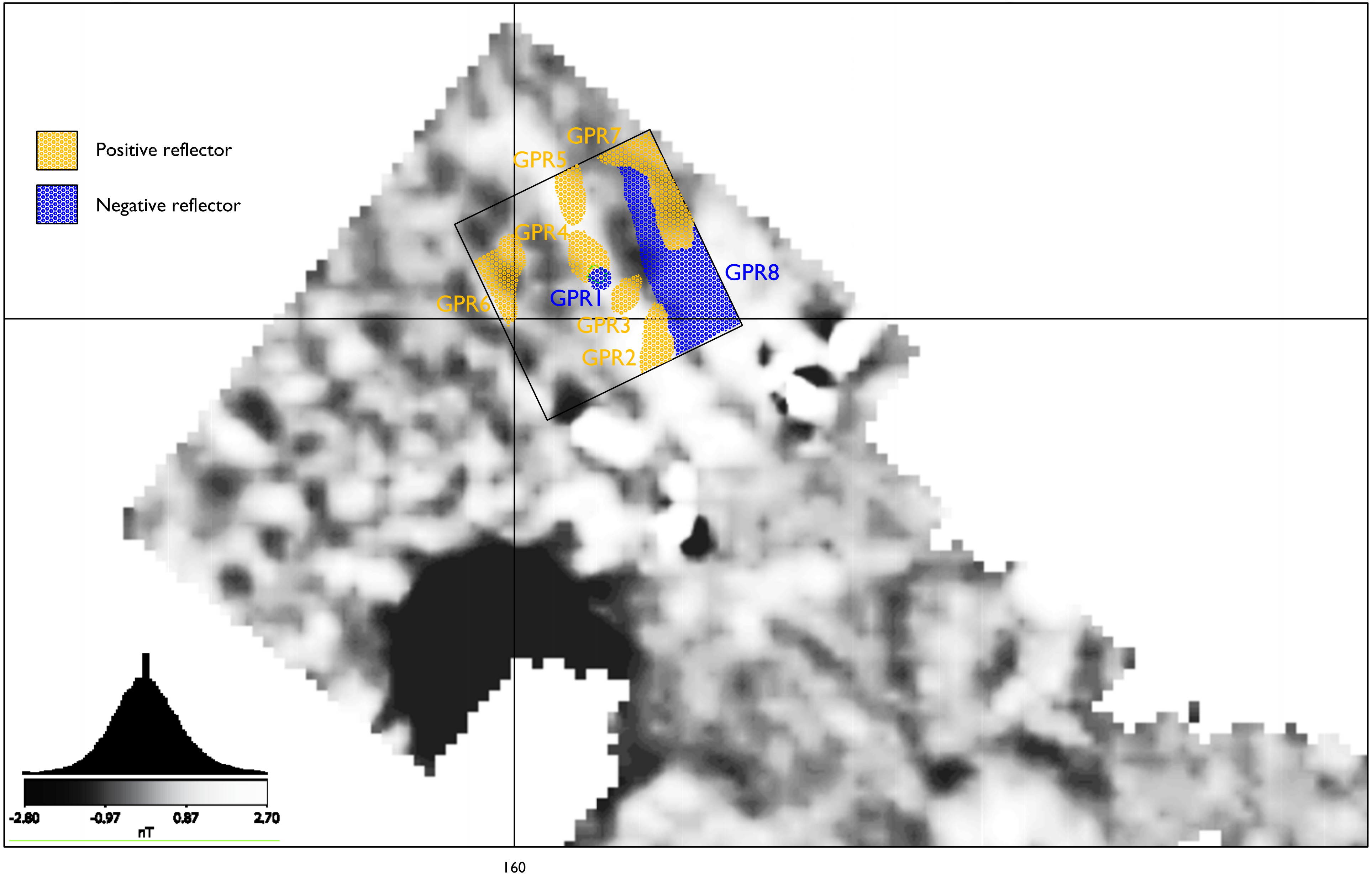
Geophysics Team 2011

ENGLISH HERITAGE

ARBOR LOW STONE CIRCLE, DERBYSHIRE

Graphical summary of significant GPR anomalies over magnetic data

Figure 6



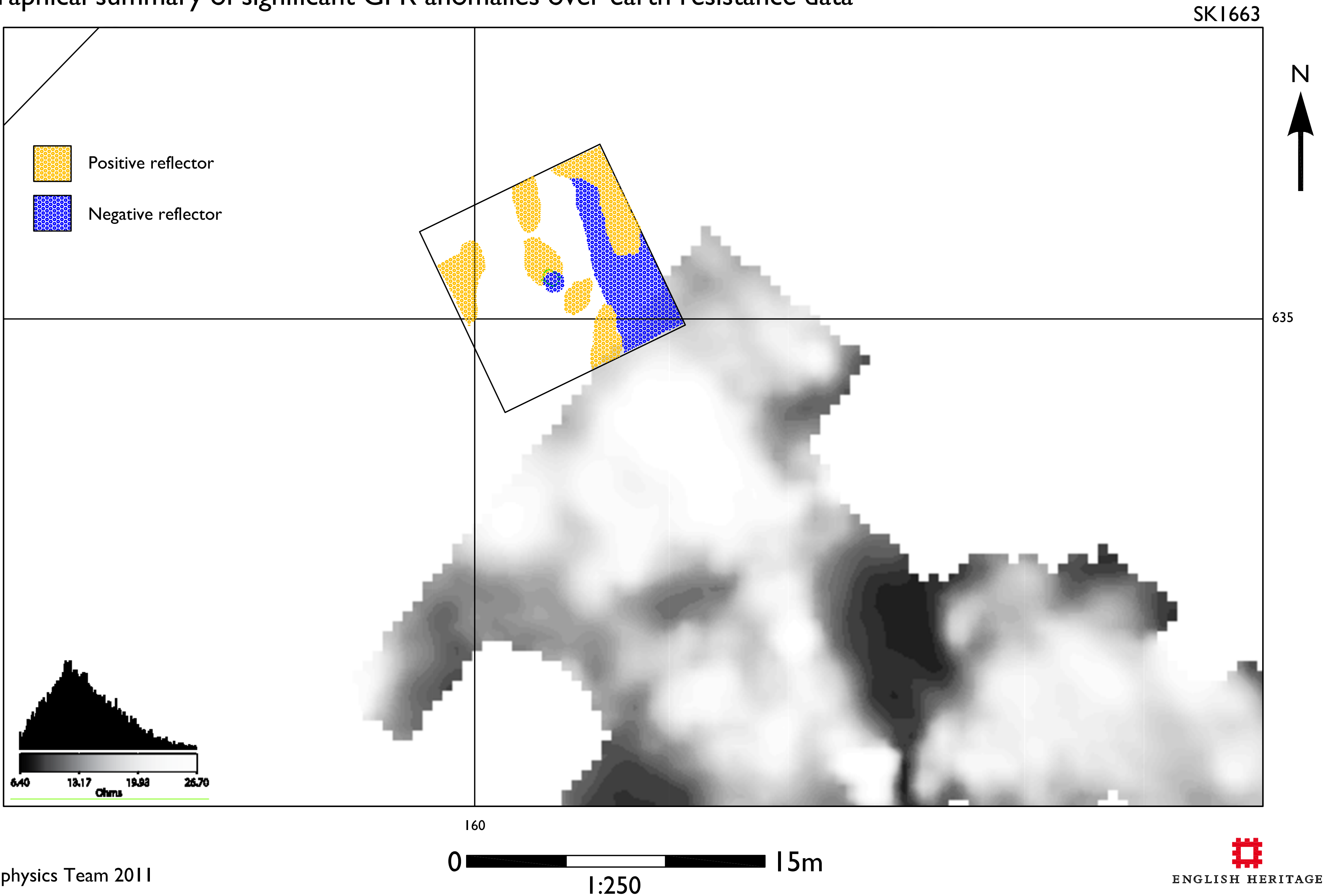
0 15m
1:250

Geophysics Team 2011

ENGLISH HERITAGE

Figure 7

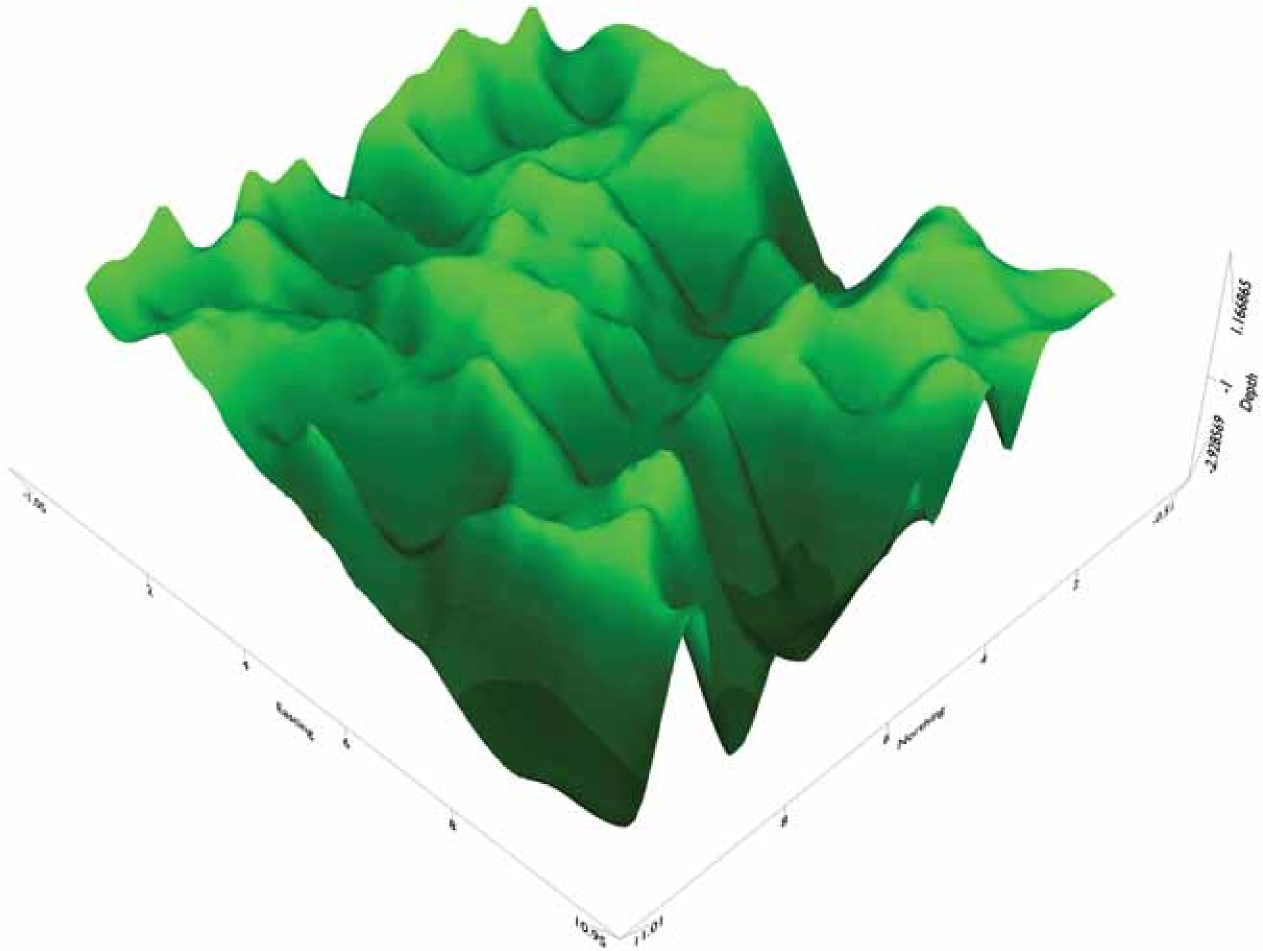
ARBOR LOW STONE CIRCLE, DERBYSHIRE
Graphical summary of significant GPR anomalies over earth resistance data



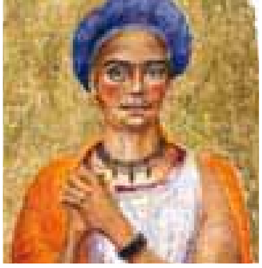
Geophysics Team 2011

ENGLISH HERITAGE

ARBOR LOW STONECIRCLE, DERBYSHIRE.
GPR subsurface relief model



Geophysics Team 2011



ENGLISH HERITAGE RESEARCH DEPARTMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.

The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:

* *Aerial Survey and Investigation*
* *Archaeological Projects (excavation)*
* *Archaeological Science*
* *Archaeological Survey and Investigation (landscape analysis)*
* *Architectural Investigation*
* *Imaging, Graphics and Survey (including measured and metric survey, and photography)*
* *Survey of London*

The Research Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support outreach and education activities and build these in to our projects and programmes wherever possible.

We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities. A full list of Research Department Reports, with abstracts and information on how to obtain copies, may be found on www.english-heritage.org.uk/researchreports

For further information visit www.english-heritage.org.uk

ENGLISH HERITAGE