High-resolution Ground Penetrating Radar (GPR) survey within the grounds of Clare Priory, Sudbury, Suffolk.

Archaeology South-East

National grid reference: TL770450

Survey date: March 2016

Project number: H1870 - 01

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1. Introduction

1.1. Terms of reference.

1.1.1. On 01st March 2016, Arrow Heritage Ltd carried out a high-resolution ground penetrating radar survey within a portion of the grounds of Clare Priory, Sudbury, Suffolk (CO10 8NX).

1.1.2. The survey was commissioned by Archaeology South-East with the aim of obtaining a better understanding of any archaeological deposits within the site. More specifically, the aim of the GPR survey is to locate any burials, chambers or funerary containers within the survey area.

1.2. Site description.

1.2.1. The geology of the site comprises Alluvium overlying Holywell Nodular Chalk Formation and New Pit Chalk Formation (BGS 2016).

1.2.2. The survey area comprises the eastern extent of the now ruined pre-Reformation church of Clare Priory, Suffolk. The site is bounded by the partly ruined walls of the priory and is lain to turf with occasional embedded tombstones. The site was generally free of obstacles but several profiles were broken due to rough ground, small trees and an altar.

Plate 1: View of the main section of the survey area with the altar in the background (looking east).

Plate 2: View of the southern section of the survey area (looking west)

Plate 3: View of the main section of the survey area with embedded tombstones in the foreground (looking west).

2. Data Acquisition

2.1. Positioning.

2.1.1. The survey grid was set out using conventional survey techniques, and tied into the OS National Grid using RTK GPS.

2.2. GPR survey.

2.2.1. Ground penetrating radar data were collected using a cart-mounted MALÅ GeoScience RAMAC/GPR system consisting principally of a 500 MHz shielded antenna, CUII control unit and XV11 monitor.

2.2.2. Profiles were collected at a line spacing of 0.5 metres and a sample spacing of two centimetres. The location of each survey profile is shown in figure 2.

2.2.3. The time window for reflection measurement was set to 73.6 nanoseconds, which corresponds to a potential penetration depth of approximately 2.6 metres at a radar wave propagation velocity of 7.0 cm/ns[a]. Because of signal attenuation and scattering due to conductive and heterogeneous subsurface conditions, practical penetration depth is often significantly less than this theoretical maximum.

3. Processing

3.1. Stacked profiles.

3.1.1. DC offset correction and time gain were applied to the GPR data to correct for low frequency noise and increase mid- to late-time signal amplitudes respectively. Profiles were then stacked for feature interpretation.

3.2. Depth slices.

3.2.1. Signal amplitudes were squared to improve signal-to-noise ratio and reduce the effect of transmitter waveform shape.

3.2.2. The resultant profile datasets were sliced at a vertical interval of 200 mm to produce depth slices suitable for feature interpretation. Depth slices from surface to 2000 mm were gridded to produce the images shown in Figure 3.

3.2.3. Radar reflectance in these images grades from low (black) to high (yellow). Amplitude thresholding has been applied to enhance feature interpretability.

[a] This velocity is based on GPR profile measurements for this site.

3.3. Software.

3.3.1. Processing was carried out using Microsoft Excel, Shakespeare[b] and Geosoft Target.

4. Interpretation

4.1. General comments.

4.1.1. The advantage of GPR depth slices is that the *spatial relationship* of individual features can be appreciated in plan view. The advantage of GPR profiles is that the *changing character* of individual features can be studied profile by profile. A combined approach - identifying features on depth slices, and ascertaining their characteristics from profiles when necessary - is usually the best method of interpreting GPR data.

4.1.2. Effective ground penetration at this site was obtained to a maximum depth of approximately 1900 mm below ground level.

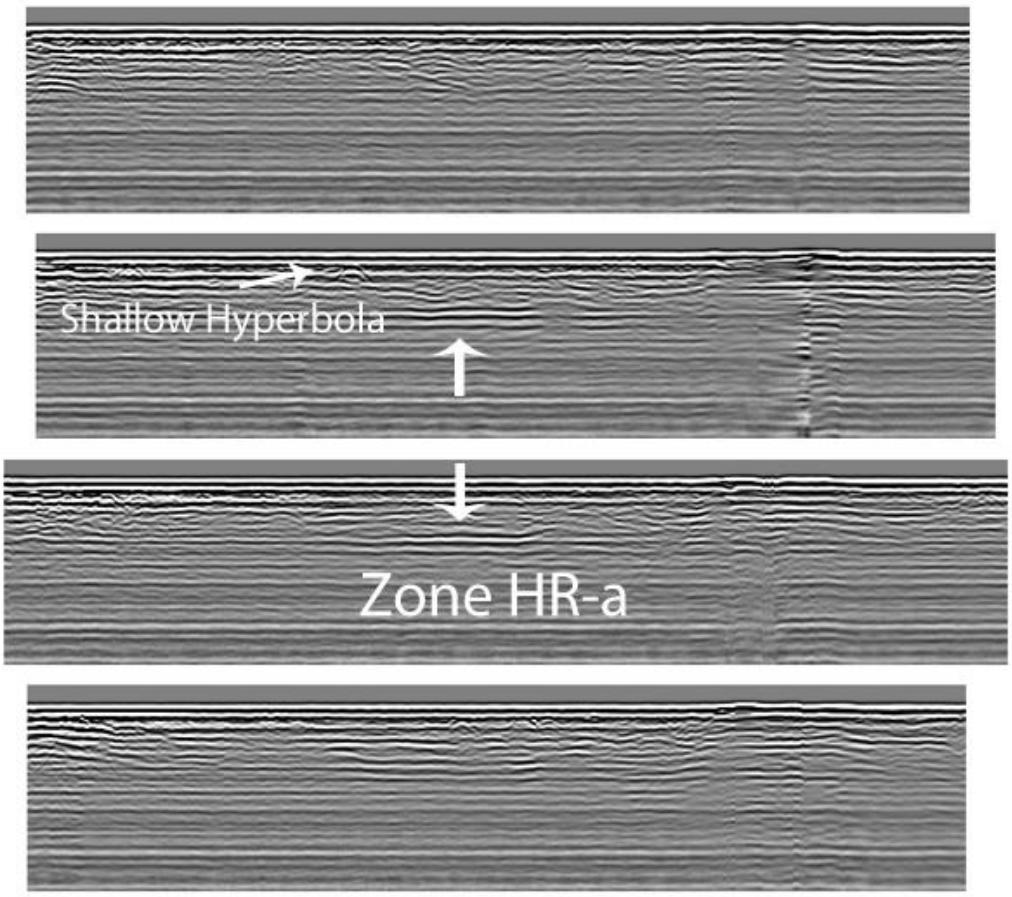
4.2. Specific features.

(Specific features interpreted from this survey dataset are summarised in Figure 4)

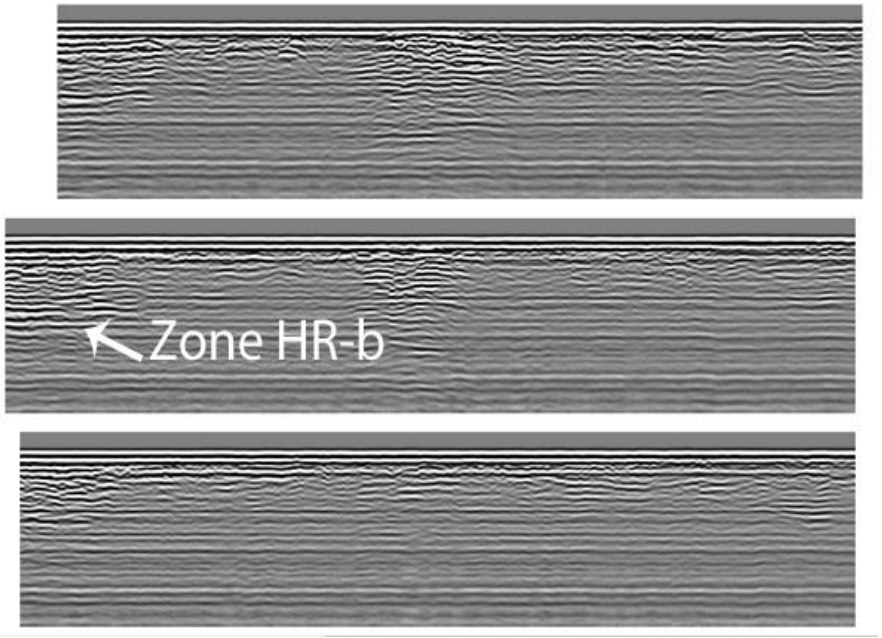
4.2.1. Areas of High Amplitude Reflectance :

Zone 'HR-a' is a well defined sub-horizontal reflector stretching over three profiles. It is approximately 1800 mm in width and is at a depth of 850 mm. This is assumed to be a geophysical layer boundary. It is noted that there is a shallow hyperbola on the northern side of this feature.

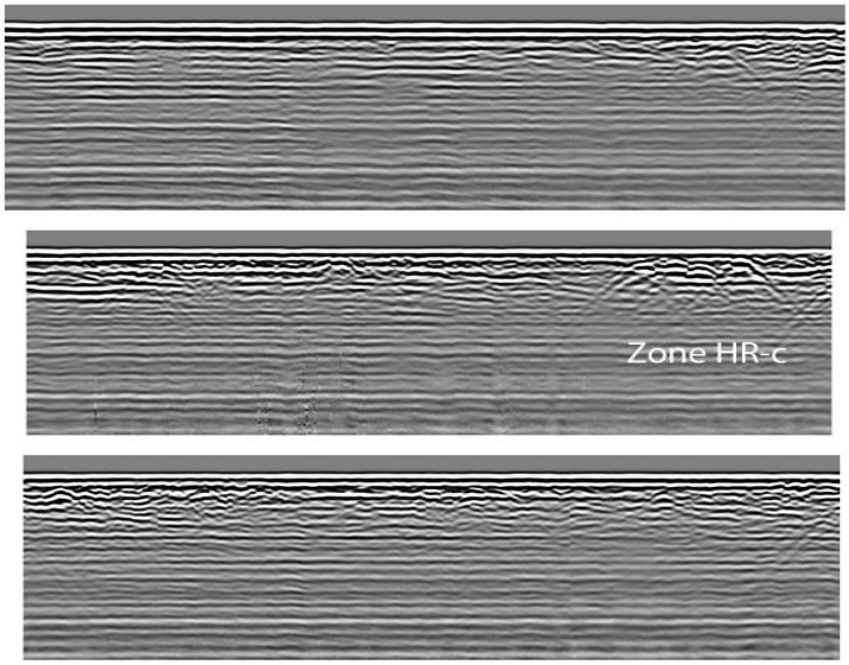
[b] Proprietary software for processing GPR data developed by Arrow Geophysics Ltd.



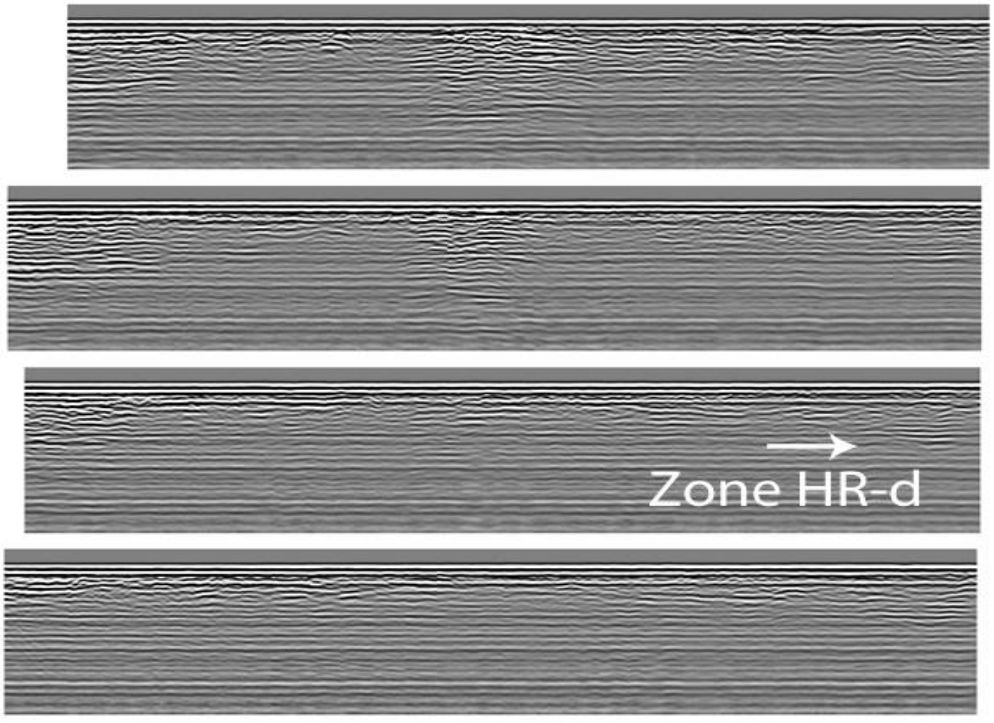
Zone 'HR-b' is a sub-horizontal reflector at the extreme south-western edge of the survey area. It is very close to the wall of the priory and is at a depth of approximately 1050 mm. The response above the reflector is fairly complex (disturbed) and it is assumed to be related to some type of excavation.



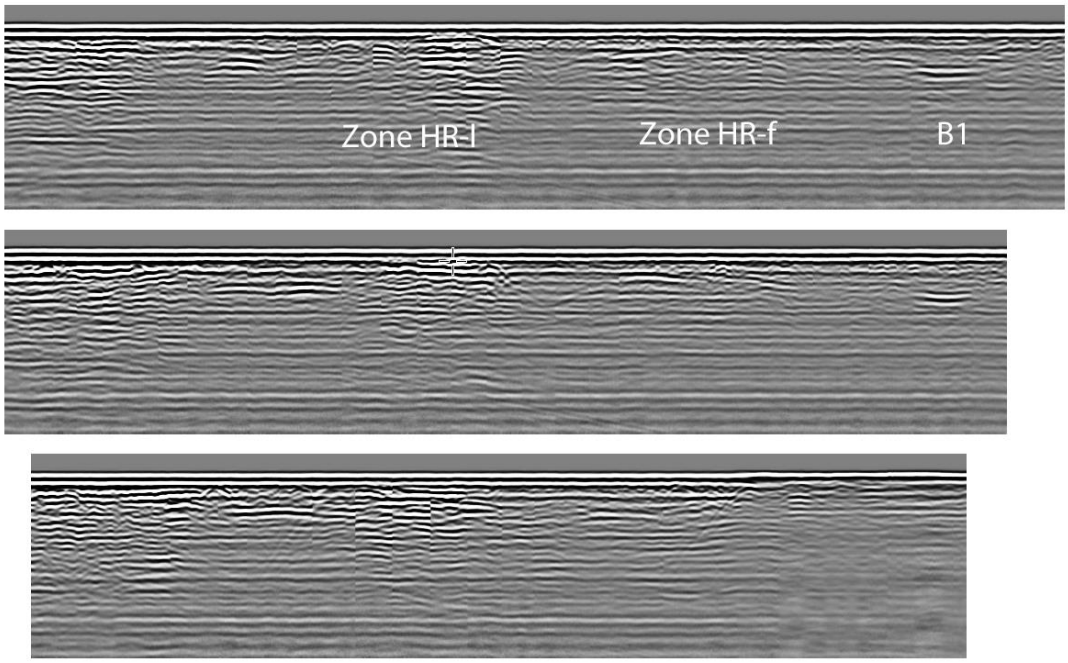
Zone 'HR-c' is a small sub-horizontal reflector at a variable depth of between 240 and 450 mm. It is very close to linear feature 'L-b' and is likely to be associated with the construction of the same.



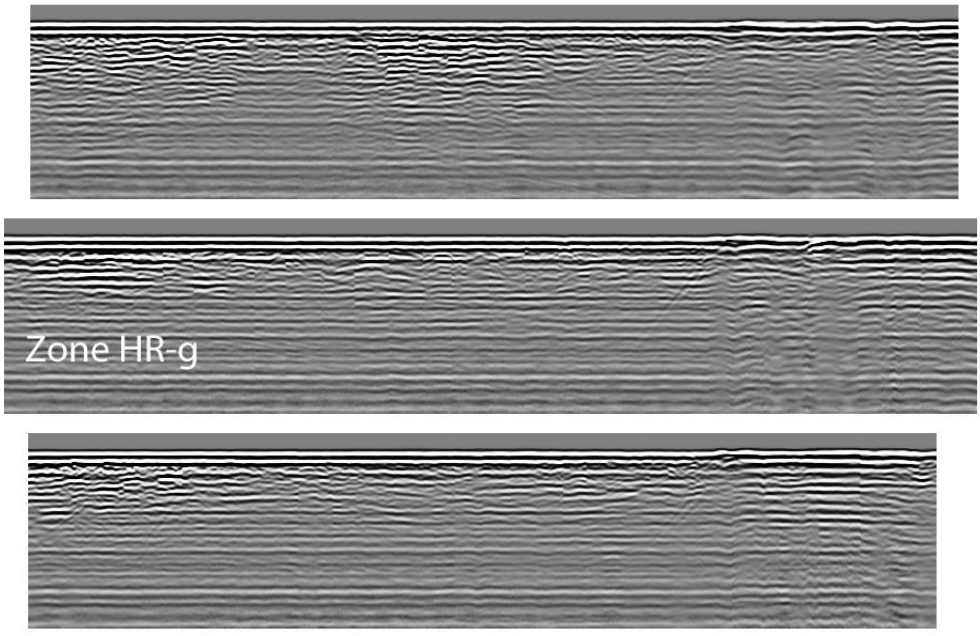
Zone 'HR-d' is a well defined sub-horizontal reflector stretching over several profiles. It is approximately 700 mm in width and is at a depth of 975 mm. It is assumed that this is a cut and fill feature. The full extent of this feature cannot be traced as it on the perimeter of the survey area.



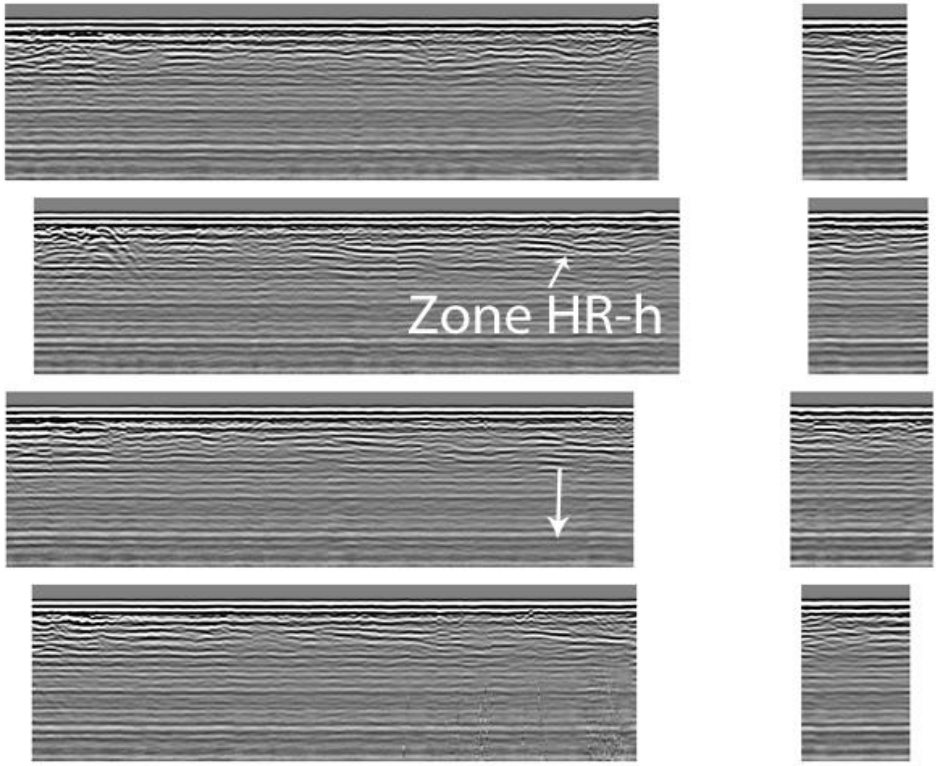
Zone 'HR-f' is a fairly well defined sub-horizontal reflector stretching over several profiles. It is of variable width and is at a depth of approximately 400 mm. It is located between zone 'HR-l' and target 'B1' and it is assumed to be some type of cut and fill feature.



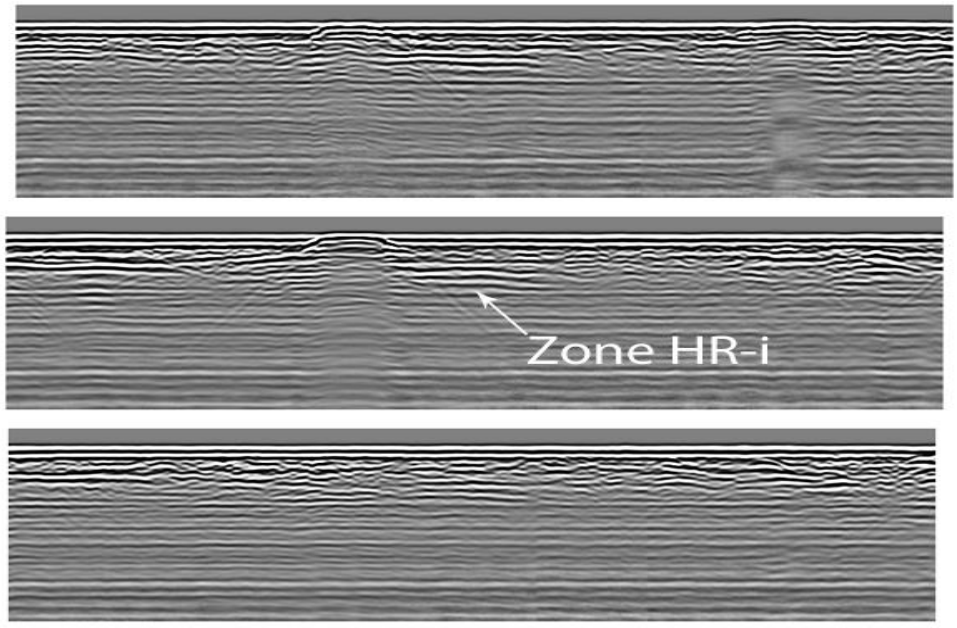
Zone 'HR-g' is a very well defined sub-horizontal reflector which is only visible on one profile. It is between 420 and 700 mm in depth and is close to the wall of the priory. It is possible this feature is associated with the construction of the wall.



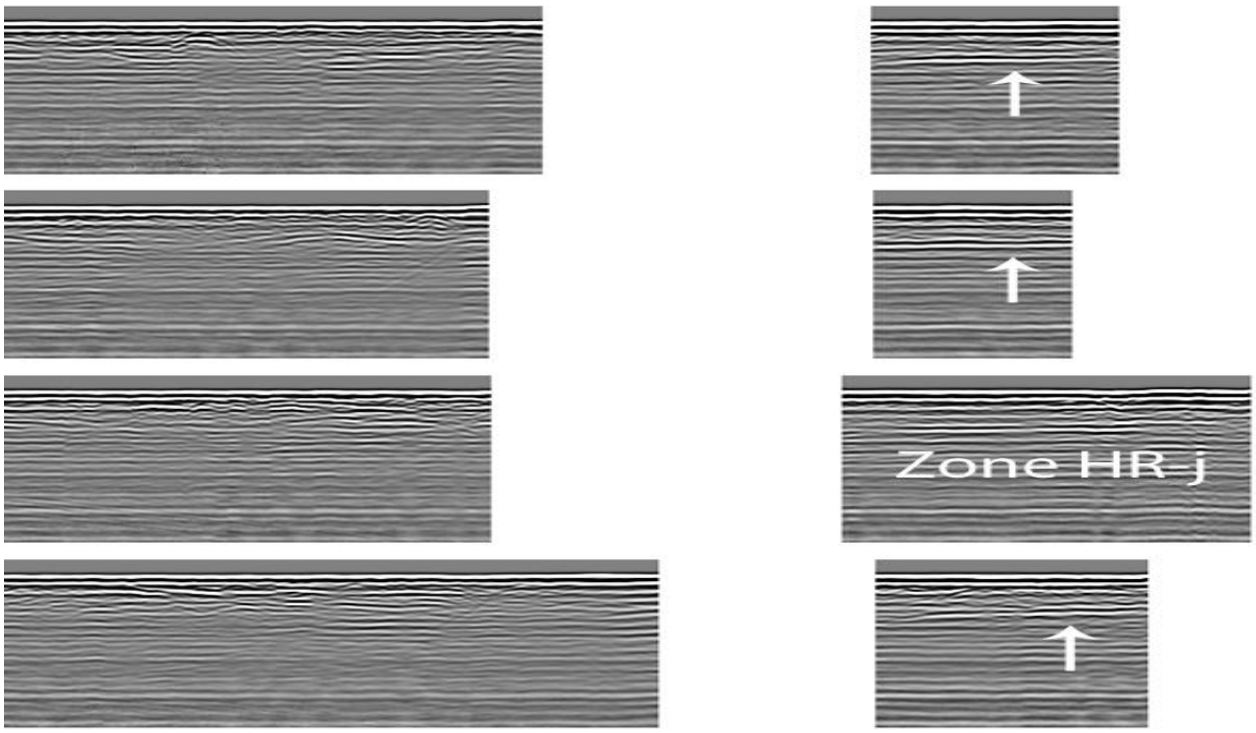
Zone 'HR-h' is a poorly defined sub-horizontal reflector. It is visible on several lines between depths of 500 and 700 mm. In the western section of this feature, it is seen as a dipping reflector. It is assumed to be associated with some type of excavation.



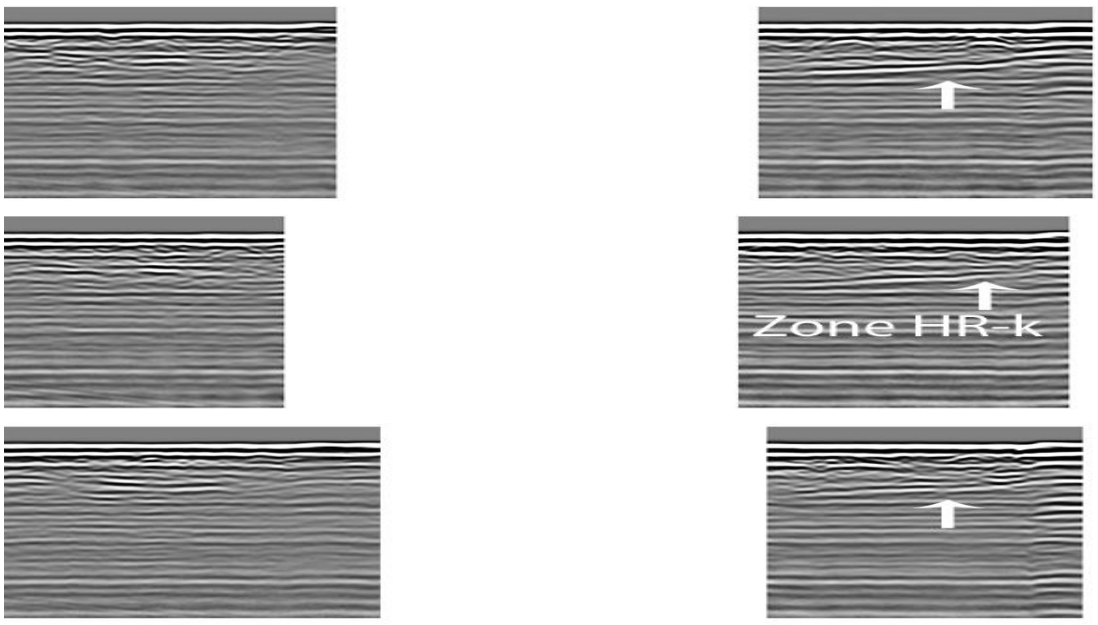
Zone 'HR-i' is a well defined sub-horizontal reflector seen on several lines. It is parallel to and adjacent to the southerly embedded tombstone at a depth of approximately 500 mm and is thought to be associated with the excavation of the same.



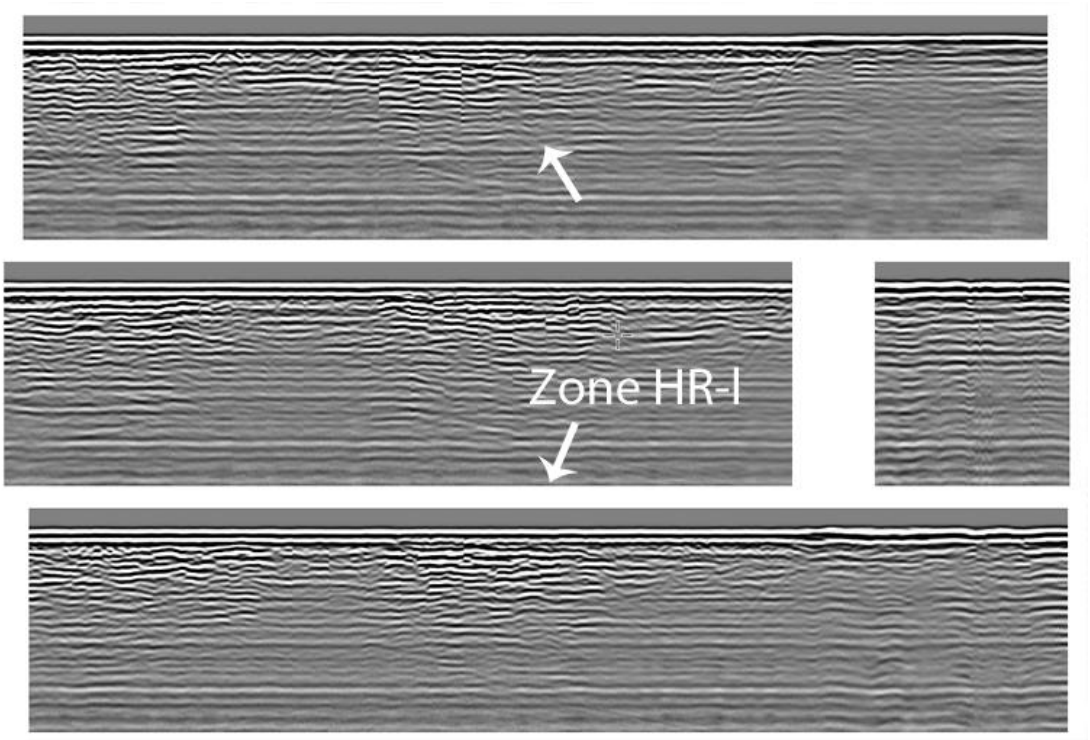
Zone 'HR-j' is a very well defined dipping sub-horizontal reflector seen on several lines. It is adjacent to the shrubbery garden at a depth of approximately 650 to 700 mm. It is possibly a cut and fill feature associated with either the shrubbery bed or the nearby interpreted linear feature.



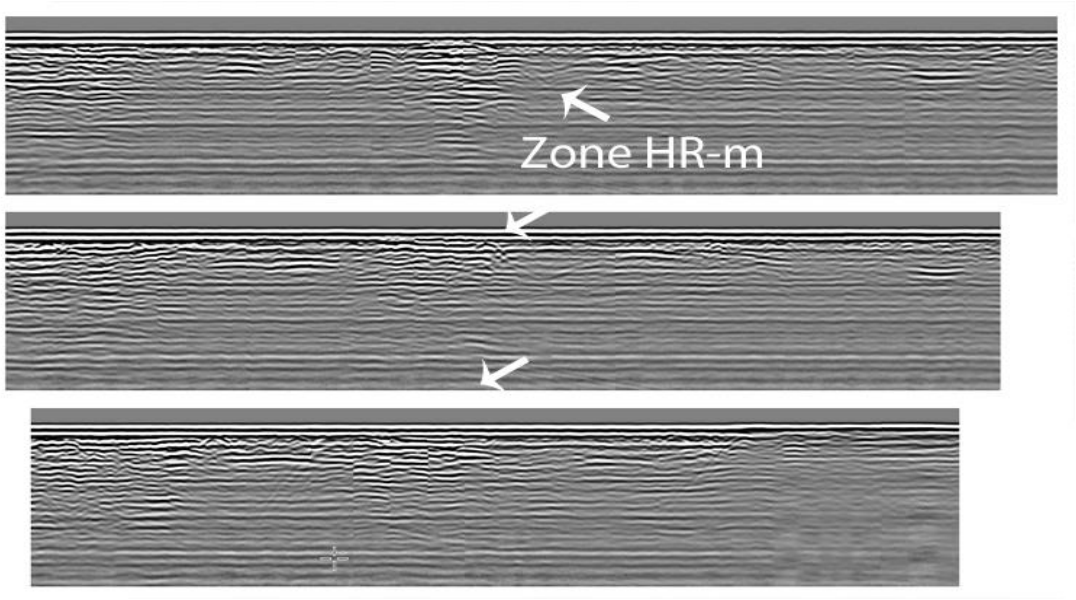
Zone 'HR-k' is a well defined dipping sub-horizontal reflector seen on several lines. It is adjacent to the shrubbery garden at a depth of approximately 650 mm. It is located very close to zone 'HR-j' and is possibly a cut and fill feature associated with either the shrubbery bed or the nearby linear feature.



Zone 'HR-l' is a poorly defined sub-horizontal reflector seen on several lines at a variable depth of between 300 to 700 mm. The sub-surface appears fairly disturbed in this feature and it is likely to be related to some type of excavation (possible a cut and fill feature). It is situated close to zones 'HR-a', 'HR-n' and 'HR-f'.



Zone 'HR-m' is a sub-horizontal reflector seen on several lines at a variable depth of between 300 to 650 mm. It is situated close to zones 'HR-b' and HR-g' and is close to the wall of the priory. The sub-surface of this feature appears fairly disturbed and it is possible this feature is associated with the construction of the priory wall.



4.2.2. Linear Features :

Features 'L-a', 'L-b' and L-c' are more easily seen on the depth slices than the stacked profiles.

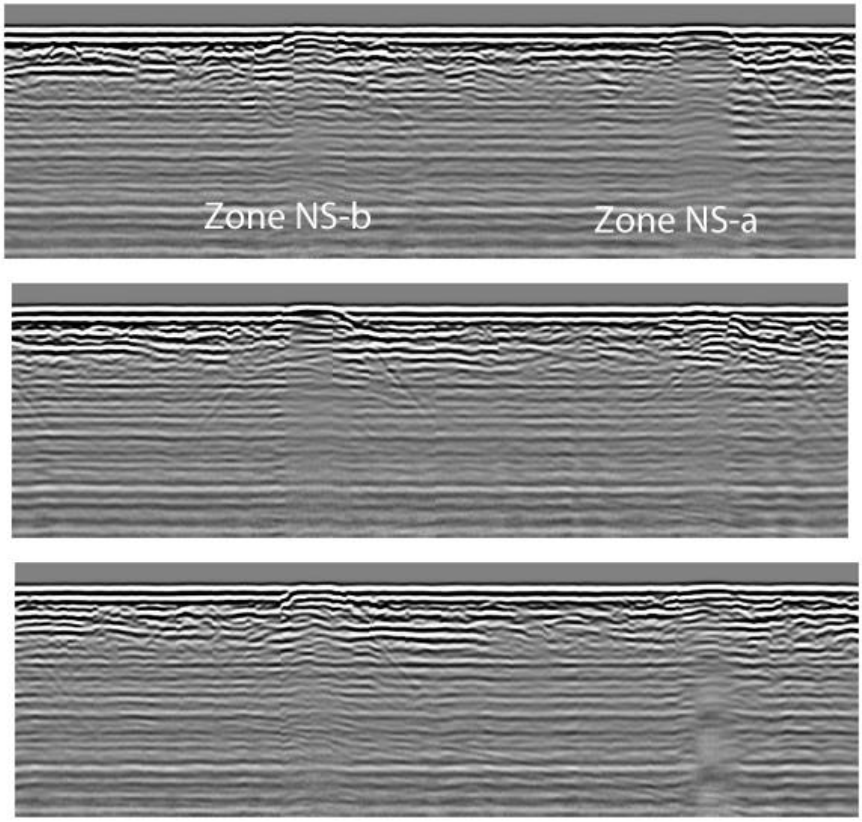
Linear features 'L-d', 'L-e', 'L-f' and 'L-g' are fairly broad features (approximately 1200 mm) which are likely to be masonry footings. They are located very close to (and parallel to) the existing priory wall.

Linear feature 'L-h' is clearly seen on the stacked profiles as a strong linear reflector at a depth of approximately 550 to 600 mm.

Linear feature 'L-i' is seen clearly on the depth slices at a depth of greater than 1500 mm.

4.2.3. Near-Surface responses :

Features 'NS-a' and 'NS-b' are the embedded tombstones that can be seen on the ground at these locations. They are approximately 0.6 m in width and between 2.1 and 2.5 m in length. They are approximately 3.0 metres from the altar.



4.2.4. Possible Graves :

Multiple small targets have been identified within the survey area. It is noted that :

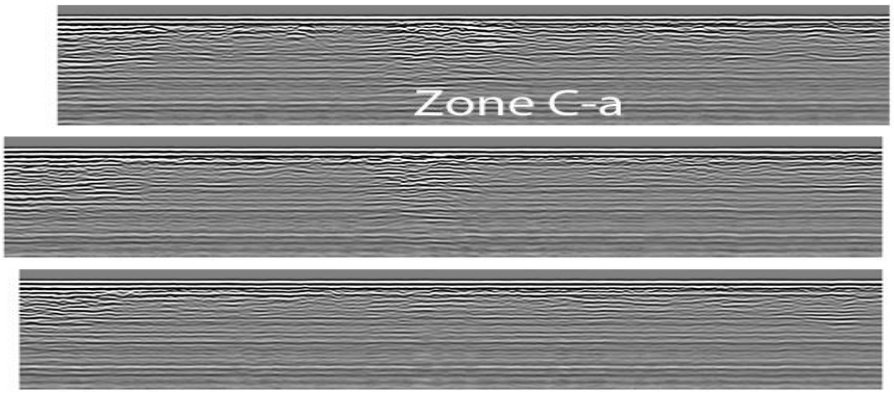
a) the majority of these targets are only visible on one line and
b) the majority of these small hyperbolae are located at a shallow depth of less than 350 mm.

Several targets have been labelled as possible burials as the hyperbolae are seen on consecutive profiles and the alignment of the targets is roughly similar (NE – SW).

The most promising of these possible targets have been labelled on the interpretation map as B1, B2, B3 and B4. These targets have a depth of between 500 and 700 mm and have a response on more than one line.

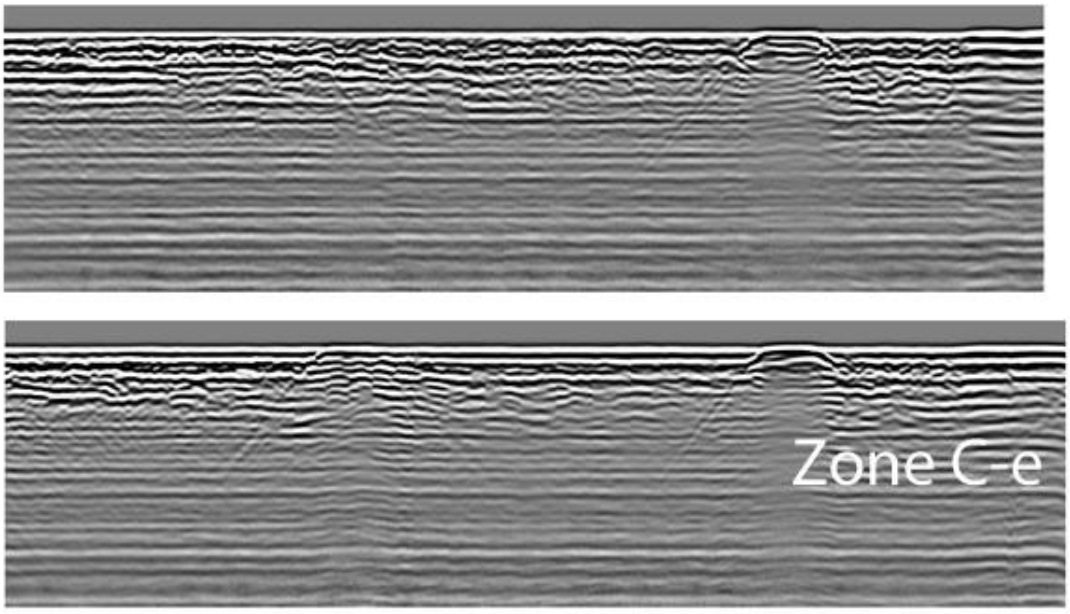
4.2.5. Areas of Complexity / Disturbed Ground:

Zones 'C-a' is a disturbed areas of ground. It is thought to be an excavation (to a depth of greater than 1200 mm). Amongst the disturbance, this area does contain some poorly defined and randomly distributed high-amplitude reflectors. Zone 'C-a' cannot be traced to its full extent as it is on the perimeter of the survey area.



Zone 'C-c' is a disturbed area of ground which is adjacent to the existing altar. It contains some high-amplitude reflectors at various depths and is likely to be associated with the construction of the altar.

Zone 'C-e' is a disturbed area of ground which is located between the linear features 'L-a' and 'L-b' and is adjacent to embedded tombstone 'NS-a'. It is believed to be associated with the construction of these features.



5. Conclusion

The ground penetrating radar (GPR) survey within a portion of the grounds of Clare Priory has successfully identified four possible burial sites for further investigation. There are several further targets of lesser priority which may also be worth investigation.

The survey has also identified several linear structures and multiple areas of either sub-surface complexity or high reflectance.

Disclaimer: Arrow Heritage Limited makes no guarantee that the record of buried services or features supplied for this GPR survey is either accurate or complete. To more properly locate such features, a dedicated utility mapping survey using an appropriate suite of non-intrusive techniques can be carried out upon request.

APPENDIX

Ground Penetrating Radar Survey

Ground penetrating radar (or GPR) is a non-intrusive geophysical technique with wide applicability within the UK. The technique is responsive to a wide range of buried obstructions, provides information on feature depth, and can be deployed across both hard and soft operating surfaces. Against these advantages, the technique is relatively time-consuming on site, can be ineffective in areas of clay-rich or saline ground, and yields data that is difficult to interpret accurately without substantial training and real-world experience.

Ground penetrating radar systems fall broadly into two categories: unshielded systems and shielded systems. Unshielded systems are typically employed for deep-looking geological surveys such as water table investigations or mapping variations in bedrock topography. Unshielded systems are substantially affected by ambient cultural contamination, and are usually unsuitable for work in urban contexts. Shielded systems are employed in the UK principally for mapping buried services, although they are also widely used for concrete imaging, roadway mapping and identifying buried obstructions such as mine workings, building remains , underground storage tanks and archaeological deposits.

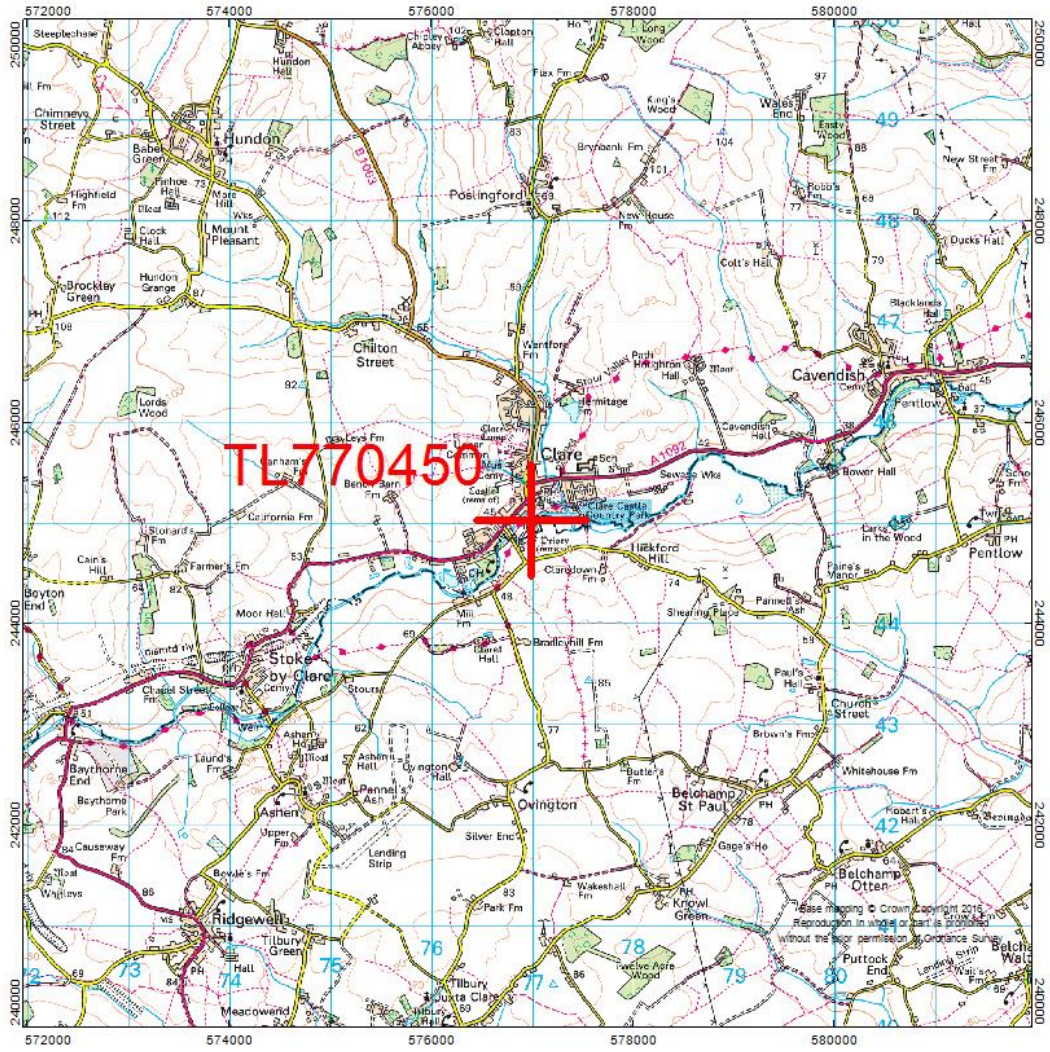
A GPR system transmits electromagnetic energy in the microwave band (UHF/VHF frequencies) of the radio system. Energy is typically directed into the ground, where objects with a dielectric contrast to the surrounding soil or rock reflect a proportion of the transmitted signal back to surface where the reflection is detected by the GPR receiver. Reflections from objects and interfaces at increasing depth below the point of measurement are recorded at delay times proportional to their depth of burial, and traces from successive points of measurement are used to build up a data profile along the direction of travel Further processing produces depth slices, which provide a plan view of the variation in GPR signal reflectance for a specified depth below surface.

The advantage of GPR depth slices is that the spatial relationship of individual featured can be appreciated in plan view. The advantage of GPR profiles is that the changing character of individual features can be studied profile by profile. A combined approach – identifying features on depth slices, and ascertaining their characteristics from profiles when necessary is usually the best method of interpreting GPR data.

Energy emitted by a GPR system exhibits a trade-off between spatial resolution and penetration depth : as the centre frequency of the transmitting antenna increases, signal penetration decreases and the ability to resolve spatial objects within the subsurface increases (all other factors being equal).

FIGURES

Figure 1



Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey Location of survey area
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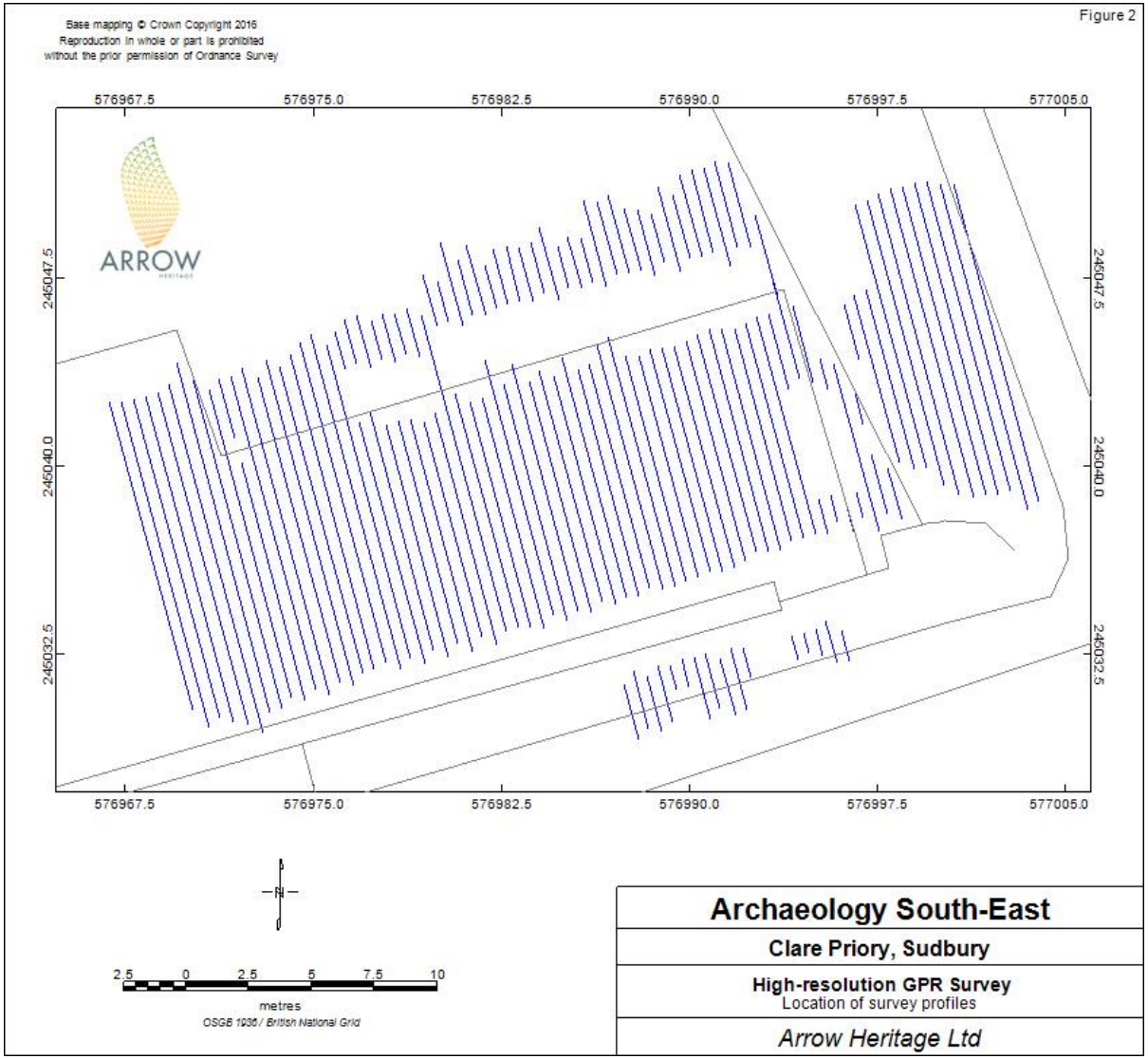
Figure 2
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Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
Location of survey profiles
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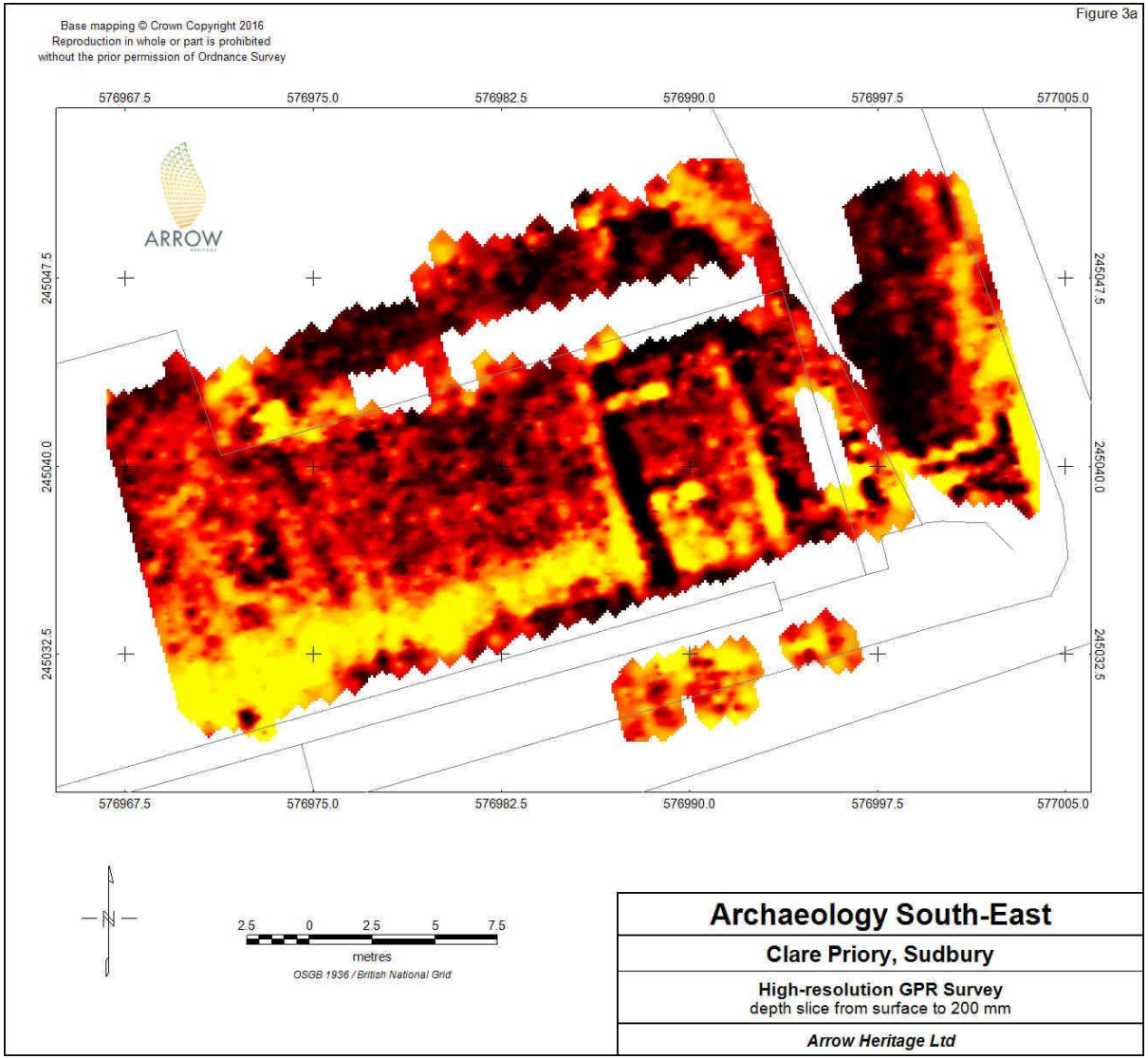
Figure 3a
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Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from surface to 200 mm
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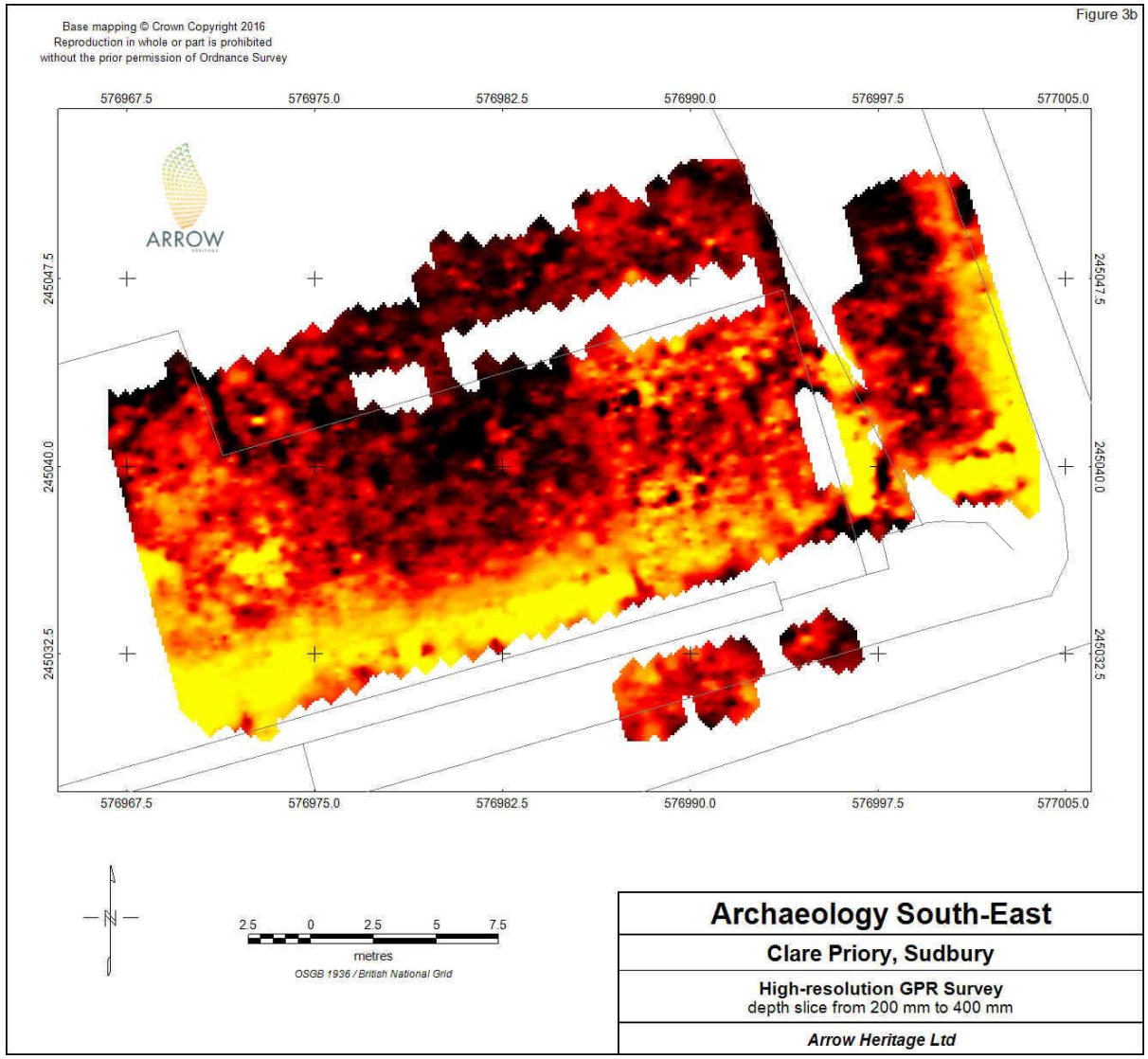
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Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from 200 mm to 400 mm
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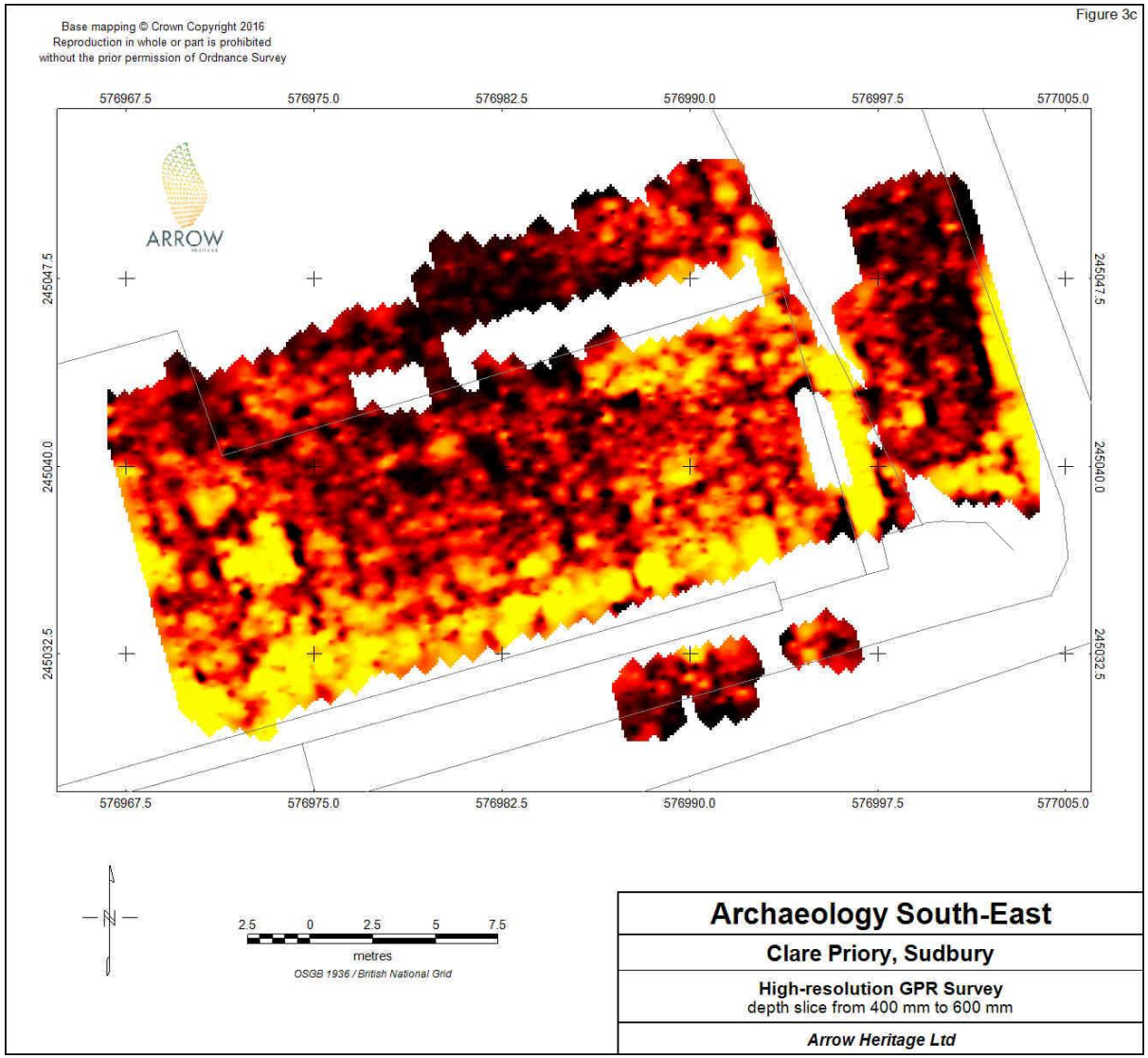
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Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from 400 mm to 600 mm
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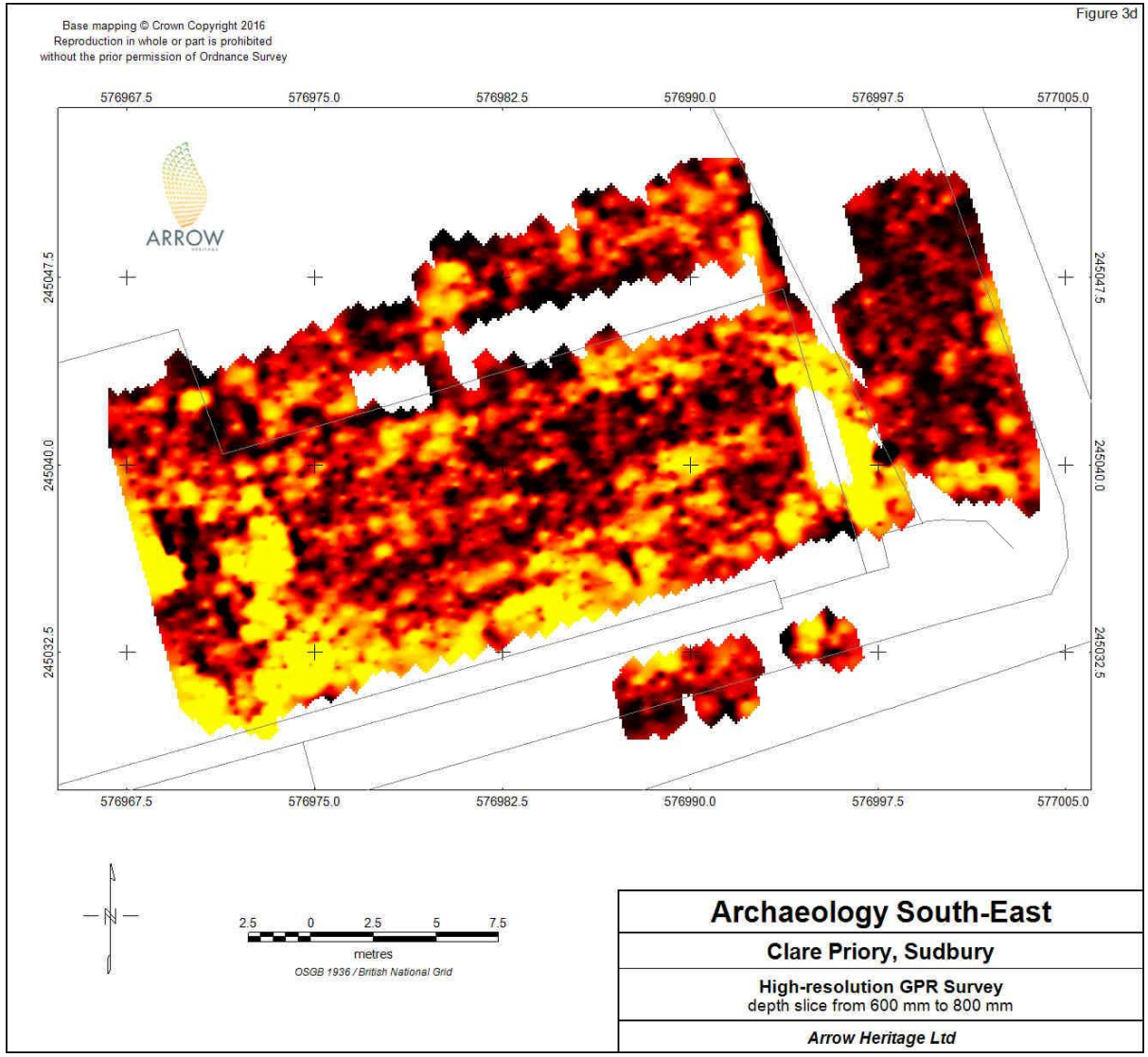
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Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from 600 mm to 800 mm
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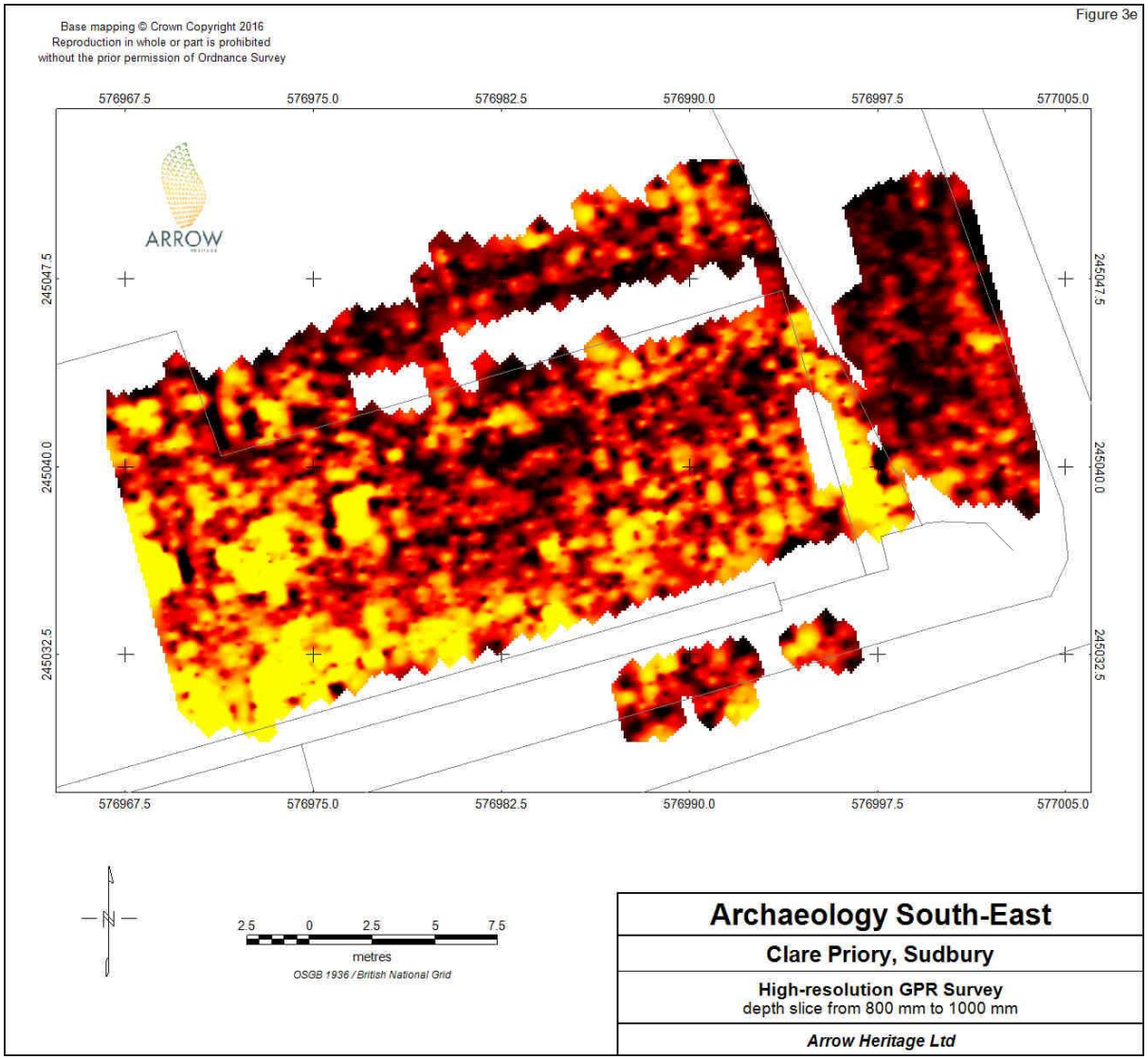
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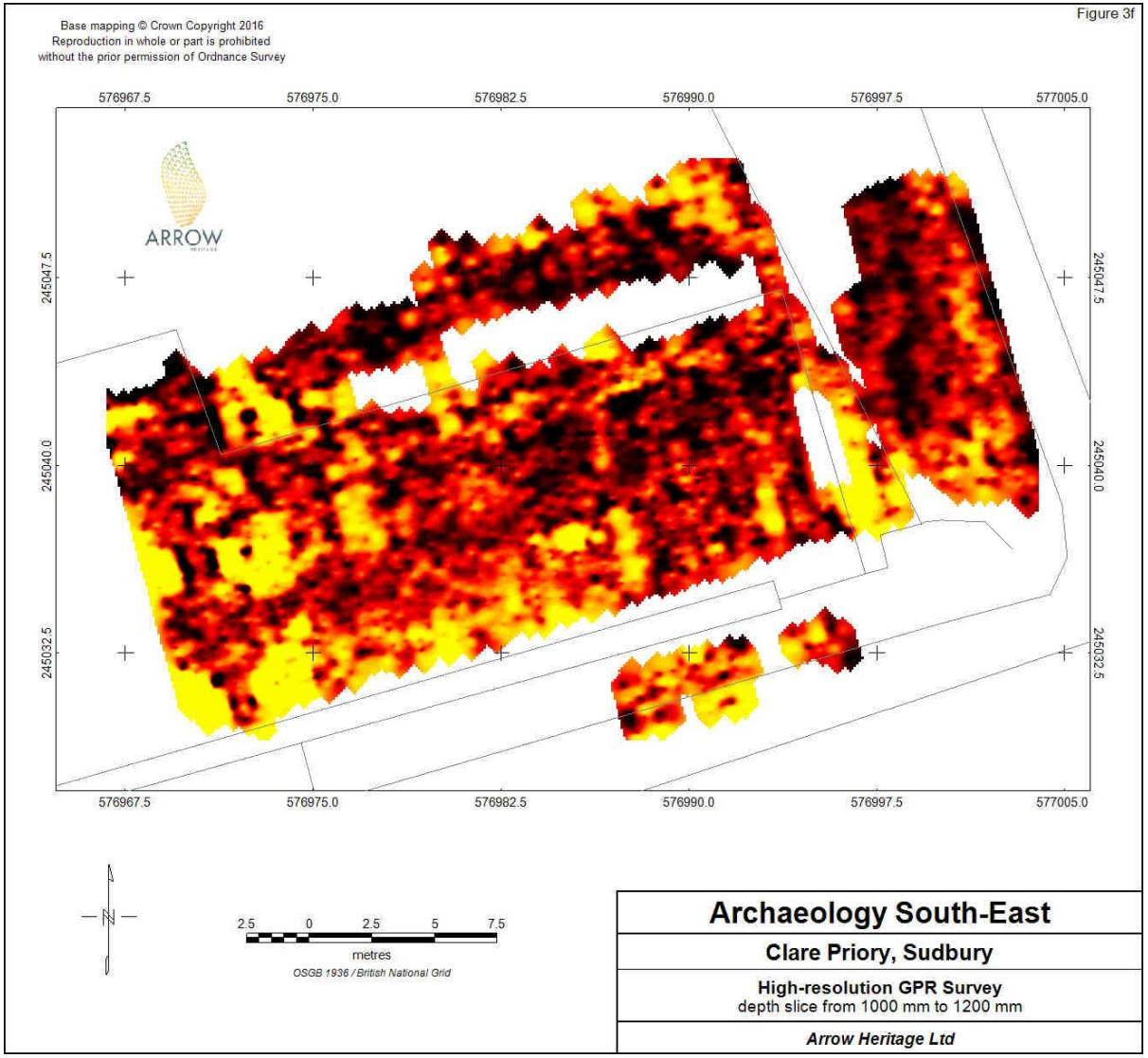
Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from 800 mm to 1000 mm
Arrow Heritage Ltd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depth slice from 1000 mm to 1200 mm
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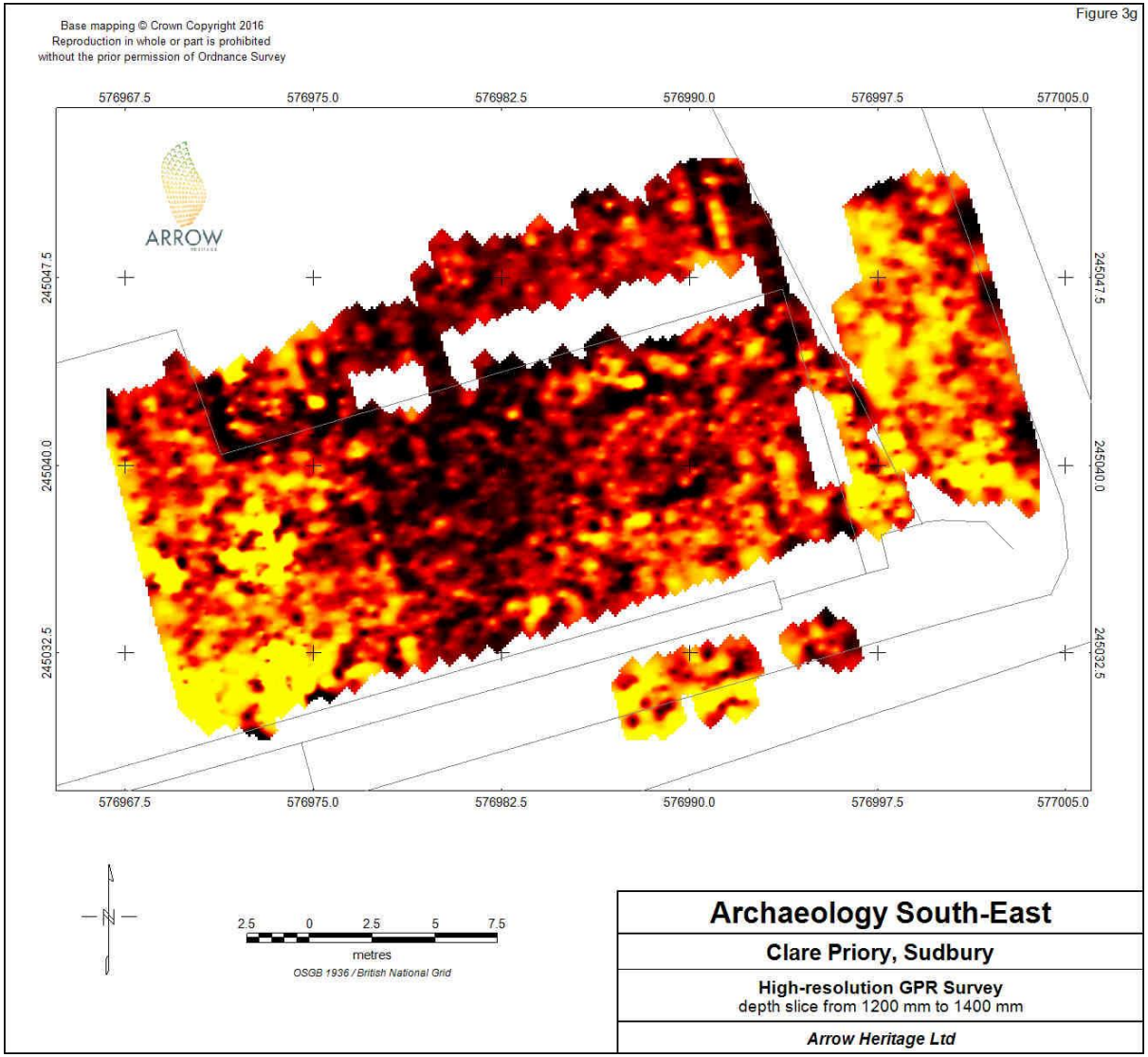
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High-resolution GPR Survey
depth slice from 1200 mm to 1400 mm
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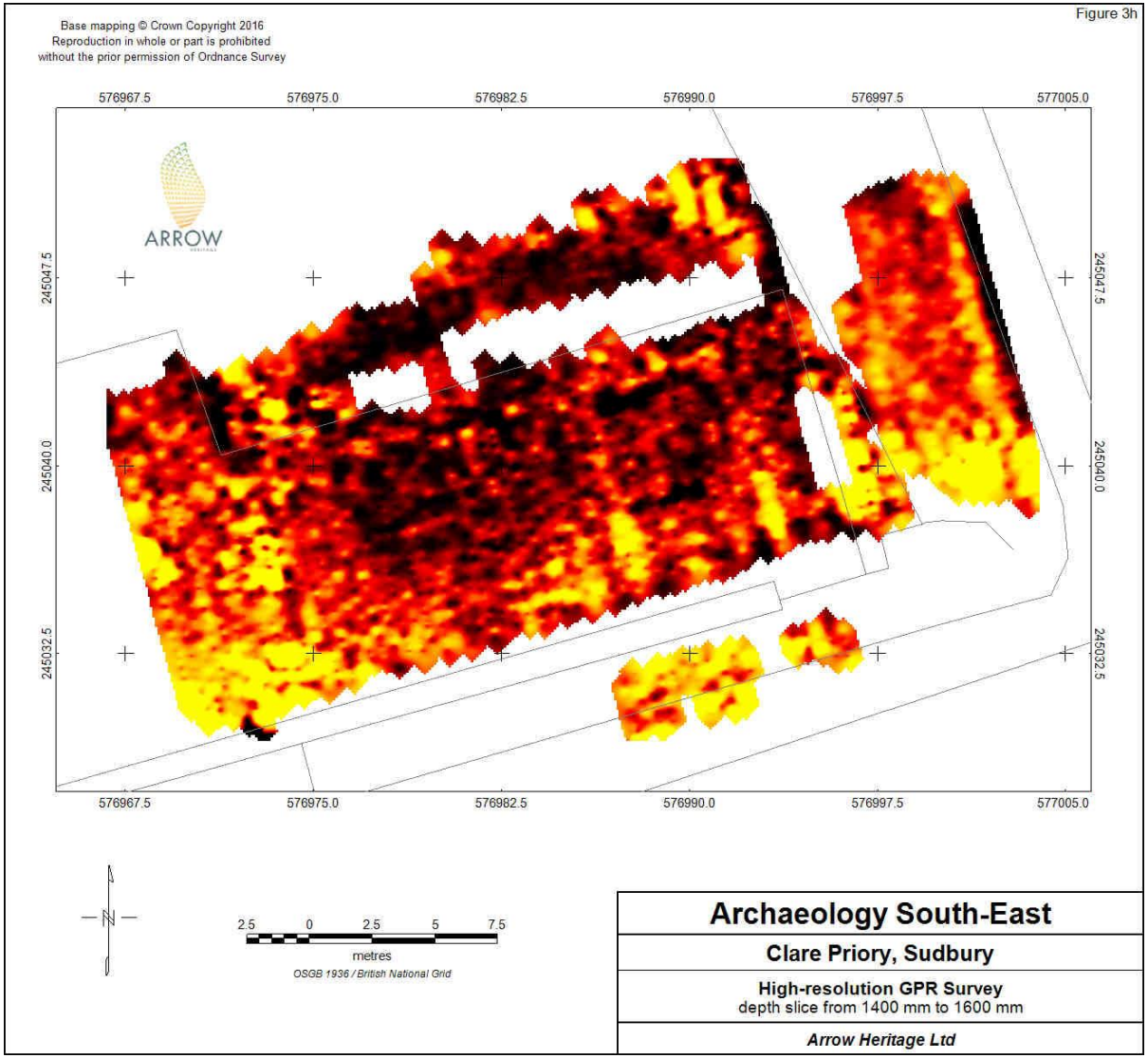
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High-resolution GPR Survey
depth slice from 1400 mm to 1600 mm
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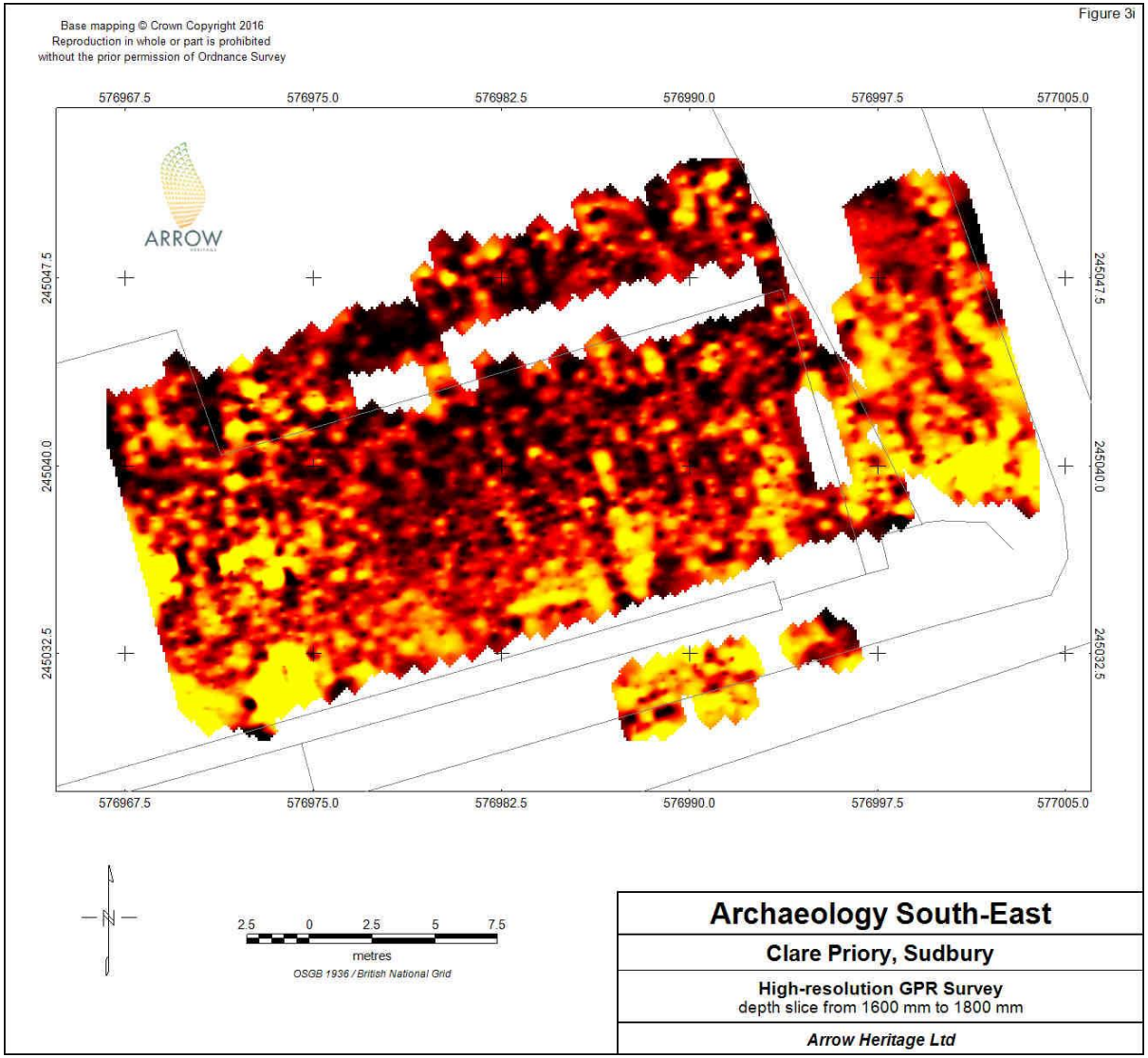
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Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from 1600 mm to 1800 mm
Arrow Heritage Ltd

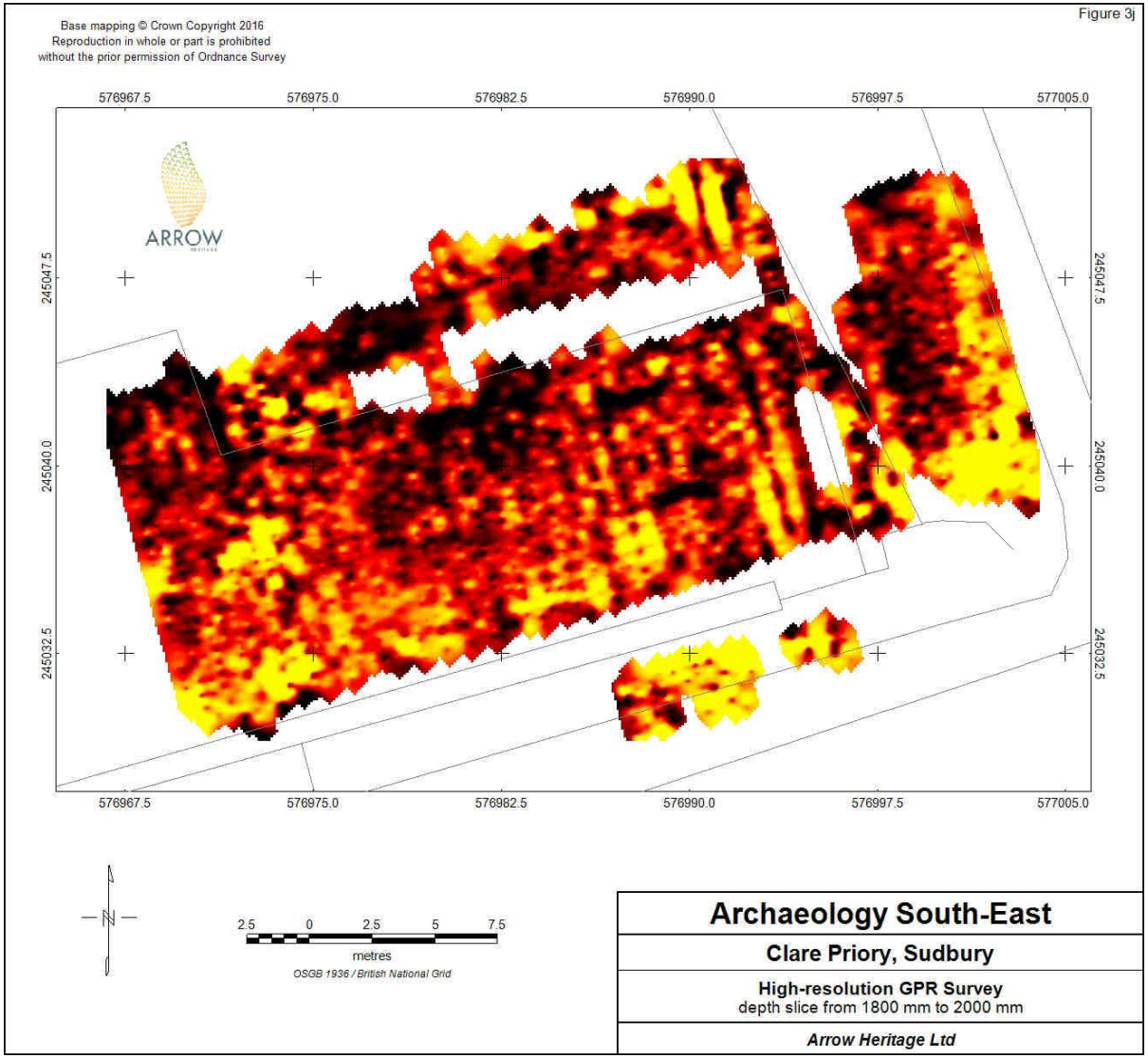
Figure 3j
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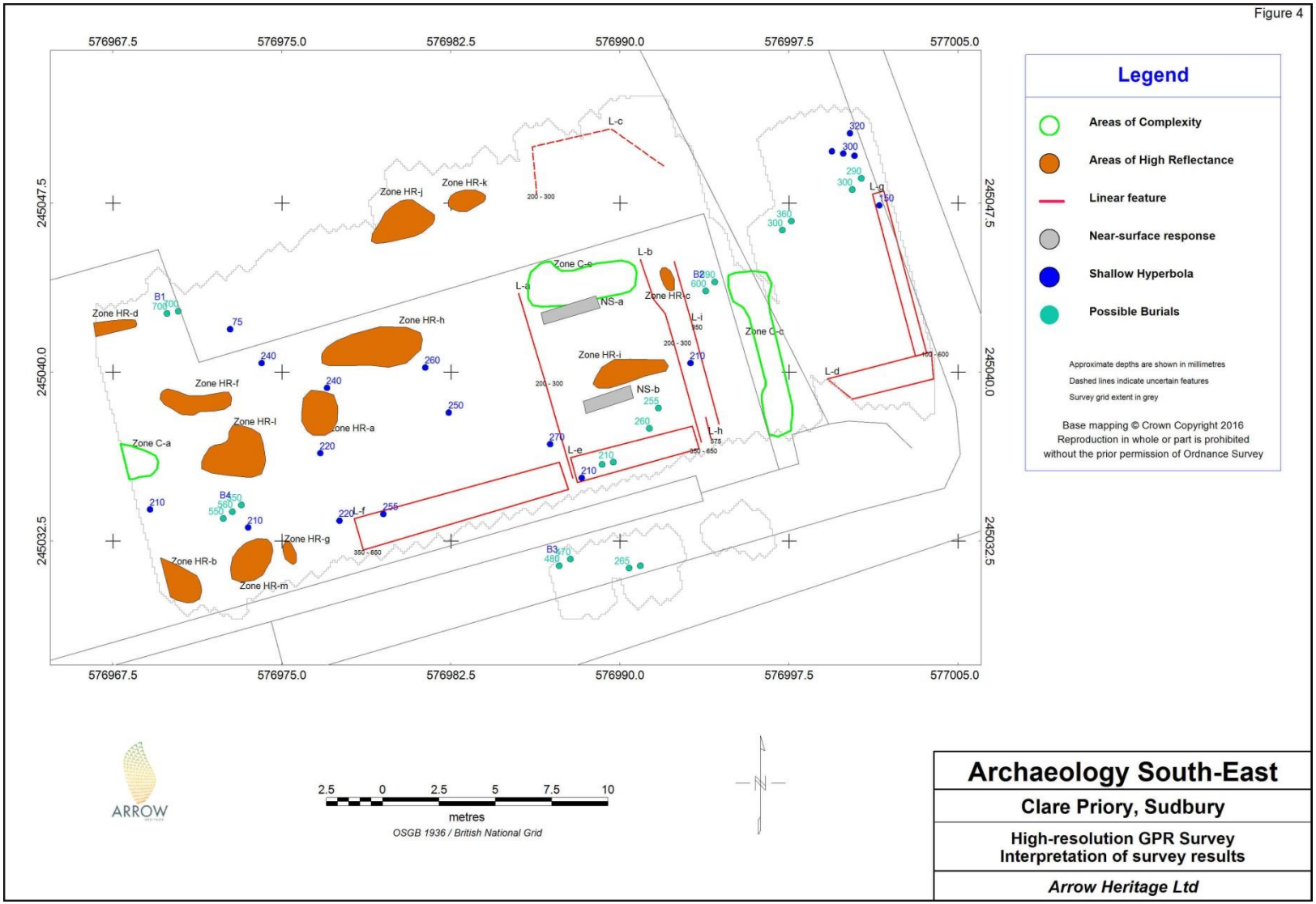
576967.5
576975.0
576982.5
576990.0
576997.5
577005.0
245047.5
245040.0
245032.5
ARROW
2.5 0 2.5 5 7.5
metres
OSGB 1936 / British National Grid
Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
depth slice from 1800 mm to 2000 mm
Arrow Heritage Ltd

Figure 4


576967.5
576975.0
576982.5
576990.0
576997.5
577005.0
245047.5
245040.0
245032.5
Zone HR-j
Zone HR-k
Zone HR-d
Zone HR-h
Zone HR-f
Zone HR-I
Zone HR-a
Zone C-a
Zone HR-g
Zone HR-b
Zone HR-m
Zone C-e
Zone HR-c
Zone HR-i
Zone C-c
NS-a
NS-b
L-a
L-b
L-c
L-d
L-e
L-f
L-g
L-h
L-i
B1
B2
B3
B4
Legend
Areas of Complexity
Areas of High Reflectance
Linear feature
Near-surface response
Shallow Hyperbola
Possible Burials
Approximate depths are shown in millimetres
Dashed lines indicate uncertain features
Survey grid extent in grey
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ARROW
2.5 0 2.5 5 7.5 10
metres
OSGB 1936 / British National Grid
Archaeology South-East
Clare Priory, Sudbury
High-resolution GPR Survey
Interpretation of survey results
Arrow Heritage Ltd