GSB

PROSPECTION Ltd

GEOPHYSICAL SURVEY REPORT
2008/60

Salisbury Cathedral

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Specialising in Shallow and Archaeological Prospection

GSB Survey No. 08/60

Salisbury Cathedral
Wiltshire

Time Team Series XVI Programme XII

NGR	SU 143 295
Location	The cathedral lies towards the south of the city of Salisbury, north of the River Nadder, Wiltshire. Salisbury Cathedral School also lies within the study area.
District	Salisbury.
Topography	Generally flat.
Current land-use	Private/public land.
Soils	"*Urban*" (SSEW 1983).
Geology	River gravel over Upper Chalk (BGS sheet 298).
Archaeology#	The present cathedral dates from c.1200AD.
Survey Methods	Fluxgate Gradiometer, Resistance and Ground Penetrating Radar (GPR).

Aims

To define the location and footprint of the Bell Tower and other features associated with the cathedral. The work forms part of a wider archaeological investigation being carried out by Channel 4's **Time Team**.

Summary of Results*

All three geophysical techniques have detected the Bell Tower, located to the north of Salisbury Cathedral. It shows particularly well in both the GPR and resistance data. GPR survey has also located the footprint of the North Chapel of the cathedral, paths associated with the former graveyard, an ornamental canal and former garden features.

Project Information

Project Co-ordinator: E Wood BSc MIfA
Project Assistants: J Adcock, Dr J Gater and G Taylor
Date of Fieldwork: 30th September, 1st & 2nd October 2008
Date of Report: 20th January 2009

***It is essential that this summary is read in conjunction with the detailed results of the survey.**
 # Taken from *Mower et al. 2008*

Survey Specifications

Method

The survey grid was set out and tied in to the Ordnance Survey (OS) grid using a Trimble R8 Real Time Kinematic (RTK) GPS system by **Dr Henry Chapman**.

Technique	Traverse Separation	Reading Interval	Instrument	Survey Size
Magnetometer - Scanning (Appendix 1)	-	-	-	-
Magnetometer – Detailed (Appendix 1)	1m	0.25	Bartington Grad 601-2	0.23ha
Resistance – Twin Probe (Appendix 1)	1m	1m	Geoscan RM15 and MPX15	0.27ha
Ground Penetrating Radar (GPR) – 250MHz (Appendix 1)	0.5m	0.05m	Sensors and Software Noggin^{Plus} 250MHz	0.3ha

Data Processing

	Magnetic	Resistance	GPR
Tilt Correct	Y	N	N
De-stagger	Y	N	N
Interpolate	Y	Y	Y
Filter	Low Pass	N	De-wow/DC-shift, Bandpass.

Presentation of Results

Report Figures (Printed & Archive CD):	Location, data plots and interpretation diagram on base map (Figures 1-9). GPR time-slices (Figures 10-14).
Reference Figures (Archive CD):	Data plots at 1:500 for reference and analysis. (See List of Figures).
Plot Formats:	See Appendix 1: Technical Information, at end of report.

General Considerations

Any depths referred to in the interpretation of GPR data *are only ever an approximation*. The conversion from delay time to depth depends upon the propagation velocity of radar waves through the ground; this can vary significantly both laterally and vertically on sites such as this. A velocity of 0.08m/ns has been used after an iterative analysis process of fitting hyperbolic curves to point-source reflections. Where there is a strong electromagnetic contrast, the GPR signal can be inter-reflected or reverberated, producing a delay in the reflection of the signal. This is termed 'ringing' and happens, to some extent, with all reflections resulting in a greater apparent depth than actually exists. As a result, it is often not possible to detect the base of features; only the tops of buried deposits are detected with any kind of certainty (Annan 1996).

Results of Survey

1. Ground Penetrating Radar Survey

Full time-slice datasets have been included in the report (Figures 10 – 14) and should be consulted in conjunction with the following discussion as well as the summary diagrams.

Area 1

1.1 The shallowest slices from this area are dominated by broad responses which, although classified as landscaping and garden features, actually pertain to the likely spread of demolition material within the topsoil from the Bell Tower and ancillary buildings (A). The *in-situ* structure of all these buildings starts to become discernible at around 0.4m below ground level and extends to a depth of approximately 1.3m for the ancillary structures and beyond 2.0m for the Bell Tower.

1.2 The ancillary buildings are not as well defined as the Bell Tower and this is likely to be a combination of the less substantial construction and the materials used; these potentially later features may well have been brick-built, a material which is less readily detectable by GPR than stone.

1.3 A reasonable level of detail has been recorded over the Bell Tower and it can be seen that the shallowest (or most robbed-out) foundations are to be found on the southeast corner, whilst the deepest are those in the southwest. The southeast buttress also has a well defined 'quiet zone' (B) at its core; the definition of this 'space' is very sharp and coincides with the remains of an internal stairwell. A wall-line (C) has also been identified which runs through the central pier (D) although, from the GPR data alone, it is not clear whether this is contemporary with the tower; in fact excavation revealed this to be part of an earlier structure.

Area 2

1.4 Again, shallow slices are characterised by a broad zone of increased amplitude (E), in this case likely to represent a former layout of the grounds and footpaths as the primary zone has a curving limit which appears to respect the Cathedral. From within this zone the obvious footprint of the North Chapel (F) is clear from around 0.5m, and remains visible down to beyond 2.0m. It is unclear as to whether the strong reflector towards the centre is anything more than just a response associated with the footings of an adjacent Cathedral buttress.

1.5 Beneath what has been interpreted as former features of the grounds' layout, disturbance has been recorded immediately north of the chapel as far out as the responses at (G), representing the deepest reflectors in this group. However, there is little within this zone, in terms of the distribution and response pattern to suggest an origin. Whilst it is possible that this is consolidation material dumped at the time of the Cathedral's construction, a more significant archaeological interpretation cannot be entirely ignored.

1.6 Linear anomaly (H) presents also something of a quandary; it is flanked on both sides by slightly offset and deeper linear trends and it is difficult to tell whether these all form part of the same feature. Initially it was thought that this may be a large culvert, however the response is nowhere near as strong or extensive as that witnessed over such a feature in Area 4 [see Paragraph 1.11], and anomalies can be seen relatively close below it. Given this and the fact that the cut for the potential service (I) breaks the anomaly, the current tentative interpretation is that this may be a former pathway with a slight camber (this appears more pronounced in the radargrams owing to the exaggerated vertical axis) and drains on either side.

1.7 Numerous other trends have been highlighted which may represent further drain or service cuts, and their significance is thought to be minimal. The only exceptions are the faint trends (J) which appear sub-circular. A suggestion was made that these may be the remnants of bell pits, but this seems unlikely given their diameter (2.5m and 3.5m) and they are more likely to be an effect of the disturbance immediately above.

Area 3

1.8 The intricate stratigraphy uncovered upon excavation of the South Chapel explains the difficulty in interpreting this complex dataset. Even the outer walls of the chapel are unclear and have not been recorded as distinctly as those of its northern counterpart. Strong responses towards the north and west appeared to be reflections from adjacent buttress footings, whilst reflector (K) seemed to be a grave slab. Other anomalies and trends within the northern half of the survey were more difficult to attribute an exact origin and it must be assumed that, as a whole, they reflect the numerous phases of use.

1.9 The southern half of the survey area is perhaps more perplexing as little was assumed to be here, however, a rectilinear distribution of reflectors have been recorded, some quite strong. It should be noted, however, that they do not share the depth extent of those anomalies recorded within the chapel and bottom-out at around 1.0m below ground level. Interpretation is not helped by the use of this area as a garden of remembrance and a number of plaques and markers were in place at the time of survey; for now, the origin of these anomalies remains unclear.

Area4

1.10 This is another area where the shallowest slices show an effect of garden layout by virtue of a broad spread of increased response (L), the limits of which can be seen on one side to curve in respect of the present trees. Within this area, from the near-surface right through to around 1.8m, a mass of high amplitude anomalies and patches of increased response (M) can be seen to form a largely rectilinear pattern. Whilst the strongest anomalies are likely to be the remnants of small buildings and/or boundary walls, some of the responses could be part of a drainage system perhaps for a formal garden or similar. Whatever the exact cause is, it is markedly different to the much 'quieter' area in the western third of the survey area.

1.11 The line of a former ornamental canal is clearly visible and, by the pattern of response, it seems that sections of the retaining walls may be relatively well-preserved. The canal runs up to a large culvert (N) that flanks the boundary wall and it appears that a number of linear anomalies and trends also terminate in this vicinity, suggesting the presence of smaller drains and culverts that feed into this outlet.

1.12 Survey towards the vestry was complicated and largely precluded by planting beds and dense vegetation. There also appeared to be a number of linear anomalies assumed to be service routes (potentially of antiquity) all of which served to complicate the interpretation. As such, it is impossible to say what the source of the responses around (O) is, and it must be assumed that they hold some archaeological potential given their proximity to the assumed position of the demolished medieval sub-treasurer's residence.

1.13 The deepest time slices show trends and zones of increased response all oriented on a southwest-northeast line; these are assumed to be an effect of the underlying alluvial gravel deposits.

2. Magnetic Survey

2.1 Within the northeastern section of the data negative anomalies relate to the foundations of the Bell Tower and correspond to some of the GPR anomalies [see Paragraph 1.1]. Potential further archaeological anomalies have been identified but as the magnetic background levels are quite noisy, the dataset is difficult to interpret. They could, however, be associated with the buildings surrounding the Bell Tower.

2.2 The trend at (i) corresponds to a former path as marked on a plan of the church and churchyard from 1786. A band of ferrous response crossing the data is a service pipe, whilst similar responses in the north and south relate to a metal fence and Heras fencing, respectively.

3. Resistance Survey

3.1 Foundations of the Bell Tower and central pillar (1) are clearly visible within the data as high resistance readings. The buttresses are well defined, and as with the GPR data, the southeast corner walls appear to be ‘robbed out’.

3.2 Towards the west of the data curving bands of high resistance (2) correspond to a former path as marked on a map by William Nash c. 1751. A number of trends are also visible within the data; (3) relates to a path which is visible in the magnetic data [Paragraph 2.2]. None of the other trends relate to the map evidence, therefore they may be related to the buildings surrounding the Bell Tower.

3.3 High resistance anomaly (4) appears rectangular, however a large tree was located at this point and it is likely that this is the cause of the response. However, on the old maps an ‘L’ shaped building is shown within this vicinity and an archaeological origin is possible.

3.4 Two negative responses within the data are likely to be service pipes leading to the cathedral.

4. Conclusions

4.1 The Bell Tower has been clearly identified within the GPR and resistance data; the clarity of the results is demonstrated by the identification of a stairwell in the southwest corner of the tower. The magnetic data show negative responses over the tower, but are not as clear as with the other two techniques. Possible ancillary buildings have also been identified to the west of the tower.

4.2 The GPR data collected abutting the cathedral, show footprints of the North Chapel and a complex series of reflections associated with differing phases of activity in Area 3. An ornamental canal and a formal garden layout has been located within Area 4.

References

Annan AP, 1996 — *Ground Penetrating Radar (workshop notes).* Sensors and Software Inc, Canada.

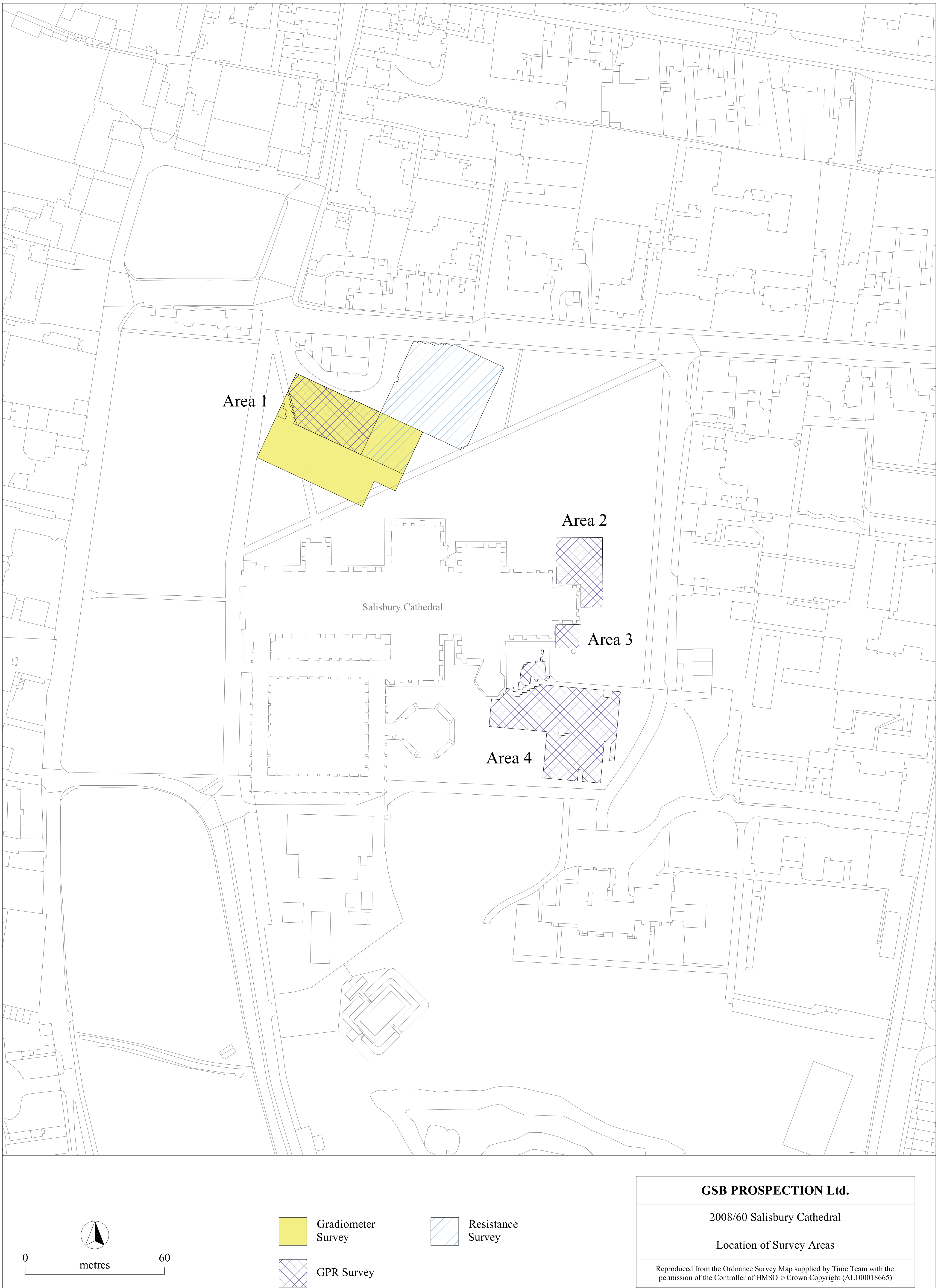
Mower, J Knappett, B & Ord, L 2008 — *Proposed Archaeological Evaluation at Salisbury Cathedral, Wiltshire.* Unpublished Report.

SSEW, 1983 — Soils of England and Wales. *Sheet 6 – South East England*. Soil Survey of England and Wales.

List of Figures

Report Figures

Reference Figures on CD



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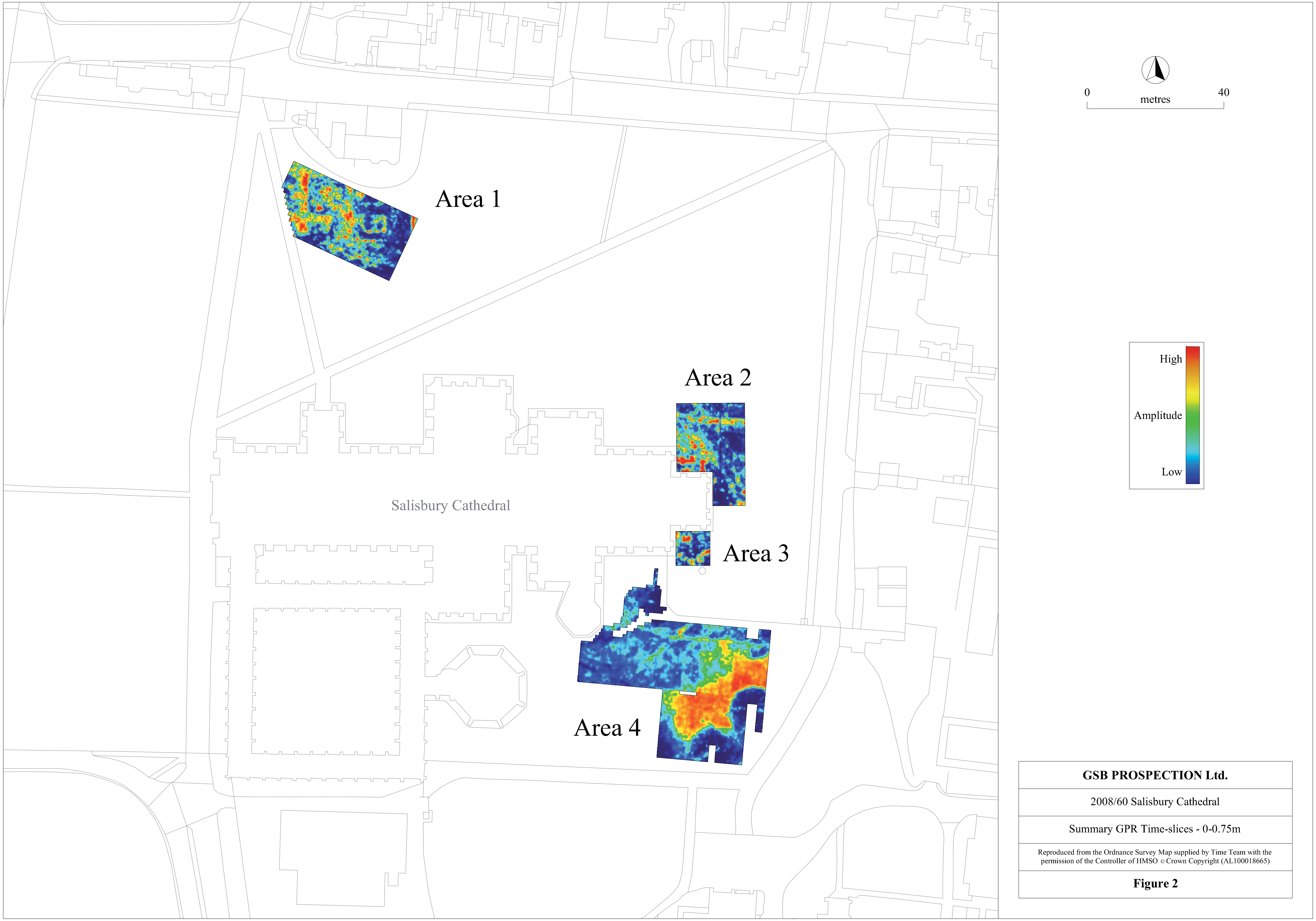
Location of Survey Areas

Figure 1



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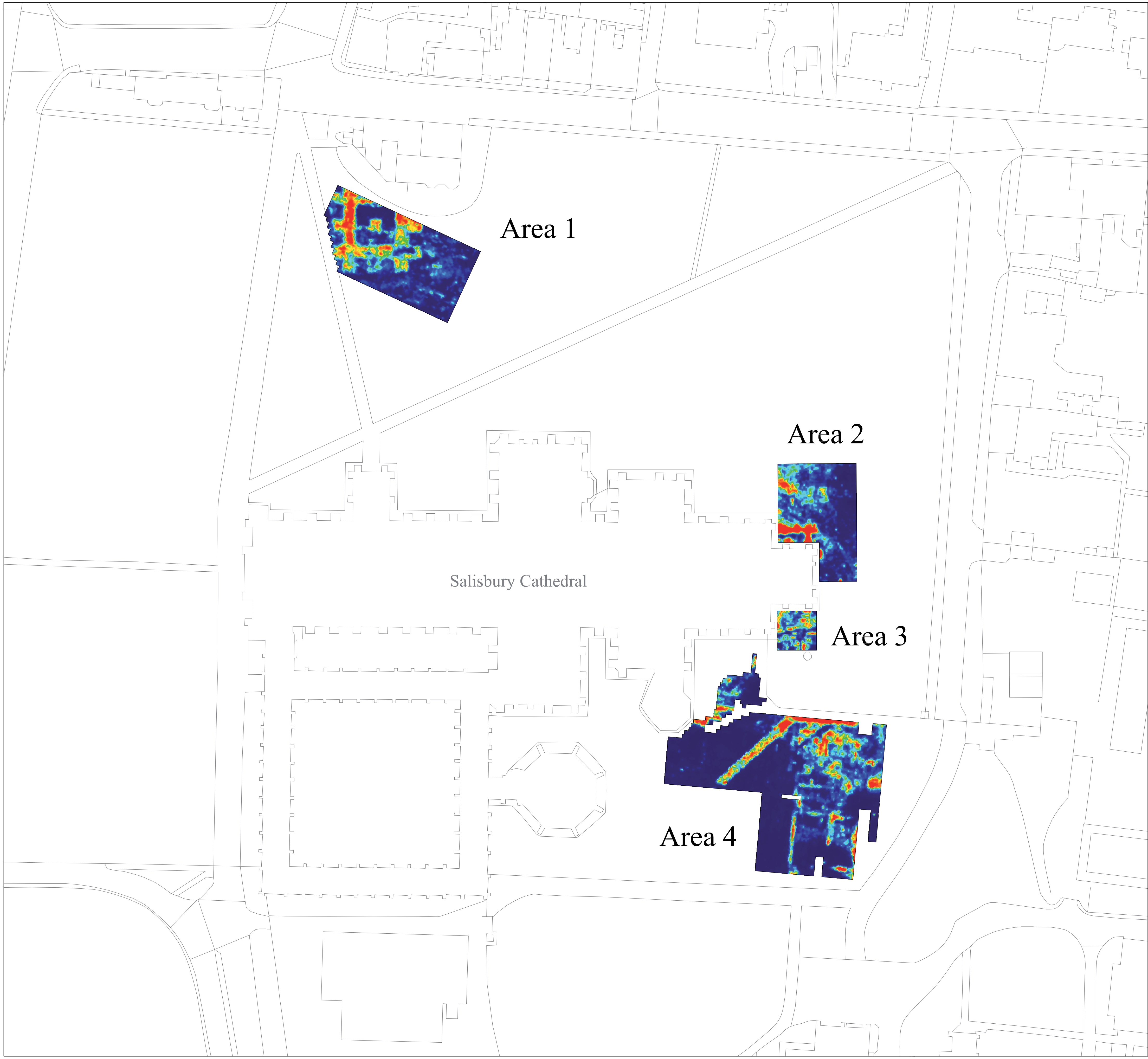
Summary GPR Time-slices - 0-0.75m

Figure 2



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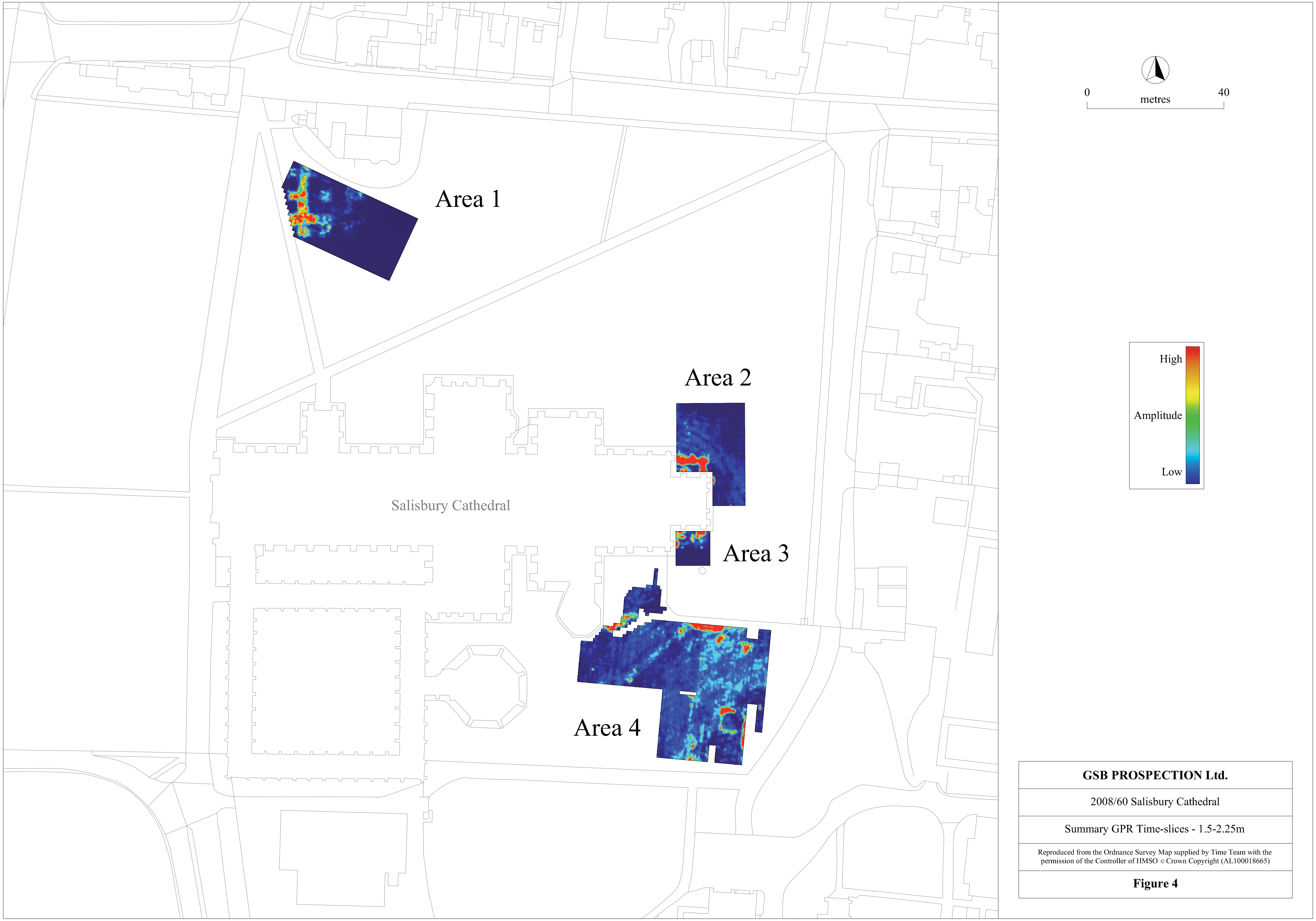
Summary GPR Time-slices - 0.75-1.5m

Figure 3



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Summary GPR Time-slices - 1.5-2.25m

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Figure 4

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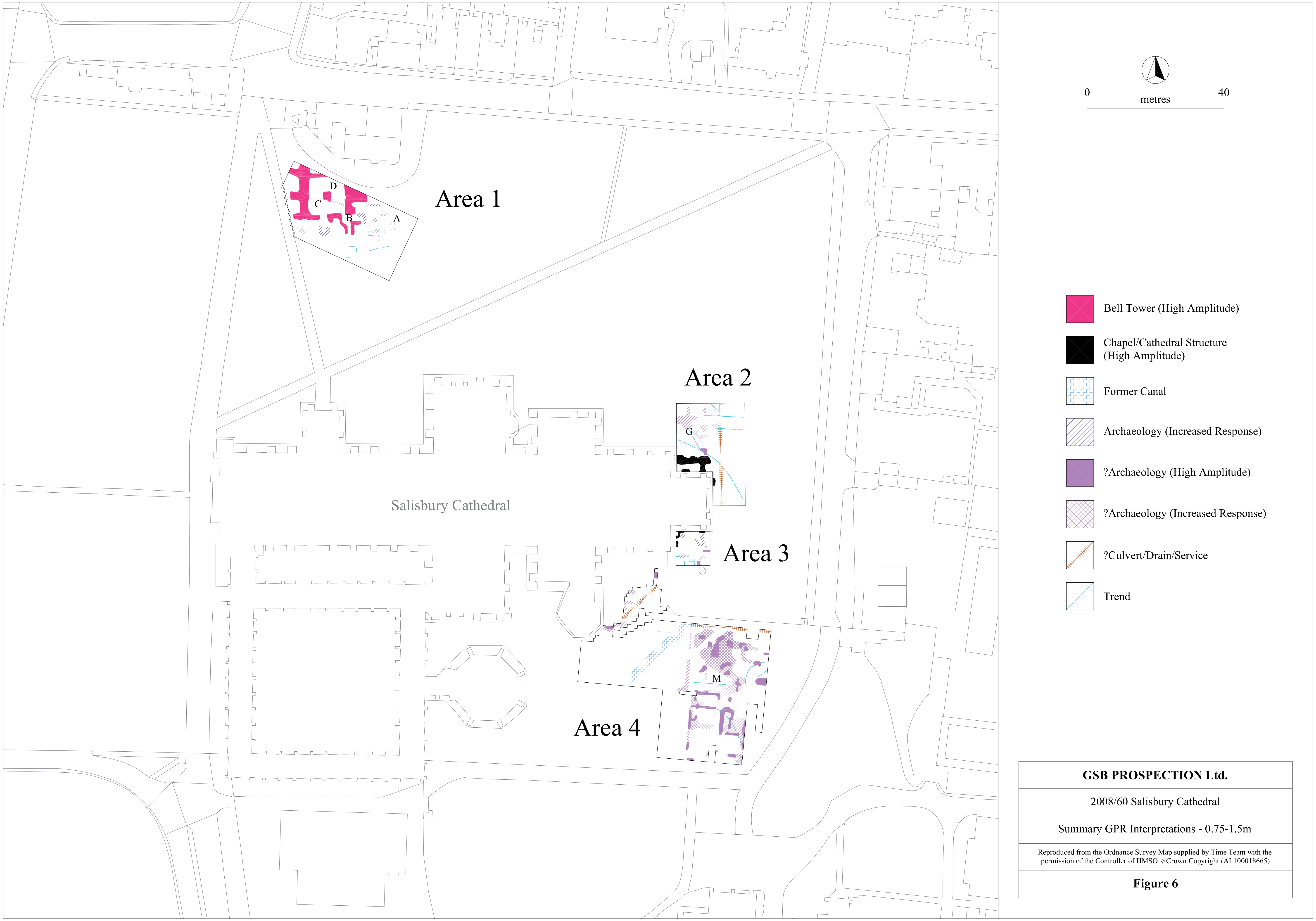
Summary GPR Interpretations - 0-0.75m

Figure 5



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Summary GPR Interpretations - 0.75-1.5m

Figure 6

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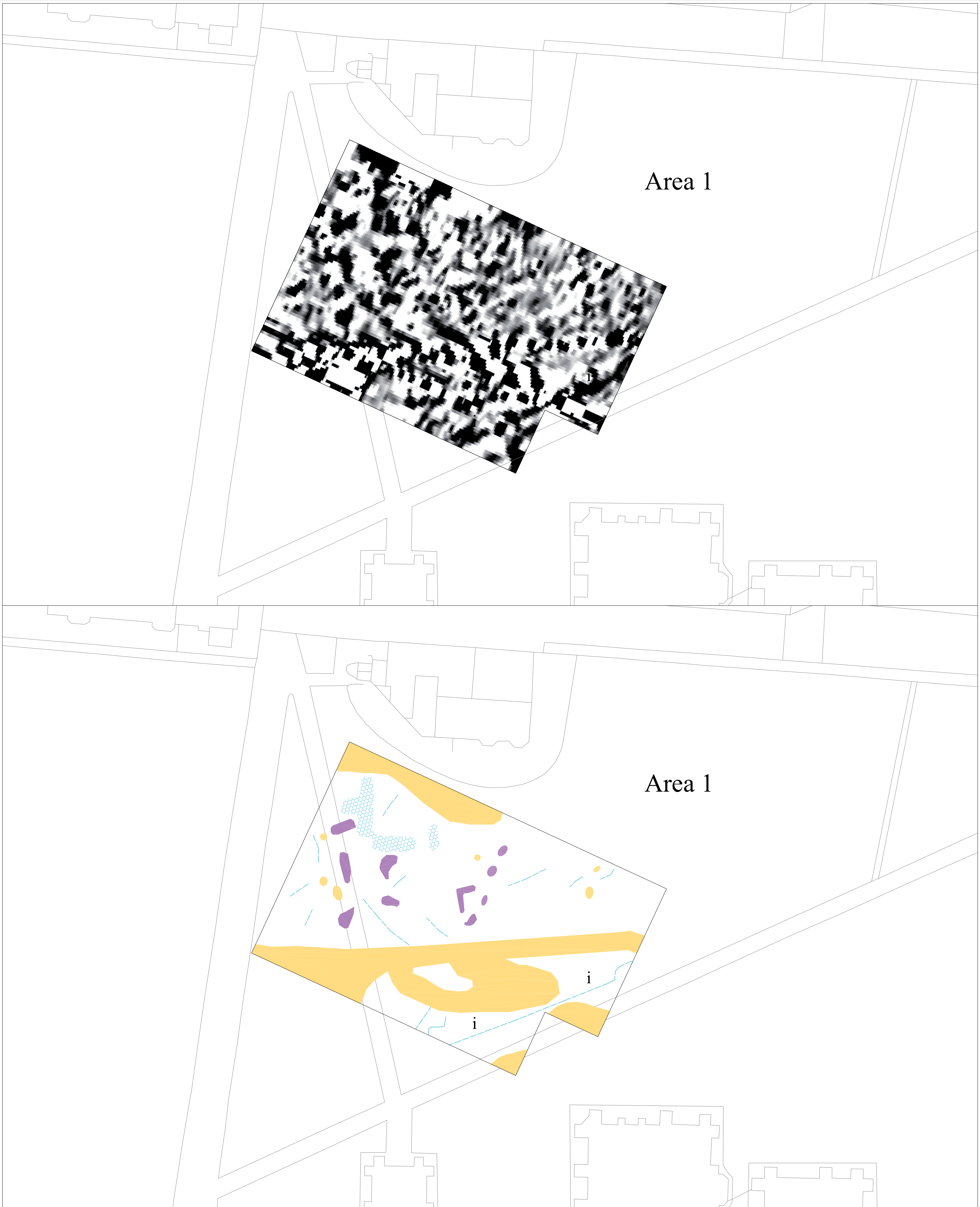
Summary GPR Interpretations - 1.5-2.25m

Figure 7



0 metres 25

nT 5 -2

Negative Anomaly - Bell Tower

?Archaeology

Trend

Ferrous

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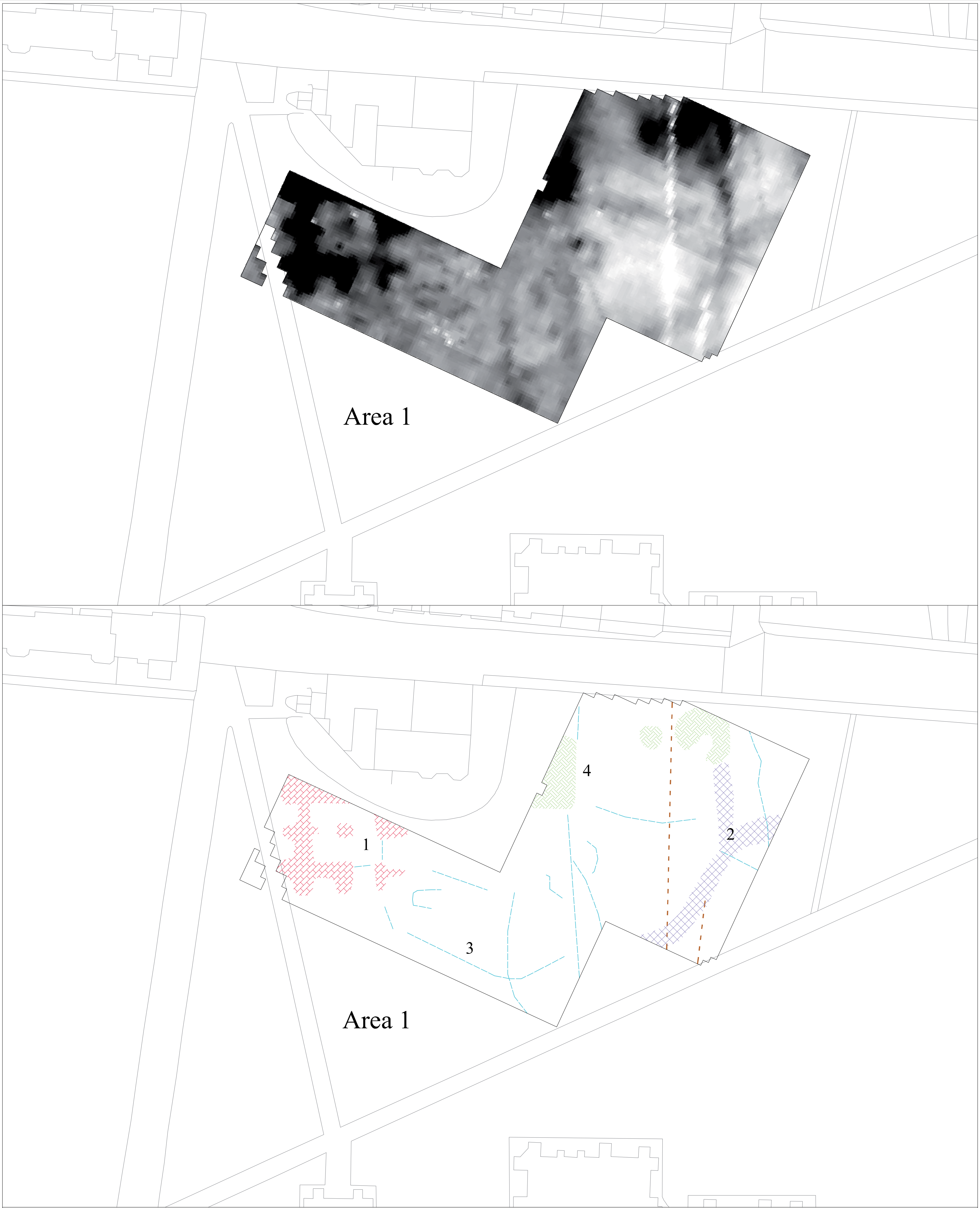
Summary Gradiometer Data

Figure 8



0 metres 25

SD
1
-1

High Resistance - Bell Tower

High Resistance - Former Path

High Resistance - Trend

High Resistance - ?Natural

Low Resistance - Service Pipe

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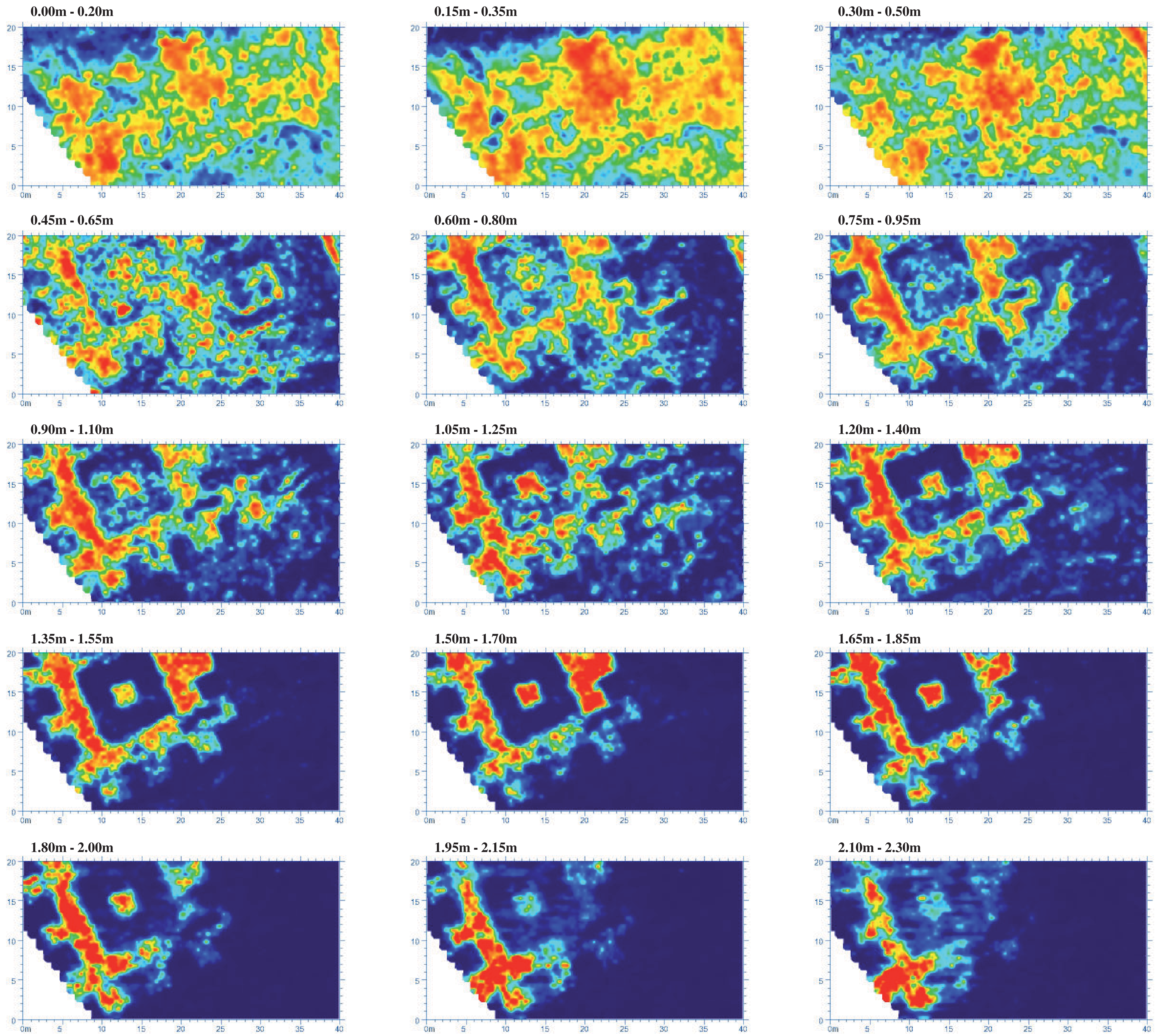
Summary Resistance Data

Figure 9



Low High
AMPLITUDE

Data processing:
De-wow/DC-shift, Bandpass filter.

0 m 20

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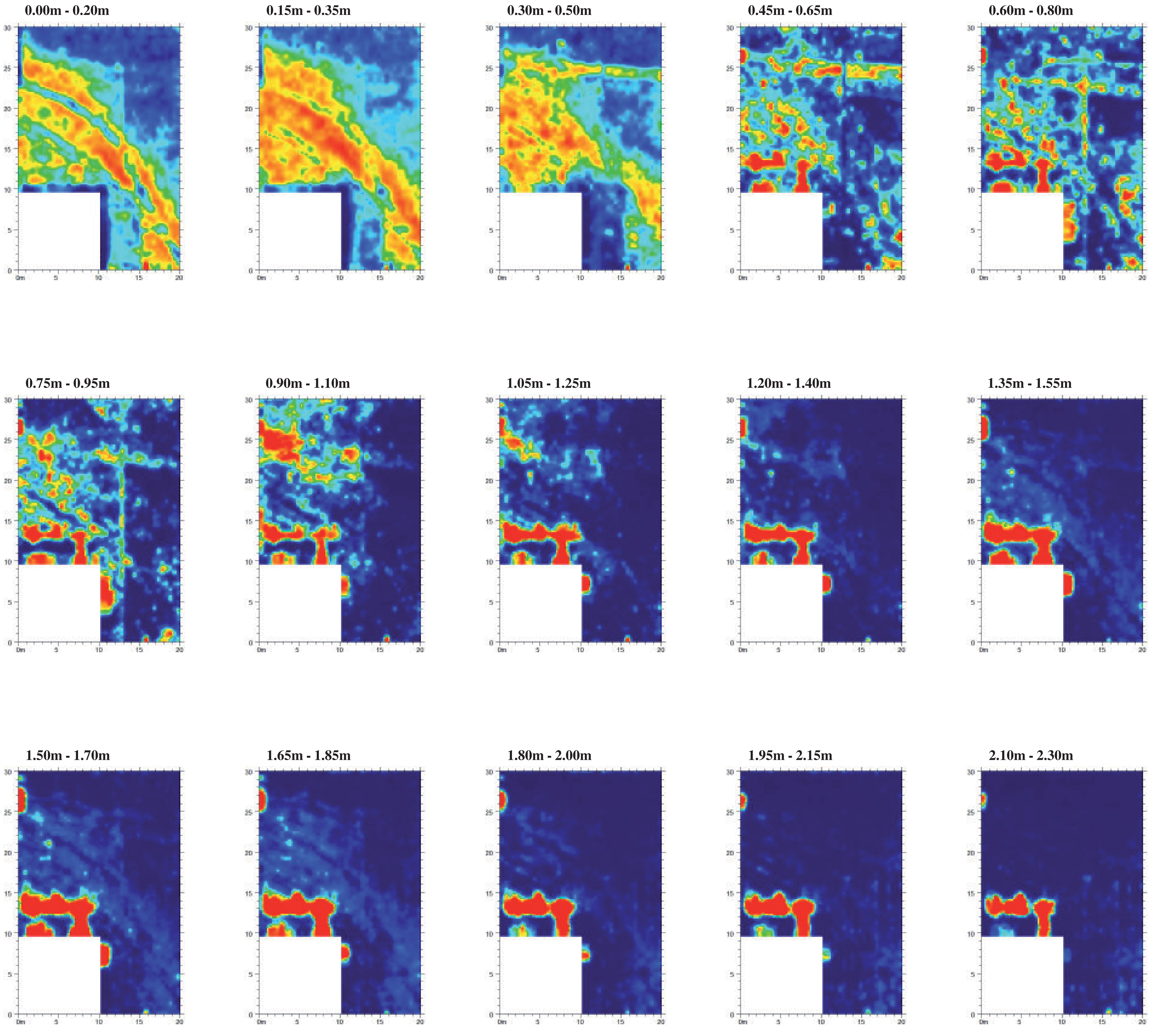
2008/60 Salisbury Cathedral
GPR Data - Bell Tower
Figure 10



Low High
AMPLITUDE

Data processing:
De-wow/DC-shift, Bandpass filter.

0 m 20

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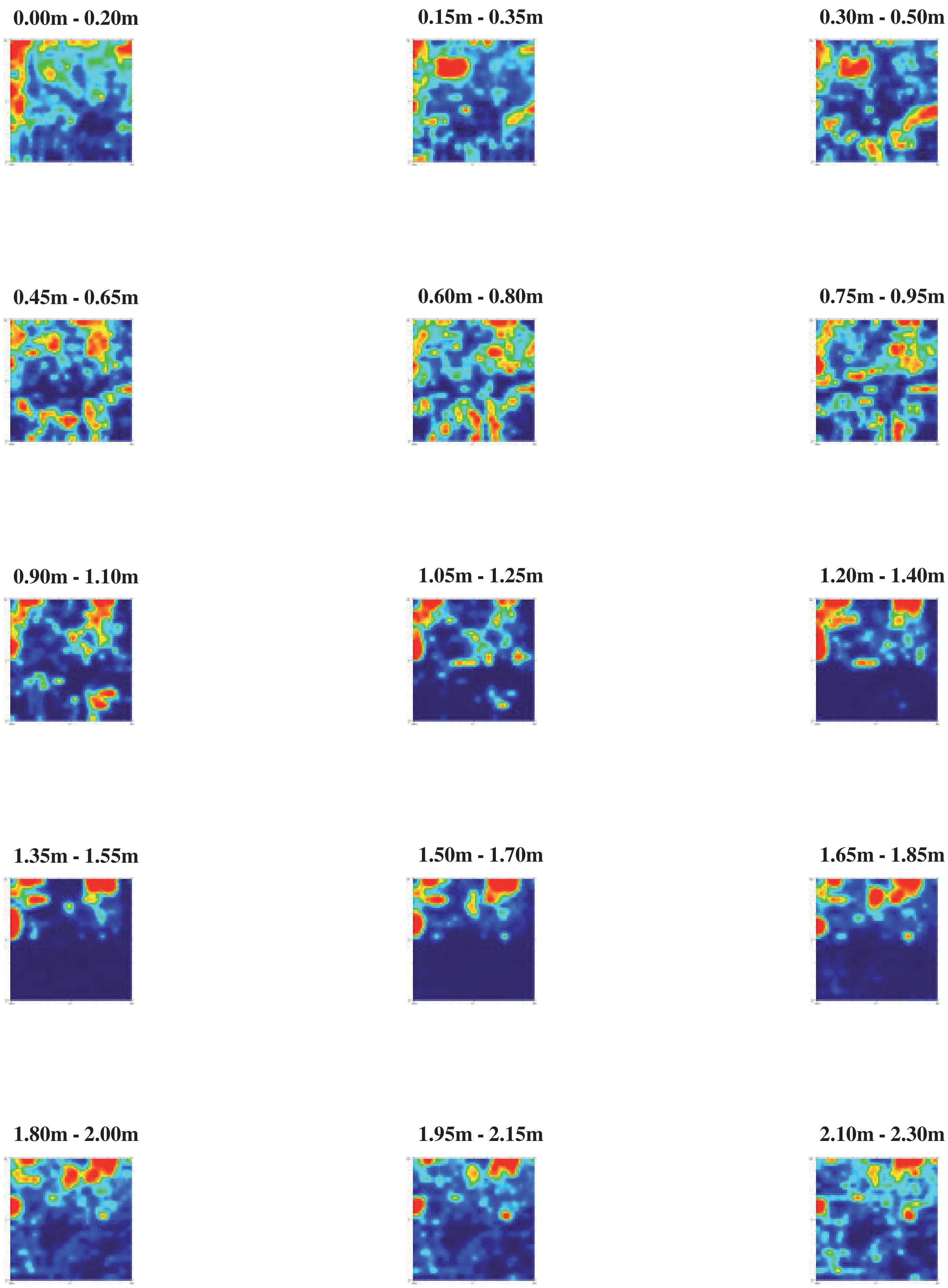
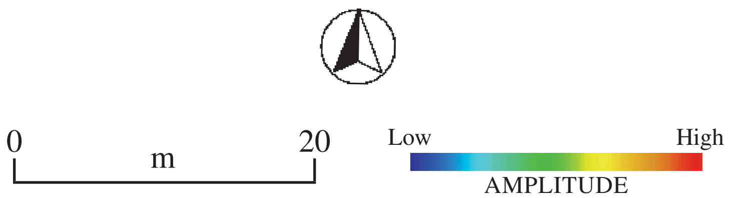
2008/60 Salisbury Cathedral
GPR Data - North Chapel
Figure 11





Data processing:
De-wow/DC-shift, Bandpass filter.

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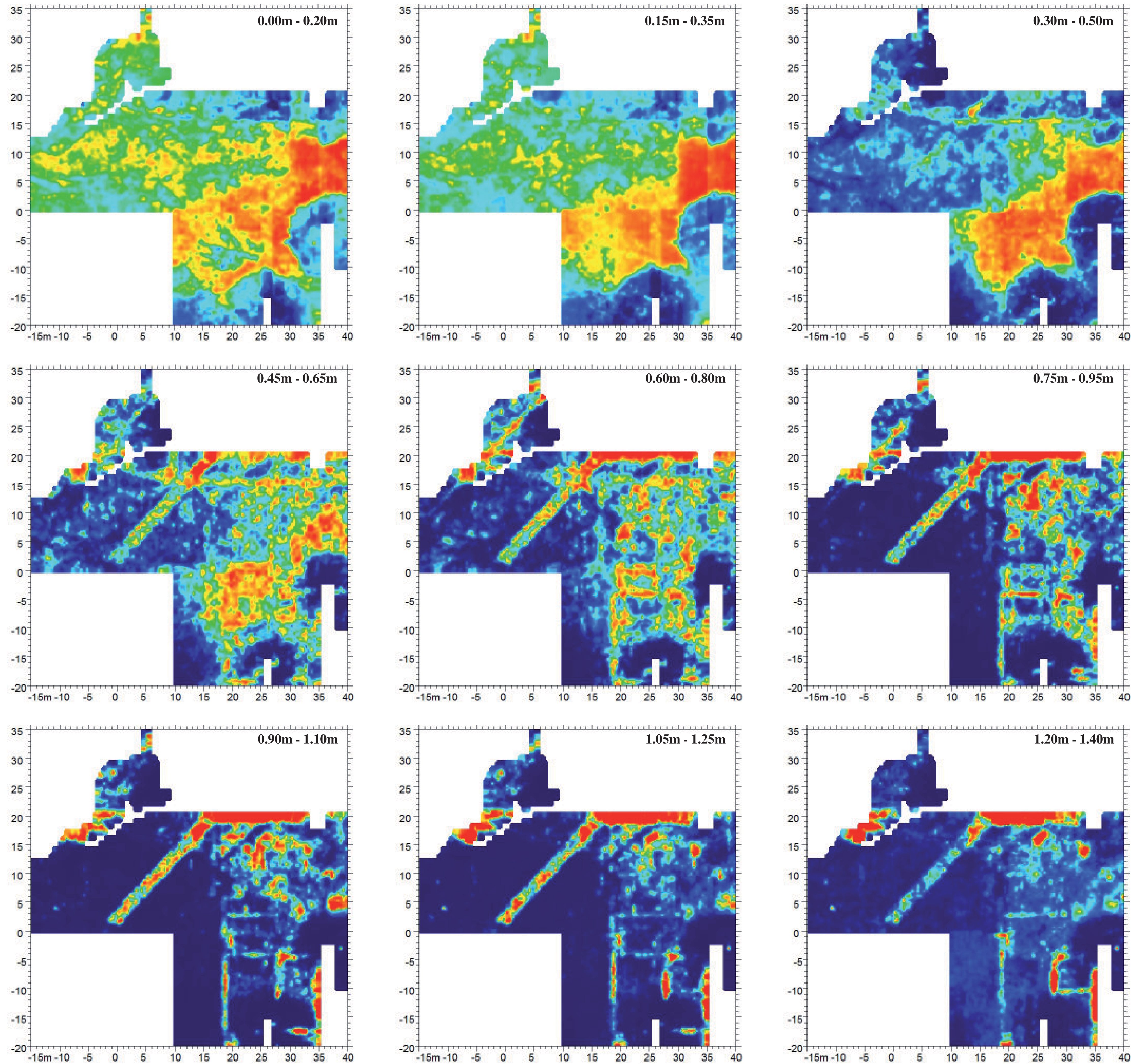
GPR Data - South Chapel

Figure 12



Low High
AMPLITUDE

Data processing:
De-wow/DC-shift, Bandpass filter.

0 m 20

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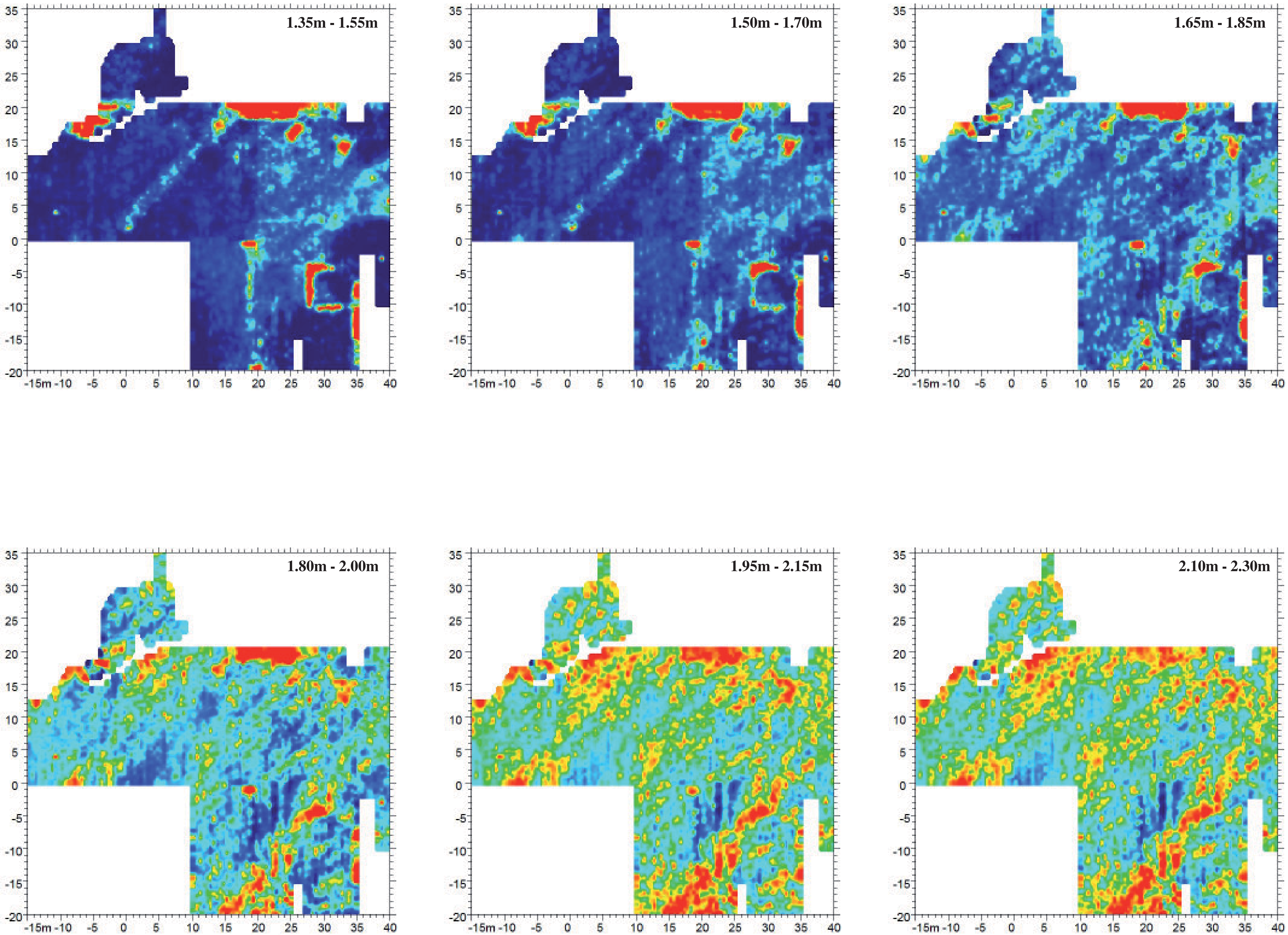
GPR Data - South Side
Figure 13



Data processing:
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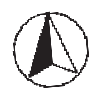

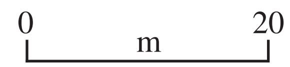

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2008/60 Salisbury Cathedral
GPR Data - South Side (cont.)
Figure 14

Appendix 1: Technical Information

Instrumentation

Fluxgate Gradiometer: Geoscan FM36/256 and Bartington *Grad*601-2

Both the Geoscan and Bartington instruments comprise two fluxgate sensors mounted vertically apart; the distance between the sensors on the former is 500mm, on the latter 1000mm. The gradiometers are carried by hand, with the bottom sensor approximately 100-300mm from the ground surface. At each survey station, the difference in the magnetic field between the two fluxgates is measured in nanoTesla (nT). The sensitivity of the instrument can be adjusted; for most archaeological surveys the most sensitive range (0.1nT) is used. The fluxgate gradiometer suppresses any diurnal or regional effects. Generally, features up to 1m deep may be detected by this method. Having two gradiometer units mounted laterally with a separation of 1000mm, the Bartington instrument can collect two lines of data per traverse.

Resistance Meter: Geoscan RM15

This instrument measures the electrical resistance of the earth, using a system of four electrodes (two current and two potential.) Depending on the arrangement of these electrodes an exact measurement of a specific volume of earth may be acquired. This resistance value may then be used to calculate the earth resistivity. The most common arrangement is the Twin Probe configuration which involves two pairs of electrodes (one current and one potential): one pair remain in a fixed position, whilst the other measures the resistance variations across a grid. The resistance is measured in ohms and, when calculated, resistivity is in ohm-metres. The resistance method as used for standard area survey employs a probe separation of 0.5m, which samples to a depth of approximately 0.75m. The nature of the overburden and underlying geology will cause variations in this depth.

GPR: Sensors & Software Noggin Smartcart

The Noggin system includes an onboard digital video logger (DVL III), 250 MHz or 500MHz antenna, an odometer wheel and battery. It is, therefore, a fully integrated system. The built-in software uses the integrated odometer to provide an accurate distance measurement to the response. The data are recorded in digital format and can be processed to produce depth slice maps, 2D sections or 3D cubes.

Display Options

XY Trace

This involves a line representation of the data. Each successive row of data is equally incremented in the Y axis, to produce a stacked profile effect. This display may incorporate a hidden-line removal algorithm, which blocks out lines behind the major peaks and can aid interpretation. The advantages of this type of display are that it allows the full range of the data to be viewed and shows the shape of the individual anomalies. The display may also be changed by altering the horizontal viewing angle and the angle above the plane. The output may be either colour or black and white.

Greyscale

This format divides a given range of readings into a set number of classes. Each class is represented by a specific shade of grey, the intensity increasing with value. All values above the given range are allocated the same shade (maximum intensity); similarly all values below the given range are represented by the minimum intensity shade. Similar plots can be produced in colour, either using a wide range of colours or by selecting two or three colours to represent positive and negative values. The assigned range (plotting levels) can be adjusted to emphasise different anomalies in the data-set.

Relief Plot

This is a method of display that creates a three dimensional effect by directing an imaginary light source on a given data set. Particular elements of the results are highlighted depending on the angle of strike of the light source. This display method is particularly useful when applied to resistance data to highlight subtle changes in resistance that might otherwise be obscured.

3D Surface Plot

This is similar to the XY trace, but in 3 dimensions. Each data point of a survey is represented in its relative position on the *x* and *y* axes and the data value is represented in the *z* axis. This gives a digital terrain, or topographic effect.

Radargram

Radar data comprise a record of reflection intensity against the time taken for the emitted energy to travel from the transmitter down to the reflector and back to the receiver. The resultant plot is effectively a vertical section through the ground along the line of the traverse, with time (depth) on the vertical axis, displacement on the horizontal axis and reflection intensity as a grey or colour scale.

Time Slice

If a number of radargrams are collected over a grid, or in conjunction with GPS data, it is possible to reconstruct the entire dataset into a 3D volume. This can then be resampled to compile 'plan' maps of response strength at increasing time (or depth) offsets, thus simplifying the visualisation of how anomalies vary beneath the surface across a survey area.

Terms Commonly used in the Interpretation of Results

Magnetic

Archaeology	This term is used when the form, nature and pattern of the response are clearly or very probably archaeological These anomalies, whilst considered anthropogenic, could be of any age.
? Archaeology	The interpretation of such anomalies is often tentative, with the anomalies exhibiting either weak signal strength or forming incomplete archaeological patterns. They may be the result of variable soil depth, plough damage or even aliasing as a result of data collection orientation.
Areas of Increased Magnetic Response	These responses show no visual indications on the ground surface and are considered to have some archaeological potential.
Industrial	Strong magnetic anomalies that, due to their shape and form or the context in which they are found, suggest the presence of kilns, ovens, corn dryers, metal-working areas or hearths. It should be noted that in many instances modern ferrous material can produce similar magnetic anomalies.
Natural	These responses form clear patterns in geographical zones where natural variations are known to produce significant magnetic distortions e.g. palaeochannels or magnetic gravels.
? Natural	These are anomalies that are likely to be natural in origin i.e. geological or pedological.
Ridge and Furrow	These are regular and broad linear anomalies that are presumed to be the result of ancient cultivation. In some cases the response may be the result of modern activity.
Ploughing Trend	These are isolated or grouped linear responses. They are normally narrow and are presumed modern when aligned to current field boundaries or following present ploughing.
Uncertain Origin	Often, anomalies (both positive and negative) will be recorded which stand out from the background magnetic variation yet show little to suggest an exact origin. This may be because the characteristics and distribution of the responses straddle the categories of "*?Archaeology*" and "*?Natural*" or that they are simply of an unusual form.
Trend	This is usually an ill-defined, weak, isolated or obscured linear anomaly of unknown cause or date.
Areas of Magnetic Disturbance	These responses are commonly found in places where modern ferrous or fired materials are present e.g. brick rubble. They are presumed to be modern.
Ferrous Response	This type of response is associated with ferrous material and may result from small items in the topsoil, larger buried objects such as pipes, or above ground features such as fence lines or pylons. Ferrous responses are usually regarded as modern. Individual burnt stones, fired bricks or igneous rocks can produce responses similar to ferrous material.

Resistance

Archaeology	High or low res responses are clearly or very probably archaeological These anomalies, whilst considered anthropogenic, could be of any age.
? Archaeology	The interpretation of such anomalies is often tentative, with the anomalies exhibiting either weak signal strength or forming incomplete archaeological patterns. They may be the result of variable soil depth, plough damage or even aliasing as a result of data collection orientation.
Natural	These responses form clear patterns in geographical zones where natural variations are known to produce significant magnetic distortions e.g. palaeochannels or magnetic gravels.
? Natural	These are anomalies that are likely to be natural in origin i.e. geological or pedological.
? Landscaping / topography	These are regular and broad linear anomalies that are presumed to be the result of ancient cultivation. In some cases the response may be the result of modern activity.
Vegetation	These are isolated or grouped linear responses. They are normally narrow and are presumed modern when aligned to current field boundaries or following present ploughing.
Trend	This is usually an ill-defined, weak, isolated or obscured linear anomaly of unknown cause or date.

GPR

Wall /Foundation/ /Vault /Culvert etc.	High amplitude anomaly definitions used when other evidence is available that supports a clear archaeological interpretation.
Archaeology	Anomalies whose form, nature and pattern indicate archaeology but where little or no supporting evidence exists. If a more precise archaeological interpretation is possible, for example the responses appear to respect known local archaeology, then this will be indicated in the accompanying text. As low amplitude responses are less obvious features it is unlikely that they would have a definitive categorisation.
? Archaeology	When the anomaly could be archaeologically significant, given its discrete nature, but where the distribution of the responses is not clearly archaeological. Interpretation of such anomalies is often tentative, exhibiting either little contrast or forming incomplete archaeological patterns.
Historic	Responses showing clear correlation with earlier map evidence.
?Historic	Responses relating to features not directly recorded on earlier maps but which appear to respect features that are. May form patterns suggestive of formal gardens, landscaping or footpaths.
Area of Anomalous Response	An area in which the response levels are very slightly elevated or diminshed with respect to the 'background'. Where no obvious surface features or documentary evidence can explain this spread of altered reflectivity it is assumed to denote some kind of disturbance, though the origins could be of any age and either anthropogenic or natural. Possible explanations are changes in subsurface composition and groundwater 'ponding'.
Natural	Anomalies relating to natural sub-surface features as indicated by documentary sources, local knowledge or evidence on the surface.
?Natural	Responses forming patterns akin to subsoil/geological variations either attenuating or reflecting greater amounts of energy. An archaeological origin such as rubble spreads or robbed out remains cannot be dismissed.
Trend	An ill defined, weak or isolated linear anomaly of unknown cause or date.
Modern	Reflections that indicate features such as services, rebar or modern cellars correlating with available evidence (maps, communications with the client, alignment of drain covers etc.).
?Modern	Reflections appearing to indicate buried services but where there is no supporting evidence. Also applies to responses which form patterns, or are at a depth which suggests a modern origin. An archaeological source cannot be completely dismissed.
Surface	Responses clearly due to surface discontinuities, the effects of which may be seen to 'ring' down through radargrams and so incorrectly appearing in the deeper time-slices.

Data Processing

Zero Mean Traverse	This process which sets the background mean of each traverse within each grid to zero. The operation removes striping effects and edge discontinuities over the whole of the data set. It is usually only applied to gradiometer data.
Step Correction	When gradiometer data are collected in 'zig-zag' fashion, stepping errors can sometimes arise. These occur because of a slight difference in the speed of walking on the forward and reverse traverses. The result is a staggered effect in the data, which is particularly noticeable on linear anomalies. This process corrects these errors
Interpolation	When geophysical data are presented as a greyscale, each data point is represented as a small square. The resulting plot can sometimes have a 'blocky' appearance. The interpolation process calculates and inserts additional values between existing data points. The process can be carried out with points *along* a traverse (the *x* axis) and/or *between* traverses (the *y* axis) and results in a smoother greyscale image.
Despike	In resistance survey, spurious readings can occasionally occur, usually due to a poor contact of the probes with the surface. This process removes the spurious readings, replacing them with values calculated by taking the mean and standard deviation of surrounding data points. It is not usually applied to gradiometer data.
High Pass Filter	Carried out over the whole a resistance data-set, the filter removes low frequency, large scale spatial detail, such as that produced by broad geological changes. The result is to enhance the visibility of the smaller scale archaeological anomalies that are otherwise hidden within the broad 'background' change in resistance. It is not usually applied to gradiometer data.
GPR Filters	There are a wide range of GPR filters available and their application will vary from project to project. The most commonly used are: Dewow (removes low frequency, down-trace instrument noise); DC-Shift (re-establishes oscillation of the radar pulse around the zero point); Bandpass Filtering (suppresses frequencies outside of the antenna's peak bandwidth thus reducing noise); Background Removal (can remove ringing, instrument noise and minimize the near-surface 'coupling' effect); Migration (collapses hyperbolic tails back towards the reflection source).