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GEOPHYSICAL SURVEY REPORT 2006/46

WINDSOR CASTLE, Berkshire



Client:



Wildfire Television

SURVEY RESULTS

2006 / 46 Windsor Castle, Berkshire

1. Survey Areas

- 1.1 Two areas were investigated: The Upper Ward and The Lower Ward - Denton's Commons. The first area was surveyed using Fluxgate Gradiometry (Bartington Grad 601-2; readings at 1.0m x 0.25m), Twin-Probe Resistance Survey (Geoscan RM15 Twin-probe configuration; readings at 0.5m x 0.5m for both 0.5m and 1.0m probe separations) and GPR (Noggin Smartcart Plus with 250 MHz antenna; readings collected orthogonally along traverses 0.5m apart); the second area was investigated solely with GPR. These areas are shown on Figure 1 at a scale of 1:1500.
- 1.2 The survey grid was set out by **GSB Prospection Ltd** and tied in to the Ordnance Survey grid by **Dr Henry Chapman** using a Trimble dGPS system.

2. Data Processing and Display

- 2.1 The magnetic data have been pre-processed by removing baseline shifts due to zig-zag data collection. Where appropriate, traverses have been corrected for minor misalignments due to variations in walking speed. Unless stated it should be assumed that no filtering has been undertaken on the datasets collected in this project. In some greyscale representations the data may have been interpolated, which reduces pixelation in the image.
- 2.2 Where necessary the resistance data have been pre-processed to correct for grid-mismatch errors resulting from survey on different days. De-spiking has been undertaken, to reduce minor errors from contact with the ground surface; this is carried out prior to interpolation, which is often employed to reduce pixelation in greyscale image. Filtering is commonly used on resistance data to suppress, for example, a geological background and where used this will be noted on the relevant diagrams.
- 2.3 The GPR data traverses (*radargrams*) have been reconstructed to form a 3-dimensional block of data which has been 'time-sliced' horizontally to produce plan maps (*time-slices*) of responses at increasing depths. Where filtering has been applied, this is indicated on the relevant data plots and details of typical filters are included in the technical Appendix.
- 2.4 The magnetic results are displayed as XY traces and greyscale images and the resistance data as greyscale images. The GPR data are portrayed as colour time-slices and selected radargrams highlight anomalies of interest. These options are discussed further in the technical Appendix.
- 2.5 Numbers and letters within the main body of the text refer to specific anomalies highlighted in the relevant resistance and GPR diagrams respectively.

3. General Considerations and Complicating factors

- 3.1 Conditions for survey on the first area in the Upper Ward were ideal, the ground being flat and the grass very short. The second area comprised a tarmac car park with a slightly raised small lawn with a tree in the middle.
- 3.2 While depths have been indicated on the GPR diagrams, these have to be viewed with caution. The conversion from time to depth depends on the velocity of the electromagnetic signal through the ground. Given the nature of the site, this may vary markedly over relatively small distances and, as a result, any depth conversion is *only an approximation*. An average velocity of 0.084m/ns has been used for the time to depth conversions following velocity analysis using graphical methods involving the fitting of curves to point source reflections.
- 3.3 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'. This happens, to some extent, with all reflections and results 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 features/deposits are detected with certainty (Annan 1997).

4. Upper Ward: Results of Resistance Survey - Figs 2, 3, 9 & 10

- 4.1 Gas, electricity and water services crossing the lawn dominate the results. In addition, a tunnel cut into the chalk bedrock at the eastern end of the quadrangle has caused a band of high resistance readings (1) A former water or fuel 'tank' is the cause of the high readings in the centre of the lawn (2).
- 4.2 High resistance anomalies (3) at the western edge of the lawn are presumably associated with the Round Tower's former moat / defences. A band of high resistance (4) in the southern centre of the lawn could be a former path or road that has been truncated, but it does not align with the George IV Gateway to the south. The origin of high readings (5) in the northern centre is unknown; they could be of archaeological interest. A poorly defined curving band of readings (6) in the south-east quadrant of the lawn, together with other high resistance values (7), have increased archaeological potential in light of the GPR results (see Section 6 below).

5. Upper Ward: Results of Magnetic Survey – Figs 4 & 10

- 5.1 The fluxgate gradiometer data reflect a magnetically disturbed site; the strength of the anomalies associated with the buried services and the large 'tank' (see 4.1) that have been identified will have clearly masked any features of potential archaeological interest. However, the results can be used to pinpoint the location of services and compare the information with existing plans. It should be noted that some plastic pipes and cables may not have been detected by the gradiometer; a full 'Catscan' is recommended prior to any invasive work.

6. Upper Ward: Results of GPR Survey – Figs 5 to 10

- 6.1 The dataset from the Upper Ward quadrangle is complex and this is largely down to the great number of services contained within it. They vary in size, depth and composition, accounting for the variation in visibility. Some of these features have a degree of ‘fall’ on them and as such show up best at different places along their length through the time-slices. Also in some places the service itself does not show as a strong reflection rather it appears as a ‘quiet zone’, probably representing the cut of the trench through the surrounding material. This is advantageous as some plastic pipes/conduit and small cables may not be readily detectable on their own.
- 6.2 The most obvious services are those under the eastern end of the lawn where a broad anomaly (A) has been produced presumably by the digging and relaying of a large swathe of turf. This manifests as a zone of few reflections in the time-slices (Figures 5, 7 and 8) and a distinct discontinuity in the radargrams (Figure 6). Within this are three main services with a branch off to the southeast.
- 6.3 Of the numerous, potentially relatively modern features mapped, the most intriguing is the large square anomaly (B). The radargrams imply a reinforced concrete structure, identifiable by the highlighted regular pattern of sharp responses (Figure 6). The strong nature of the responses from the top of the feature make an estimation of its depth extent impossible but it seems likely that this is some form of tank or reservoir. An inlet/outlet is obvious (C) on the northern side (and coincides with a parched mark in the grass) and there is also potentially a pipe running out from this side (D). It may be that anomaly (E) is associated with the ‘tank’ (B), given its proximity to the presumed service (D). The former shows some strong reflections and an element of ringing (Figure 6) down through the section. This suggests that (E) is perhaps another tank or a backfilled feature such as a shallow chamber. It should be born in mind that the apparent relation to (D) and (E) may simply be a chance alignment given the ‘busy’ nature of the site.
- 6.4 Archaeologically, the dataset has several anomalies of potential interest. The first of these is the semi-circular feature (F). This correlates with the resistance data and is believed to indicate the position of the moat east of the Round Tower, which is now back-filled. Within this zone, highlighted as ‘?Archaeology’ in the time-slices (Figure 5) and noted on the radargrams (Figure 6), are a number of large reflectors which do not correlate with the presumed service routes. These may be a combination of construction features *in situ* and, or, large pieces of masonry or similar within the backfill.
- 6.5 There is seemingly a central band of increased reflectivity, as indicated by the ‘increased amplitude response’ category in the interpretation diagrams (Figure 5), which is in contrast to the responses further west. The presence of services (A) has made ascertaining the eastern limit to this increased response impossible. Within this zone, as the time-slices deepen, more well-defined zones of high amplitude responses become apparent. Some of these (G) show little diagnostic form to aid interpretation, but they may still warrant further investigation as they are not obvious services.
- 6.6 As opposed to (G), anomaly (H) and the group of reflectors (I) do have distinct shape and form and, for the most part, are also relatively clear in the radargrams. This suggests that they are potentially significant structural features; the main question remaining being their age and thus importance. The broad anomaly (H) is also apparent in the resistance data (4) and may represent a former pathway, though this interpretation has already been questioned (see Paragraph 4.2.).
- 6.7 The anomalies (J) are interesting, forming a distinct rectilinear pattern towards their northern limits. The two diagonal ‘legs’ of this feature then extend south from this and represent some very strong reflections considering the lack of such intensity across the remainder of the survey area at this depth. The break in these anomalies is seemingly caused by a possible service feature (K) higher in the section which has subsequently masked any responses from beneath it. The slight

quandary is that, despite being offset from the main services forming (A), the eastern side of (J) is aligned perfectly with this feature. It is possible, especially upon viewing the radargrams (Figure 6) that these are further services or some other modern feature, perhaps even being related to (B), however at the same time their potential as legitimate archaeological targets (historic culverts perhaps) cannot be ignored.

- 6.8 Encompassing (I) and (J) is a weak but very distinctive curving feature (L). It seems highly unlikely that this is a service route and as such has been interpreted as potentially of great archaeological significance. Whilst not readily identifiable in the individual radargrams, the subtlety of (L) should not detract from its possible significance.
- 6.9 In the deepest slices a broad, yet relatively faint band of responses are thought to be a facet of the local geology showing through. Whilst features showing at the limits of penetration must be viewed with caution, the fact that the striations seem to be coherent across the slices it seems that this is probably a real effect of the underlying bedrock.

Figure 10 is a summary diagram showing the location of all the services detected by the three geophysical techniques plotted alongside the Ploughman Craven Associates (PCA) plan of known services. While there appears to be good correlation of the evidence the possibility that other services remain undetected or unmapped cannot be ignored.

7. Lower Ward - Denton's Commons: Results of GPR Survey – Figs 11, 12 & 13

- 7.1 As with the Upper Ward, the results from Denton's Commons have been dominated by services. A network of pipes/cables has been identified and there is little that could be categorically identified as potential archaeological remains. The raised bed has also introduced unwanted noise into the dataset.
- 7.2 In the southwest of the data a zone of high amplitude (M) extends down into the deeper time-slices. Despite being in the region of a purported wall corner, the archaeological potential is low as it lies under a service line and correlates with small areas where the tarmac has been taken up and re-laid.

8. Conclusions

- 8.1 The geophysical investigations have successfully mapped a number of buried services in both areas and in the Upper Ward defined the extent of a subway/service corridor.
- 8.2 The Upper Ward surveys, in particular the GPR, have identified a number of 'targets' of possible archaeological interest. Potentially the most interesting is a curving response in the south-east corner of the lawn that may be associated with other potential structures. A second curving response at the western edge of the lawn is presumably associated with the Round Tower moat and shows potential structural features. There is an unusual response in both the resistance and GPR data in the centre of the lawn; it may be a former path or roadway but it doesn't align with the George IV Gateway that lies to the south. A presumed water or fuel 'tank' has been located in the centre of the lawn.
- 8.3 The Lower Ward – Denton's Commons - GPR survey failed to identify any features that equate with the documentary / plan evidence for a Great Hall. The number of services that cross the survey is clearly having a detrimental effect on the clarity of the GPR results and as such they may be masking any buried archaeology.

Project Co-ordinators: J Gater & J Adcock
Project Assistants: G Taylor, I Wilkins & E Wood

Date of Survey: 12th – 14th June 2006
Date of Final Report: 28th June 2006

References:

- Annan A. P. 1997 *Ground Penetrating Radar Workshop Notes*, Sensors & Software Inc., Canada.
- Woodhead, R. *in prep.* *Project design for Archaeological Investigations in the Upper Ward and Lower Ward at Windsor Castle*, Wildfire Television document.

SITE SUMMARY SHEET

2006 / 46 Windsor Castle, Berkshire

NGR: SU 969770-496985/177029 (centred)

Location, topography and geology

Windsor Castle is located on the top of a steep chalk cliff which rises sharply from the south bank of the River Thames to a height of approximately 50m AOD. Thames Street, the northern extension of Windsor High Street, forms the western boundary of the castle while the other three sides are bounded by Home Park. The areas under investigation comprised a lawn in the Upper Ward Quadrangle and a tarmac car park in the Lower Ward at Denton's Commons; the former is level while the latter slopes gently downwards to the west. The underlying geology is an outcrop of Upper Chalk surrounded by river terrace gravels (Geological Survey of Britain, Sheet 269).

Archaeology

Windsor Castle is a Scheduled Ancient Monument (WN80) that measures some 5.3ha in area. A Section 42 Licence (Ref CB63/E; AA056157) was issued by English Heritage in order for the geophysical survey to be carried out. The history of the Castle is summarised in Woodhead (*in prep.*).

Aims of Survey

It was hoped that geophysical survey using resistance, magnetometry and ground penetrating radar (GPR) would provide information on the character and archaeological stratigraphy in the areas selected for investigation. In particular it was hoped that the surveys might identify structural or cut features and provide an indication to the depth of the underlying bedrock. A further aim was to identify the locations of buried services and other modern underground features.

Summary of Results *

The surveys have successfully mapped a number of buried services in both areas and in the Upper Ward defined the extent of a subway/service corridor.

The Upper Ward surveys, in particular the (GPR), have identified a number of 'targets' of possible archaeological interest. Potentially the most interesting is a clear curving response in the south-east corner of the lawn that may be associated with other potential structural features. A second curving response at the western edge of the lawn is presumably associated with the Round Tower moat and shows potential structural features. There is an unusual response in both the resistance and GPR data in the centre of the lawn; it may be a former path or roadway but it doesn't align with the George IV Gateway that lies to the south. A presumed 'tank' is visible in the centre of the lawn.

The Lower Ward – Denton's Commons. The GPR survey failed to identify any features that equate with the documentary / plan evidence for a Great Hall. The number of services that cross the survey area are clearly having a detrimental effect on the clarity of the GPR results and as such they may be masking any buried archaeology.

Background information taken from R Woodhead (*in prep.*)

* It is essential that this summary is read in conjunction with the detailed results of the survey.

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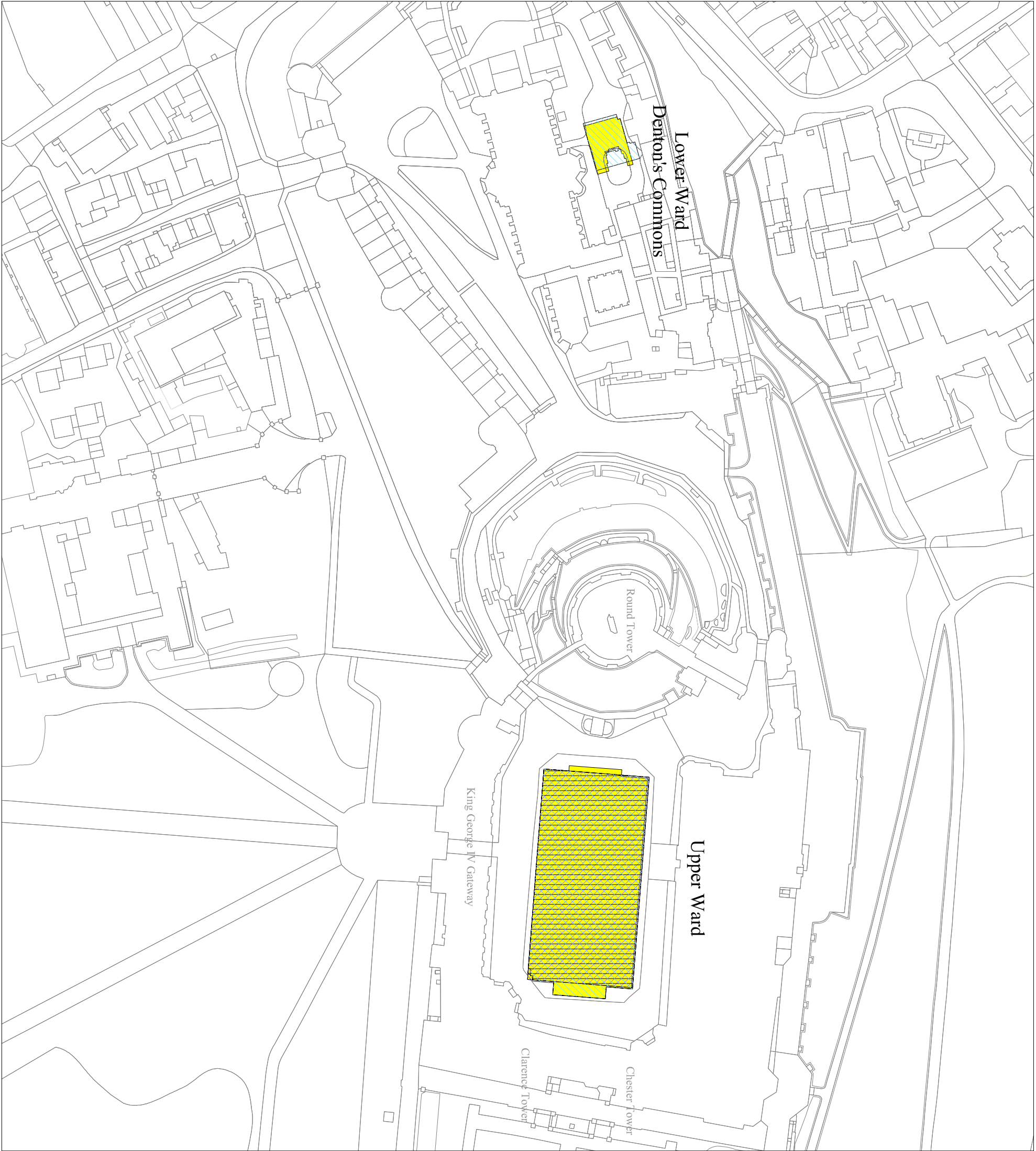
Main Report

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Archive CD

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GSB PROSPECTION Ltd.
PROJECT: 2006/46 Windsor Castle
TITLE: Location of Survey Areas
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


-  Gradiometer Survey
-  Resistance Survey
-  GPR Survey - X Direction
-  GPR Survey - Y Direction



Figure 1

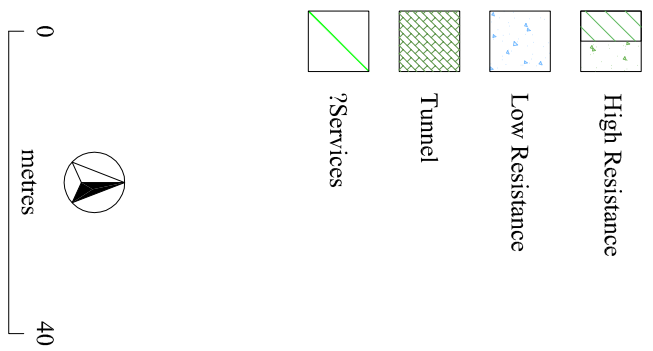
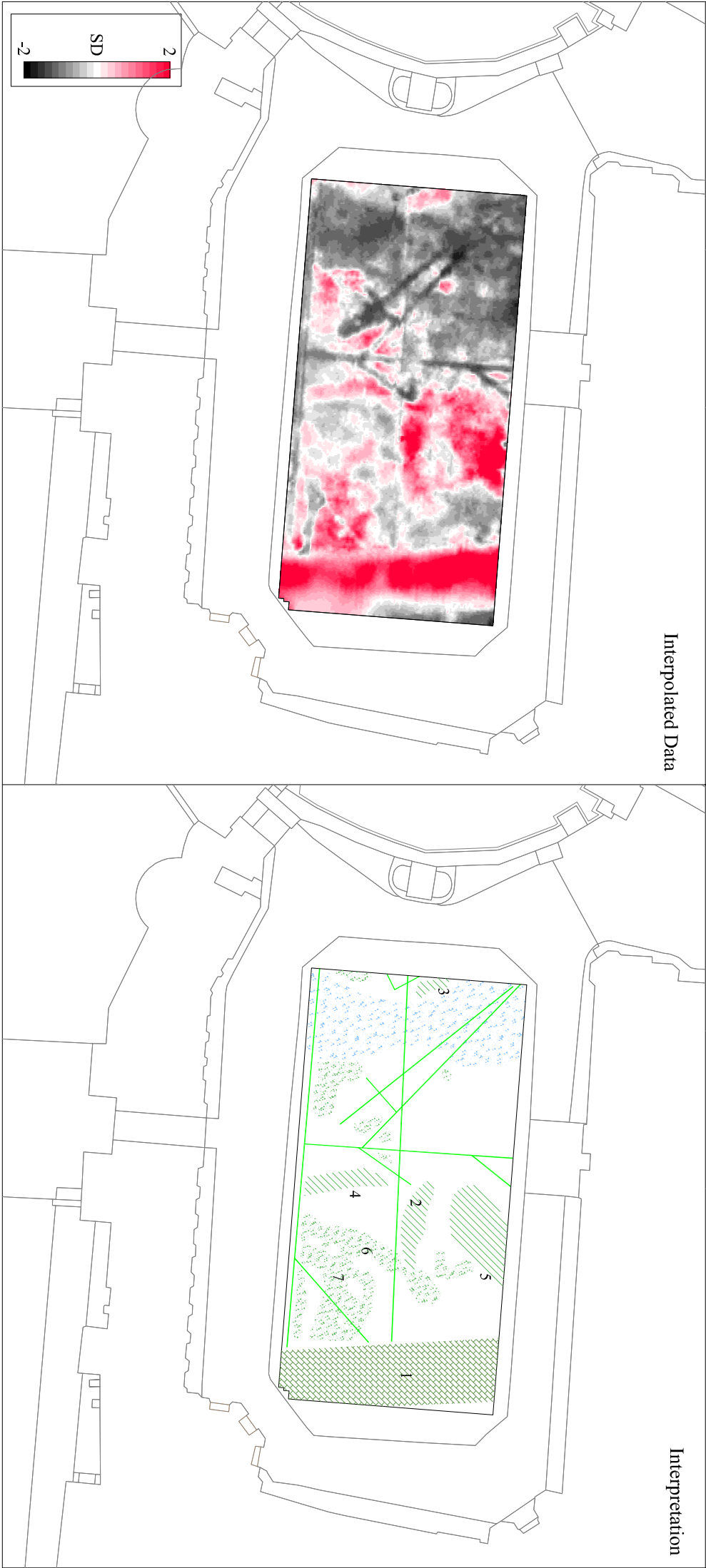
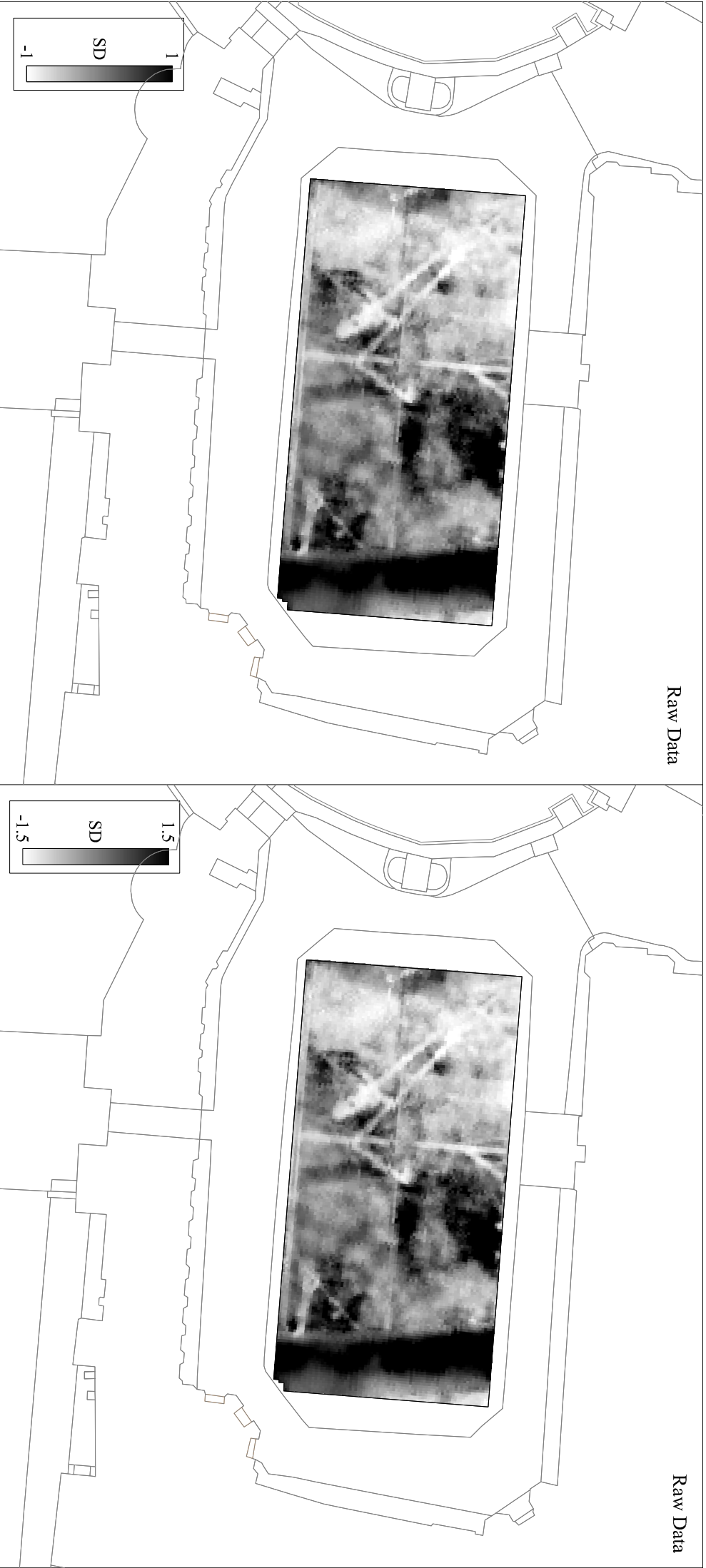


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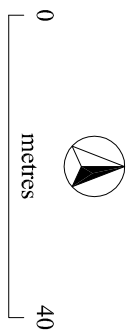
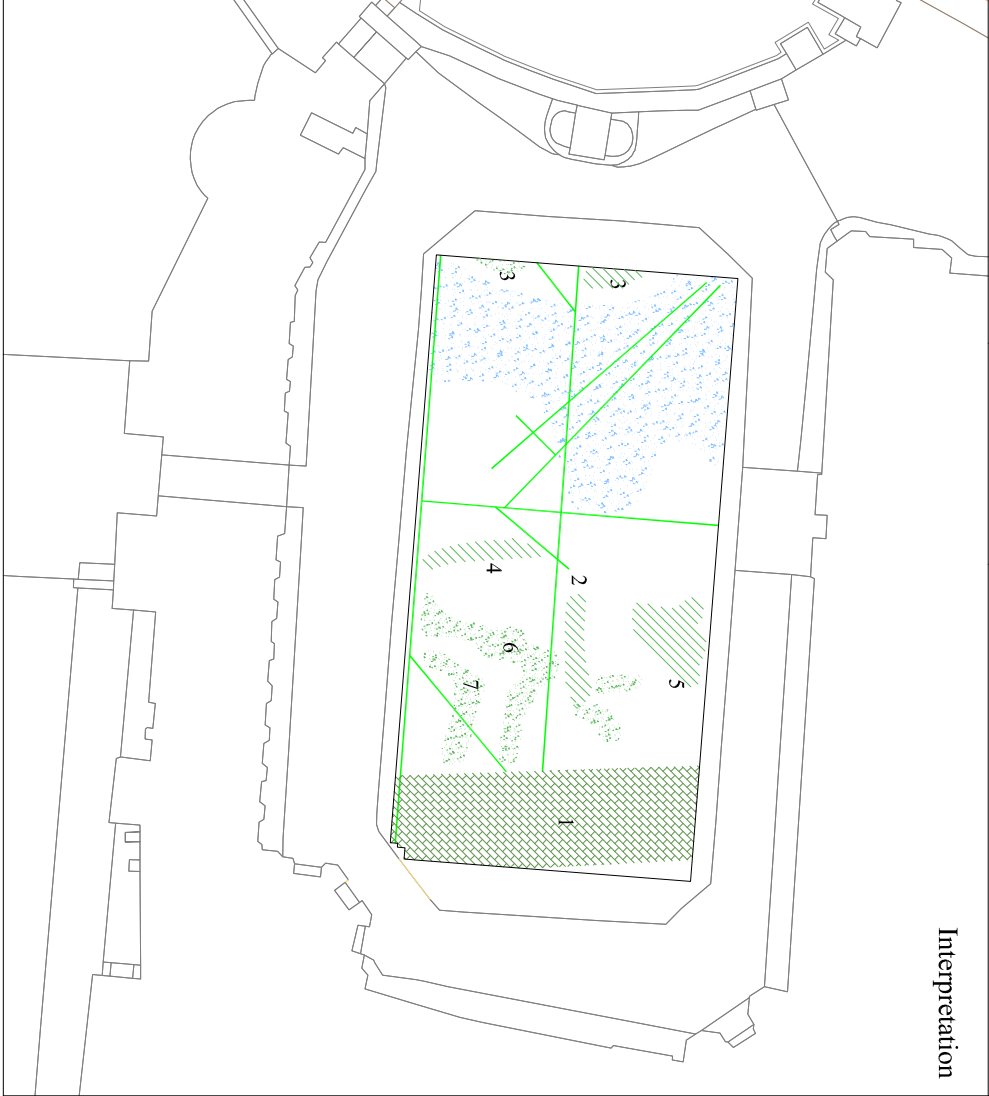
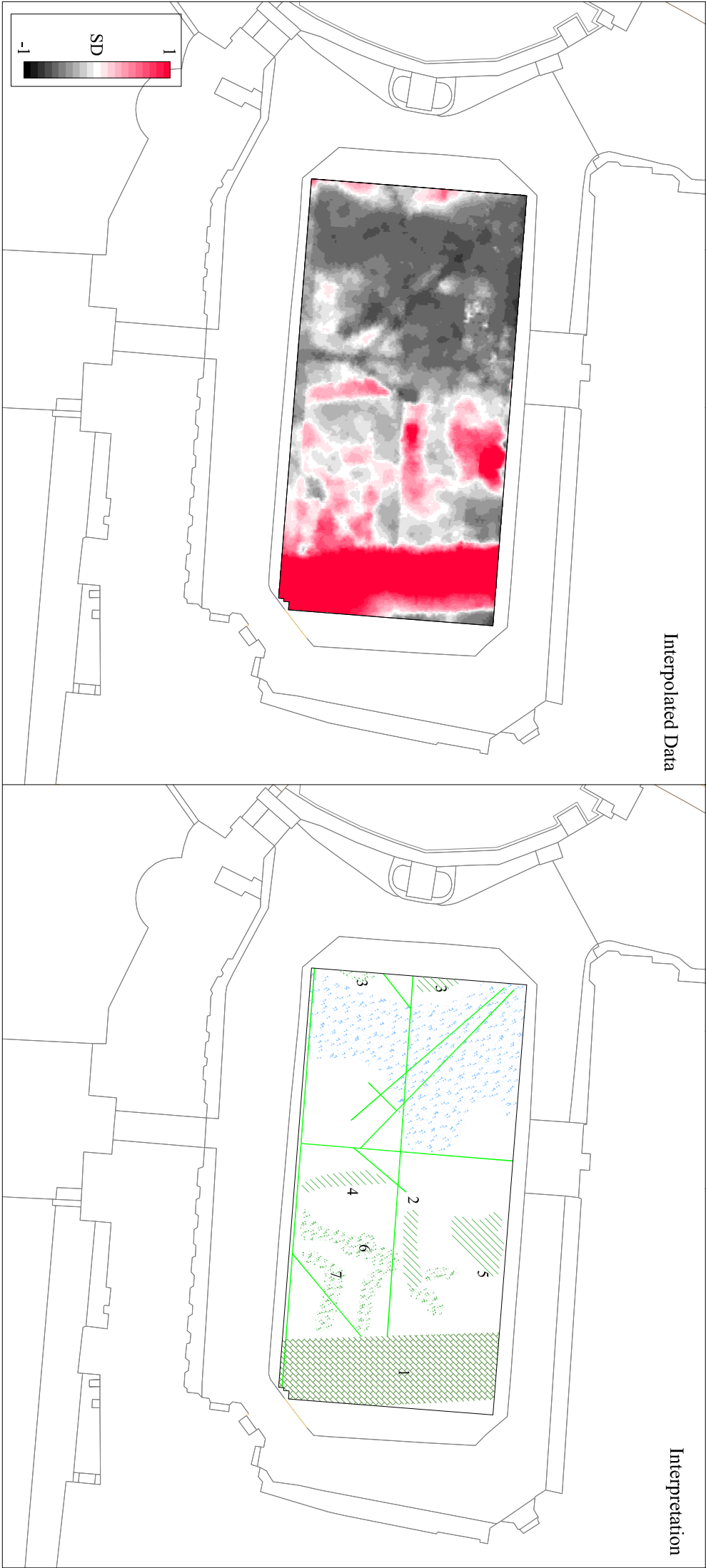
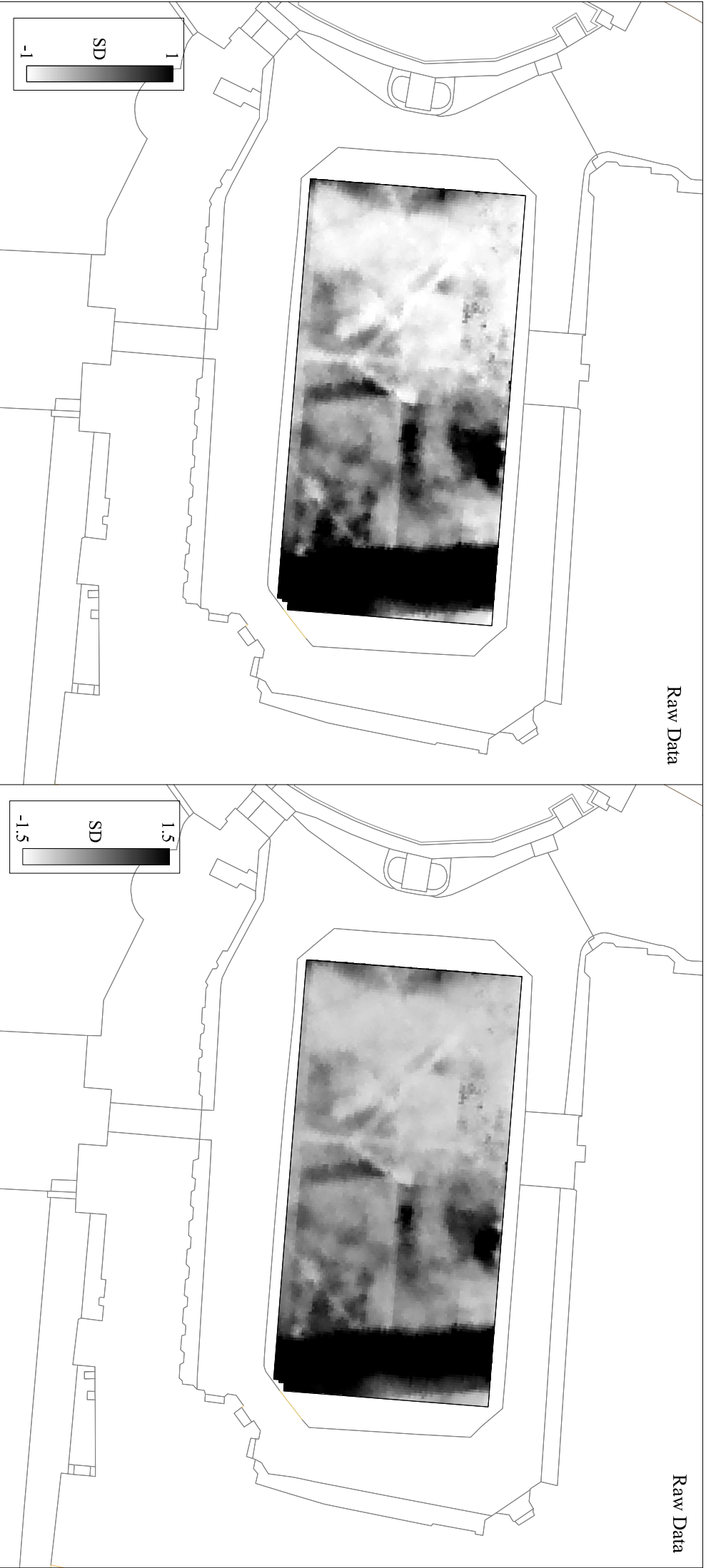


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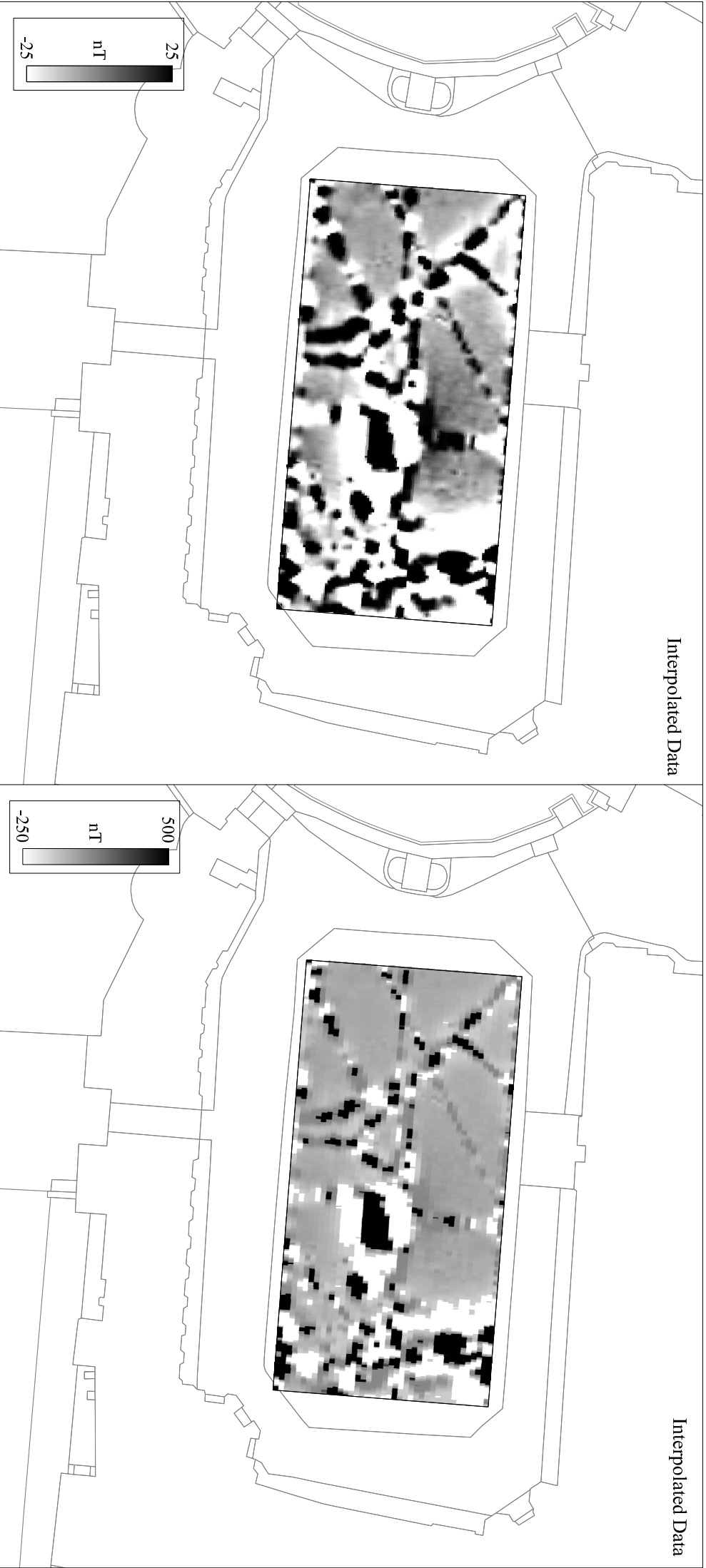


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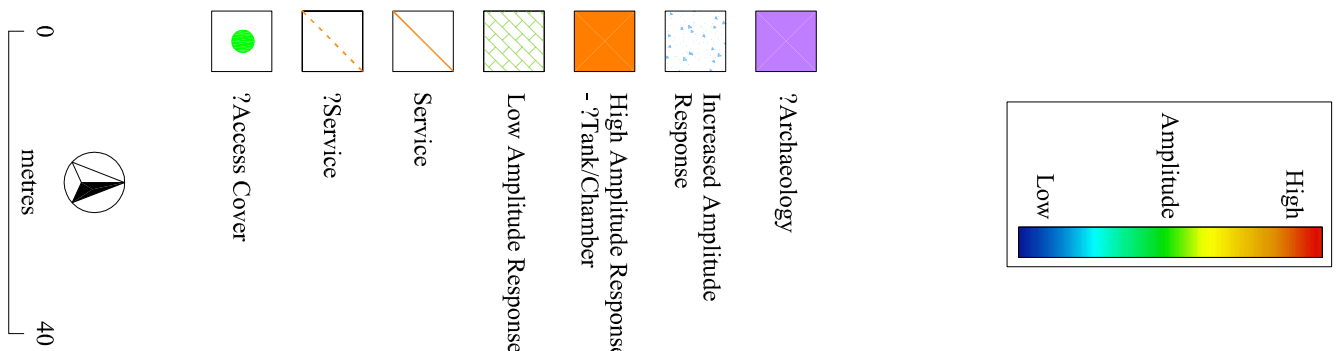
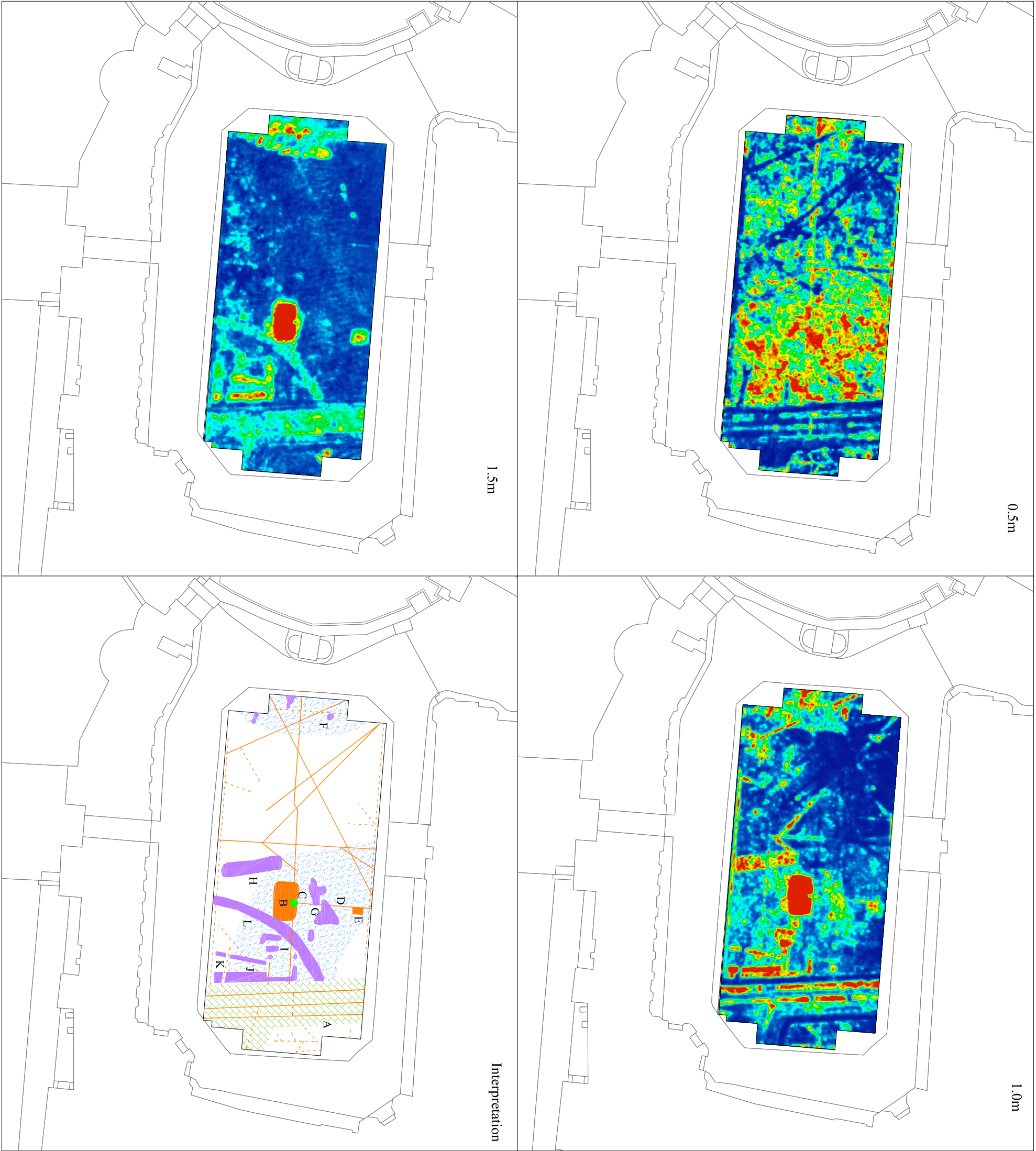
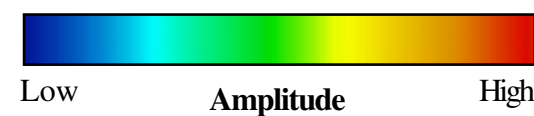
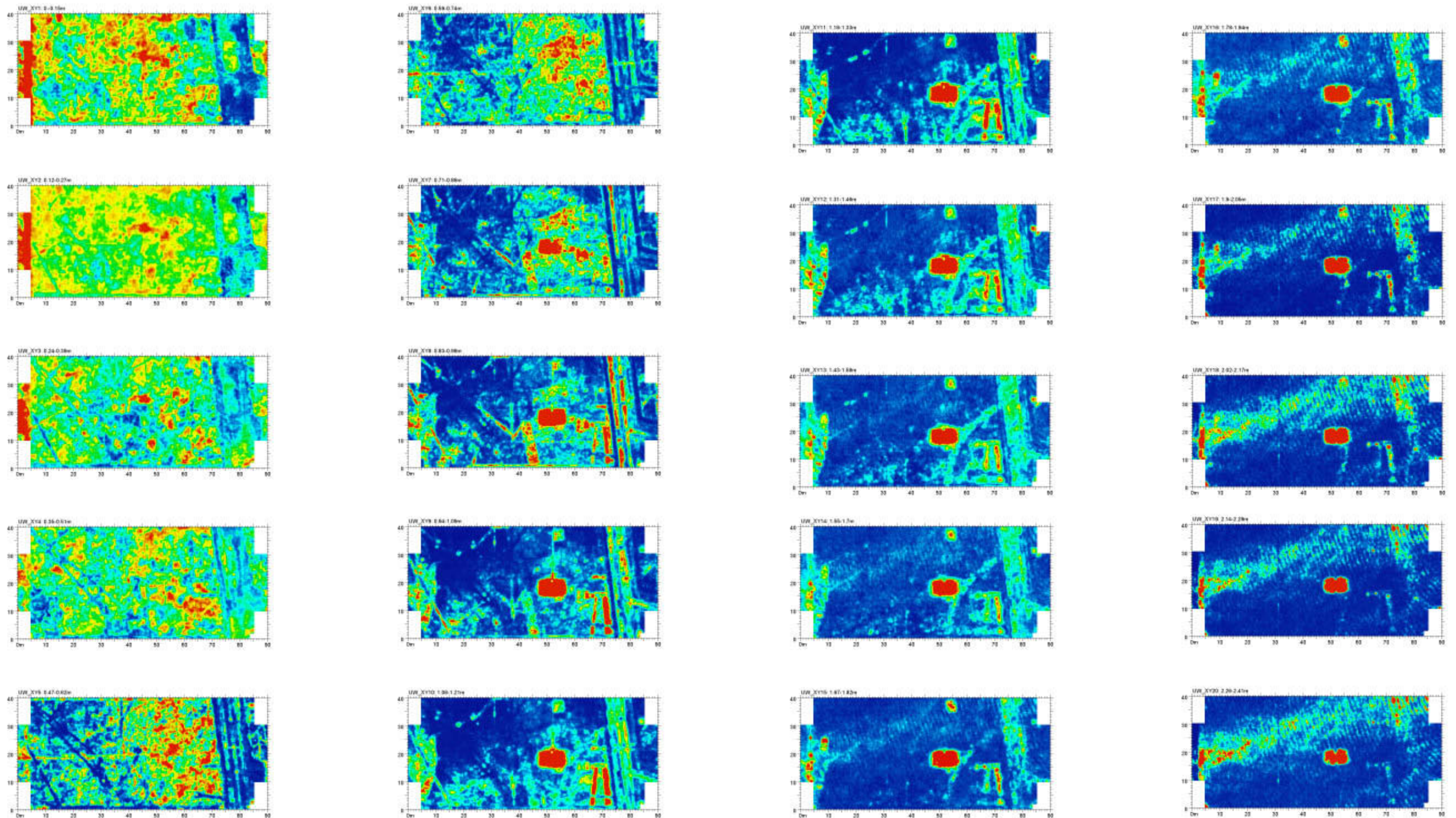


Figure 5

WINDSOR CASTLE

Upper Ward - GPR Time-slices

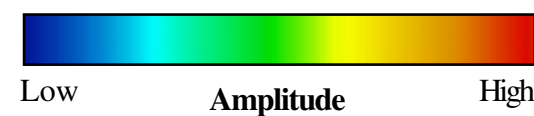
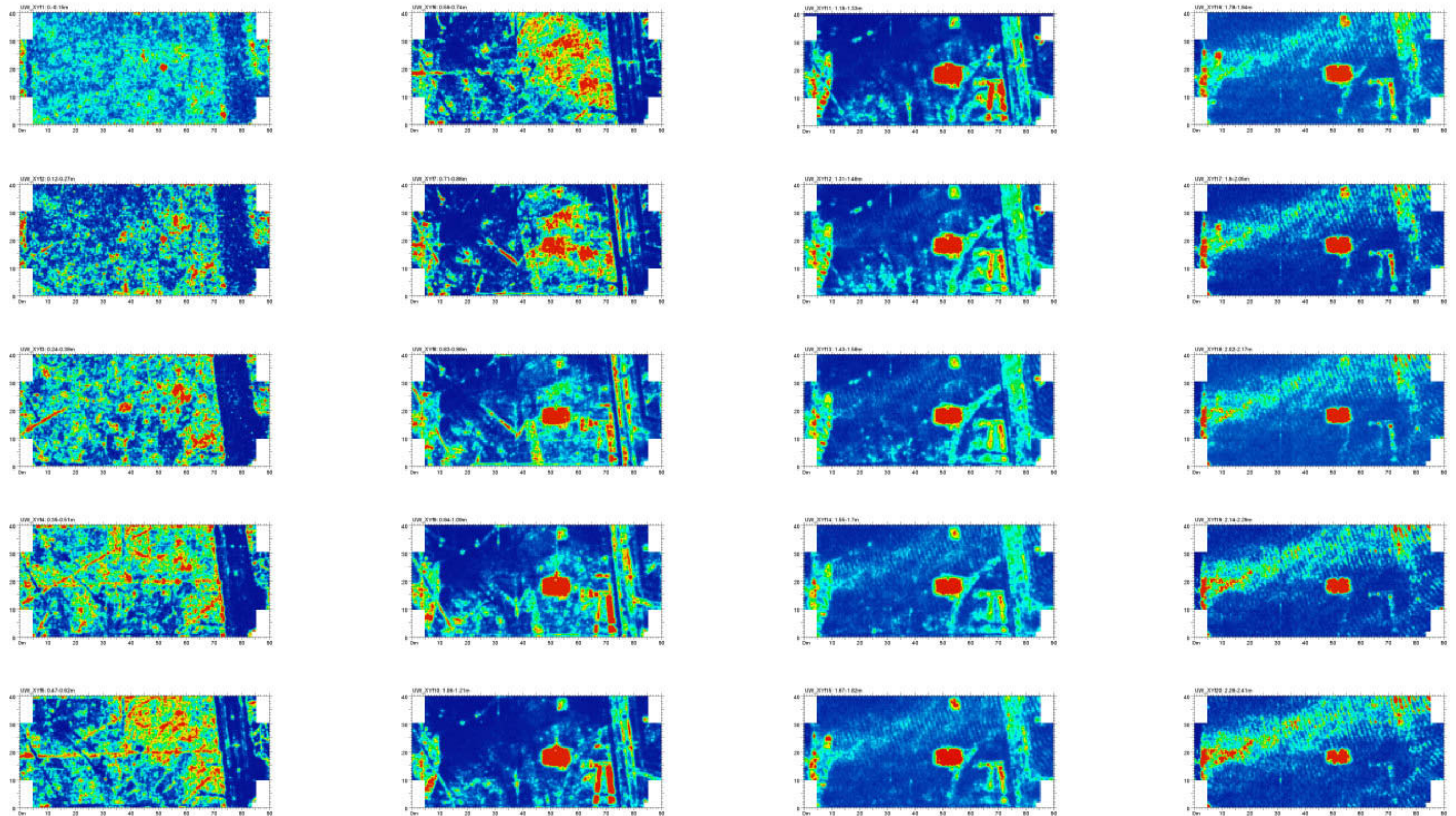
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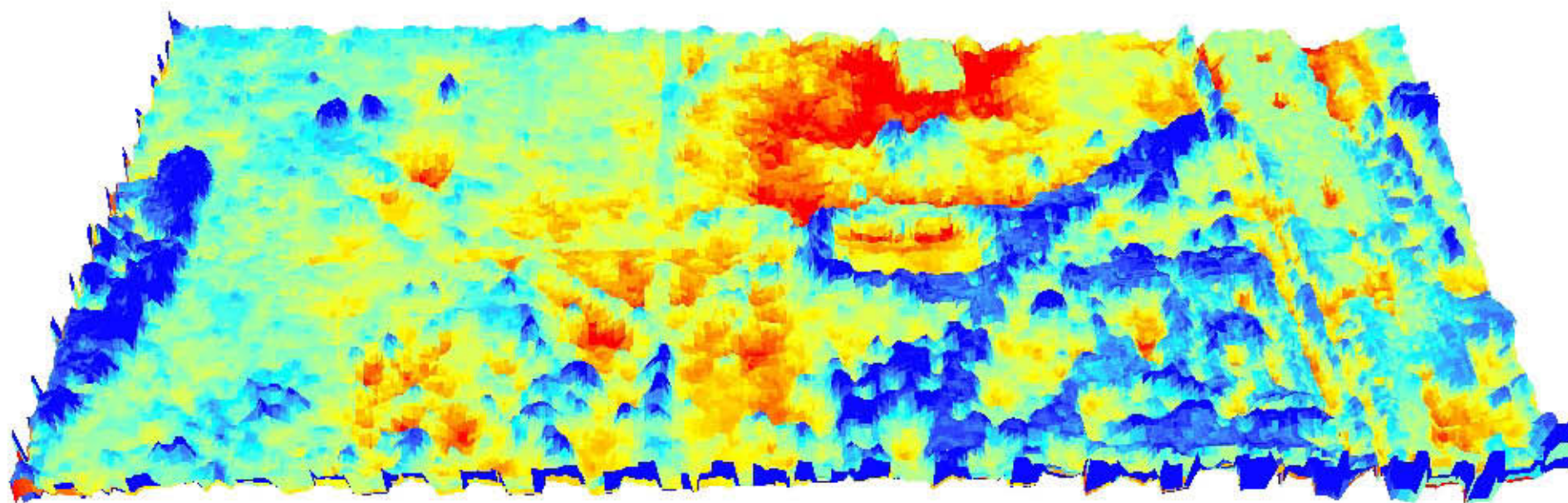
WINDSOR CASTLE

Upper Ward - GPR Time-slices

(Combined Traverse Direction - Filtered)



WINDSOR CASTLE
Upper Ward
Combined GPR & Resistance Data



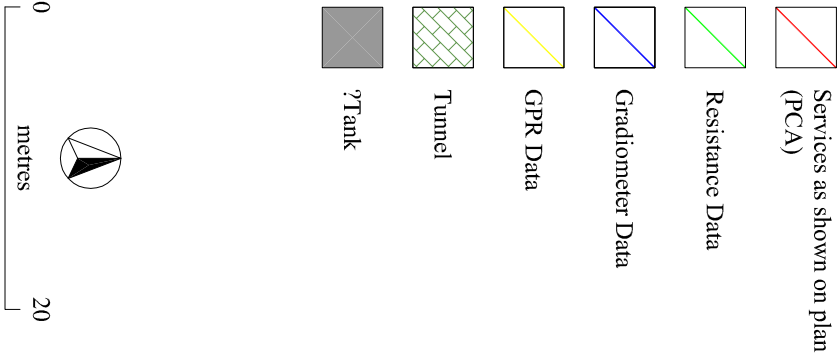
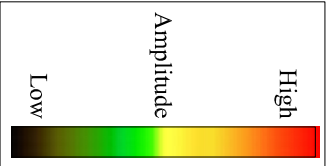
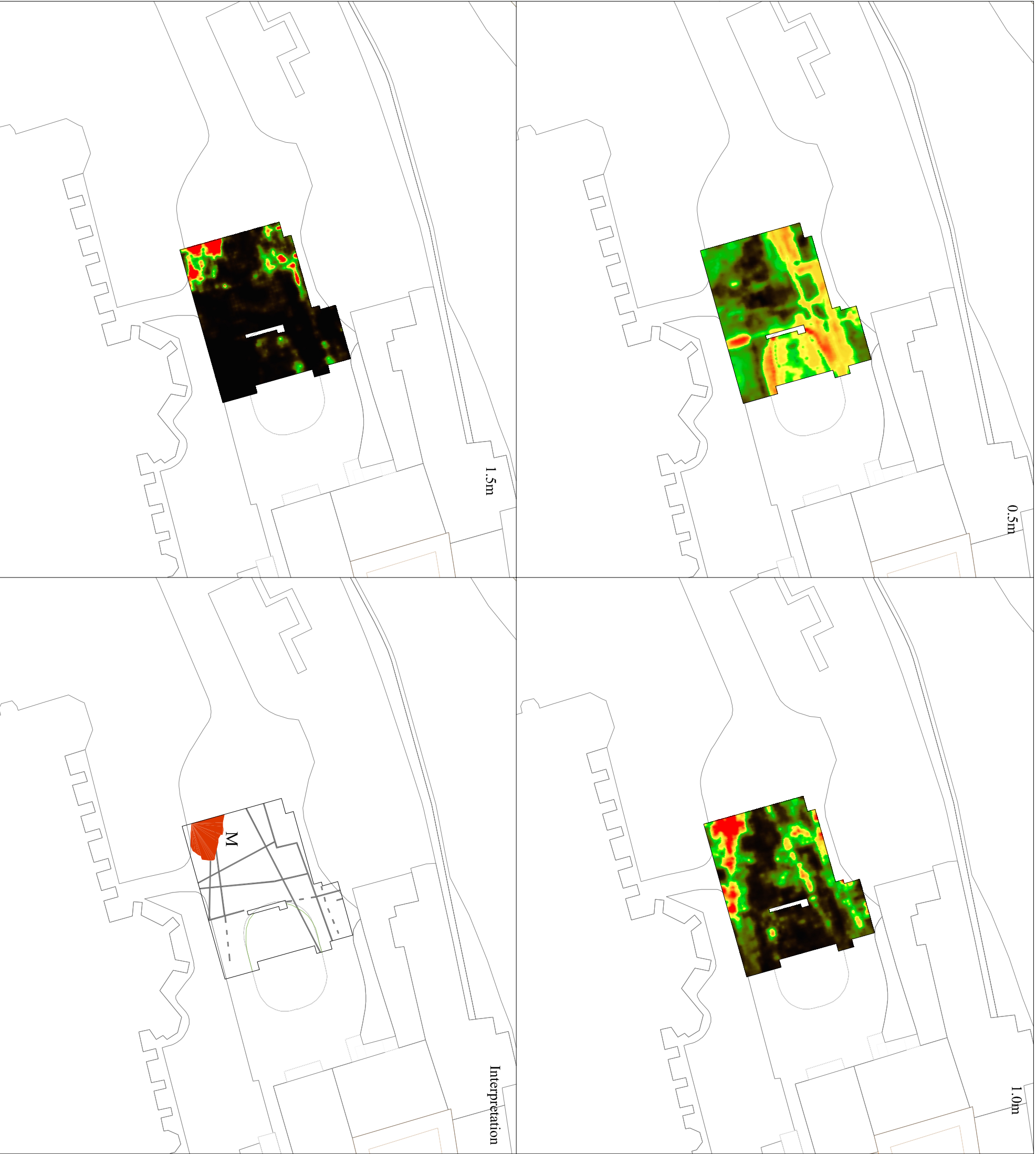


Figure 10



- Increased Amplitude Response
- Service
- ?Service
- Edge of Raised Lawn

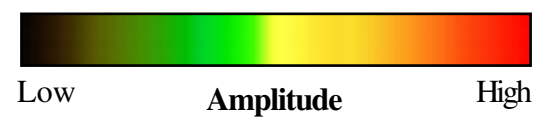
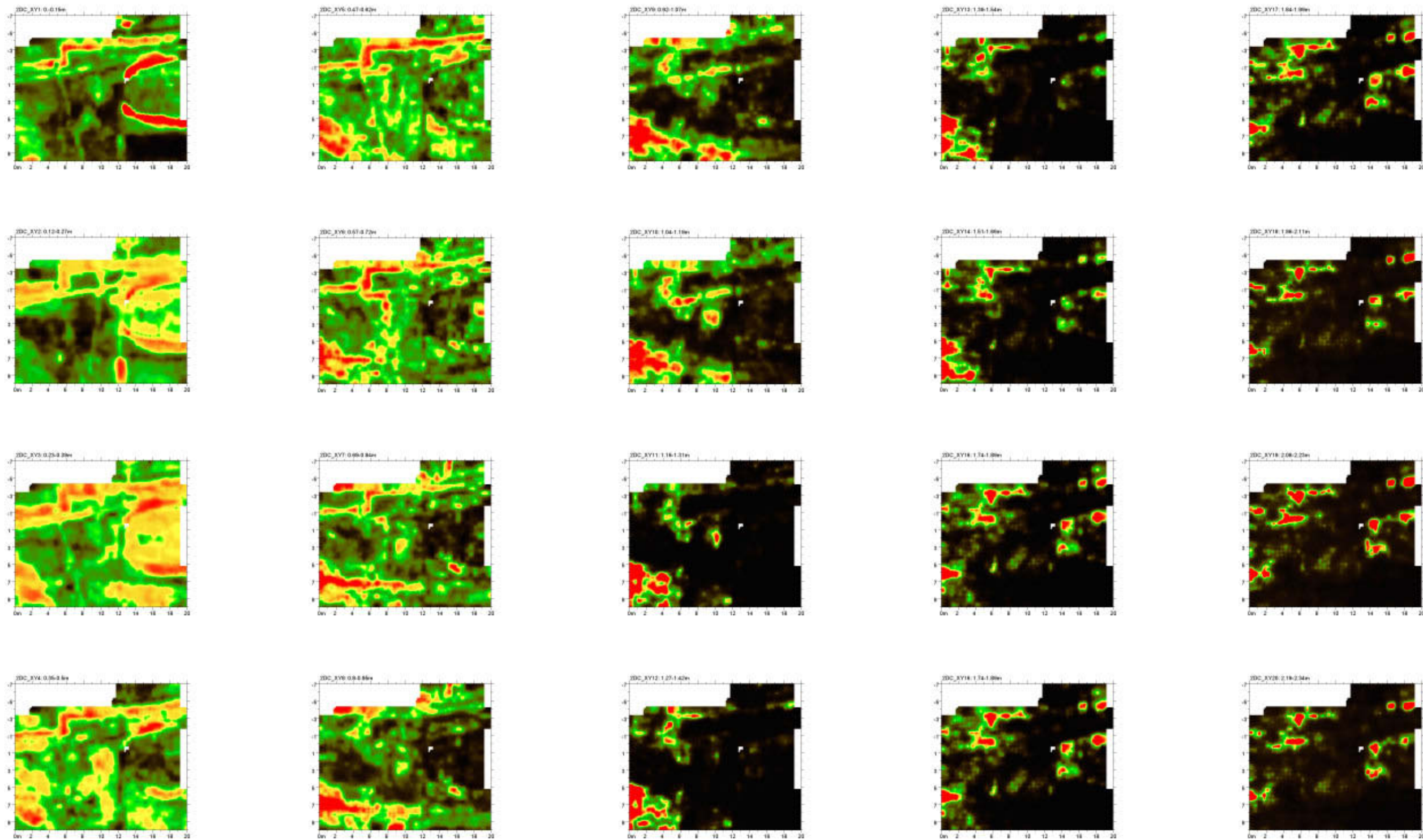


Figure 11

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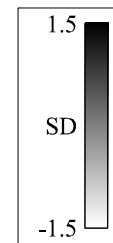
Denton's Commons - GPR Time-slices

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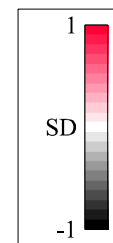
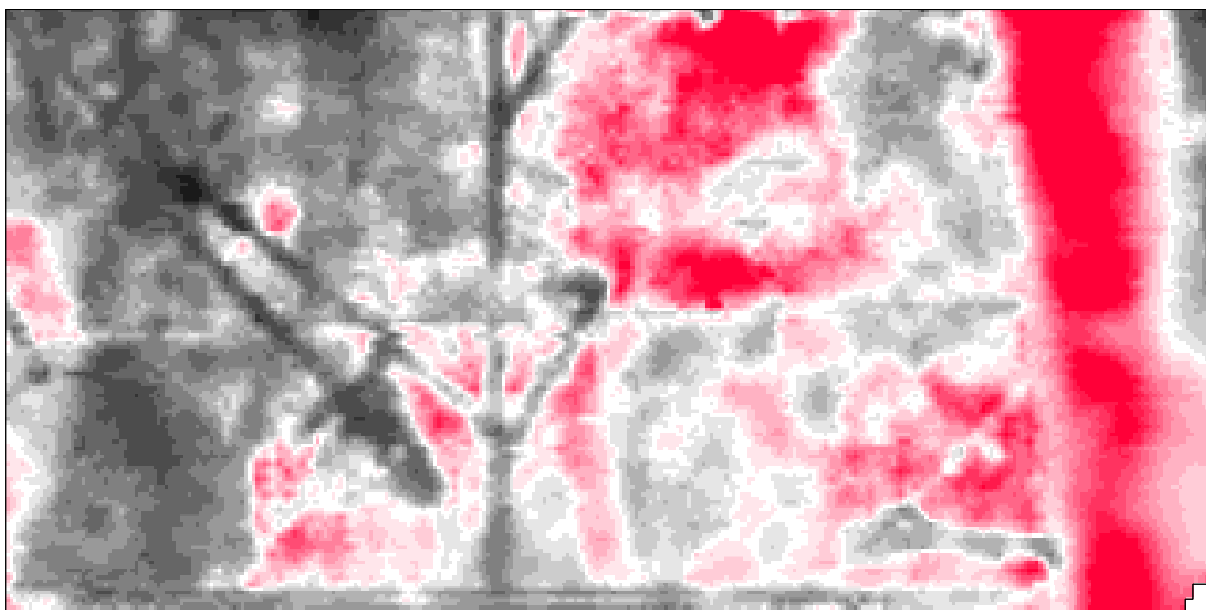


WINDSOR CASTLE Resistance Data - 0.5m Upper Ward

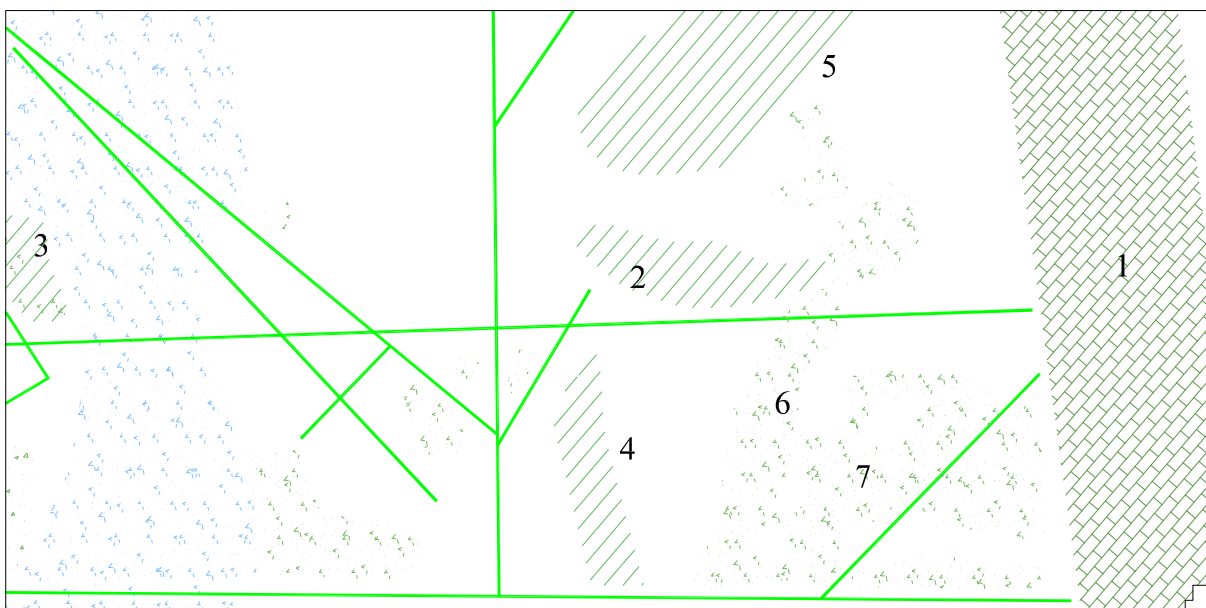
Raw Data



Interpolated Data



Interpretation



High Resistance



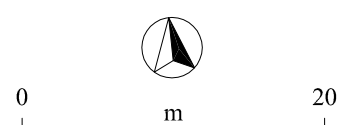
Low Resistance



Tunnel

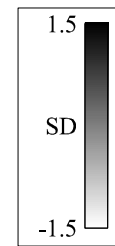
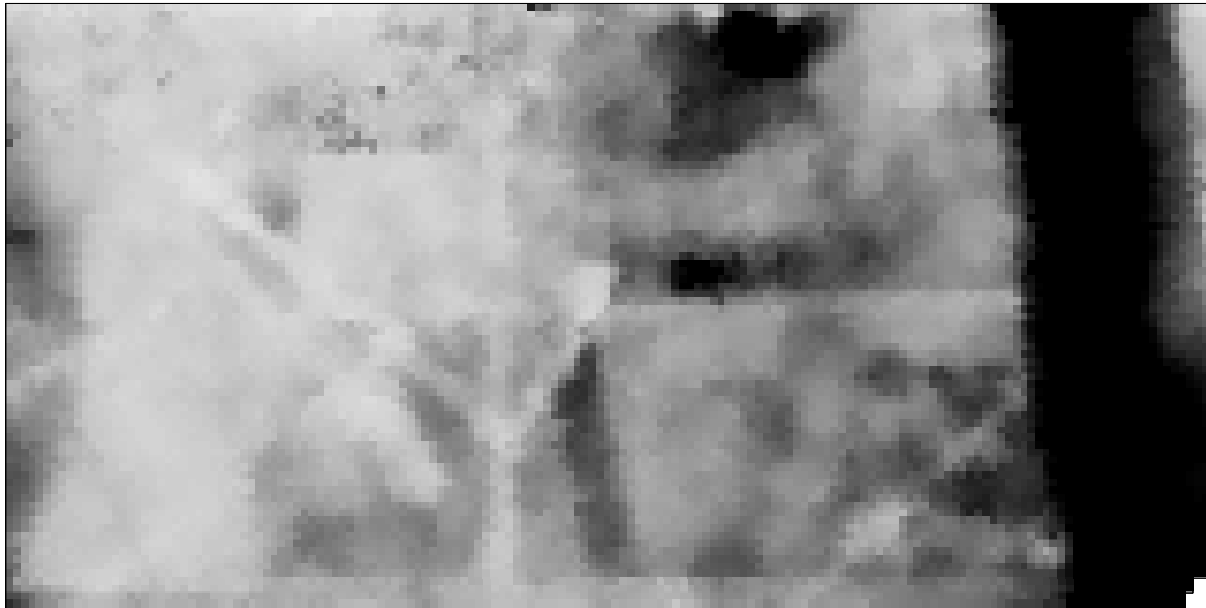


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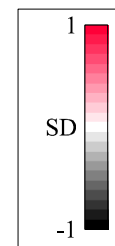
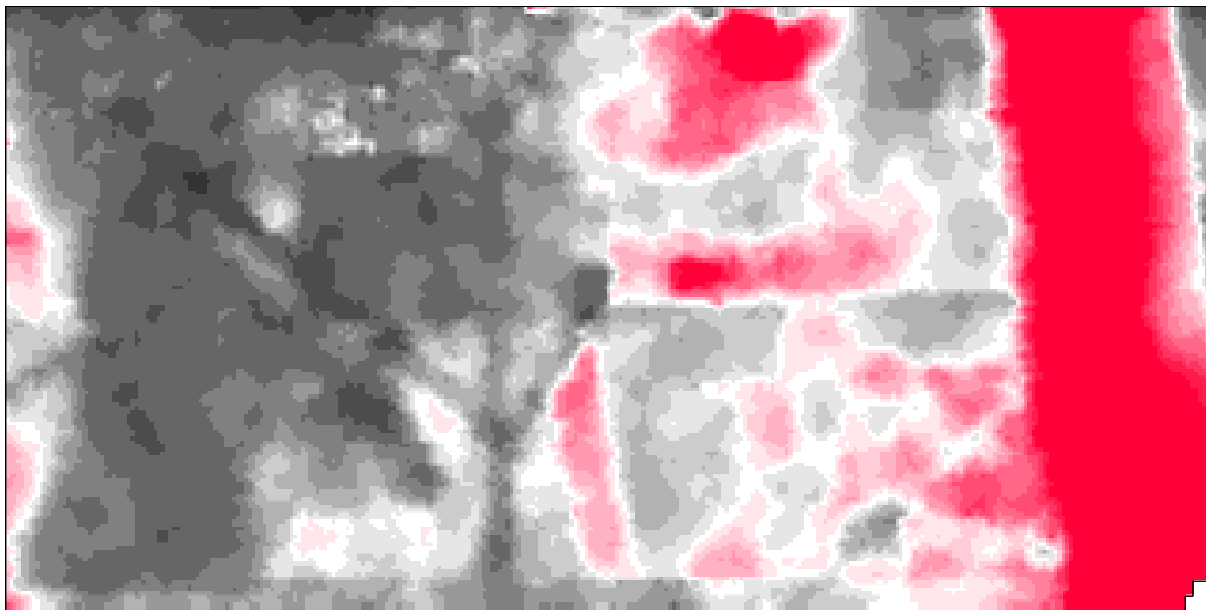


WINDSOR CASTLE Resistance Data - 1.0m Upper Ward

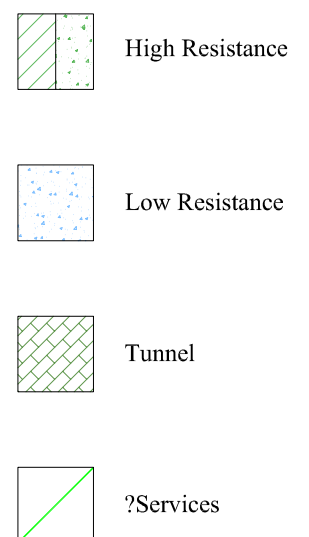
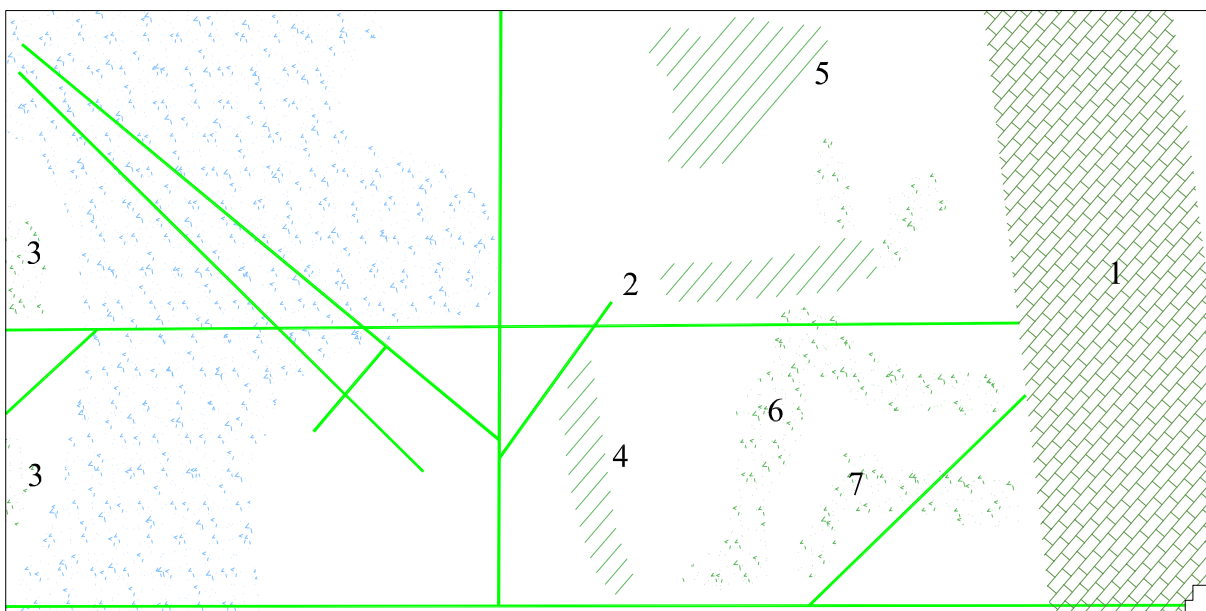
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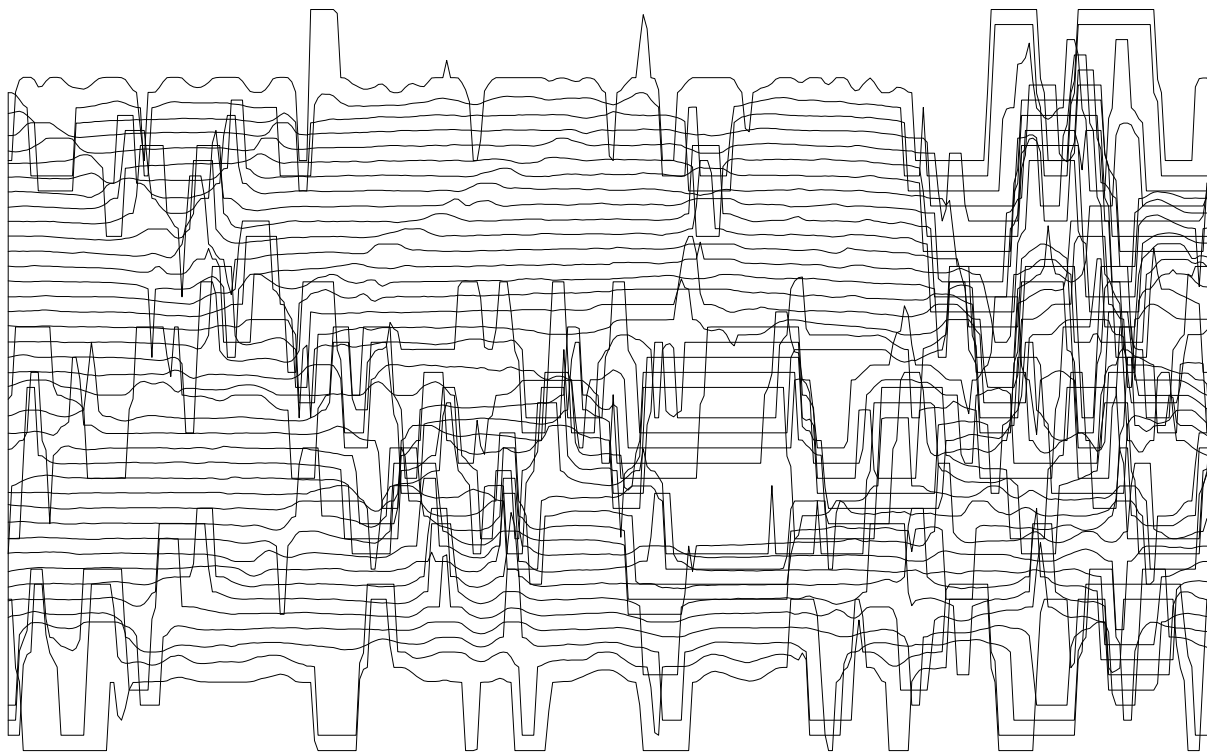
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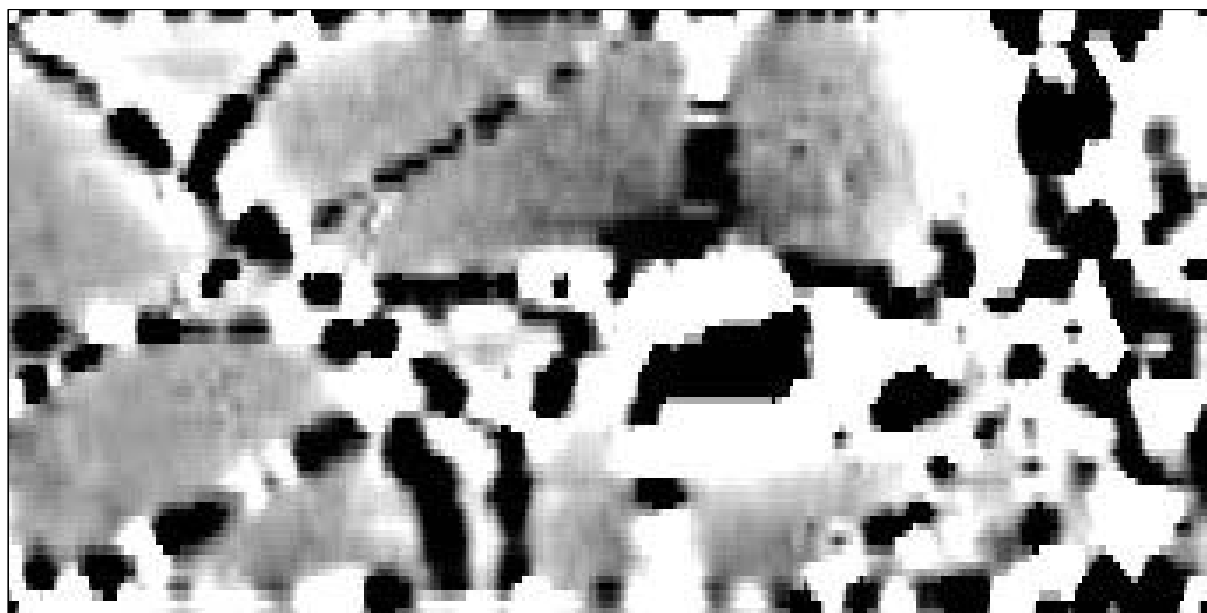
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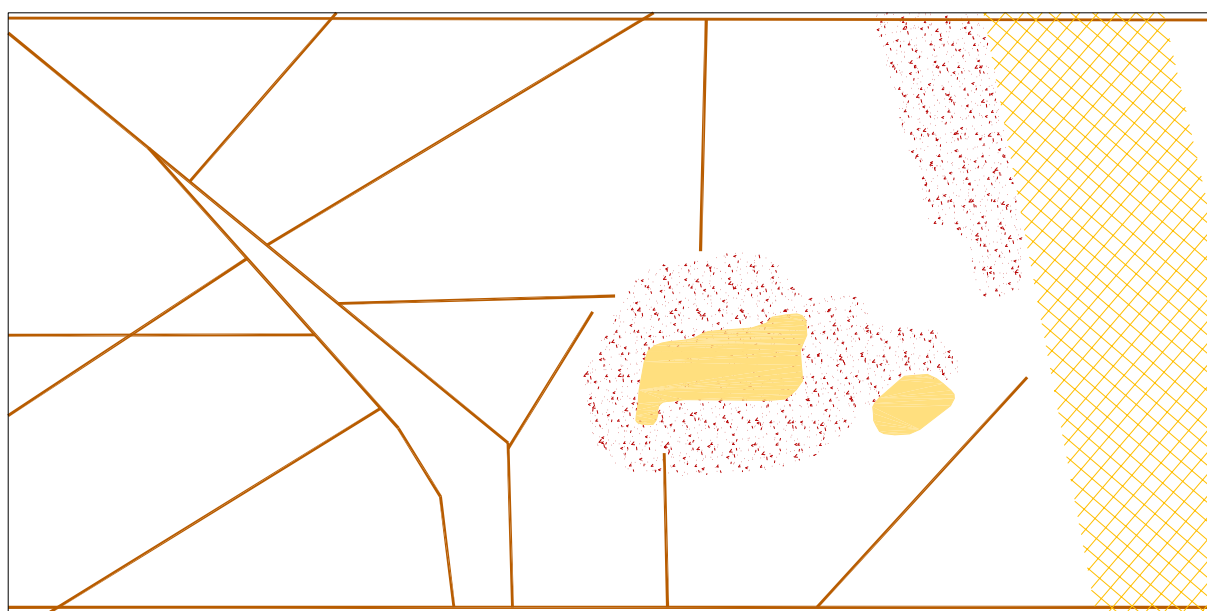
WINDSOR CASTLE Gradiometer Data Upper Ward







100 nT



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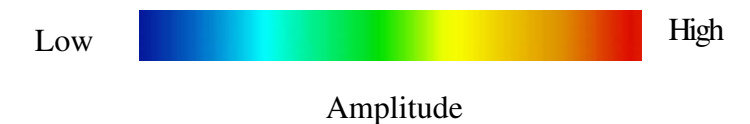
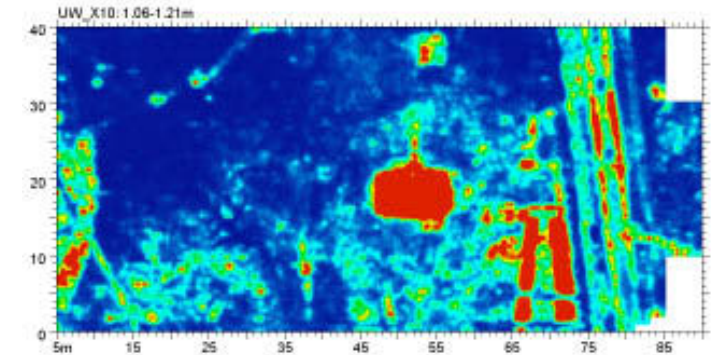
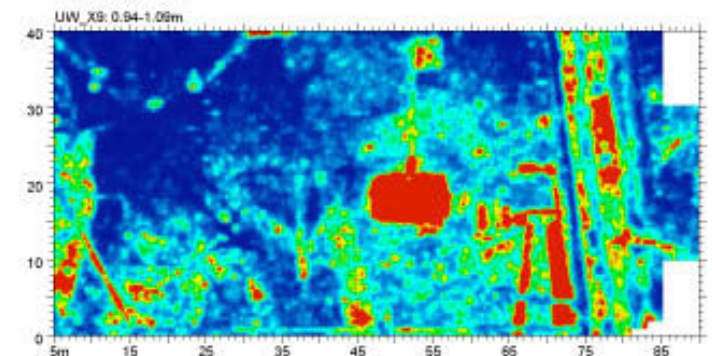
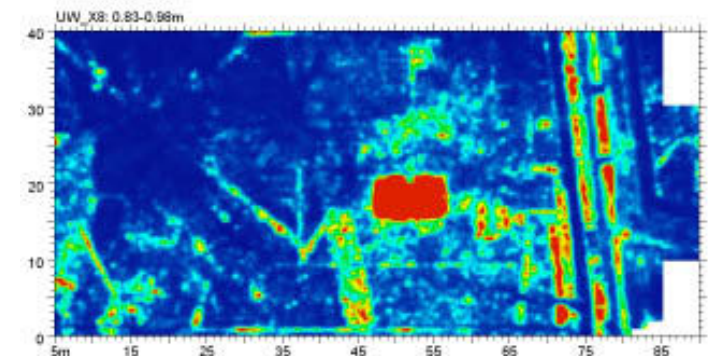
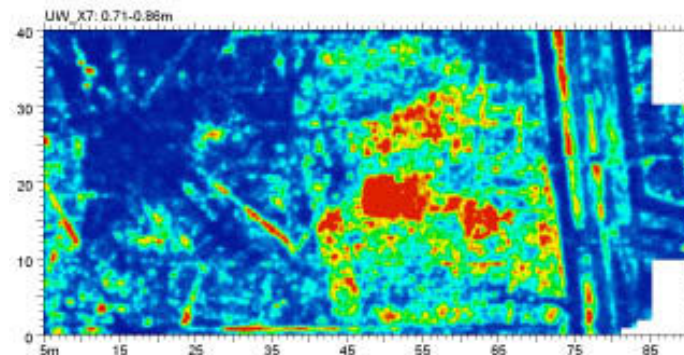
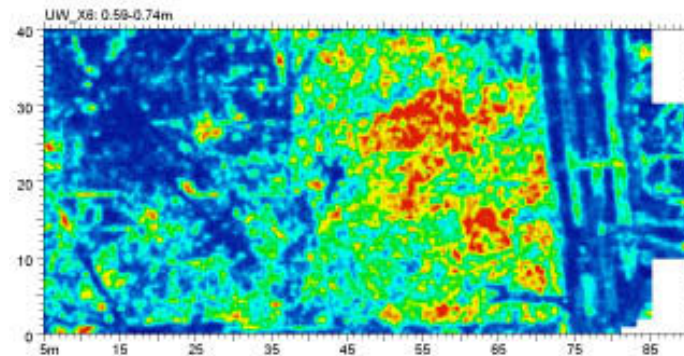
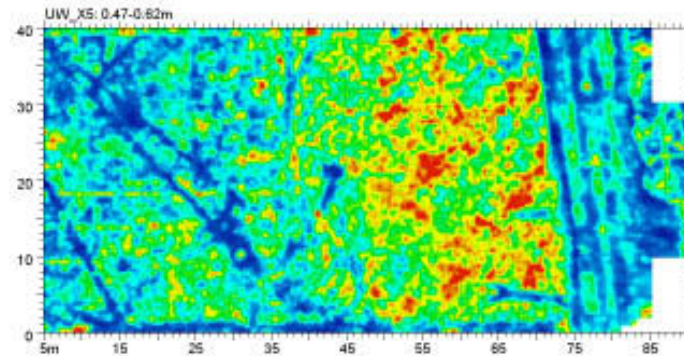
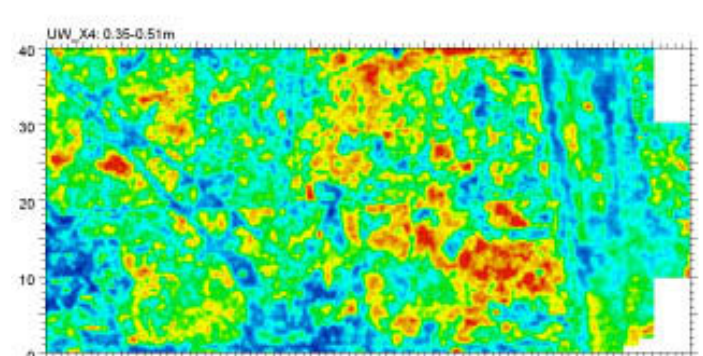
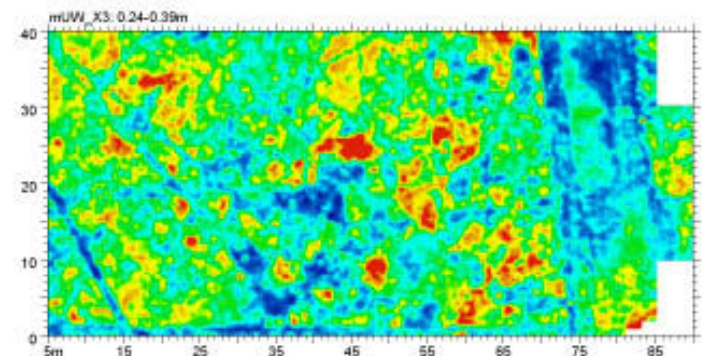
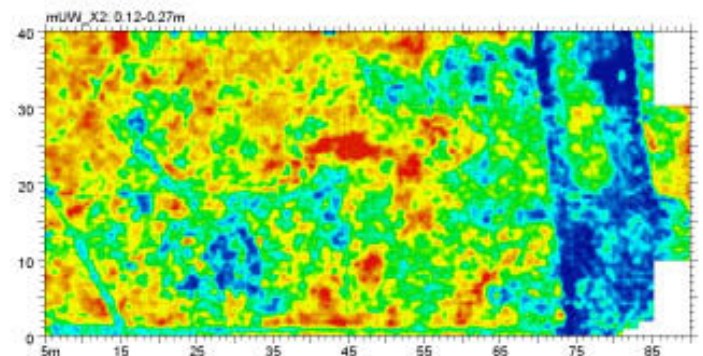
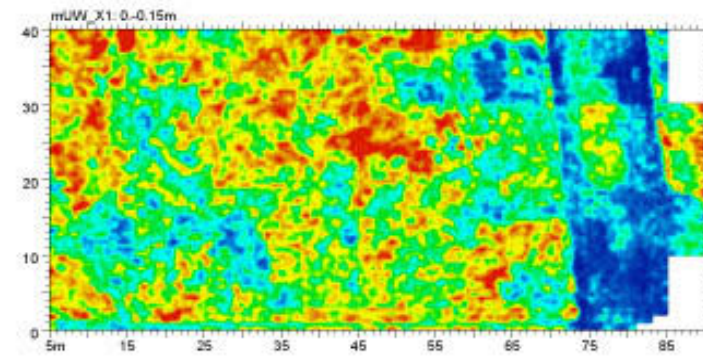


-  Positive Magnetic Anomaly
-  Negative Magnetic Anomaly
-  Magnetic Disturbance - Tunnel
-  ?Services

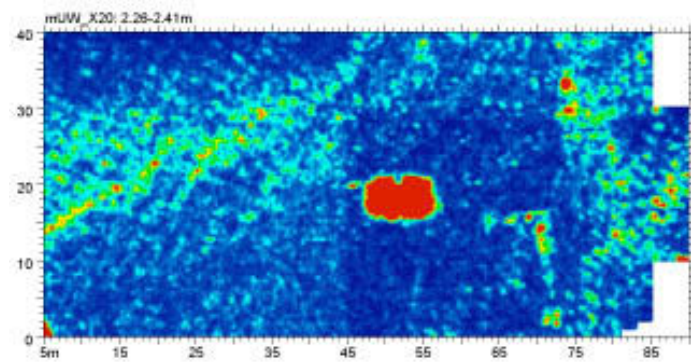
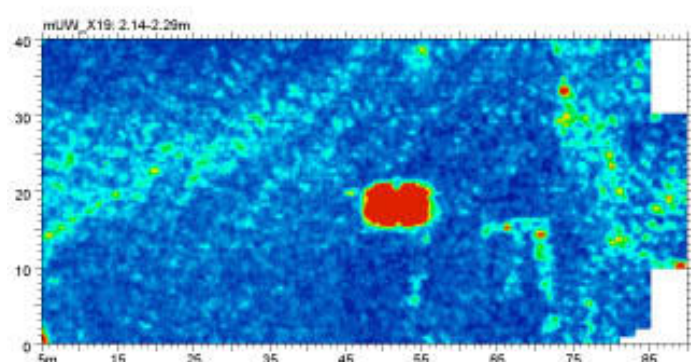
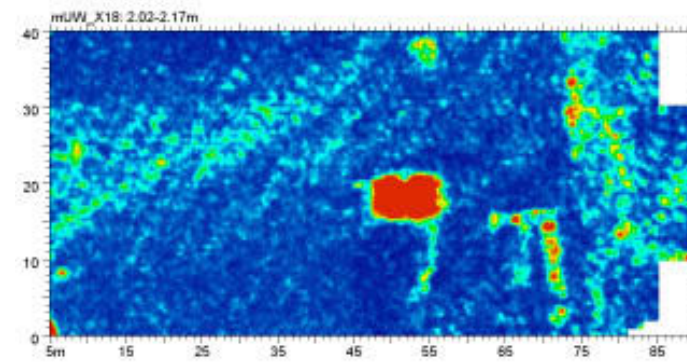
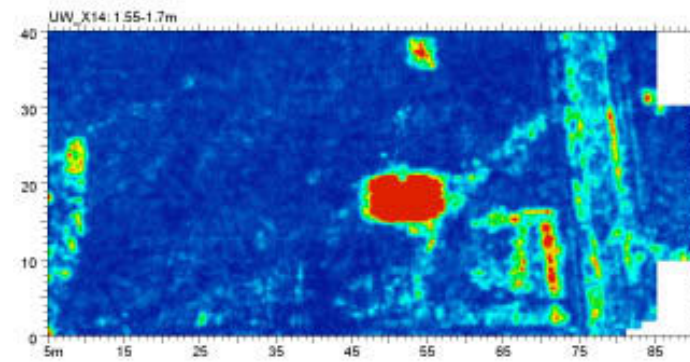
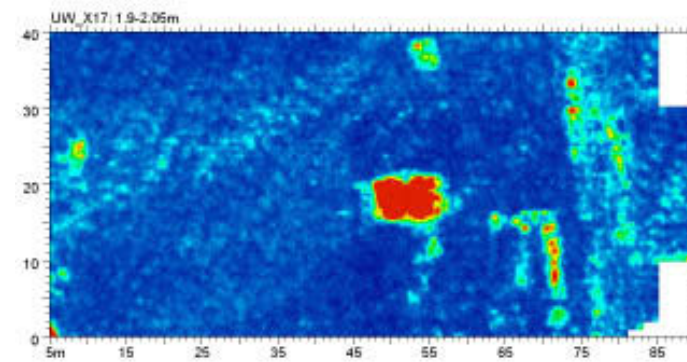
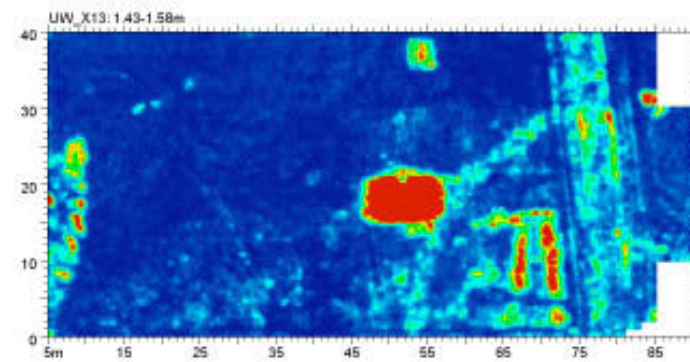
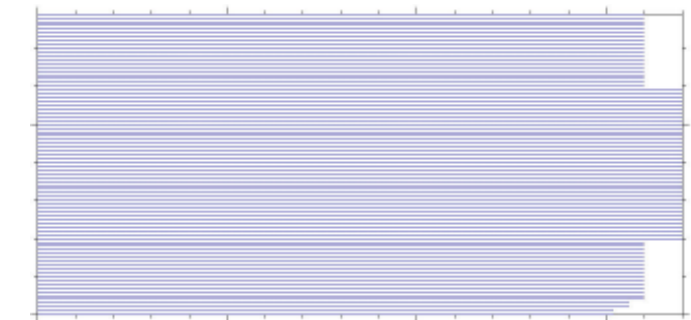
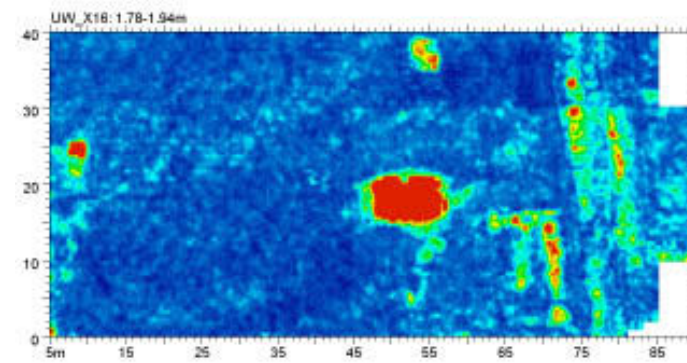
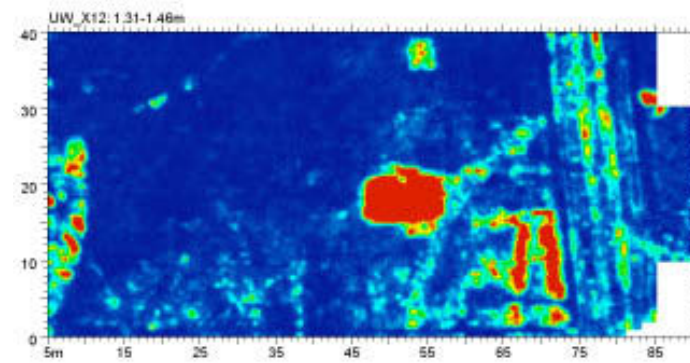
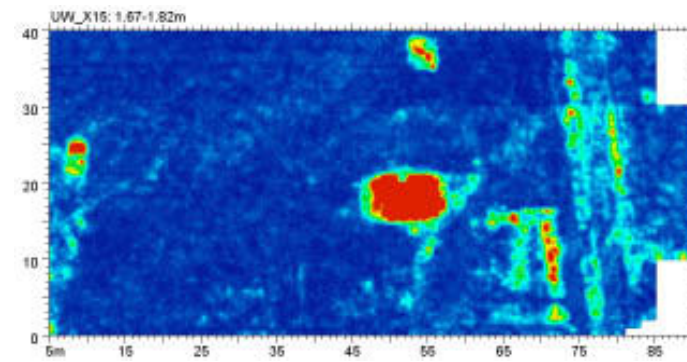
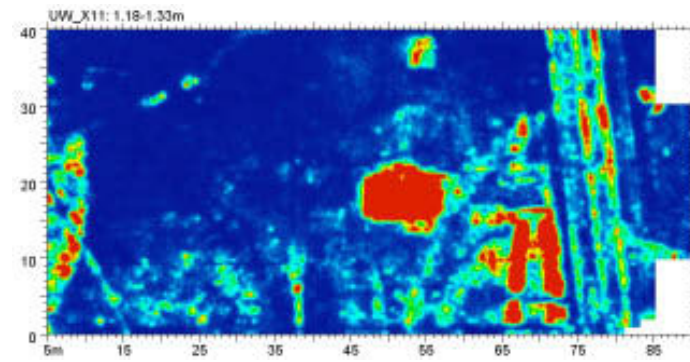
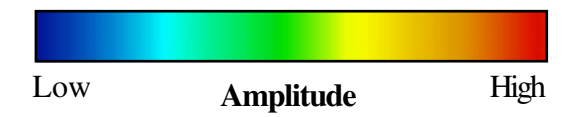
0 20
m

WINDSOR CASTLE

Upper Ward - GPR Time-slices (E-W Traverse Direction)



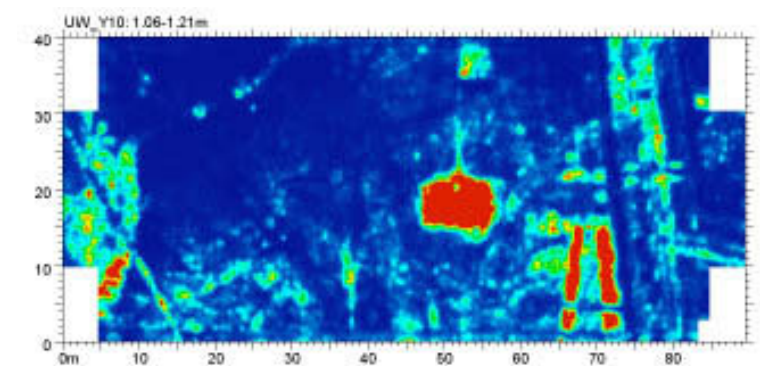
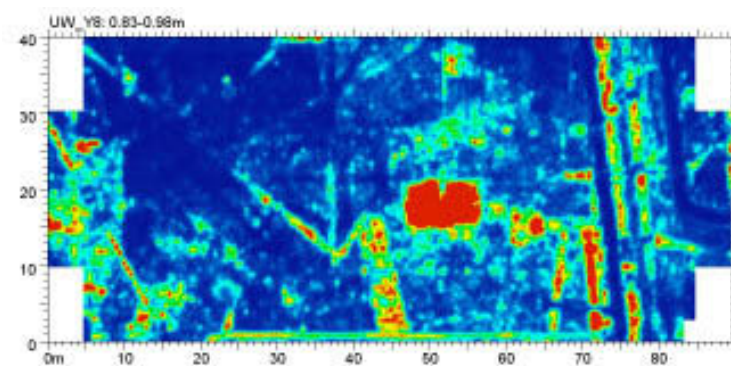
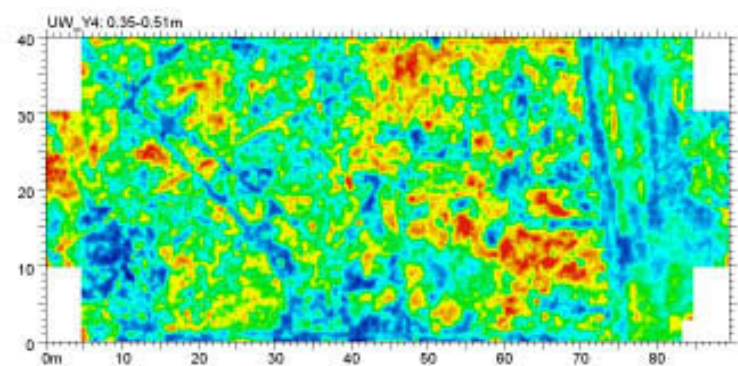
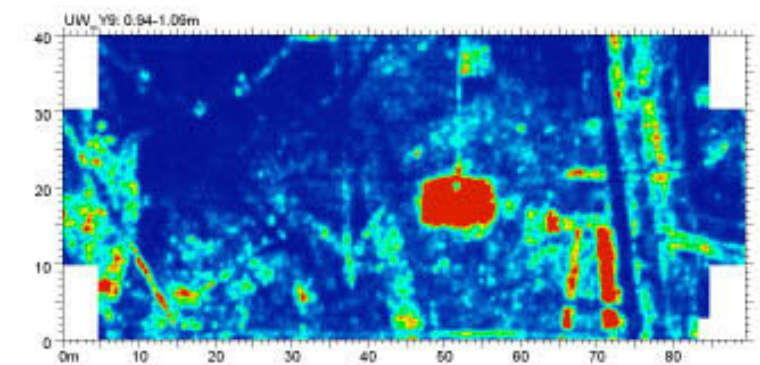
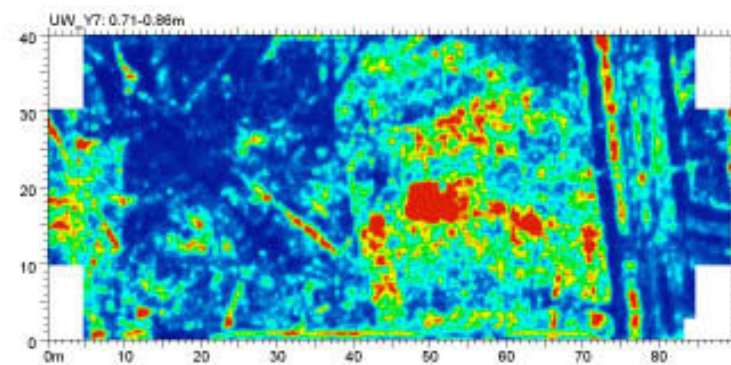
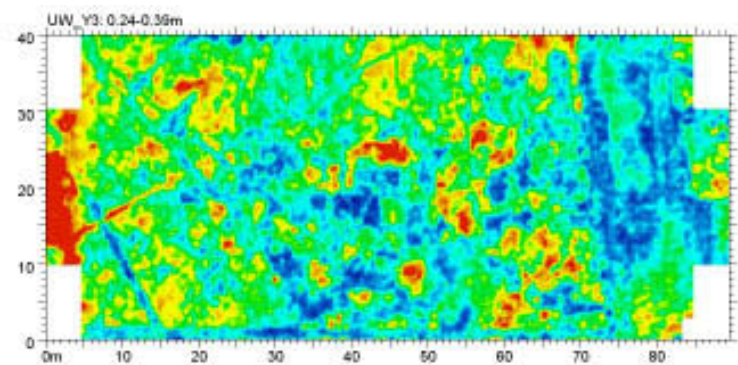
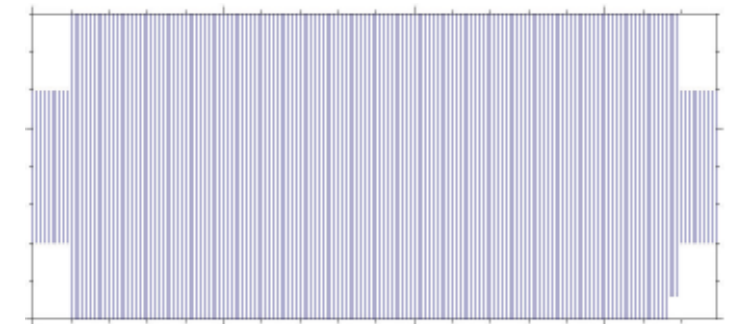
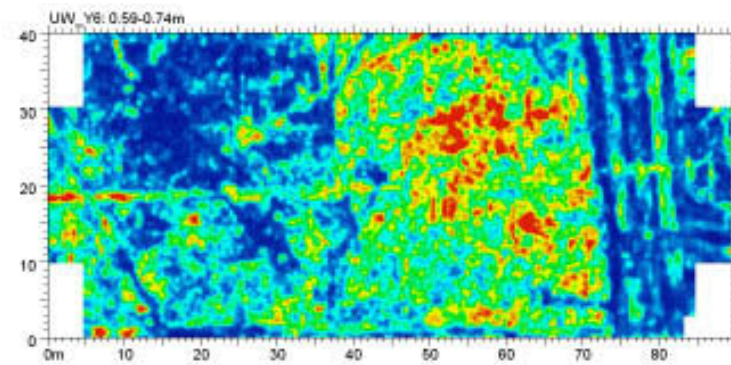
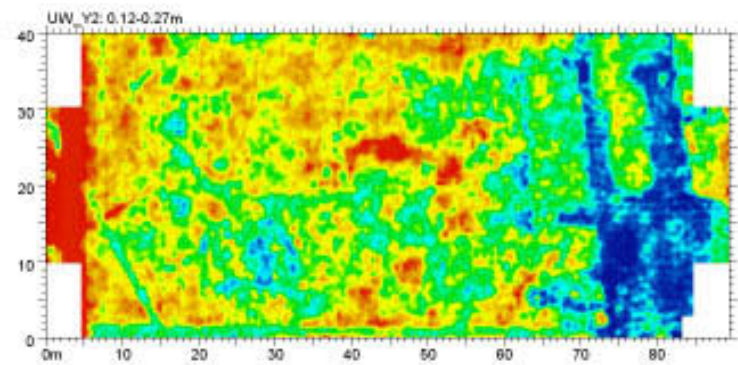
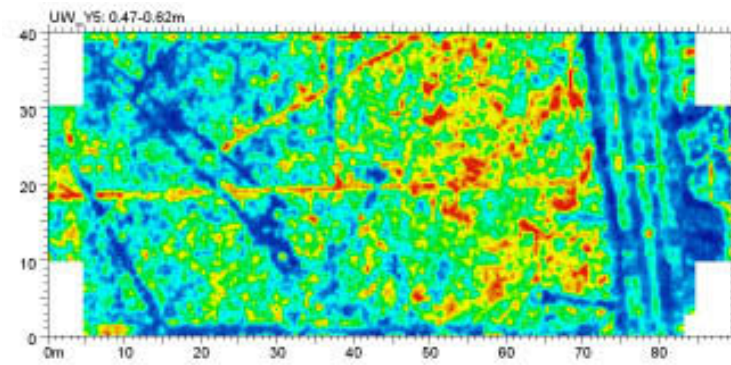
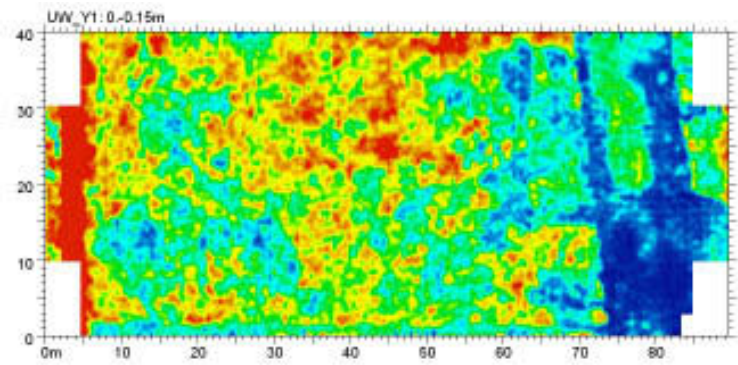
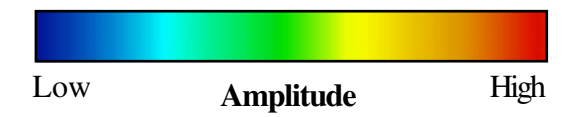
WINDSOR CASTLE Upper Ward - GPR Time-slices (E-W Traverse Direction)



WINDSOR CASTLE

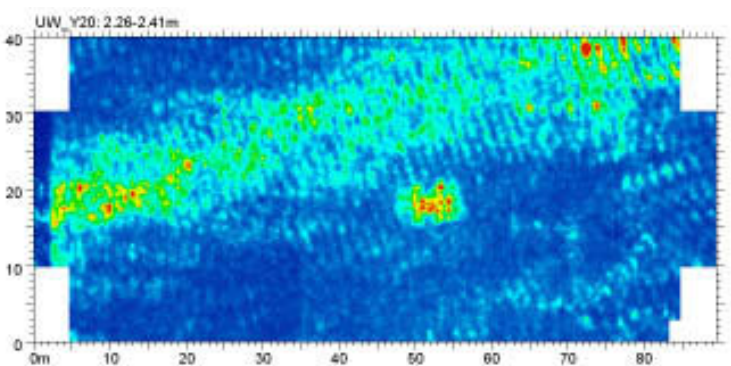
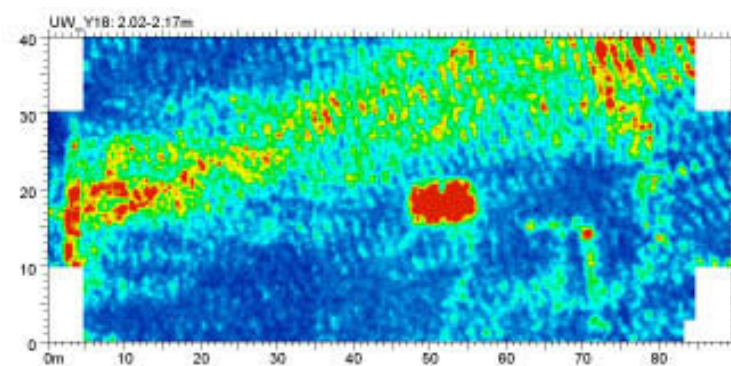
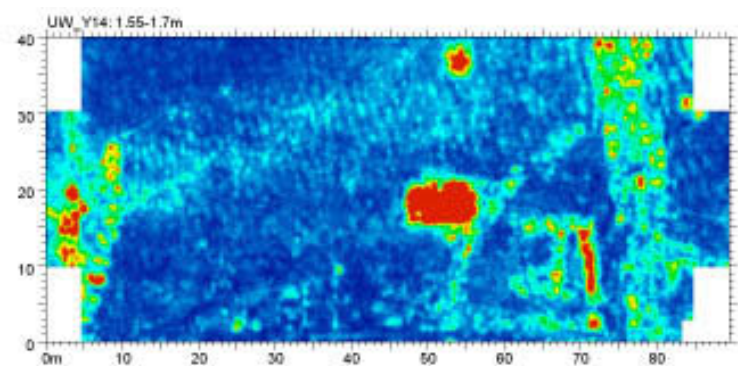
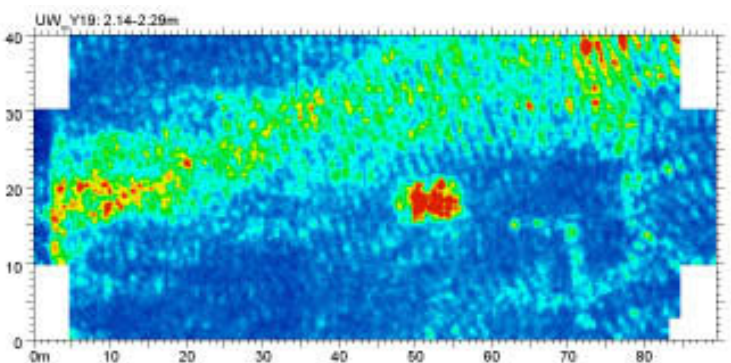
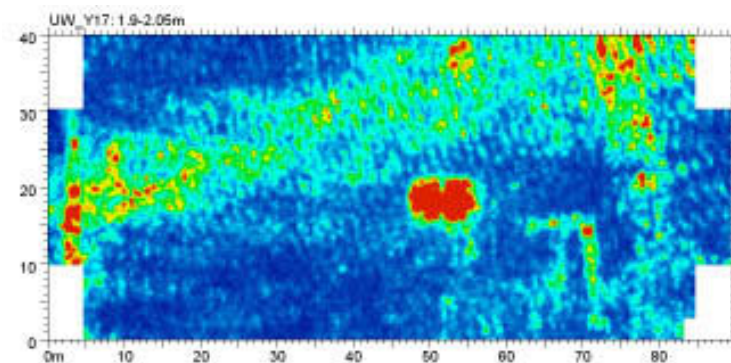
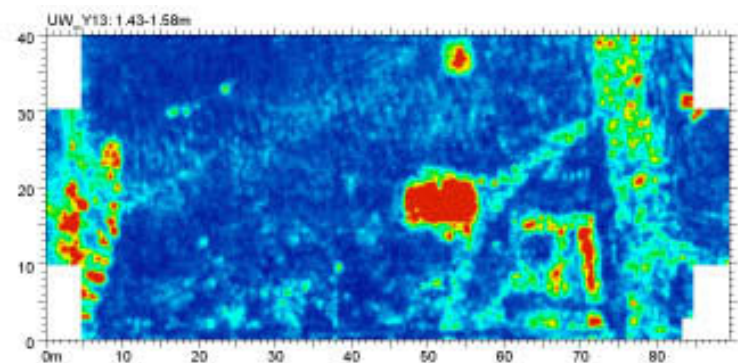
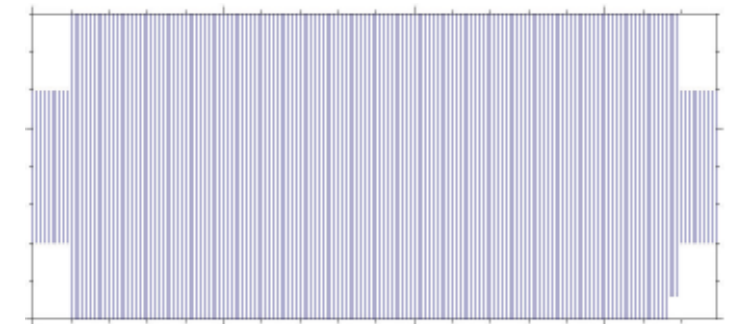
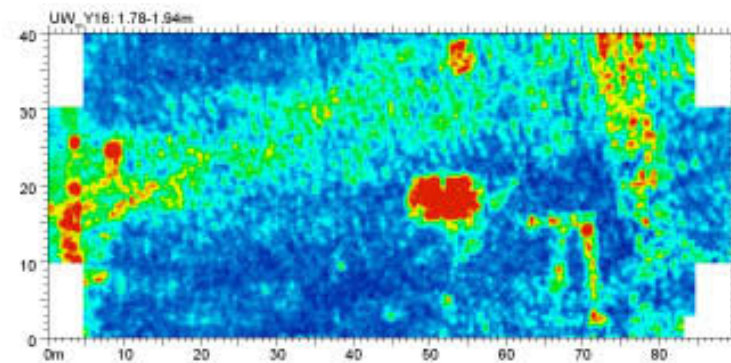
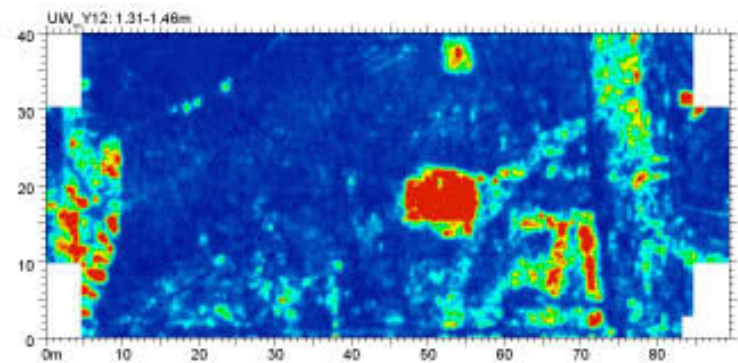
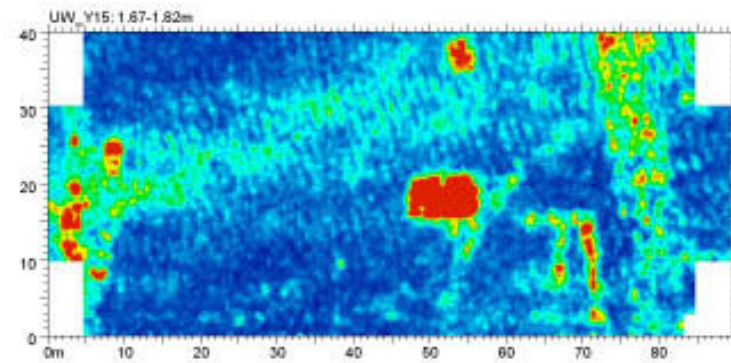
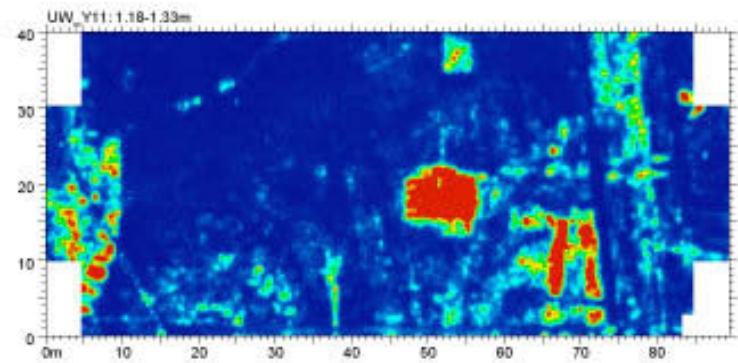
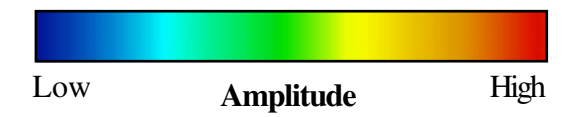
Upper Ward - GPR Time-slices

(N-S Traverse Direction)



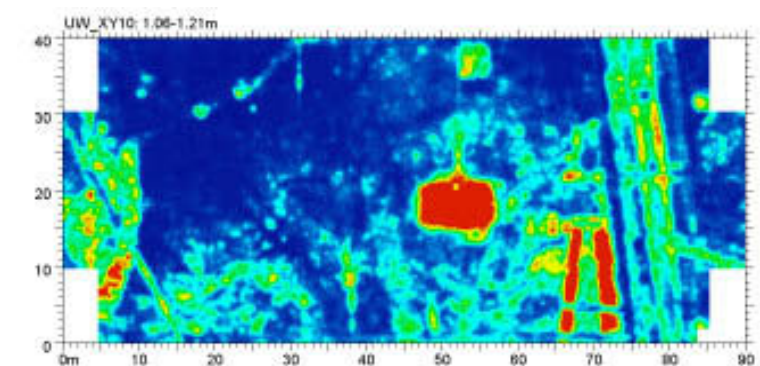
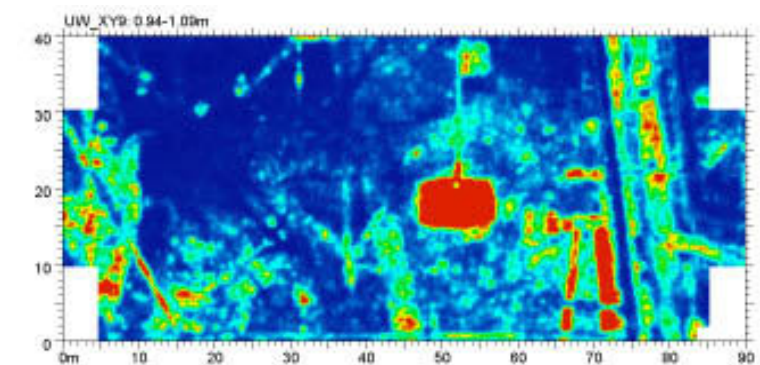
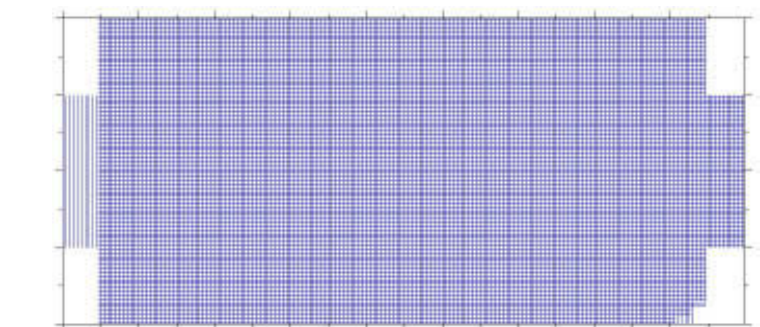
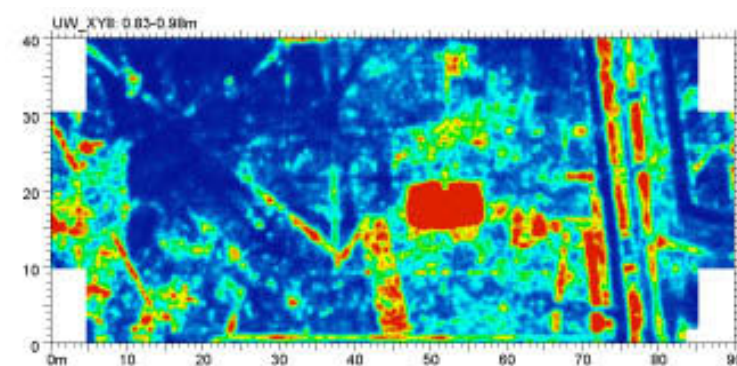
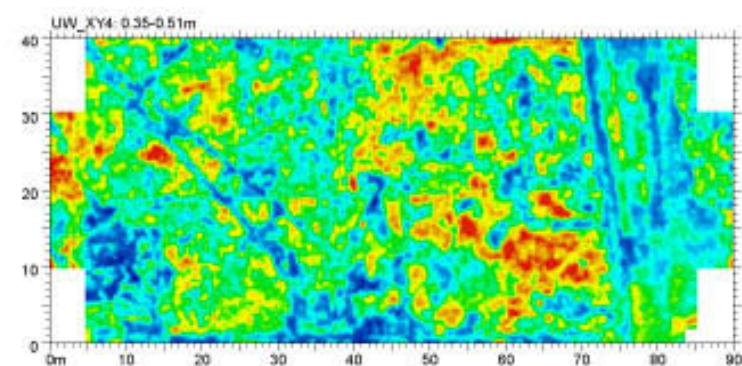
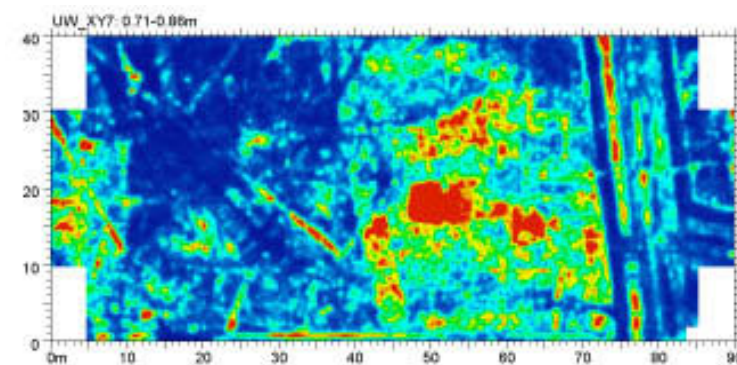
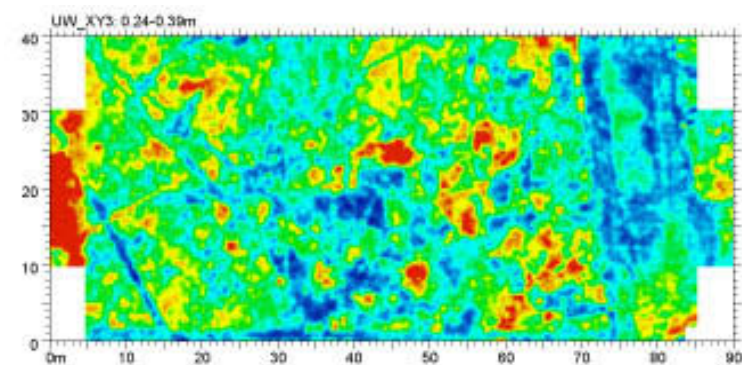
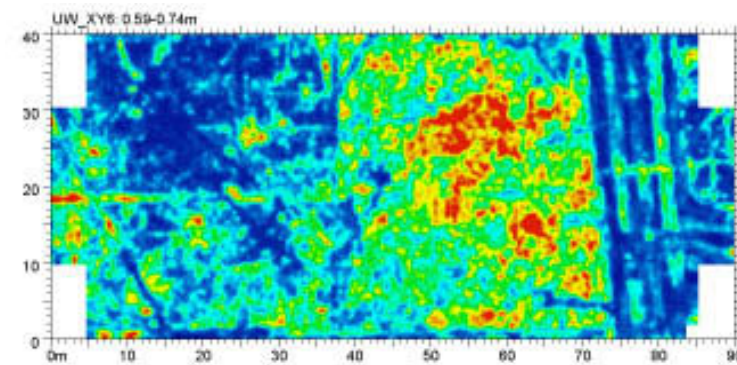
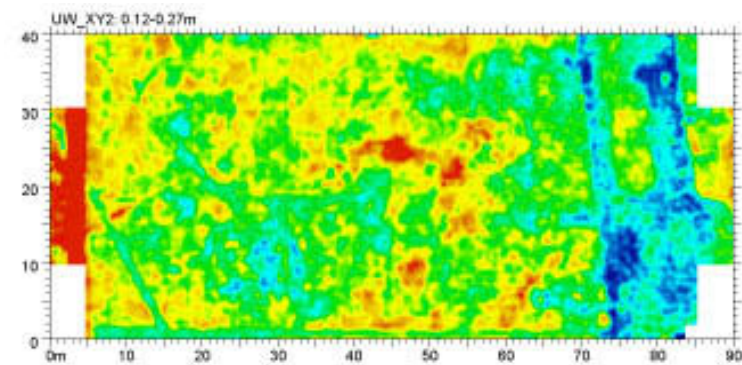
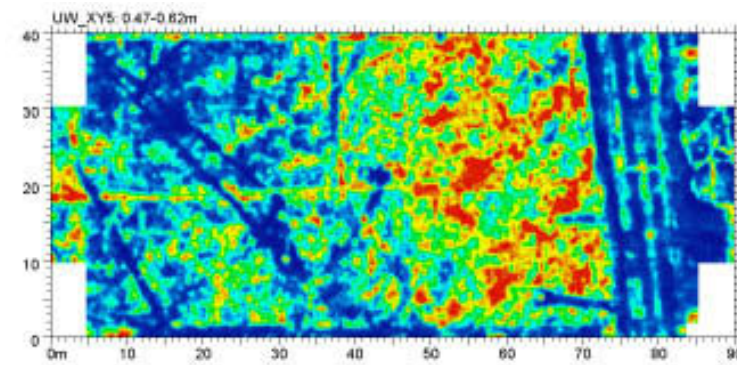
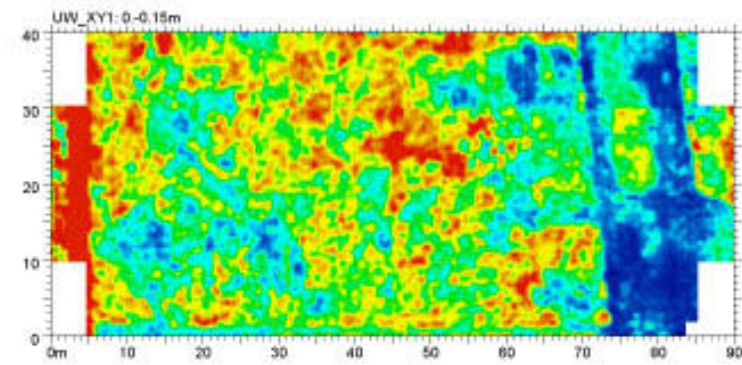
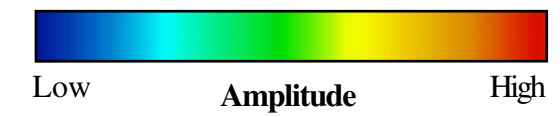
WINDSOR CASTLE

Upper Ward - GPR Time-slices (N-S Traverse Direction)



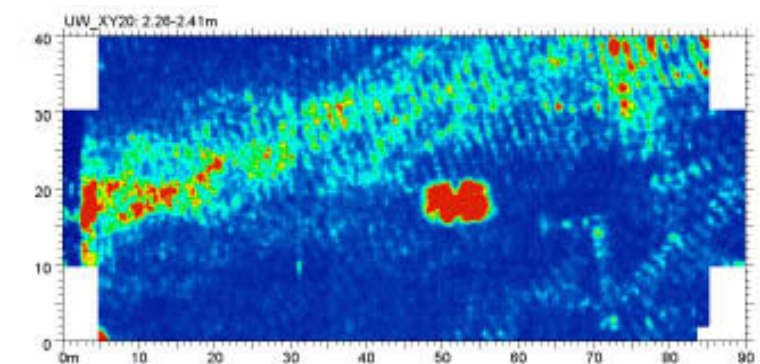
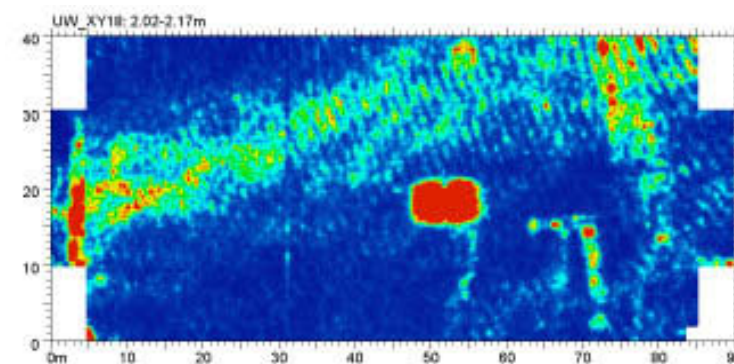
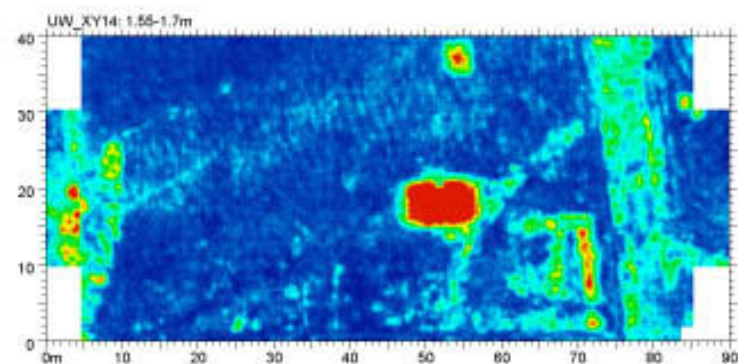
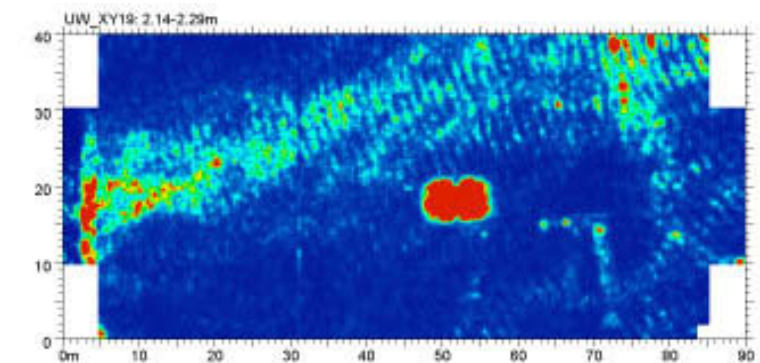
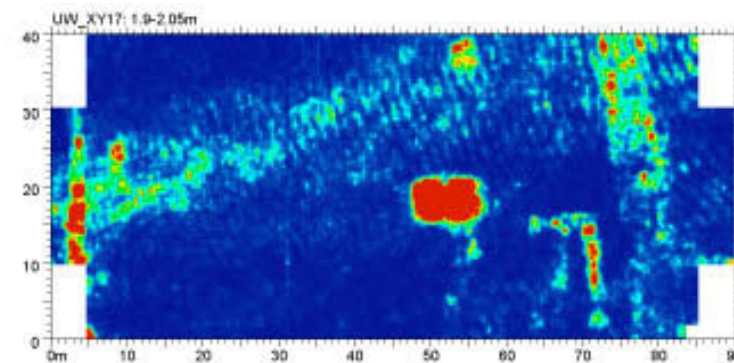
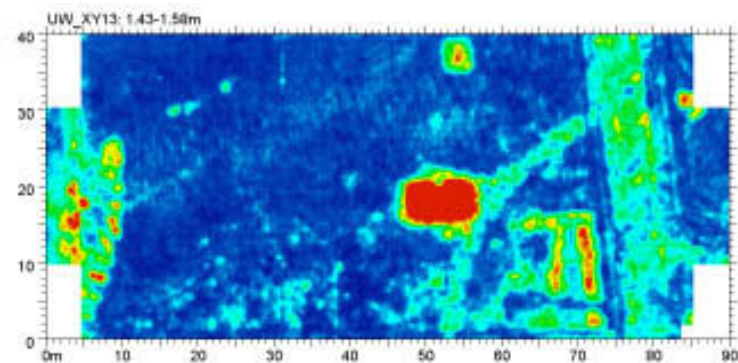
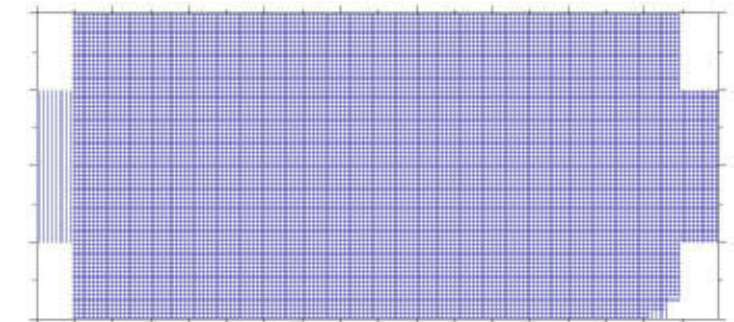
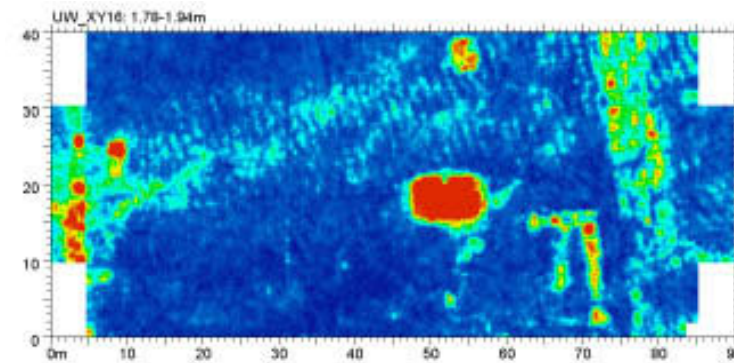
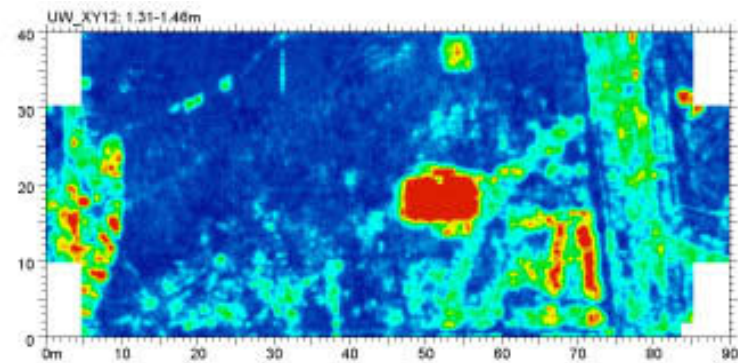
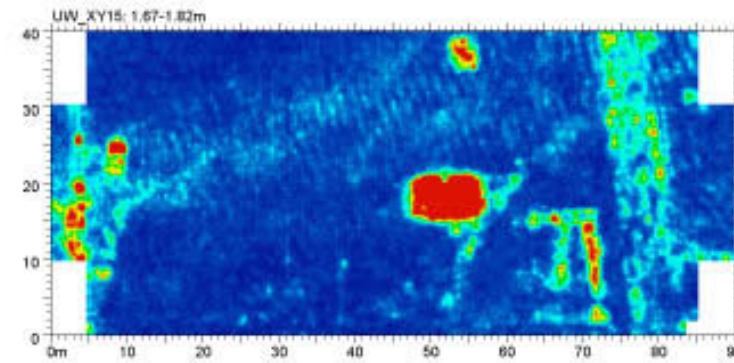
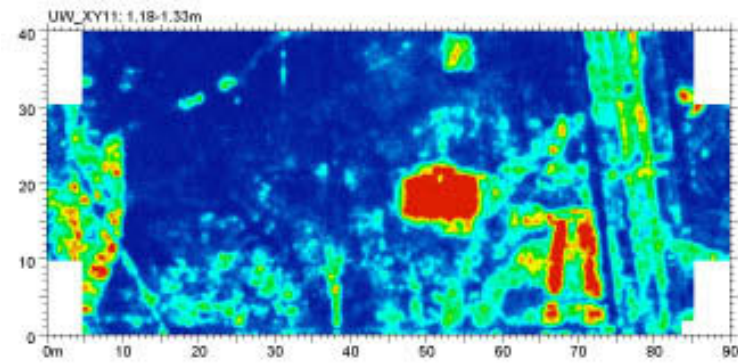
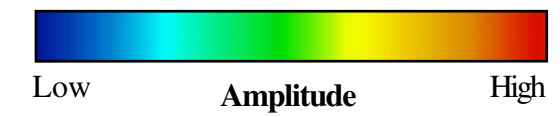
WINDSOR CASTLE

Upper Ward - GPR Time-slices (Combined Traverse Direction)



WINDSOR CASTLE

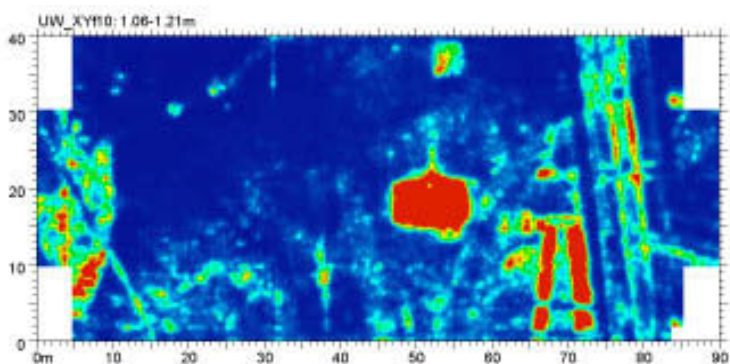
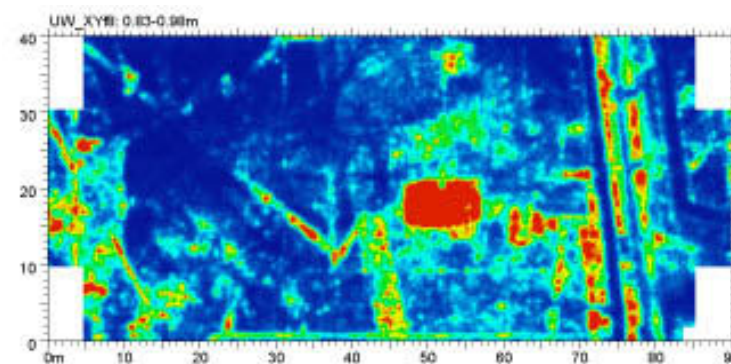
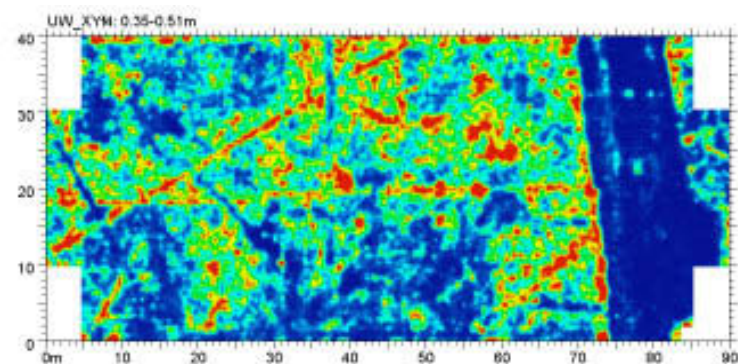
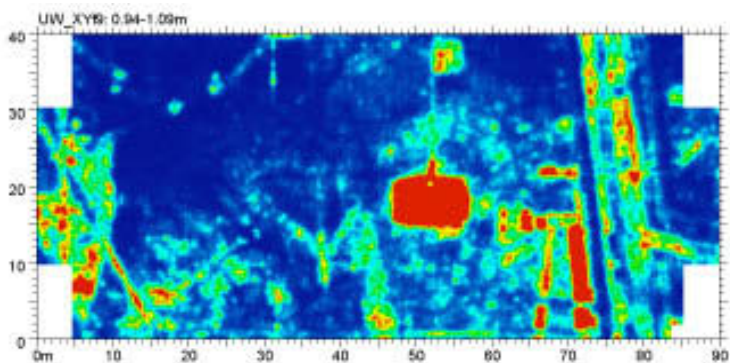
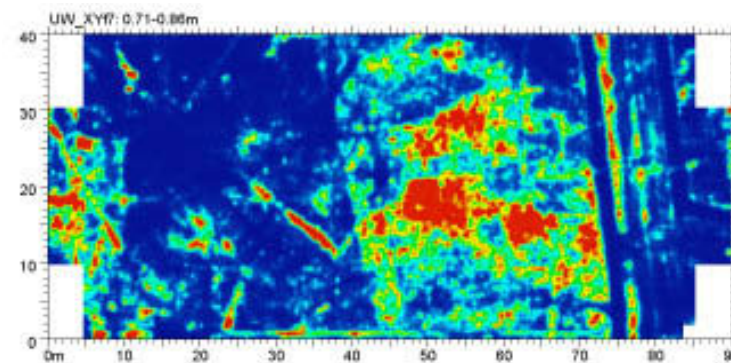
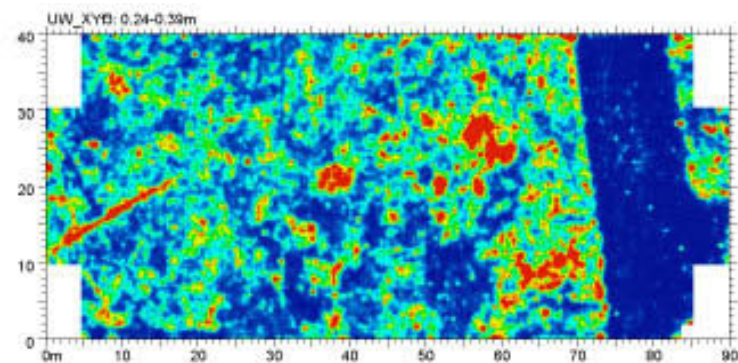
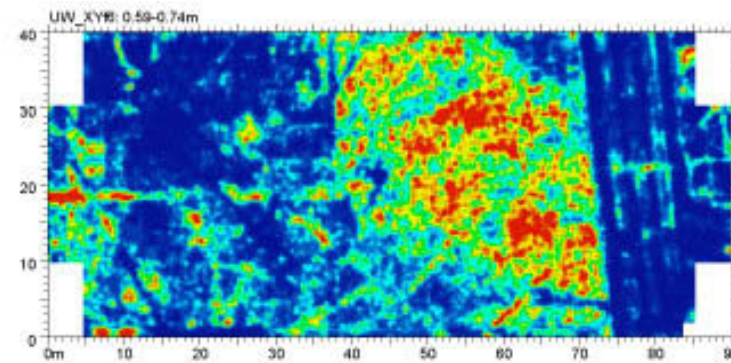
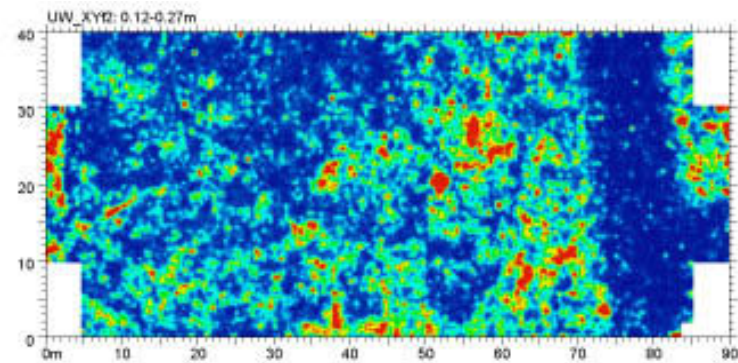
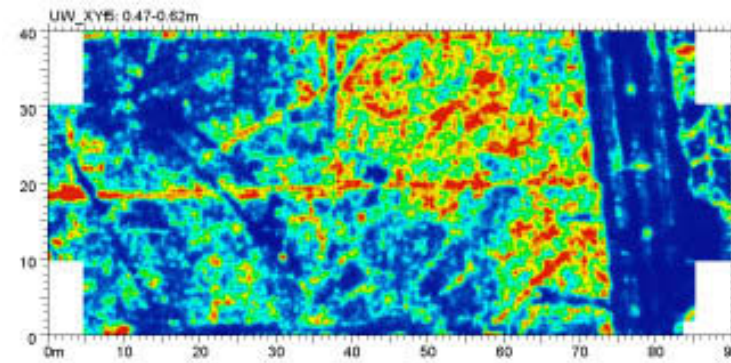
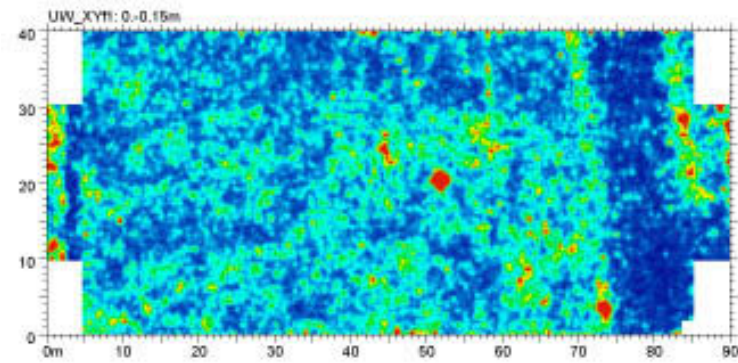
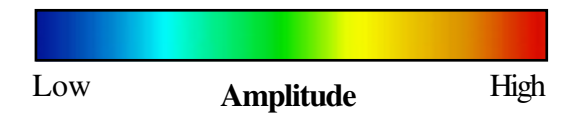
Upper Ward - GPR Time-slices (Combined Traverse Direction)



WINDSOR CASTLE

Upper Ward - GPR Time-slices

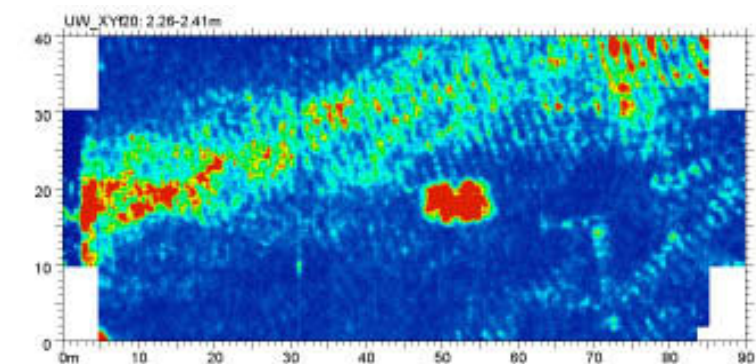
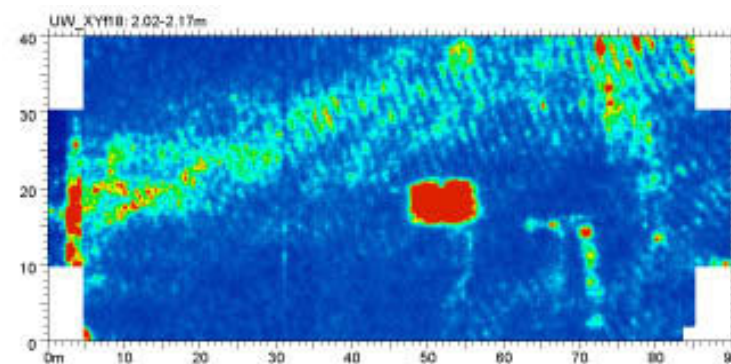
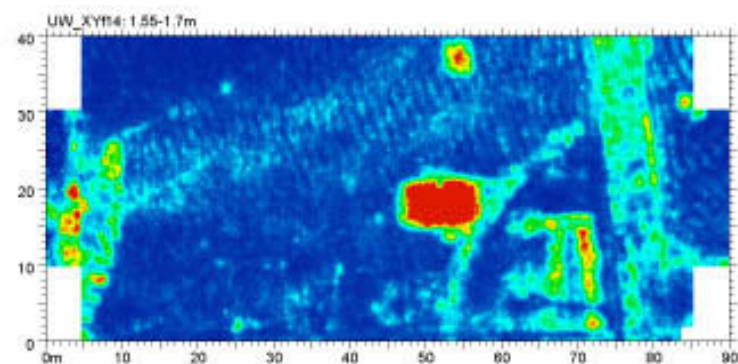
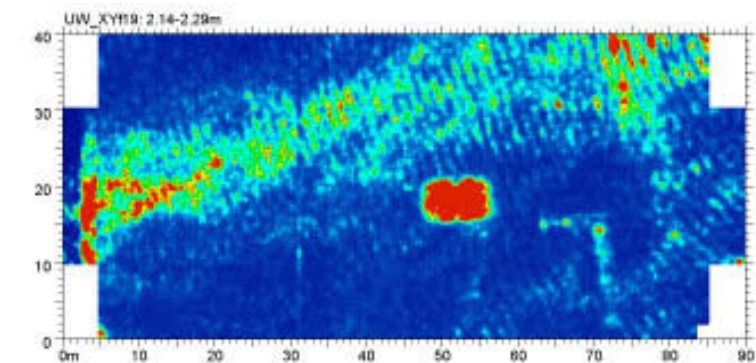
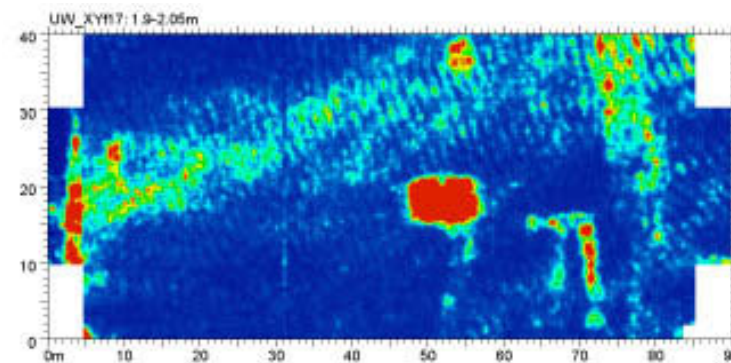
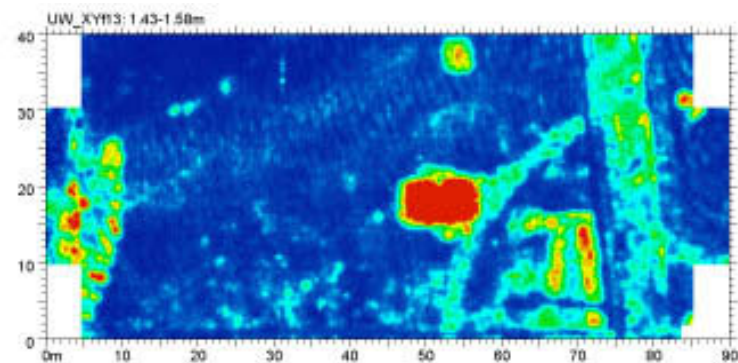
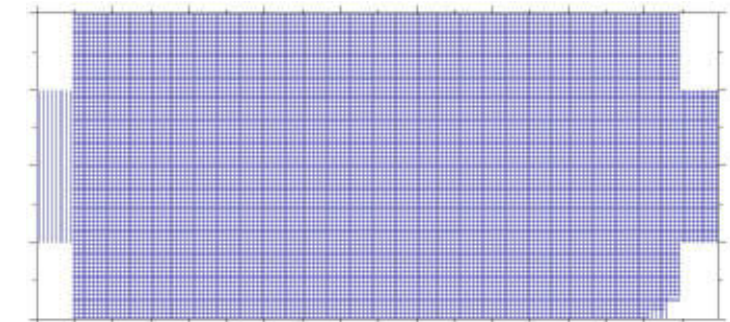
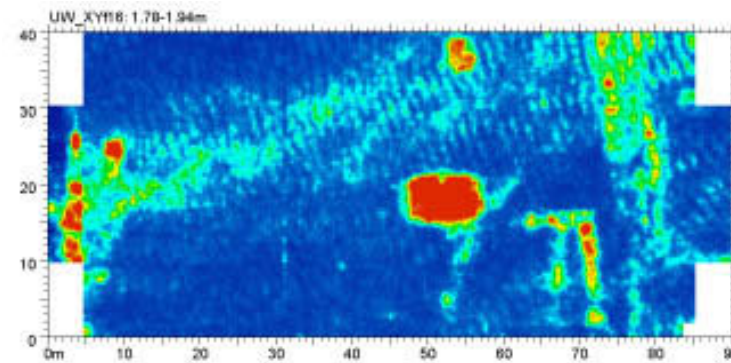
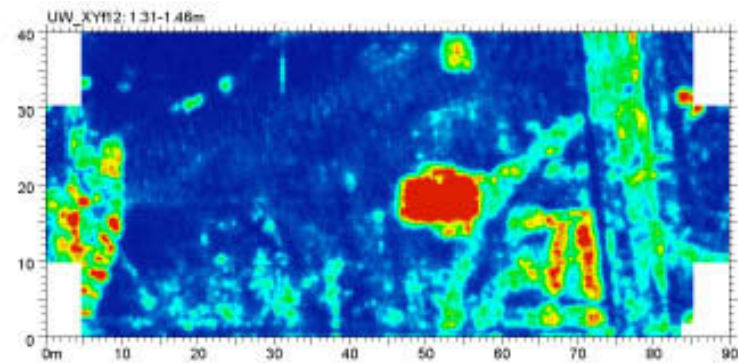
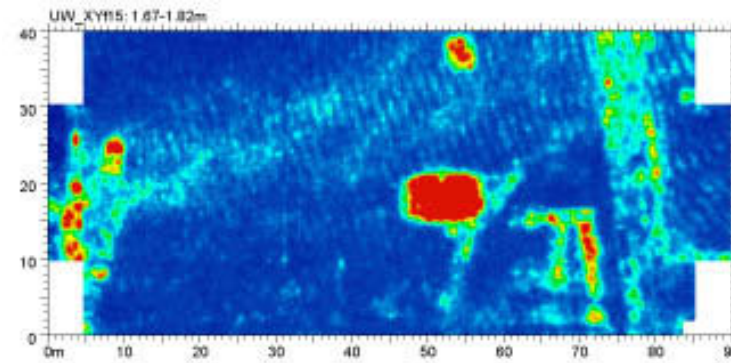
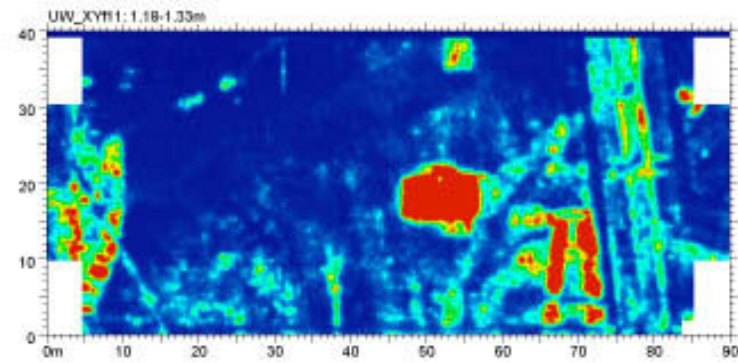
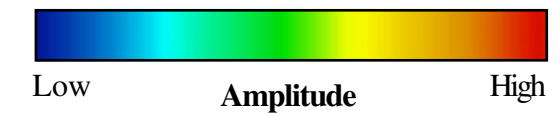
Filtered Data - Background Removal (Combined Traverse Direction)



WINDSOR CASTLE

Upper Ward - GPR Time-slices

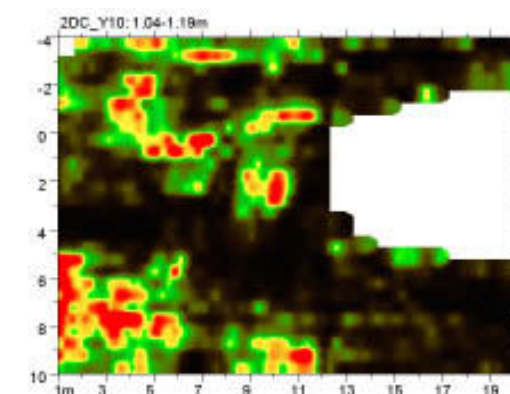
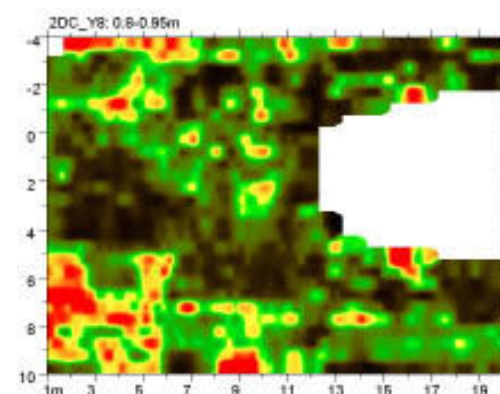
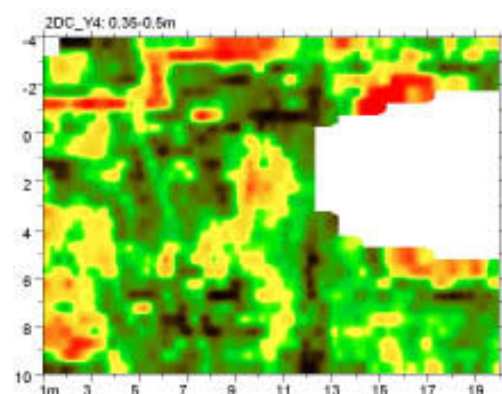
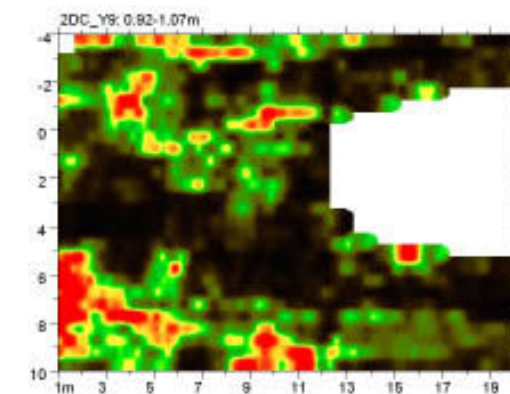
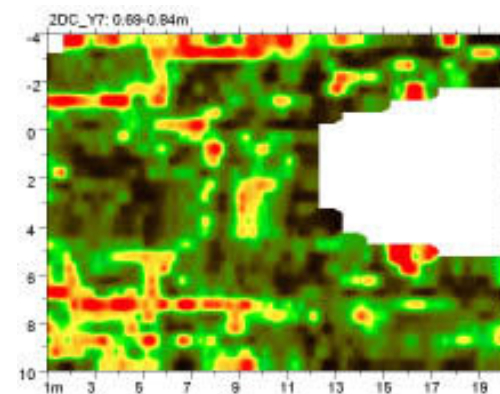
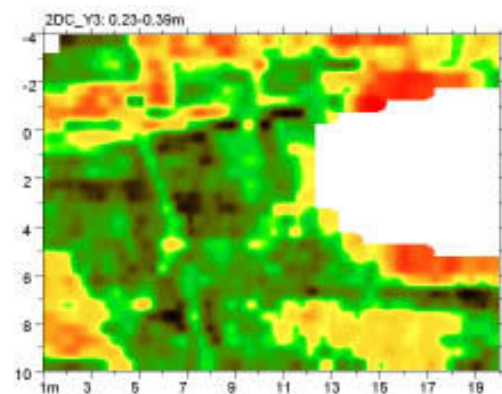
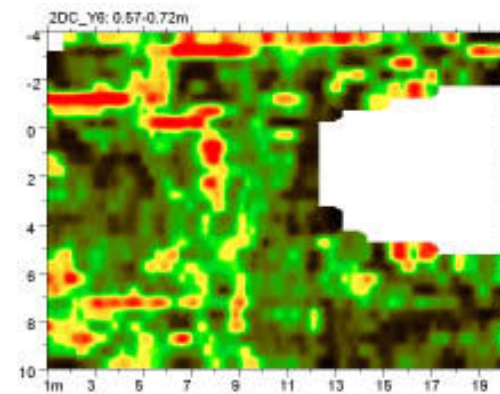
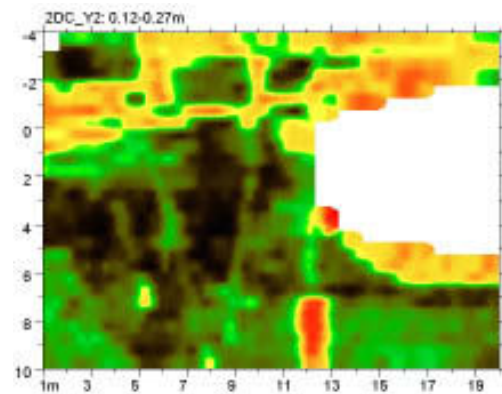
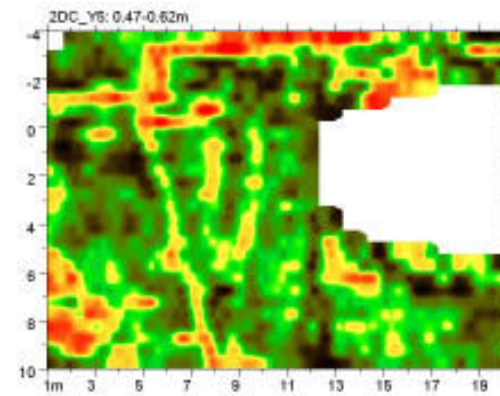
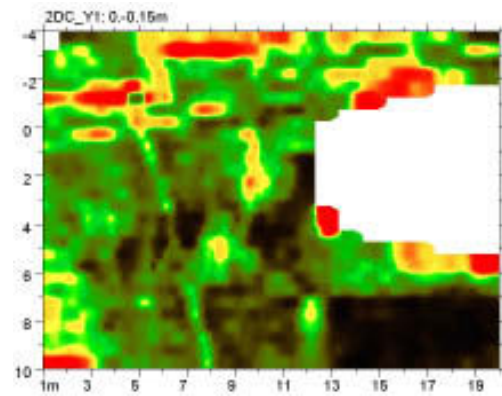
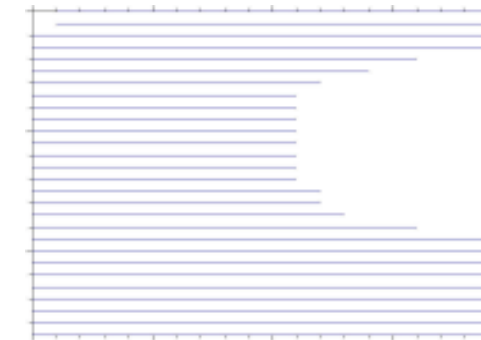
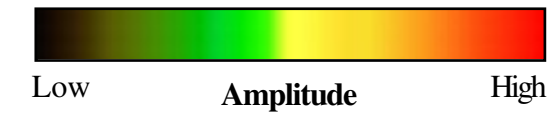
Filtered Data - Background Removal (Combined Traverse Direction)



WINDSOR CASTLE

Denton's Commons - GPR Time-slices

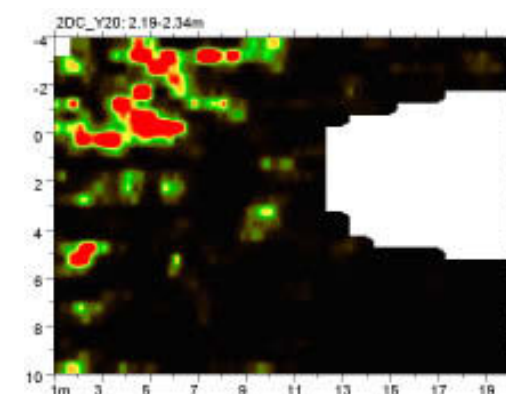
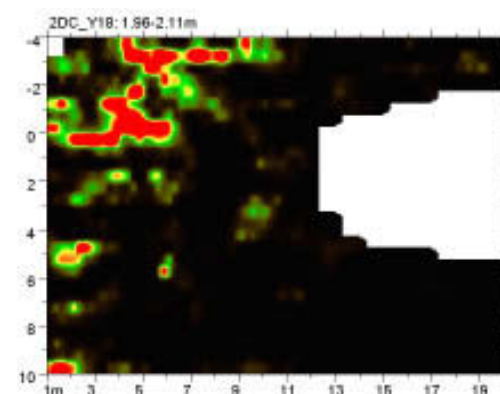
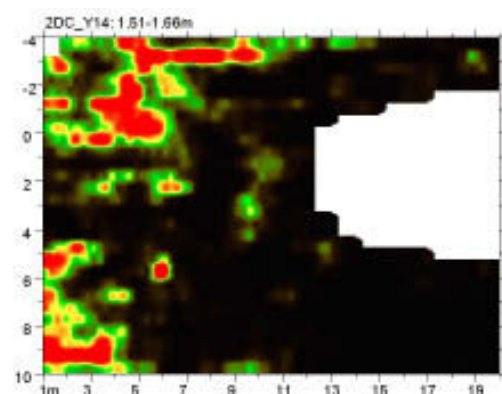
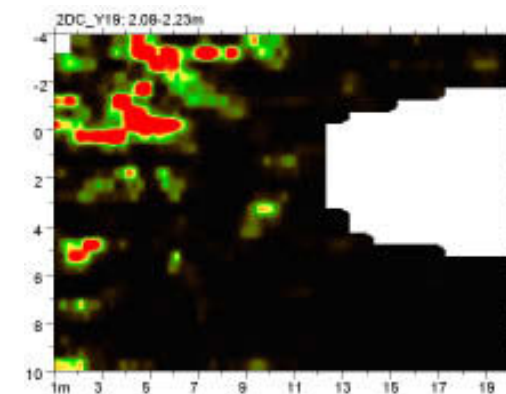
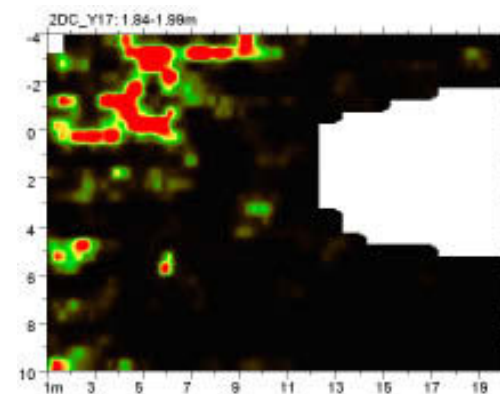
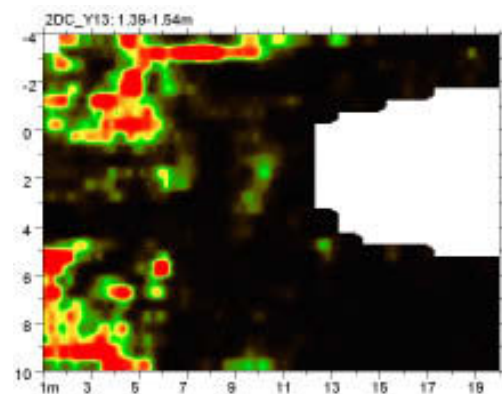
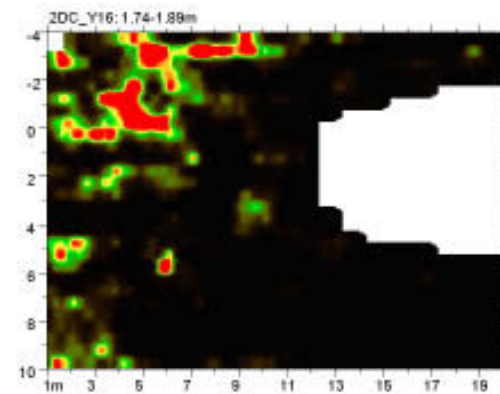
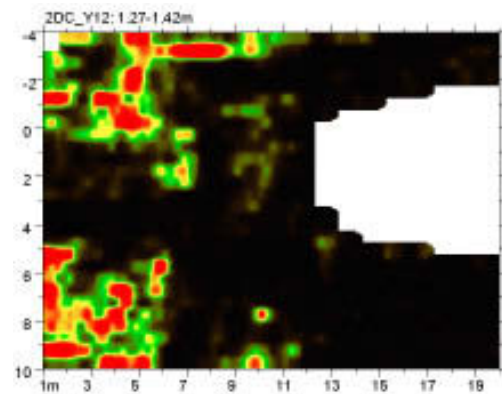
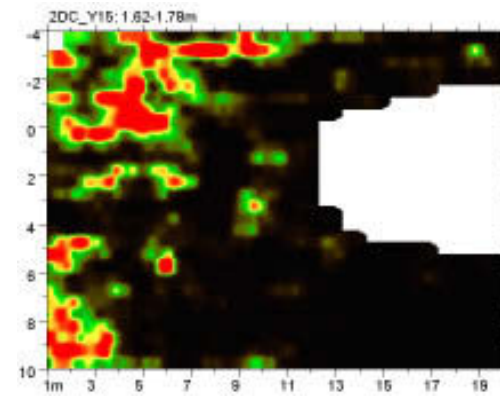
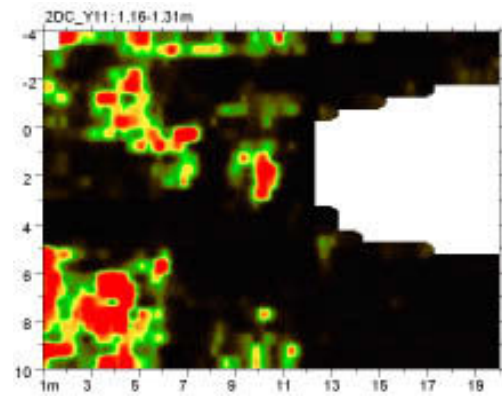
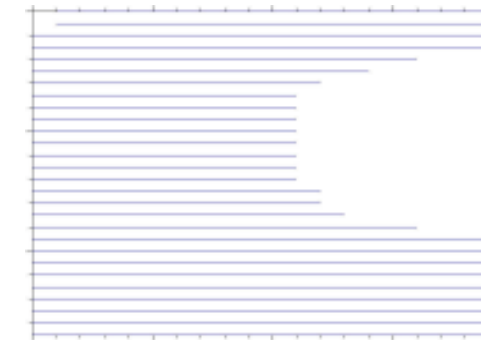
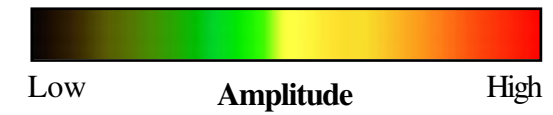
(E-W Traverse Direction)



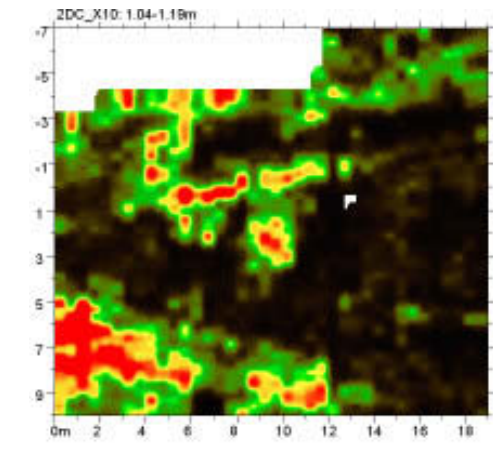
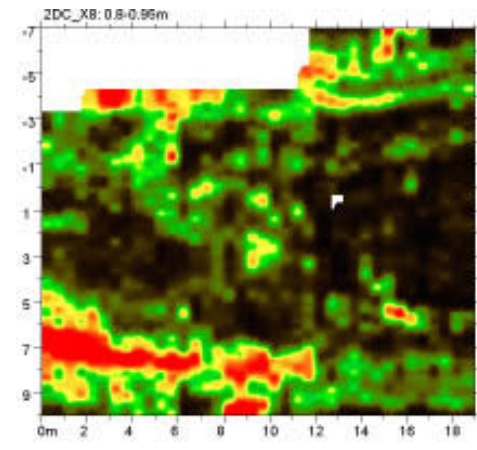
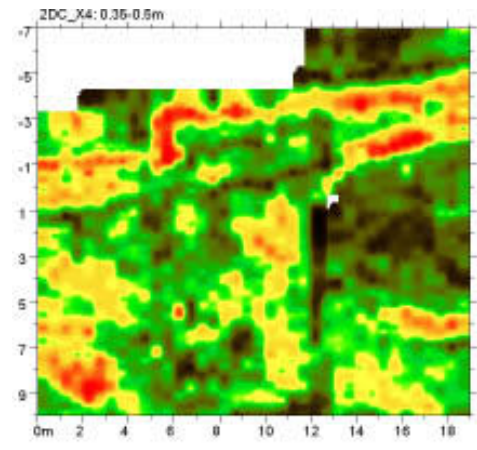
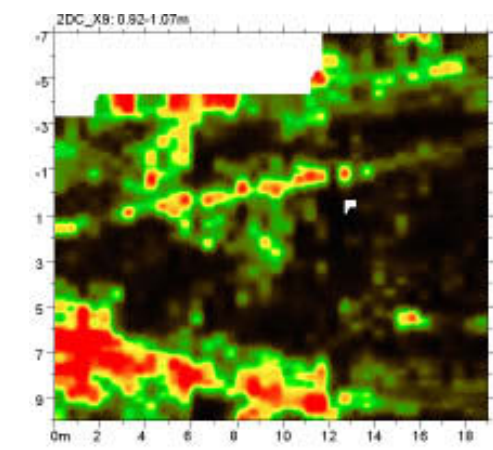
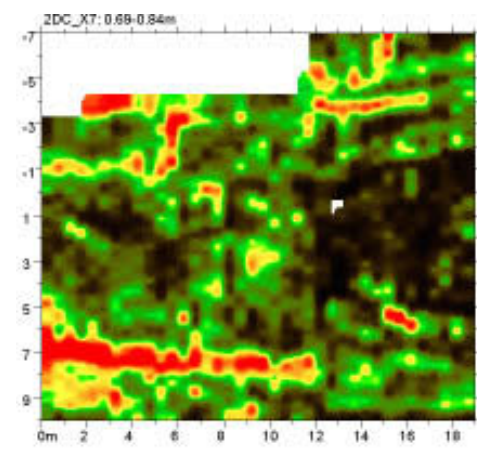
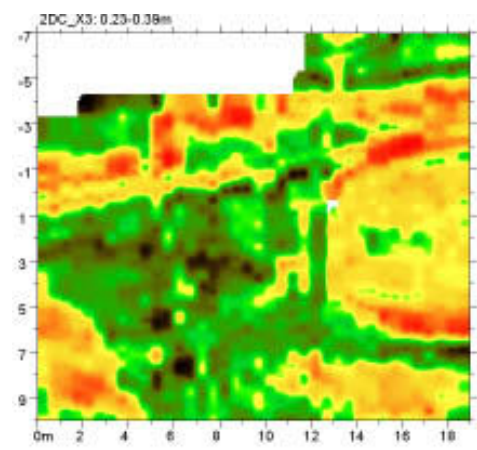
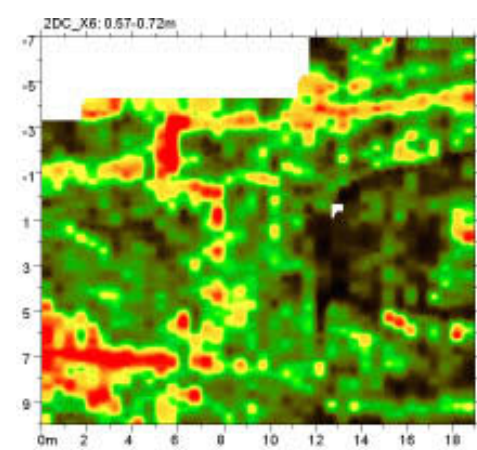
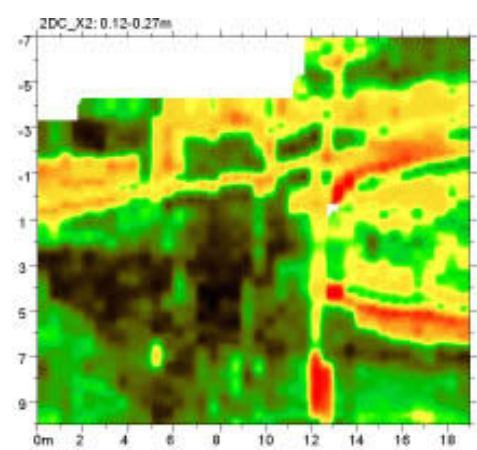
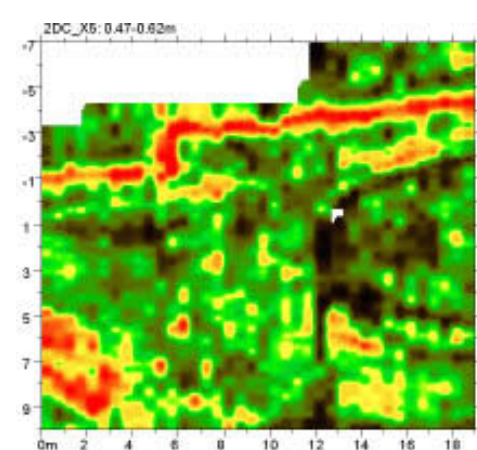
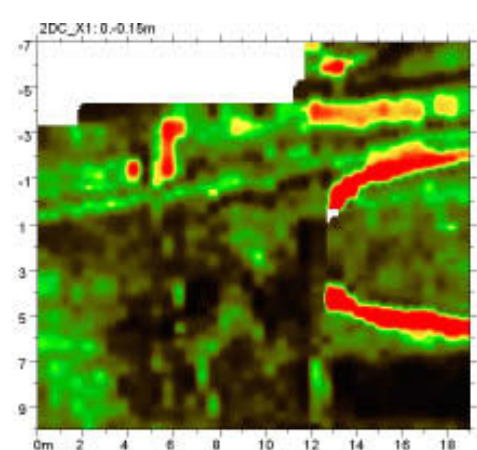
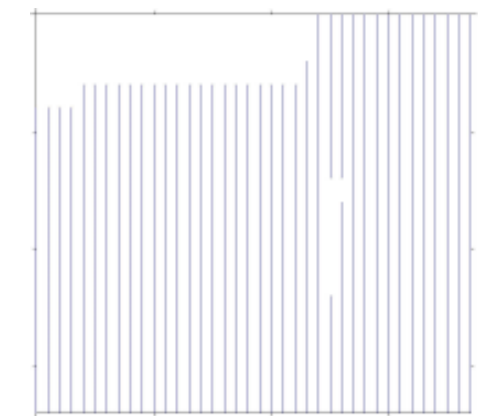
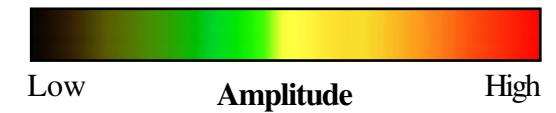
WINDSOR CASTLE

Denton's Commons - GPR Time-slices

(E-W Traverse Direction)



WINDSOR CASTLE **Denton's Commons - GPR Time-slices** **(N-S Traverse Direction)**



WINDSOR CASTLE Denton's Commons - GPR Time-slices (N-S Traverse Direction)

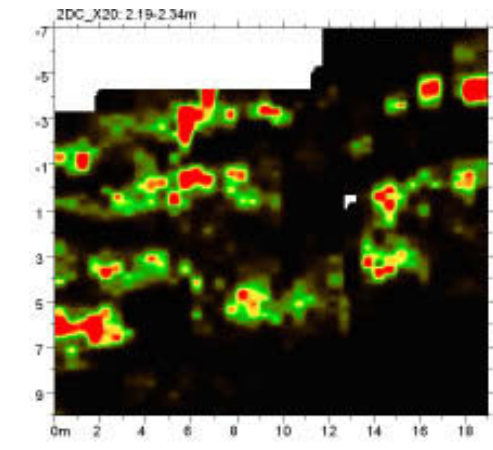
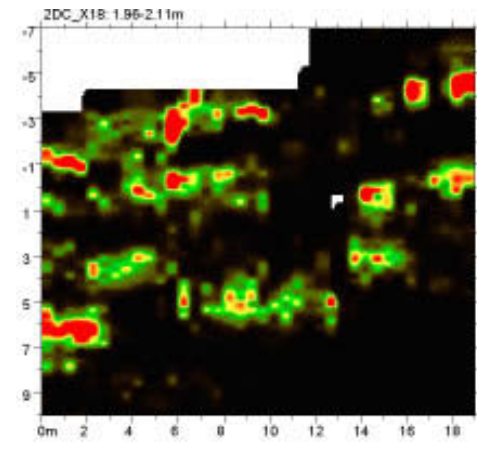
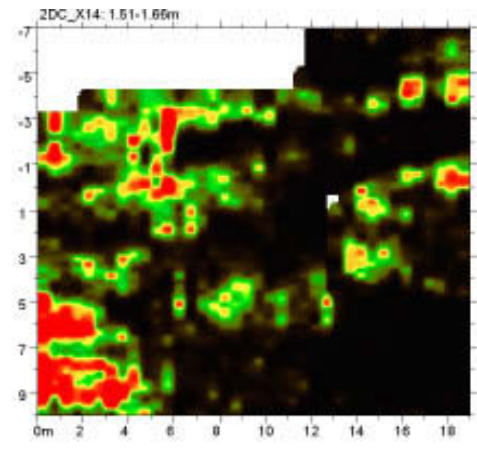
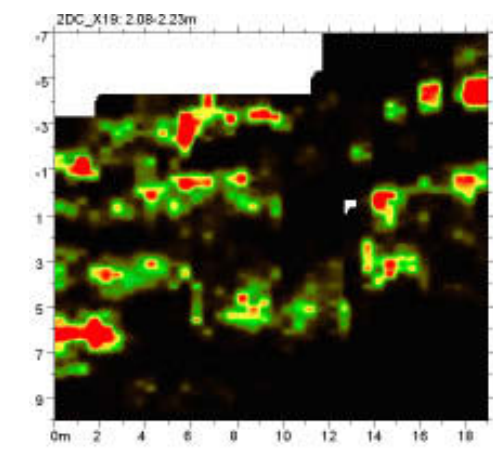
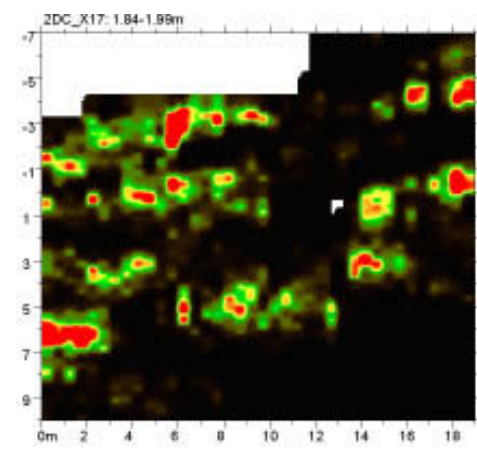
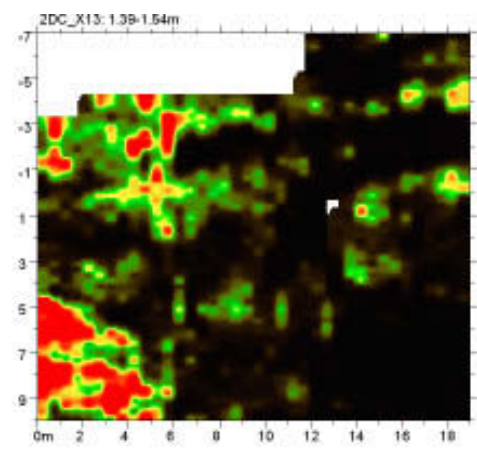
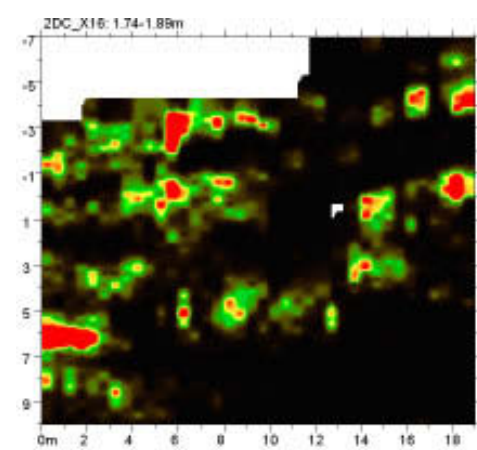
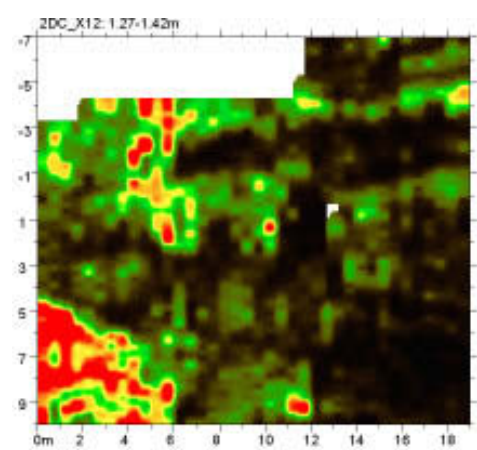
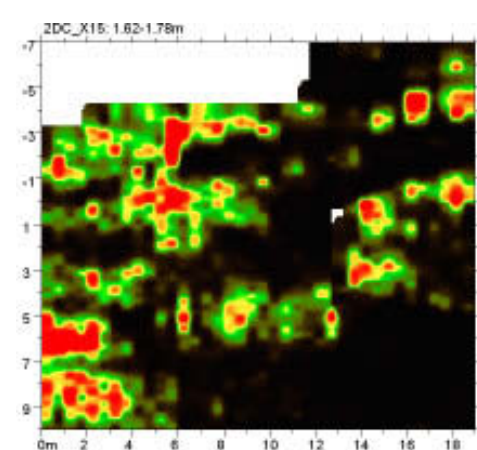
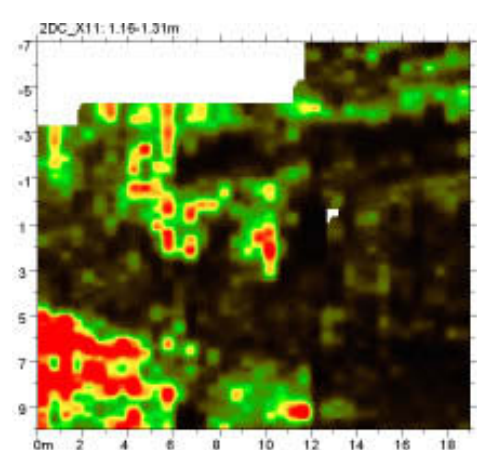
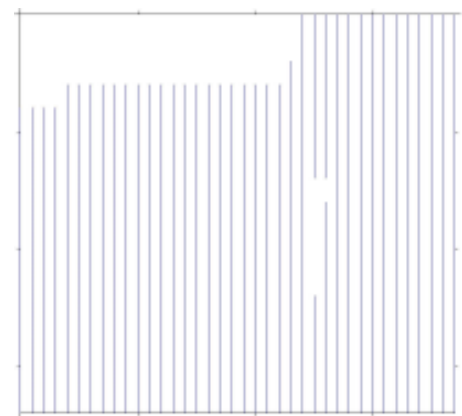
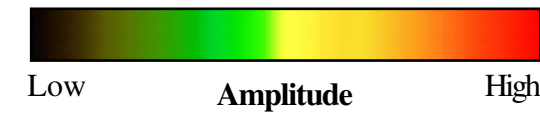
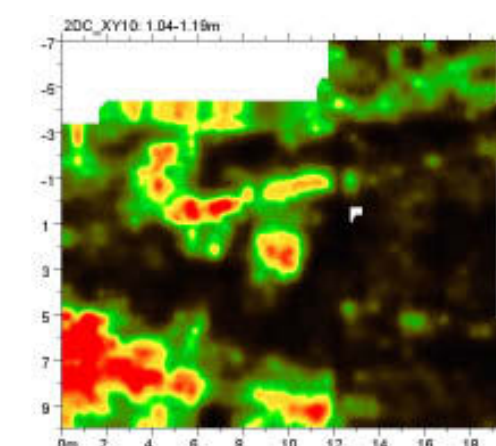
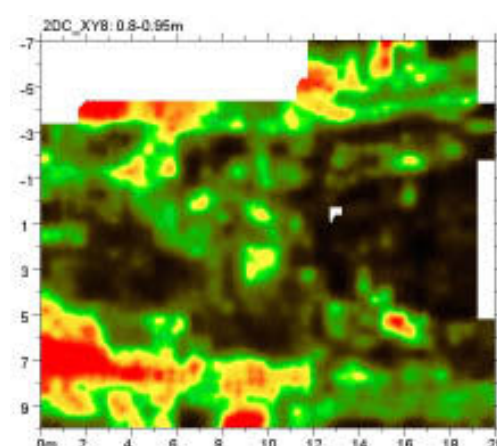
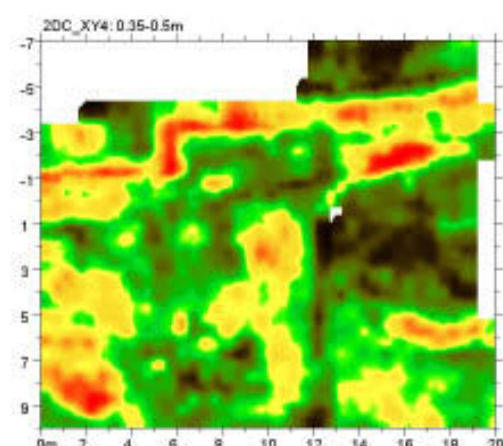
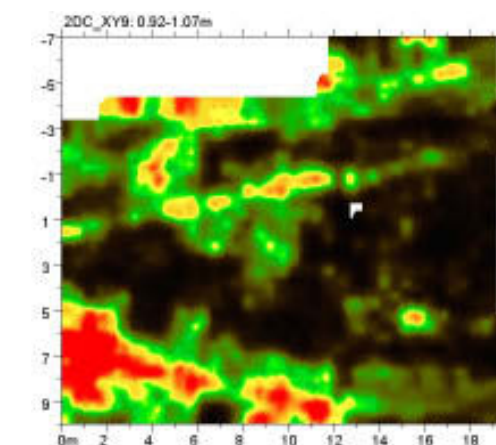
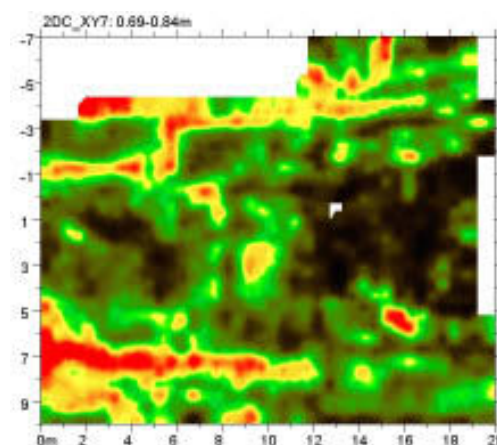
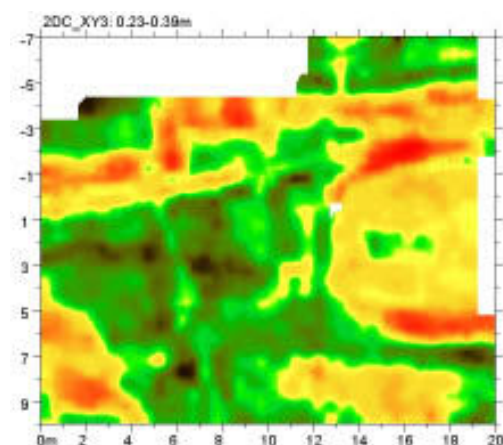
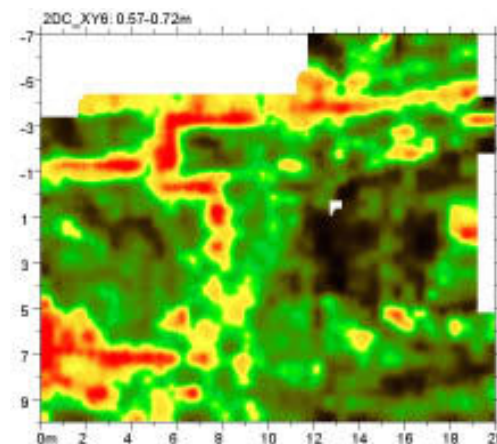
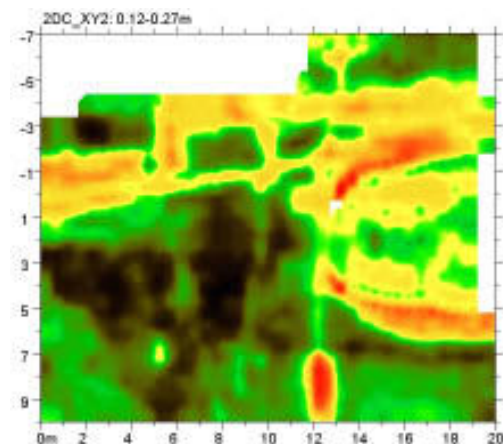
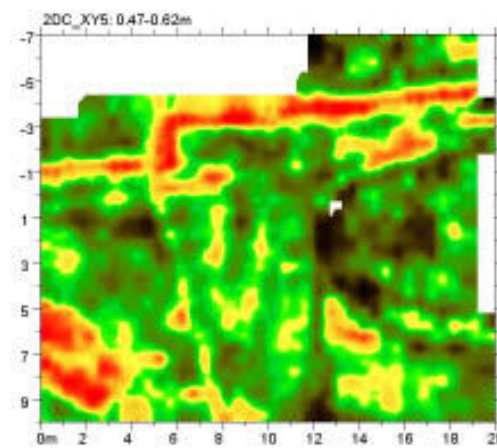
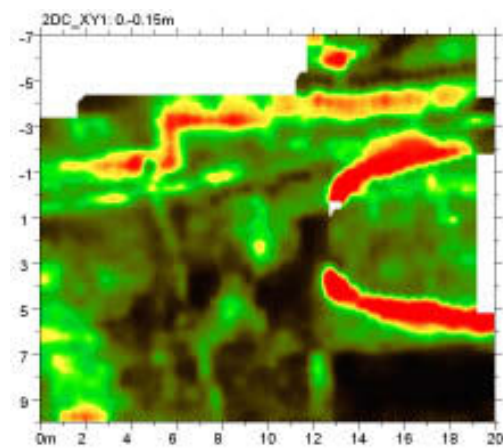
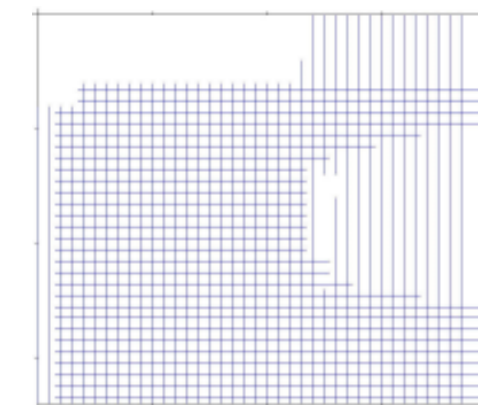
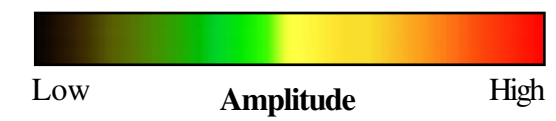


Figure A15

WINDSOR CASTLE

Denton's Commons - GPR Time-slices (Combined Traverse Direction)



WINDSOR CASTLE

Denton's Commons - GPR Time-slices (Combined Traverse Direction)

