Centre for Archaeology Report 29/2005

Kenilworth Castle, Warwickshire. Report on Geophysical Surveys, June and July 2004.

Neil Linford, Paul Linford and Louise Martin

ISSN 1473-9224

Centre for Archaeology Report 29/2005

Kenilworth Castle, Warwickshire. Report on Geophysical Surveys, June and July 2004.

Neil Linford[1], Paul Linford[2] and Louise Martin[3]

Summary

As part of an English Heritage project to investigate, and possibly reconstruct, the original Elizabethan garden at Kenilworth Castle, geophysical surveys were carried out within the castle grounds focussing on the area to the north of the keep. The surveys formed the initial phase of a multidisciplinary investigation and were intended provide information to guide trial excavation trenches. Although data collection was hampered by the presence of an existing formal garden on the site, established in the 1970s, it was possible to identify a number of anomalies that were later investigated and confirmed by excavation. Further geophysical surveys were conducted in other areas of the castle and on the Pleasance, an artificial earthwork platform 1km west of the castle used as a pleasure ground for feasting during the late medieval period. Anomalies likely to indicate the presence of structural remains were detected in both locations and it has thus been possible to identify the probable original and final sites of buildings that Henry VIII is recorded to have ordered to be removed from the Pleasance and reconstructed within the castle.

Keywords

Geophysical Survey
Earth Resistance
Magnetometer
Electromagnetic

Author's address

English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth, PO4 9LD.
[1]Telephone: 02392 856761. Email: neil.linford@english-heritage.org.uk
[2]Telephone: 02392 856749. Email: paul.linford@english-heritage.org.uk
[3]Telephone: 02392 856760. Email: louise.martin@english-heritage.org.uk

KENILWORTH CASTLE, Warwickshire.

Report on geophysical surveys, June and July 2004.

Introduction

Geophysical surveys of approximately 0.8 hectares were conducted over the site of the former Elizabethan Garden and surrounding areas at Kenilworth Castle, Warwickshire (SAM 21576) and of approximately 1.2 hectares over the raised portion of a moated platform, known as the Pleasance, found 1 km to the west of the castle (SAM 21557).

The original Elizabethan Garden was created by Robert Dudley, Earl of Leicester for a 19 day royal visit to Kenilworth Castle by Elizabeth I in 1575. This was just one part of the lavish preparations that transformed the castle and surrounding landscape into a vast pleasure ground of pageantry and spectacle. Most of our knowledge of the original garden comes from a contemporary account written by Robert Laneham in August 1575. He vividly describes the area to the north of the castle keep as being divided into a system of compartments and grass walks bordered by sand, and filled with flowers, fragrant herbs and fruit trees. In the middle of it all there stood a tall sculptured fountain topped by Dudley's emblem of a ragged staff, which was also used to adorn obelisks in the quarters and along the terrace. Opposite the keep stood a richly decorated timber aviary. The only known plan of the garden was published some 81 years later, in 1656 by William Dugdale, but the detail it contains does not convincingly reflect Laneham's description. Moreover, an 18th century copy of a lost fresco painting from c.1620 indicates only a terrace, steps and fountain surrounded by lawn further questioning the accuracy of Dugdale's plan. However, both the fresco and the Dugdale plan indicate buildings, albeit of different arrangements, in the area close to the Swan Tower: the suggested location of timber buildings removed from the Pleasance and re-erected within the castle walls.

In more recent times the garden area was under cultivation until the 1930's and then used as an orchard before the removal of the trees in 1970 prior to excavations by Beric Morley (Ellis 1995, 83). These excavations were designed to test the survival of any features relating to the original Elizabethan Garden, with the aim of accurately establishing Dugdale's plan so the layout of the garden could be recreated with modern planting for public display (*ibid.*). Two diagonal trenches excavated across the garden floor failed to produce evidence correlating with Dugdale's plan and although the results were considered disappointing, a reconstructed garden was planted in 1975 by Harry Gordon Slade to a design that is now considered unconvincing when compared with Robert Laneham's contemporary description (English Heritage 2004, 4).

The Pleasance was created by Henry V as a site for a feasting pavilion on the far side of the Mere, a shallow expanse of water originally extending from the west of the castle, (Colvin *et al.* 1963, 685) whose buildings were found to be too public for the King's liking (Renn 1973, 18). The Pleasance consisted of two concentric moats around a central diamond shaped platform, with the corners orientated on the points of the compass (*ibid.*). The stone footings of four timber buildings can still be traced: on the south-west side once stood a timber-framed hall; and rectangular towers stood on the north, south and east corners, one being known as the 'Clarence Tower' (Colvin *et al.* 1963, 685). The central area was most probably a garden (*ibid.*), or diamond shaped courtyard (Renn 1973, 18). The buildings were later demolished under the orders of Henry VIII, but records indicate that the timber was used to rebuild structures, and possibly even the complete buildings, within the castle – probably in the vicinity of the Swan Tower (Colvin *et al.* 1963, 685; Colvin *et al.* 1975, 258; Renn 1973, 18).

The aim of the survey over the site of the current Elizabethan style garden was to determine whether any geophysical evidence for the survival of original garden remains of 1575 could be recovered in advance of further limited excavation. In addition, the survey of areas within the curtain wall adjacent to the garden in the vicinity of the Swan Tower, was conducted in an attempt to locate any remains of further buildings, in particular those that might relate to the re-erected structures from the Pleasance. To complement this work a survey over the Pleasance was undertaken, with the aim of identifying the original location (and perhaps size) of building structures later removed to the castle.

The Castle (SP 278 723) lies on reddish fine loamy soils of the Whimple 2 association and stoneless mostly reddish clayey soils of the Compton association (Soil Survey of England and Wales 1983) both developed over the Kenilworth Sandstone formation (British Geological Survey 1984). The Pleasance (SP 267 725) lies on slowly permeable seasonally waterlogged reddish fine loamy soils of the Salop association and stoneless mostly reddish clayey soils of the Compton association (Soil Survey of England and Wales 1983) developed over Alluvium and Ashow formation Sandstone (British Geological Survey 1984). At the time of the survey the Elizabethan garden area was laid out with metalled paths dividing parterres planted with box hedging, holly, yew, lavender and sage. The Pleasance was under pasture.

Method

The survey grids were laid out with a real-time kinematic Global Positioning System (GPS). A topographic survey of the Pleasance was also conducted using GPS, recording continuously every 2m along lines ~4m apart.

The Castle

Earth resistance

Earth resistance techniques have been shown to successfully identify anomalies relating to previous garden design (Cole *et al.* 1997), and stone building foundations (Clark 1990, see chapter 6). Therefore, the whole of the garden area directly north of

the keep, an area to the west of this around the Swan Tower, an area directly east of the keep and a smaller area along side the curtain wall by Lunn's tower were surveyed with an earth resistance meter in an attempt to locate building and garden remains (Figures 1 and 2).

Measurements were collected with a Geoscan RM15 resistance meter, MPX15 multiplexer and an adjustable PA5 electrode frame in the Twin-Electrode configuration. Readings were collected using the standard method outlined in note 1 of Annex 1 with a mobile electrode separation of 0.5m, taking readings at a sample interval of 1.0m x 1.0m. Plots of the data-set are presented as both an X-Y traceplot and a linear greyscale, at a scale of 1:1250 in Plan A. A linear greyscale plot of the filtered data has been superimposed over the base OS map (1:1000) in Figure 3 and with the location of the 2004 trenches (after Dix and Prentice 2004) at 1:500 in Figure 4.

The data was processed using a 2m by 2m thresholding median filter (Scollar *et al.* 1990, 492), to reduce the distracting, localised, high-magnitude effects produced by contact resistance. This was followed by the application of a steerable second derivative Gaussian filter (Freeman and Adelson 1991), with 0.75m standard deviation, to enhance linear anomalies of the order of ~1.5m wide over the gradual regional variations of background earth resistance. The results after this latter process are displayed in Figures 3 and 4 and Plan A3.

Electromagnetic survey

Due to the presence of extant planting within the garden, continuous reading survey techniques requiring an instrument to be carried at a constant rate (such as fluxgate magnetometry) were impractical. However, the magnetic response of the subsurface can also be measured with a non-contacting soil conductivity meter that will also respond to the presence of highly conductive features, such as lead water supply pipes fragments of which were identified during excavations in the 1970s (Ellis 1995, 89).

A Geonics EM38B conductivity meter was used over the part of the garden indicated on Figure 2. Unfortunately, due to technical problems associated with inclement weather during the survey, it was not possible to cover the whole garden with this instrument. However, it was hoped that the surveyed grids would be likely to cover the area where remains of the central fountain described by Laneham (Ellis 1995, 86) might be situated. This fountain formed the focus of the original garden and is where any surviving water pipes would be expected to be found. The Geonics EM38B operates at a frequency of 14.2 KHz and allows the simultaneous acquisition of both in-phase and quadrature response, proportional to the magnetic susceptibility and conductivity of the subsurface respectively. In this case, the instrument was operated with a vertical coil orientation, for maximum depth of signal penetration, and data was collected at 1m × 1m sample interval. Plots of both in-phase and quadrature data-sets are presented as X-Y traceplots and equal area greyscales at a scale of 1:1000 on Plan B. An addition equal area greyscale of both the in-phase and quadrature phase data superimposed over the base OS map (1:1000) is shown in Figure 5.

Ground Penetrating Radar survey
In the area just west of the garden, between the Strong and Swan towers, a Ground Penetrating Radar (GPR) survey was conducted with a Pulse Ekko PE1000 console and a 450MHz centre frequency antenna in an attempt to better define suspected building remains detected by the earth resistance survey. The 450MHz antenna was selected as the most suitable centre frequency for obtaining the optimum depth of penetration and lateral resolution required to image the expected archaeological targets. A 30m x 30m grid was surveyed to allow data to be collected from parallel north-south traverses separated by 0.5m (Figure 10 and Plan C). Individual traces along each profile were separated by 0.05m and recorded the amplitude of reflections through a 60ns time-window. Post acquisition processing involved the adjustment of time-zero to coincide with the true ground surface, removal of any low frequency transient response (dewow), noise removal and the application of a suitable gain function to enhance late arrivals.

The visualisation of GPR reflections from individual profiles are often emphasised by presenting the data as series of horizontal amplitude time slices. In this case, time-slices were created from the entire data set, after applying a 2D-migration algorithm, by averaging data within successive 2ns (two-way travel time) windows (David and Linford 2000; Sensors and Software 1996) assuming an average velocity of the radar wavefront in the ground of 0.05m/ns (the velocity was estimated from the analysis of hyperbolic reflections in the acquired data). Each resulting time slice, illustrated as a greytone image in Plan D represents the variation of reflection strength through successive ~0.05m intervals from the ground surface.

The Pleasance
Earth resistance
As stone building foundations were suspected, an earth resistance survey was conducted at the Pleasance. Measurements were collected with a Geoscan RM15 resistance meter, MPX15 multiplexer and an adjustable PA5 electrode frame in the twin-electrode configuration, using the standard method outlined in note 1 of Annex 1 but in the parallel twin mode. A mobile electrode separation of 0.5m was used to collect readings at a sample density of 1.0m x 1.0m. Plots of the data-set are presented as an X-Y traceplot and various greyscales, at a scale of 1:1500 in Plan E. An equal area greyscale of raw data has been superimposed over the base OS map (1:1500) in Figure 6. Plan G shows a greyscale plot of the resistance data draped over a Digital Terrain Model (DTM), created using Geosoft OASIS Montaj 5.8 software from the topographic data. For visual clarity, the vertical scales in this plan are exaggerated by a factor of 8.

The data-set was ‘despiked’ through the application of a 2m by 2m thresholding median filter (Scollar *et al.* 1990, 492). This operation reduces the distracting, localised, high-magnitude effects produced by contact resistance. The plot presented on Plan E3 was further processed using Pratt’s crispening operation (Pratt 1978, 322) and that on Plan E4 using the Wallis contrast enhancement algorithm (Wallis 1976).

Magnetometer survey
The central mound platform shaded in Figure 2 was surveyed with two Bartington *Grad601* fluxgate gradiometers following the standard method outlined in note 2 of Annex 1. A plot of the data-set is superimposed over the OS base map (1:1500) on Figure 6. Plots of the data-set are presented as both an X-Y traceplot and a linear greyscale, at a scale of 1:1000 on Plan F. Plan G shows a linear greyscale of the magnetometer data draped over a DTM, created using Geosoft OASIS Montaj 5.8 software from the topographic data. For visual clarity, the vertical scales in this plan are exaggerated by a factor of 8.

Corrections made to the measured values displayed in the plots were to zero-mean each instrument traverse to correct for instrument heading errors and to 'despike' the data through the application of a 2m by 2m thresholding median filter (Scollar *et al.* 1990, 492). This latter operation reduces the distracting, localised, high-magnitude effects produced by surface iron objects. A Butterworth band-reject filter in the frequency domain was applied to the data from some grid-squares to remove periodic artefacts caused by operator gait. To improve the presentation of the traceplot shown in Plan F, the data-set has had the magnitudes of extreme values truncated to ±20nT/m.

Results

The Elizabethan garden area within the castle

The area to the north of the keep is devoted to the garden laid out by Harry Gordon Slade in 1975 inspired by the layout published by Dugdale. The hedges, walkways and the formal plantings of herbs and bushes comprising this layout complicated data collection and it was not possible to take measurements in some locations. This has resulted in a larger than usual number of missing readings particularly in the earth resistance survey. Furthermore, the extant garden will also be responsible for many of the anomalies detected in the geophysical surveys of this area. It should be borne in mind that such anomalies are likely to confuse and mask any map of deeper anomalies relating to earlier garden layouts.

Earth Resistance Survey
A graphical summary of the significant anomalies discussed below is provided on Figure 8. Numbers in [ ] refer to annotations in this figure. Unless otherwise stated, references to excavation trenches relate to the investigations of Dix and Prentice in 2004 (Dix and Prentice 2004).

Inspection of Figure 8 reveals many anomalies in the area presently covered by Slade's garden, however, a large number of these correlate with the visible plantings and are likely to be due to differences in soil moisture and compaction caused by the present horticultural regime. This is particularly true in the eastern half of the garden but further west there are some anomalies that cannot be accounted for in this way. At [R1] a high resistance linear anomaly runs east from the Swan Tower, disappearing at a point just short of Trench C. Thompson (1969)

records that footings of the former curtain wall run east from the Swan Tower for approximately 30m before continuing as a robber trench and this might explain the anomaly. However, no continuation as a negative linear anomaly has been detected further east to correspond with the reported robber trench. Dix and Prentice found no evidence of curtain wall footings in their Trench C, concluding that the trench was possibly aligned with the entrance to an additional, now demolished, rectangular tower visible in Dugdale's plan. The earth resistance survey does not show any further anomalies that might suggest a rectangular tower here but they may lie beneath the unsurveyable area immediately to the north which is obscured by a high hedge. Some further linear high resistance anomalies running parallel to those at [R1] can be discerned to the north of this hedge and these may also be associated with the Castle's medieval defences.

A shorter roughly linear high resistance anomaly is apparent south of the path at [R2]. It is possible that this represents a continuation of the linear anomaly marked further east and examined by Trench D. The anomaly here was found to be caused by a C19th AD path and associated gulley, the remains of which were also found in the southern part of Trench C. However, the anomaly at [R2] is of greater magnitude and does not quite extend into the area covered by Trench C, so it is possible that more substantial buried remains are the cause.

Two strong discrete areas of high resistance are apparent at [R3]. Whilst these may be caused by modern plantings, they are not inconsistent in magnitude with the response expected from buried masonry. Thus it is possible that they represent the remains of statue bases or other similar features from an earlier garden layout. Immediately east at [R4], a more continuous pattern of high resistance anomalies has been detected. It is not clear what these might represent but they do not correlate with present plantings in this area. Trench 5 investigated part of this area and revealed a roughly square stone packed feature likely to relate to the Elizabethan garden. It is thus possible that further stone features exist here. Southwest at [R5] a semicircular area of slightly raised resistance readings have been detected, possibly surrounded by a linear low resistance anomaly, suggestive of a former planting bed. Excavation trenches 4a and 4b were dug to investigate this anomaly but found nothing other that a possible increase in soil compaction to account for it.

A discrete high resistance anomaly some 2m across is apparent at [R6], consistent in strength with that which might be expected from buried masonry. The anomaly is in close proximity to Trench B where the stone footings of the base of a fountain were discovered along with a stone-lined channel. It is possible that the geophysical anomaly relates to these remains, however, it is not clear whether the anomaly extends into the area covered by Trench B where stone remains were found (although a second smaller high resistance anomaly is apparent in the eastern extension of this trench).

At [R7] a further group of particularly high resistance anomalies can be discerned. Some of these may be caused by soil compaction under the walkways between extant planting beds but not all are aligned with these walkways. It is thus possible

that remains from an earlier garden layout survive here. In particular, the 1m wide east-west linear anomaly [R8] appears to correlate with a similar anomaly in the in-phase electromagnetic survey (see below).

South of the present garden a broad (~5m wide) high resistance anomaly is apparent running east-west in front of the north face of the keep [R9]. This is likely to represent the remains of former a gravel path noted in Trench 1a. The low resistance anomaly to its immediate south also correlates with a ditch detected in this trench and is ascribed to the slighting of the Castle's defences during the Civil War. A clear north-south negative anomaly about 2m wide cutting through the gravel path anomaly at [R10] correlates with Trench 1 from Morley's 1970 excavation.

Up the slope immediately to the south, a second set of east-west linear high resistance anomalies are apparent [R11]. These are likely to be caused by remains of the Elizabethan terrace that Laneham describes as being on the north side of the keep in this area. Trench 1b which cuts the anomaly found evidence for this terrace. Particularly high resistance anomalies are visible at the western end of this group suggesting buried masonry. Trench 2 did indeed reveal large quantities of broken roof tile and sandstone fragments and Dix and Prentice suggest that this may well be dumped rubble from demolition works elsewhere in the castle. Evidence for the extension of the terrace to the east of the keep may be provided by the linear high resistance anomalies at [R12]. In close proximity, an approximately rectangular low resistance anomaly may suggest robber trenches indicating that a structure once stood here.

Some 30m to the north at [R13] a sub-rectangular high resistance anomaly may indicate the survival of footings of a wall tower linked to the curtain wall that used to run between the Swan tower and the gatehouse.

Electromagnetic survey
A graphical summary of the significant anomalies discussed below is provided on Figure 9. Numbers in [ ] refer to annotations in this figure.

The anomalies recorded in the quadrature phase data primarily relate to modern features, such as the two floodlights [QP1-2] and current paths [QP3]. Two more widely spread areas of high conductivity [QP4-5] may be indicative of robbed out remains, however, their overall coincidence with the line of the paths, and the lack of correlation with the resistance somewhat weakens such an interpretation.

The in-phase data also records a disturbed response to the floodlights [IP1-2] and, through the patterning of positive anomalies at [IP3-5], elements of the modern garden design. The latter two anomalies also correlate with high resistance readings. However, this data-set also potentially provides more significant archaeological information: various linear anomalies e.g. [IP6-8] have been recorded that are not coincident with the line of current paths. These may relate to previous cinder paths around the garden. In Trench B traces of a clinker path were discovered and in Trench D a gravel path which probably extended into Trench F.

Other areas within the castle

Earth Resistance Survey
A graphical summary of the significant anomalies discussed below is provided on Figure 7. Numbers in [ ] refer to annotations in this figure.

The earth resistance survey was extended to the east of the garden area in two locations to look for evidence for a former curtain wall linking the keep with Lunn's tower. Whilst some linear high resistance anomalies are apparent to the immediate east of the keep [R14], these relate to visible drainage culverts or, in the case of the easternmost, are likely to be due to soil moisture deficit caused by a tree. A narrow linear low resistance feature running to the northeast through this area is likely to be a response to a modern utility trench.

The extension of the survey to the west of Lunn's tower has also not detected any high resistance anomalies indicative of the masonry footings of a curtain wall. However, a complex group of low resistance anomalies [R15] might suggest the robbed out remains of a structure here.

The survey was also extended to the west of the Elizabethan garden to determine if there was any evidence for additional structures in these, now open, areas. At [R16] a group of parallel, high resistance anomalies to the south of the Swan Tower might indicate the remains of a former structure (or the line of an earlier wall) here. A particularly high magnitude complex of both high and low resistance anomalies further south at [R17] is highly suggestive of the buried remains of a structure. Henry VIII is known to have demolished the buildings on the Pleasance and re-erected at least one at a location in this vicinity within the castle and anomaly group is probably the best candidate to represent its remains. A fainter group of anomalies is visible nearby at [R18] but their interpretation is less clear. The area covering [R17] and [R18] was also examined using GPR and the results of this survey are discussed below.

A further complex of high resistance responses detected beneath the bank adjacent to the Strong Tower at [R19] are of similar magnitude to those at [R17] and are also highly likely to be masonry footings, perhaps indicating the position of an earlier tower here. To the southwest at [R20] lies another group of relatively weak high resistance anomalies. These may indicate evidence that buildings were once situated here as well but, given their relatively low magnitude might also represent the remains of further formal garden features.

Ground Penetrating Radar
Significant GPR responses, [GPR1 – GPR5], discussed in the following text are superimposed on selected data profiles (Plan C) and shown together with a graphical summary of the anomalies in Figure 10b.

The area chosen for the trial GPR survey was positioned to include the remains of two possible former buildings: the first expressed as a high resistance response

[R17] against the W curtain wall, and the second as both a resistance anomaly [R18] and topographic variation in the vicinity of an internal fireplace built into the wall below the Strong Tower. Further buildings within the curtain wall would certainly be expected and could well have been of timber construction, such as the postulated structures removed from the Pleasance, with only the underlying stone wall footings surviving today.

The general response of the site to GPR survey is good, with strong responses generated from the first 20ns of data, although a consistent horizontal reflection (e.g. Plan C, Line 20) across the profiles suggests a marked change in soil type and the rapid attenuation of signal penetration with the 450MHz centre frequency antenna below this depth (~0.5m). Despite this attenuation the amplitude time slices (Plan D) do still appear to contain coherent anomalies to approximately 50ns, representing a maximum estimated depth of ~1.25m.

Earth resistance anomaly [R17] is replicated in the GPR data as a diffuse area of bright reflections within the near surface data that obtains a more regular morphology [GPR1] for amplitude time slices between 12 to 30ns (~0.3 to 0.75m). Individual profiles through [GPR1] show a complex series of reflections, the expected response from the rubble of a former building platform, with some indication of more substantial, wall-type anomalies, extending to a greater depth (e.g. Plan C: Line 5). The response to [GPR1] becomes more diffuse with increasing depth and is replaced by a less well defined, rectilinear anomaly [GPR2] that lies slightly to the east of [GPR1] and extends further north within the survey area. It is difficult to identify the response to [GPR2] within the unprocessed profiles (e.g. Plan C: Line 20) but a distinct anomaly is visible within successive amplitude time slices between 30 to 50ns (~0.75 to 1.25m), possibly due to the combination of densely sampled data from adjacent profiles abstracted into each time slice and the refocusing of dispersed reflections through the application of migration. The close spatial relationship between [GPR1] and [GPR2] may suggest either two, partially inter-cut structures or, perhaps, a single building that has collapsed against the curtain wall forming a near surface rubble spread represented by [GPR1].

A more complicated earth resistance anomaly [R18] suggests the presence of an additional building and this is replicated by high amplitude reflections [GPR3] and [GPR4]. The anomaly at [GPR3] is readily discernible within the individual profiles as a horizontal reflection event coincident with a topographic rise noted in the field (e.g. Plan C: Line 35). The stacked multiple reflections evident over [GPR3] suggest a strong, near-surface reflector, such as a stone wall footing or solid flooring, in contrast to the more subtle responses forming the double linear response found at [GPR4] (e.g. Plan C: Line 50). There is no clear expression of the rectilinear low resistance response associated with [R18] in the radar data and it is possible that this represents the course of a deliberately robbed out wall foundation. Anomalies [GPR3] and [GPR4] are not, necessarily, related to the same causative feature but share a close physical proximity in terms of both location and estimated depth between 10 to 20ns (~0.25 to 0.5m).

Finally, part of the high resistance anomaly [R19] found beneath the Strong Tower is replicated in the radar as linear response [GPR5] expressed as a high amplitude, multiple reflection in the near surface data between 10 to 20ns (~0.25 to 0.5m). Radar data was only collected over the level areas of the site and did not extend over the steep slope to the east to fully describe the more complete resistance anomaly [R19]. However, the radar data indicates that [GPR5] is the response to a strong reflector, such as a buried wall foundation, perhaps forming part of a rectangular building or tower following the outline of [R19].

The Pleasance

Earth resistance survey
A graphical summary of the significant anomalies discussed below is provided on Figure 11a. Numbers in [ ] refer to annotations in this figure.

A polygonal area of raised resistance [PR1] is likely to be compacted ground which might be the diamond shaped courtyard described by Colvin *et al*. (Colvin *et al.* 1963, 685). Plots of the filtered data indicate more discrete areas of high and low resistance within [PR1] that may be relate to former planting here.

Anomalies [PR2-4] in the north, east and south corners of the moated enclosure are coincident with the purported locations of towers at the Pleasance. Of these [PR2], to the north, has a clear rectilinear high resistance response. That at [PR3] has a less clear outline, and may be more indicative of a rubble spread. The response at [PR4] is primarily an approximately rectilinear low resistance anomaly, possibly caused by the remains of a floor or cellar or perhaps a generally looser material lying between the foundation walls. The remains of the fourth tower at the western corner are more difficult to identify. However, after enhancement a rectilinear area of low resistance can be discerned in the westernmost corner of the earth resistance survey.

A group of linear anomalies at [PR5] are suggestive of buried structures with both high and low resistance responses being represented. It is likely that the high resistance anomalies correspond to surviving wall footings or buried spreads of rubble whilst the linear low resistance anomalies indicate robber trenches where masonry has been removed for re-use. The differing alignments of some of the linear anomalies suggest that more than one phase of construction may have occurred here. The potential presence of robbed out wall footings in this area might be indicative of the original site of the pavilion that was relocated by Henry VIII from the Pleasance to an area within the castle near the Swan Tower (Colvin *et al.* 1975, 258-9).

Another probable building is suggested by a rectilinear high resistance anomaly at [PR6]. Further, weaker, linear high resistance anomalies can also be discerned within the survey area and these could indicate the presence of additional structures or garden features. However, they are not clear enough to be amenable to detailed interpretation.

Magnetometer survey
A graphical summary of the significant anomalies discussed below is provided on Figure 11b. Numbers in [ ] refer to annotations in this figure.

The overall variation in background signal at the site is fairly low being typically <1nT/m. However, two areas of strong modern disturbance can be seen at [PM1] and [PM2].

A polygonal strong magnetic anomaly [PM3] in the northern corner of the moated platform correlates with [PR2] and it is suggested that this represents a tower base. The steep magnetic gradients here ~15nT/m are typical of thermoremanently magnetised features. It is possible that this is an indication that the tower walls were built of brick but the anomaly may also be caused by structural remains that have been exposed to fire.

At the eastern corner of the platform another positive magnetic anomaly [PM4] corresponds with the earth resistance anomaly [PR3], providing further evidence for the location of a tower here. In the southern corner a weak magnetic anomaly [PM5], similar in shape but not orientation to [PM3], corresponds with the position of resistance anomaly [PR4]. It is likely that this represents a third corner tower. The location of the magnetic anomaly encircles the position of the earth resistance anomaly – suggesting that [PM5] is a response to the walling and [PR4] to the interior of the structure.

Along the south-western side of the moated platform is a collection of both positive and negative magnetic anomalies [PM6]. At the northern end of these, linear magnetic anomalies are evident and these correlate well with the high resistance anomalies [PR5] also recorded here. Towards the southern end of [PM6], the linear anomalies are less clear but many small discrete anomalies are visible and the general level of variation in magnetic gradient is higher than in other parts of the site. It is thus probable that the magnetic mineralogy of the soils here has been enhanced by burning or deposition of organic material at some time in the past.

Conclusions

Geophysical survey in the area of the Elizabethan garden was complicated by the presence of extant planting. Many anomalies have been detected across the survey area but the majority of these correlate with visible features in the present garden layout. However, it has been possible to indicate a number of anomalies likely to relate to previous land use. Most notable are the linear magnetic anomalies detected in the in-phase electromagnetic survey that were found, on excavation, to represent the remains of (post-Elizabethan) cinder paths. The earth resistance survey also detected a number of anomalies that do not correlate with surface features and are suggestive of buried remains of former garden structures. However, given the limitations on the survey method imposed by the extant garden, it must be acknowledged that these could, in general, only be interpreted after exploratory

excavations had been conducted. Indeed it is notable that whilst the signature of Trench 1 from Morley's 1970 excavation has been detected in the earth resistance survey to the south of the formal garden, no evidence has been detected for his much longer diagonal Trenches A and B through the garden area. This suggests that only substantial buried garden features are likely to be detected in the area beneath the present garden layout.

Immediately north of the garden, the earth resistance survey has detected the possible remains of the slighted curtain wall running east from the Swan tower and, to the northeast of the garden, the possible remains of a demolished tower depicted in the fresco of c. 1620. To the south, remains of a revetment have been detected immediately north of the keep and these are likely to relate to the raised terrace that Laneham's description locates here. To the east, no evidence for curtain wall footings has been detected either immediately east of the keep or west of Lunn's tower. However, west of the garden, the possible locations for several now demolished structures have been identified. In particular, potential footings for an earlier tower immediately north of the Strong tower are evident in the earth resistance survey. Furthermore, an interesting earth resistance survey anomaly against the west boundary wall of the castle, [R17], was investigated by GPR which revealed it as a strong candidate for the building visible in this location in the c. 1620 fresco. It may well be one of the structures re-erected here by Henry VIII when he ordered the buildings on the Pleasance to be demolished.

The additional geophysical surveys over the Pleasance have also successfully detected anomalies likely to represent the remains of features dating from the time of its use as a pleasure ground. A large hexagonal compacted area has been detected in the centre of the diamond shaped mound and this may well be the remains of a central garden or courtyard. At three of the corners of the mound, remains of footings for towers have been detected. It is possible that robbed out remains of the fourth, western, tower have also been detected although the anomaly is only apparent in an enhanced version of the earth resistance survey data. Possible evidence for a range of buildings has been detected on the southwest side of the mound. Anomalies in this area have been detected by both the earth resistance survey, suggesting wall footings and robber trenches, and the magnetometer survey, suggesting ditches and other cut features filled with magnetically enhanced material. Given that magnetic enhancement is often the result of burning or the burial of organic matter, it is tempting to suggest that kitchens and food preparation areas were situated here. It is also likely that this range of structures provided the materials for the buildings re-erected by Henry VIII within the castle after he ordered the buildings on the Pleasance to be demolished.

Surveyed by: N Linford
P Linford
L Martin
A Payne
A David (18/07/2004 only)

Dates of surveys: 21-25/06/2004
18/07/2004

Reported by: N Linford
P Linford
L Martin

Date of report: 26/04/2005

Geophysics Team,
English Heritage.

Acknowledgements

The authors wish to express the thanks of the team to the site staff at Kenilworth for accommodating us during our time at the castle and also extend the thanks of English Heritage to Mr Lucas of Pleasance Farm for permitting access to the Pleasance site at short notice.

List of enclosed figures

Figure 1 Location plan of survey grid over base OS map (1:4000).

Figure 2 Location plan of survey grid over base OS map (1:2500).

Figure 3 Greyscale of earth resistance data from castle over base OS map (1:1000).

Figure 4 Greyscale of earth resistance data from garden over base OS map (1:500).

Figure 5 Greyscale of electromagnetic data over base OS map (1:1000).

Figure 6 Greyscale of earth resistance and magnetometer data from the Pleasance over base OS map (1:1500).

Figure 7 Graphical summary of significant resistance anomalies from castle (1:1000).

Figure 8 Graphical summary of significant resistance anomalies from garden (1:1000).

Figure 9 Graphical summary of significant electromagnetic anomalies (1:1000).

Figure 10 Greyscale plot and graphical summary of significant GPR anomalies (1:500).

Figure 11 Graphical summary of significant geophysical anomalies from the Pleasance (1:1500).

Plan A Traceplot and linear greyscale of earth resistance data from castle (1:1000).

Plan B Traceplot and linear greyscale of electromagnetic data (1:1000).

Plan C Profiles of GPR data.

Plan D Amplitude Time Slices of GPR data (1:750).

Plan E Traceplot and linear greyscale of earth resistance data from the Pleasance (1:1500).

Plan F Traceplot and linear greyscale of magnetometer data from the Pleasance (1:1000).

Plan G Linear greyscale of earth resistance and magnetometer data draped over DTM.

Annex 1: Notes on standard procedures

1) **Earth Resistance Survey:** Each 30 metre grid square is surveyed by making repeated parallel traverses across it, all aligned parallel to one pair of the grid square's edges, and each separated by a distance of 1 metre from the last; the first and last traverses being 0.5 metres from the nearest parallel grid square edge. Readings are taken along each traverse at 1 metre intervals, the first and last readings being 0.5 metres from the nearest grid square edge.

   Unless otherwise stated the measurements are made with a Geoscan RM15 earth resistance meter incorporating a built-in data logger, using the twin electrode configuration with a 0.5 metre mobile electrode separation. As it is usually only relative changes in earth resistance that are of interest in archaeological prospecting, no attempt is made to correct these measurements for the geometry of the twin electrode array to produce an estimate of the true apparent resistivity. Thus, the readings presented in plots will be the actual values of earth resistance recorded by the meter, measured in Ohms (Ω). Where correction to apparent resistivity has been made, for comparison with other electrical prospecting techniques, the results are quoted in the units of apparent resistivity, Ohm-m (Ωm).

   Measurements are recorded digitally by the RM15 meter and subsequently transferred to a portable laptop computer for permanent storage and preliminary processing. Additional processing is performed on return to the Centre for Archaeology using desktop workstations.

2) **Magnetometer Survey:** Each 30 metre grid square is surveyed by making repeated parallel traverses across it, all parallel to that pair of grid square edges most closely aligned with the direction of magnetic North. Each traverse is separated by a distance of 1 metre from the last; the first and last traverses being 0.5 metre from the nearest parallel grid square edge. Readings are taken along each traverse at 0.25 metre intervals, the first and last readings being 0.125 metre from the nearest grid square edge.

   These traverses are walked in so called 'zig-zag' fashion, in which the direction of travel alternates between adjacent traverses to maximise survey speed. Where possible, the magnetometer is always kept facing in the same direction, regardless of the direction of travel, to minimise heading error. However, this may be dependent on the instrument design in use.

   Unless otherwise stated the measurements are made with either a Bartington *Grad601* or a Geoscan FM36 fluxgate gradiometer which incorporate two vertically aligned fluxgates, one situated either 1.0m or 0.5 metres above the other; the bottom fluxgate is carried at a height of approximately 0.2 metres above the ground surface. Both instruments incorporate a built-in data logger that records measurements digitally; these are subsequently transferred to a

portable laptop computer for permanent storage and preliminary processing. Additional processing is performed on return to the Centre for Archaeology using desktop workstations.

It is the opinion of the manufacturer of the Geoscan instrument that two sensors placed 0.5 metres apart cannot produce a true estimate of vertical magnetic gradient unless the bottom sensor is far removed from the ground surface. Hence, when results are presented, the difference between the field intensity measured by the top and bottom sensors is quoted in units of nano-Tesla (nT) rather than in the units of magnetic gradient, nano-Tesla per metre (nT/m).

3) **Resistivity Profiling:** This technique measures the electrical resistivity of the subsurface in a similar manner to the standard resistivity mapping method outlined in note 1. However, instead of mapping changes in the near surface resistivity over an area, it produces a vertical section, illustrating how resistivity varies with increasing depth. This is possible because the resistivity meter becomes sensitive to more deeply buried anomalies as the separation between the measurement electrodes is increased. Hence, instead of using a single, fixed electrode separation as in resistivity mapping, readings are repeated over the same point with increasing separations to investigate the resistivity at greater depths. It should be noted that the relationship between electrode separation and depth sensitivity is complex so the vertical scale quoted for the section is only approximate. Furthermore, as depth of investigation increases the size of the smallest anomaly that can be resolved also increases.

Typically a line of 25 electrodes is laid out separated by 1 or 0.5 metre intervals. The resistivity of a vertical section is measured by selecting successive four electrode subsets at increasing separations and making a resistivity measurement with each. Several different schemes may be employed to determine which electrode subsets to use, of which the Wenner and Dipole-Dipole are typical examples. A Campus Geopulse earth resistance meter, with built in multiplexer, is used to make the measurements and the Campus Imager software is used to automate reading collection and construct a resistivity section from the results.

References

British Geological Survey (1984). Warwick, England and Wales Solid and Drift Sheet 184. 1:50000 scale.

Clark, A 1990 *Seeing Beneath the Soil*, London: Batsford.

Cole, M A, David, A E U, Linford, N T, Linford, P K and Payne, A W 1997 'Non-destructive techniques in English gardens: geophysical prospecting'. *Journal of Garden History*, **17**, 26-39.

Colvin, H M, Brown, R A and Taylor, A J, Eds. (1963). *Kenilworth, Warkwickshire*. The History of the King's Works. Volume II: The Middle Ages. London, Her Majesty's Stationery Office.

Colvin, H M, Ransome, D R and Summerson, J, Eds. (1975). *Kenilworth, Warkwickshire*. The History of the King's Works. Volume III: 1485-1660 (Part I). London, Her Majesty's Stationery Office.

David, A and Linford, N 2000 'Physics and archaeology'. *PhysicsWorld*, **13** (5), 27-31.

Dix, B and Prentice, J (2004). Archaeological evaluation in The Elizabethan Garden, Kenilworth Castle, Warwickshire. Northamtonshire County Council.

Ellis, P 1995 'The Elizabethan gardens and Leicester's stables at Kenilworth Castle'. *Birmingham and Warwickshire Archaeological Society Transactions*, **99**, 81-116.

English Heritage (2004). Kenilworth Castle Elizabethan Garden Project. Project Design for Evaluation. Unpublished **v1.2**.

Freeman, W T and Adelson, E H 1991 'The Design and Use of Steerable Filters'. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **13**, 891-906.

Pratt, W K 1978 *Digital Image Processing*, Chichester: Wiley Interscience.

Renn, D 1973 *Kenilworth Castle*, London: Her Majesty's Stationery Office.

Scollar, I, Tabbagh, A, Hesse, A and Herzog, I, Eds. (1990). Archaeological Prospecting and Remote Sensing. Cambridge.

Sensors and Software (1996). PulseEKKO 1000 User's Guide. Sensors & Software. Technical Manual, Mississauga. **24**.

Soil Survey of England and Wales (1983). Soils of England and Wales Sheet 3. 1:250000 scale.

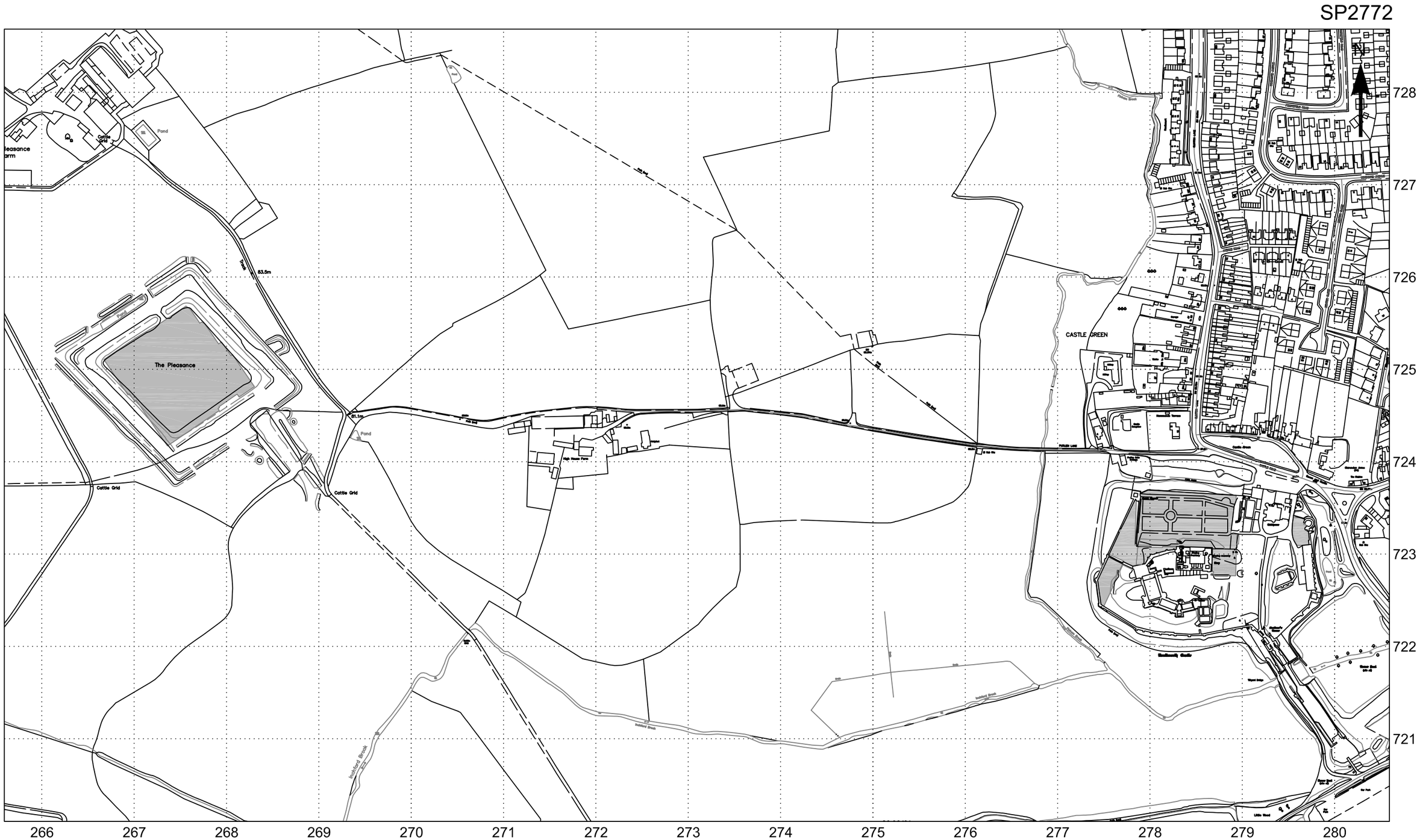
Thompson, M W 1969 'Kenilworth Castle since 1962'. *Medieval Archaeology*, **13**, 218-220.

Wallis, R H (1976). *An Approach for the Space Variant Restoration and Enhancement of Images*. In, Proceedings Symposium on Current Mathematical Problems in Computer Science 1976 (Monterey California).

KENILWORTH CASTLE, WARWICKSHIRE

Figure 1

Location of geophysical survey sites, June 2004



Survey location

0 120m

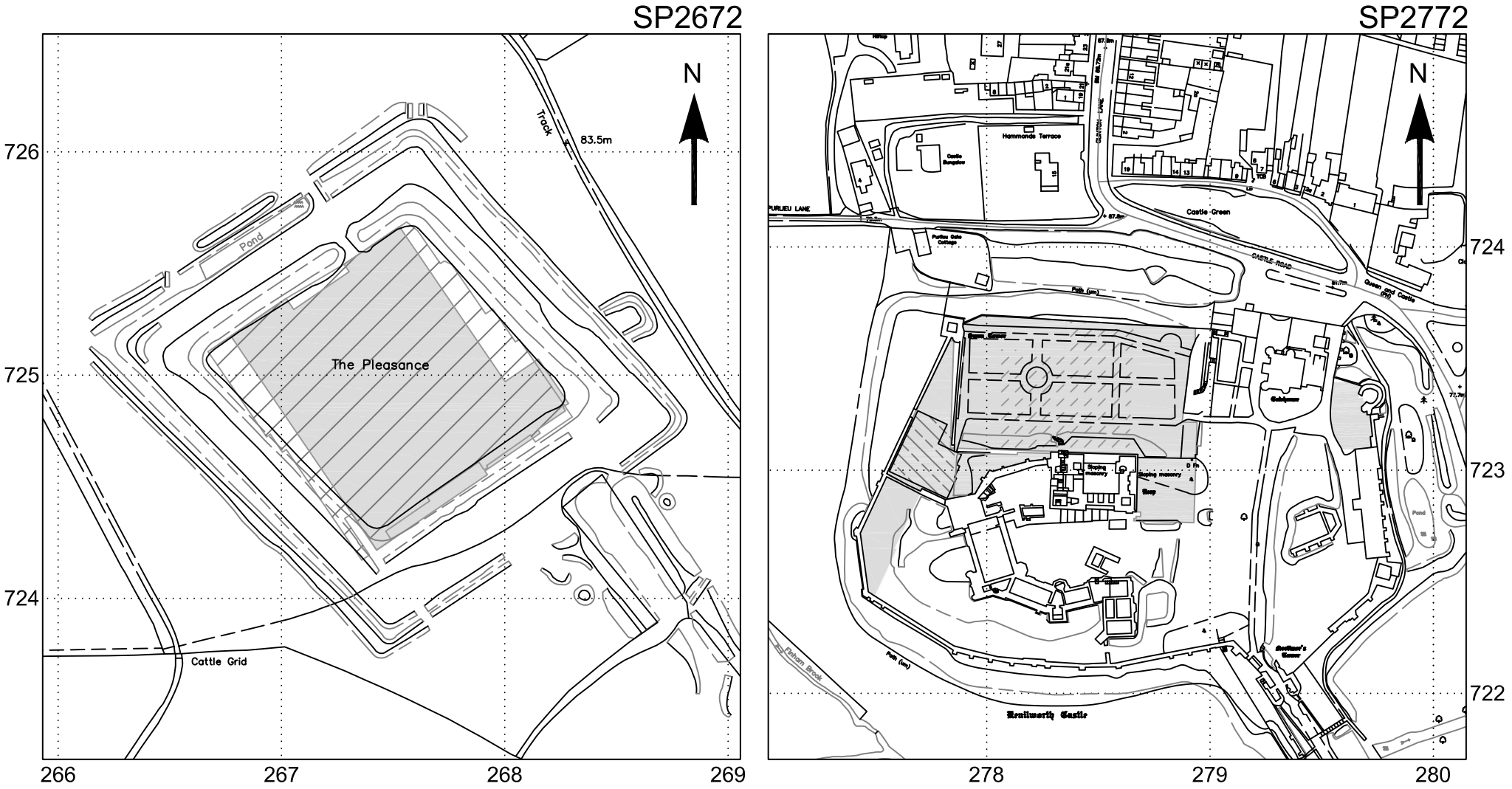
1:4000

English Heritage 2005

KENILWORTH CASTLE, WARWICKSHIRE

Figure 2

Location of geophysical surveys, June 2004



Earth resistance survey

Magnetometer survey

Electro-magnetic survey

Ground Penetrating Radar survey

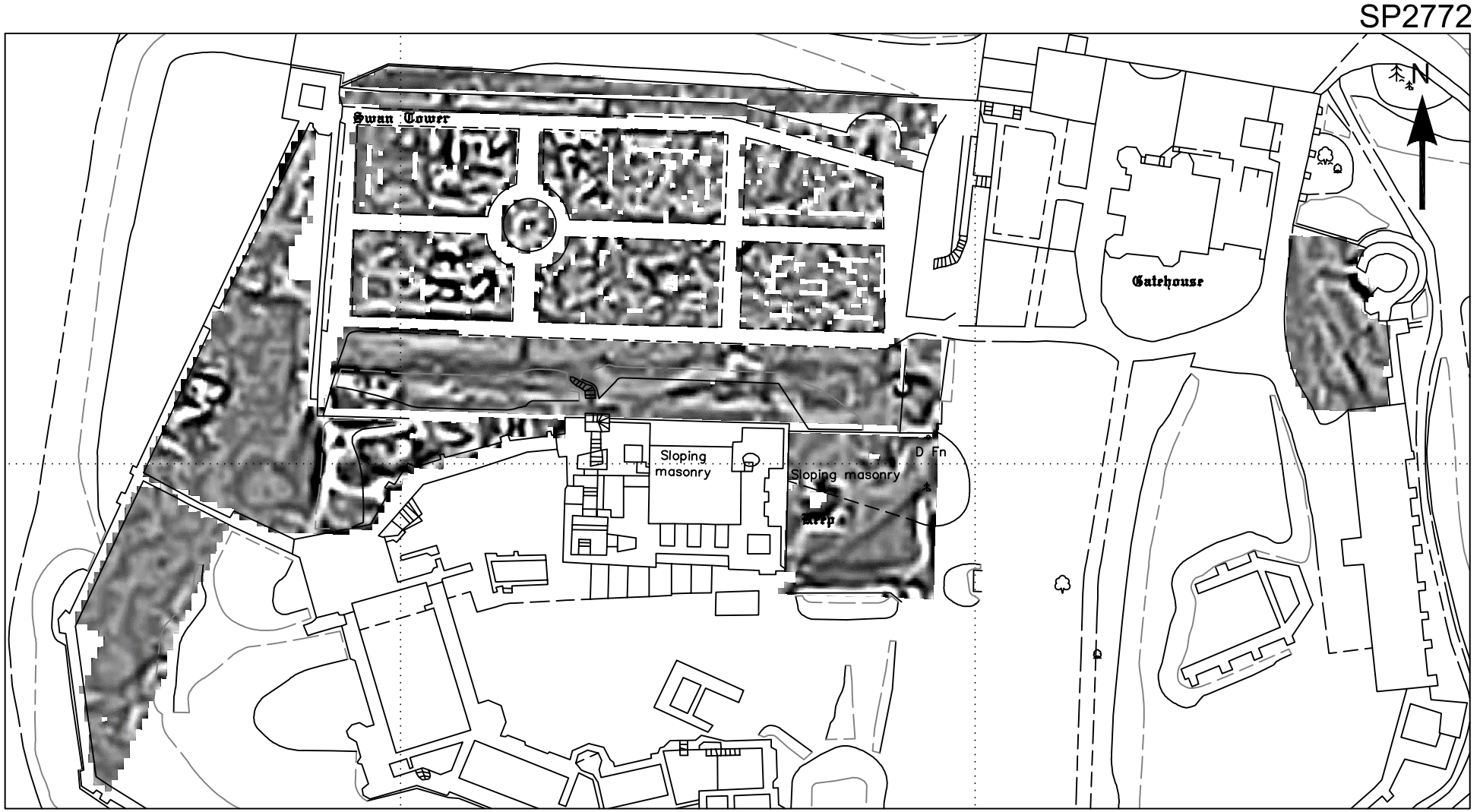
0 90m

1:2500

KENILWORTH CASTLE, WARWICKSHIRE

Figure 3

Earth resistance survey, June 2004

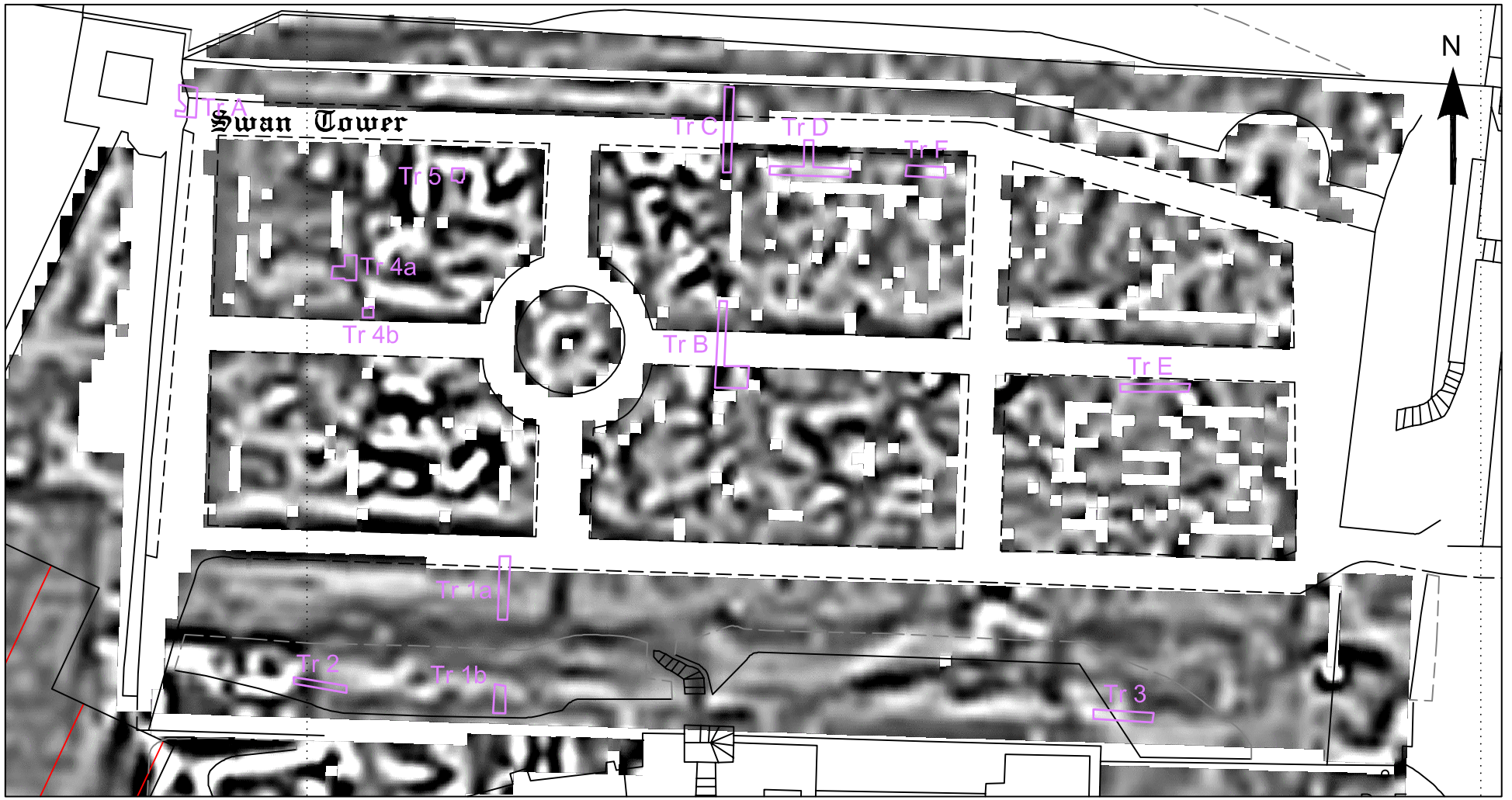


KENILWORTH CASTLE, WARWICKSHIRE

Figure 4

Earth resistance survey, June 2004

SP2772



English Heritage 2005

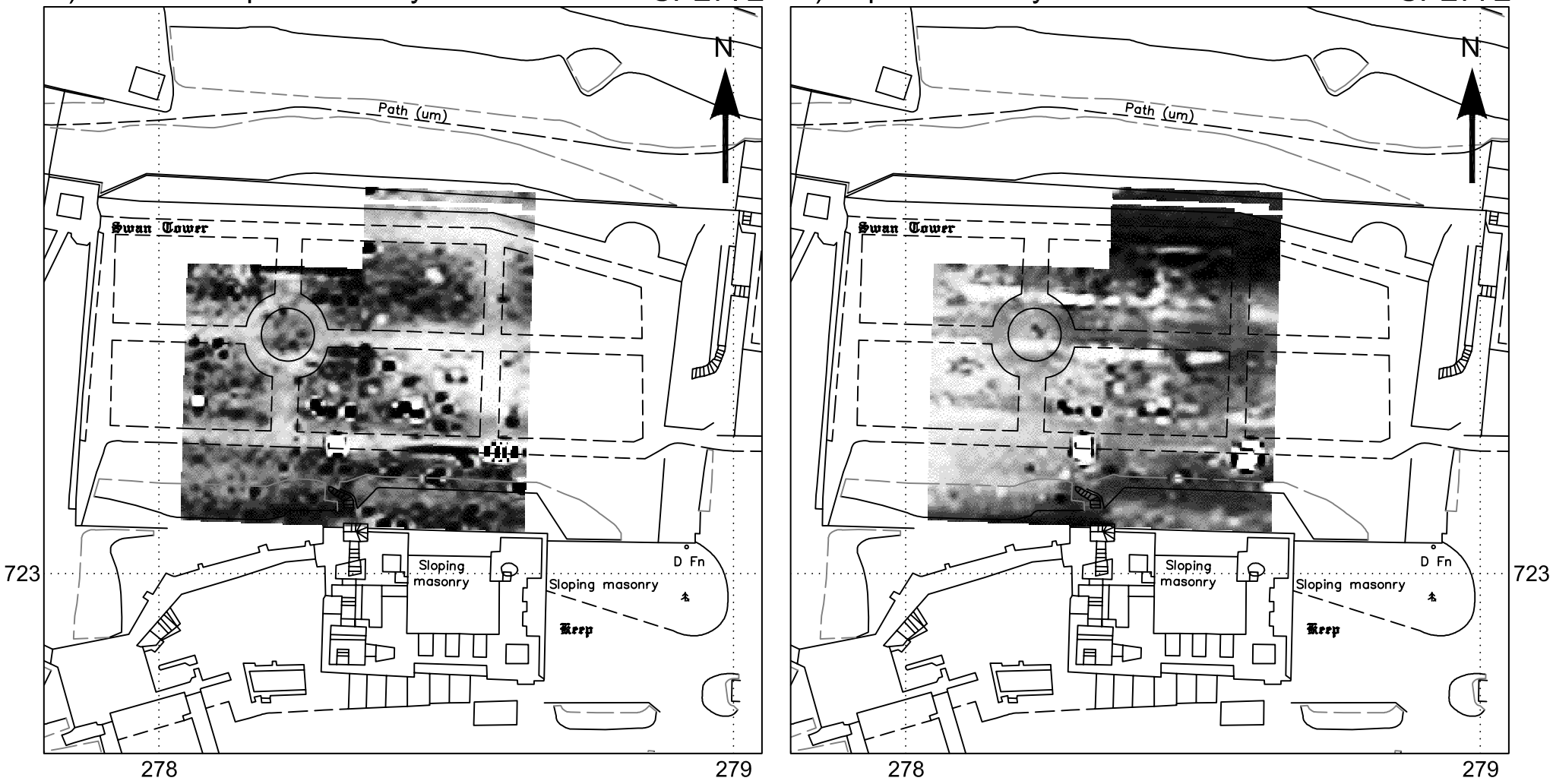
KENILWORTH CASTLE, WARWICKSHIRE

Figure 5

Electromagnetic survey, June 2004

a) Quadrature phase survey

b) In-phase survey



English Heritage 2005

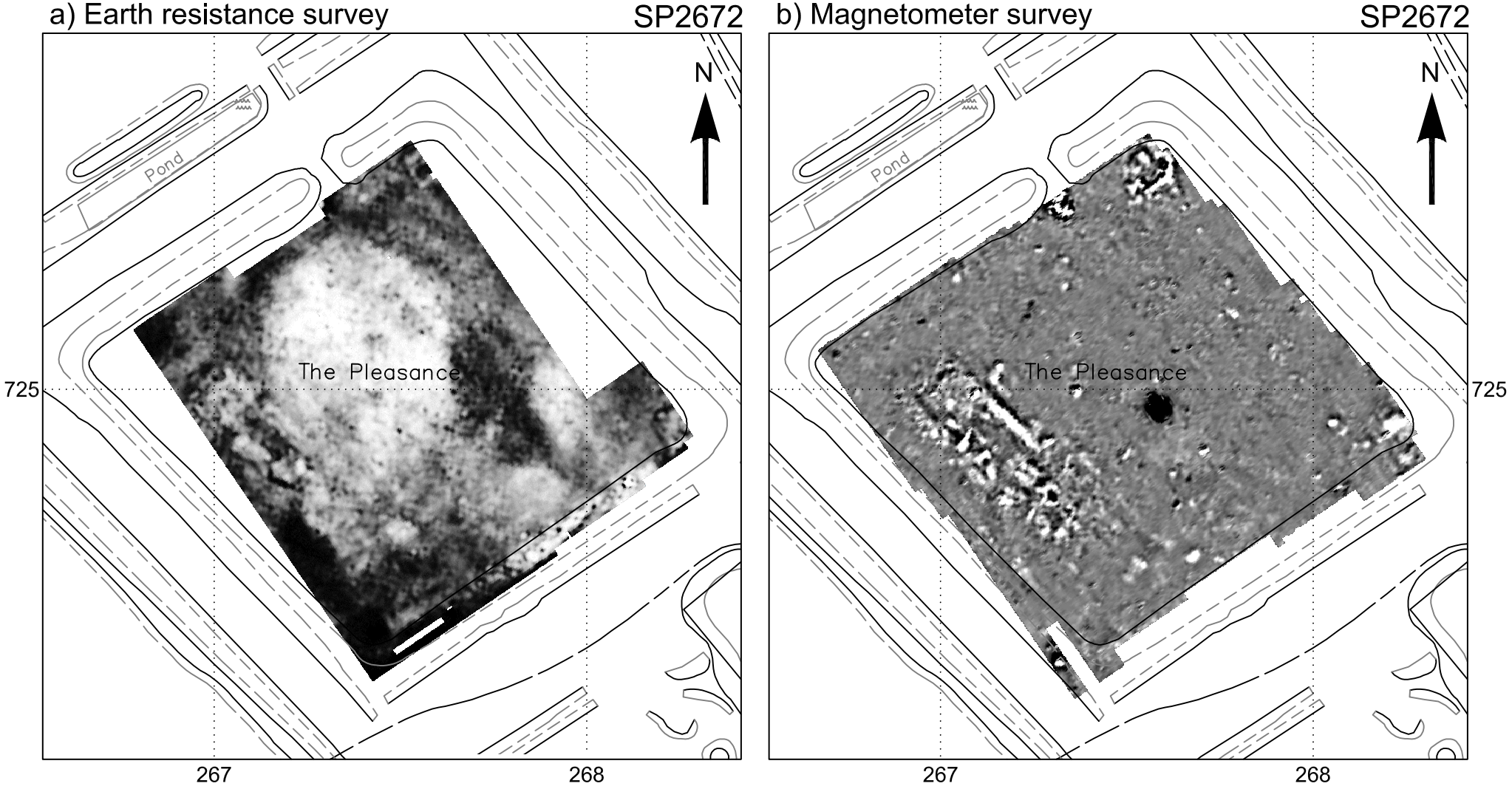
KENILWORTH CASTLE, WARWICKSHIRE

Figure 6

Earth resistance and magnetometer survey of the Pleasance, June 2004

a) Earth resistance survey

b) Magnetometer survey

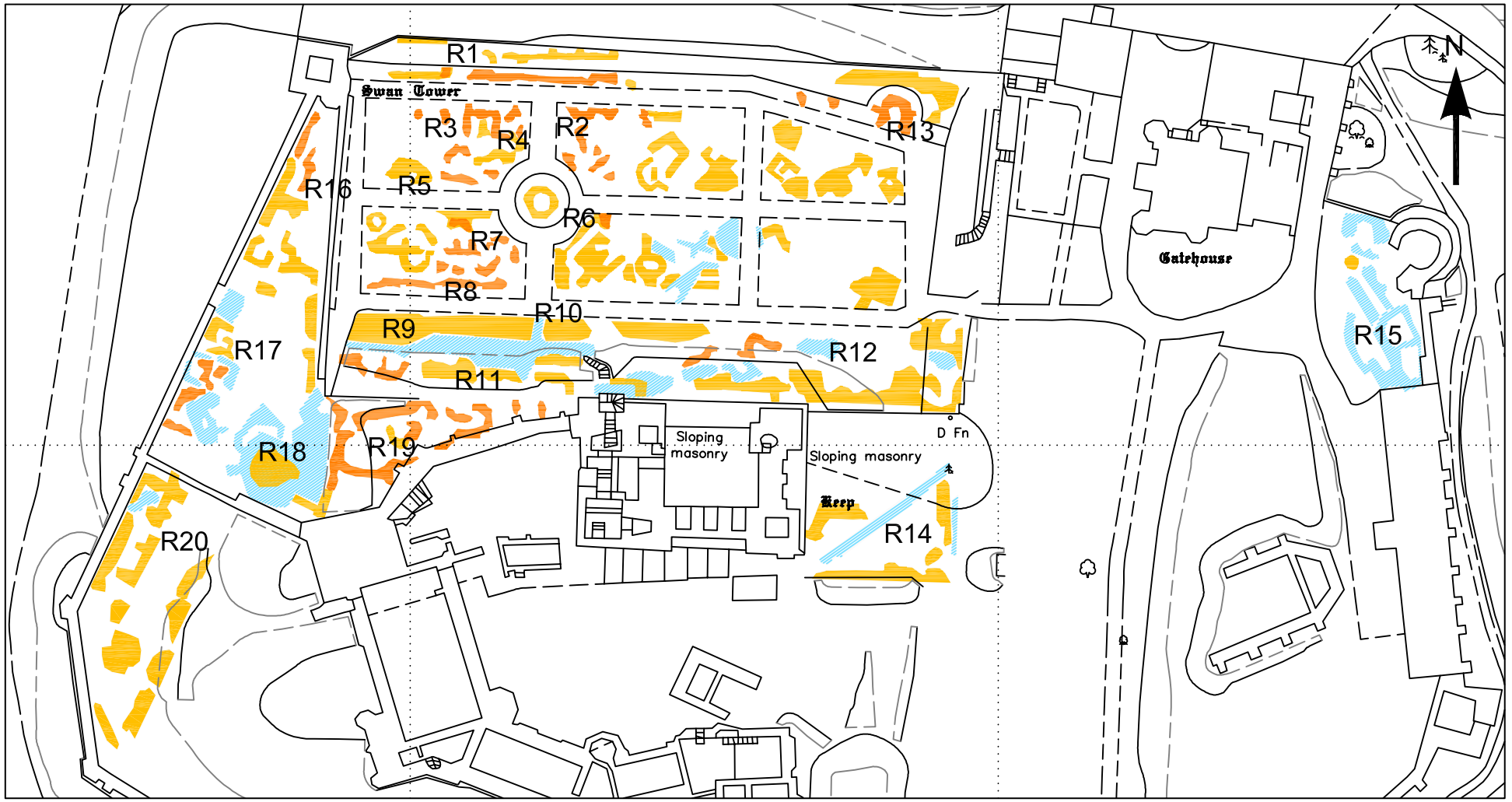


KENILWORTH CASTLE, WARWICKSHIRE

Figure 7

Graphical representation of significant resistance anomalies, June 2004

SP2772



Very high resistance anomaly

High resistance anomaly

Low resistance anomaly

0 30m

1:1000

English Heritage 2005

KENILWORTH CASTLE, WARWICKSHIRE

Figure 8

Graphical representation of significant resistance anomalies, June 2004

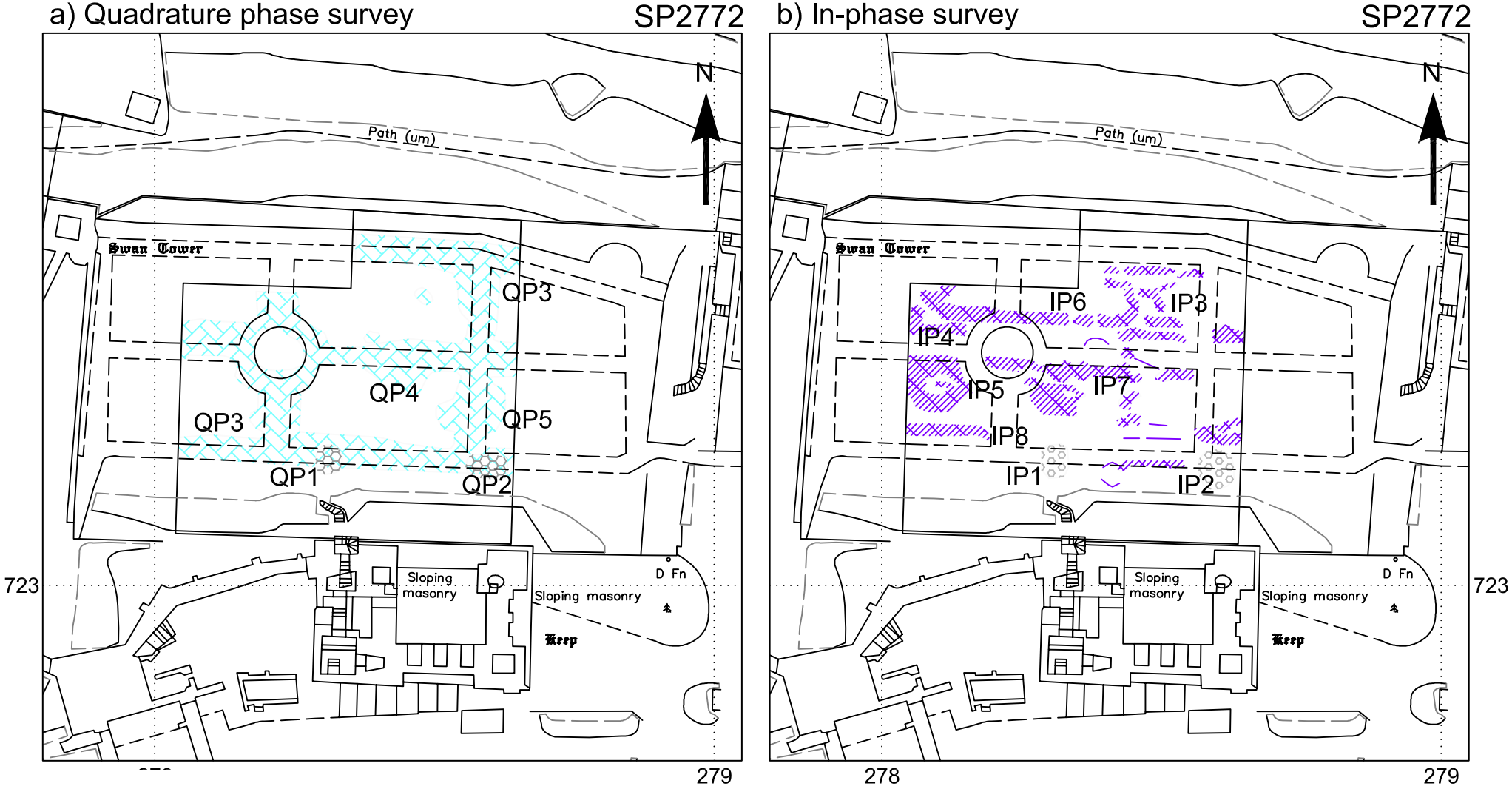
KENILWORTH CASTLE, WARWICKSHIRE

Figure 9

Graphical representation of significant electromagnetic anomalies, June 2004

a) Quadrature phase survey

b) In-phase survey



High quadrature phase anomaly

Area of disturbance

High in-phase anomaly

Area of disturbance

0 30m

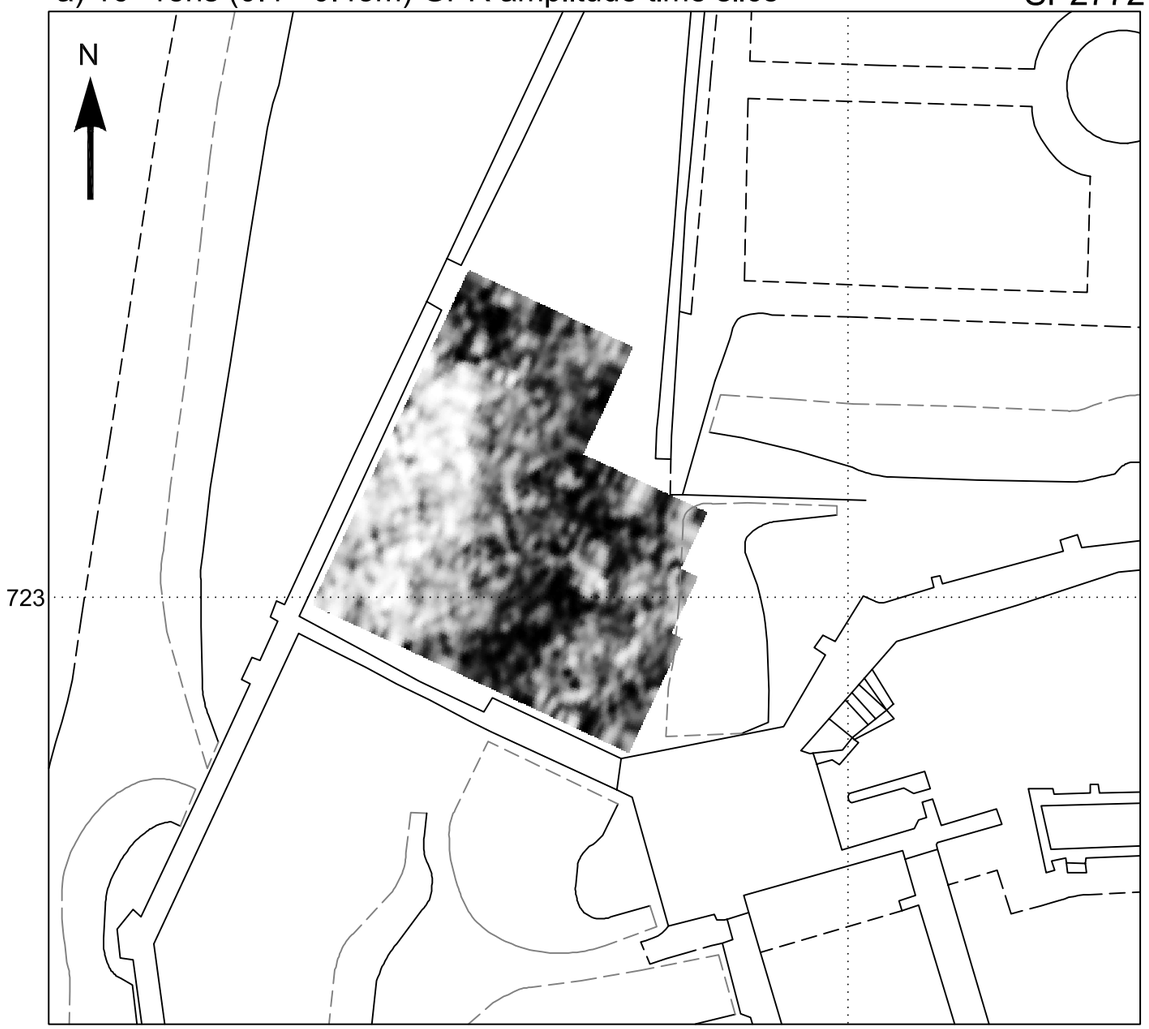
1:1000

KENILWORTH CASTLE, WARWICKSHIRE

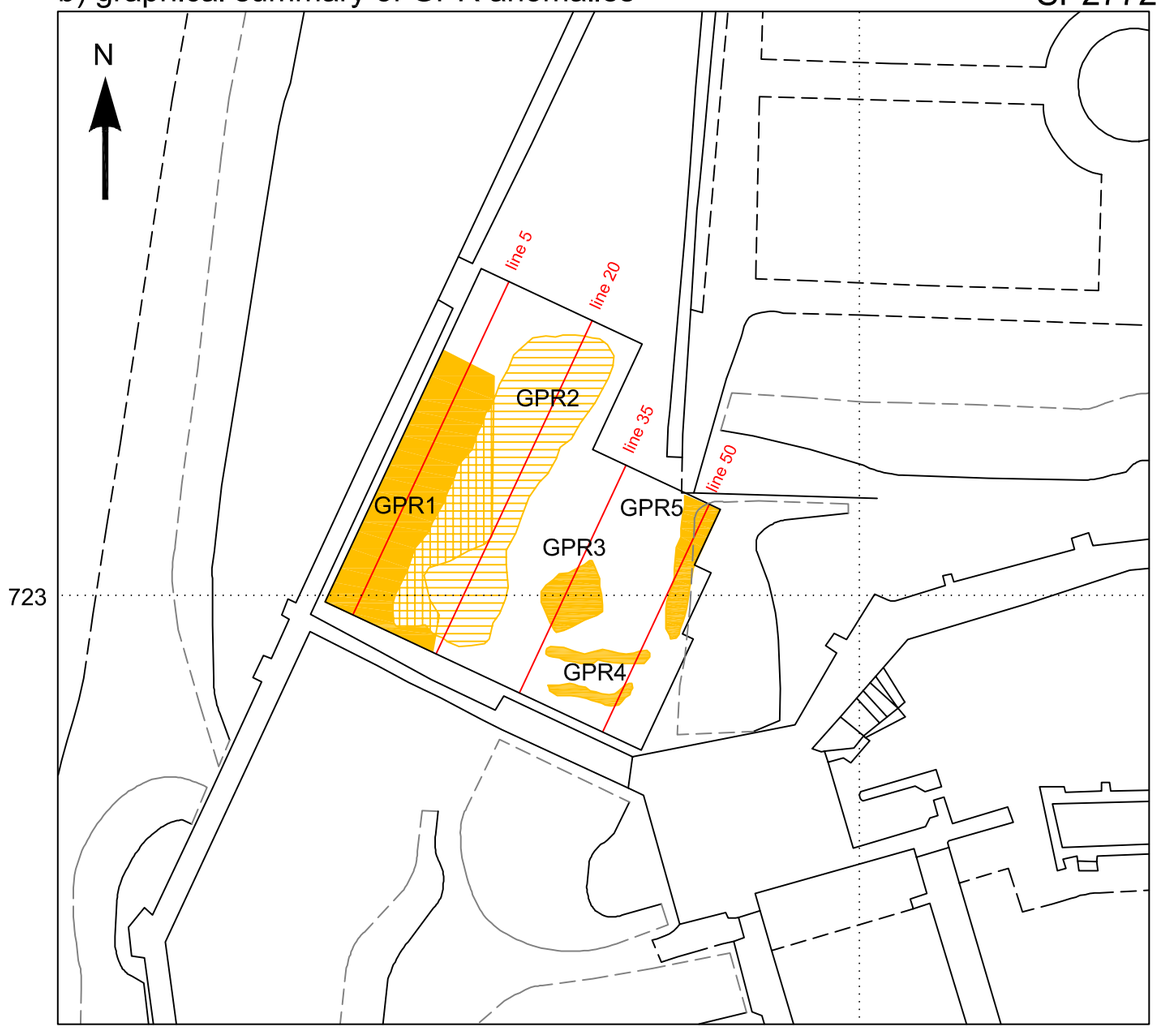
Ground Penetrating Radar survey, June 2004

Figure 10

a) 16 -18ns (0.4 - 0.45m) GPR amplitude time slice



b) graphical summary of GPR anomalies



high amplitude

low amplitude

high amplitude reflection (cross-hatching indicates overlap with underlying response)

more diffuse reflection

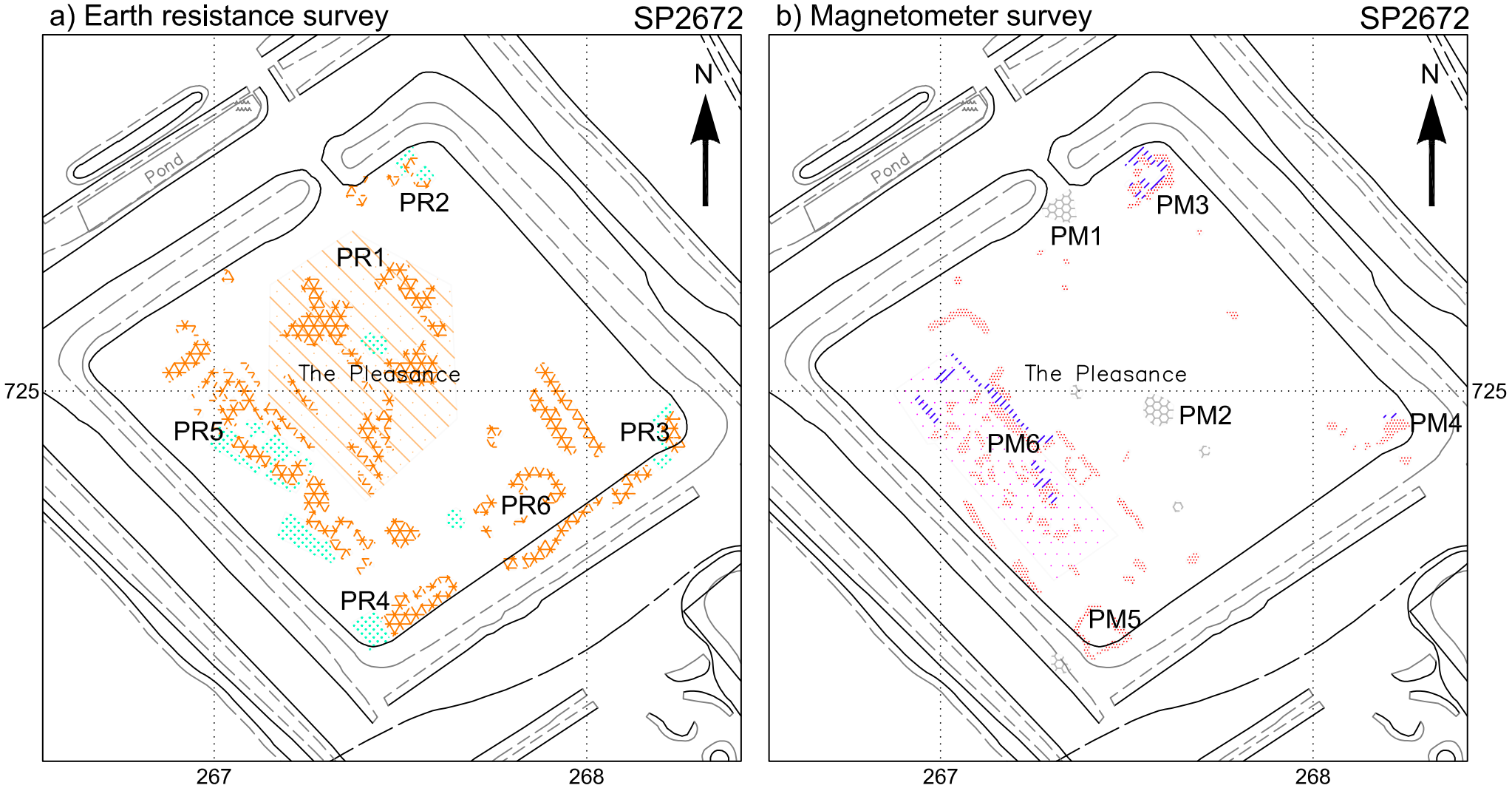
0 30m

1:500

KENILWORTH CASTLE, WARWICKSHIRE

Figure 11

Graphical representation of significant geophysical anomalies at the Pleasance

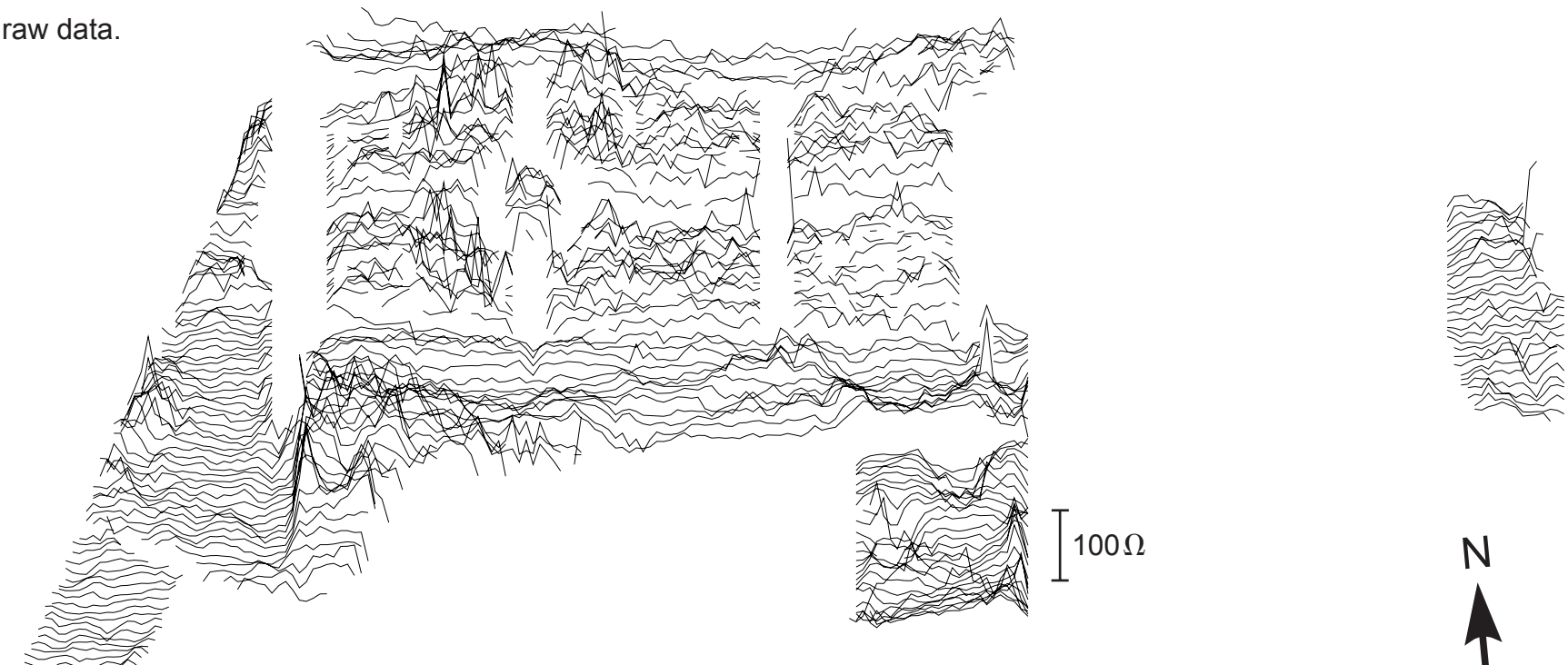


English Heritage 2005

KENILWORTH CASTLE, Warwickshire
Earth resistance survey of the garden, June 2004.

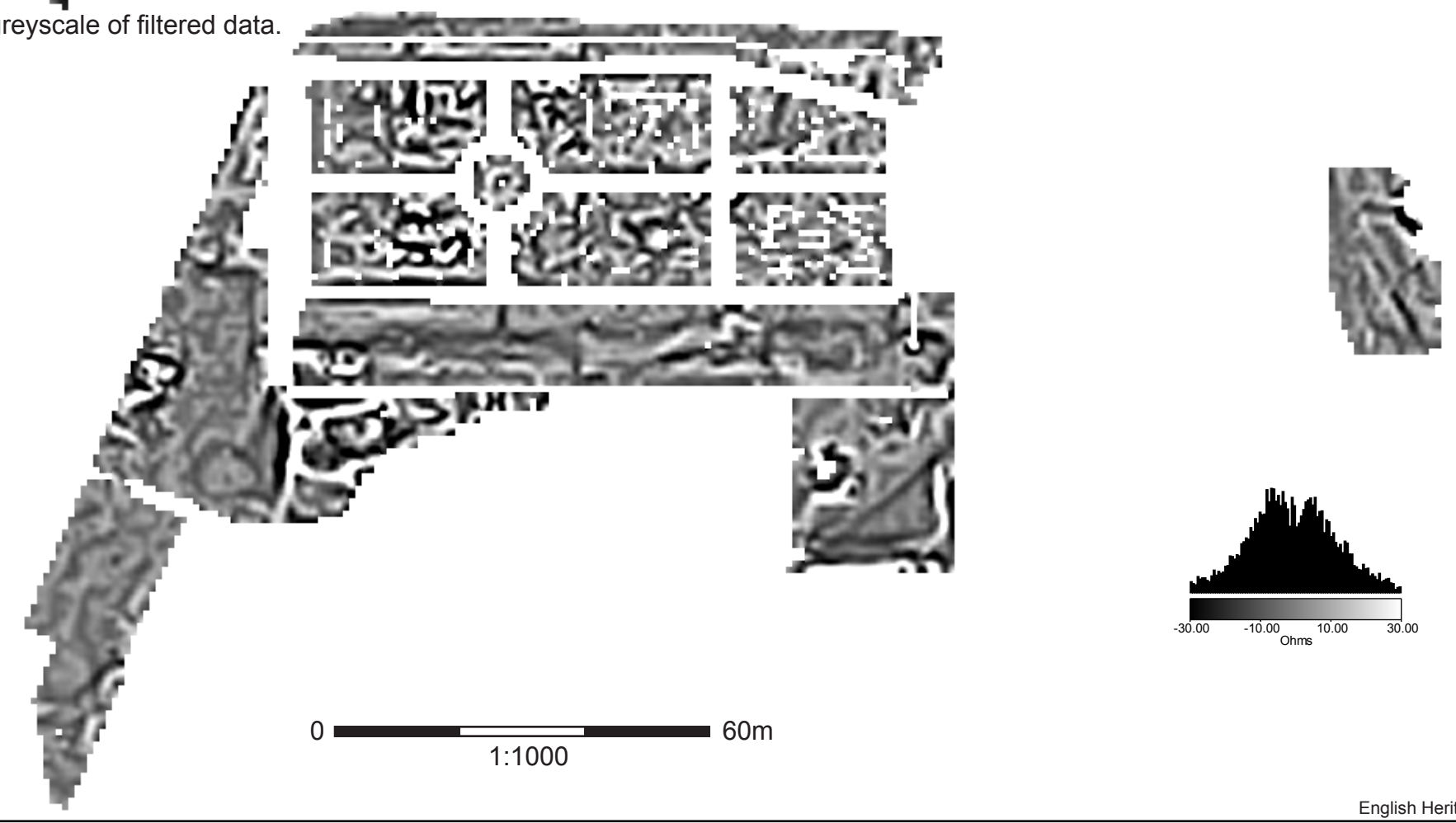
PLAN A

1) Traceplot of raw data.



2) Greyscale of raw data.

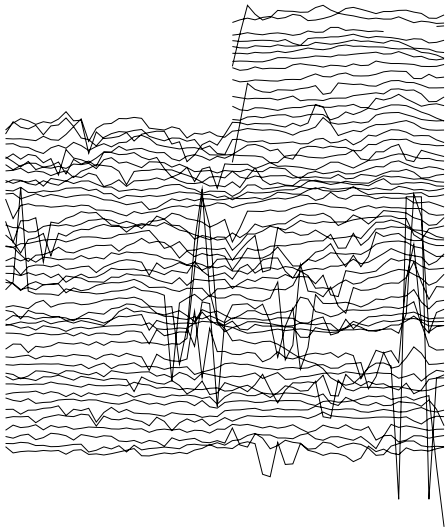
3) Linear greyscale of filtered data.



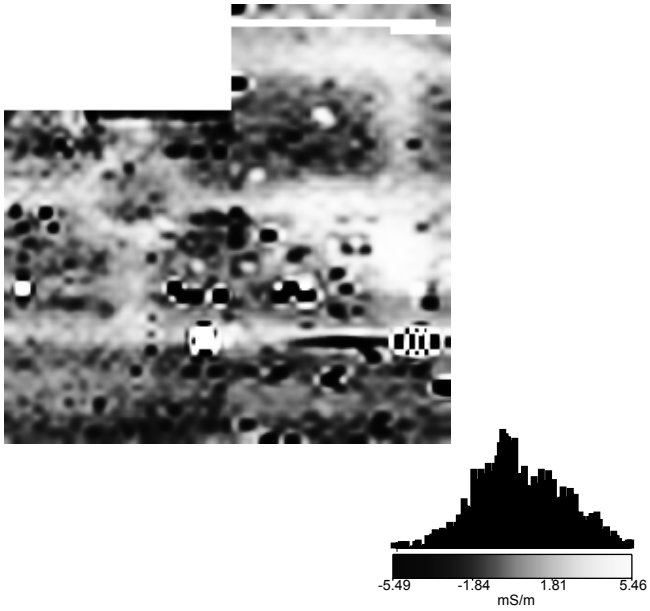
KENILWORTH CASTLE, Warwickshire
Electromagnetic survey of the garden, June 2004.

PLAN B

1) Traceplot of quadrature phase data.

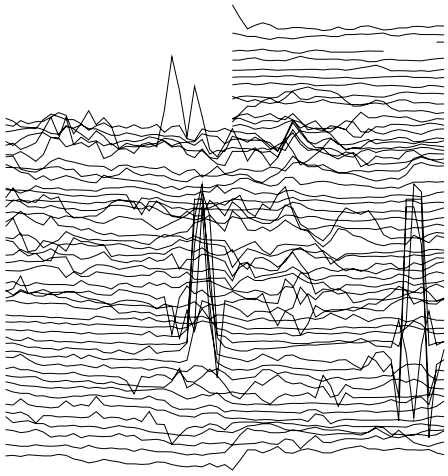


2) Greyscale plot of quadrature phase data.

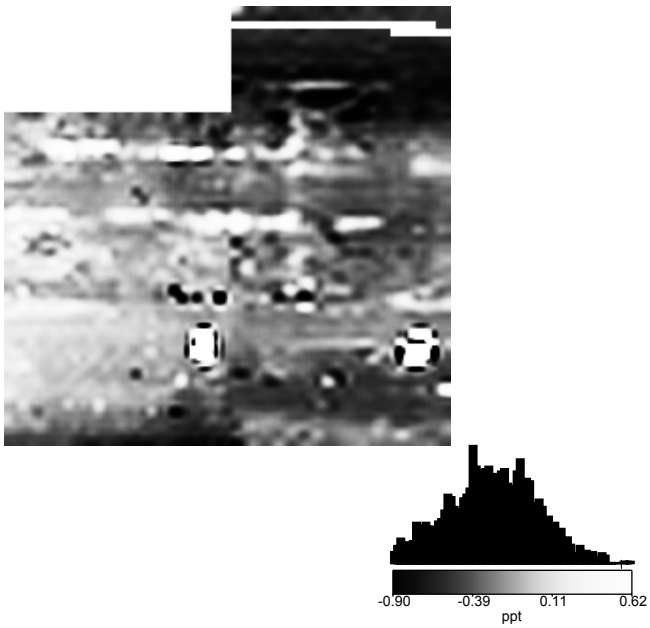


N

3) Traceplot of in-phase data.



4) Greyscale plot of in-phase data.

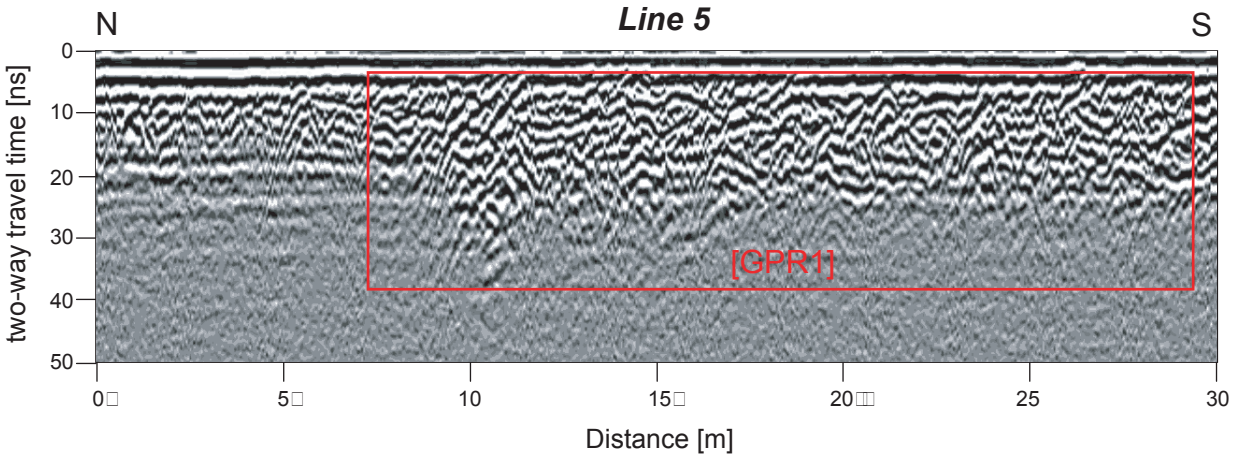


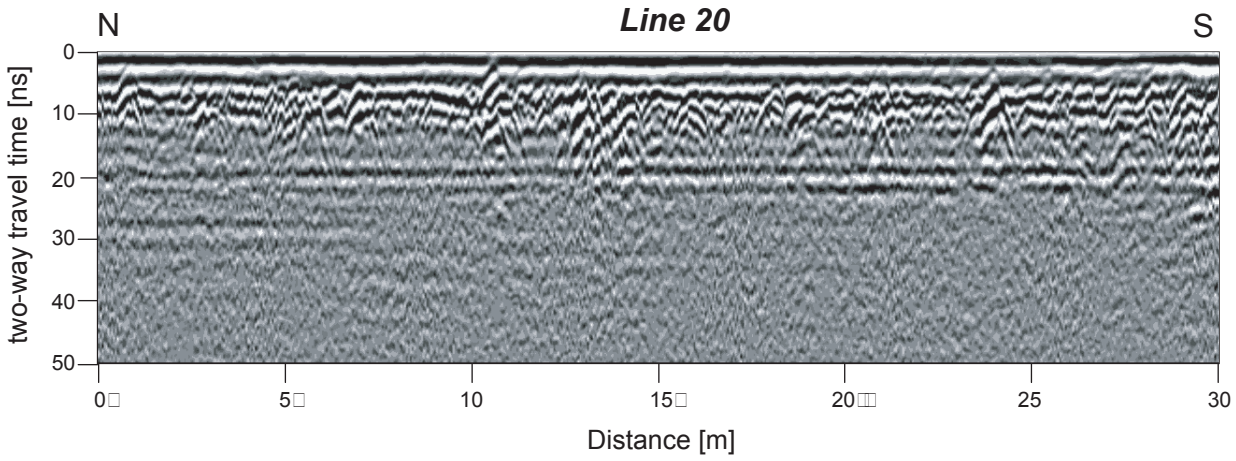
0 90m

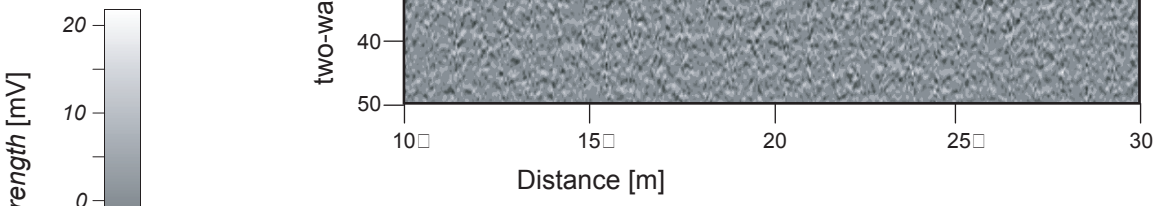
1:1000

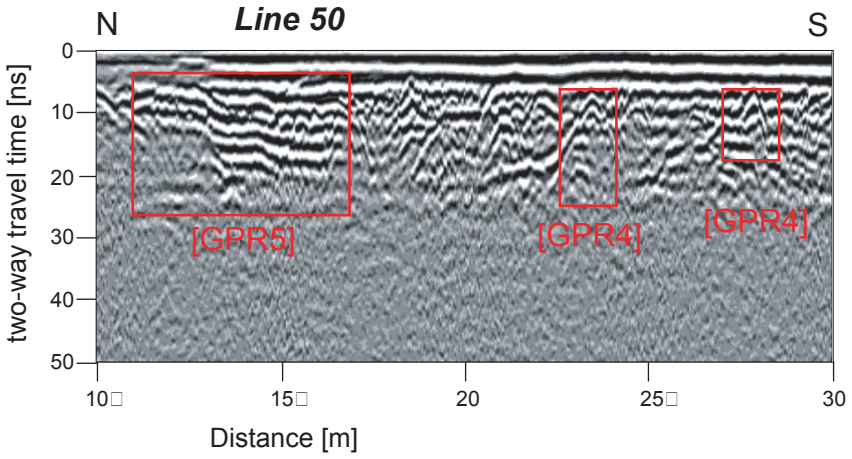
KENILWORTH CASTLE, Warwickshire.
Selected 450MHz GPR profiles

PLAN C





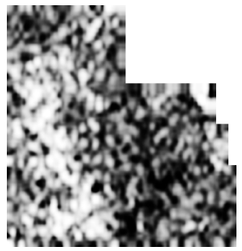




PLAN D

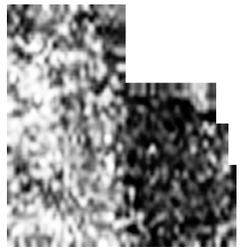
KENILWORTH CASTLE, Warwickshire.
GPR Amplitude Time Slices 450MHz data

0 - 2ns (0.0 - 0.05m)



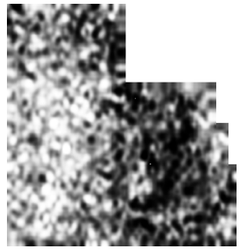
2 - 4ns (0.05 - 0.1m)

4 - 6ns (0.1 - 0.15m)



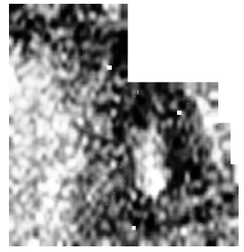
6 - 8ns (0.15 - 0.2m)

8 - 10ns (0.2 - 0.25m)

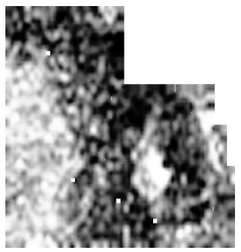


10 - 12ns (0.25 - 0.3m)

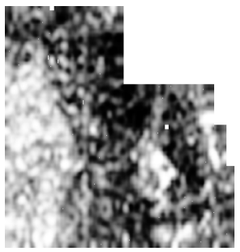
12 - 14ns (0.3 - 0.35m)



14 - 16ns (0.35 - 0.4m)



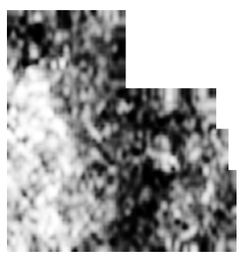
16 - 18ns (0.4 - 0.45m)



18 - 20ns (0.45 - 0.5m)

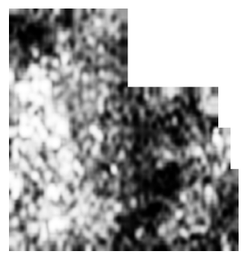
20 - 22ns (0.5 - 0.55m)

22 - 24ns (0.55 - 0.6m)



24 - 26ns (0.6 - 0.65m)

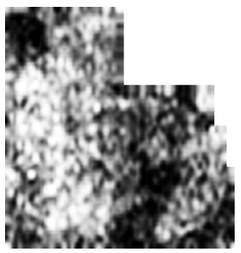
26 - 28ns (0.65 - 0.7m)



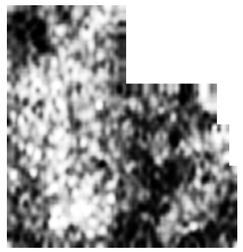
N

28 - 30ns (0.7 - 0.75m)

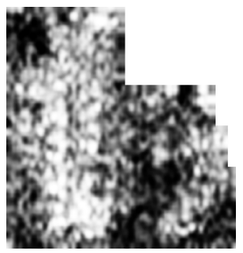
30 - 32ns (0.75 - 0.8m)



32 - 34ns (0.8 - 0.85m)



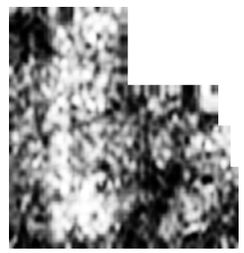
34 - 36ns (0.85 - 0.9m)



36 - 38ns (0.9 - 0.95m)

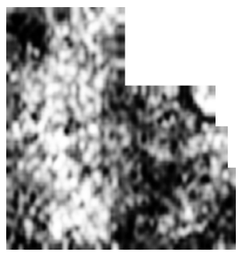
38 - 40ns (0.95 - 1.0m)

40 - 42ns (1.0 - 1.05m)



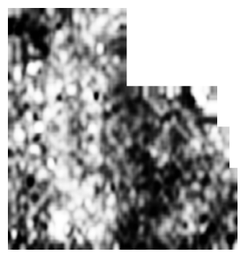
42 - 44ns (1.05 - 1.1m)

44 - 46ns (1.1 - 1.15m)



46 - 48ns (1.15 - 1.2m)

48 - 50ns (1.2 - 1.25m)



low *high*

relative reflector amplitude

0 30m

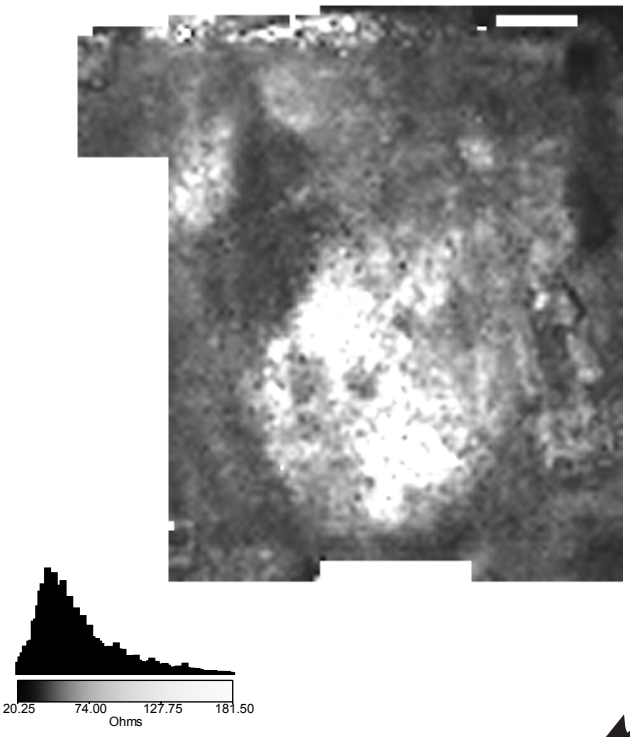
1:750

KENILWORTH CASTLE, Warwickshire

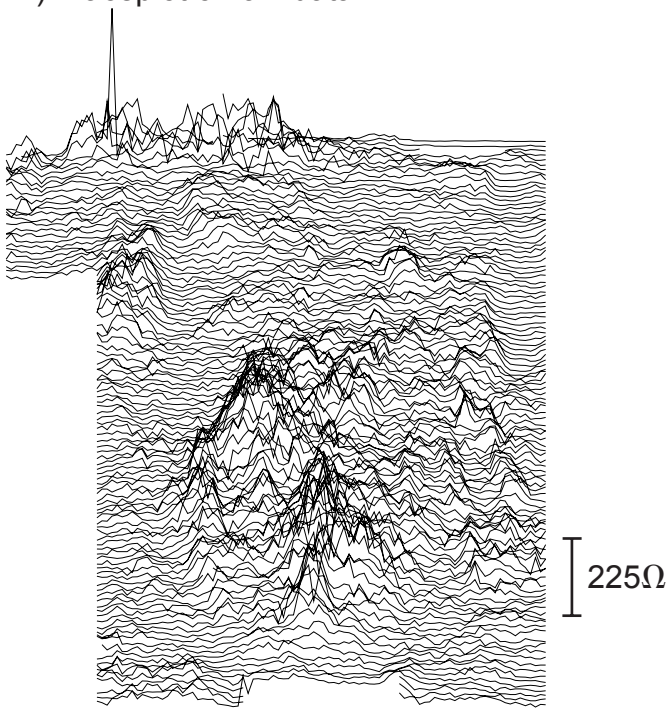
PLAN E

Earth resistance survey of the Pleasance, June 2004.

1) Linear greyscale of raw data.



2) Traceplot of raw data.



3) Linear greyscale of sharpened data.

4) Linear greyscale of wallis filtered data.

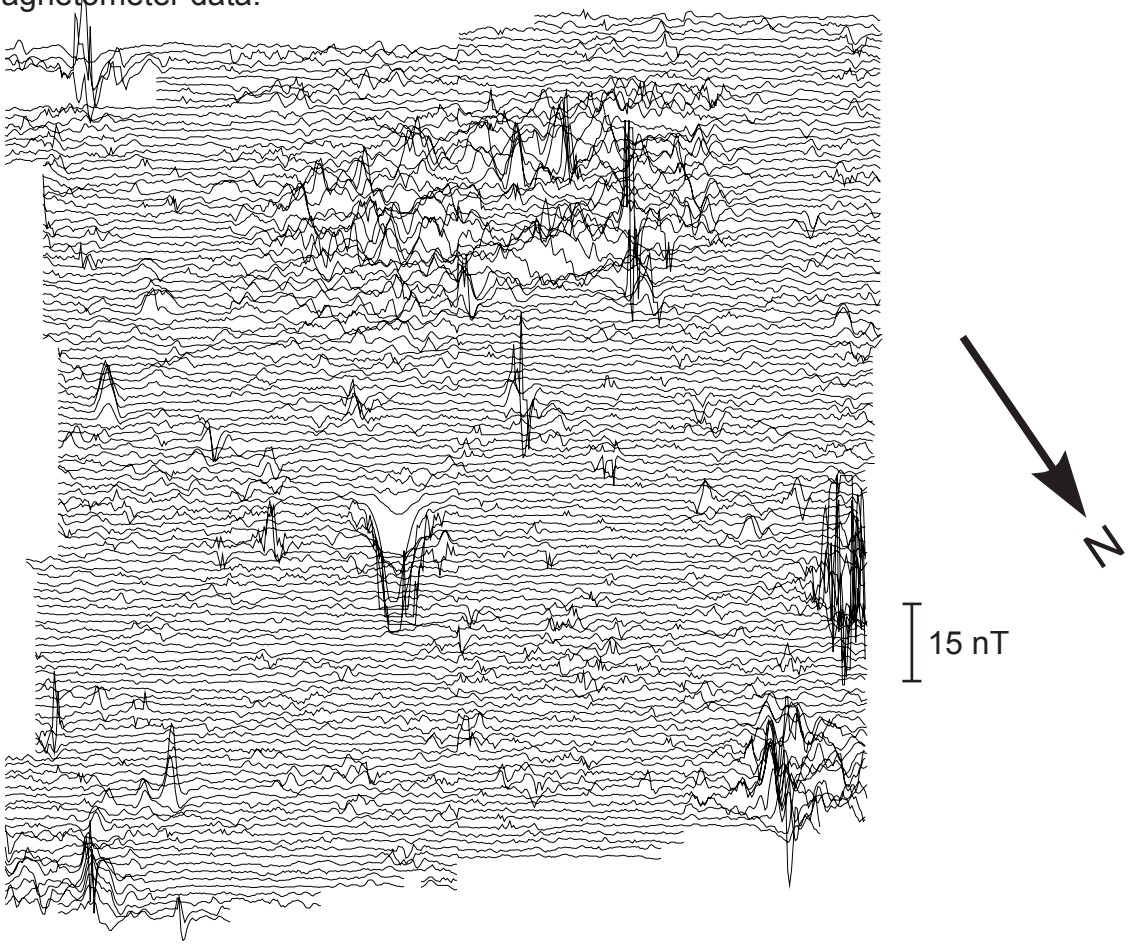
1:1500

KENILWORTH CASTLE, Warwickshire

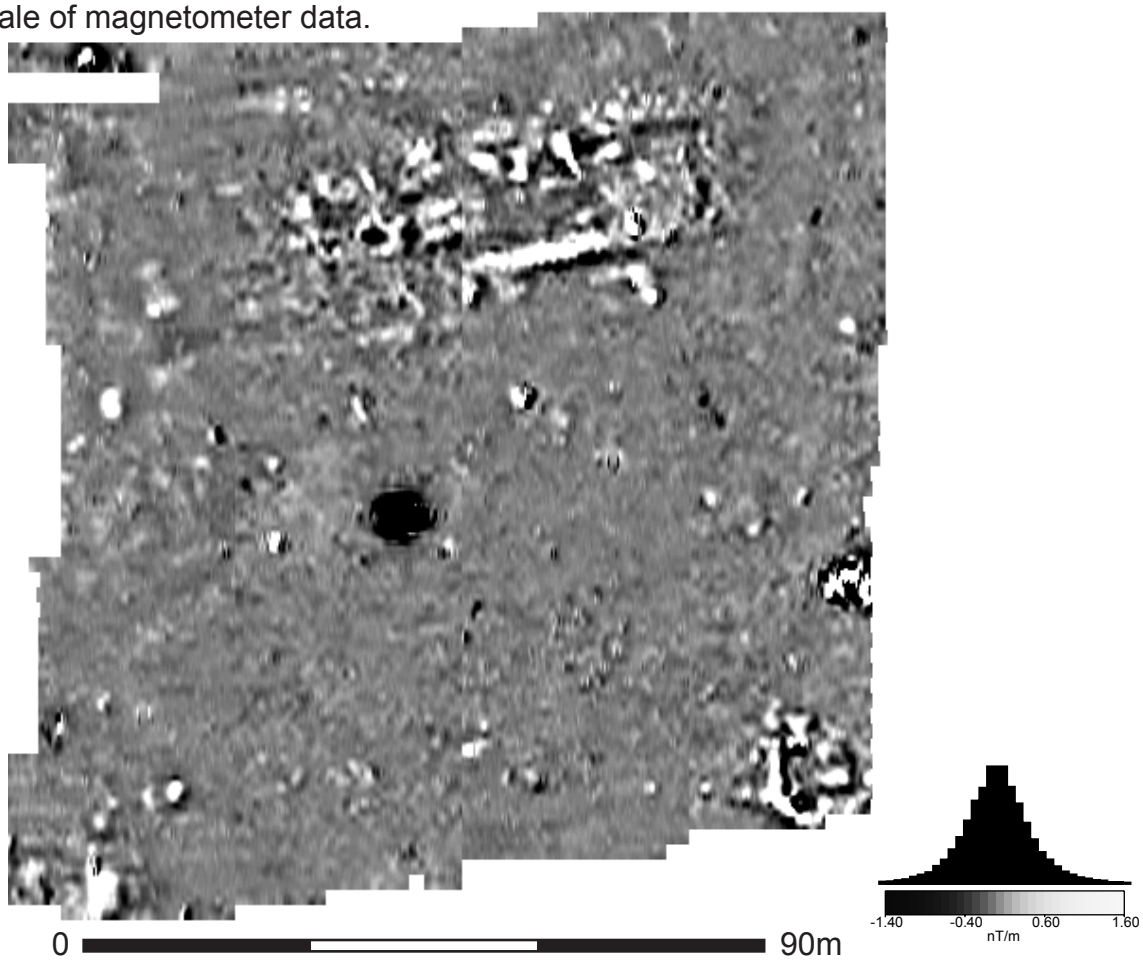
PLAN F

Magnetometer survey of the Pleasance, June 2004.

1) Traceplot of magnetometer data.



2) Linear greyscale of magnetometer data.

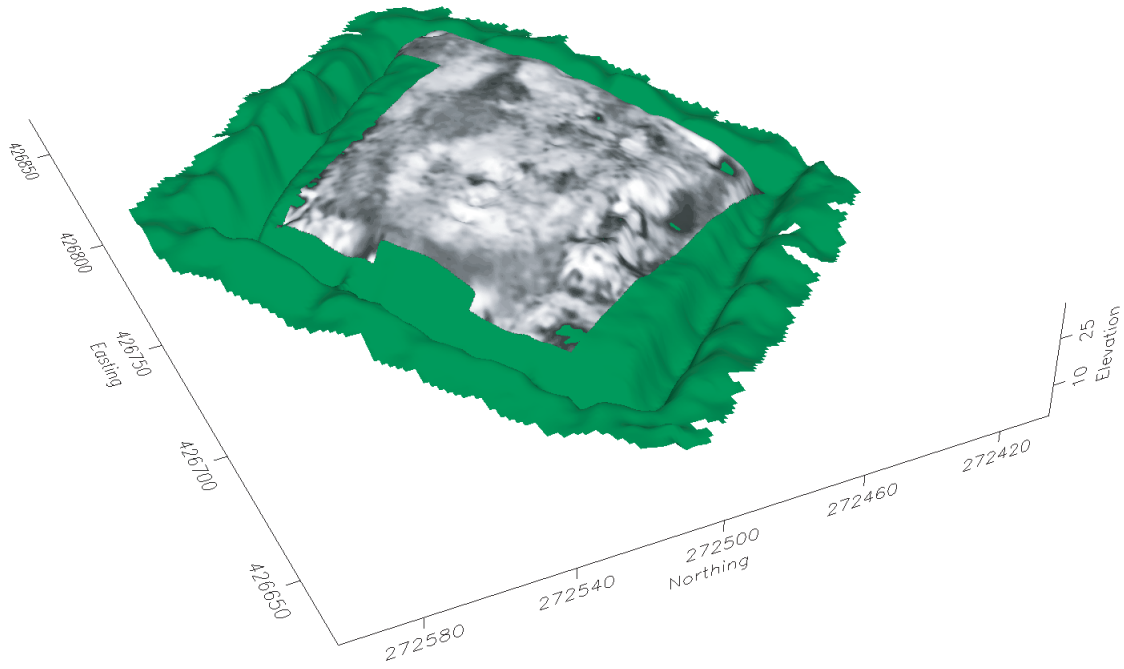


1:1000

KENILWORTH CASTLE, Warwickshire PLAN G

Geophysical plots draped over a DTM of the Pleasance, June 2004.

a) Greyscale of earth resistance data over DTM.



b) Greyscale of magnetometer data over DTM.