Geophysical Surveys
of
Pistil Meadow, Lizard Point
(Cornwall)
Report II

(Central OS NGR 169854 011626),
Surveyed November 2012 & October 2014

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Bournemouth, 3rd February 2014.
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1.0 Non-technical Summary

Geophysical surveys were undertaken at the Pistil Meadow, Lizard Point (Cornwall), in November 2012 and October 2014, with the aim of establishing whether any geophysical anomalies detected can be related to the reports of a number of multiple occupancy or mass graves of the victims of the wreck of the Royal Anne Galley. Magnetic and slingram electromagnetic techniques were used in 2012 and this was followed in 2014 with earth resistivity area 3D imaging, ground penetrating radar (GPR) and additional slingram electromagnetic surveys.

The surveys identified a number of anomalies that have the potential to result from sub-surface features that could be large graves. One, in particular, has the responses and morphological characteristics of mass grave and in is considered that ground truthing is needed to establish the true nature of this and three other anomalies detected.

2.0 Aims and objectives

The aim was to locate the sites of an unknown number of single or multiple occupancy graves thought to be located on the site containing victims from the Royal Anne Galley, which was wrecked off the Lizard on 10th November 1721.

To achieve this a number of established geophysical techniques were intended to be employed all of which have had proven, if in some cases limited, success in locating single and multiple occupancy graves (Cheetham 2005).
Plate 2. The southern end of the site looking from the north in 2012. The surface water ‘stream’ can be seen running south from the bottom the right of the image.

3.0 Site ground conditions

The site (Plates 1 and 2) was completely waterlogged in November 2012, with a running stream down the spine of the survey area and standing water in the many parts of the hollow (Plate 3). This effectively made the likelihood of the successful detection of any graves extremely unlikely by methods that rely solely or partly on moisture changes affecting the conductivity of the ground (i.e. earth resistivity, EM conductivity and GPR). That said, such waterlogging will not affect magnetic surveys employing magnetometry systems. Conversely, EM in-phase magnetic susceptibility measurements can be compromised in environments where the conductivity is greater than 30mS m\(^{-1}\) (the quadrature measurements show the site’s conductivity is of the order of 20-40mS m\(^{-1}\)). However, the uniform waterlogging of the site would suggest this should not cause false anomalies.

Plates 3a & b. These illustrate the severely waterlogged conditions in 2012 which severely restricted the use of methods that rely on moisture contrasts. However, magnetic (magnetometry – shown left) and electromagnetic surveys (Slingram EM – shown right - and GPR) were undertaken despite the likely poor contrast conditions for the latter techniques.
In October 2014 the situation was quite different in that there had been a warm dry July and an exceptionally dry September which had been broken by heavy rain in October leaving the ground superficially damp but in no parts waterlogged. These conditions are more favourable for producing the moisture contrasts that earth resistance and EM conductivity could map, while providing better conditions for GPR penetration.

Plate 4. Twin electrode earth resistance (ER) survey in 2014. The RM15 instrument with its multiplexer unit took readings every metre at 0.25, 0.5, 0.75, 1.00, 1.25 and 1.5 m electrode separations giving six depths of survey, nominally to a depth approximating to the separation used. This allows both shallower and deeper survey and consequently some ability to separate anomalies at different depths and make some estimation of the depth. However, the greater separations reduce the resolution of the array.

4.0 Methods

Owing to the extremely wet ground conditions earth resistivity imaging was not undertaken in 2012 and so the three methods employed for the surveys were ground penetrating radar (GPR), slingram electromagnetic survey (EM) and fluxgate gradiometry (magnetometry). In the dryer conditions of 2014 the GPR and EM VMD surveys were repeated and the twin electrode earth resistance surveys undertaken for the first time. Instrument details and reading intervals are shown in Table 1.

Table 1. Instrumentation and survey sampling intervals

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Interval along traverses</th>
<th>Interval between traverses</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPR: Mala RAMAC X3M with a 500MHz shielded antenna</td>
<td>0.02 m</td>
<td>0.5 m</td>
<td>Nov 2012 Oct 2014</td>
</tr>
<tr>
<td></td>
<td>0.05 m</td>
<td>0.5 m</td>
<td></td>
</tr>
<tr>
<td>EM: Geonics EM38B in HMD and VMD orientations recording both in-phase and quadrature.</td>
<td>1.0 m</td>
<td>1.0 m</td>
<td>Nov 2012 Oct 2014 (VMD)</td>
</tr>
<tr>
<td>Magnetometry: Geoscan Research FM256</td>
<td>0.0125 m</td>
<td>0.5 m</td>
<td>Nov 2012</td>
</tr>
<tr>
<td>Earth Resistance: Geoscan Research multiplexed RM15 twin electrode array @ 0.25, 0.5, 0.75, 1.00, 1.25 and 1.5 m electrode separations.</td>
<td>1.0 m</td>
<td>1.0 m</td>
<td>Oct 2014</td>
</tr>
</tbody>
</table>
4.1 Equipment used

GPR has an established record of effectiveness in historic grave detection and has been shown to be effective when ground conditions are good. Good in this context usually means dry ground conditions over sandy soils/base geology. GPR is less effective in wet silt/clay geologies. The 500MHz frequency employed should provide both the penetration depth and resolution to define graves although both higher and lower frequencies can be more effective in specific circumstances.

EM has a very limited published record of effectiveness for grave detection although the author has demonstrated the success over a number of animal mass graves and the EM38B should provide complementary data for both the magnetometry and earth resistance surveys. In particular the EM in-phase data will show variations in magnetic susceptibility which magnetometry, in the form of gradiometry, is less effective at detecting.

Magnetometry (fluxgate gradiometry) in this context is most likely to be useful in detecting areas of anthropogenic activity that may be associated with a grave rather than the grave structure itself. Graves can be associated with the redistribution of topsoil and burnt deposits as well as ferrous debris that can be incorporated in the grave or around activity sites and so these results need to be considered in concert with the results from the other techniques employed here.

Earth resistance/resistivity imaging, when site conditions are favourable for its use, has been shown to be the most consistently effective method of grave detection known. While the relatively flat and open site provided suitable physical survey conditions, when the surveys were undertaken the saturated ground conditions were not.

The Geoscan Research RM15 Earth resistivity equipment with a 1.5m multiplexed twin electrode (also known as the two-probe or pole-pole) array, providing mobile electrode separations of 0.25, 0.5, 0.75, 1.0, 1.25, and 1.5 m, and so an effective maximum depth of survey being nominally 1.5 m, or more in the case of high contrast anomalies.

This system can provide plans at six depths, depth profiles and 3D data volumes. As with all such systems increasing depth of detection is offset by a loss in lateral resolution (EM and GPR being similar). In any geophysical survey programme of this type this technique should and would have been employed as a matter of course, if survey conditions permitted. However, the results of the slingram EM quadrature phase demonstrate that due to waterlogging conductivity contrasts did not exist at the time of the survey and that earth resistivity imaging, which is a time consuming survey technique, should be undertaken at a later date under more favourable conditions.

4.2 Survey grid and georeferencing

The surveys were undertaken on the same 10 x 10m grid laid out using a sighted and taped north-south baseline down the spine of the survey area with grids set off to either side by tape trilateration. As the site was relatively flat grid point accuracy was likely to be within +/- 10cm at 10m from the central baseline. The survey grid was georeferenced by trilateration to points available on Ordnance Survey digital mapping by Tom Cousins. The georeferenced survey grid with grid reference numbers used in the report is shown in Plots 1 and 2. In 2014 the grid was set out from control points recorded in 2012 by trilateration with tapes and there is excellent correspondence between the directly comparable 2012 and 2014 EM VMD surveys.
Plot 1. The 10 x 10m survey grid georeferenced on an OS digital base map of the site (Central OS NGR 169854 011626).
Plot 2. The 10 x 10m survey grid georeferenced on an aerial photograph of the site (Central OS NGR 169854 011626).
5.0 Results

5.1 Magnetometry: Fluxgate Gradiometry

The Geoscan Research FM256 0.5m fluxgate magnetometer was selected for this survey over the Bartington 601 dual 1m fluxgate gradiometer (which was available) due to the undulating topography of the site for which the Barrington 601 dual gradiometer instrument is not appropriate. The FM256 instrument can detect magnetic features down to a nominal depth of 1.5m.

Graves generally do not show on magnetic surveys except in special circumstances because the grave fill is usually the same material that was dug out and human remains do not intrinsically have any magnetic effect. However, there are a number of possible reasons why a grave can show magnetically. These are discussed in more detail in Cheetham 2005, but in brief they are:

- Ferrous objects - personal items, weapons, surface rubbish, etc. – incorporated into the backfill can be detected, so indicating the site of a grave. This will produce in the data the characteristic dipolar responses consisting of a high positive ‘spike’ and associated, but less extreme, negative ‘spike’ immediately adjacent, often, but not always, to the north of the positive spike.
- The mixing of magnetically enhanced topsoil and less magnetic subsoil during the digging of the grave can produce a negative magnetic anomaly over a grave or at least show a disrupted ‘noisy’ response over the area disturbed.
- It has been suggested that the decomposition of a mass of bodies can, under certain environmental conditions, cause the reduction and re-oxidisation of iron oxide minerals in such a way that they become change to magnetically enhanced forms. The specific environmental conditions and mechanism that causes this is currently not known or understood. Nevertheless, it does seem to happen in some cases.
- Finally, and of more relevance here, is that as decomposition of the bodies in a grave takes place the grave fill will subside due to the soft tissue decomposing together with general compaction of the disturbed soil leaving a clear depression even on individual graves. A mass grave should create a more significant depression, especially if bodies were laid on top of one another. If the site is not flattened or otherwise disturbed by ploughing, then over time magnetically enhanced topsoil will wash into and fill the depression producing a significant positive magnetic anomaly.

The magnetometry results (Plots 3, 5 and 12) indicate that there are a number of anomalous areas which are likely to result from anthropogenic activity that may represent the sites of graves.

Area A (see Plot 14) is a well-defined positive magnetic anomaly approximately 2m wide and 11m in length. While the anomaly extent will be larger than the physical feature or deposit that caused it, this feature is likely to be of similar extent to that of the anomaly observed, taken the relatively weak strength of the anomaly (+4 to +11nT). On the topographic model overlaid with the magnetometry results (Plot 11) it appears Area A is in a depression and that alongside it is a ‘bank’ that could be the remains of the excess upcast from a series of graves. That the magnetic anomaly has some enhanced magnetic response to its north suggest that this could be the source and direction of the material filling a possible depression. Added to this, the fact that the anomaly stops both abruptly at its southern extent and has the larger response at this end does strongly suggest that this is a discrete depression with finite limits. The feature that created this anomaly is a clear candidate to be one of the mass graves sought.

Area B (see Plot 14) shows another positive linear anomaly that, though less well-defined, also has the potential to represent further features that could be graves, based on similar logic to that of Area A. It is of note that there is a clear area of background level responses between Area A and Area B which again suggest that we are dealing with discrete features rather than a continuous ditch-like feature that the bank showing on the LiDAR.
topographic model may suggest (Plot 11). There is also a concentration of ferrous objects between Area A and Area B that may be significant. It is conceivable that bodies brought up for burial were stripped of items prior to being placed in the graves and these ferrous objects could be associated with the activities related to the burial. Of course, they could be no more than modern contamination.

Area C is rather different. Although slightly more magnetic (or less in some parts) it is the general variability or noisiness of the responses in this area that suggest possible disruption by one or more dug features, while a concentration of ferrous responses, as explained in the previous paragraph, could relate to activities surrounding the burial or be within the grave fills. This noisy response in Area C is best seen in the X-Y plot Plot 3.

Overall the gradiometry does suggest three strong candidate areas requiring further investigation. The ferrous items should also be recovered – see the recommendations for further work.

Plot 3. Fluxgate gradiometry X-Y plot to help distinguish the strong dipolar responses resulting from ferrous objects. North is to the right. This should be examined in conjunction with Plot 4 below. Also note the broad increased magnetic response in Areas A and B and the disrupted nature of the magnetic response in Area C. Compared this to the magnetometry in plan in Plot 4 and the EM HMD in-phase responses in Plot 6.
Plot 4. Georeferenced fluxgate gradiometry showing a number of areas of positive responses together with individual and groups of ferrous dipolar responses.
5.2 Slingram Electromagnetic (EM)

The results for this instrument are split into four sections. The Geonics EM38B is a 1m coil separation slingram EM instrument capable of operating in horizontal and vertical magnetic dipole orientations (HMD and VMD respectively) and simultaneously recording in-phase and quadrature reading which relate predominately to magnetic susceptibility (MS) and conductivity (the reciprocal of resistivity) respectively. The in-phase is plotted higher or lower in parts per million relative to the site background and so has no units. Conductance, measured in the quadrature phase, has the units of millisiemens per metre ($\text{mS m}^{-1}$).

Both the HMD and VMD slingram EM results show an increase in conductance from the higher ground to the west to the lower ground in the east of the survey area which corresponds to the increasing waterlogging of the ground and so likely to reflect the change of topography and not be due to any anthropogenic activities. In the HMD orientation the sensitivity of the EM38B instrument falls off directly from a maximum at the surface while in the VMD orientation the sensitivity is zero at the surface, rising to a maximum sensitivity at a depth of around 0.25m. This is why the surface water 'stream' appears more strongly in the HMD plot but otherwise due to the lack of conductivity contrast resulting from the extremely wet to full waterlogged ground, the plots are similar. As a slingram EM instrument detects all types of metal, unlike a magnetometer that only detects strongly magnetic metals, most commonly iron, there are in both plots a number of isolated high conductivity anomalies that are likely to result from iron objects. However, as smaller ferrous objects are detectable by magnetometry only and all these detectable in the EM plots are found on the magnetometry plot, such ferrous targets are detailed in the results for that instrument.

5.2.1 VMD and HMD in-phase

Apart from showing a number of isolated high in-phase responses resulting from buried metal objects, the main anomalous area is that of Area C. As the VMD orientation detects shallower magnetic effects than seen in the HMD orientation and it is seen on both plots (Plots 5 and 6). This means that Area C has both shallow and deeper elements, the latter confirmed by the fluxgate gradiometer response in this area (Plot 4). However Areas A and B are different. They show much more strongly in the HMD plots suggesting that these are deeper seated (at a greater depth). These results indicate that the nature of the anomalous areas A and B, differs from the anomaly(ies) in Area C. In light of the magnetometry results, Area A and Area B have EM results which further suggest anomalies, that can reasonably be interpreted as potential graves of the type and size expected.

Note that the slightly higher response linear anomaly running down the length of the site where the stream is found on both the VMD and HMD plots (stronger on the VMD plot) should not be there. This is an effect of the high conductivity response of the stream 'leaking' from the quadrature to the in-phase part of the signal and so should be ignored. However, faint higher areas along the western edge of the VMD in-phase plot would appear to represent a build-up of more magnetically susceptible soil at the base of the steep slope along the western edge of the survey area.

5.2.2 VMD and HMD quadrature

The two 2012 surveys shown in Plots 7 (HMD) and 8a (VND) produced no discernible anomalies related to possible graves. In the quadrature phase it is the HMD orientation, which has a shallower detection capability, that shows part of the stream course, otherwise the plots are broadly similar with higher conductance to the lower, wetter eastern side of the survey area. Both plots show discrete individual high and low conductivity anomalies related to conducting metal objects, most of which correspond to the ferrous objects detected by magnetometry. However, the 2014 VMD survey shown in Plot 8B does show greater variation and some stronger anomalies, but these are comparable to those detected in the larger separation deeper earth resistance surveys (e.g. Plot 9e and 9f) and will be considered along with the resistance results.
Plot 5a. The 2012 georeferenced electromagnetic in-phase vertical magnetic dipole (VMD) orientation showing a number of areas of shallow stronger magnetic response and a number of isolated individual responses resulting from metal objects. In comparison with the fluxgate gradiometry results in Plot 4 only area C shows as strongly.
Plot 5b. The almost identical 2014 georeferenced electromagnetic in-phase vertical magnetic dipole (VMD) orientation showing a number of areas of shallow stronger magnetic response and a number of isolated individual responses resulting from metal objects. In comparison with the fluxgate gradiometry results in Plot 4 only Area C shows as strongly.
Plot 6. Georeferenced electromagnetic in-phase horizontal magnetic dipole (HMD) orientation showing a number of areas of deeper (than VMD orientation) stronger magnetic response and a number of isolated individual responses resulting from metal objects. Compare the three areas indicated with those on the fluxgate gradiometry results on Plot 4.
Plot 7. The 2012 georeferenced electromagnetic quadrature horizontal magnetic dipole (HMD) orientation showing the gradient of conductivity across the survey area, part of the line of the surface stream, and a number of individual responses from metal objects.
Plot 8a. The 2012 georeferenced electromagnetic quadrature vertical magnetic dipole (VMD) orientation showing the gradient of conductivity across the survey area and a number of individual responses from metal objects.
Plot 8b. The 2014 georeferenced electromagnetic quadrature vertical magnetic dipole (VMD) orientation showing a number of discrete areas higher and lower conductivity across the survey area and a number of individual responses from metal objects. Area C is showing as a distinct area of lower conductivity, but is also exhibiting signs of disturbance.
5.3 Earth Resistance: Geoscan Research RM15 0.5 - 1.5m Twin Electrode Array

Earth resistance survey was only undertaken in 2014 due to the waterlogged conditions in 2012. The instrument used has an additional multiplexing capability to allow up to six depths of investigation to be obtained in one survey. For the twin electrode array the nominal depth of investigation is approximately equal to the mobile electrode separation so the six surveys with electrode separations of 0.25 m to 1.5 m in 0.25 m increments equate to nominal depths of survey of around 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 m. Because the electrode separation is increasing, the increase in depth of survey is, unfortunately, offset by a loss in lateral resolution, leading to the inability to detect and delimit smaller features and so the loss of finer detail in the plots.

The results are show in Plots 9a-9f and each survey will be considered separately in the following sub-sections.

5.3.1 The 0.25 m earth resistance survey (Plot 9a)

The 0.25 m survey will show anomalies within and immediately below the topsoil and has the greatest lateral resolving power and so will map small shallow resistance variations. The results show that while there is a distinct area of low resistance anomalies at D, where the stream ran, and at B, the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous Area C appears rectangular and consisting of a grouping of smaller anomalies.

5.3.2 The 0.50 m earth resistance survey (Plot 9b)

While surveying deeper to a depth of 0.5 m this is the standard electrode separation for this array for general archaeological survey. The results show that as in the 0.25 m survey, there is a distinct area of low resistance anomalies at D, where the stream ran and that the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous area E has two very distinct rectangular anomalies within it, one approximately 6 x 2 m and the other 5 x 2 m. Anomalous Area C now appears to comprise of two smaller anomalous areas.

5.3.3 The 0.75 m earth resistance survey (Plot 9c)

Though deeper there is a still a less distinct area of low resistance anomalies at D, where the stream ran. The survey is dominated by the two large, higher resistance anomalous areas C and more strongly E. Anomalous Area C continues to appear to comprise of two smaller anomalous areas.

5.3.5 The 1.00 m earth resistance survey (Plot 9d)

At this electrode separation the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous Area C appears to comprise of two now conjoined anomalous areas.

5.3.5 The 0.125 m earth resistance survey (Plot 9e)

At this electrode separation the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous Area C appears now form one contiguous anomalous area. The results at this separation are largely comparable with the EM VMD quadrature results seen in Plot 8b.

5.3.6 The 1.50 m earth resistance survey (Plot 9f)

At this electrode separation the survey is dominated by the two large higher resistance anomalous Areas C and E, the latter being much reduced in intensity and so probably resulting from a relatively shallow high resistance feature. The results at this separation are largely comparable with the EM VMD quadrature results seen in Plot 8b.
Plot 9a. The 2014 georeferenced 0.25 m earth resistance survey. While there is a distinct area of low resistance anomalies at D, where the stream ran, and at B, the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous area C appears rectangular and consisting of a grouping of smaller anomalies.
Plot 9b. The 2014 georeferenced 0.50 m earth resistance survey. While there is a distinct area of low resistance anomalies at D, where the stream ran, the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous Area C appears to comprise of two smaller anomalous areas, while two rectangular anomalies are evident in E.
Plot 9c. The 2014 georeferenced 0.75 m earth resistance survey. While there is a distinct area of low resistance anomalies at D, where the stream ran, the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous Area C appears to comprise of two smaller anomalous areas.
Plot 9d. The 2014 georeferenced 1.00 m earth resistance survey. At this electrode separation the survey is dominated by the two large higher resistance anomalous Areas C and E. Anomalous Area C appears to comprise of two now conjoined anomalous areas.
Plot 9e. The 2014 georeferenced 1.25 m earth resistance survey. At this electrode separation the survey is dominated by the two large higher resistance anomalous areas C and E. Anomalous Area C appears now form one anomalous area.
Plot 9f. The 2014 georeferenced 1.50 m earth resistance survey. At this electrode separation the survey is dominated by the two large higher resistance anomalous areas C and E.
Plot 10. Georeferenced 2014 ground penetrating radar composite at nominal depths of 0.55 - 0.70m. Towards the east can be seen the line of strong reflections from the ‘stream’ course shown well in Plot 11. To the north-west can be seen a darker rectangular area of strong reflections which corresponds to the slight bank at this point running parallel to the anomalous magnetic Area A showing clearly on Plots 4 and 6. Area C and E also show as anomalous areas of reflectors.
Plot 11. Georeferenced 2012 ground penetrating radar at a nominal depth of around 0.60m dominated by the strong reflections mainly by stony deposits but some caused by standing surface water, which are masking any more subtle anomalies likely to be caused by graves.
Plot 12. GPR traverse 80 (with its position shown on the map of the site and GPR survey above) showing the ringing effect of areas of surface water (at 6m) and the stony fill of what appears to be a stone rubble filled stream channel between 7.5 and 11m. To the west of this are a number of reflectors at a nominal depth of 0.5-0.6m, presumably stony surfaced areas. The red dashed line shows the interface suggested to be a possible buried ground surface.
5.4 GPR: Mala RAMAC X3M with a 500MHz antenna

The 2014 GPR results are better than the 2012 results because the ground was drier and there was no standing water. As such the depth of penetration was found to be up to 2 m and so any graves should be detectable if present and providing enough contrast. The responses of graves in GPR surveys is highly dependent on the nature of the geology and in soft sediments it is less likely that the actual grave cut is detected, but rather the general disturbance and disruption caused by the digging of the grave. To detect such minor disturbances it was decided not to use amplitude time-slice processing as this can process out such ‘noise’ and in this case GPR-Slice did lose anomalies clearly visible in the single slice data when it was viewed animated in MALA Easy 3D. Plot 10 is a composite of three areas of the survey that are single slices indicating a noisy areas of reflectors with one covering an area of similar size and directly alongside anomalous Area A so clearly defined in the magnetic survey. This GPR anomaly corresponds to the slight linear bank adjacent to and may represent the stony up-cast from digging a grave feature in Area A.

Because this analysis is based on viewing animated sub-sets of the overall data so the individual slices do not show clear anomalies and further single slice images are not included in this report. Anomalies identified have been transcribed onto Plot 14. In addition to Area A there is also noisy GPR data in Area C and E. The latter is coincident with a large high resistance anomaly that is interpreted tentatively as geological in origin.

The 2012 GPR results suffered particularly due to the areas of standing water. Such standing water causes an extremely strong reflection due to the high relative dielectric permittivity of water. This causes a strong reflection at the surface which both strongly attenuates the transmitted wave and causes ‘ringing’ - repeated reflections appearing in the radar reflections making these surface reflections appear deeper in the radar profile than they are. The amplitude time slice shown in Plot 8 is at a nominal depth of between 0.55-0.65m, a depth at which one would expect to be able to differentiate between undisturbed natural deposits and those disturbed, but the reflections that predominate are those created by what appear to be the stone infill of a stream bed, other stony areas, and the standing water and the surface water stream.

Plot 9 shows one of the GPR profiles (traverse 80) which suggest there is up to 0.5-0.6m of fill material in the centre of the survey area, sealing a possible buried ground surface that thins out in the east but is still 0.5 m deep at the western edge of the traverse, which is at the western edge of the survey area against the steep slope where the ground rises sharply. The date of the suggested buried ground surface is unknown, but it is possible that the depth of the deposit (nominally up to 0.6m based on the GPR profile – assumed velocity of 100m µs⁻¹) is masking any graves that do exist on the site.

6.0 Discussion of the combined results

Plots 13 and 14 indicate the positions of areas of interest in that they show strong corresponding evidence from multiple techniques. Areas of magnetic enhancement or areas of magnetic enhancement also associated with some ferrous objects disturbance evident in the GPR (Areas C and E). Of these, Area E has two clear rectangular resistivity anomalies that could represent graves within an area of GPR noise which could also result from their construction. Area C has responses from multiple techniques. Area D would seem to relate to the stream course and so is not considered further.

Overall, the results demonstrate that anthropogenic activity has been detected on the site, but without further evidence it is not possible to definitively interpret any of the anomalies detected as the graves sought. As with all such surveys, absence of evidence is not evidence of absence. Geophysical surveys only work when there is a significant physical contrast between the feature sought and the surrounding material in which it lies. Graves are notorious for not creating such a clear contrast as they are backfilled with the material that was dug out and human remains, when skeletonised, have very little or no geophysical contrast.
Plot 13. Combined magnetic and electromagnetic HMD in-phase anomalies. Area A is a 2 x 11 m grave-sized and relatively deep anomaly that clearly shows on both magnetic techniques and has a parallel matching GPR anomaly running alongside, whereas Areas B, and rather more so C, show signs of disruption and activity but not a clear grave like anomalies.
Plot 14. This shows the magnetometry results overlain on an aerial photograph and then draped over a LiDAR generated topographical surface of Pistil Meadow looking north. A, B and C are the three areas showing strong evidence from the geophysical survey results of anthropogenic activity. In the opinion of the author the dark anomaly showing in Area A is the best candidate for a large grave followed by Area C.

7.0 Conclusions

Magnetometry, in-phase EM, and earth resistance surveys have detected anomalies that may be a result of the digging of graves, one of these (A) is also associated with a GPR anomaly. EM quadrature results have not produced anomalies that have clear characteristics of graves but they have detected subsurface variations and specific anomalies or anomalous area that could result from anthropogenic activities. Of the anomalous areas detected by the current surveys the Area A anomaly has the clear characteristics of the large grave-like features sought. Area C is regarded by the author as the second most likely anomalous area that could be indicators of the site of a grave or graves, but Area E also has structures evident in the earth results that could represent graves.

8.0 Recommendations for further non-invasive survey and invasive ground truthing

8.1 Ground truthing

The surveys have detected a number of anomalies that could represent graves or the sites of disturbance that may result from the digging of graves. The anomaly marked as A on Plot 12 has the characteristics of a grave in respect of its dimensions (approx. 2m x 11m) and that it has a response on both the magnetometry and EM HMD in-phase that would indicate a well-defined and potentially deep subsoil feature. That the GPR has detected an anomalous area of reflectors of similar dimensions alongside further support the digging of a deep disturbance here. Areas B, C and E also demonstrate anomalous responses that should also be tested by evaluation trenches to determine the nature of the deposits and disturbances. The suggested buried ground surface detected should also be investigated by test excavation so as to fully understand any post depositional processes that may have occurred on the site.
8.2 Metal Detecting

Both the magnetometry and EM surveys detected ferrous and non-ferrous objects that could be associated with any burials. It is suggested that if possible these items are recovered not only guided by the existing surveys, but also by a further conventional metal detection survey across the site. BU has an appropriate range of magnetometers and metal detectors available to undertake such a survey.

8.3 3D laser scanning and Structure from Motion

Other potential non-invasive survey techniques would be to 3D laser scan the site to detect micro topographical changes that could further indicate the presence of graves and would certainly enhance the interpretation of the geophysical survey results. Bournemouth University has a suitable laser scanner available for use within the project, but this is best undertaken in a period of minimal vegetation. Currently the only topographical digital data is airborne LiDAR and that is at too coarse a resolution for the detection of graves. 3D modelling by quadcopter photogrammetry is also a possibility as we should have such equipment available in the Spring of 2015. A Structure from Motion (SfM) survey of Pistil Meadow was undertaken in 2014 by Kevin Camidge, but the result provided had topographic inaccuracies that need resolving for it to be used as a base for the surveys reported here.

8.4 Further geophysical survey

While further geophysical survey is not proposed it should be noted that all the techniques that measure or respond to moisture differences could be repeated under different conditions to obtain additional and possibly better results. As such, no individual survey employing these techniques can be considered definitive.

9.0 Sources
