Electrical Resistance Tomography (ERT) Survey Report, Bryn Celli Ddu, Anglesey

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Summary

This document reports on the electrical resistance tomography survey of the Neolithic passage grave at Bryn Celli Ddu, Anglesey. The survey was undertaken in conjunction with Manchester Metropolitan University and Cadw excavations of a rock-art site in close proximity to the tomb. The survey aimed to establish the presence or absence of the proposed outer bank that may surround the ditch enclosing the tomb. The monument itself is reconstructed, but the survey over the mound body provided an opportunity to test the ability of ERT to map the voids comprising the chambers in the mound. The survey was successful in locating anomalies that may represent an outer bank, and characterised the effectiveness of ERT on this type of site.

1. Background

1.1 *Introduction*

This document reports on an electrical resistance tomography (ERT) survey of the Neolithic passage grave at Bryn Celli Ddu, Anglesey, in compliance with the Section 42 consent granted by Cadw to undertake such work on the site. A partial topographic model of the mound body is also provided, as the data was collected in order to provide surface information for the ERT processing. The site is located at OS 250759, 370184. Bryn Celli Ddu is a Scheduled Ancient Monument, protected by law (NPRN 93827).

1.2 *The Site*

The site comprises an extant Neolithic passage tomb, now consisting of a mound set within an encircling ditch. However, the site has been heavily reconstructed (including the chamber) and the mound now does not fill the entirety of the space within the enclosing ditch. Neither the mound body nor the chambers can be considered precisely representative of the site prior to excavation.

The passage tomb was excavated in 1929 (Hemp 1930). The earliest phase of activity comprised five postholes in front of the tomb entrance, which probably significantly pre-dated other activity at the site. Pine charcoal from two of these features was radiocarbon dated to the 6th millennium (Burrow 2012), the subsequent development of the site has been interpreted variously (O'Kelly 1969; Eogan 1983; Bradley 1998; Burrow 2012), with the most recent interpretation (Burrow 2012, 263) suggesting a two phase construction (excluding the much earlier activity associated with the postholes), comprising a first phase stone circle associated with the use of the central pit, ditch, chamber, inner passage and small mound, and a final phase comprising the outer passage kerbs and enlarged mound. Burrow (2012) suggests the construction of the monument could have occurred over a relatively short period of time. Cremated bone was recovered from some of the stone holes. From the centre of the site, a pit containing a single human ear bone was excavated, and from beside this feature, the highly decorated 'pattern stone' was recovered. It is suggested that the stone was moved from elsewhere on the site, as the artefact was decorated on both sites. Other remodelling of the site occurred with the construction of the passage grave, when the stone circle must have been decommissioned (Lynch 1969, 112). The passage tomb mound, and passage were constructed, with the passage defined by a line of kerb stones following the line of the old henge ditch. Lynch (1969, 111) suggests that the monument holds affinities with sites in Brittany, rather than Irish examples. The central chamber is polygonal, with a smoothed stone pillar on its northern side. One of the chamber stones bears a small spiral carving which is probably Neolithic.

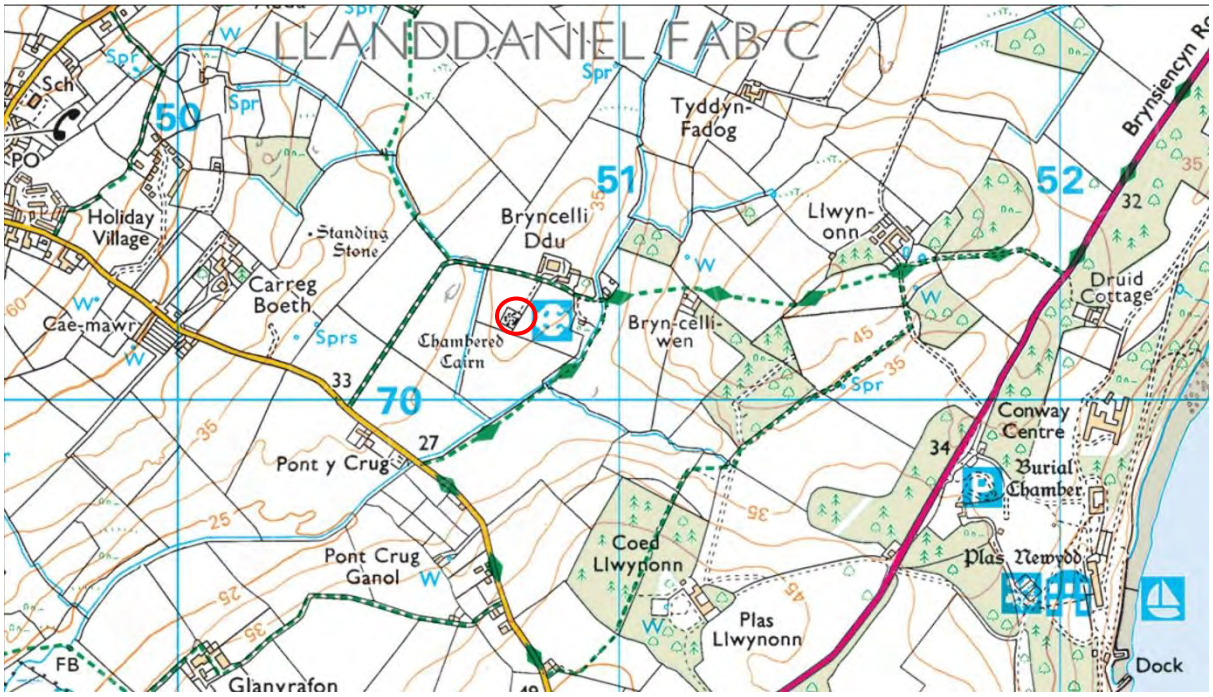

Figure 1: Location of Bryn Celli Ddu (red circle)

1.3 *Aims of the Survey*

- To inform the debate as to the existence of an external bank associated with the encircling ditch.

- To locate previously unrecorded archaeological features within the scheduled area at Bryn Celli Ddu.

- To test the resolution of ERT as a technique to examine the internal structure of burial mounds and other buried stratigraphic information.

2. Methodology

2.1 *Area*

The site encompassed roughly 0.15ha, of which the ERT survey covered about half, describing a half-section through the monument, with transects set at parallel 2m intervals. Figure 2 displays the location of the survey transects.

2.2 *Date and Duration*

The survey was undertaken between 19th and 20th June 2015. This report was completed between 1st September and 15th September.

2.3 *Weather Conditions*

The weather throughout the survey was dry and cloudy with sunny intervals. The ground was dry but not parched.

2.4 *Geo-location*

The geophysical survey area was marked with temporary markers on the days of survey, set-out and provided with OS National Grid coordinates using a TS06 Leica total station. The location and height data for each ERT probe was provided using the same instrument.

2.5 *Technical Details*

Electrical Resistance Tomography (ERT) Survey	
Traverse Length	36-38m
Equipment	Allied Tigre 64
Sample Interval	1m
Number of Transects	10
Traverse Interval	2m
Geo-location & Set-Out	Leica TS06 Total Station
Data Processing	Res2DInv
Map Data	OS Mastermap Multiscale

2.6 *Rationale*

ERT (Electrical Resistance Tomography) is based upon the basic principles of standard resistivity surveying, i.e. the greater the moisture content of the soil, the greater the conductivity and lower the resistance. Readings are, likewise, subject to an inversion calculation, similar to standard earth resistance survey, providing true readings of 'resistivity'. Where the techniques differ, however, is in the ability of ERT to provide a detailed appreciation of resistivity at varying depths along a transect (similar to a GPR pseudosection) rather than at a fixed depth in plan. Parallel transects can be combined to produce a 3-dimensional plot, or a series of time-slices.

2.7 In the method reported here, an array of 36 to 38 probes (varying due to the underlying shape of the burial mound causing a longer slope-distance) are spaced along a transect at a separation of 1m, and a series of Wenner-type resistance measurements are taken at varying probe separations. This provides both detailed overlapping readings, and determinations at varying depths, with the potential to detect subtleties in anomaly shape

at a smaller resolution than the minimum separation of the probes – particularly at shallow depths.

2.8 The value of ERT in this instance is its ability to provide detailed plots of complex stratigraphy. ERT should be used as the method of choice where traditional magnetometry or resistivity has located potentially interesting and or complex anomalies that require more detailed understanding. It cannot, however, be efficiently used over large areas due to the static nature of the array and the time required to deploy it; it is suited to targeted use.

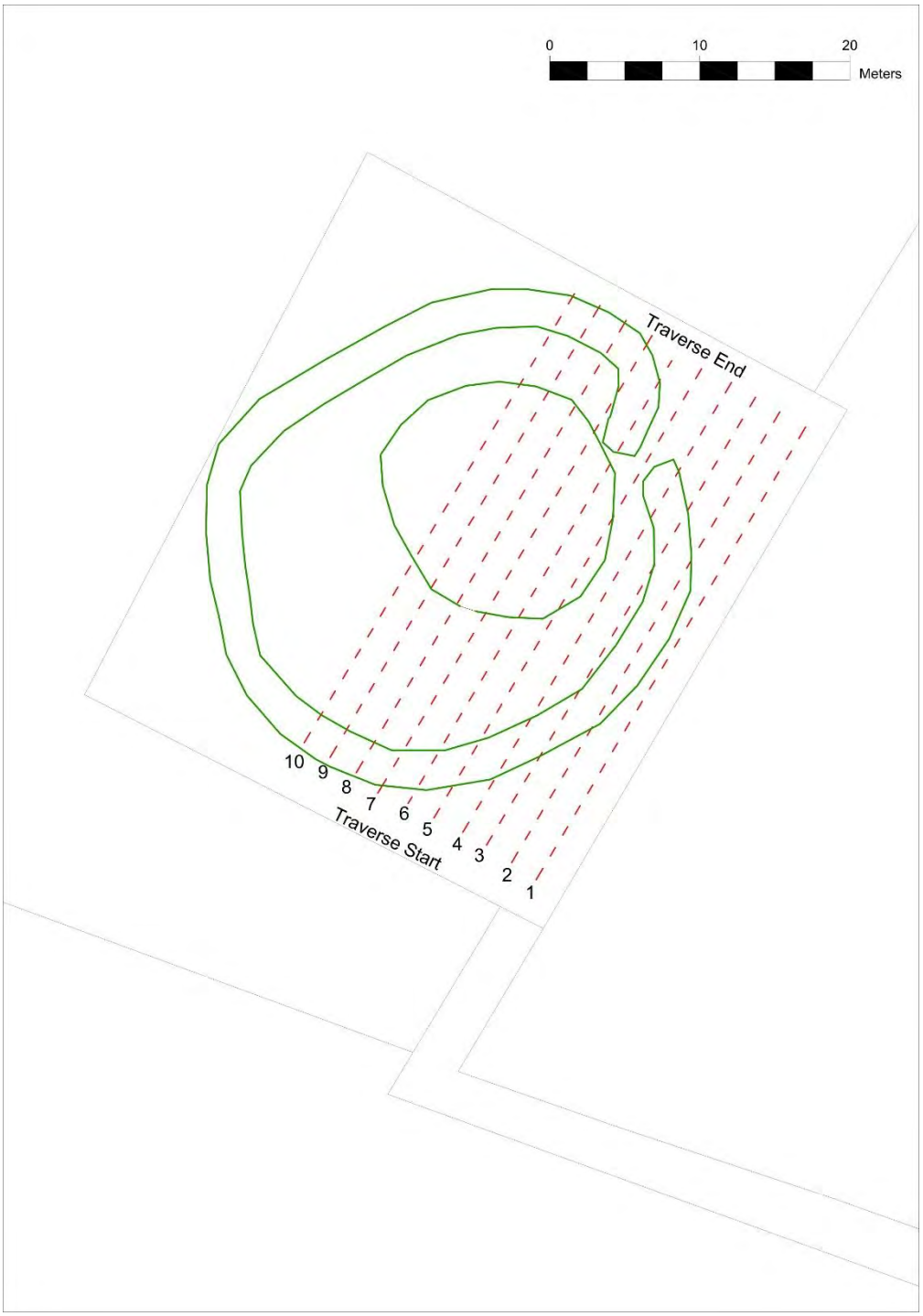

Figure 2: Location of traverses (numbered)

3. ERT Survey: Results and Interpretation

3.1 *Geology*

Bryn Celli Ddu lies on the metamorphic bedrock of the Central Anglesey Shear Zone, overlain by glacial diamicton till deposits. Such deposits have no known negative effect on earth resistance survey, and the soils are relatively well-drained, preventing waterlogging that could obscure or affect resistivity measurements.

3.2 *Electrical Resistance Tomography (ERT) Results – General Remarks*

Figure 3 displays the results of the ERT survey and the location of the transects on the site plan. All meaningful variations in resistivity occur in the top three metres of each plot when measured down from the ground surface, with the obvious exclusion of the plots where the mound is pronounced, with the green/blue response below representing variation in the bedrock. The anomalies have been identified A-K; where it is likely that anomalies continue between transects, the lettering is consistent. Results are described below by transect and by anomaly, with a description of the anomaly and its interpretation kept separate.

4.8 *Electrical Resistance Tomography (ERT) Results – Anomalies*

Transect 1: *Anomaly A*

A slight anomaly, some 4m in width at its lowest recognisable depth, narrowing to 2.5m at the surface. Falling into the range 771-1395Ω, becoming more highly resistant with depth.

Given that this anomaly is only slightly more resistant than the surrounding soil, but appears relatively narrow in the plot, this could represent the now flattened remains of a bank beyond the ditch encircling the monument.

Transect 2: *Anomaly A*

A slight anomaly, but here 5m in width, narrowing to 3m at the surface. Falling into the range 771-1395Ω, becoming more resistant with depth.

The continuation of the anomaly in a similar location on this transect, as on number one, strengthens the interpretations that this represents a damaged bank feature, made of more highly compacted material than the surrounding soil.

Transect 3: *Anomaly B*

This anomaly occurs in two locations (see below). A strongly negative anomaly (426-573Ω), 8m in width, by 1m in depth in both locations.

Given the location in the transect, this anomaly represents where the line of probes intersects with the ditch surrounding the monument. As the transect passes through the ditch in two places at an extreme angle, an almost longitudinal section has been recorded, hence the width of the anomalies.

Anomaly C
A complex, shallow and slightly upstanding, high resistance anomaly, 5m in width, in the range 1036-3880Ω.

As this anomaly falls between the two areas of ditch, it certainly represents the transect clipping the edge of the area of monument within the ditch. The extremely high resistance area represents the stones that line the inner face of the ditch at various points.

Transect 4: *Anomaly B*
A negative anomaly 426-771Ω, width 6m, depth 1m deepening to 1.5m towards the north.

Similar to transect 3, this negative anomaly represent the ditch surrounding the monument, again traversed at an angle from the perpendicular, hence its width.

Anomaly D
An anomaly characterised by slightly higher resistance (771-1036Ω) than the surrounding topsoil, 2m in width narrowing to 1m near the surface.

The nature of this anomaly is unknown, but may represent structural features of the monument now no longer visible on the surface, or an artefact of the reconstruction of the monument into its present form.

Transect 5: *Anomaly B*
A negative anomaly 426-771Ω, width 5m, depth 1.5m deepening to 2m towards the north.

Similar to transect 3 and 4, this negative anomaly represents the ditch surrounding the monument, again traversed at an angle from the perpendicular, hence its width.

Anomaly E
A large anomaly, 15m in width, slightly raised above the normal ground surface, in the range 426-771Ω.

This anomaly represents where the transect clips the lower eastern edge of the mound body proper, hence the slight rise above the normal ground surface level. The low resistance indicates that the mound body in its reconstructed 20th century form, is largely composed humic soil, with little stone debris.

Anomaly F
A high resistance anomaly 1874-2520Ω, 3m in width, corresponding to a dip in the topography, with a depth of 1m.

This anomaly corresponds to where the transect cuts through the northern arc of the ditch surrounding the monument. However, its high resistance character is unusual. It may be that reconstruction work has

filled this area of ditch with stony material, or the passage of visitors has rendered the soil particularly compact and therefore dry.

Transect 6: *Anomaly B*
A negative anomaly 426-771Ω, width 3m, depth 1.5m deepening to 2m towards the north.

Similar to transect 3, 4 and 5, this negative anomaly represents the ditch surrounding the monument. At this point, the width of the anomaly more precisely reflects a perpendicular section through the feature.

Anomaly E
A large anomaly, 15m in width, slightly raised above the normal ground surface, in the range 426-771Ω.

This anomaly represents where the transect clips the eastern edge of the mound body proper, hence the slight rise above the normal ground surface level. The low resistance indicates that the mound body in its reconstructed 20th century form, is largely composed humic soil, with little stone debris.

Anomaly F
A high resistance anomaly 1874-2520Ω, 2m in width, corresponding to a dip in the topography, with a depth of 1m.

This anomaly corresponds to where the transect cuts through the northern arc of the ditch surrounding the monument. However, its high resistance character is unusual. At this point, the ditch is shallowing almost to nothing as the transect passes close to the entrance to the passage into the monument. It may be that reconstruction work has filled this area of ditch with stony material, or the passage of visitors has rendered the soil particularly compact and therefore dry.

Anomaly G
A 2m wide, 1m deep anomaly in the range 1036Ω, visible only because of its slight higher resistance than the surrounding topsoil and mound body material.

This anomaly may be similar in character to anomaly D (transect 4), and may represent structural features of the monument now no longer visible on the surface, or an artefact of the reconstruction of the monument into its present form in the 20th century.

Transect 7: *Anomaly B*
A negative anomaly 426Ω, width 2m, depth 1.5m; only just visible at the southern edge of the transect.

Similar to transect 3, 4 and 5, this negative anomaly represents the ditch surrounding the monument. At this point, the transects began on the very edge of the ditch, hence its poor resolution in this plot.

Anomaly E
A large anomaly, 15m in width, raised above the normal ground surface, in the range 426-771Ω.

This anomaly represents the mound body proper. The low resistance indicates that the mound body in its reconstructed 20th century form, is largely composed humic soil, with little stone debris.

Anomaly G
A 2m wide, 1m deep anomaly in the range 1394Ω.

In this transect anomaly G has a higher resistance profile than in transect 6. Given its proximity to the edge of the mound body, it could represent an encircling revetment put in place to prevent the 20th century reconstruction of the mound slipping outward.

Anomaly H
A pair of low resistance anomalies (573-771Ω), both 1.5m in width and approximately 1m in depth.

These anomalies have no direct correlation with changes in the topography, but they do occur around the reconstructed façade of the monument as it now exists. It is likely that these anomalies represent construction features for the placement of the large stones forming the façade and kerb of the monument in this location.

Transect 8:

Anomaly B
A negative anomaly 426Ω, width 2m, depth 1.5m; only just visible at the southern edge of the transect.

Similar to transect 3, 4 and 5, this negative anomaly represents the ditch surrounding the monument. At this point, the transects began on the very edge of the ditch, hence its poor resolution in this plot.

Anomaly E
A large anomaly, 15m in width, raised above the normal ground surface, in the range 426-771Ω.

This anomaly represents the mound body proper. The low resistance indicates that the mound body in its reconstructed 20th century form, is largely composed humic soil, with little stone debris.

Anomaly H
A pair of low resistance anomalies (573-771Ω), both less than 1m in width and approximately 1m in depth.

These anomalies have no direct correlation with changes in the topography, but they do occur around the reconstructed façade of the monument as it now exists. It is likely that these anomalies represent construction features for the placement of the large stones forming the façade and kerb of the monument in this location.

Anomaly I
A 2m wide very high resistance (2520+Ω) anomaly.

This anomaly occurs where the transect directly crossed the monoliths forming the entrance to the monument.

Transect 9: *Anomaly I*
A 2m wide very high resistance (2520-3388Ω) anomaly.

This anomaly occurs where the transect directly crossed the monoliths forming the entrance to the monument, and stones forming the kerb that it joined.

Anomaly J
A narrow (1m) high resistance (2520Ω) anomaly just to the south of the crest of the mound.

This anomaly occurs where the transect crosses the area, on the south-western side of the monument, where the partial 20th century reconstruction of the site has left an artificial stone-framed viewing window into the interior of the mound to the rear of the chamber.

Anomaly K
An 11m high resistance anomaly beneath the surface of the mound in the range 1874-2520Ω.

Given the location and longitudinal form of this anomaly, it is likely to represent the void in the monument where the passage leads to the central chamber. It is below the surface of the ground, however, which may be a result of the error inherent in depth calculation using ERT equipment. An alternative interpretation is that the equipment has detected the compacted and gravelled *floor* of the passage, rather than the void itself, though it is rather too deep in profile for this to be a convincing explanation.

Transect 10: *Anomaly F*
A high resistance anomaly 2520-3588, 1m in width, corresponding to a dip in the topography, with a depth of 1m.

This anomaly corresponds to where the transect cuts through the northern arc of the ditch surrounding the monument. However, its high resistance character is unusual. At this point, the ditch is shallowing almost to nothing as the transect passes close to the entrance to the passage into the monument. It may be that reconstruction work has filled this area of ditch with stony material, or the passage of visitors has rendered the soil particularly compact and therefore dry.

Anomaly G
A 2m wide, 1m deep anomaly in the range 1036Ω, visible only because of its slight higher resistance than the surrounding topsoil and mound body material.

This anomaly may be similar in character to anomaly D (transect 4), and may represent structural features of the monument now no longer visible on the surface, or an artefact of the reconstruction of the monument into its present form in the 20th century.

Anomaly J
A 2m high resistance (3388+Ω) anomaly just to the south of the crest of the mound.

This anomaly occurs where the transect crosses the area, on the south-western side of the monument, where the partial 20th century reconstruction of the site has left an artificial stone-framed viewing window into the interior of the mound to the rear of the chamber. At this point, the transect crossed directly over the laid gravel before the viewing window.

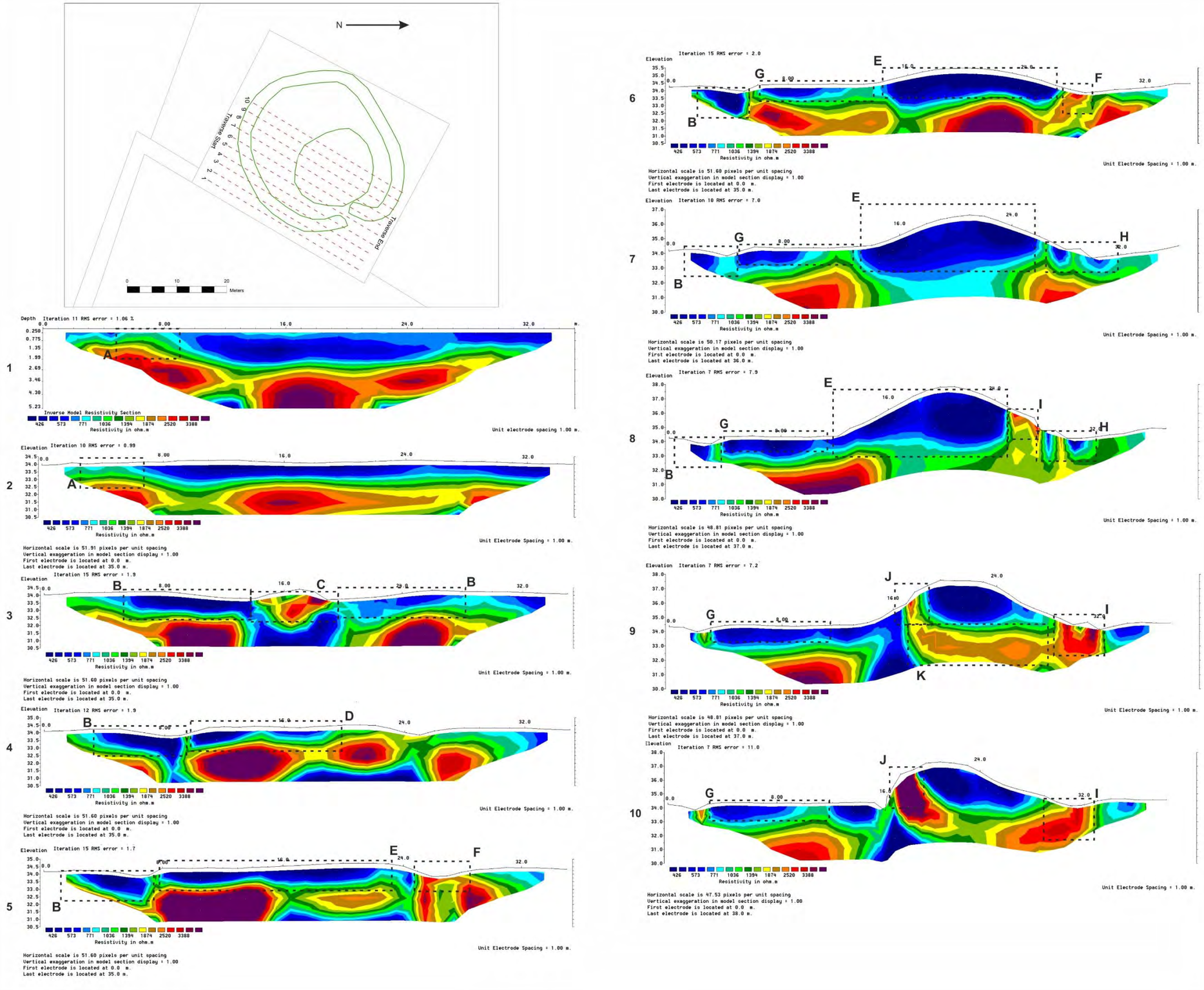

Figure 3: ERT sections and their location

4. Discussion and Conclusions

4.1 *The Ditch and Potential Outer Bank*

One of that aims of this survey was to test the existence of a potential outer bank that existed in the original form of the monument prior to its remodelling, excavation and 20th century reconstruction. This may have been located in the form of anomaly A on transects 1 and 2. Its position and width is correct for this interpretation, and it is of slightly higher resistance than the surrounding topsoil both outside and within the ditch. This would be consistent with a now denuded bank feature comprising compacted humic topsoil that now exists only below ground level.

4.2 The ditch is well-represented on many transects as anomaly B. This is unsurprising given that, at least in its reconstructed form, the ditch is an obvious topographic feature on the site. Slightly more interesting is the fact that this feature appears low resistance to the south of the monument, consistent with a ditch now slightly silted, but higher resistance on the northern edge in close proximity to the entrance. This is explicable if one considers that the ditch *per se* does not formally exist in this location (despite OS data to the contrary), and instead shallows towards the entrance. As this is not a ditch proper, and also the location where access is most easily gained to the portal entrance to the mound, it is likely that this area is either highly compacted or slightly metalled as a result of the 20th century reconstruction of the site.

4.3 *The Mound Body*

The mound body (anomaly E) shows clear differentiation from the other features discussed above. Its consistent low resistance character indicates that it is (in its reconstructed form at least) composed of humic topsoil material with good water retention. The ERT survey has also detected and accurately characterised the stone elements of the reconstruction of the mound, both around the portal entrance (anomaly I), and around the artificial window into the chamber on the southern side (anomaly J). More interesting is the high resistance anomaly K, with a longitudinal profile on transect 9. This is in the right location to represent either the void of the passageway into the mound, or its stone construction. However, its depth is incorrect, being too deep. It is likely, therefore, that the anomaly is the passageway, but its erroneous depth is a function of the *estimated* nature of depths calculated by ERT equipment – being the result of calculations made on the probe spacing at which anomalies are detected.

4.4 In conclusion, the survey has been largely successful against its aims. As the first example of ERT survey over an upstanding monument of this type in the UK, it has been a useful research exercise, and one that has shown the effectiveness of the technique.