Ancient Monuments Laboratory
Report No. 110/2001

RICHBOROUGH AMPHITHEATRE, KENT.
REPORT ON GROUND PENETRATING RADAR SURVEY, JULY 2001.

N. Linford

RICHBOROUGH, KENT.

Ground Penetrating Radar survey, July 2001.

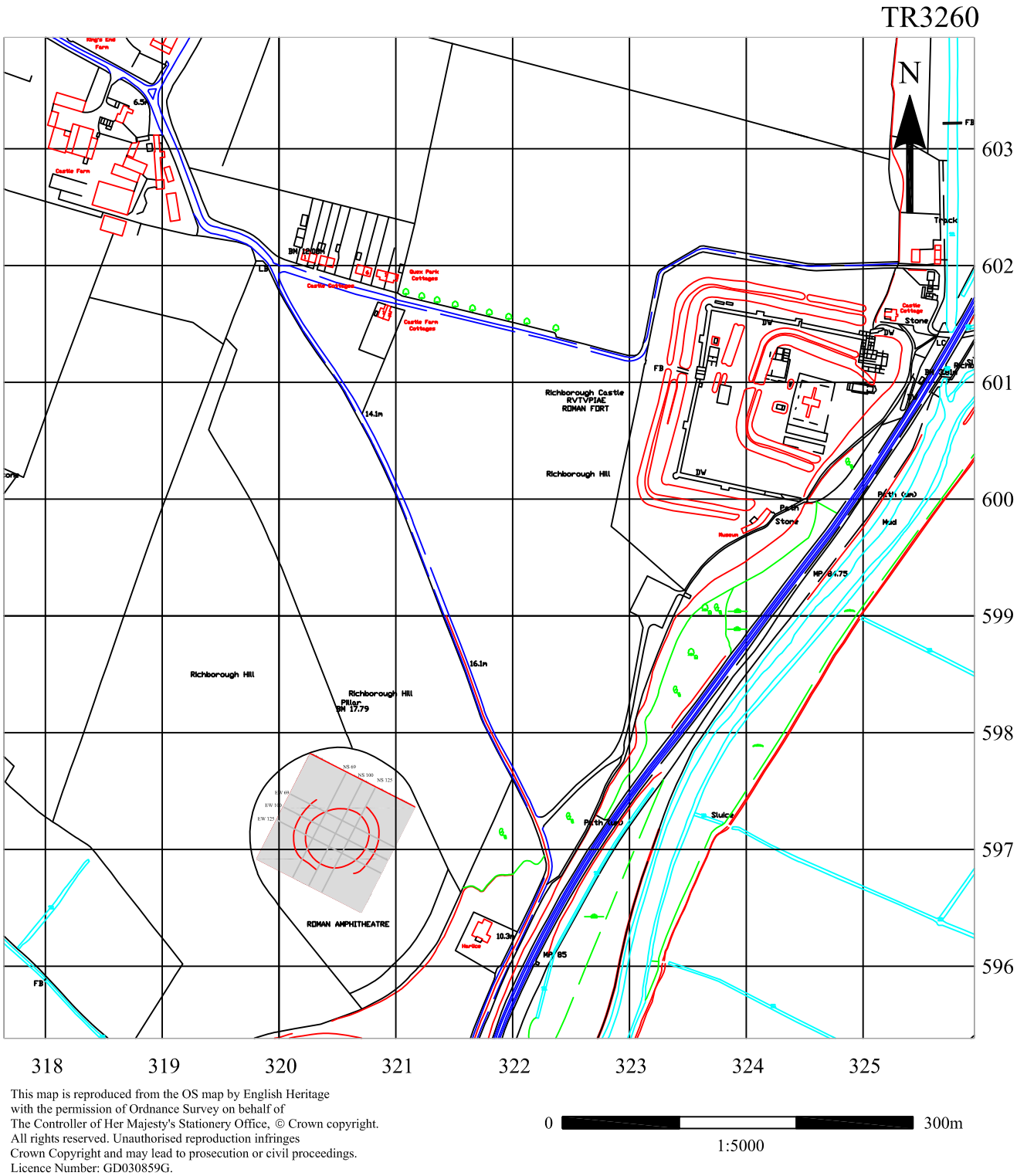

Figure 1; Richborough Amphitheatre, Kent, *Location of the GPR survey of the amphitheatre in relation to the Roman fort.*

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Summary

A ground penetrating radar (GPR) survey covering an area of 1ha was conducted over the remains of the Roman amphitheatre at Richborough, Kent. The survey successfully identified anomalies related both to the structure of the monument and to more recent wartime activity at the site. Attenuation of the radar wave limited the depth penetration of the survey although more diffuse anomalies, possibly due to more substantial entranceways or towers within the amphitheatre walls, were detected to a depth of approximately 2.5m from the ground surface. No convincing evidence was revealed for any substantial activity pre-dating the amphitheatre.

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Introduction

The Roman amphitheatre at Richborough, Kent (SAM KE25) is situated on raised ground to the SW of the third-century Roman fort built to protect the Wantsum channel. The site of the amphitheatre commands extensive views across the relatively low-lying surrounding landscape and would, no doubt, have provided an ideal vantage point to identify marine traffic entering the harbour below. Today, the amphitheatre survives as a pronounced topographic feature with a raised sub-circular mound encompassing a central, circular depression. Results from a recent geophysical survey (earth resistance, magnetic and electromagnetic techniques) conducted over the amphitheatre considerably improved the interpretation of the monument and identified a number of significant near-surface anomalies that enhanced scant records of limited antiquarian excavation at the site (Martin 2001).

Whilst some of these anomalies were suspected to be related to more recent second World War military activity the earth resistance survey provided considerable evidence for the location of both the walls of the amphitheatre and two entrances, situated on an approximate SE-NW alignment. Other intriguing anomalies included two high resistance responses within the walls of the amphitheatre that may well represent additional entrances to the monument. It was hoped that a Ground Penetrating Radar (GPR) survey of the amphitheatre would aid the interpretation of the complicated palimpsest of near-surface anomalies within the earth resistance data and reveal any earlier phases of activity at greater depth.

The site (TR 320 598) is used as permanent pasture and lies over calcareous clayey soils of the Newchurch 2 association developed over Brickearth and Thanet Beds (Soil Survey of England and Wales 1983, Institute of Geological Sciences 1966). Results from the previous electromagnetic survey indicate that despite torrential rain during the fieldwork the maximum conductivity over the site was less than 15 milli Siemens, suggesting GPR survey would not be unduly curtailed through rapid signal attenuation in the near surface deposits.

Method

Field trials were conducted with a Pulse Ekko PE1000 console and antenna with centre frequencies of 450MHz and 225MHz. From this data the 225MHz antenna was selected as the most suitable centre frequency for obtaining the optimum depth of penetration and lateral resolution required. The velocity of the radar wavefront in the subsurface was estimated through both a common mid-point (CMP) velocity analysis conducted in the field and a constant velocity test subsequently performed on extracts of the data (Leckebusch 2000). Both methods suggested that a velocity of 0.1057m/ns was a reasonable average value to adopt for processing the data from this site and for the estimation of depth to reflection events in the recorded profiles.

The 100m survey grid was surveyed with parallel traverses separated by 0.5m in both NS and EW orientations, resulting in a total of 400 recorded GPR profiles (Figure 1). Individual traces along each profile were separated by 0.1m. 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 automatic gain function to enhance late arrivals. Amplitude time slices were subsequently created from the entire data set by averaging data within successive 2ns (two-way travel time) windows (David and Linford 2000; Pulse Ekko 1996). Topographic variation was recorded with a kinematic Global Positioning Satellite (GPS) system collected at a 2m sample interval over the site. This data was subsequently used for the 2D-migration and topographic correction of the individual GPR profiles.

Representative profiles from the EW and NS survey grids are displayed in Plans A and B respectively together with annotation identifying significant anomalies discussed in the following text. A topographic correction has been applied to this data based on the elevation data recorded in the field and the average velocity of 0.1057m/ns estimated for the site. Note that the 0ns origin of the vertical two-way travel time axes on Plans A and B is defined by the first-break encountered on the trace recorded at the highest physical elevation along the profile.

The identification of significant reflection events is greatly enhanced through the display of data as a series of horizontal amplitude time-slices. In this case, the data is illustrated as greyscale images produced from the combined orthogonal survey grids, following the application of 2D-migration, together with similar images produced from the separate NS and EW orientated survey grids (Figure 2; Plans C, D and E). Each time-slice represents the variation of reflection strength at successive 2ns (~0.1m) intervals from the ground surface opposed to an absolute “depth” from a site datum. For comparison, the near-surface 1-2ns time-slice shown in Figure 2 is also displayed as a greyscale image draped over a digital terrain model of the site to illustrate the influence of the topography (Figure 3).

A graphical summary of significant anomalies is also provided with numerical annotation that refers to the following discussion of the results (Figure 4).

Results

General response and modern interference

Conditions at the site were generally good for GPR survey although the transport of the antenna was hampered in places due to patches of nettles and other resistive vegetation. Depth penetration was reasonable with significant reflections recorded to a maximum two-way travel time of ~50nS that would equate to an approximate depth of 2.5m based on the adopted average velocity of 0.1057m/ns. However, the true depth to targets may vary due to the inhomogeneous nature of the subsoil that often results in a reduced velocity with depth as moisture increases.

In addition, all the recorded profiles demonstrate a rapid attenuation of the recorded signal below a high amplitude reflection event found at a depth of approximately 30ns below the ground surface (Plans A and B). This extensive anomaly may well indicate a layer of well rounded river pebbles found throughout the area that was encountered during the construction of cess pits at

Castle Cottages ~500m N of the amphitheatre (Mr Daw *pers comm*). A similar layer described as a *"hard floor of pebble and clay"* is also reported at a depth of seven feet (2.1m) during the antiquarian excavations (Roach-Smith 1850) although it is unclear whether this is a natural feature or a deliberate metalled surface.

The location of a former cattle feeder [1] is also evident within the very near surface data and corroborates similar low resistance/high conductivity responses in the earth resistance and electromagnetic data (Martin 2001; Plans B and C). The highly conductive nature of the organic rich, odoriferous deposit surrounding the cattle feeder produced a paradoxical negative in-phase response within the electromagnetic survey. This response may well account for the persistence of [1] as a "ringing" reflection event in the GPR data, similar to that often observed over ferrous services, evident to a depth of at least 0.9m, far beyond the likely physical extent of this near-surface layer.

The highly conductive linear anomaly evident within the electromagnetic survey has also been detected in the GPR data [2] but only as an extremely faint reflection in the NS orientated grid (Plan E; 8-9ns). It seems likely that this anomaly is caused by a buried pipe or cable of modest diameter at a depth of approximately 0.9m, possibly associated with some form of Second World war defensive structure, such as a searchlight or anti-aircraft battery.

Significant anomalies

The near-surface data (0 to 10ns) provides evidence for high amplitude reflections [3] and [4] broadly similar to the high resistance anomalies that define the general configuration of the amphitheatre. These responses are seen, within the initial time-slices (0 to 4ns), to contain a more complex internal structure consisting of areas of lower amplitude response [5], [6], [7] and [8] that may represent a concentric outer and inner wall packed with rubble or a series of enclosed rooms. These structures are most evident within the very near-surface data and it seems likely that the subsequent collapse of the monument has led to the more consistent response found at greater depth.

Draping the near-surface data over a digital terrain model demonstrates the spatial variation of the GPR response over the topography of the monument (Figure 3). In particular, the broad response [3] that defines the general configuration of the amphitheatre is mainly situated on the raised rim of the monument with additional, less well defined anomalies occurring lower down the outer slopes. The most obvious of these is a wall-type response [4] that appears to partially enclose the raised walls of the amphitheatre. Additional complexity is suggested by the time-slices between 8-10ns but it is difficult to produce a definitive interpretation of the data at this depth.

To the SW, the entrance to the amphitheatre is evident as a break in [3], similar to the earth resistance anomaly. However, the entrance to the NE is not so well defined but can be identified in the NS data set (Plan E; 1-2ns). A highly diffuse anomaly [9] is visible in the near-surface data apparently heading south from the NE entrance. It is unclear whether [9] represents a significant subsurface feature, such as a compacted surface, or an anomaly caused by the irregular nature of the ground surface in the central depression of the amphitheatre, where the softer soil is more easily disturbed by grazing animals.

A semi-circular anomaly [10] is also evident within the near surface data (*eg* 6 to 7ns time slice) and this remains visible until an approximate depth of 0.8m. Similar anomalies [11] and [12] are visible from 9ns and extend to an apparent depth of 15ns. Although these anomalies occur at different depths, together they would appear to describe a similar course to that of the elliptical '*external wall*' revealed during the antiquarian excavations. This latter feature was reported to have a long diameter of 200 feet (61m) and short diameter of 166 feet (50.6m) with a thickness of 3'6" (~1m), dimensions that closely match the ellipse partially described by [10], [11] and [12].

Two of the most intriguing anomalies from the earth resistance data are the high resistance responses situated within the opposing walls of the monument. The GPR survey detects the general form of these anomalies, [13] and [14], from the very near-surface time-slice and begins to elucidate additional structural elements with depth. Beneath the initial near-surface response [13] reveals a sub-circular anomaly that becomes evident from approximately 8 to 11ns. Below this depth the main anomaly becomes more diffuse (possibly due to the reduced horizontal resolution of the GPR data with increasing depth) but remains evident as a reflection event to the final time-slice at a depth of 25ns. This response may well be caused by a substantial structure of (semi)circular form, such as an entranceway or tower, where the more diffuse near-surface response is due to a layer of rubble from its partial collapse.

The second high-resistance response, in the E wall, demonstrates a similar structural form that is particularly evident within the high-pass filtered earth resistance data (Martin 2001; Plan B (4)). The corresponding GPR anomaly [14] replicates the earth resistance response in the near-surface time-slices and again suggests a more complete, semi-circular form to the causative feature with depth. The extent of [14] would appear to be greater than [13] if the reflections identified in the 1-2, 7-8 and 8-9ns time-slices do indeed represent the outer radius walls of the causative feature. However, these latter reflection events do not extend to so great a depth as those from [13] and appear to fade by an approximate depth of 20ns.

The relationship between [14] and the diffuse linear anomaly [15] (visible in the NS data, 1-2ns time-slice) is difficult to discern as the response is limited in extent but does follow an alignment through the centre of the amphitheatre towards [13]. Perhaps, if [13] and [14] do indeed represent entranceways then [15] may be part of a compacted path leading from the entrance to the centre of the amphitheatre (a suggestion corroborated by the resistivity data).

A rectangular anomaly [16] corresponds with the location of a low resistance response immediately east of [14] and has a similar physical extent. The GPR data provides little additional information although the reflection would appear to originate from a near-surface causative feature and extends to a maximum apparent depth of 0.9m (Plan E; 0-1ns and 8-9ns). Martin (2001) suggests the corresponding earth resistance anomaly may be due to either post-Roman quarrying activity or to a C20th feature related, perhaps, to the war time activity at the site. Whilst either interpretation seems plausible the limited vertical extent of [16] may dispel the possibility of extensive quarrying activity at the site. In addition, the near-surface data (Plan C; 1-2ns) reveals a linear anomaly [17] that partially encloses [16] and the two responses may, perhaps, be due to a more significant causative feature forming part of the amphitheatre structure.

The curious linear anomaly crossing the SW entrance in both the earth resistance and

electromagnetic data is also evident within the GPR survey. In this case, the anomaly appears as a broken linear response within the near-surface data and as a very faint continuous reflection [18] visible at a more considerable depth (Plan E; 18-19ns). Inspection of the relevant GPR profiles (*eg* Plan B; NS 125) suggests [18] represents a break in the continuity of the reflective layer found at this depth, possibly caused by a trench cut. These reflections only occur within the NS orientated GPR survey lines orthogonal to the apparent course of the causative feature. Whilst a more significant archaeological origin cannot be entirely discounted, [18] would appear to be of more recent origin, possibly a non-ferrous service trench.

Attenuation of the radar signal increases beyond the 14-15ns time-slice and noise within the data becomes more evident with depth. Despite this attenuation reflections due to the walls of the amphitheatre [3] and the two anomalies [13] and [14] within the walls continue as diffuse responses to a depth of approximately 2.0m. Only anomaly [13] extends below this depth and remains visible in the final time-slice at a depth of approximately 2.5m.

Conclusion

GPR survey has proved moderately successful at this site and provides a complementary data set to aid the interpretation of the earth resistance, magnetic and electromagnetic results reported by Martin (2001). In particular, near-surface structural elements of the monument have been better resolved in the GPR data. For example, the discrepancy between the elliptical feature described during the antiquarian excavation and the extent of the amphitheatre revealed by the earth resistance survey may be explained by evidence from the GPR data, that suggests the presence of an interior wall with similar dimensions to the excavated feature.

The attenuation of the radar wave front with depth at the site limited the vertical resolution of GPR survey, using a 225MHz antenna, to a maximum depth below the ground surface of approximately 2.5m. Indeed, the majority of significant anomalies were evident within 1m of the surface and reflections recorded from below this depth become increasingly more diffuse. Part of this attenuation may be explained by the layer of pebbles reported to exist over the site that may well reflect most of the incident radar energy. Despite this effect anomalies from the structure located within the E wall of the amphitheatre have been identified to a depth of 25ns (2.5m). This would indicate quite a considerable causative feature although this is not matched by the anomaly from the opposing structure in the W wall that extends to a more limited depth of approximately 2.0m.

No indication of anomalies related to activity pre-dating the amphitheatre has been revealed by the GPR survey. However, due to the attenuation of the radar wave front noted above only quite substantial stone built structures would be likely to be identified and the presence of more ephemeral activity cannot be discounted.

Surveyed by: N. Linford
L. Martin
A. Payne

Date of survey: 16-18 & 24-26/7/2001

Reported by: N. Linford

Date of report: 21/11/2001

Archaeometry Branch,
English Heritage.
Centre for Archaeology.

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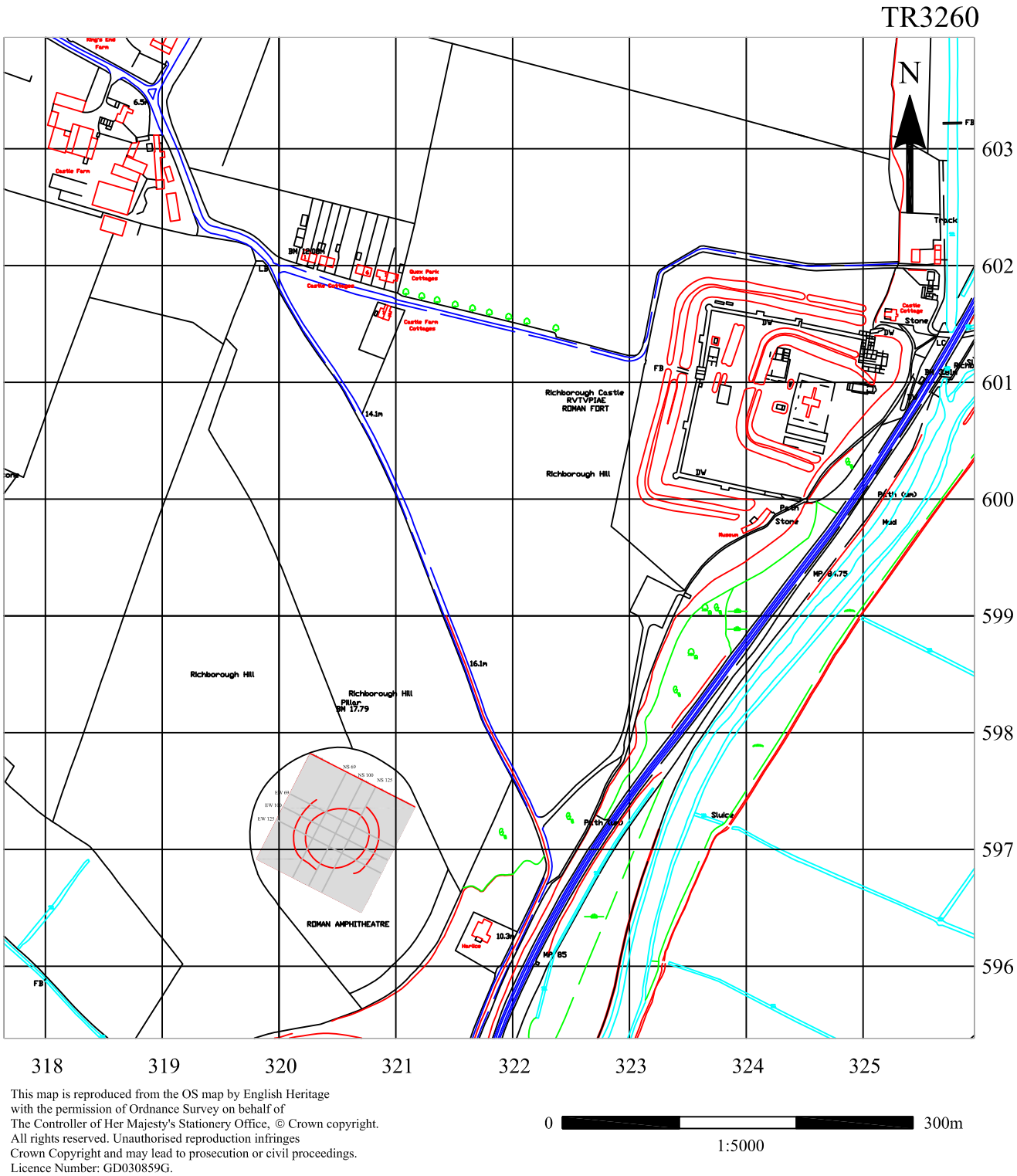
Plan D	Amplitude time-slice data from EW survey grid. (1:2500)
Plan E	Amplitude time-slice data from the NS survey grid. (1:2500)

RICHBOROUGH, KENT.

Ground Penetrating Radar survey, July 2001.



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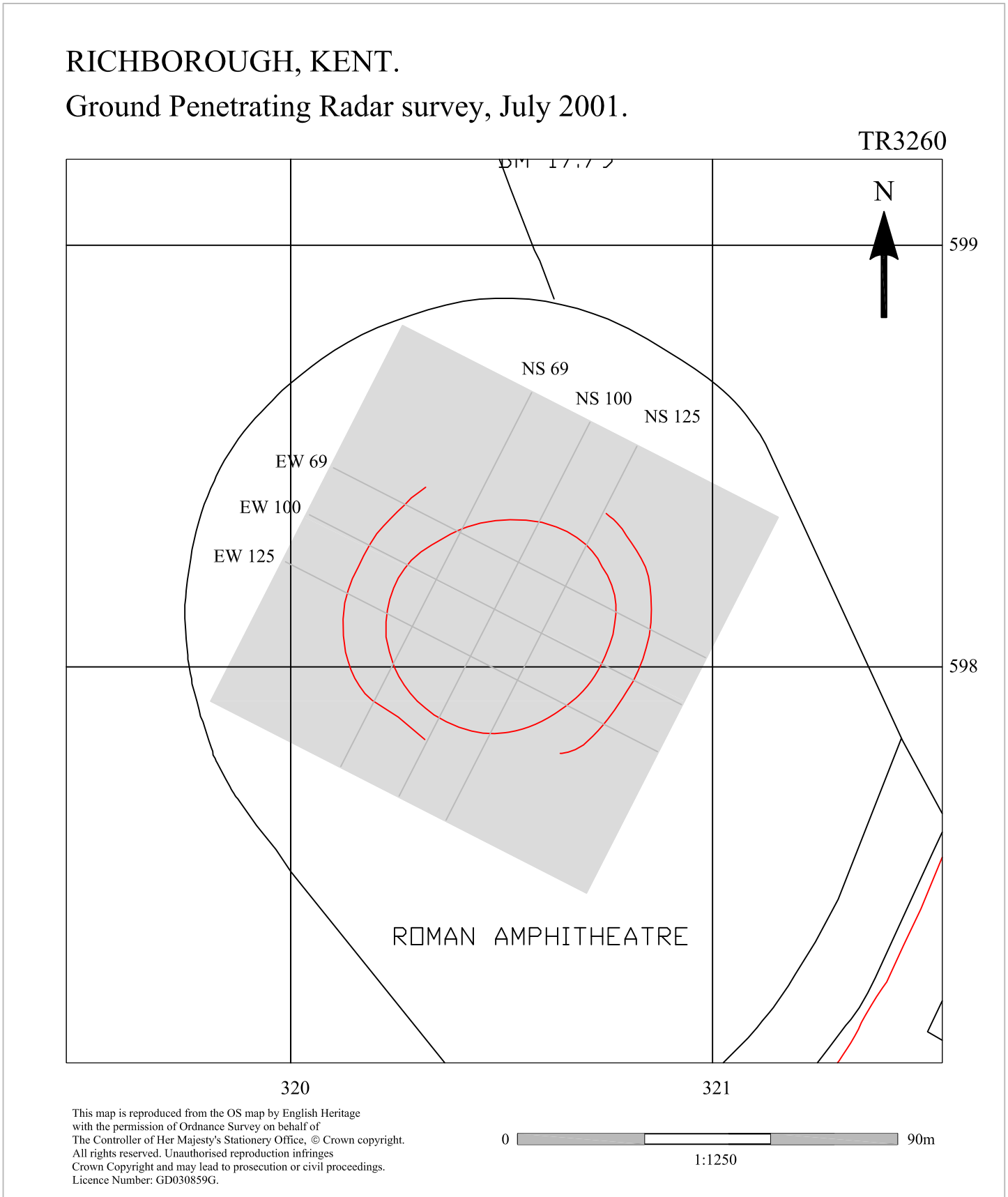

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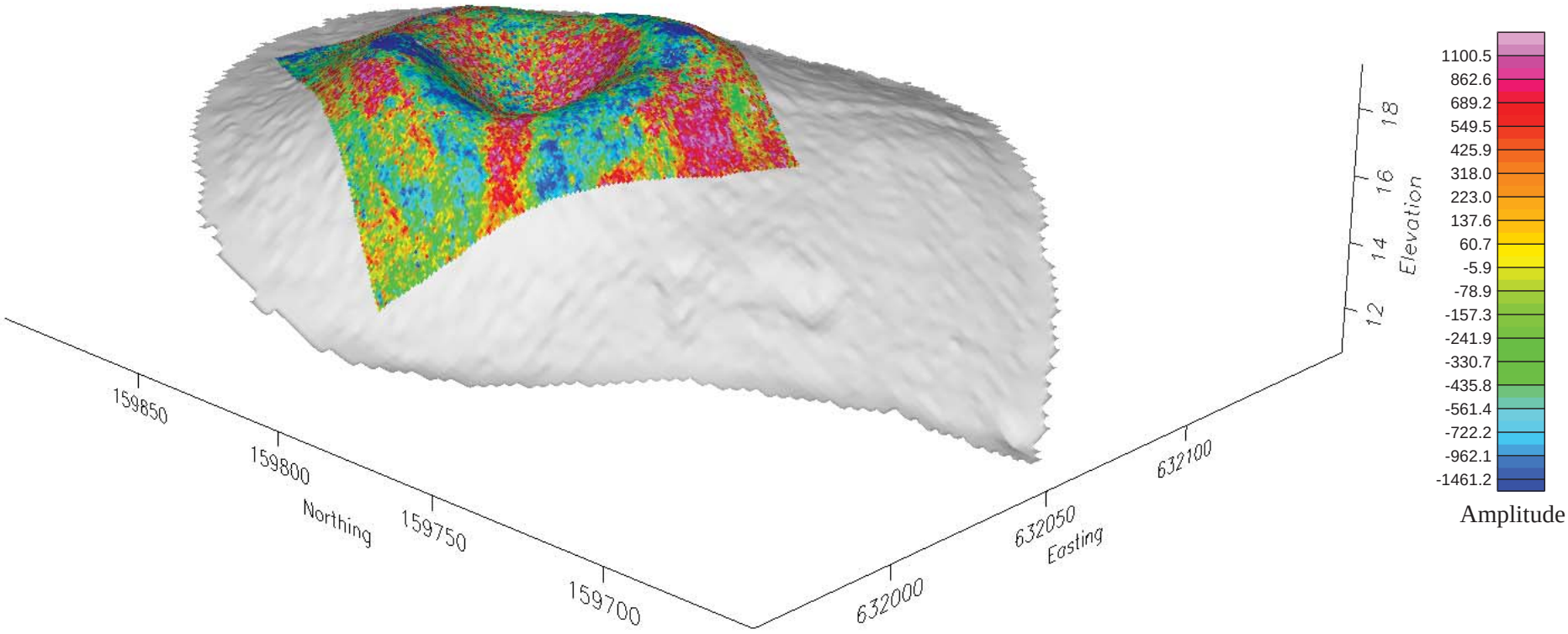

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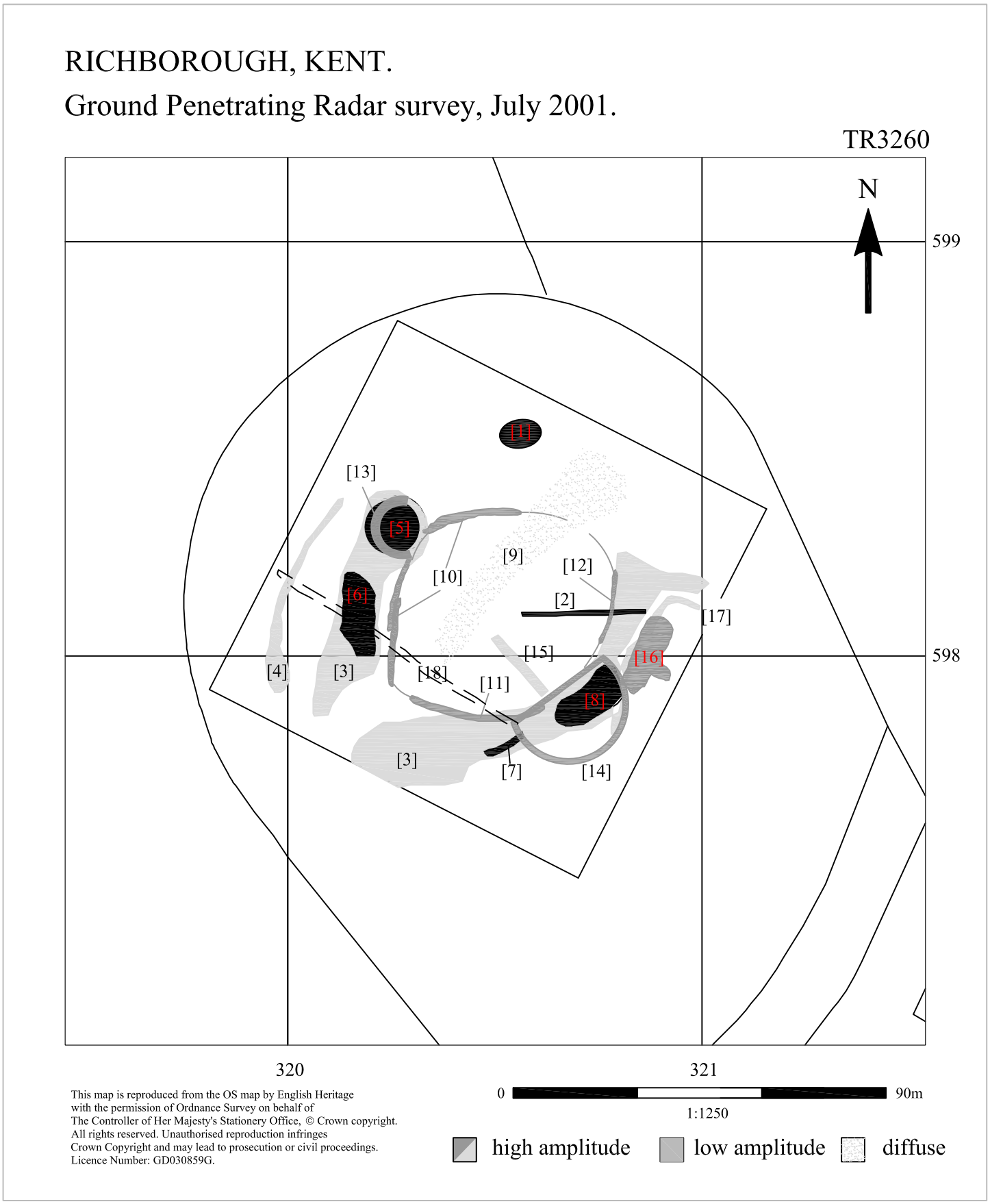


***Figure 4; Richborough Amphitheatre, Kent.**, Graphical summary of significant GPR anomalies.*

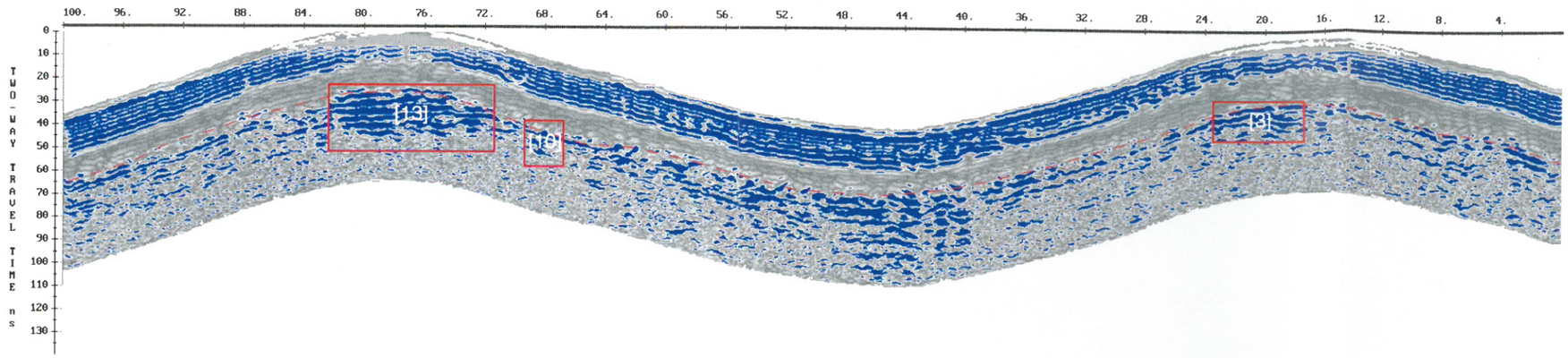
RICHBOROUGH AMPHITHEATRE, KENT
Ground Penetrating Radar survey, July 2001.

PLAN A

Representative EW Profiles

EW Line 75

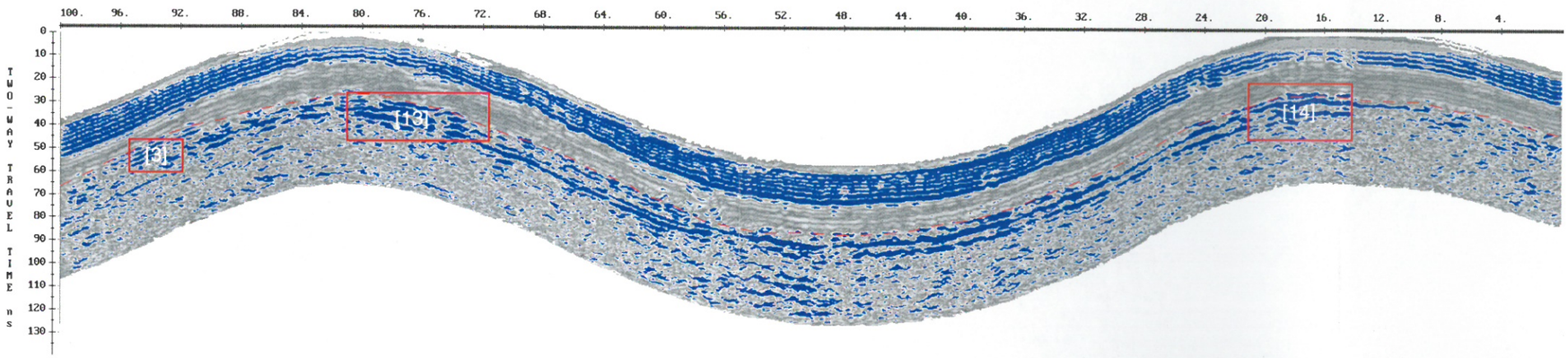
E



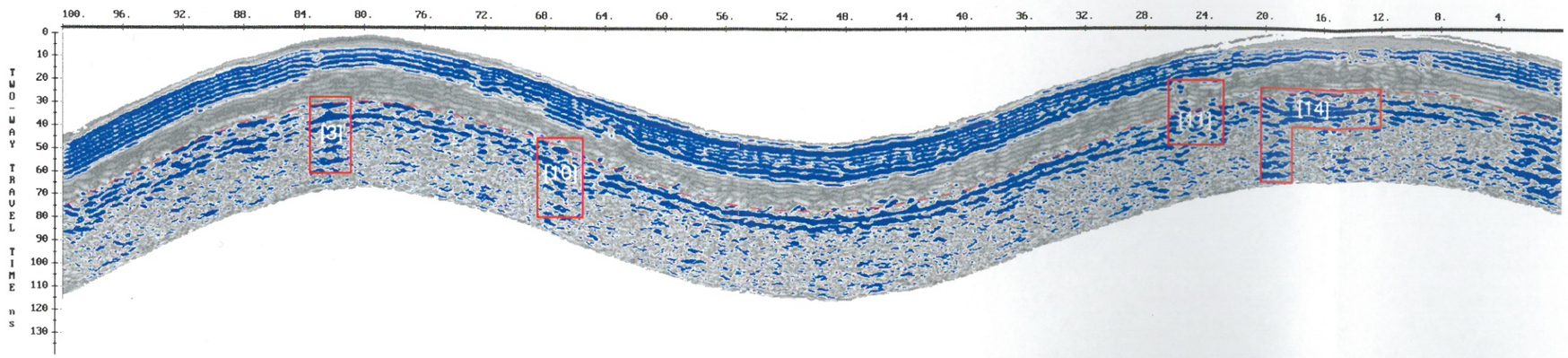
W

reflective layer

EW Line 100



EW Line 125



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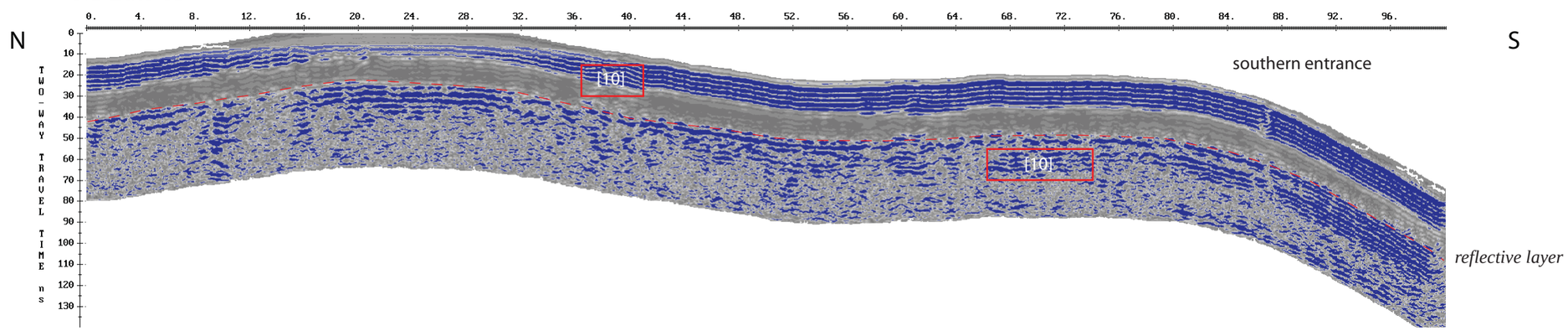
RICHBOROUGH AMPHITHEATRE, KENT
Ground Penetrating Radar survey, July 2001.

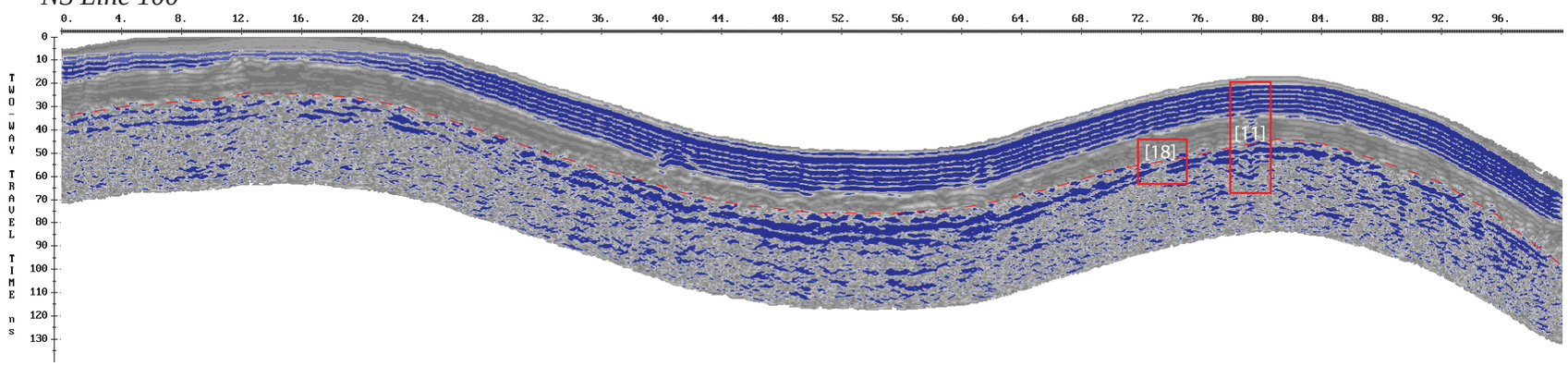
PLAN B

Representative NS Profiles

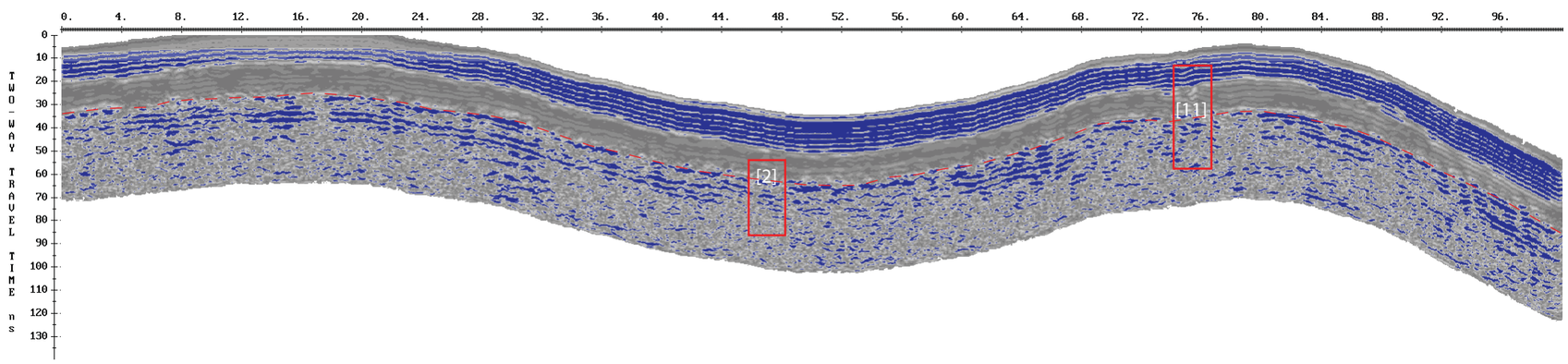
NS Line 69



NS Line 100



NS Line 125



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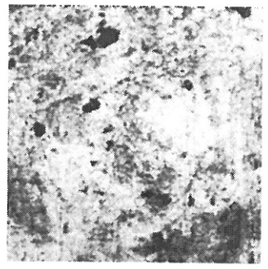
PLAN C

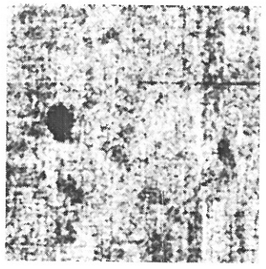
0-1ns (0.0-0.1m)

1-2ns (0.1-0.2m)

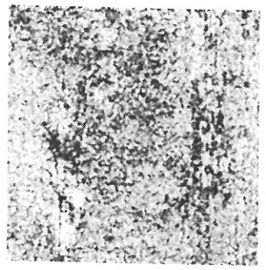
2-3ns (0.2-0.3m)



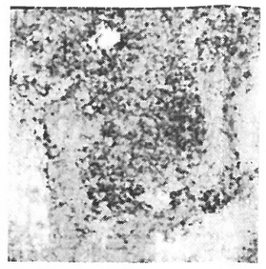
3-4ns (0.3-0.4m)



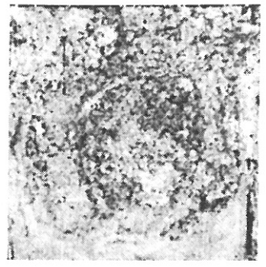
4-5ns (0.4-0.5m)



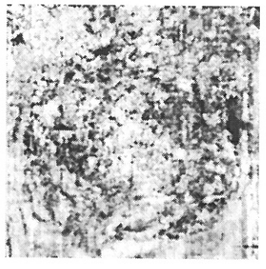
5-6ns (0.5-0.6m)



6-7ns (0.6-0.7m)



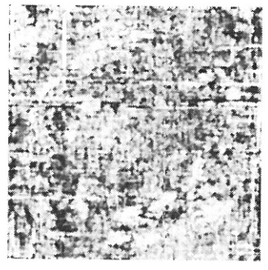
7-8ns (0.8-0.9m)



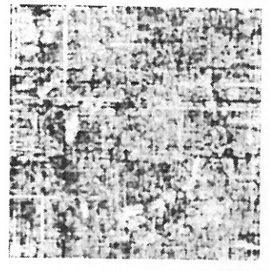
8-9ns (0.8-0.9m)

9-10ns (0.9-1.0m)

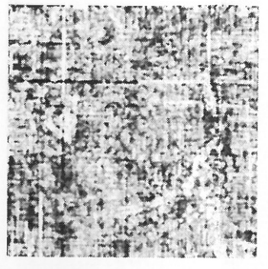
10-11ns (1.0-1.1m)



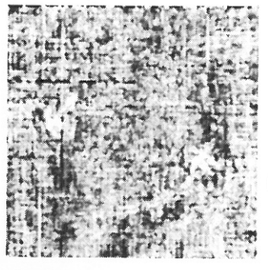
11-12ns (1.1-1.2m)



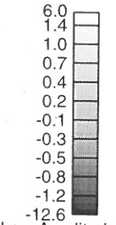
12-13ns (1.2-1.3m)



13-14ns (1.3-1.4m)

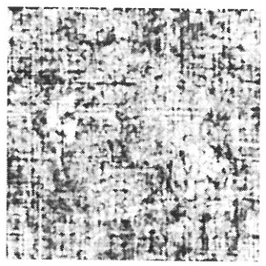


High Amplitude

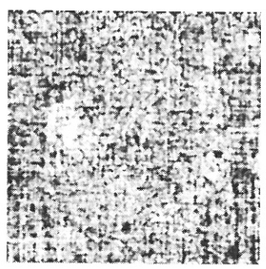


Low Amplitude

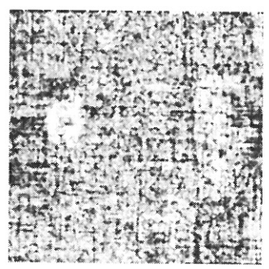
14-15ns (1.4-1.5m)



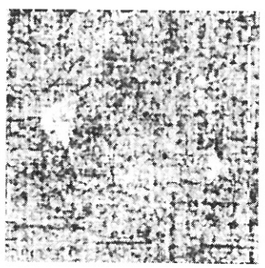
15-16ns (1.5-1.6m)



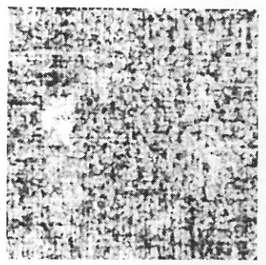
16-17ns (1.6-1.7m)



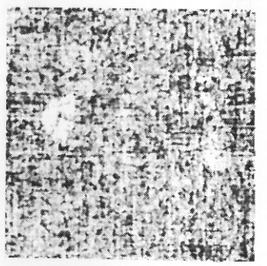
17-18ns (1.7-1.8m)



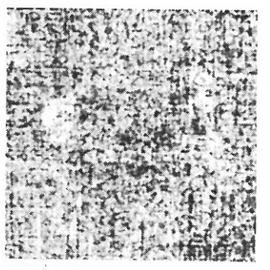
18-19ns (1.8-1.9m)



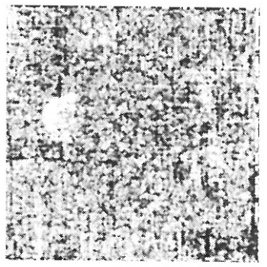
19-20ns (1.8-2.0m)



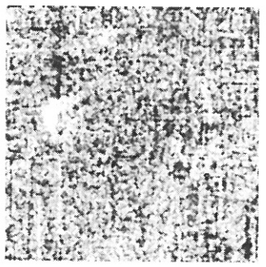
20-21ns (2.0-2.1m)



21-22ns (2.1-2.2m)

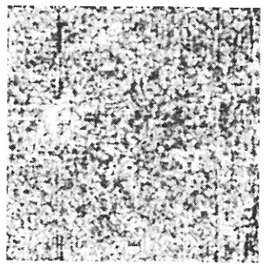


22-23ns (2.2-2.3m)

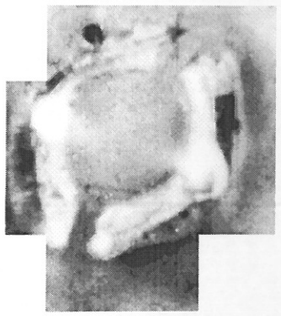


23-24ns (2.3-2.4m)

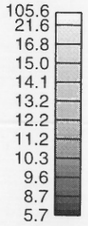
24-25ns (2.4-2.5m)

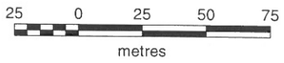


Earth resistance data



Ohms





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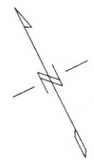
Combined migrated data (filtered)



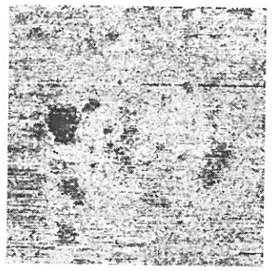
PLAN D

0-1ns (0.0-0.1m)

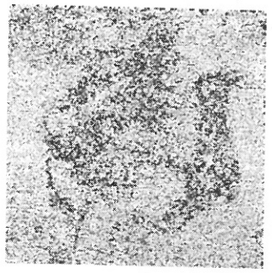
1-2ns (0.1-0.2m)

2-3ns (0.2-0.3m)

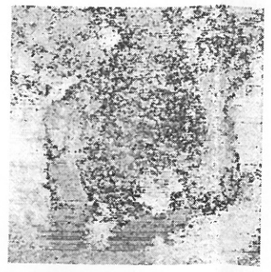
3-4ns (0.3-0.4m)



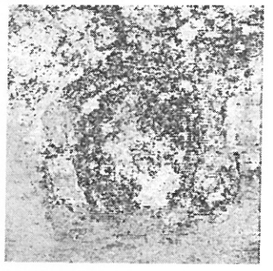
4-5ns (0.4-0.5m)



5-6ns (0.5-0.6m)



6-7ns (0.6-0.7m)



7-8ns (0.8-0.9m)

8-9ns (0.8-0.9m)

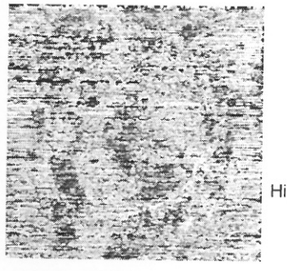
9-10ns (0.9-1.0m)

10-11ns (1.0-1.1m)

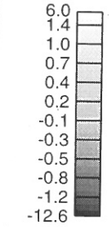
11-12ns (1.1-1.2m)

12-13ns (1.2-1.3m)

13-14ns (1.3-1.4m)



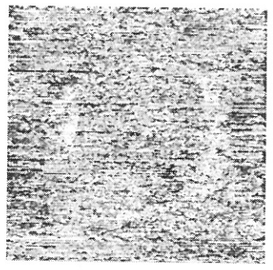
High Amplitude



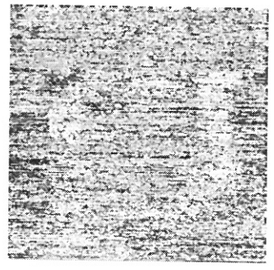
Low Amplitude

14-15ns (1.4-1.5m)

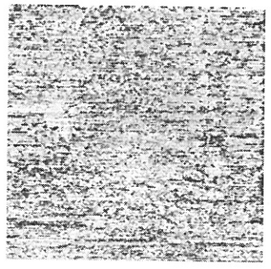
15-16ns (1.5-1.6m)



16-17ns (1.6-1.7m)

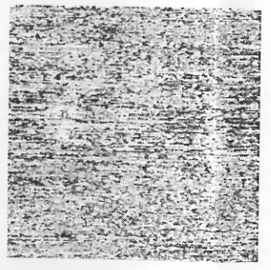


17-18ns (1.7-1.8m)

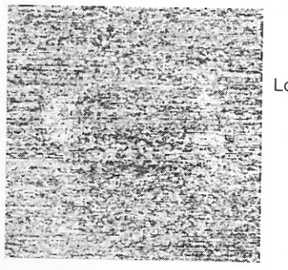


18-19ns (1.8-1.9m)

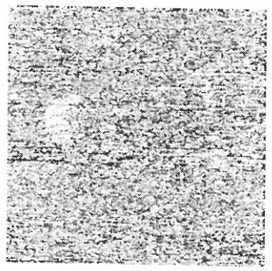
19-20ns (1.8-2.0m)



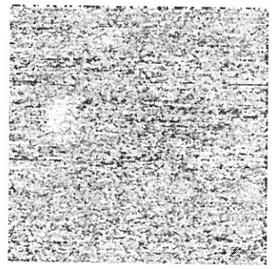
20-21ns (2.0-2.1m)



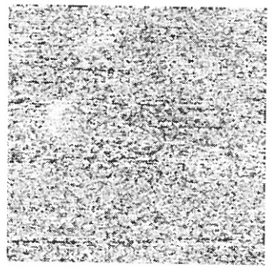
21-22ns (2.1-2.2m)



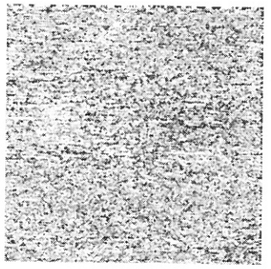
22-23ns (2.2-2.3m)



23-24ns (2.3-2.4m)

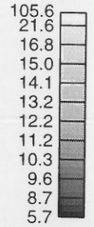


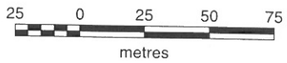
24-25ns (2.4-2.5m)



Earth resistance data

Ohms





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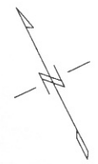
EW lines migrated data



PLAN E

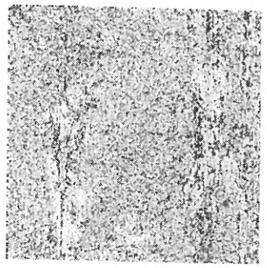
0–1ns (0.0–0.1m)

1–2ns (0.1–0.2m)

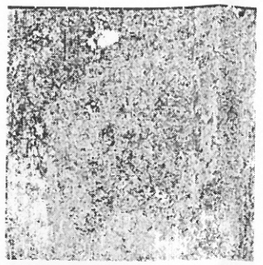
2–3ns (0.2–0.3m)

3–4ns (0.3–0.4m)

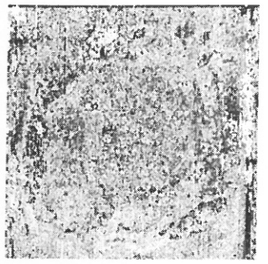
4–5ns (0.4–0.5m)



5–6ns (0.5–0.6m)



6–7ns (0.6–0.7m)



7–8ns (0.8–0.9m)

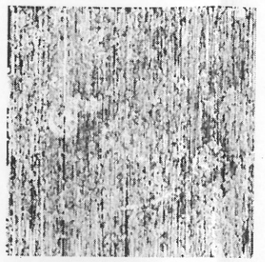
8–9ns (0.8–0.9m)

9–10ns (0.9–1.0m)

10–11ns (1.0–1.1m)

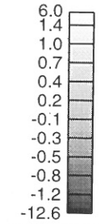
11–12ns (1.1–1.2m)

12–13ns (1.2–1.3m)



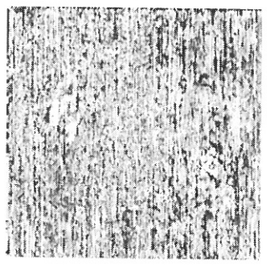
13–14ns (1.3–1.4m)

High Amplitude

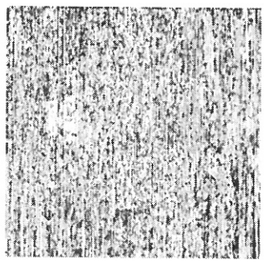


Low Amplitude

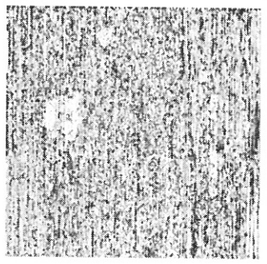
14–15ns (1.4–1.5m)



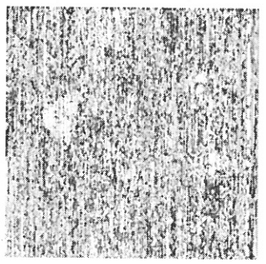
15–16ns (1.5–1.6m)



16–17ns (1.6–1.7m)

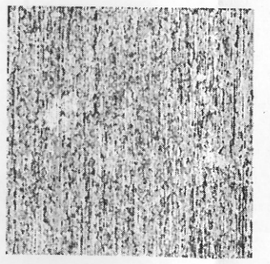


17–18ns (1.7–1.8m)

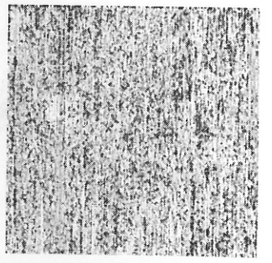


18–19ns (1.8–1.9m)

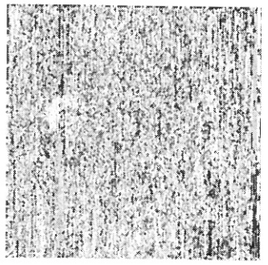
19–20ns (1.8–2.0m)



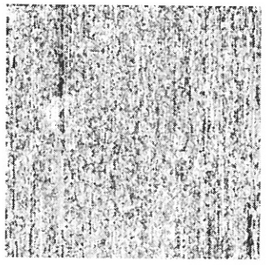
20–21ns (2.0–2.1m)



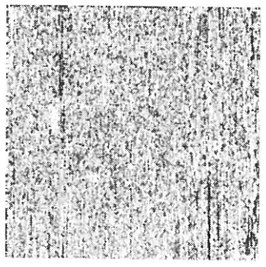
21–22ns (2.1–2.2m)



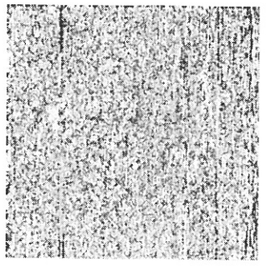
22–23ns (2.2–2.3m)



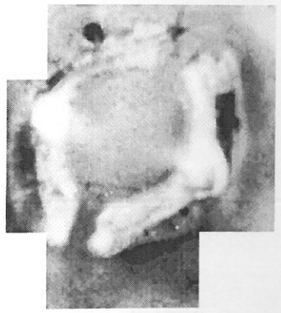
23–24ns (2.3–2.4m)



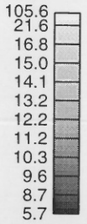
24–25ns (2.4–2.5m)

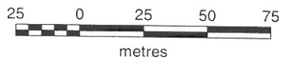


Earth resistance data



Ohms





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NS lines migrated data