GEOPHYSICAL SURVEY REPORT

CHERISH Ireland-Wales Project - Dinas Dinlle Hillfort, Llandwrog

Client

Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW)

Survey Report

16438

Date

January 2020

Survey Report 16438: CHERISH Ireland-Wales Project – Dinas Dinlle Hillfort, Llandwrog

Survey dates	18 -22 October 2019
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1 EXECUTIVE SUMMARY

A Ground Penetrating Radar (GPR) survey was conducted over an area of approximately 11380 m² at Dinas Dinlle Iron Age Hillfort in Llandwrog, Gwynedd. The objective was to search for evidence of archaeological features associated with the fort. A Mala MIRA High Density Array Radar was used for the investigation.

Seven significant categories of anomalies were identified by the GPR. Three categories of anomalies are considered to be of potential archaeological significance – geometric features broad linear feature and linear features. The geometric anomalies have rectilinear, curvilinear, annular, circular and other more complex shapes typically associated with man-made features of an archaeological origin. These anomalies could be associated with the remains of roundhouses, building walls, foundations and enclosures amongst other features.

A broad linear to curvilinear anomaly that follows most of the western site boundary could be an infilled perimeter ditch or rampart, or a section of the modern coastal path. A number of relatively short, narrow linear anomalies scattered across the site may be associated with features such as ditches, gullies or tracks.

Many of the GPR anomalies displayed good correlation with the results of a previous magnetometer survey.

Roundhouse walls were uncovered in two trenches that intersected annular shaped anomalies in the south-west corner of the site.

2 INTRODUCTION

2.1 Background synopsis

SUMO Geophysics Ltd were commissioned by the **Royal Commission on the Ancient and Historical Monuments of Wales** as part of their CHERISH – Climate Change and Coastal Heritage - project, aimed at raising awareness and understanding of the past, present and near future impacts of climate change, storminess and extreme weather events on the rich cultural heritage of the sea and coast (http://www.cherishproject.eu/). CHERISH is a five-year Ireland-Wales project, between the Royal Commission on the Ancient and Historical Monuments of Wales, the Discovery Programme, Ireland, Aberystwyth University: Department of Geography and Earth Sciences and the Geological Survey Ireland. It began in January 2017 and will run until December 2021; the project will receive €4.1 million of EU funds through the Ireland Wales Co-operation Programme 2014-2020. The survey objective was to search for evidence of archaeological features associated with the prehistoric coastal fort.

2.2 Site details

NGR / Postcode	SH 4370 5635 / LL54 5TW
Location	Dinas Dinlle is a coastal hillfort formed of a series of banks and ditches immediately south of the village of Dinas Dinlle, Gwynedd at the western edge of the reclaimed wetlands of the Caernarfonshire Coastal Plains. The site is located on the Wales Coast Path and owned by the National Trust.
NHLE	CN048
Civil Parish	Llandwrog
Unitary Authority	Gwynedd

Geology (BGS 2020)	Solid: sandstone and siltstone from the Cambrian Fachwen Formation Superficial: Devensian glacial till (diamicton)
Soils (CU 2020)	Loamy and clayey soils of coastal floats with naturally high groundwater (21)
Archaeology	Dinas Dinlle (NPRN: 95309; PRN: 1570) is a coastal Iron Age hillfort situated on a glacial drift deposit at the western edge of the Caernarfonshire coastal plain where it overlooks both the plain and Caernarfon Bay to the west. The monument itself is formed of a series of banks and ditches which exploit the dramatic natural slopes of the glacial feature where they enclose its crest. There is a simple entrance on the south east, typical of similar hillforts in this part of Wales such as Dinas Dinonvig, Llanddeiniolen and Craig-y-Dinas, Llanllyfni (Riley & Smith 1993) and following the recent CHERISH earthwork survey a second entrance to the north east has been postulated. The fortifications are largely regarded as bivallate, however, through detailed analytical earthwork and geophysical survey (Barker & Hunt forthcoming; Hopewell 2018) they appear to be more complex than this interpretation suggests, with several phases of construction now apparent. Only three sides of the fortifications remain today, with the western side having been subject to large-scale terrestrial and coastal erosion. Within the interior of the fort there are also the earthwork and sub-surface remains of several possible roundhouses along with other discernible features, including a distinct mound in the north east corner demonstrating the fort was likely settled at points during its lifespan (Hunt 2019)
Survey Methods	Ground Penetrating Radar (GPR)
Study Area	11380 m^2
Equipment	Mala MIRA High Density Array Radar in conjunction with 8 x 400MHz antennae

2.3 Aims and Objectives

The key objective of the survey was to search for evidence of archaeological features associated with the prehistoric fort.

3 METHODS, PROCESSING & PRESENTATION

3.1 Standards & Guidance

This report and all fieldwork have been conducted in accordance with the latest guidance documents issued by Historic England (EH 2008) (then English Heritage), the Chartered Institute for Archaeologists (CIfA 2014) and the European Archaeological Council (EAC 2016).

3.2 Survey methods

The GPR technique was used as an efficient and effective method for detecting archaeological features. More information regarding the GPR method is given in Appendix A.

3.3 Survey Equipment

Technique	Instrument	Traverse Interval	Sample Interval
GPR	Mala High Density Array System	0.08m	0.05m

3.4 Survey Procedure

A survey grid was established over the site area as a reference for the site work. The antenna system was towed by quad bike over the survey area. Plate 1 shows the GPR survey in progress.

A parallel grid of radar profiles was completed at 0.08m intervals over the accessible parts of the site. The positions of all the radar profiles are presented in Figure 1.

Plate 1 - GPR Survey in Progress

3.5 Data Processing & Presentation

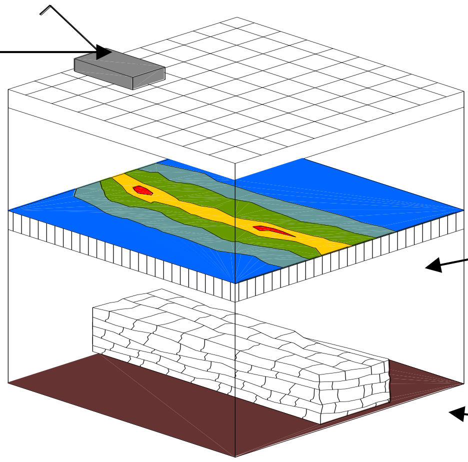
Ground Penetrating Radar Data – Mala Mini MIRA

Processing is performed using specialist software (Mala Rslicer). There are a wide range of filters available, the application of which will vary depending on the project. The below table shows the processes used for this data:

Gain	Amplification to correct for weakening of signal with depth.
DC-Shift	Re-establishes oscillation of the radar pulse around the zero point)
Dewow / Ringdown Removal	Removes low frequency, down-trace instrument noise
Bandpass Filtering	Suppresses frequencies outside of the antenna's peak bandwidth thus reducing noise
Background Removal	Can remove ringing, instrument noise and minimize the near surface 'coupling' effect
Migration	Collapses hyperbolic tails (also known as 'diffractions') back towards the reflection source
Amplitude Envelope	Simplifies pulses for production of time-slice maps by summing peak values, regardless of polarity, over a given time-window.

Timeslice Plots

In addition to a manual abstraction from the radargrams, a computer analysis was also carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within a range. The 3D file can be sampled to produce activity plots at various depths. As the radar is measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Based on an average velocity calculation have been made to show the equivalent depth into the ground.

The weaker reflections in the time slice windows are shown as light grey colour. The stronger reflections are represented by colours such black and dark grey.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as foundations or surfaces within the soil matrix.

4 INTERPRETATION OF RESULTS

4.1 Introduction

Most ground conditions contain electrically contrasting layers which produce reflection events on the GPR profiles. Features such as soil or fill boundaries provide the background signals around unusual features such as archaeological structures. Processing and interpretation procedures are designed to separate reflections into various target categories and then map the different reflection types on to a plan diagram. This process involves an areal interpretation of the timeslice data.

The data is presented as a series of timeslices between depths of 0.10 to 2.00m at 0.10m intervals, which are presented in Figures 2 to 21. Seven significant categories of reflection targets were identified from the interpretation of the timeslices.

i) Geometric feature – probable archaeological origin
ii) Broad linear feature – possible archaeological origin
iii) Linear feature – possible archaeological origin
iv) Discrete feature – uncertain origin
v) Linear near surface feature – modern origin
vi) Possible service
vii) Recent trench anomaly

4.2 Geometric Feature – probable archaeological origin

A number of discrete, complex moderate to high amplitude anomalies have been identified by the GPR survey across the study area at depths of 0.20 – 2.70m. These anomalies have regular, geometric shaped outlines suggestive of a man-made origin. Shape types include rectilinear, curvilinear, annular, circular and more complex shapes that are suggestive of an archaeological origin. These anomalies could correspond to the remains of roundhouses, building walls, foundations and enclosures amongst other archaeological features.

4.3 Broad Linear Feature – possible archaeological origin

This forms a distinct, 0.50 – 2.00m wide moderate to high amplitude linear to curvilinear anomaly, mainly at a depth of 0.30 – 0.50m that follows most of the western site boundary. This anomaly is located fairly close to the coastal path but extends to a depth of up to 0.50m, making a modern origin unlikely. The shape and position of the anomaly is suggestive of an archaeological feature such as an infilled ditch or rampart.

4.4 Linear Feature - possible archaeological origin

A number of relatively short, moderate to high amplitude linear anomalies were detected by the GPR survey at depths of 0.30 – 1.70m scattered across the site. The distinctive linear shape is suggestive of an archaeological origin associated with linear archaeological features such as ditches, wall facings, gullies or tracks.

4.4 Discrete Feature - uncertain origin

A number of small, variably shaped high amplitude anomalies were found between depths of 0.20 to 0.70m. The anomalies do not display any characteristic shape, nor obviously correlate with any other anomalies detected by the previous site investigations.

4.5 Near Surface Feature – modern origin

A number of near surface, high amplitude anomalies of linear and more irregular shape were detected crossing the site in a predominantly north-south direction at depths of 0.00 – 0.15m metres. The near surface anomalies are most likely to be associated with modern pathways. The irregular anomalies are of uncertain origin.

4.6 Possible Service

An extensive linear anomaly crossing the central part of the study area in a north-south orientation may be service related.

4.7 Recent Trench Anomaly

Several linear features were detected at the edges of two archaeological trenches excavated across the site during a recent programme of archaeological investigations (Lynes et al 2019).

5 DATA APPRAISAL & CONFIDENCE ASSESSMENT

The MIRA system was selected as an optimum method for producing high resolution time slices of an archaeological site. The survey data displays a good contrast between strong complex and discrete responses associated with archaeological features and the background response from the windblown sand, suggesting that the site conditions are conducive to GPR survey.

A maximum depth penetration of 2.00 – 2.50m was achieved over most of the site area. Three categories of anomalies associated with archaeological features (geometric features broad linear features and linear features) were detected by the GPR survey indicating that the survey has been effective.

6 SUMMARY OF RESULTS

6.1 Ground Penetrating Radar Anomalies

The processed timeslice data is presented between depths of 0.10 to 2.00m in Figures 2 to 21. The interpreted results of the GPR survey are presented as a plan interpretation in Figure 23.

Seven significant categories of anomalies were identified by the GPR survey with three categories – geometric features, broad linear features and linear features - of potential archaeological significance. The geometric anomalies have a variety of shapes including rectilinear, curvilinear, annular, circular and other more complex shapes, all suggestive of man-made, archaeological origin. These anomalies could be associated with the remains of roundhouses, building walls, foundations and enclosures amongst other features. The most distinctive geometric shapes are the circular anomalies suggestive of roundhouses or hut circles, which are analysed further below.

A distinct, broad linear to curvilinear feature follows most of the western site boundary is suggestive of an infilled perimeter ditch or rampart, although an alternative more recent origin associated with the coastal path may be possible.

A number of discrete, relatively short and narrow linear anomalies are scattered across the site. The shape is suggestive of an archaeological origin associated with linear features such as ditches, tracks and gullies.

Two other categories of anomalies are of uncertain origin (discrete features and linear near surface features).

6.2 Correlation with Previous Surveys

Figure 22 presents the results of earlier magnetometer (Hopwell 2018) and earth resistance (Barker 2019) geophysical investigations on the hillfort. Figure 24 presents the GPR survey results superimposed onto the results of previous trench excavations carried out by Gwynedd Archaeological Trust (Lynes et al 2019). Figure 25 displays the GPR survey results superimposed on to both the magnetic anomalies and trenches.

The GPR result did not display any obvious correlation with main earth resistance anomaly in the northern half of the site due to a lack of GPR survey coverage in this area.

There was good degree of correlation between the radar anomalies and annular magnetic anomalies at 21 and the northern half of 17, and with linear/curvilinear magnetic anomalies 22, 23 and 24. A limited degree of correlation was also evident with magnetic anomalies 9, 20, 25 and 26. However some of the annular shaped magnetic anomalies notably 18 and the southern half of 17 did not have corresponding GPR anomalies. Conversely there were no matching magnetic anomalies for some annular and horseshoe shaped radar anomalies, particularly in the south-west corner of the site.

The large planar, vaguely rectangular shaped anomaly in the centre of the site between magnetic anomalies 21 – 24, did not have a matching magnetic anomaly.

Two annular shaped radar anomalies in the south-west corner of the site were intersected by archaeological trenches TR01 and TR02. The trenches uncovered curved stone-built structures interpreted as roundhouse walls, at the positions of the radar anomalies. However, the trenches did not uncover any features over the positions of the magnetic anomalies in this area. The trench data suggests the GPR system detected the interface between stonework of the roundhouse structures and overlying compacted sand. The absence of magnetic anomalies at these positions suggests the boulders in the roundhouse wall are not magnetically enhanced. There was no information obtained from the trenching to assist the categorisation of the linear and curvilinear radar anomalies.

The combined results of GPR survey and trench data suggests the uncorroborated annular magnetic anomalies 18 and the southern half of 17 may not correspond to roundhouse structures.

7 CONCLUSIONS

7.1 The GPR survey of the Dinas Dinlle Hillfort in Llandwrog identified seven significant categories of radar anomalies. Three categories of anomalies are considered to be archaeologically related – geometric features, broad linear features and linear features. Two other categories of anomalies have an uncertain or recent origin – discrete features and linear near surface features.

The GPR anomalies displayed a good degree of correlation with magnetic anomalies from a previous gradiometer magnetometer survey of the site.

Archaeological trenches that intersected two annular shaped radar anomalies in the south-west corner of the site uncovered roundhouse walls at the positions of the anomalies.

8 REFERENCES

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KEY

(symbol)	Survey area
(symbol)	Radar traverse

SUMO Survey GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: Location of Survey Area

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

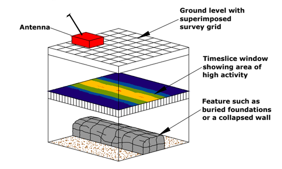
Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 01

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



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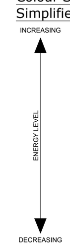
The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 0.10m	
Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES	
Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG	
Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)	Fig No: 02

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

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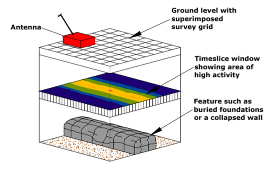

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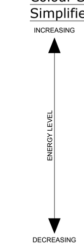
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.20m

Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 03

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

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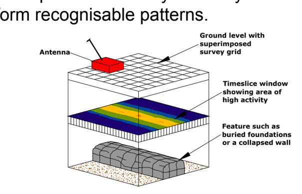

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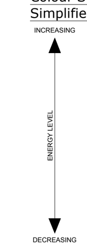
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey — GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 0.30m

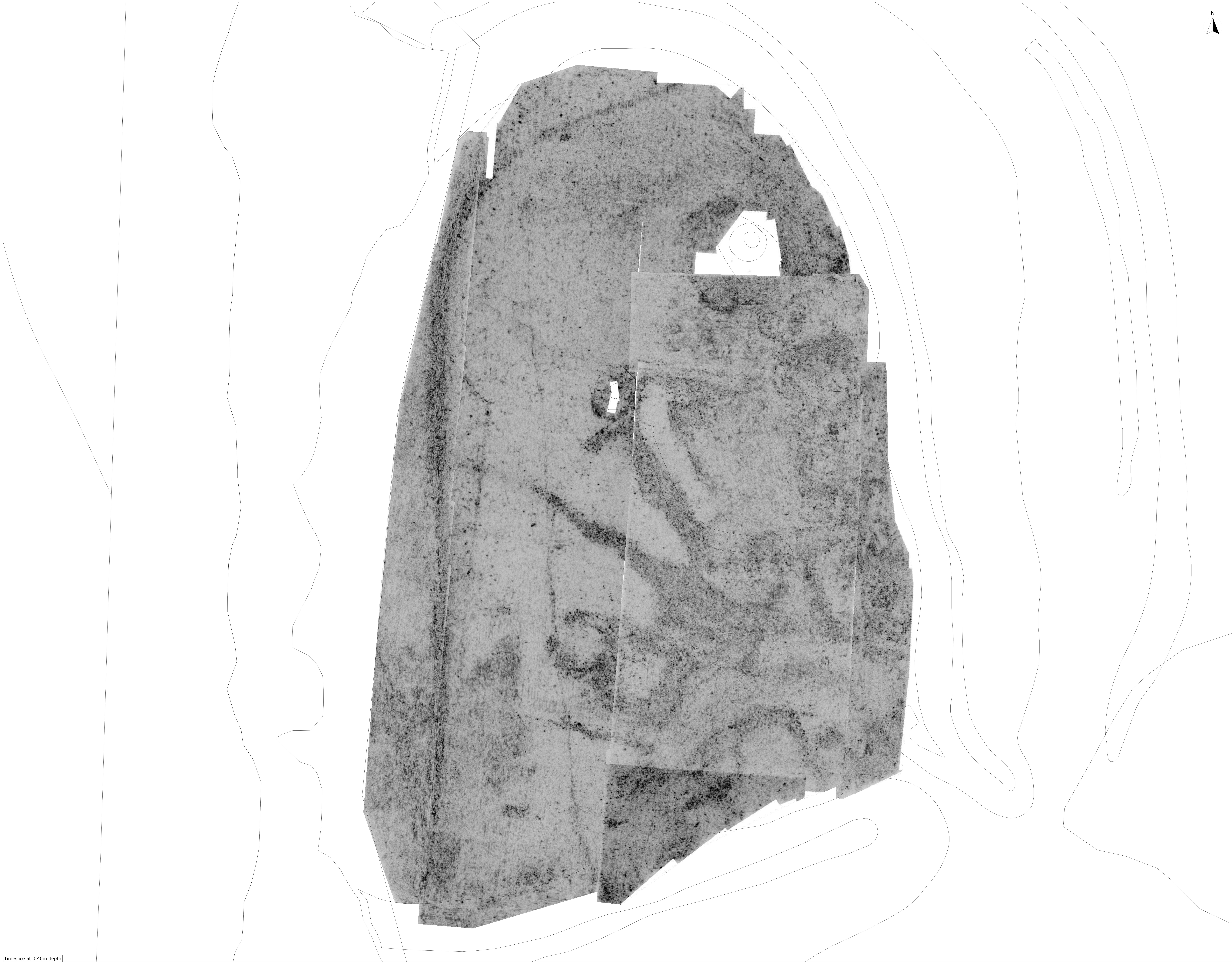
Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 04

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



Timeslice at 0.40m depth

TIMESLICE PLOTS

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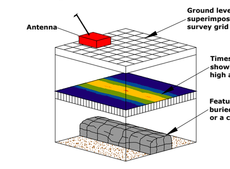

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING — ENERGY LEVEL — DECREASING

- High Energy Return -Possible Target
- Medium Energy Return -Mixed Ground
- Low Energy Return -Homogenous Ground

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 0.40m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)

Fig No: 05

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

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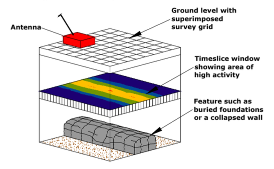

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING
ENERGY LEVEL
DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.50m

Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No:
06

Survey date	Drawn by	Checked by
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TIMESLICE PLOTS

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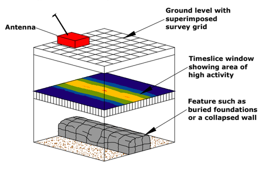


The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Calculations, based on an average velocity, have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING
ENERGY LEVEL
DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.60m

Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

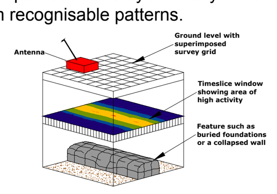
Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No:
07

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



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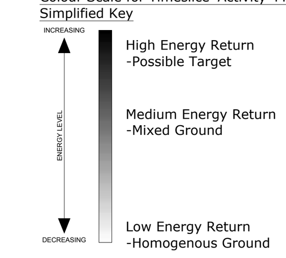
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 0.70m

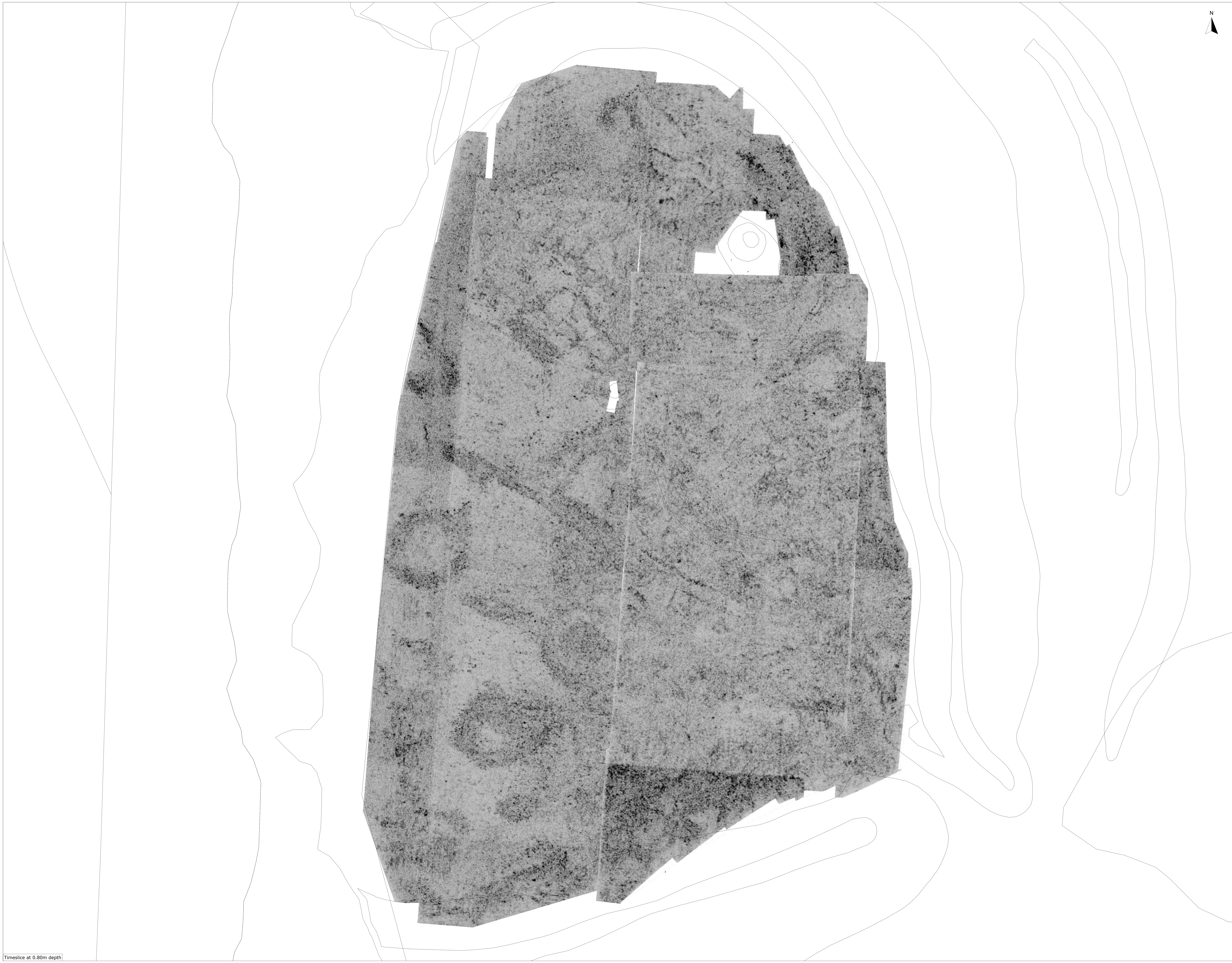
Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 08

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



TIMESLICE PLOTS

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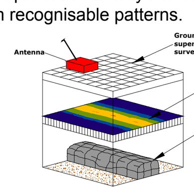

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING

ENERGY LEVEL

DECREASING

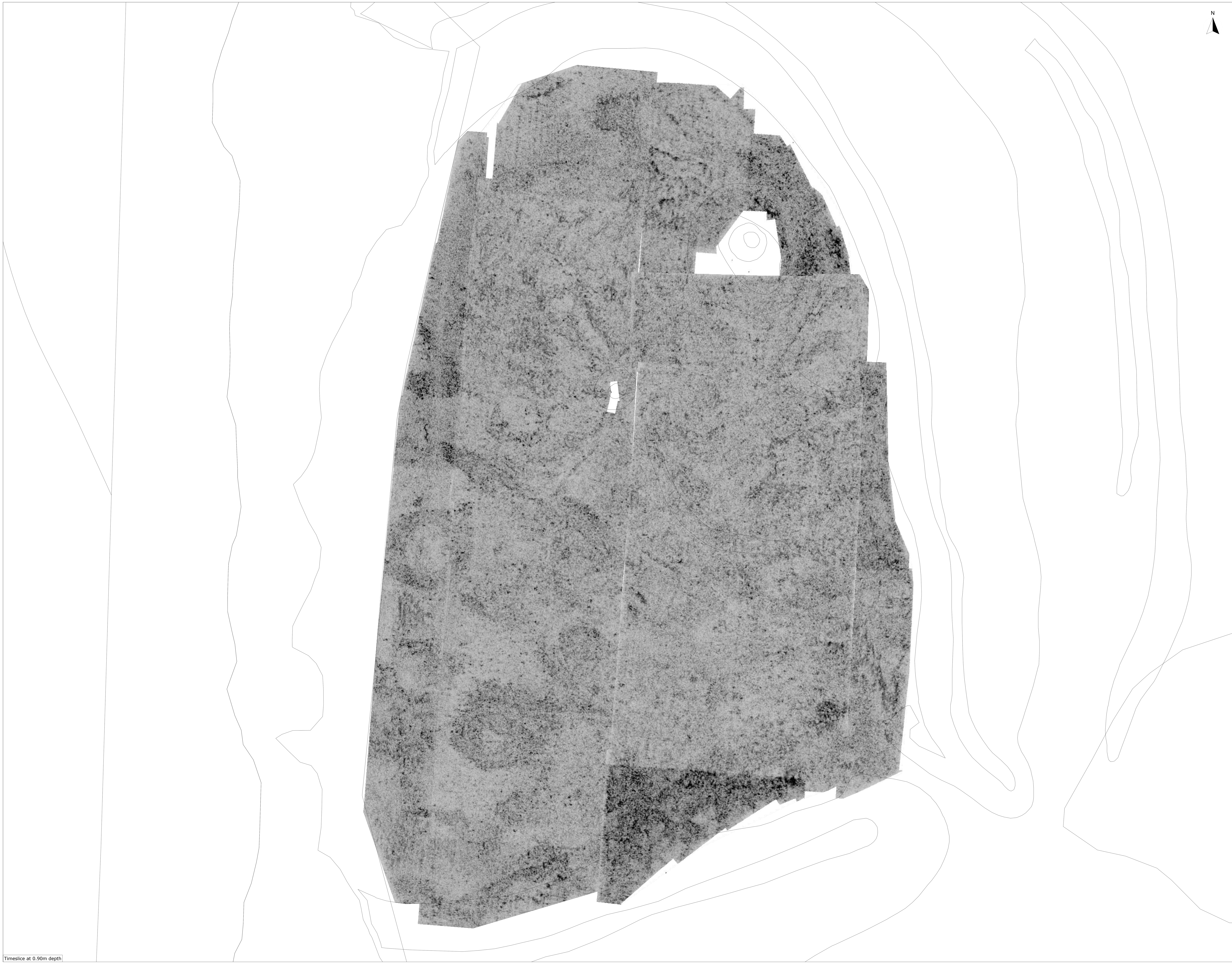
High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 0.80m		
Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES		
Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG		
Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)		Fig No: 09
Survey date: November 2019	Drawn by: MUK	Checked by: PPB



TIMESLICE PLOTS

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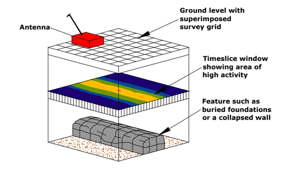

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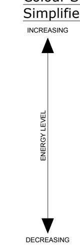
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

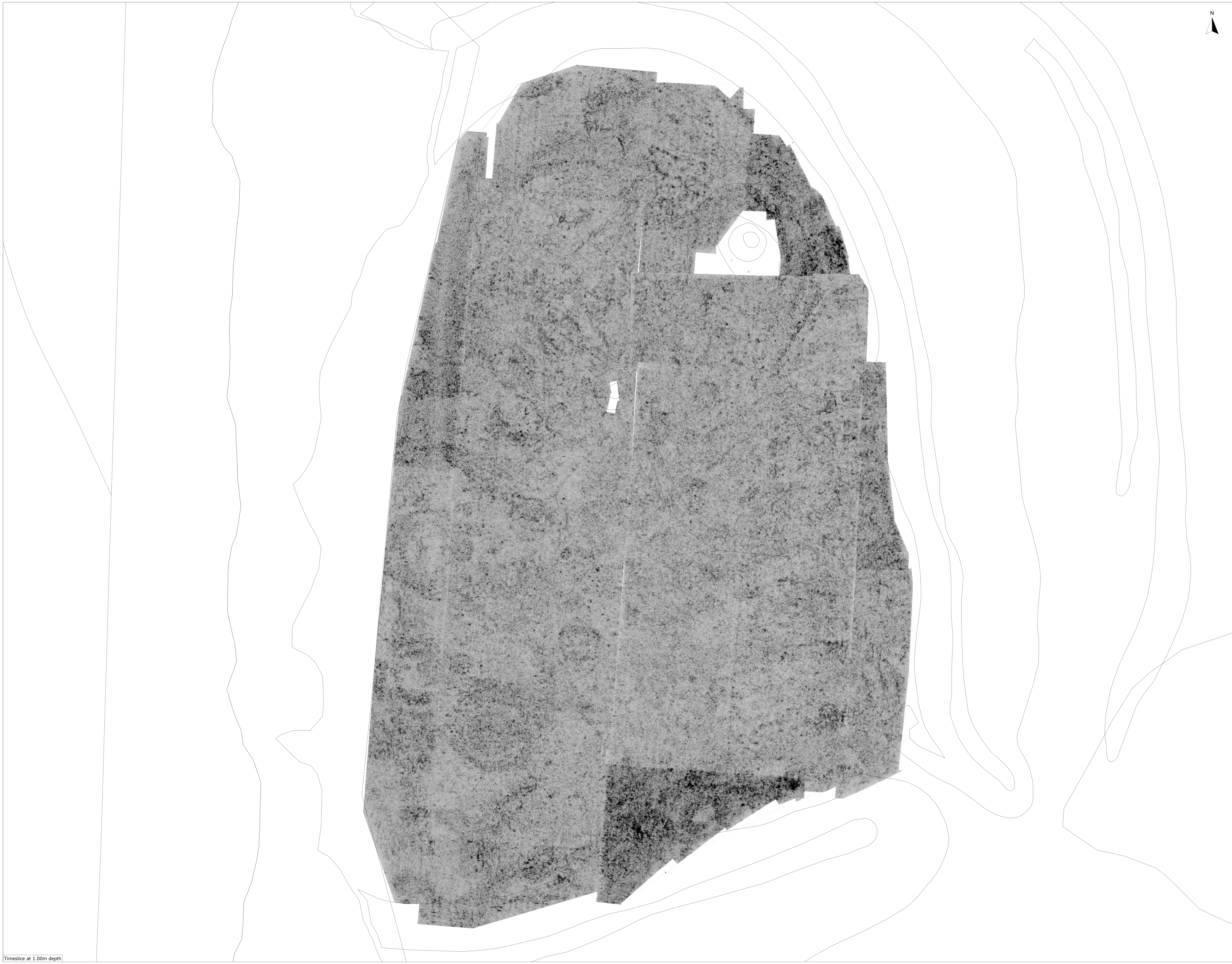
Title: GPR Survey - Timeslice at 0.90m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)	Fig No: 10

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



Timeslice at 1.00m depth

N

TIMESLICE PLOTS

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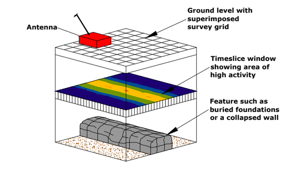

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING
ENERGY LEVEL
DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 1.00m

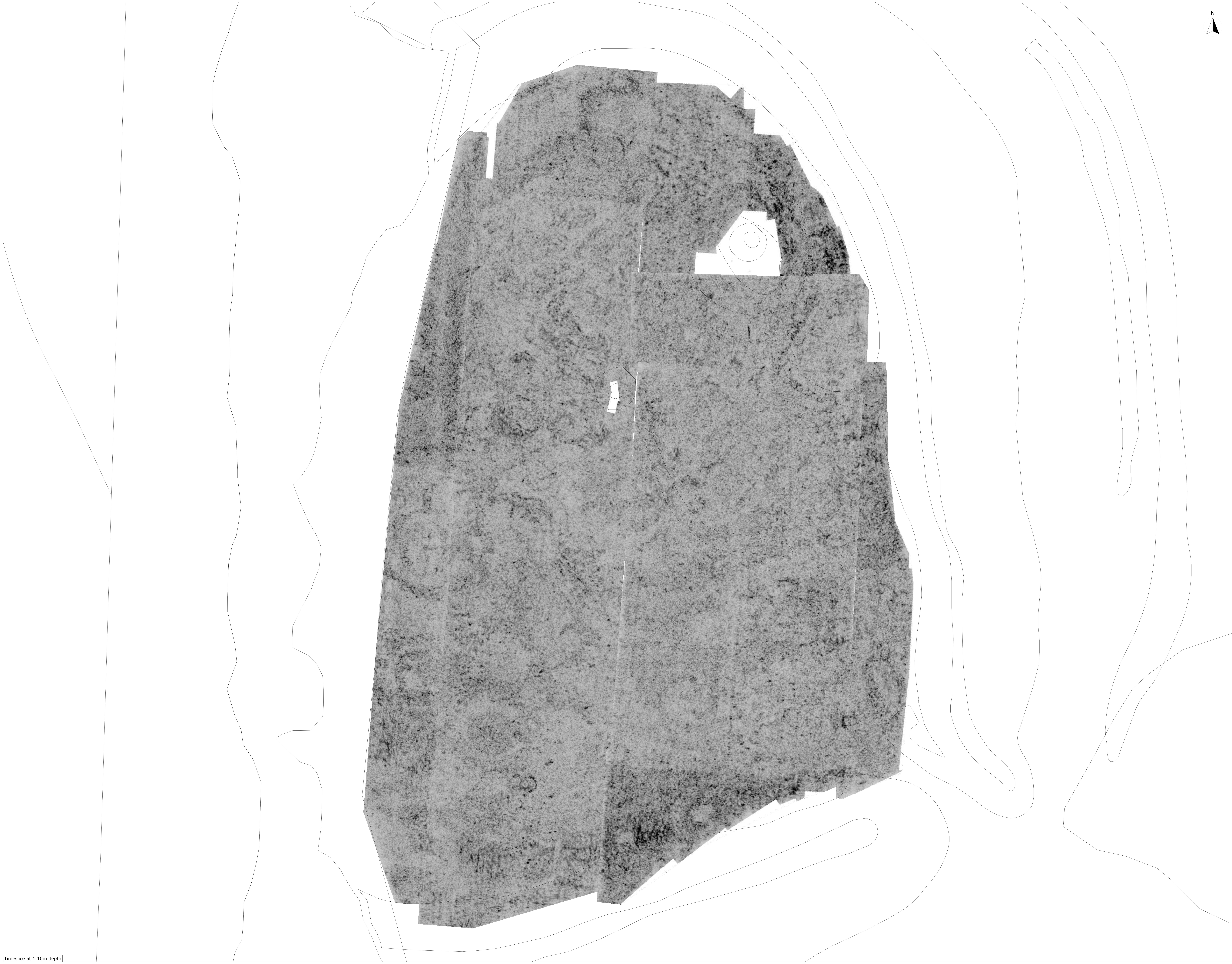
Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No:
11

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



TIMESLICE PLOTS

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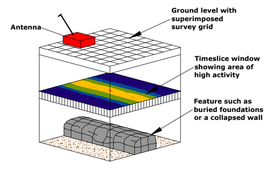

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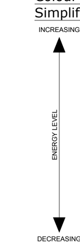
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



SUMO Survey — GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.10m

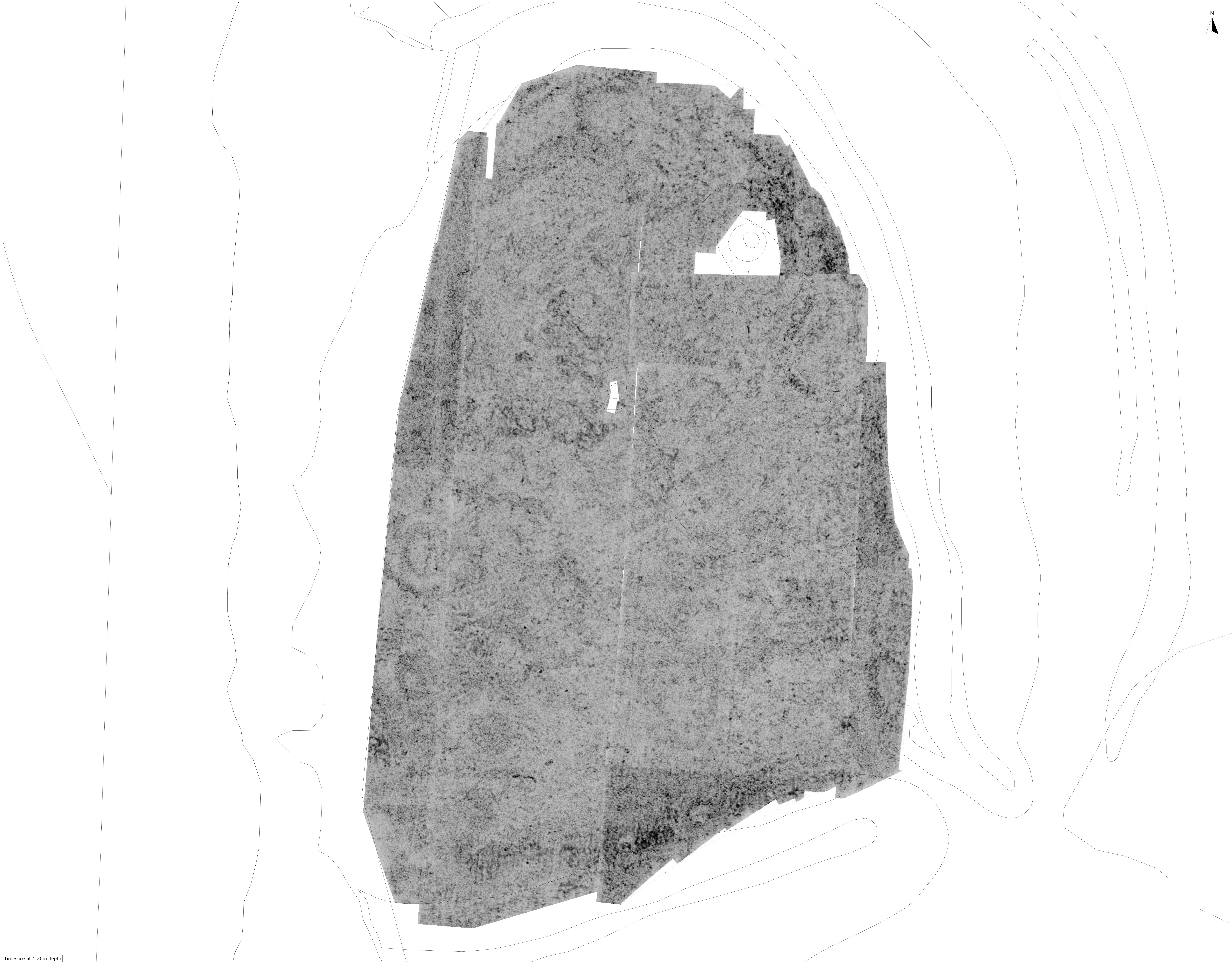
Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)

Fig No: 12

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



TIMESLICE PLOTS

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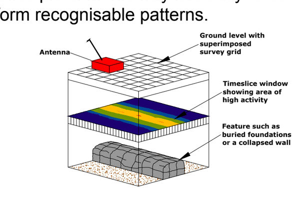

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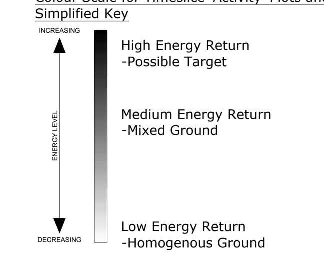
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 1.20m

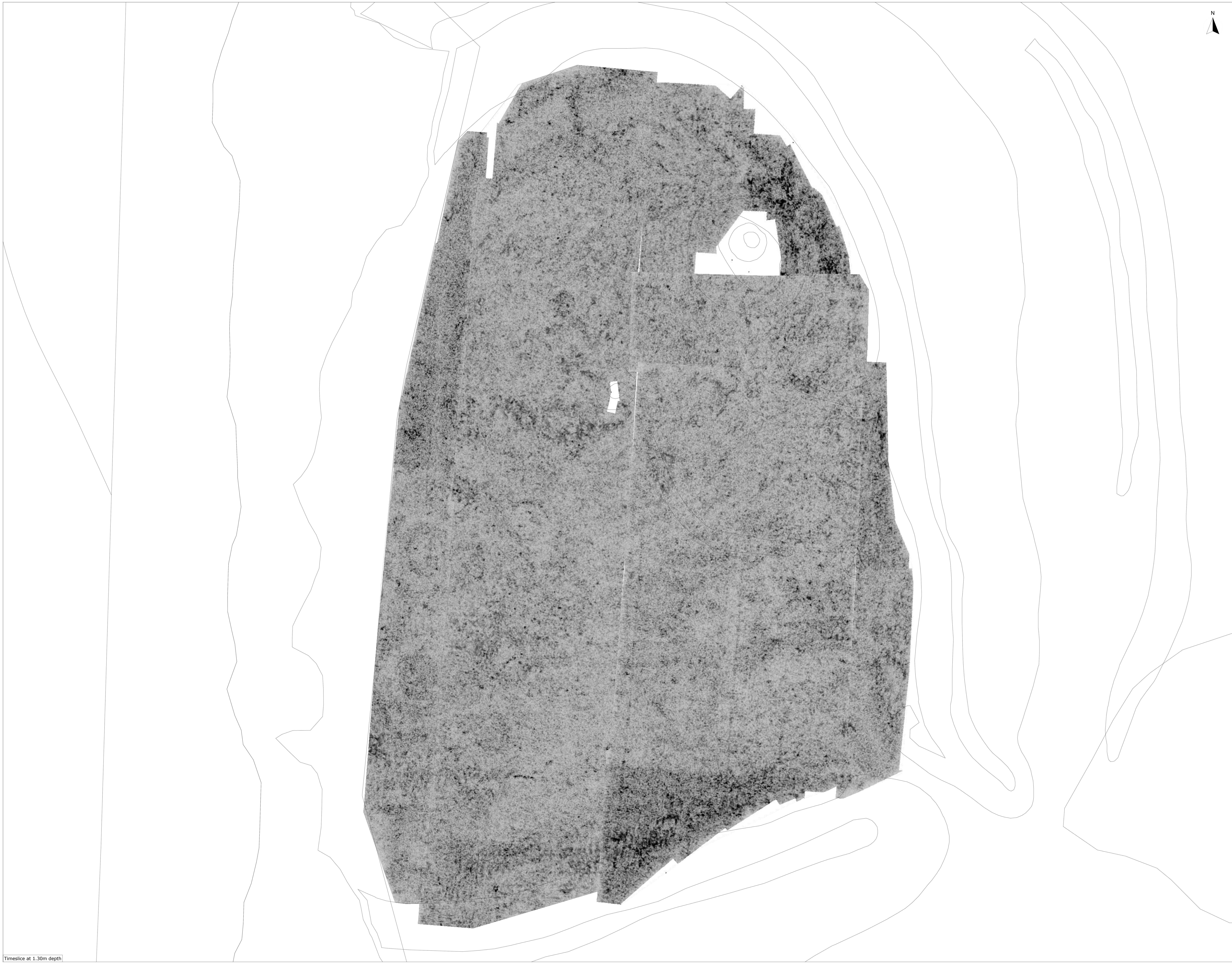
Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 13

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



TIMESLICE PLOTS

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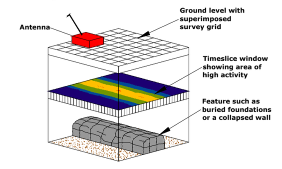

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING — High Energy Return -Possible Target

ENERGY LEVEL — Medium Energy Return -Mixed Ground

DECREASING — Low Energy Return -Homogenous Ground

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.30m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 — 0m 3 6 9 12 15 18

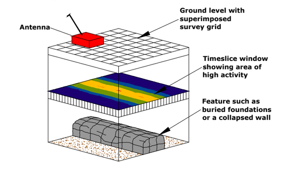
Fig No: 14

Survey date: November 2019 | Drawn by: MUK | Checked by: PPB

Timeslice at 1.40m depth

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



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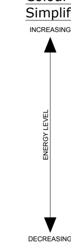
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.40m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

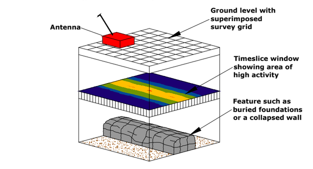
Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 15

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



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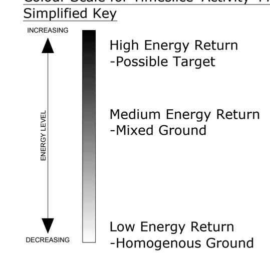
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.50m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

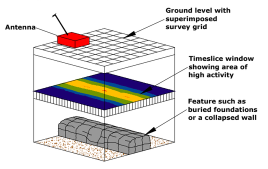
Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 16

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



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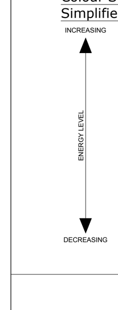
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.60m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 17

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

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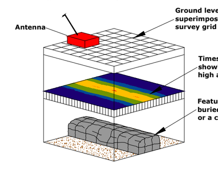

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING / ENERGY LEVEL / DECREASING

High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey — GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.70m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

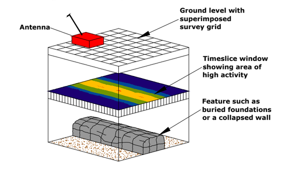
Scale: 1:300 @ A1 — 0m 3 6 9 12 15 18

Fig No: 18

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.

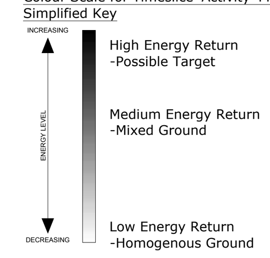


The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Calculations, based on an average velocity, have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



SUMO Survey — GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 1.80m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

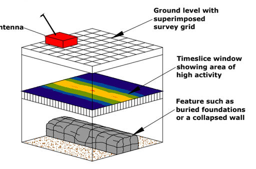
Scale: 1:300 @ A1 — 0m 3 6 9 12 15 18

Fig No: 19

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Calculations, based on an average velocity, have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING / ENERGY LEVEL / DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 1.90m

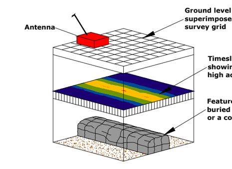
Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)		Fig No: 20
Survey date November 2019	Drawn by MUK	Checked by PPB

TIMESLICE PLOTS

In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.

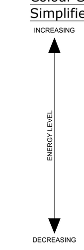


The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Calculations, based on an average velocity, have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

SUMO Survey — GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

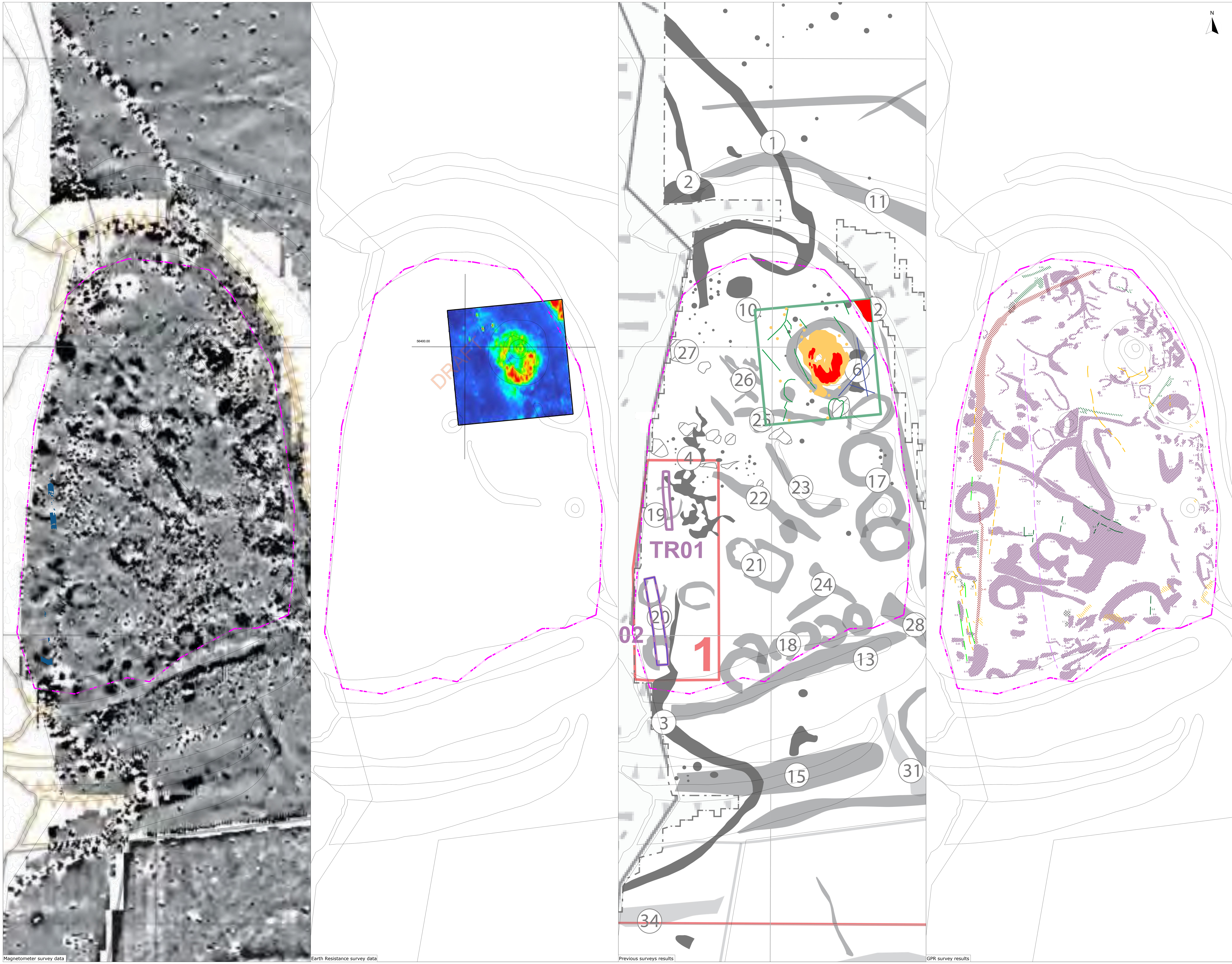
Title: GPR Survey - Timeslice at 2.00m

Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)	Fig No: 21

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



KEY

	Geometric feature - probable archaeological origin
	Broad linear feature - possible archaeological origin
	Linear feature - possible archaeological origin
	Discrete features -uncertain origin
	Near surface feature
	Possible service
	Recent trench anomaly
	Magnetic anomalies (previous survey)
0.60	Depth to the top of the feature (in m)

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
Results of Previous Magnetometer and Earth Resistance Surveys together with GPR Results

Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

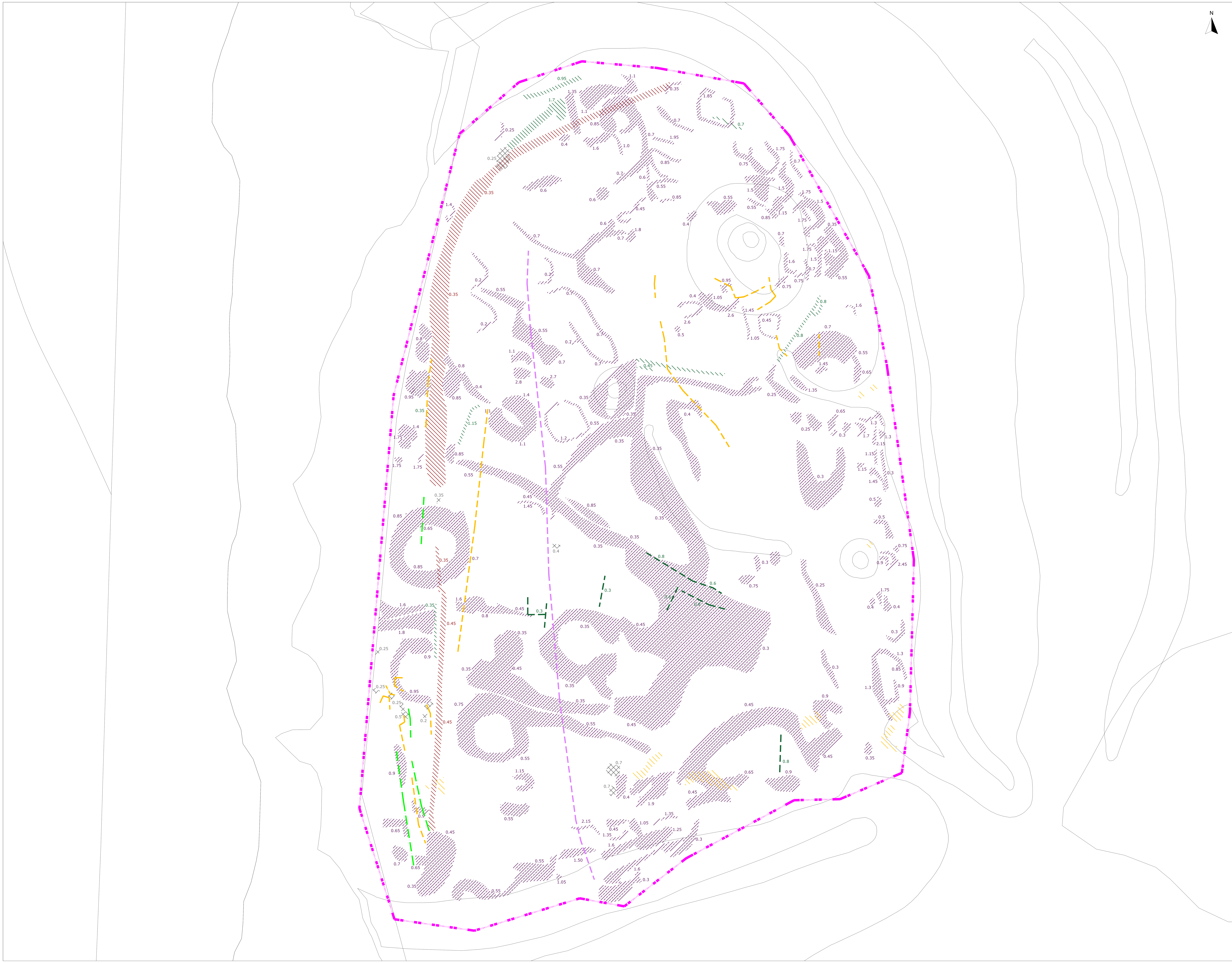
Scale: 1:600 @ A1
0m 6 12 18 24 30 36m

Fig No:
22

Survey date
November 2019

Drawn by
MUK

Checked by
PPB



KEY

	Geometric feature - probable archaeological origin
	Broad linear feature - possible archaeological origin
	Linear feature - possible archaeological origin
	Discrete features -uncertain origin
	Near surface feature
	Possible service
	Recent trench anomaly
	Magnetic anomalies (previous survey)
0.60	Depth to the top of the feature (in m)

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Interpretation

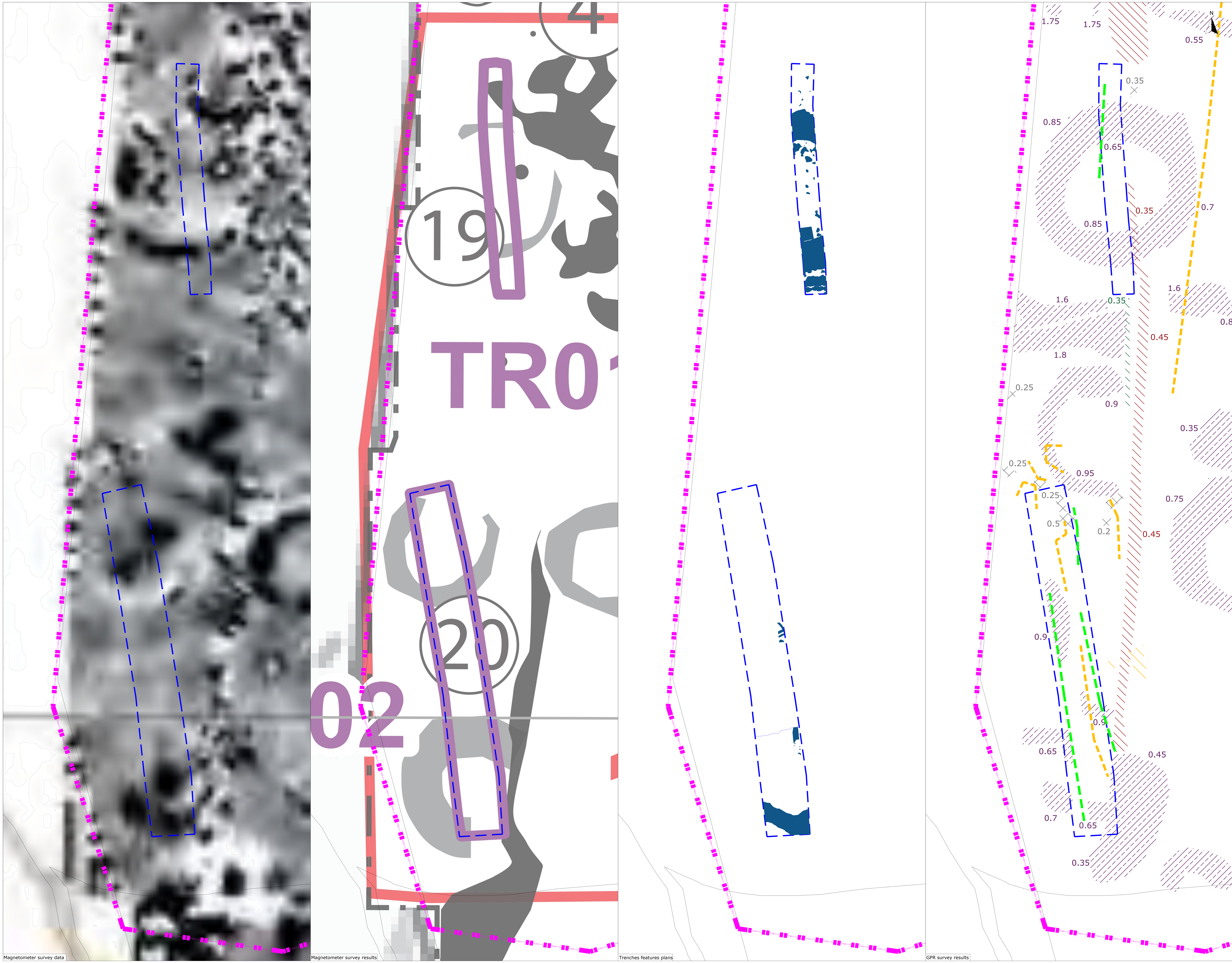
Client: ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project: 16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1 (0m 3 6 9 12 15 18)

Fig No: 23

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



KEY

	Geometric feature - probable archaeological origin
	Broad linear feature - possible archaeological origin
	Linear feature - possible archaeological origin
	Discrete features -uncertain origin
	Near surface feature
	Possible service
	Recent trench anomaly
	Magnetic anomalies (previous survey)
0.60	Depth to the top of the feature (in m)

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Interpretation over Trenching

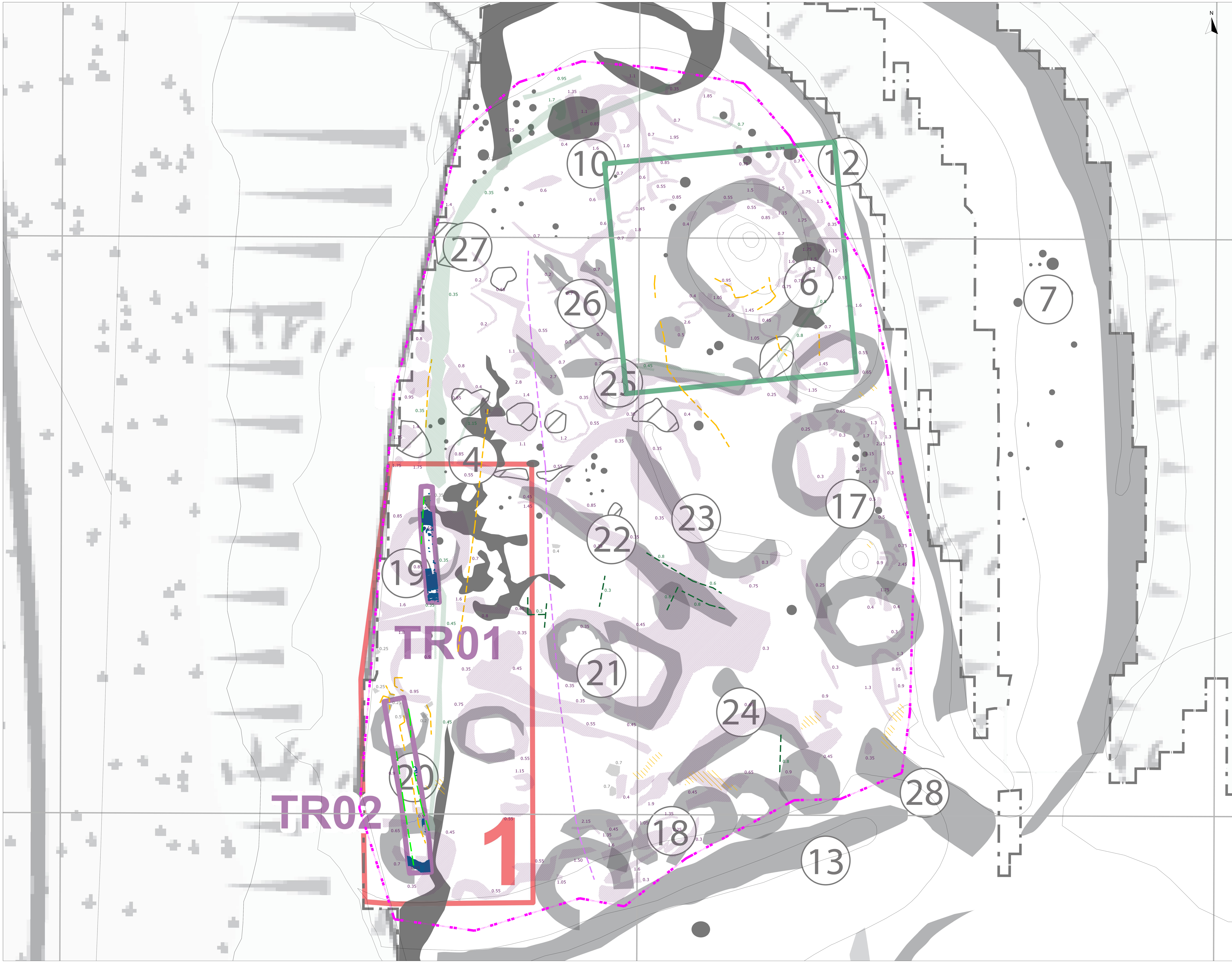
Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:150 @ A1
0m 1 2 3 4 5 6 7 8 9m

Fig No:
24

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



KEY

(purple dashed hatch)	Geometric feature - probable archaeological origin
(red hatch)	Broad linear feature - possible archaeological origin
(green hatch/dashed line)	Linear feature - possible archaeological origin
(cross hatch)	Discrete features -uncertain origin
(yellow cross hatch/dashed line)	Near surface feature
(pink dashed line)	Possible service
(green dash-dot line)	Recent trench anomaly
(grey fills)	Magnetic anomalies (previous survey)
0.60	Depth to the top of the feature (in m)

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Interpretation overlaying Previous Survey Results

Client:
ROYAL COMMISSION ON THE ANCIENT AND HISTORICAL MONUMENTS OF WALES

Project:
16438 - DINAS DINLLE HILLFORT, LLANDWROG

Scale: 1:300 @ A1
0m 3 6 9 12 15 18

Fig No: 25

Survey date: November 2019
Drawn by: MUK
Checked by: PPB

Appendix A - Technical Information: Ground Penetrating Radar (GPR)

Grid locations
The location of the survey traverses has been plotted in Figure 1.

Survey equipment and configuration
Two of the main advantages of radar are its ability to give information of depth as well as work through a variety of surfaces, even in cluttered environments which normally prevent other geophysical techniques being used.

A short pulse of energy is emitted into the ground and echoes are returned from the interfaces between different materials in the ground. The amplitude of these returns depends on the change in velocity of the radar wave as it crosses these interfaces. A measure of these velocities is given by the dielectric constant of that material. The travel times are recorded for each return on the radargram and an approximate conversion made to depth by calculating or assuming an average dielectric constant (see below).

Drier materials such as sand, gravel and rocks, i.e. materials which are less conductive (or more resistant), will permit the survey of deeper sections than wetter materials such as clays which are more conductive (or less resistant). Penetration can be increased by using longer wavelengths (lower frequencies) but at the expense of resolution.

As the antennae emit a "cone" shaped pulse of energy an offset target showing a perpendicular face to the radar wave will be "seen" before the antenna passes over it. A resultant characteristic diffraction pattern is thus built up in the shape of a hyperbola. A classic target generating such a diffraction is a pipeline when the antenna is travelling across the line of the pipe. However, it should be pointed out that if the interface between the target and its surrounds does not result in a marked change in velocity then only a weak hyperbola will be seen, if at all.

The Ground Penetrating Impulse Radars used was High Density Array system manufactured by Mala. This system collects data using 400MHz antenna.

Sampling interval
Readings were taken at 0.05m intervals. All survey traverse positioning was carried out using a Trimble S6 Robotic Total Station.

Depth of scan and resolution
The average velocity of the radar pulse is calculated to be 0.1m/nsec which is typical for the type of sub-soils on the site. With a range setting of 100nsec this equates to a maximum depth of scan of 2m but it must be remembered that this figure could vary by ± 10% or more. A further point worth making is that very shallow features are lost in the strong surface response experienced with this technique.

Under ideal circumstances the minimum size of a vertical feature seen by a 200MHz (relatively low frequency) antenna in a damp soil would be 0.1m (i.e. this antenna has a wavelength in damp soil of about 0.4m and the vertical resolution is one quarter of this wavelength). It is interesting to compare this with the 400MHz antenna, which has a wavelength in the same material of 0.2m giving a theoretical resolution of 0.05m. A 900MHz antenna would give 0.09m and 0.02m respectively.

Data capture
Data is displayed on a monitor as well as being recorded onto an internal hard disk. The data is later downloaded into a computer for processing.

- Archaeological
- Geophysical
- Laser Scanning
- Measured Building
- Topographic
- Utility Mapping

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