Research Report Series 32/2023

St Stephen's Beacon, St Stephen-in-Brannel, Cornwall

Report on Geophysical Surveys, March 2023

Megan Clements, Neil Linford and Andrew Payne

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St Stephen's Beacon
Beacon Road
Foxhole, Cornwall

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Summary

Earth Resistance and Ground Penetrating Radar (GPR) surveys were conducted at St Stephen's Beacon in the parish of St Stephen-in-Brannel, Cornwall as part of wider ongoing works to remove the Beacon from the Heritage at Risk (HAR) register. The Earth Resistance survey (0.53ha) identified the main beacon as well as internal areas of high and low resistance. Possible clay extraction pits have been detected and the impact of modern bonfires are evident in the data. Additional anomalies of a possible archaeological or natural origin have also been identified. The vehicle towed GPR survey (2.35ha) responded to modern surface features, such as footpaths across the site, and the underlying geology.

Contributors

The geophysical fieldwork was conducted by Megan Clements, Neil Linford and Andrew Payne.

Acknowledgements

The authors are grateful for the landowner's permission to allow access for the survey to be conducted. The cover image shows the vehicle towed GPR survey in progress looking over the southern ramparts of the beacon (photo taken by Neil Linford).

Archive location

Fort Cumberland, Fort Cumberland Road Portsmouth, PO4 9LD.

Cornwall and Scilly HER: 20650; 20651; 20695

Date of survey/research/investigation

The fieldwork was conducted between the 13th and 15th March 2023 and the report completed on the 1st June 2023.

Contact details

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Contents

Introduction

Earth Resistance and Ground Penetrating Radar (GPR) surveys were conducted at St Stephen's Beacon in the Parish of St Stephen-in-Brannel, Cornwall. The geophysical surveys were undertaken to support ongoing work by Historic England's (HE) South-West Region to remove St Stephen's Beacon (National Heritage List for England No.1003091) from the Heritage at Risk (HAR) register. The site consists of a large hilltop enclosure and an early Bronze Age cairn with evidence of post-medieval China clay extraction.

Prior to the geophysical survey, the Historic England Archaeological Investigation Team (AIT) also conducted a level 3 analytical earthwork survey and a contextual aerial survey of the Monument and its surrounding landscape.

The site lies over a metamorphic aureole of St Austell Intrusion lithium-mica bearing medium granite, with coarse granite to the north and an approximately northeast-southwest orientated intrusion of fine granite with megacrysts passing through the centre of the Beacon. Lower Devonian Meadfoot beds of calcareous slate, grit and thin limestone are found to the south metamorphosed by the granite intrusion (Geological Survey of Great Britain 1970). Well-drained, humuse, gritty loamy soils of Moor Gate (612b) association have developed over the site (Soil Survey of England and Wales 1983). The summit of the Beacon was recently cleared of vegetation by volunteers in advance of the non-intrusive survey work and is currently used as rough grazing with public access as a local amenity space. Weather conditions were wet and windy throughout the survey, with occasional spells of dry weather.

Method

Earth Resistance

The Earth Resistance survey was focused on the area in the immediate vicinity of the upstanding remains at the summit of the Beacon.

Measurements were recorded over six 30m grids established with a Trimble R8s GNSS (Figure 1) using a Geoscan RM85 earth resistance meter, internal multiplexer, and a PA5 electrode frame in the Twin-Electrode configuration, to allow two separate surveys with electrode separations of 0.5m and 1.0m to be collected simultaneously. The 0.5m electrode separation coverage was designed to detect near-surface anomalies in the upper 0.5m of the subsurface whilst the 1.0m separation survey allowed anomalies to a depth of about 1-1.25m to be detected. For the 0.5m electrode separation survey readings were taken at a sample density of 0.5m x 1.0m whilst for the 1.0m separation survey they were taken at a density of 1.0m x 1.0m.

Extreme values caused by high contact resistance were suppressed using an adaptive thresholding median filter with radius 1m (Scollar *et al.* 1990). Additionally, rainfall during the survey modified the subsurface resistivity as measurements were taking place leading to some discontinuities between edges of adjacent grids. Hence, these discontinuities were corrected using an edge matching algorithm that partitions the columns of data adjacent to either side of each grid edge into high spatial frequency (local detail) and low frequency (regional) components then averaging the regional components so they match across the edge. The results for the near-surface 0.5m electrode separation survey are depicted as a greyscale image in Figure 3 superimposed on the base Ordnance Survey (OS) mapping data. Figure 5 shows the minimally processed data from both the 0.5m and 1.0m electrode separation data presented as trace plots and histogram equalised greyscale images following the suppression of extreme data values. Processed datasets are also presented as linear grayscale images after the application of Gaussian high- (5.0m radius) and low- (1.0m radius) pass filters to emphasise archaeological scale anomalies and suppress measurement noise respectively.

Ground Penetrating Radar

A 3d-Radar MkIV GeoScope Continuous Wave Step Frequency (CWSF) Ground Penetrating Radar (GPR) system was used to conduct the survey collecting data with a multi-element DXG1820 vehicle towed, ground coupled antenna array (Linford *et al.* 2010; Eide *et al.* 2018). A roving Trimble R8s Global Navigation Satellite System (GNSS) receiver was mounted on the GPR antenna array, that together with a second R8s base station was used to provide continuous positional control for the survey collected along the instrument swaths shown on Figure 2. The GNSS base station receiver was adjusted to the National Grid Transformation OSTN15 using the Trimble VRS Now Network RTK delivery service. This uses the Ordnance Survey's GNSS correction network (OSNet) and gives a stated accuracy of 0.01-0.015m per point with vertical accuracy being half as precise.

Data were acquired at a 0.075m x 0.075m sample interval across a continuous wave step frequency range from 40MHz to 2.99GHz in 4MHz increments using a dwell time of 2ms. A single antenna element was monitored continuously to ensure data quality during acquisition together with automated processing software to produce real time amplitude time slice representations of the data as each successive instrument swath was recorded in the field (Linford 2013).

Post-acquisition processing involved conversion of the raw data to time-domain profiles (through a time window of 0 to 75ns), adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Representative profiles from the full GPR survey data set are shown on Figure 6. To aid visualisation amplitude time slices were created from the entire data set by averaging data within successive 2.5ns (two-way travel time) windows (e.g. Linford 2004). An average sub-surface velocity of 0.112m/ns was assumed following constant velocity tests on the data and was used as the velocity field for the time to estimated depth conversion. Each of the resulting time slices therefore represents the variation of reflection strength through successive ~0.14m intervals from the ground surface, shown as individual greyscale images in Figures 4, 7, 8 and 9. Further details of both the frequency and time domain algorithms developed for processing this data can be found in Sala and Linford (2012).

Due to the size of the resultant dataset a semi-automated algorithm has been employed to extract the vector outline of significant anomalies shown on Figure 11. The algorithm uses edge detection to identify bounded regions followed by a morphological classification based on the size and shape of the extracted anomalies. For example, the location of possible pits is made by selecting small, sub circular anomalies from the data set (Linford and Linford 2017).

Magnetic survey

A magnetometer survey was also attempted using two Bartington grad-601 fluxgate magnetometers. However, this was unsuccessful due to equipment malfunction and no usable results were obtained.

Results

Earth Resistance Survey

A graphical summary of significant earth resistance anomalies [**r1-6**] discussed in the following text superimposed on the base OS mapping data is provided in Figure 10.

The earth resistance survey has detected a broad high resistance response [**r1**] about 20m in diameter associated with the beacon itself. High-pass filtering (Figure 5C and 5F) reveals smaller scale variation with this including some very high magnitude anomalies with local maxima of around 80-160 ohms. Two low resistance local minima within [**r1**] potentially correspond with ground depressions of similar scale observed during the survey.

Three high resistance anomalies [**r2**] to the southwest of the beacon could relate to outlying stonework associated with it, or natural variation in the background resistance caused by the underlying geology. Similarly, the north-south orientated area of low resistance [**r3**] between [**r2**] could be related to either an extension of the beacon or geological variation.

Two low resistance anomalies [**r4**] to the south correspond with the visible remains of bonfires mapped during the survey. Likely because the residue ash from the bonfires is water retentive thus creating low resistance anomalies in the data. A low resistance linear anomaly [**r5**] could, tentatively, represent a more significant ditch due to its proximity to the beacon, although it may also be associated with the remains of the bonfires.

In the southeast corner of the survey area are a cluster of discrete anomalies of mixed positive and negative responses [**r6**] corresponding with pits containing stones and likely to be related to clay extraction activity.

Ground Penetrating Radar Survey

A graphical summary of the significant GPR anomalies, [**gpr1-11**] discussed in the following text, superimposed on the base OS map data, is provided in Figure 11.

The very near-surface response between approximately 0.0 and 5.0ns (0.0 to 0.23m) contains anomalies due to compacted vehicle access [**gpr1**], foot paths [**gpr2**] and animal runs [**gpr3**], that reverberate through the deeper data. Although the uneven nature of the terrain over the beacon could not be covered by the GPR survey, a low amplitude anomaly [**gpr4**] partially corresponds with the visible remains of the bonfires at [**r4**]. Some areas of amorphous, high amplitude response [**gpr5**] are also found in the vicinity of [**r2**], but it is difficult to suggest any more definitive interpretation. There is some evidence for high-amplitude anomalies [**gpr6**] in close proximity to the beacon, mainly to the east, possibly representing further stonework associated with the cairn.

A series of linear low-amplitude anomalies [**gpr7**] are found across the summit of the beacon from approximately 15.0ns (0.68m) onwards and in general follow the orientation of the igneous intrusion, suggesting a geological origin. One deeper response [**gpr8**] is found to the south of the beacon with more shallow anomalies passing through the location of the cairn [**gpr9**] and immediately to the north [**gpr10**]. While [**gpr9**] and [**gpr10**] may represent more significant ditches this, perhaps, seems unlikely due to the apparent depth of burial from the surface. Other more amorphous areas of high amplitude response [**gpr11**] between 5.0 and 15.0ns (0.23 to 0.68m) are possibly associated with either the geological response or clay extraction works.

Conclusions

The earth resistance survey has detected anomalies associated with the main beacon cairn, together with responses to areas of visible clearance bonfires and possible historic clay extraction. Additional anomalies of possible archaeological or geological origin are also evident within the data. The Ground Penetrating Radar survey has responded to near-surface compacted ground due to vehicle tracks, footpaths and animal runs with deeper, mainly low amplitude anomalies associated with the underlying igneous geology.

The geophysical surveys have not detected any unequivocal evidence for additional subsurface remains due to Bronze Age or later activity at the site. However, some anomalies to the southwest of the cairn, [**r2**] and [**gpr5**], may tentatively be suggested to have an association with it.

List of Enclosed Figures

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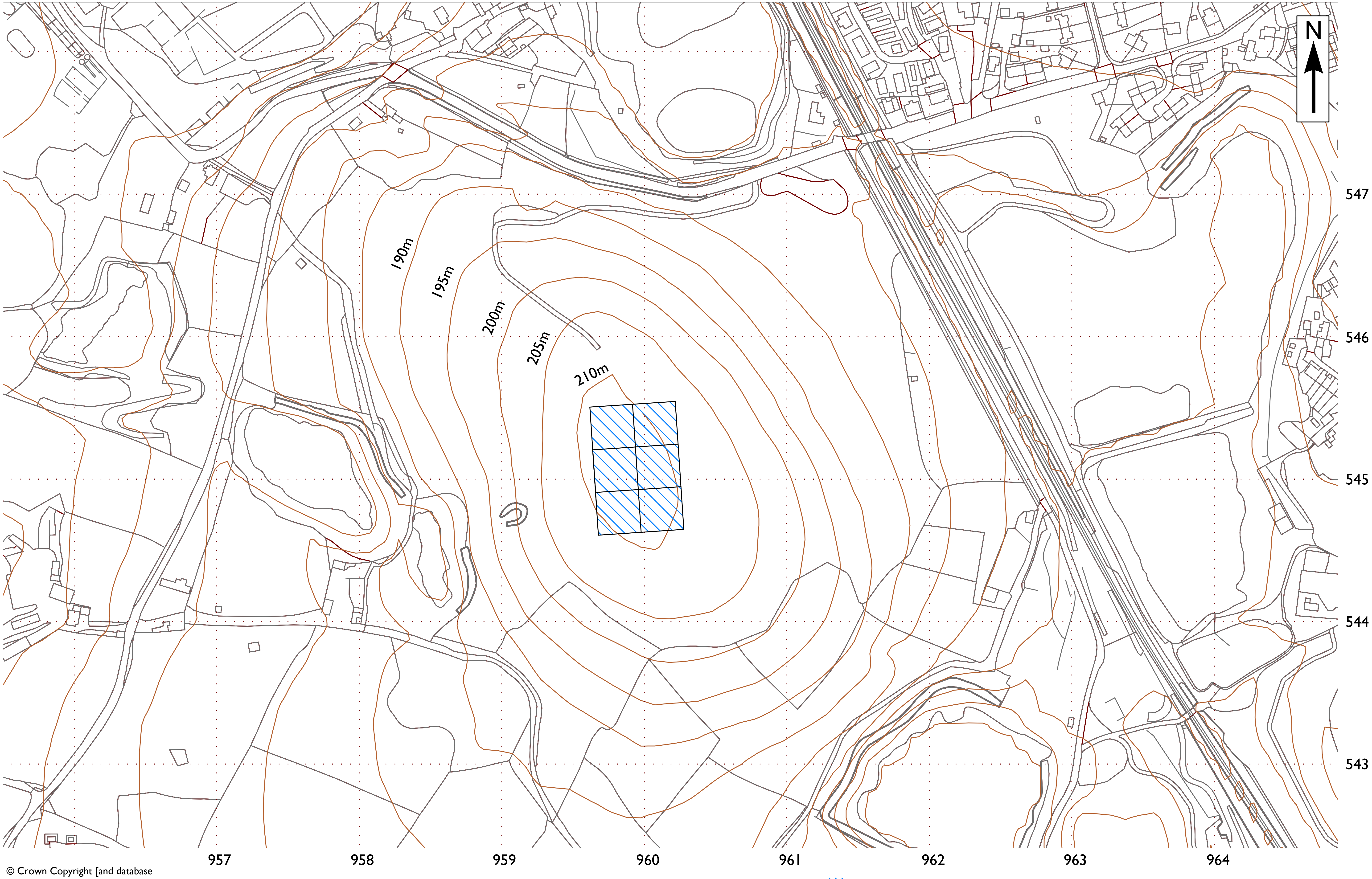
Figure 1

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL

Location of earth resistance survey, March 2023

SW9554



0 150m
1:2500

earth resistance

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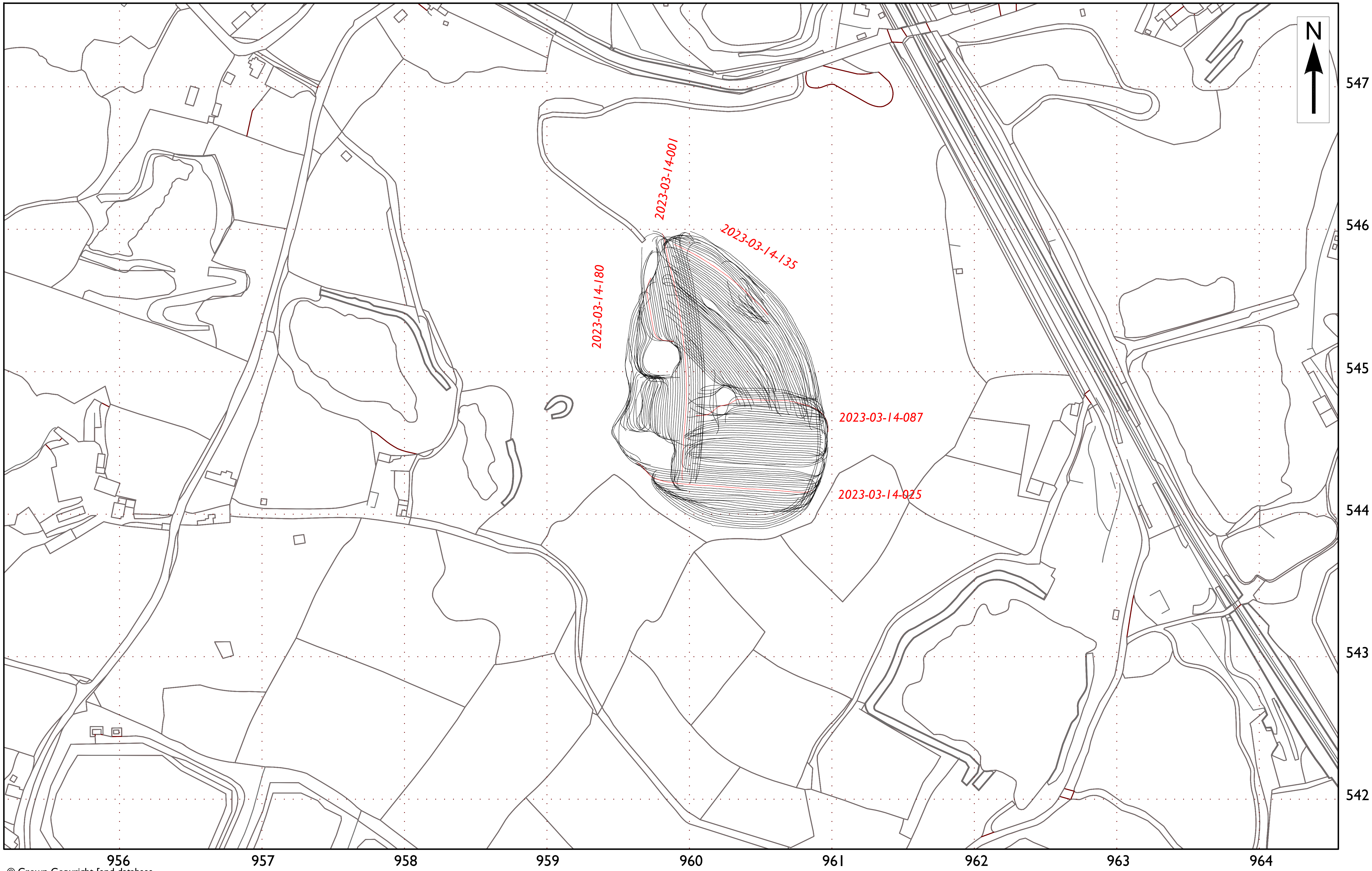
Figure 2

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
Location of GPR instrument swaths, March 2023



0 150m
1:2500

Ground Penetrating Radar survey swaths

2022-08-03-001 Location of selected GPR profiles shown on Figure 6

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Figure 3

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL

Location of 0.5m electrode separation earth resistance data, March 2023

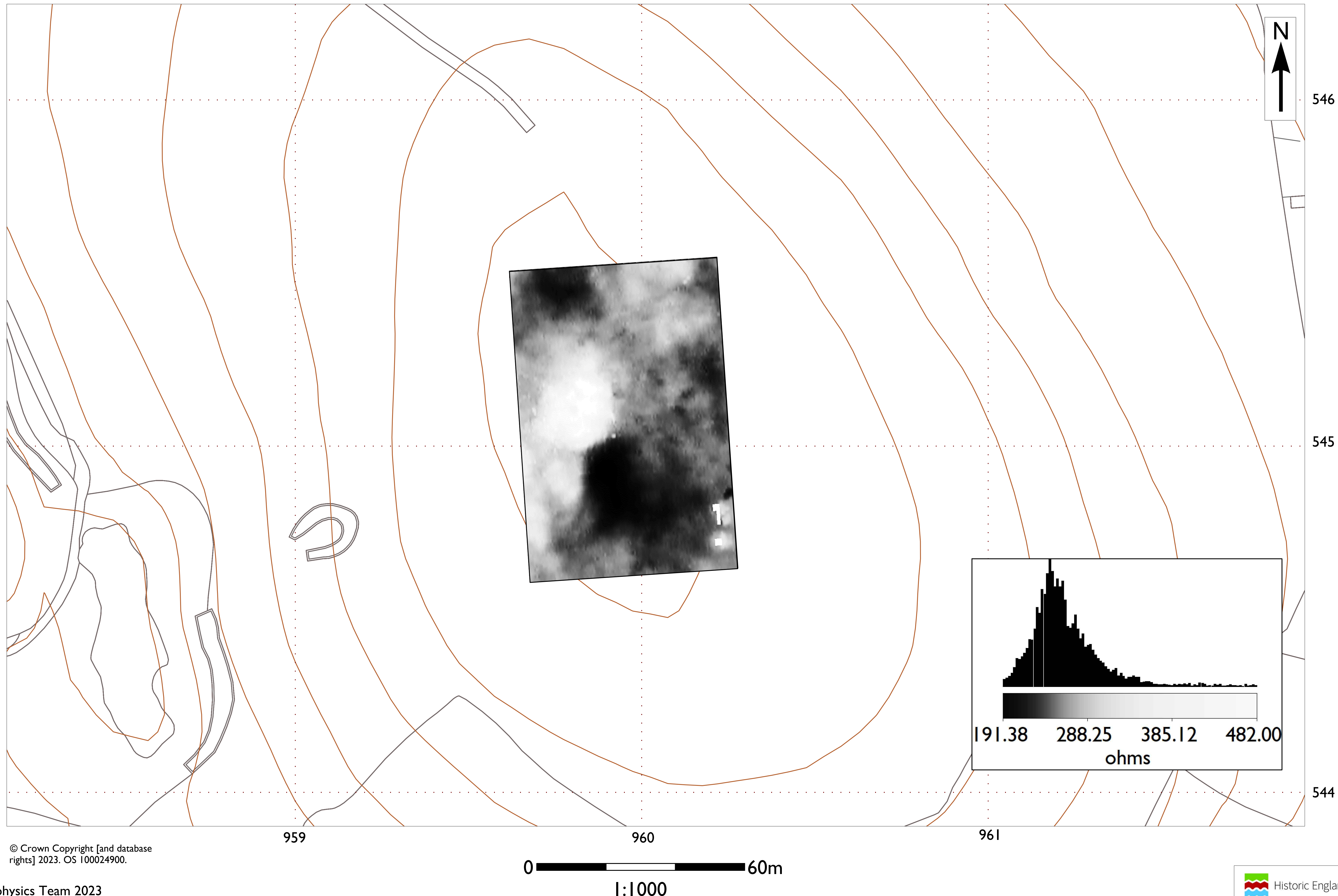

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Figure 4

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
GPR amplitude time slice between 47.5ns and 50.0ns (2.14m to 2.25m), March 2023

SW9554

0 150m

1:2500

Low High
relative reflector strength

2022-08-03-001 Location of selected GPR profiles shown on Figure 6

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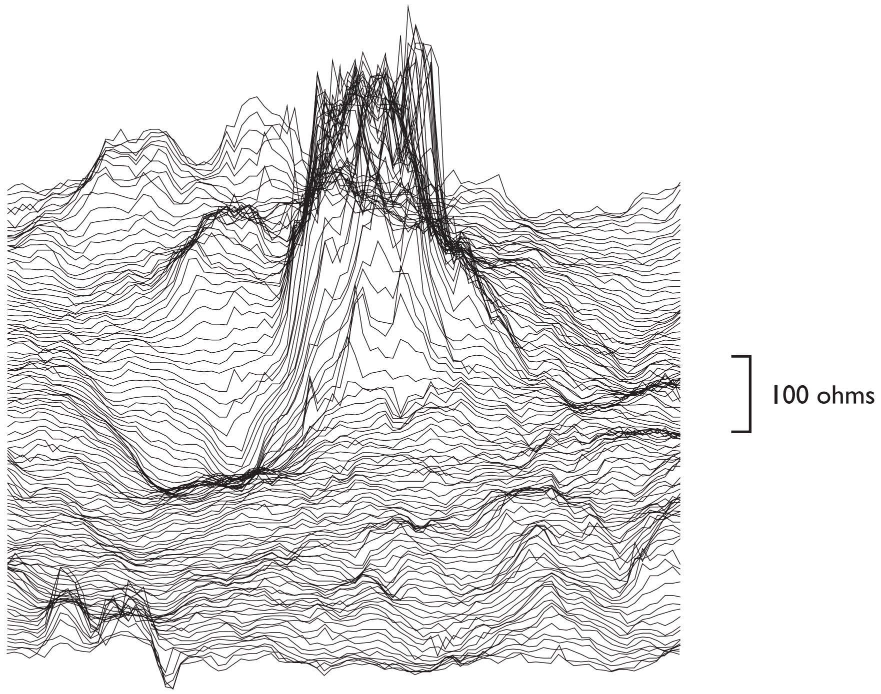
Figure 5

ST STEPHEN'S BEACON, STSTEPHEN-IN-BRANNEL, CORNWALL

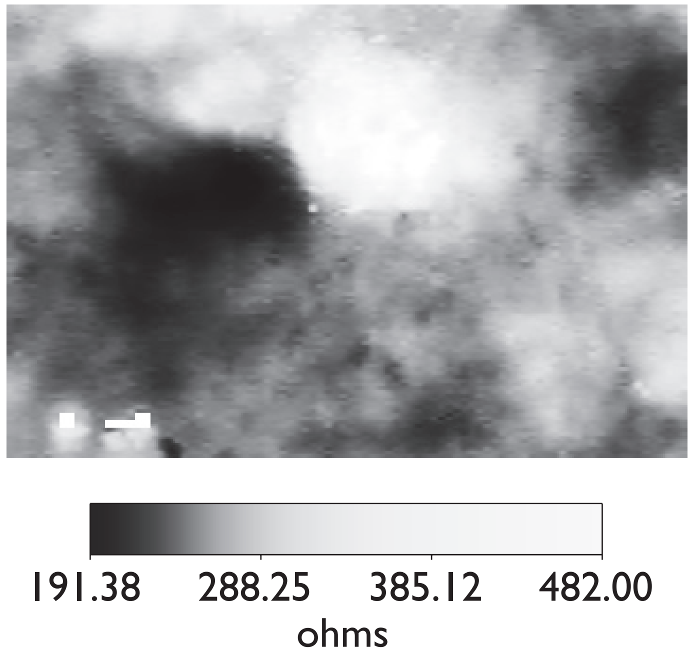
Earth resistance survey, March 2023

0.5m electrode separation data

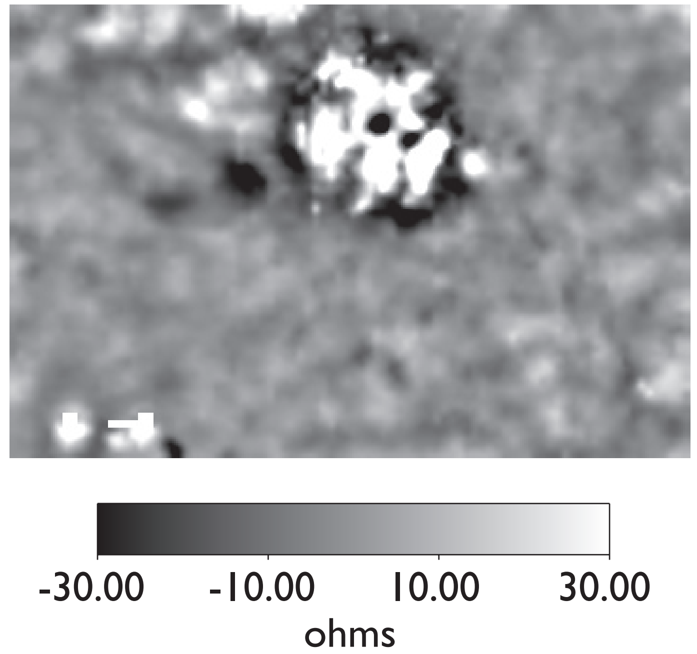
(A) Trace plot of minimally processed data



(B) Histogram equalised greyscale image of minimally processed data after noise removal

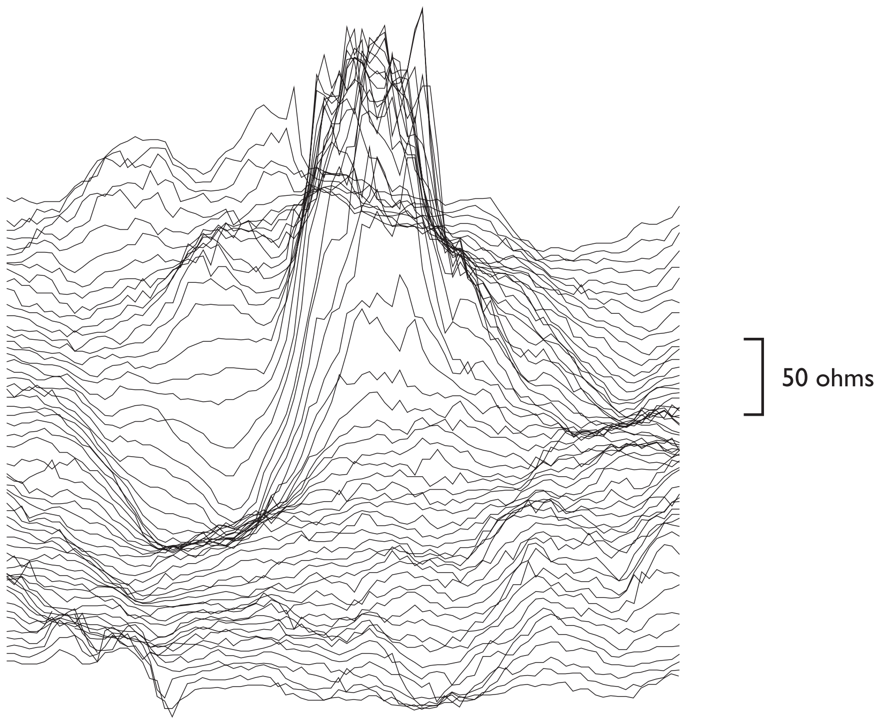


(C) Linear greyscale image of high and low pass filtered data after noise removal

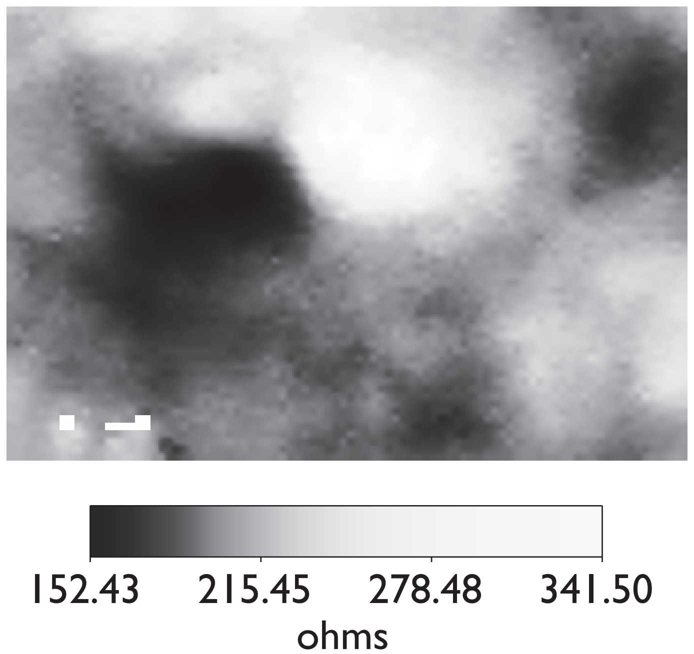


1.0m electrode separation data

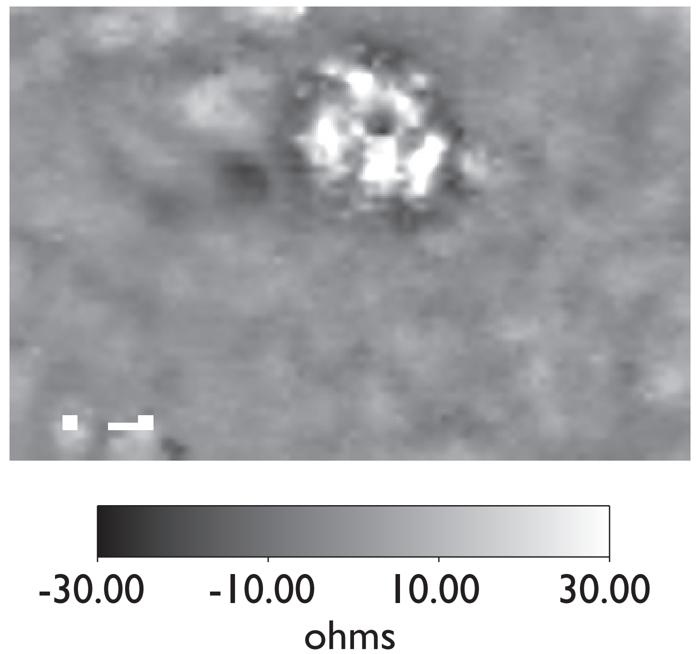
(D) Trace plot of minimally processed data



(E) Histogram equalised greyscale image of minimally processed data after noise removal



(F) Linear greyscale image of high and low pass filtered data after noise removal



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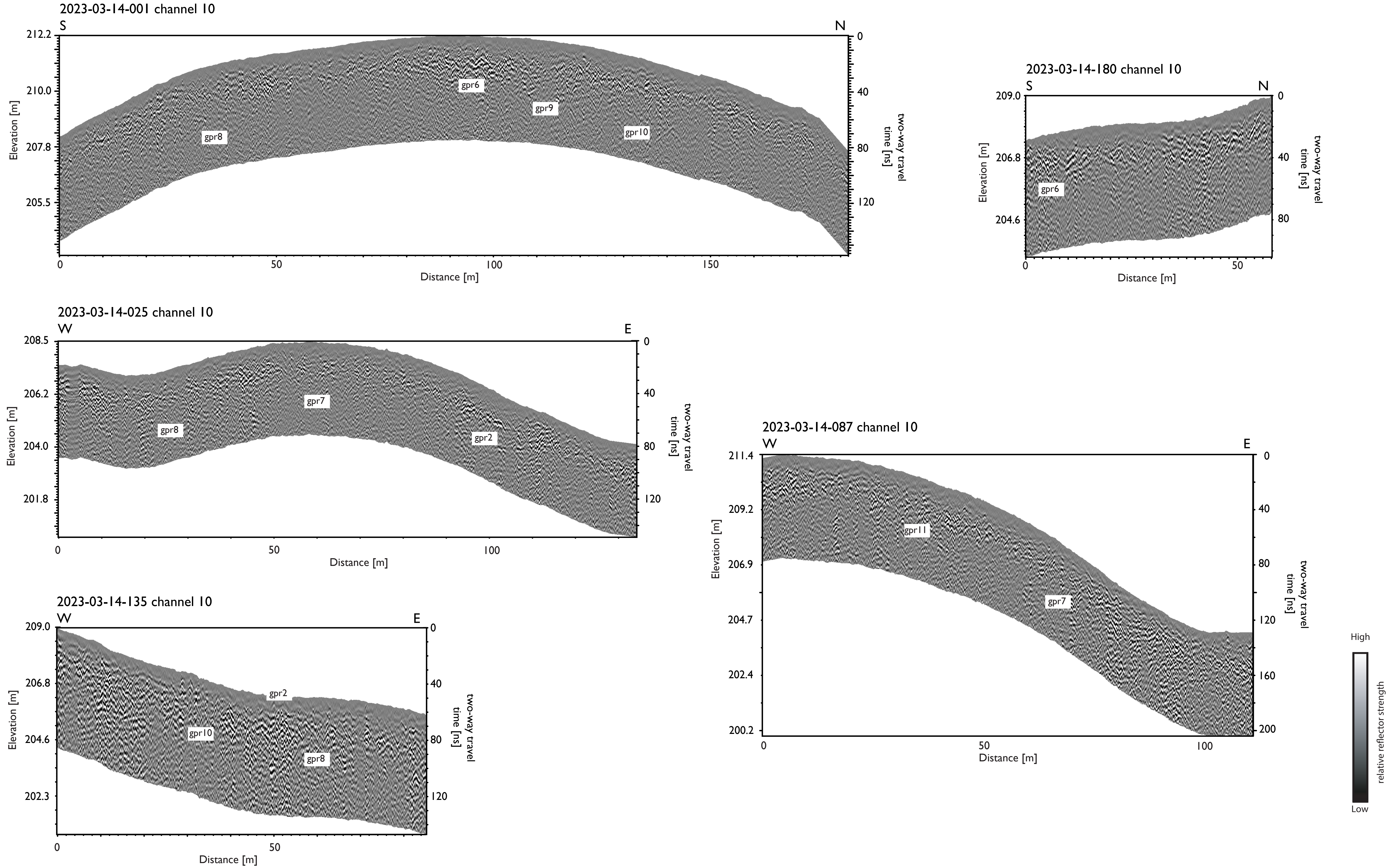
ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
Topographically corrected GPR profiles, March 2023

Figure 6



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ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
GPR amplitude time slices between 0.0 and 25.0ns (0.0 to 1.13m), March 2023

Figure 7

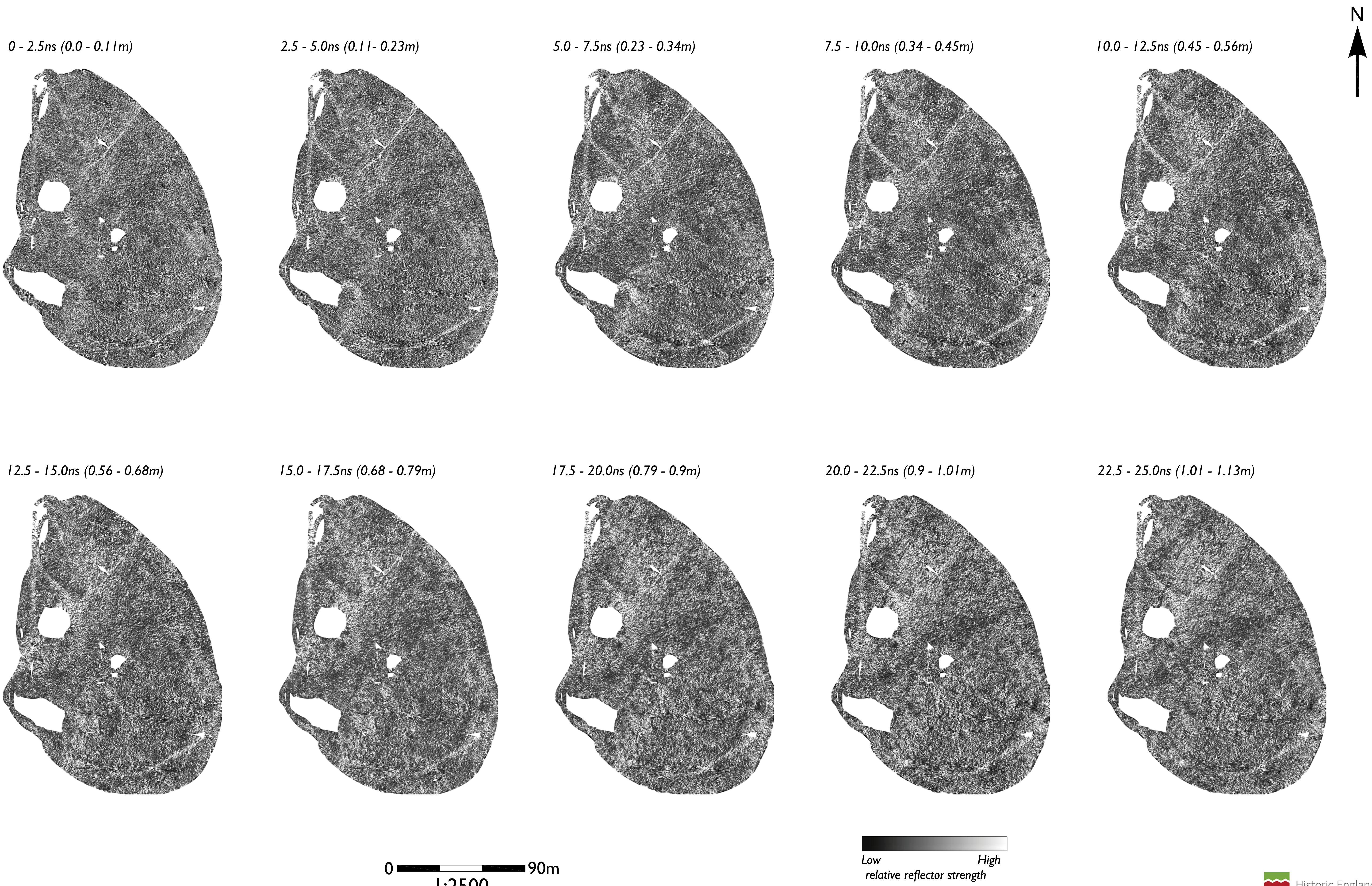

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Figure 8

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
GPR amplitude time slices between 25.0 and 50.0ns (1.13 to 2.25m), March 2023

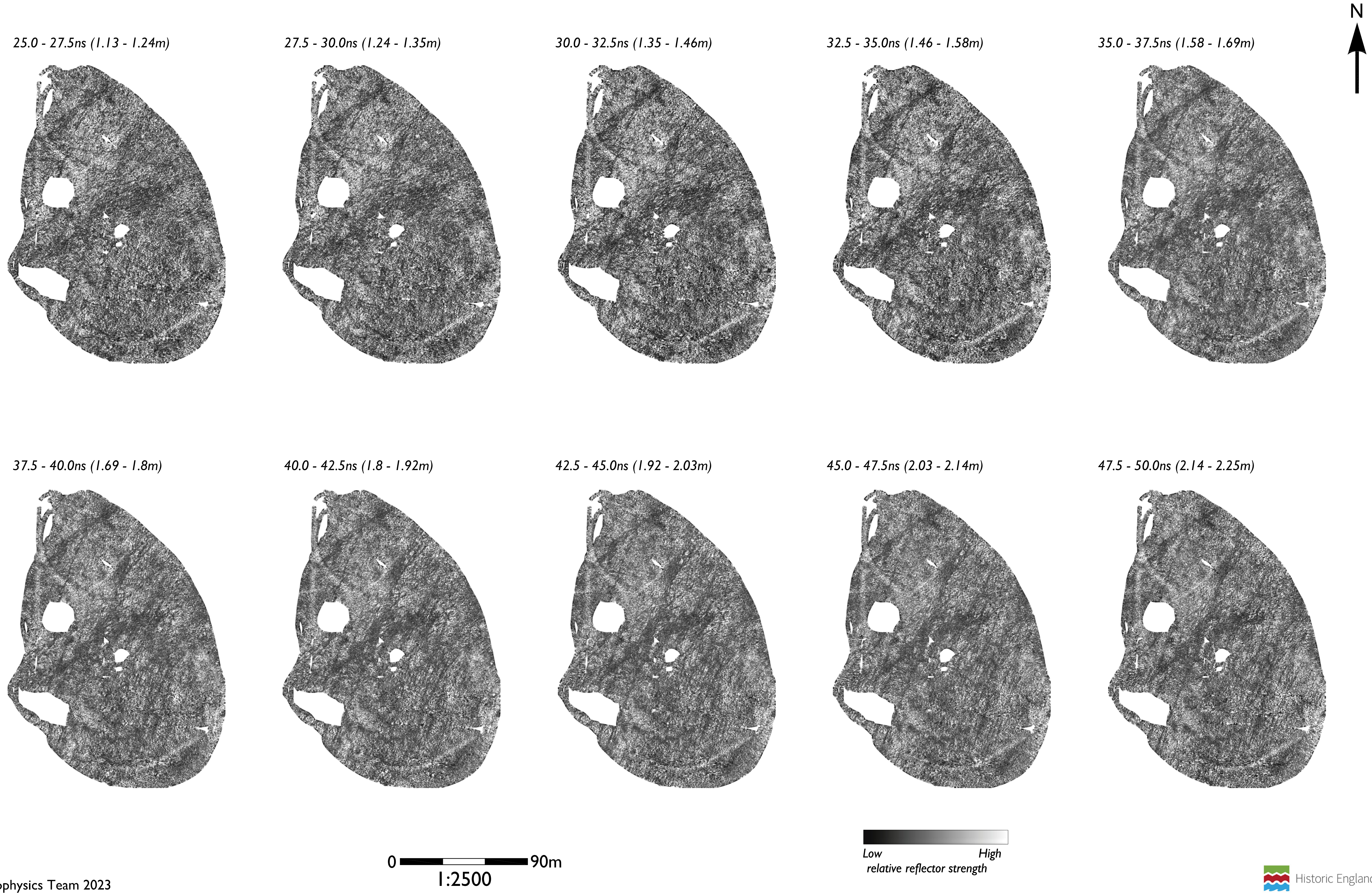

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Figure 9

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
GPR amplitude time slices between 50.0 and 75.0ns (2.25 to 3.38m), March 2023

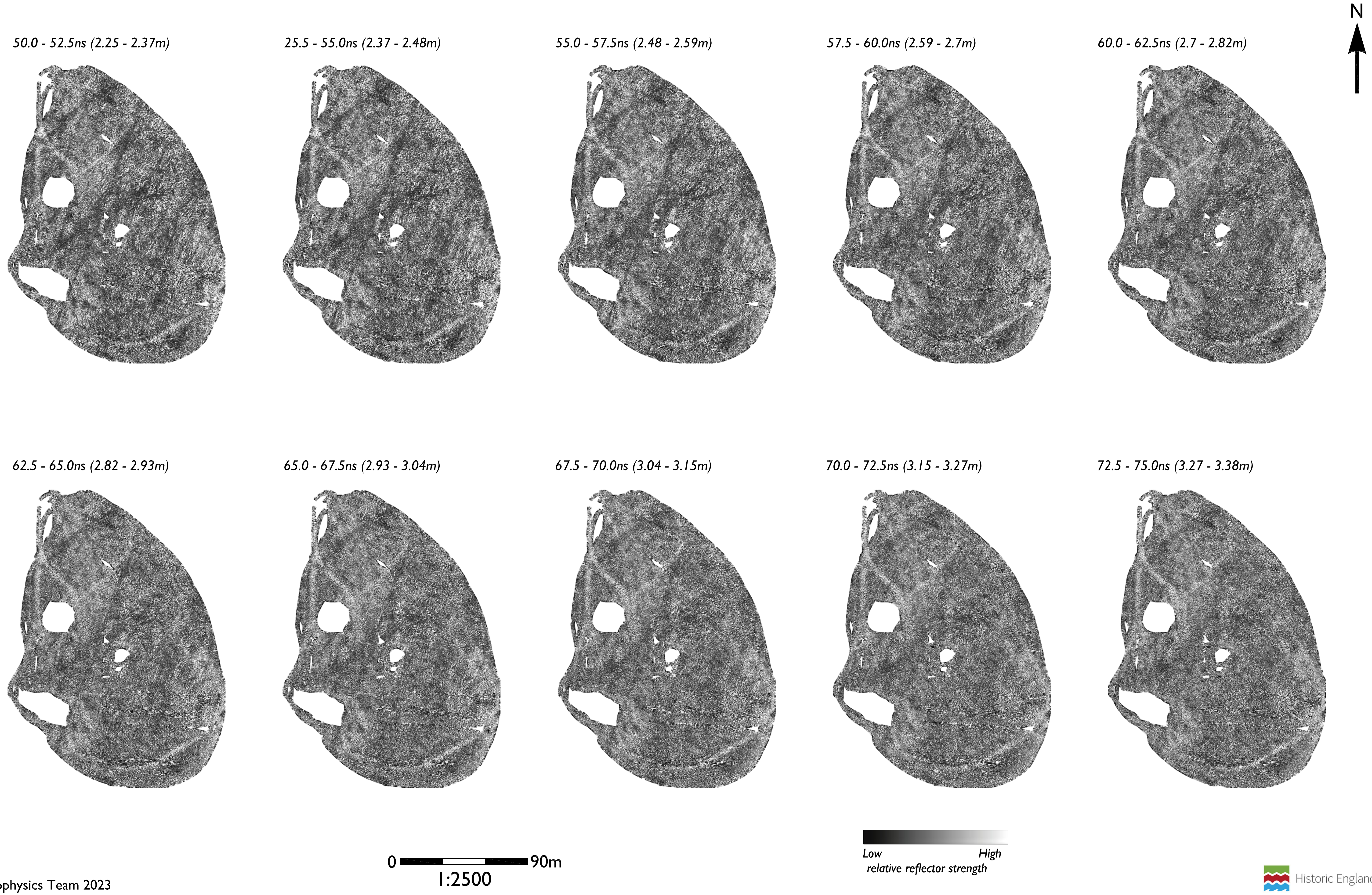

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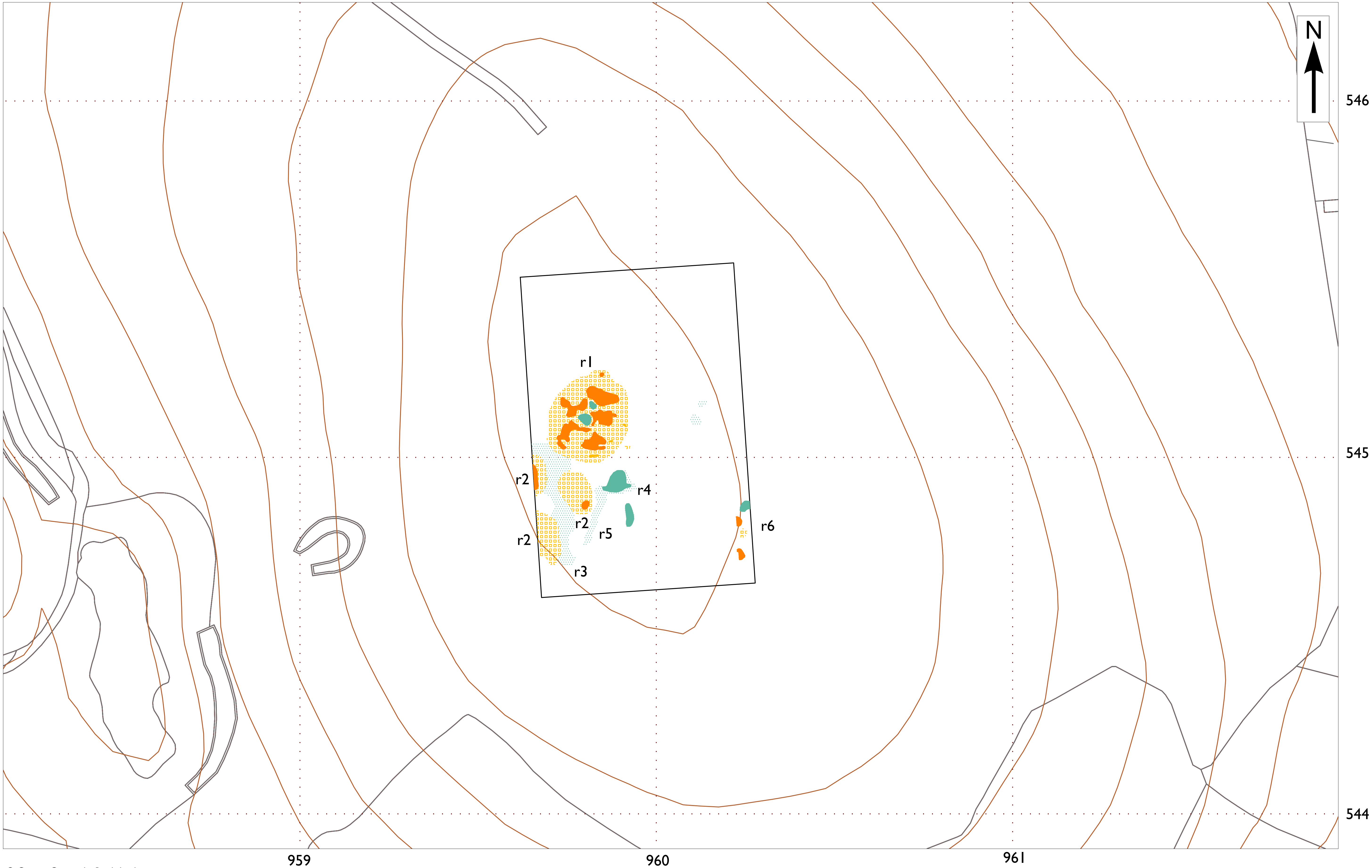
Figure 10

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL

Graphical summary of significant earth resistance anomalies, March 2023

SW9554



0 60m
1:1000

high resistance
very high resistance
low resistance

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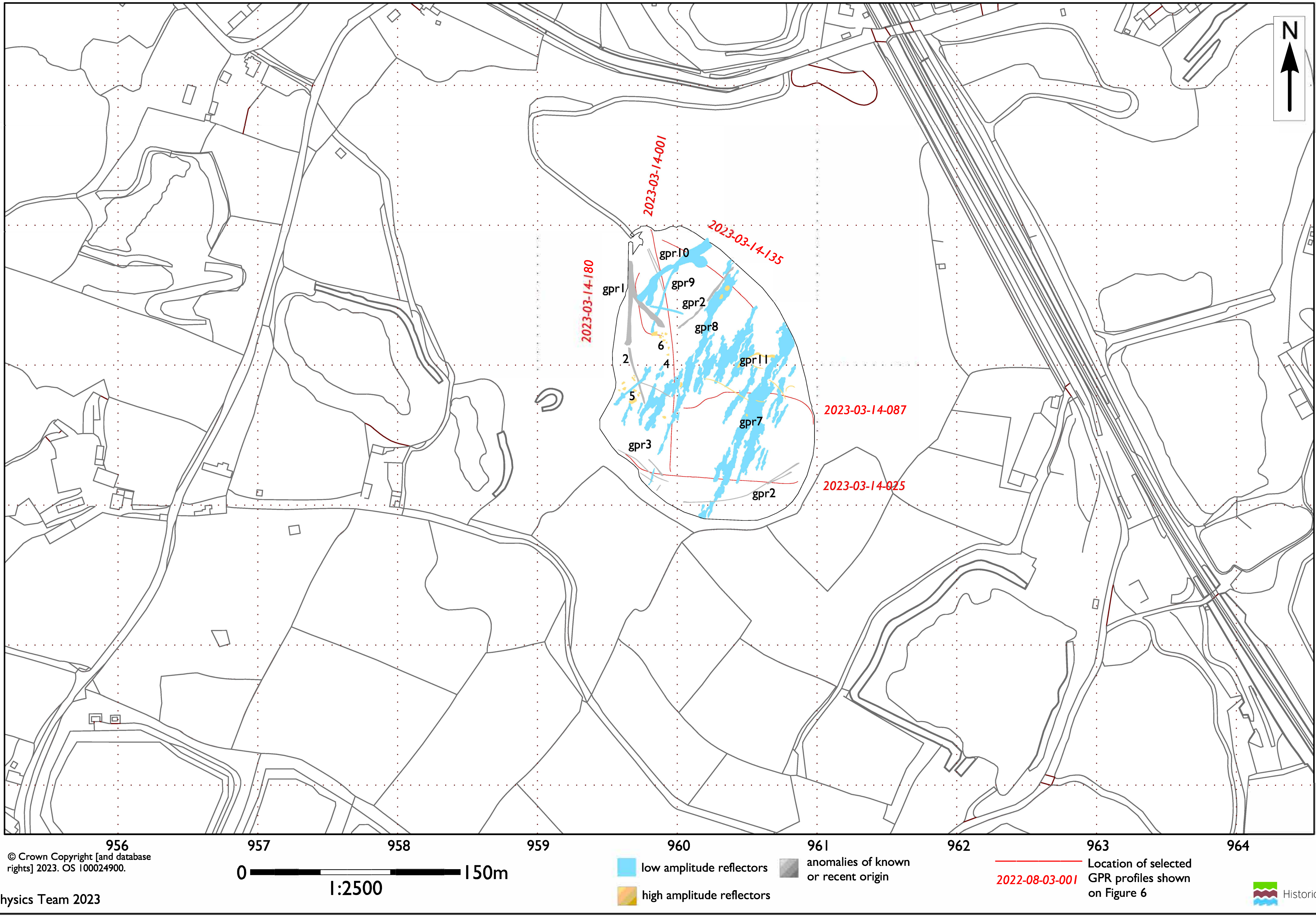
Figure 11

ST STEPHEN'S BEACON, ST STEPHEN-IN-BRANNEL, CORNWALL
Graphical summary of significant GPR anomalies, March 2023

SW9554



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