REPORT 77727/R/1

BRITISH MUSEUM

GPR SURVEY

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GPR SURVEY

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This report comprises:
Cover page
3 pages of text
Figures 1 to 2
Plates 1 to 2
Appendix A of 3 pages
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For the attention of Nigel Snell

17 July 2024

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GPR SURVEY

Instruction: Email instruction from Mr Nigel Snell of Acorn Restorations dated 12 July 2024.

1 INTRODUCTION

Sandberg was instructed to undertake a Ground Penetrating Radar (GPR) survey at the British Museum, Great Russell St, London WC1B 3DG.

The purpose of the survey was to establish the presence and location of embedded steel/metallic features within the nominated areas of the iron railing and gate in front of British Museum. Two areas, the main gate pier and the granite support wall, were to be scanned.

The site survey was undertaken on 16 July 2024.

This report documents the methods used, the results of data analysis and our interpretation.

2 METHOD

Mr Nigel Snell of Acorn Restoratins nominated two areas for the survey, shown in Plates 1 and 2.

General information about the principles of GPR is presented in Appendix A.

2.1 GPR Survey Equipment

A GSSI SIR 4000 Ground Penetrating Radar system (serial number E91.3) was used with a 2.0 GHz antenna (serial number E90.1).

GPR scans can be conducted using antennas with different central frequencies. A higher frequency antenna provides better resolution and more detail; however, the penetration depth is limited. The 2.0 GHz antenna used for this survey would typically penetrate to a depth of 500 mm in stonework and was considered the most appropriate.

2.2 GPR Survey Methods

Vertical and horizontal GPR scan lines were collected in the nominated areas as required.

Access to the nominated areas was good.

Due to the antenna size and configuration, scanning right up obstructions is impossible. This results in an unscanned blind zone. The width of this zone depends on the antenna used – for the 2.0 GHz Palm antenna, this zone is 45 mm. GPR would not have detected any features within this zone.

All radar data was stored electronically and uploaded at our Clapham office for analysis and record purposes.

2.3 GPR Calibration

The GPR equipment utilises a survey wheel that measures the distance travelled by the antenna and regulates the scan rate so that scans have a meaningful proportion. Distance measurement is regularly calibrated and saved within the GPR system. An on-site check over 1 metres was conducted and found to be accurate.

Depth calibration was undertaken on gate pier. The pier thickness was measured physically, and the relative permittivity was adjusted on our GPR equipment until the correct thickness reading was achieved. A figure of 5.8 was thus derived for the relative permittivity, which we used to calculate the depths and thicknesses quoted in this report.

Variations in materials, moisture content and compaction, can all affect the velocity of the radio waves through the medium. Hence the estimated depths may also be affected by these parameters.

2.4 GPR Data Analysis

GPR is an imaging technique that detects changes in the sub-surface (referred to as anomalies); however, it cannot determine the exact nature of the detected changes. Some features exhibit specific characteristics, which help their identification. For example:

- Metallic elements and voids usually produce a high-amplitude reflection.
- Linear features are likely to be services or reinforcement if at regular centres.
- Layer Interfaces between different materials produce a reflection, the magnitude of which depends on the contrast in electrical properties between the two materials.

Data processing included surface position correction, gain adjustment and migration (see Appendix A for a brief description of the techniques). The GPR data files were then visually inspected and analysed.

3 RESULTS

GPR successfully detected embedded steel elements and metallic features in the areas nominated for the survey.

The gate pier contains a steel element at 290-340 mm depth from the scanned surface to the full height of the scanned faces (Plate 1).

3No. linear metallic features were detected in the granite support wall at various depths to the full height of the granite support (Plate 2).

Annotated radargrams showing the features detected by GPR in the scanned elements are presented in Figures 1-2.

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For the attention of Nigel Snell

Surveyor/EW/MA/Inspection

File: 77727R_Report

Prepared by

Calvin Smith
GPR Surveyor

For Sandberg LLP

Ewa Krylowicz
Department Manager

17 July 2024

FIGURES

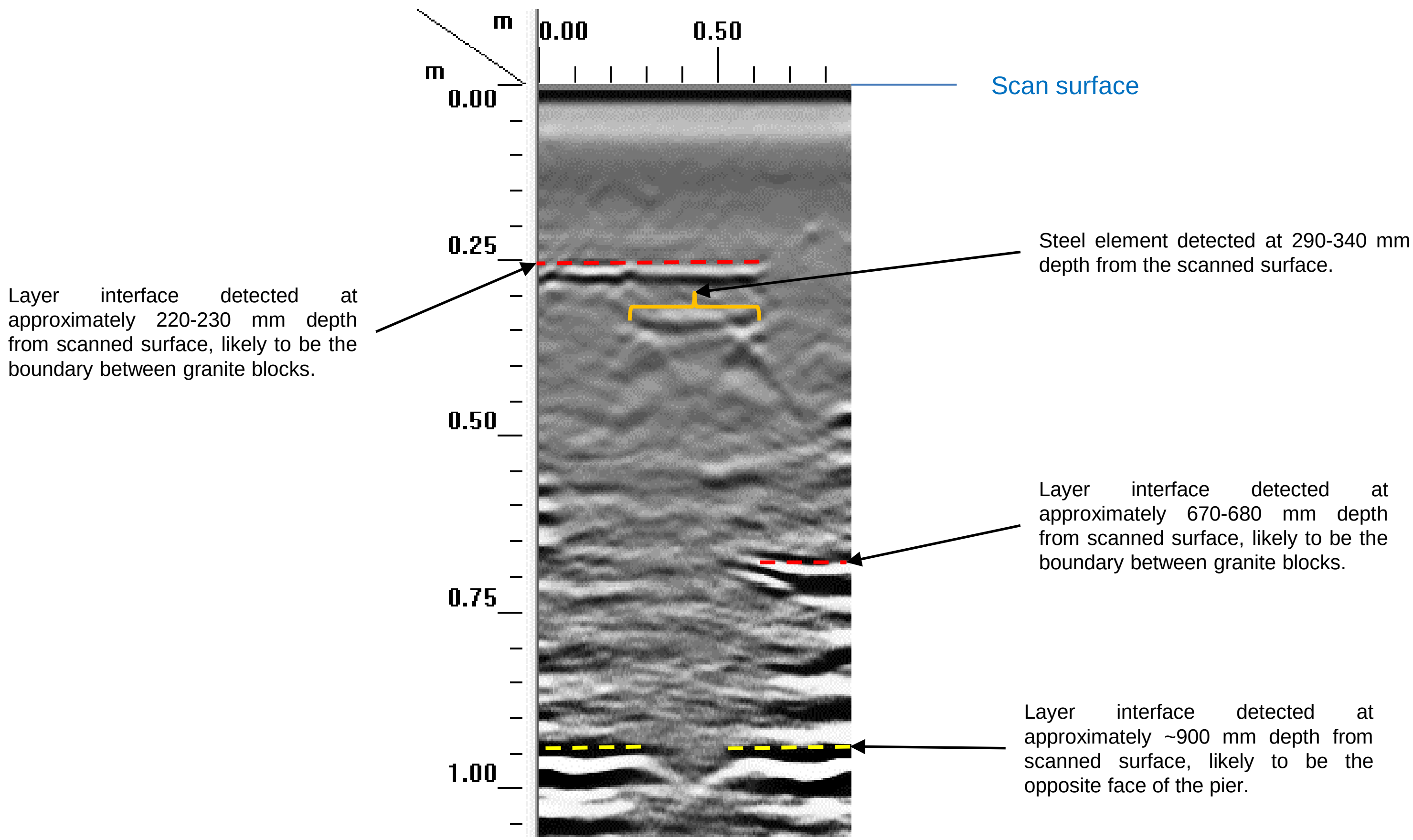

Figure 1: Typical radargram collected on the gate pier showing the features detected. All depths quoted are from the scanned surface.

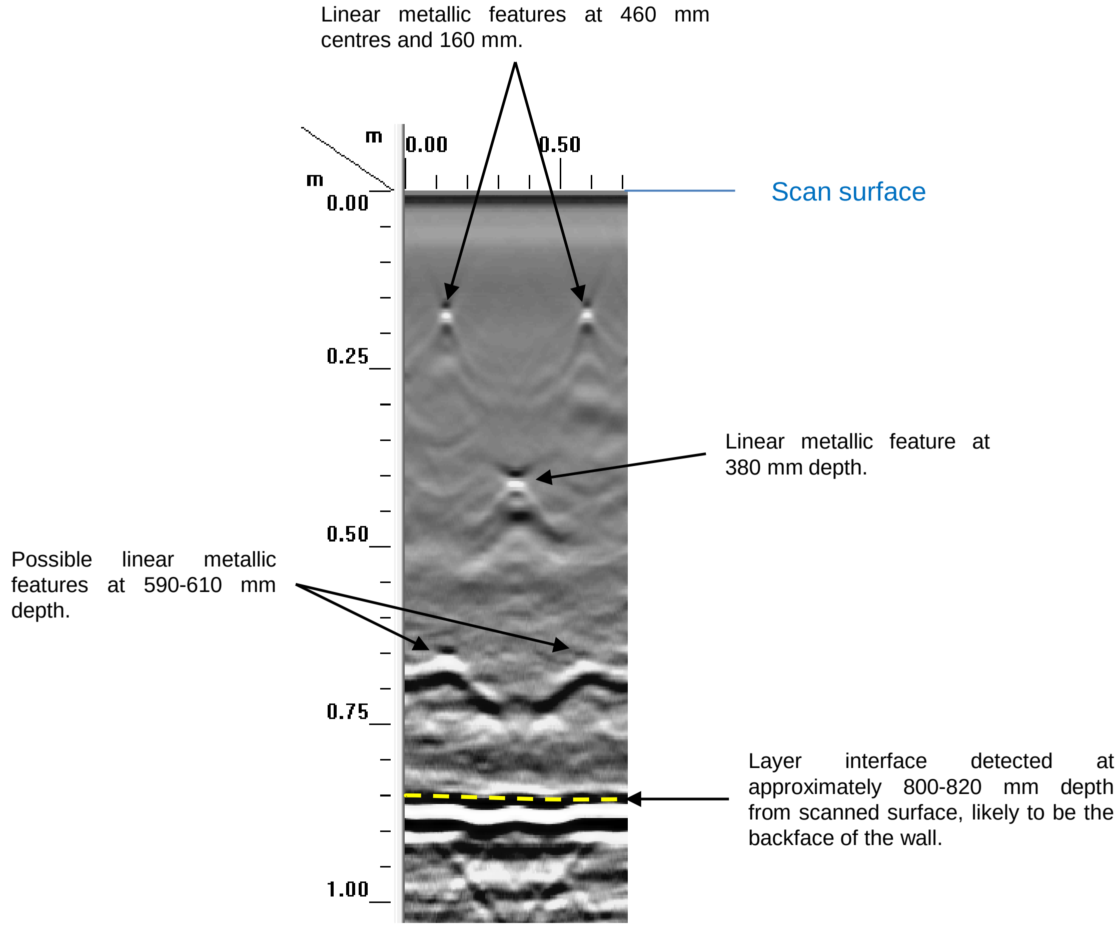

Figure 2: Typical radargram collected on the face of the granite support wall showing the features detected. All depths quoted are from the scanned surface.

PLATES

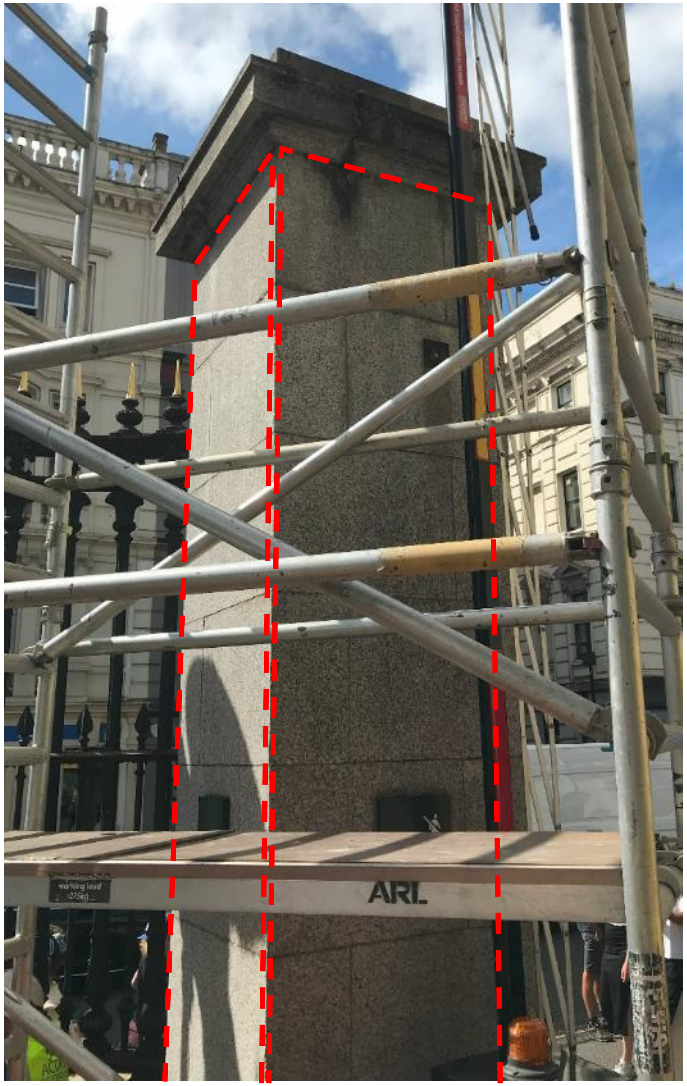

Plate 1: Photograph of the gate pier showing the two faces scanned during the GPR survey (highlighted in red).

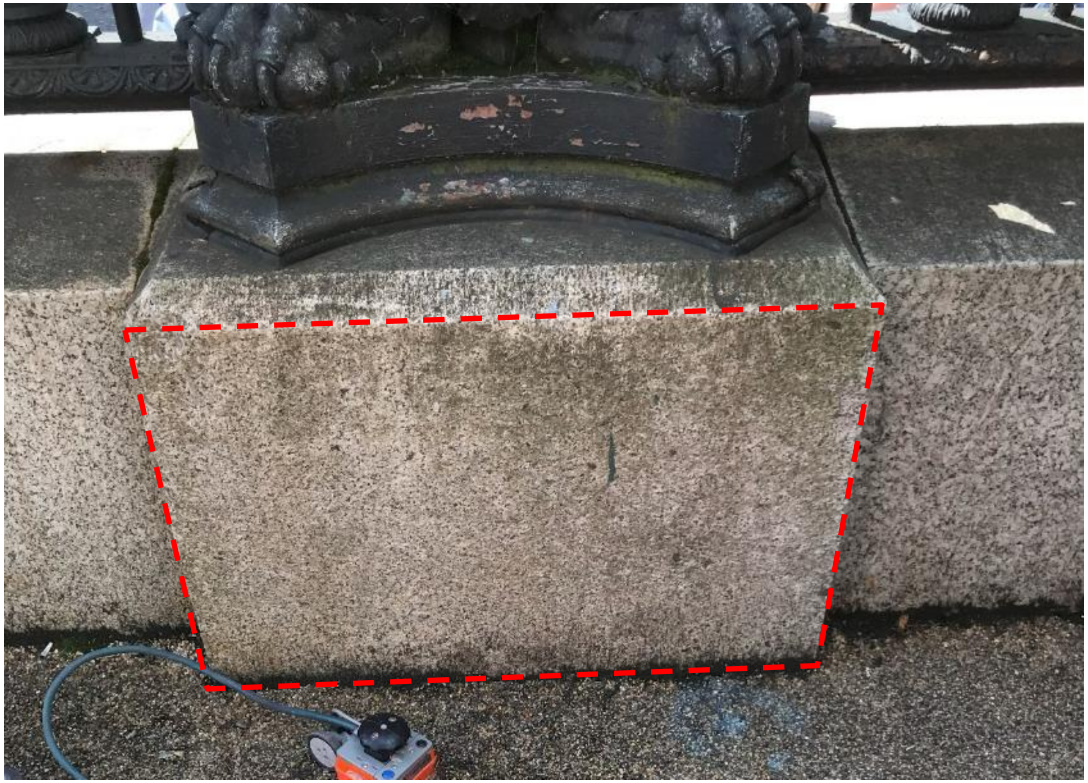

Plate 2: Photograph of the granite support wall showing the area scanned during the GPR survey (highlighted in red).

APPENDIX A

GROUND PENETRATING RADAR

GROUND PENETRATING RADAR (GPR)

A1 Principles of Ground Penetrating Radar

Ground Penetrating Radar (GPR) is a non-intrusive technique used to analyse the internal features of a material. It can be used successfully on various construction materials, such as concrete, soil, rock, brick and asphalt.

An antenna (transmitter and receiver combined) is passed over the material under investigation. Pulsed radio waves are transmitted into the material at a high frequency. The radio waves travel through the material, but a small proportion is reflected from interfaces between layers of differing composition; the reflection is an effect caused by a change in the medium's electrical, magnetic or dielectric properties through which the signal is passing. A receiving element within the antenna detects the reflected radio waves and sends the data to the GPR system's control unit, where it is stored electronically and displayed in real time on a screen.

GPR can estimate the depth and thickness of materials by measuring the time taken for the radio signal to travel from the transmitter to a material boundary and back to the receiver. The velocity with which the radio waves travel through a material is dependent on the relative permittivity. If this is known, for instance, as a result of a calibration exercise, the depth or thickness of detected features can be determined.

GPR can be used to identify items such as pipes, cables, reinforcing steel, voids, interfaces between separate layers of construction and the thicknesses of those layers; it also reveals imperfections such as voids and honeycombing.

A2 Survey Equipment

GPR equipment consists of three principal components:

i) A control unit incorporating a data recording facility and a display screen.

ii) An antenna that transmits an outgoing electromagnetic signal and receives back the reflected waves.

iii) A distance-measuring wheel attached to the antenna that enables recorded data to be positioned along a scan line.

The antenna is drawn over the target surface along a series of straight lines, most commonly forming a regular grid.

GPR scans can be conducted using antennas with different central frequencies. A higher frequency antenna provides better resolution and more detail; however, the penetration depth is limited. A 1.5 GHz antenna would typically penetrate to a depth of 400 mm in concrete.

A lower frequency provides better depth penetration, but the resolution is not as good, and difficulties may be experienced in penetrating beyond layers of reinforcement. Under favourable conditions, a 400 MHz antenna can penetrate to a depth of at least 1.5 m in concrete.

A3 Calibration

Depth measurement may be calibrated by scanning an area of known depth or thickness and then using this information to calculate the material's relative permittivity. Subsequent depths or layer thicknesses identified in scans can then be determined by analysis of the recorded data.

Variations in moisture content, density, and the material's compaction all affect the velocity of the radio waves through the medium. The calculated depths of features will also be affected by these parameters.

The GPR equipment utilises a survey wheel that measures the distance travelled by the antenna and regulates the scan rate so that scans have a meaningful proportion. Distance measurement is regularly calibrated and saved within the GPR system, and an on-site check is always conducted during a survey.

A4 Data Analysis and Interpretation

All radar data is stored electronically and uploaded at our Clapham office for analysis and record purposes. Analysis of the GPR data is conducted using GSSI Radan 7 software.

Manual processing, visual interpretation and plotting are first carried out on the collected GPR data. The following is a brief summary of the more common processing techniques:

1. Surface Position Adjustments

   Sometimes, it is necessary to adjust the whole profile's position vertically in the data window (adjust time-zero). A corrected 0-position will give you a more accurate depth calculation because it sets the top of the scan to a close approximation of the ground surface.

2. Surface Normalisation (Adjusting for Elevation Changes)

   Surface Normalisation adjusts the vertical scale to remove topographic effects, resulting in horizontal or near-horizontal reflectors appearing as they are in reality.

3. Increasing Visibility Of Low Amplitude Features

   Gain may be used to emphasise low-amplitude sections of data or accentuate small amplitude differences. GPR data will often exhibit large amplitude variations. The low amplitude regions of survey data are often difficult to interpret from the raw field data. There are three methods in RADAN to enhance low amplitude sections of data or accentuate small amplitude differences:

   i) Adjust Range Gains
   ii) Adjust Display Gain
   iii) Change the Colour Transform

4. Migration

The radar antenna radiates energy with a wide beamwidth pattern such that it may detect objects several feet away. Consequently, objects of finite dimensions may appear as hyperbolic reflectors in the radar record as the antenna detects the object as it approaches it, moves over it, and then past it. Migration collapses the hyperbolic reflectors to a single point visually representative of features within the sub-surface.

5. Data Filtering

A variety of filters are available to remove system noise and interference. The filters include:

i) Vertical High Pass Filter
ii) Horizontal High Pass Filter
iii) Spatial Filter
iv) Background Removal
v) Vertical Low Pass Filter
vi) Horizontal Low Pass Filter
vii) Spatial Filter

3D models may then be generated for the areas by combining the data from the individual scanlines. All data is appraised for information about construction details, services, and other relevant features.

GPR can be used to map reinforcement, differentiate between dissimilar materials, detect voids and locate debonding between layers of otherwise homogeneous materials. However, other properties such as variable moisture content, different compaction levels, cracking or segregation can also affect the GPR signal; interpretation of the data, therefore, includes a subjective element. Wherever the results are relevant to safety (e.g. structural design or analysis), it is recommended that physical methods are used to confirm the interpretation of the site measurements.

Where test results are given, the results and our conclusions relate only to the samples tested and apply to the sample(s) as received, except where sampling has been conducted by Sandberg LLP.

Materials, samples and test specimens are retained for a period of 2 months from the issue of the final report.

Tests reported on sheets not bearing the UKAS mark in this report/certificate are not included in the UKAS accredited schedule for this laboratory.

Opinions and interpretations expressed herein are outside the scope for UKAS accreditation.

End of report.

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