Geophysical Survey Report

Church of St Michael, Cropthorne, Worcestershire

For

Stainburn Taylor and Michael Reardon

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J2061

Hannah Heard BSc (Hons)

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Field Team:	Hannah Heard BSc (Hons) and Swinnertons Steeplejacks
Project Manager:	Peter Barker C.Eng MICE MCIWEM MIFA

Report written by:	Hannah Heard BSc (Hons)
CAD draughting by:	Hannah Heard BSc (Hons)
Checked by:	Peter Barker C.Eng MICE MCIWEM MIFA

Stratascan Ltd.

Vineyard House
Upper Hook Road
Upton upon Severn
WR8 0SA

Tel: 01684 592266
Fax: 01684 594142
Email: ppb@stratascan.co.uk

www.stratascan.co.uk

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1 SUMMARY OF RESULTS

A GPR survey was carried out on the external walls of the Tower of the Church of St Michael in Cropthorne, Worcestershire. A large number of small voids have been identified across all faces of the tower most of which are likely to have been incorporated into the fabric at the time of construction. Further erosion of these construction voids can be identified across all external walls of the tower. Three possible voids have been identified within the radar data, two within the south wall and one within the west. A general reduction in the number of anomalies have been identified towards the bottom sections of the west and north walls, suggesting an absence of voids within these areas.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey of an area outlined for development. This survey forms part of an investigation being undertaken by Stainburn Taylor and Michael Reardon subject to a repair scheme of the Church in 2006.

2.2 Site location

The site is located at the church of St Michael in Cropthorne, Worcestershire at OS NGR ref. SO 001 452

2.3 Description of site

The site is the 12th century church tower of St Michaels. The survey area covers the four external walls of the tower. Obstructions include a clock on the south wall and a belfry window on each wall. The tower is approximately 16m tall and approximately 6 metres square.

The construction of the tower consists mainly of lias and mortar with oolitic limestone ashlar quoins and mullions. The surface of the tower is rough with areas of surface erosion.

Plate 1: Showing construction material and surface of the church tower

2.4 Survey objectives

The objective of the survey is to assess the extent of any voids within the thickness of the rubble masonry walls of the tower.

2.5 Survey methods

Ground Penetrating Radar (GPR) was considered to be the most suitable method for the survey due to its ability to penetrate though building material and identify changes in the sub-surface material.

More information regarding this technique is included in the Methodology section below.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over 2 days from the 20-21st of September 2005 when the weather was fine.

3.2 Grid locations

The location of the survey grids has been plotted in Figure 1.

3.3 Description of techniques and equipment configurations

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 and 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 (see 3.4.2 below).

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 Probing Impulse Radar used was a SIR2000 system manufactured by Geophysical Survey Systems Inc. (GSSI).

The radar surveys were carried out with a 1500MHz antenna. This high-range frequency offers an exceptional spatial resolution for a given depth of penetration.

The radar traverses were collected with the assistance of Swinnertons steeplejacks. A bosun's chair and electric winch were set up at the top of the tower to allow the radar antenna to be placed on the surface of the walls and lowered down at a steady speed.

3.4 Sampling interval, depth of scan, resolution and data capture

3.4.1 Sampling interval

Radar scans were carried out along traverses 0.5m apart where possible on a parallel grid as shown in Figure 3. Data was collected at 400 scans/metre. Due to the rough surface of the wall, constricting the use of a survey wheel, the survey was carried out in a continuous mode with markers placed manually at every metre.

3.4.2 Depth of scan and resolution

The average velocity of the radar pulse is calculated to be 0.09m/ns which is typical for the type of material of the tower walls. With a range setting of 10ns this equates to a maximum depth of scan of 0.45m 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.

3.4.3 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.

3.5 Processing, presentation of results and interpretation

3.5.1 Processing

The radar plots included in this report have been produced from the recorded data using Radan software. Filters were applied to the data to remove background noise.

3.5.2 Presentation of results and interpretation

Manual abstraction
Each radargram has been studied and those anomalies thought to be significant were noted and classified as detailed below. Inevitably some simplification has been made to classify the diversity of responses found in radargrams.

i. Strong and weak discrete reflector.
These may be a mix of different types of reflectors but their limits can be clearly defined. Their inclusion as a separate category has been considered justified in order to emphasise anomalous returns which may be from archaeological targets and would not otherwise be highlighted in the analysis.

ii. Complex reflectors.
These would generally indicate a confused or complex structure to the subsurface. An occurrence of such returns, particularly where the natural soils or rocks are homogeneous, would suggest artificial disturbances. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface, which in turn may be associated with a marked change in material or moisture content.

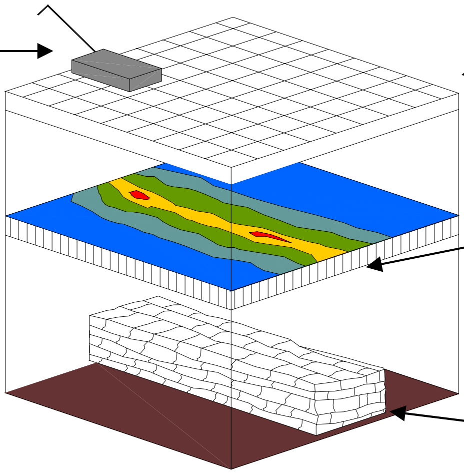
iii. Point diffractions.
These may be formed by a discrete object such as a stone or a linear feature such as a small diameter pipeline being crossed by the radar traverse (see also the second sentence in 4. below).

iv. Convex reflectors and broad crested diffractions.
A convex reflector can be formed by a convex shaped buried interface such as a vault or very large diameter pipeline or culvert. A broad crested diffraction as opposed to a point diffraction can be formed by (for example) a large diameter pipe or a narrow wall generating a hybrid of a point diffraction and convex reflector where the central section is a reflection off the top of the target and the edges/sides forming diffractions.

v. Planar returns.
These may be formed by a floor or some other interface parallel with the surface. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface which in turn may be associated with a marked change in material or moisture content.

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 (Figures 2-5). 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. Based on an average velocity calculations 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.

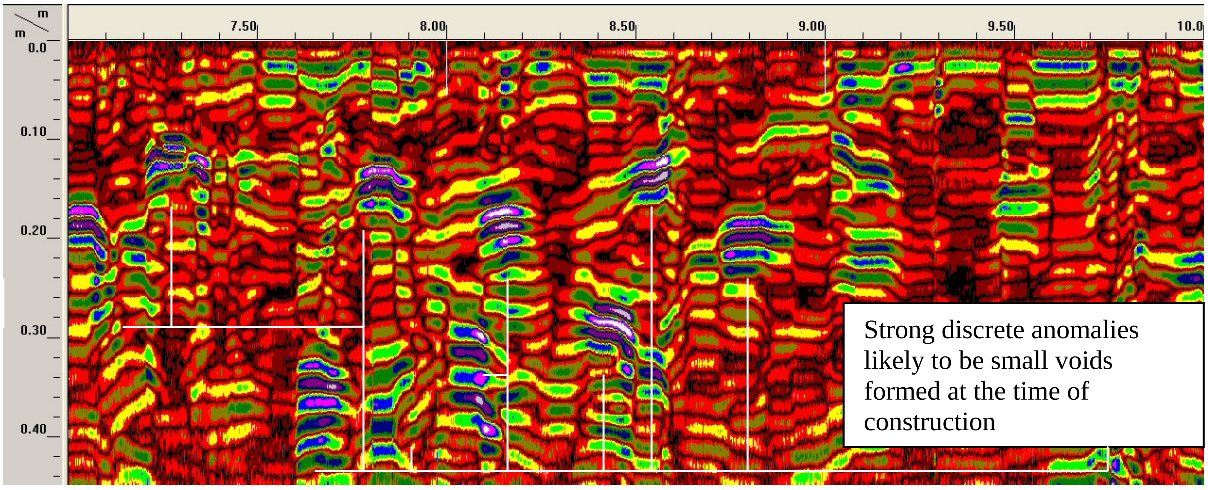
The weaker reflections in the time slice windows are shown as dark colours namely blues and greens. The stronger reflections are represented by brighter colours such as light green, yellow, orange, red and white (see key provided in Figures 2-5).

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 RESULTS

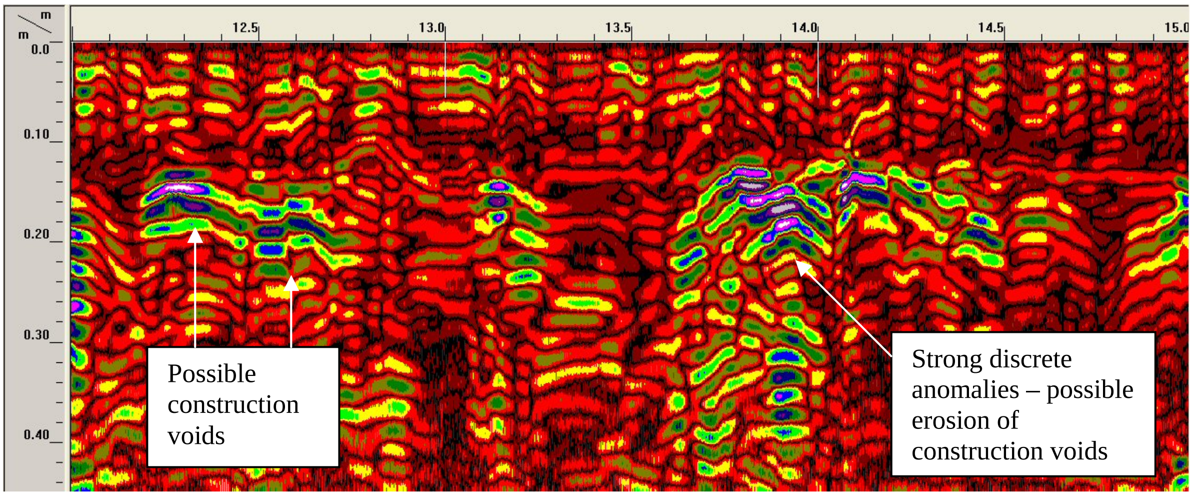
The manual abstraction of the radar has produced a large number of radar anomalies. The data is dominated by a large number of strong discrete responses with an average length of 0.1m ranging in depth from 0.07 to 0.35m. These anomalies appear frequently within the radar data and may represent small voids created during the construction of the tower. The responses mainly appear at a depth of 0.09-0.15m. It is likely that these voids lie to the rear of the outer face of lias blocks (Example Radargram 1). Therefore, any anomalies larger in size, depth or thickness to these possible construction anomalies must be considered as possible voiding or further erosion of the construction voids.

The south wall has produced the strongest evidence for possible voiding or faults present within the wall construction. The lower half of the west wall has produced the least amount of radar anomalies, suggesting the absence of possible voiding.



Example Radargram 1: West wall, 5.2E, 7-10. Showing strong discrete responses that may be the caused by the tower construction

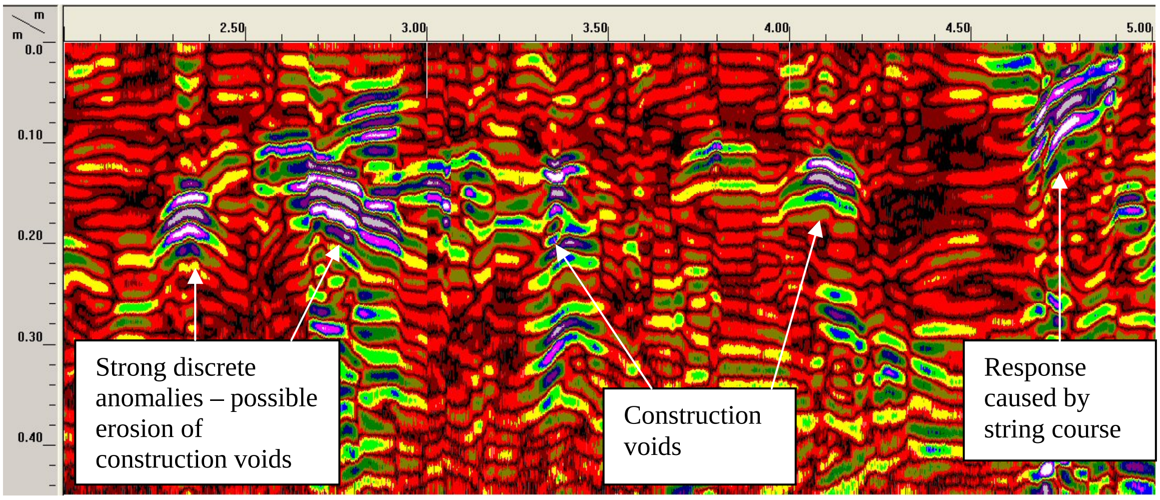
North wall
A large number of possible construction voids have been identified within the north wall. Particularly strong discrete responses have been targeted as possible areas of further degradation of original construction voids (Example Radagram 2). No evidence for substantial voiding has been identified within the north wall.



Example Radargram 2: North wall, 4.5E, 12-15. Strong discrete response possibly indicating erosion of construction voids

East wall

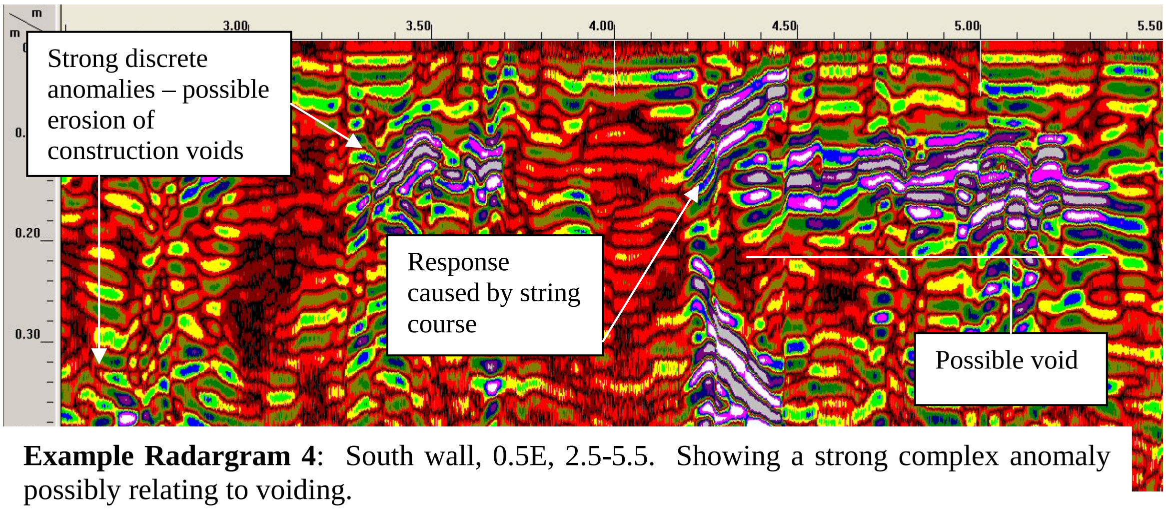
A number of possible construction faults have been identified within the east wall, mainly situated around the central window at depths of 0.07-0.13m (Example Radargram 3). No substantial voiding can be identified within the east wall.



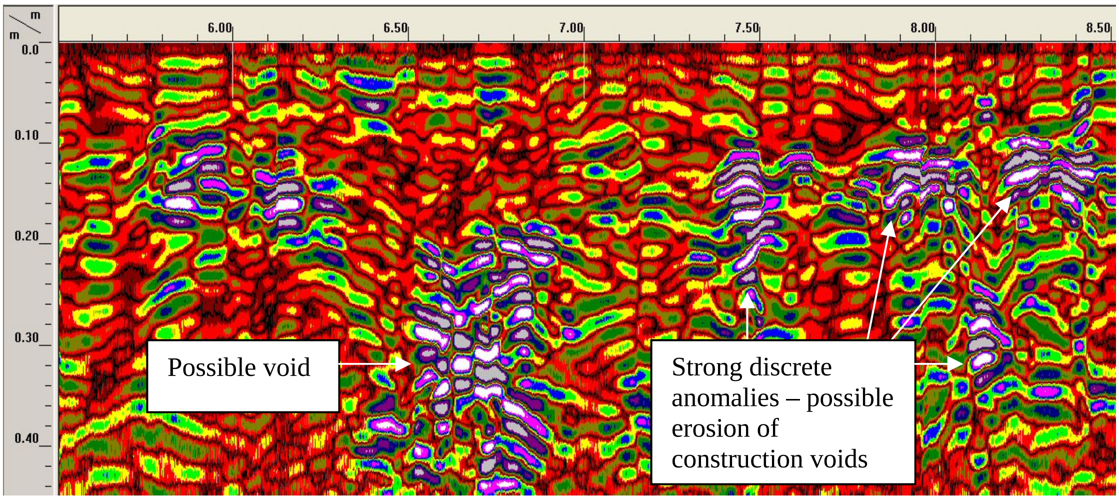
Example Radargram 3: East Wall, 1.5E, 2-5. Strong discrete responses possibly indicating further erosion of construction voids

South wall

Two large areas of strong complex and discrete responses have been identified to the left of the main window. These two area responses indicate possible voids, with the lower void extending to depth (example Radargram 4 and 5)



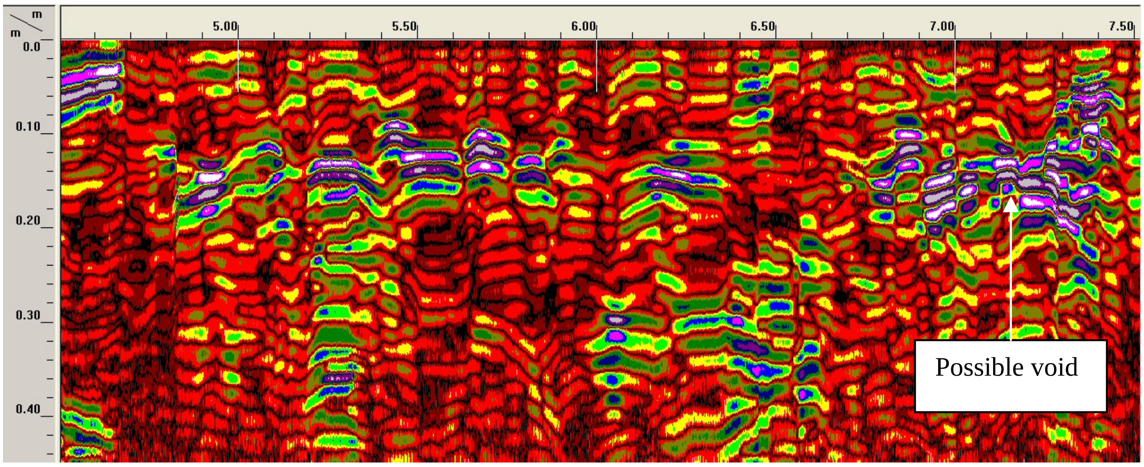
Example Radargram 4: South wall, 0.5E, 2.5-5.5. Showing a strong complex anomaly possibly relating to voiding.



Example Radargram 5: South wall, 0.5E, 5.5-8.5. Strong complex area indicating a possible void extending to depth

West wall

Within the west wall a large number of possible areas of erosion from construction voids can be identified. A small void has been identified within the centre right of the wall (Example Radargram 6). However, there appears to be a reduction in discrete responses towards the bottom left of the tower, suggesting an absence of construction voids.



Example Radargram 6: West Wall, 4.2E, 4.5-7.5. Showing strong complex anomaly possibly indicating a void

5 CONCLUSION

Three possible larger voids have been identified with the GPR survey. Two possible voids are situated in the south wall left of the main window, the lower void may extend to depth (see Example Radargram 5). Another possible void has been identified within the centre right of the west wall (see Example Radargram 6). The radar data is dominated by strong discrete anomalies at depths of 0.07-0.15m. These anomalies have been interpreted as small voids created during the construction of the tower. Areas of particularly strong responses may represent further erosion of these construction voids and have been identified across all four faces of the tower. A reduction in the number of anomalies identified towards the bottom of the west and north wall suggest the absence of possible voiding within these areas.