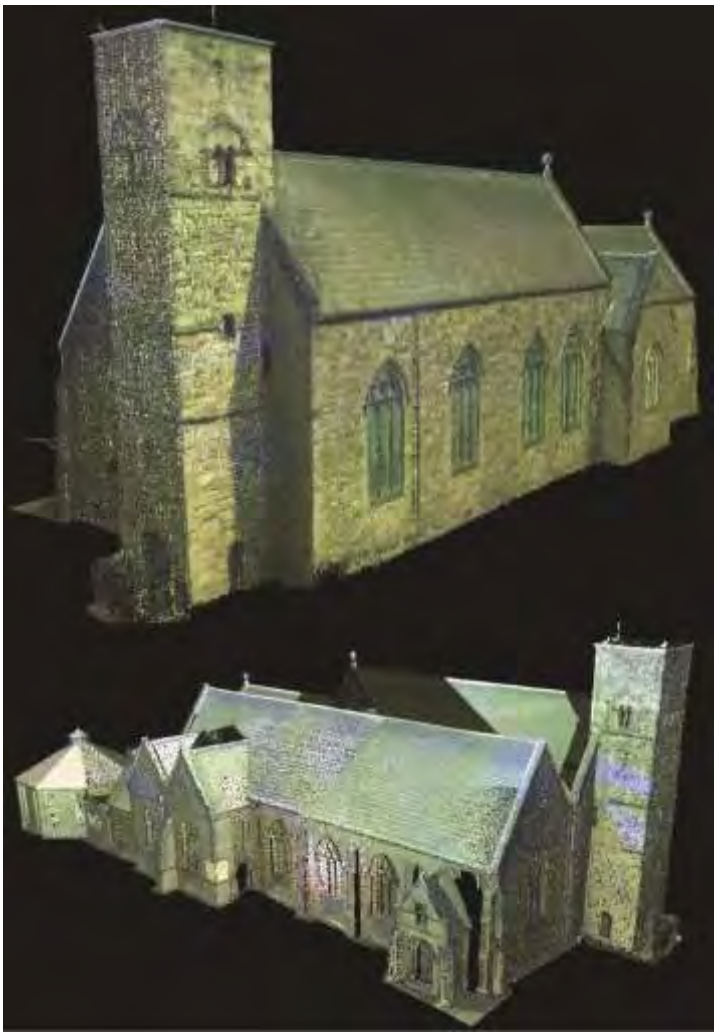
Report on the HDS Laser Scanning of St Paul's, Jarrow and St Peter's, Wearmouth 2010 and 2011



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McCord Centre Report 2014.4

Newcastle University

McCord Centre for Historic and Cultural Landscape

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Front piece: Point cloud for St Peter's, Wearmouth viewed from west end. Opaque views using colours from camera.

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SUMMARY

A Leica Scanstation II was used to create a high definition scan of the early medieval structural components of St Paul's, Jarrow and St Peter's, Wearmouth. In addition further scans were made of the later fabric of both buildings to enable a complete model of each church to be established. This data was further used to create solid mesh models of elements of each of the churches and combined with the petrological data to examine the physical distribution of the stone materials through time. Additional ultra-high resolution scans by Conservation Technologies, National Museums' Liverpool were carried out in advance of conservation work on the carved reliefs of the porch at St Peter's Church, Wearmouth. Some areas of both structures were not scanned due either to problems of access or constraints of time. Additional work outside of the scope of this project will be carried out to address some of these issues in 2014.

ACKNOWLEDGEMENTS

The author would like to thank Bill Braviner, Tom Gibbons, Jimmy Guy, Jenny Lancaster, Ian Nicholson and Ian Stockton for facilitating access to St Peter's and St Paul's and providing assistance during the surveys. The author would also like to thank Professor John Mills, Dr Pauline Miller and Martin Robertson for their invaluable assistance with the provision of equipment and processing of the scanning data.

INTRODUCTION

During June and July 2010 a series of laser scans were undertaken around the churches of St Paul's, Jarrow and St Peter's, Wearmouth. The aim of these scans was to create an accurate surface record of the stone material used in both buildings with the intention of both assisting the conduct of the petrological survey (Figure 1) and subsequently integrating the resulting three dimensional data with the detailed petrological information. The scan data was also used to plan the position of the samples for OSL dating. (Figure 2) In addition it was hoped that the sub-surface GPR data collected as part of the geophysical survey phase of the project could be integrated with the above ground survey data to create a unified model of the structure of the church. Ultimately, due to the nature of the data collected at both churches, this was limited to St Paul's, Jarrow where the potential evidence for the existence of a crypt provided by the GPR data has been married with the above surface laser scanning data of the eastern chancel of the church to generate a hypothetical model of the church complete with crypt. The potential for further processing and analysis of this data still remains but this will be outside the scope of this project and will be the subject of future application of new equipment, software and modelling techniques.

METHODOLOGY

The digital survey of the structure of both churches was carried out using a Leica Scanstation II pulsed dual-axis compensated very-high speed laser scanner.

The data was used in conjunction with the petrological examination of each structure to provide data suitable for use in VRMesh and 3Dstudio Max for the examination and modelling of the changes in stone-construction techniques through time for each building. The acquisition of

some data at a higher resolution was based on the physical examination of the building and was undertaken in consultation with the petrological specialist. The instrument used was a Leica Scanstation II which provided an accuracy of 4 mm for measurement of distance and 6 mm for accuracy of position, within a measurement range of between 1.5 m and 50 m. The accuracy for horizontal and vertical angles is defined as 60 micro-rad. The resolution for the scanning took into account the accuracy limitations of the instrument and followed current practice and EH recommendations in using a point cloud density of between 0.5mm, for detailed examination of individual architectural elements such as the carvings on the porch at St Peter's Church, and 35mm for capture of data for the later Victorian elements of both structures (EH 2007, 10).

A network of stations was established around each building using a Trimble DR5600 Total Station and the Scanstation was used to make a traverse of scans from each of these points around each of the structures. Nine survey stations were established at St Peter's (Figure 3) and 12 stations were established at St Paul's (Figure 4). Where additional stations were needed but couldn't be physically marked with survey nails, for example with the porch at St Peter's, temporary stations were established only for the duration of the scanning. Additionally, during the scanning phase the positional data of several temporarily positioned reflective targets was collected but means of additional high resolution scans and these were used as control points along as part of the processing of the high resolution scans. In order to complete the surveys at both churches multiple stations were required. Medium resolution digital photographs were taken as an integrated part of the scanning process.

Cyclone v6.3 software was used to align the point clouds acquired by the laser scanner and to generate global 3D models using the Survey Registration and Cloud Registration procedures. Each scan was roto-translated to the local grid system utilising the coordinates of the control points. VRMesh 6.1.1 and Autodesk 3DStudio MAX 2010 software was used to manage the 3D models and generate meshes, combined with the petrological data to provide textural representation of the structures (Figure 5).

RESULTS

St Paul's, Jarrow (Figures 1, 4, 5, 6, 7)

The chancel of St Paul's was scanned at a resolution of 10mm for all the major structural elements. Some additional scans of the south wall were undertaken with at a resolution of 5mm. The western Victorian end of the church was undertaken with a scanning resolution of 20mm. The resultant scans were registered in Cyclone 6.03 and filtered for extraneous data. A single unified point cloud was generated for export as a .PTS file to VRMesh 6. Within VRMesh the point cloud was converted into a series of mesh surfaces and exported to 3DStudio MAX for texturing. Data from this textured model was also combined with the petrological surface to build the final petrological model of the location of all the early new and re-used Roman stone at St Paul's.

St Peter's, Wearmouth (Figures 3, 8, 9)

The same approach to survey of the structure was used at St Peter's, as was the processing methods. However, here the original petrological survey drawing were scanned and applied as a texture to the final solid model within VRMesh rather than the model construction approach used at St Paul's. This enable a good comparison of the merits of the two methodologies as far as understanding the results was concerned. The approach used at St Peter's was simpler and less time consuming in terms of the construction of a usable model but is lacking in some of the ability to generate future hypothetical models of the sequence of building construction.

In addition to the scanning of the building a further series of scans was carried out of the topographic surroundings of the church. This was done using a 5cm resolution and modelled within ArcGIS as an aid to understanding the relationship between the two sides of the church. The 4 metres+ of ballast to the north of the church has a significant effect on the visualisation of the monastic settlement in the pre-industrial era. The model of the terrain also proved useful, in conjunction with the borehole data, in understanding the results from the GPR survey.

Conservation Technologies, National Museums Liverpool, St Peter's Porch, Wearmouth

As part of the pre-conservation process an ultra-high resolution scan of the carved reliefs of the porch at St Peter's was undertaken. The report and metadata are included below.

ILLUSTRATIONS

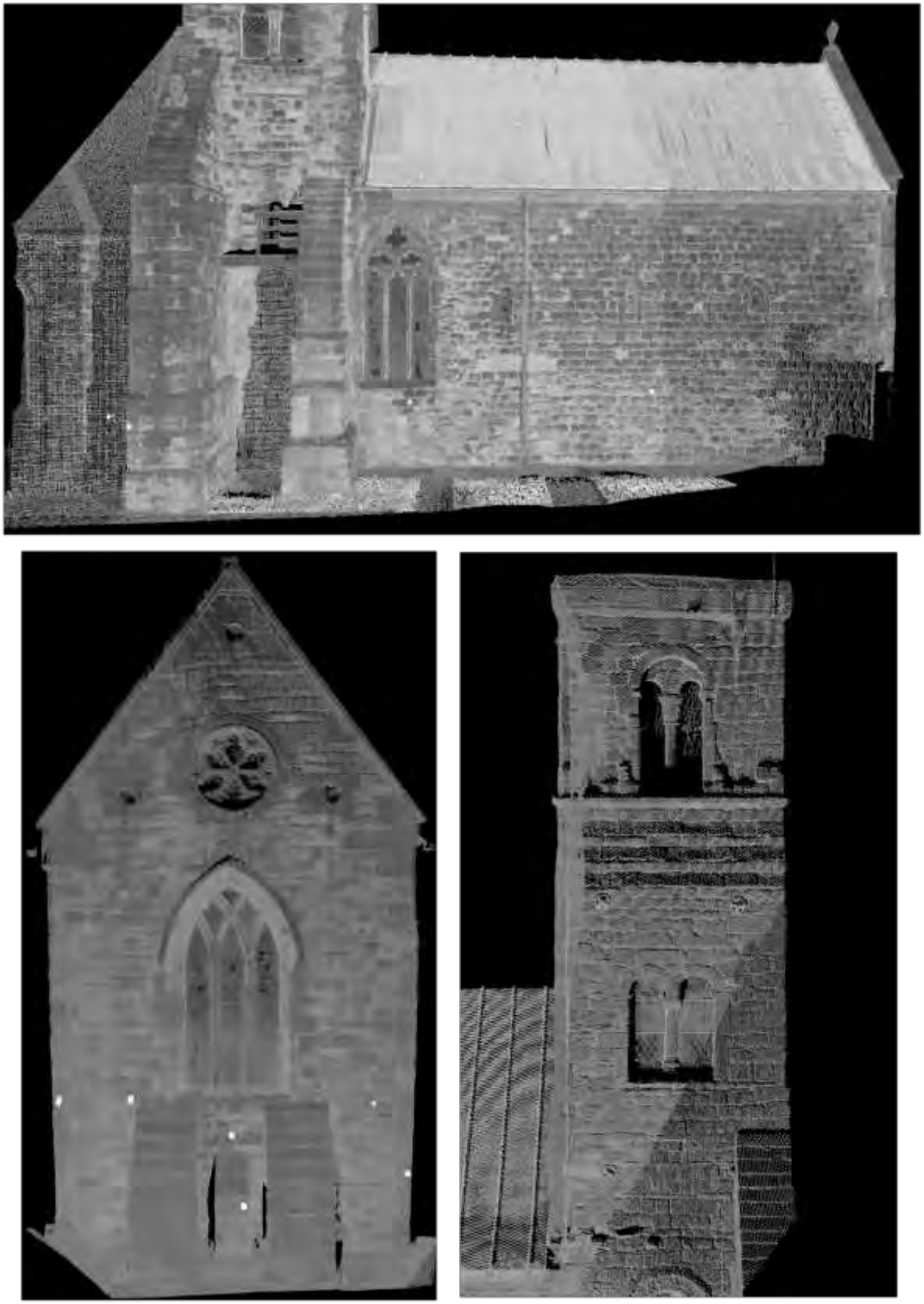


Figure 1: St Paul's, Jarrow. Monochrome images of the laser scanning used to assist in the recording of the petrology.

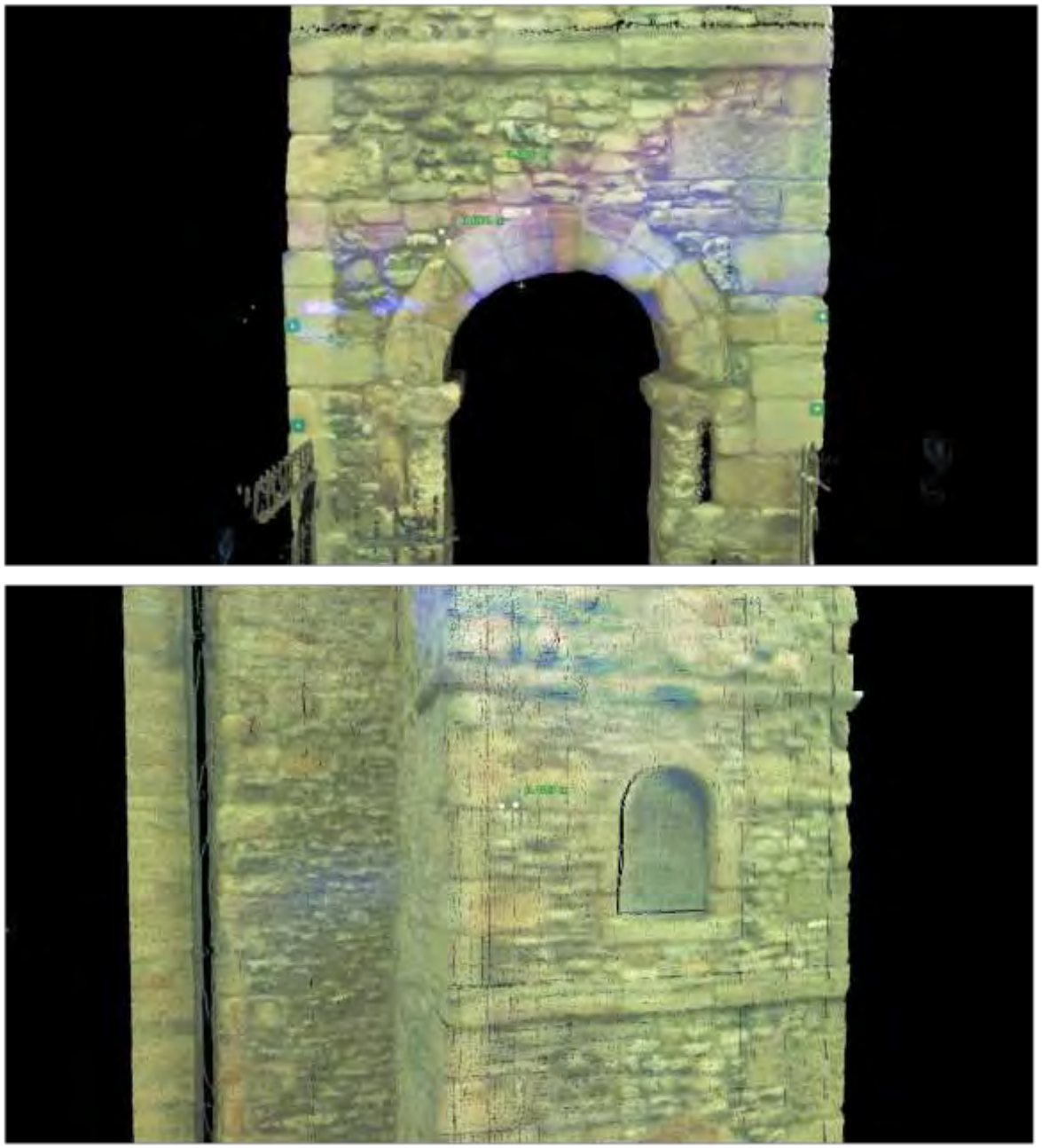


Figure 2: Two proposed OSL locations St Peter's, Wearmouth. Basic scans were used to assist in deciding OSL sample locations.

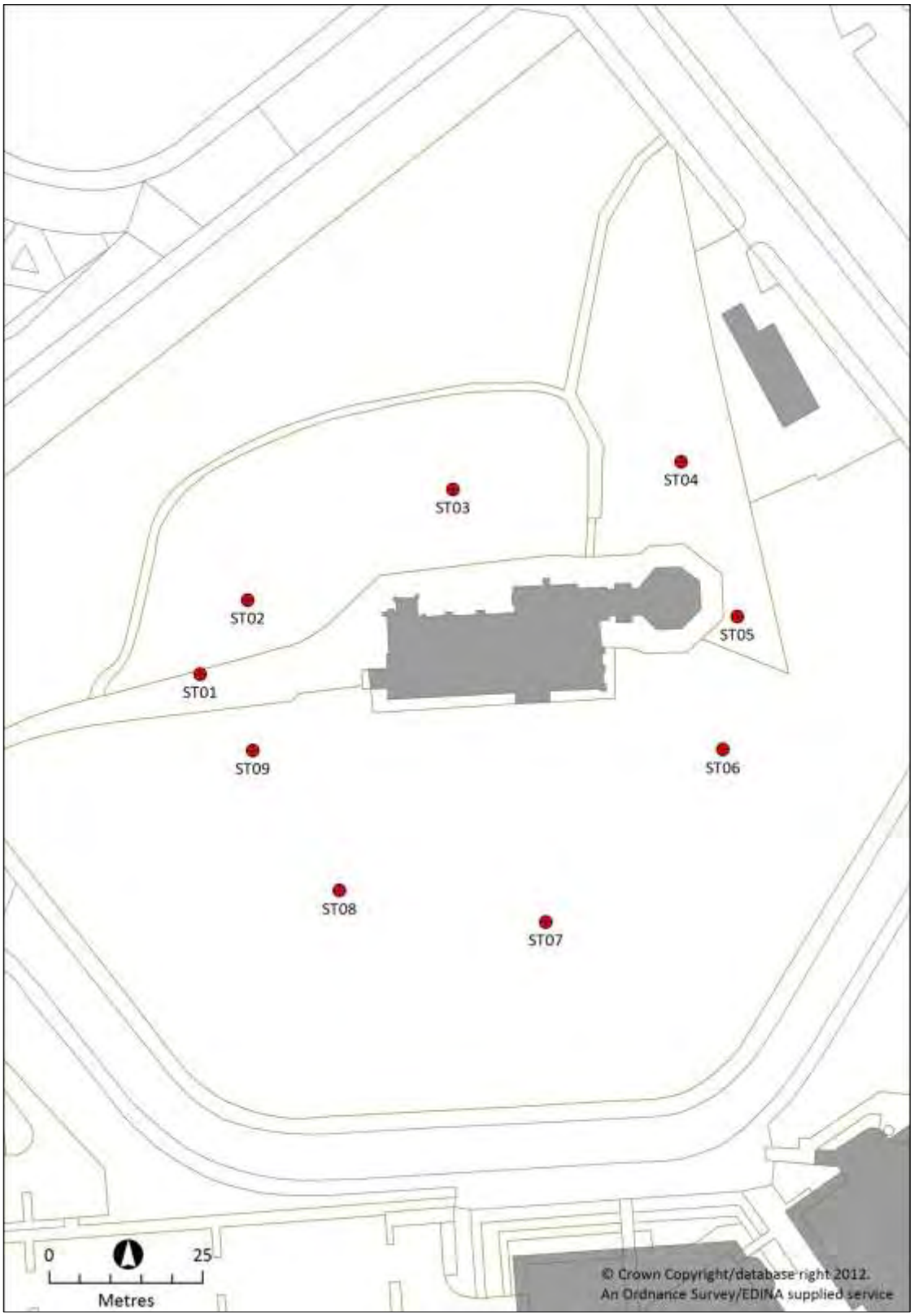


Figure 3: Location of fixed survey stations at St Peter's, Wearmouth

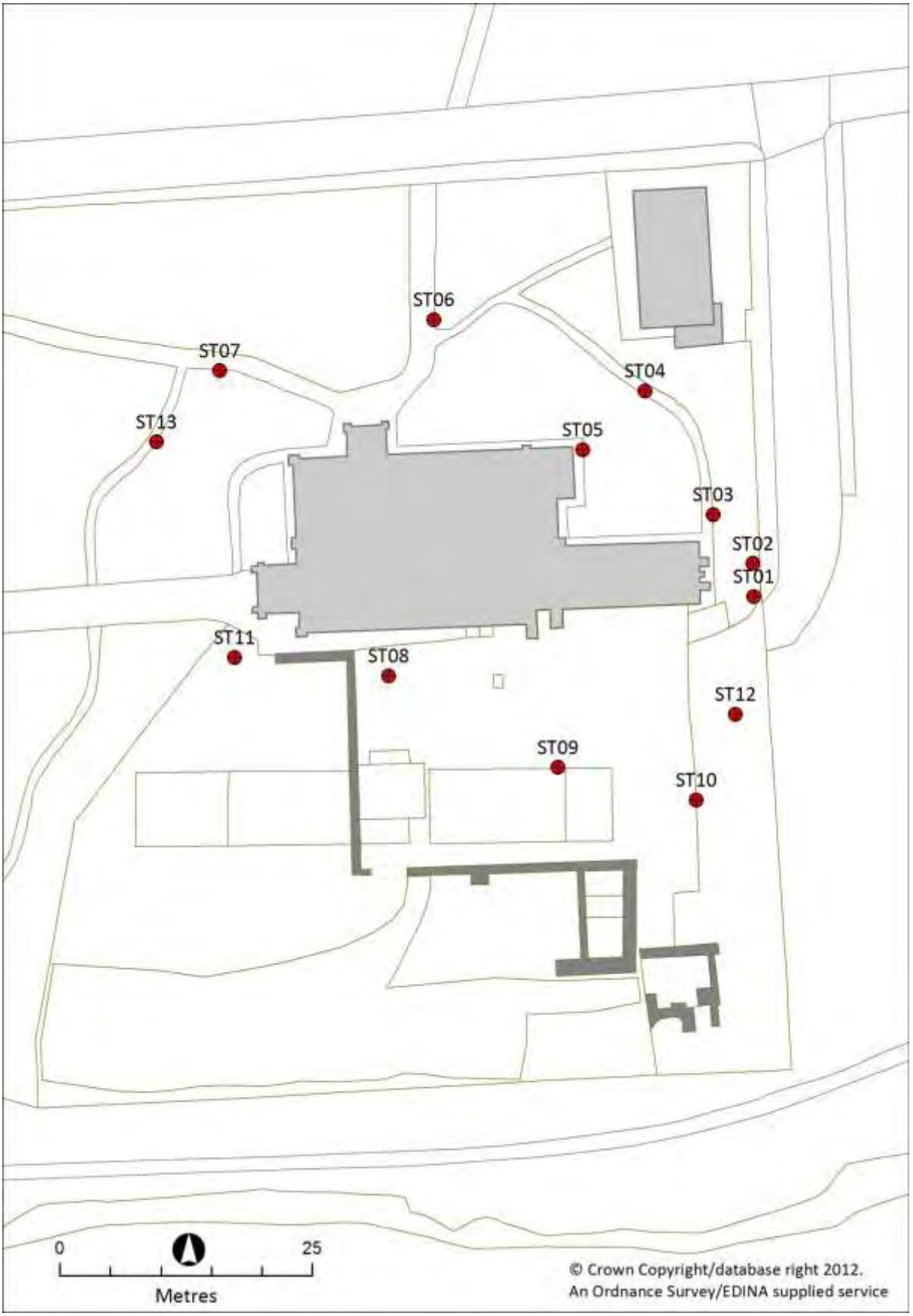


Figure 4: Location of fixed survey stations at St Paul's, Jarrow

Figure 5: Point cloud for St Paul's, Jarrow viewed from east end. Top opaque view and bottom transparent view using colours from camera.

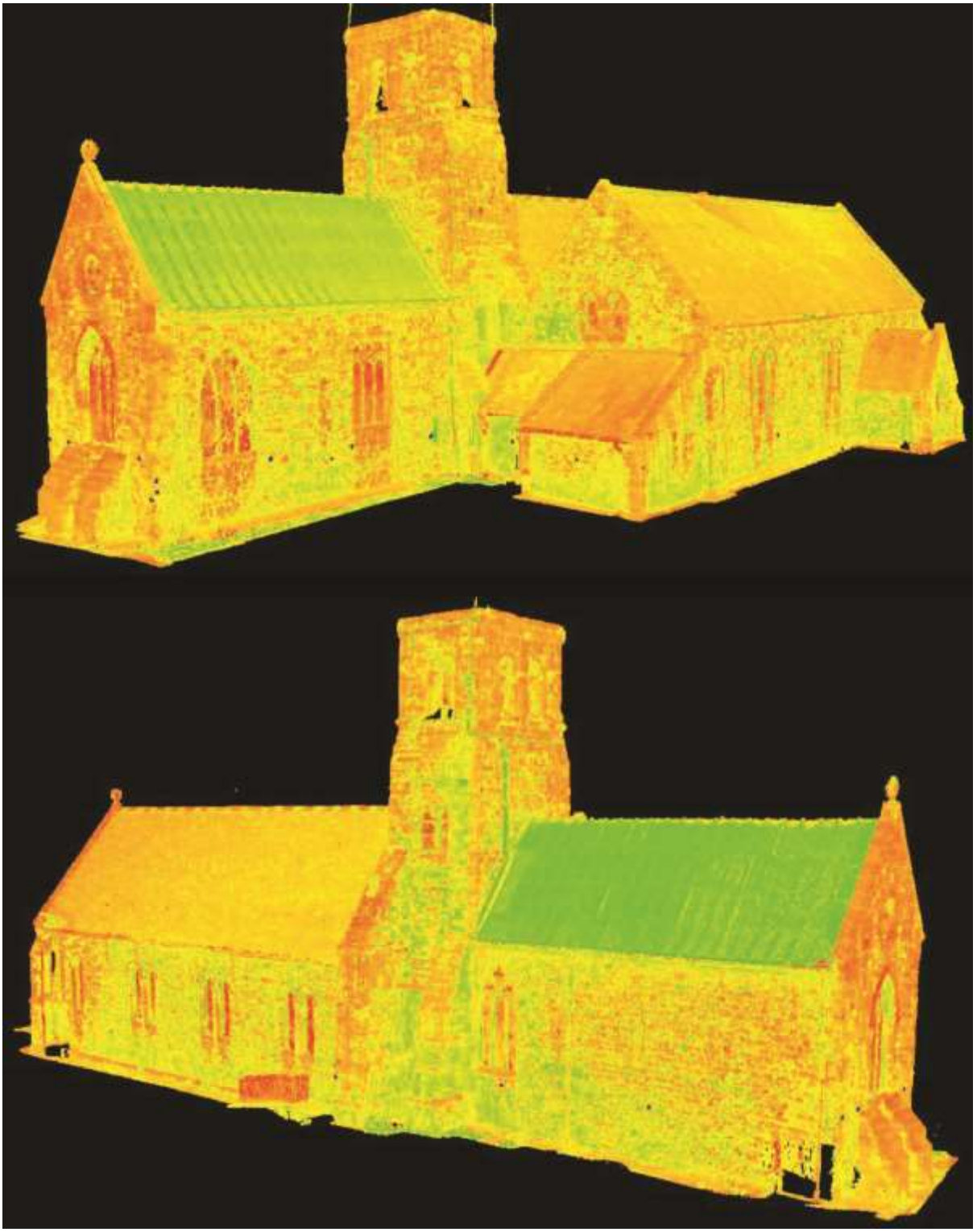


Figure 6: Point cloud for St Paul's, Jarrow viewed from east end displayed using intensity values

Figure 7: Point cloud for St Paul's, Jarrow viewed from west end. Opaque views using colours from camera.

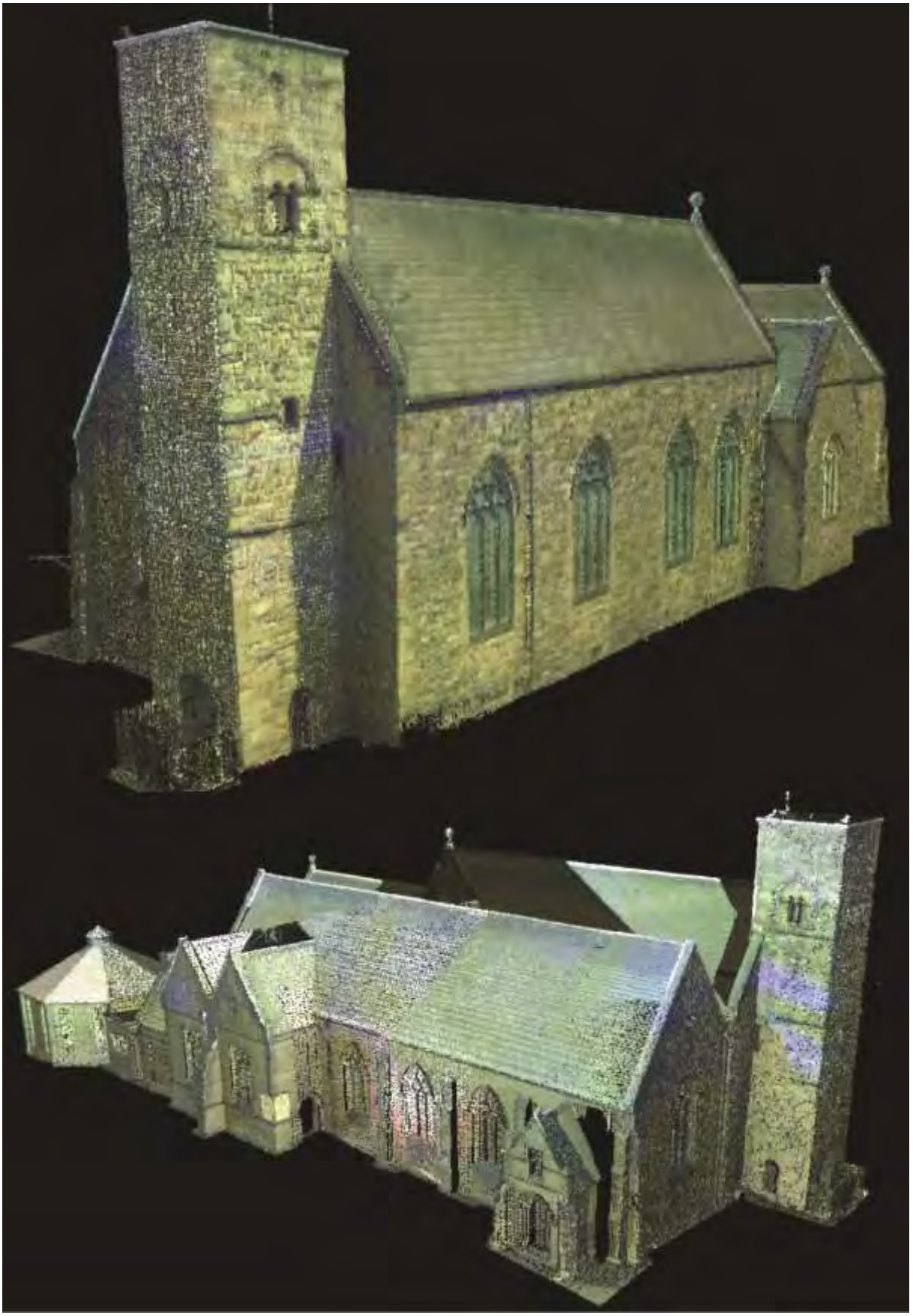


Figure 8: Point cloud for St Peter's, Wearmouth viewed from west end. Opaque views using colours from camera.

Figure 9: Internal (Top) and External (Bottom) point clouds for porch at St Peter's, Wearmouth viewed from west end. Opaque views using colours from camera.

CONSERVATION TECHNOLOGIES: 3D SCANNING METADATA

Job	
Job title:	St Peter's Church (Wearmouth)
Client:	Durham University/Newcastle University
Reason for scanning:	Documentation of carvings before conservation work carried out. Possible repeat scanning in future and evaluation of surface loss. Carvings at risk.
Deliverables:	Raw scan data; polygon mesh model(s) (suitable for monitoring); digital photographs; metadata.
Object	




Carved 7th-century stone reliefs in west porch of St. Peter's church, Wearmouth.

Brief description:	Badly eroded sandstone surfaces. Cobwebs removed as far as possible before scanning – some remained where stone very delicate. Evidence of previous consolidation work. Some areas of stone extremely friable.
Approximate size (mm)	Height of relief and baluster approx. 195cm Width of relief approx. 53cm Depth of relief approx. 32cm Left and right (as viewed from outside)
Nature of surface:	See above
Level of detail:	Sub- millimetre

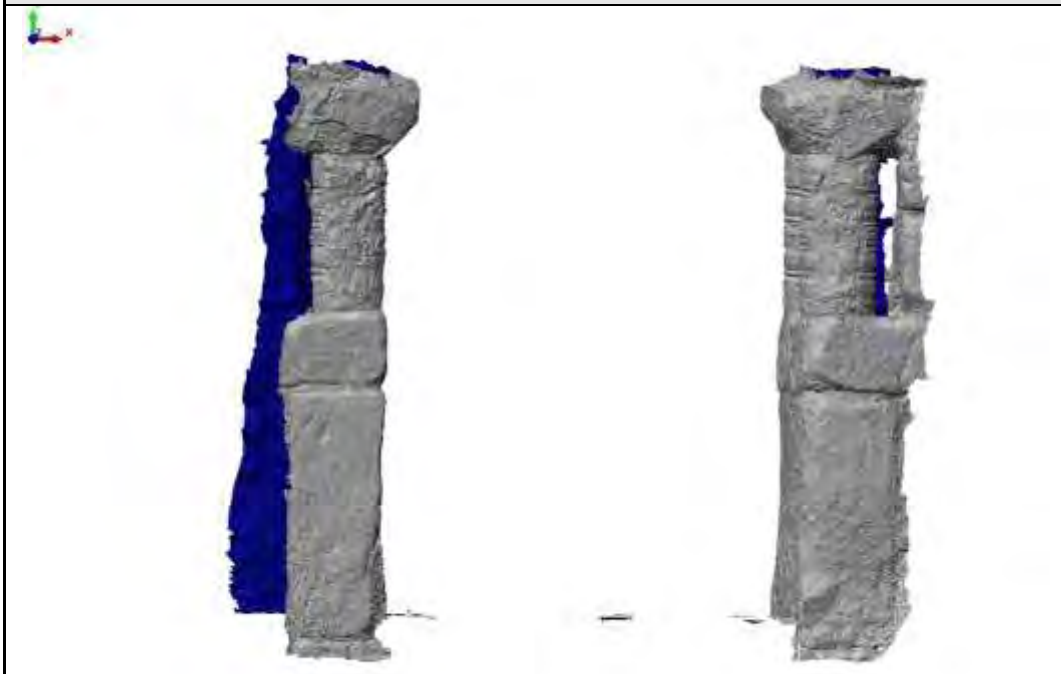
Scanning Process and Scanner Calibration Information			
Location:	St. Peter's church, St. Peter's Way, Sunderland, Tyne and Wear, SR6 0DY		
Scanning set-up:	Modelmaker on portable tripod		
Lighting:	Natural daylight; blankets/umbrellas used later in day to reduce ambient light. Porch facing west so ambient light more of a problem after late morning. Weather was sunny on day 1 and day 2 (am); cloudy day 2(pm) and day 3.		
Carried out by:	AL/MC		
Date:	27-29/07/2011		
Scanner:	ModelmakerX[1]		
Sensor:	X70		
Scanner Calibration			
Arm calibration:	*2σ*	0.0427mm	
	1) RMS (mm):	0.036	
	2) RMS (mm):	0.032	
	3) RMS (mm):	0.039	
Sensor calibration:	*Plane:*	*RMS (mm) (Probe):*	*RMS (mm) (Stripe):*
	1	0.0113	0.020
	2	0.008	0.023
	3	0.011	0.024
	4	0.010	0.017
	5	0.009	0.019
	Distance:		
	Planes 1-3	99.882	100.145
	Planes 2-4	94.888	95.061
	Error:		
	Planes 1-3	-0.204	0.059
	Planes 2-4	-0.184	-0.011

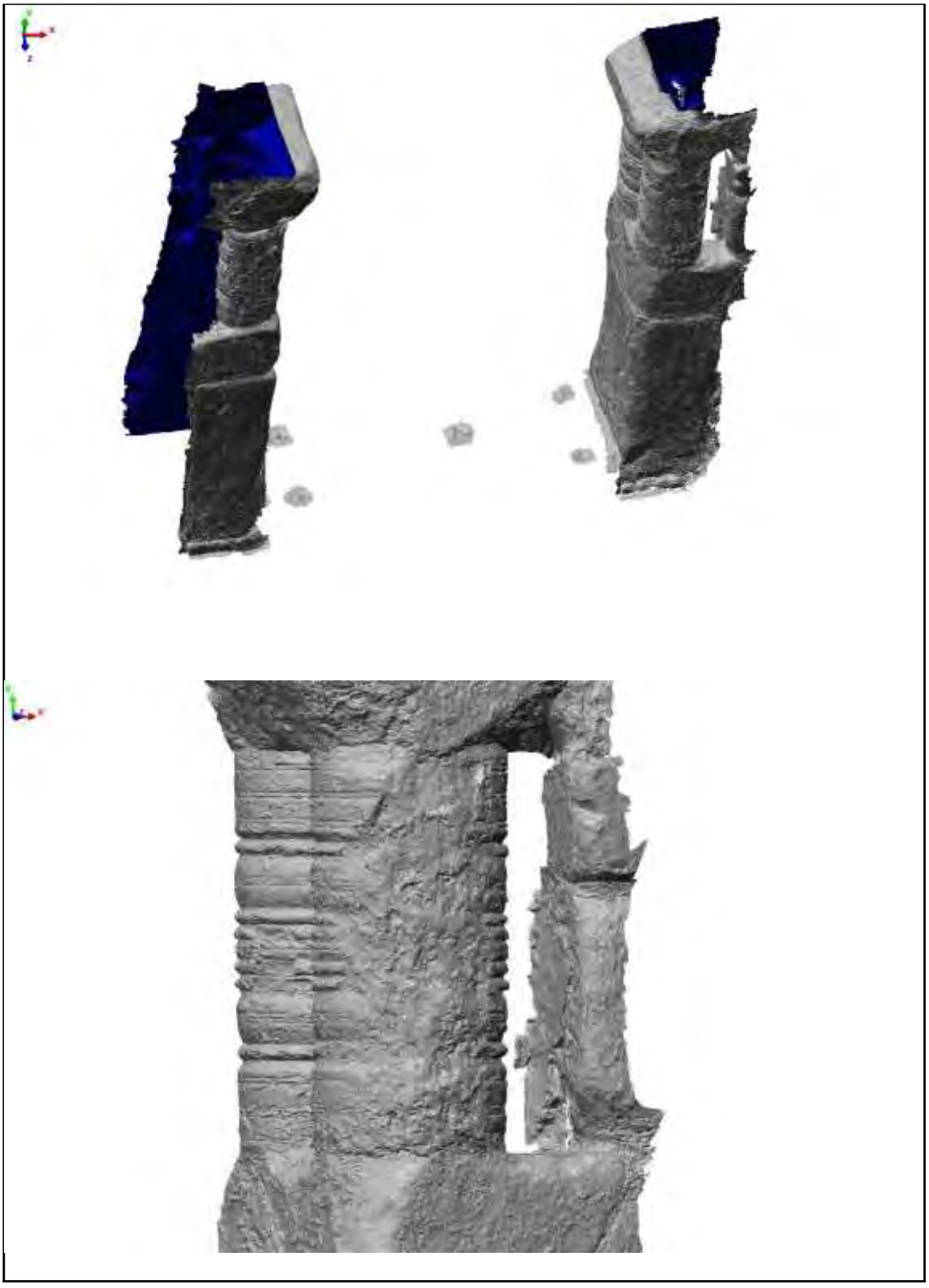
Sensor to arm calibration checks (Liverpool):	
Corner (mm):	RMS 1) 0.0227, RMS 2) 0.0305
Plane ov. plane (mm):	RMS 1) 0.0326, RMS 2) 0.0305
Cross (mm):	RMS 1) 0.0468, RMS 2) 0.0266
Parallel planes 1-3 (mm): *Parallel planes 2-4 (mm):*	RMS 1) NSP = 0.0468, SP = 0.0271, Dev. = -0.037 RMS 2) NSP = 0.0373, SP = 0.035, Dev. = 0.017

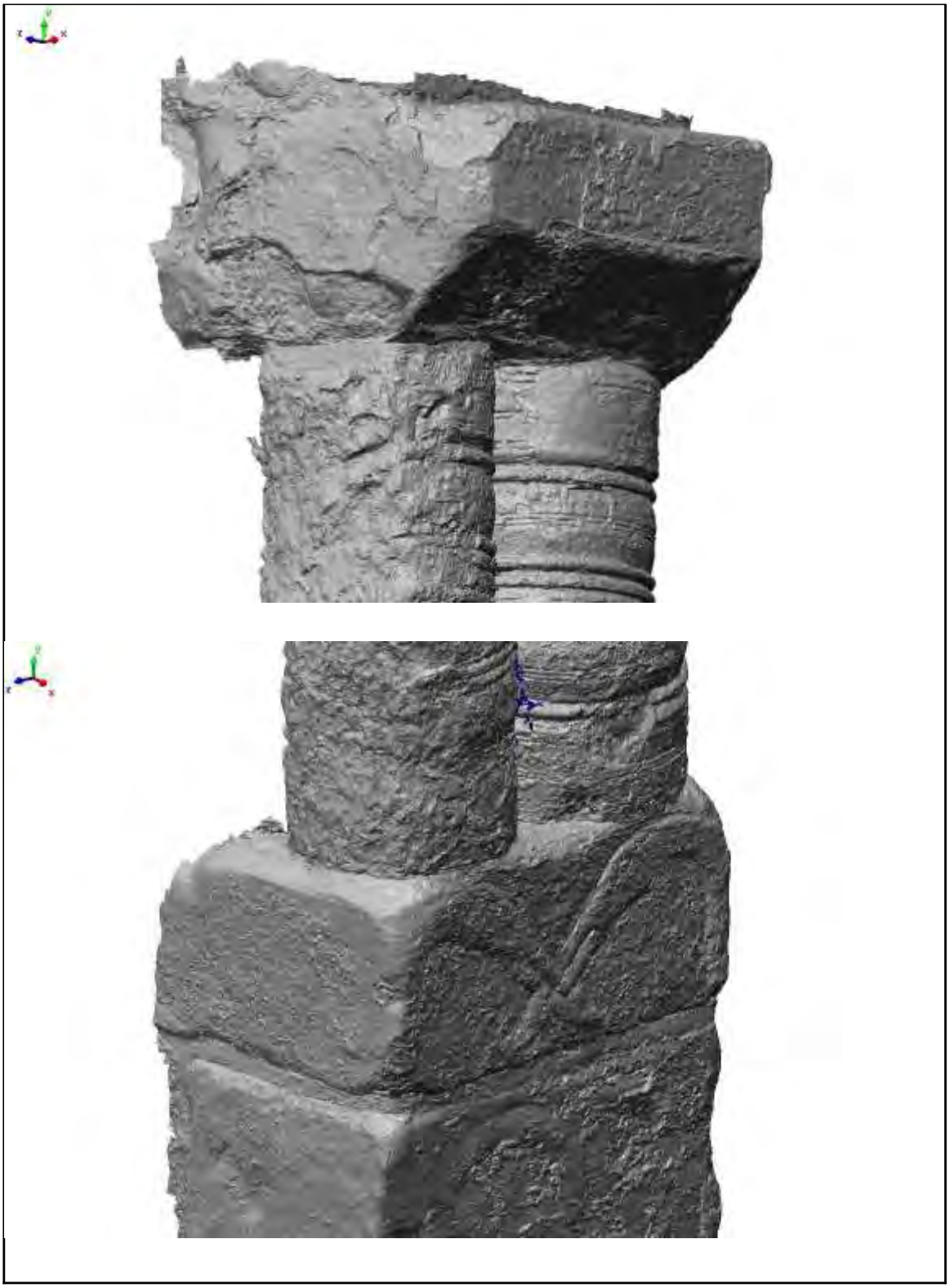
Sensor to arm calibration checks (On-Site):
Not carried out – not possible in the scanning environment. Processing showed that the data collected was within tolerance of the above calibration.

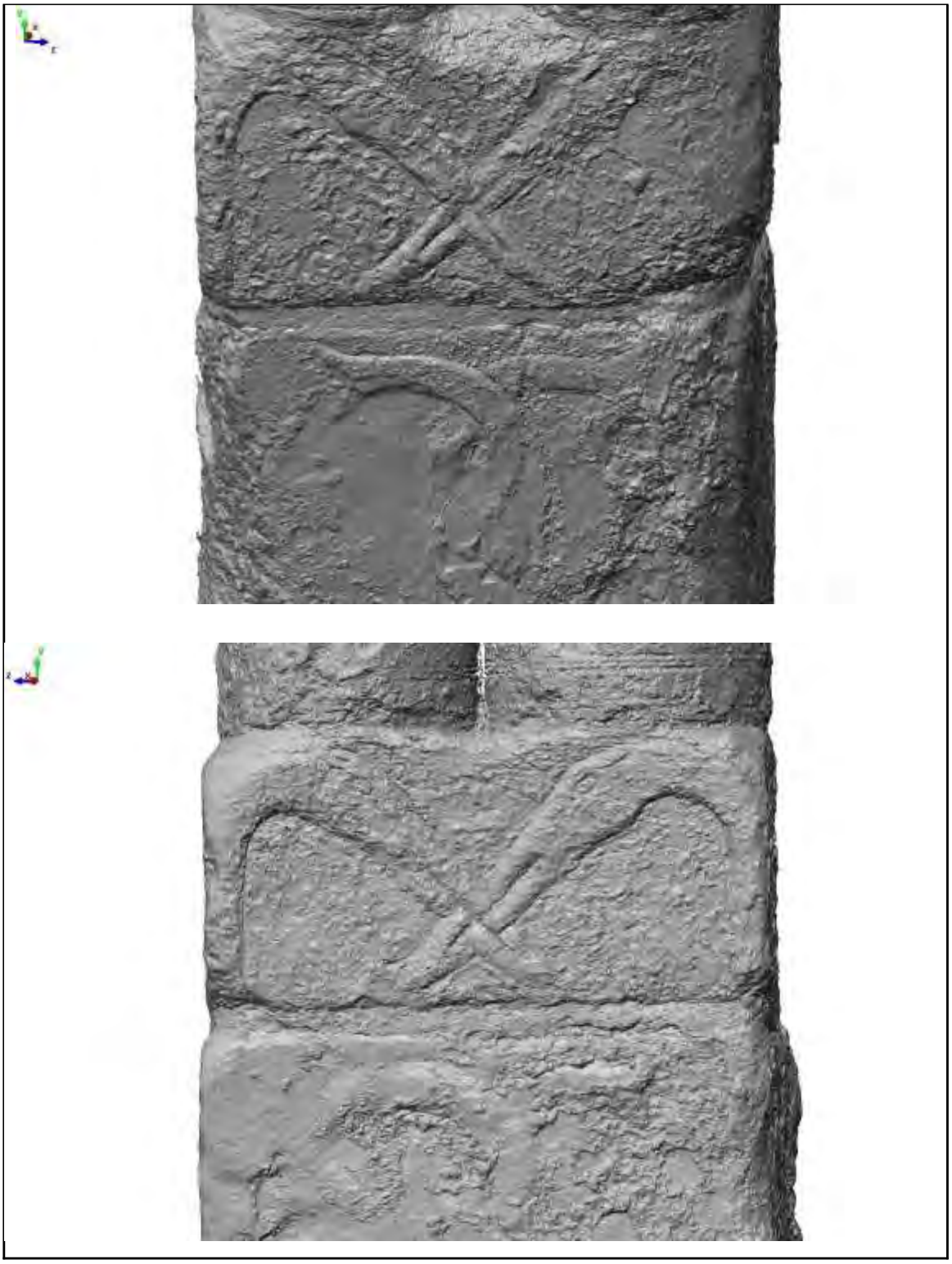
Scanning Parameters	
Tripod:	Faro portable (not glued); on solid stone floor
Power source:	Mains 240V
Ambient threshold:	Variable (~ 2.8 - 3.4)
Laser power:	Variable (~ 110-130)
Stripe width:	Wide
Number of stations:	Three (ST1; ST2; ST3). See below for approx. positions. (Also witness sketch in paper file). 
Filenames:	wm st1a/1b/1c/1d/1e/1f/1g wm st2a/2b/2c/2d/2e/2f/2g/2h/2i/2k/2l/2m/2n/2o/2p wm st3a/3b/3c Approximately, 178 million points were collected during data capture.
File format:	SAB2

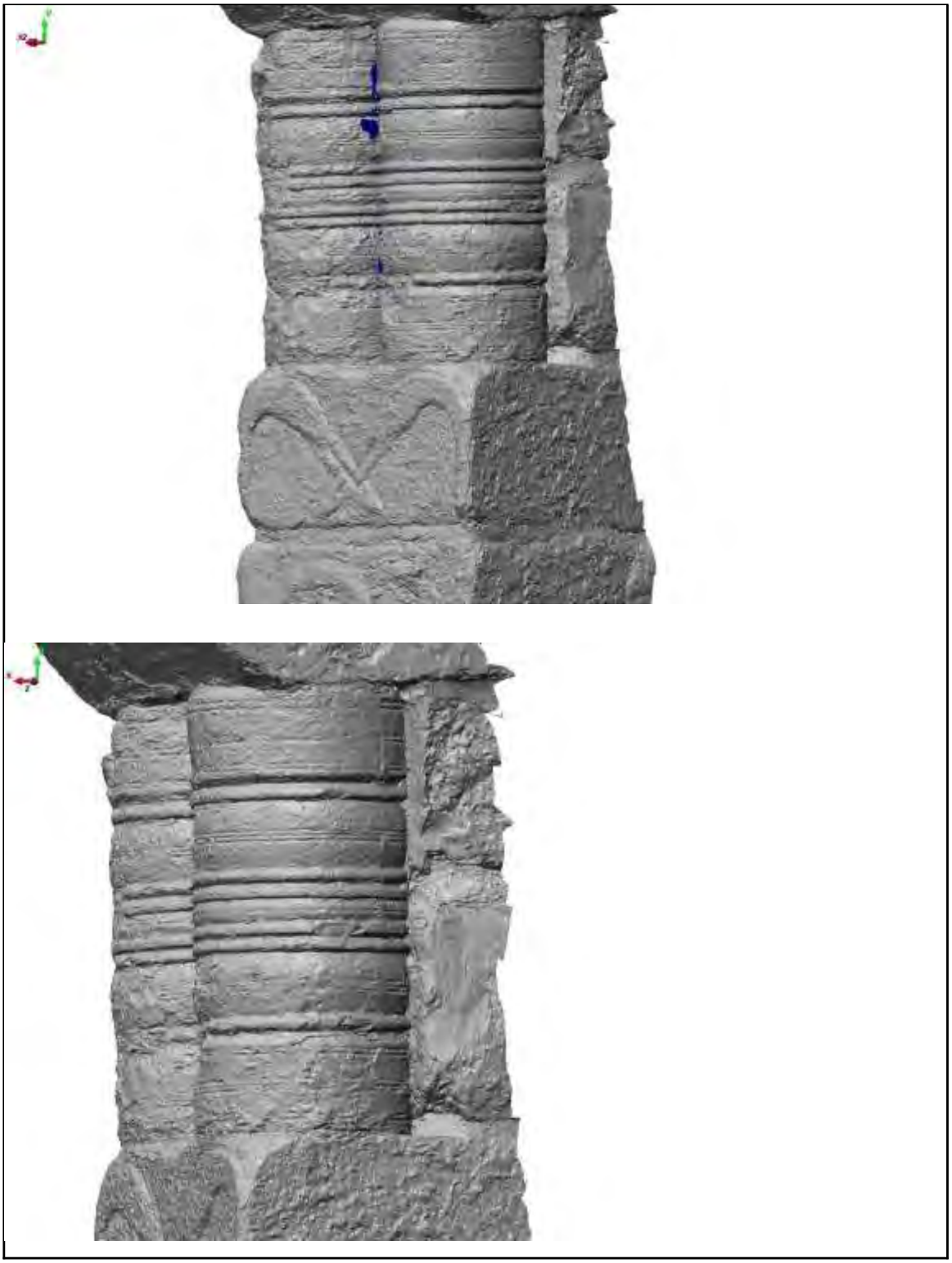
Post-Processing	
Carried out by:	AL
Software used:	Polyworks v11, RF2006
IMAlign Parameters:	
Max. distance (mm):	1.8
Int. step (mm):	0.3 (applied in Modelmaker software)
Max. angle (°)	89
Comp. distance (mm)	2.5, 1, 0.15, and 0.09
Overlap red. (mm)	Applied during meshing – see below
IMMerge Parameters	
N.B. The two pillars were meshed, compressed and hole filled separately, but using the same parameters. Once mesh editing was complete they were merged and the final compression was applied.	
Max. distance (mm):	1.8
Int. step (mm):	0.3
Standard dev. (mm):	0.042
Smoothing level:	Low
Smoothing rad. (mm):	0.6
Smoothing tol. (mm):	0.13
Reduction tol. (mm):	0.0099
Mesh polygon count:	South side = 50 million North side = 47.5 million
IMCompress tol (mm):	(South side = 12 million, North side = 13 million) (South side = 7.9 million, North side = 8.3 million)
Deletion of poor data:	-
Merging:	In IMEdit of South and North side.
Hole filling:	All holes with less than 30 edges were filled automatically. (Wearmouth - autoHF only-13-6 mill.STL) Further hole filling was carried out using IMEdit. There is one hole for which there is some hold filling documentation in the images folder. It concerns an area of fill on the right (north side).
Ab. faces cleaned:	Yes.
Compression tol (mm):	0.084 on merged mesh (9.7 million in complete model) 0.1 to create a lower resolution viewing file (7.4 million polygons) 0.12 to create a low resolution viewing file (5.8 million polygons)
Processing procedure:	Registration, alignment, meshing, compression, hole filling and compression.[2]

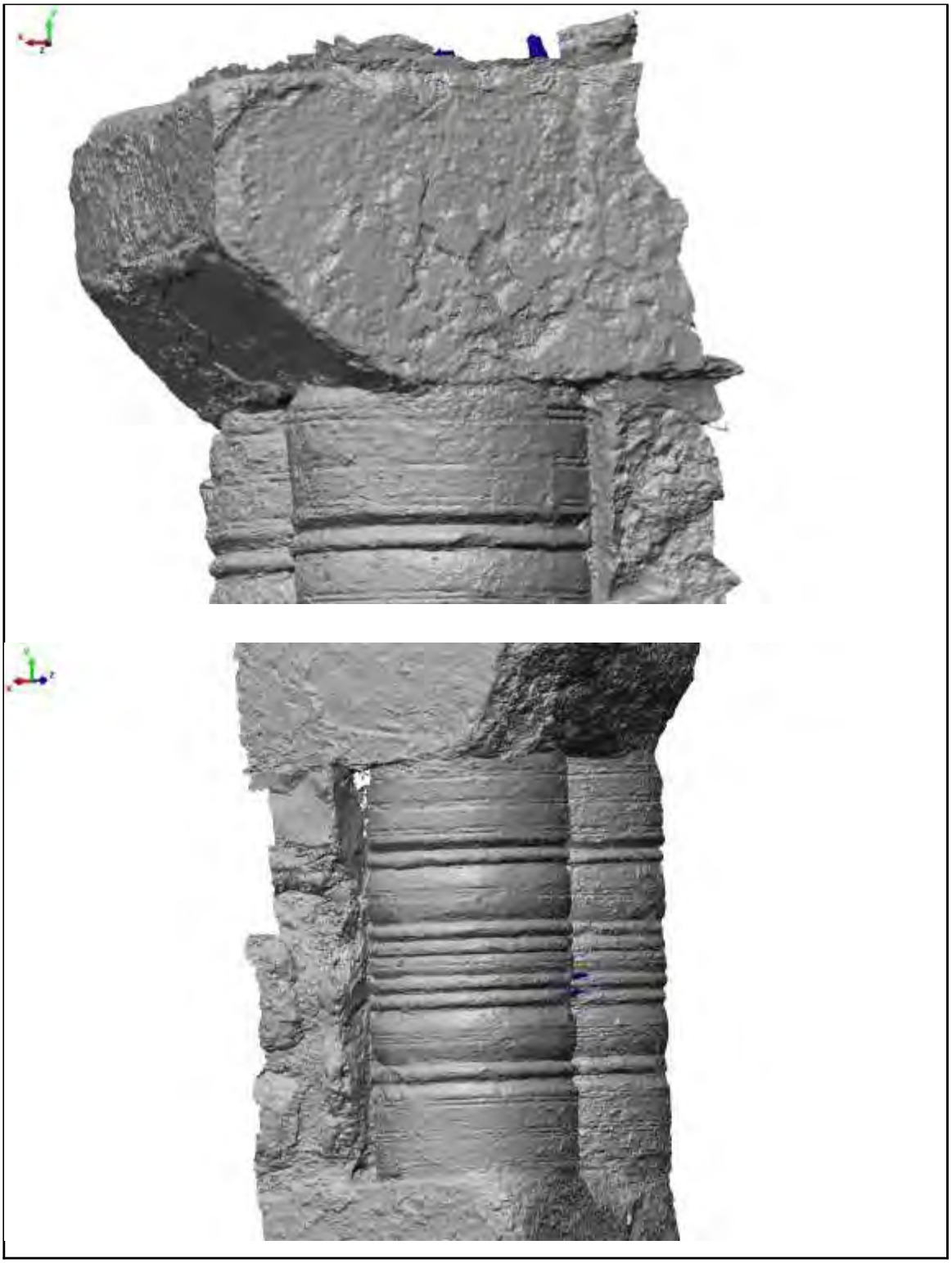
	Complete filenames with description: Wearmouth - autoHF only-13-6 mill.STL All holes with less than 30 edges filled automatically. Wearmouth - Complete-HF-5-8 mill.STL All fill that can be filled are filled – low resolution mesh. Wearmouth - Complete-HF-7-4 mill.STL All fill that can be filled are filled – medium resolution mesh. Wearmouth - Complete-HF-9-7 mill.STL All fill that can be filled are filled – medium resolution mesh. Wearmouth - Complete-HF-14 mill.STL All fill that can be filled are filled – high resolution mesh.
Images:	
	

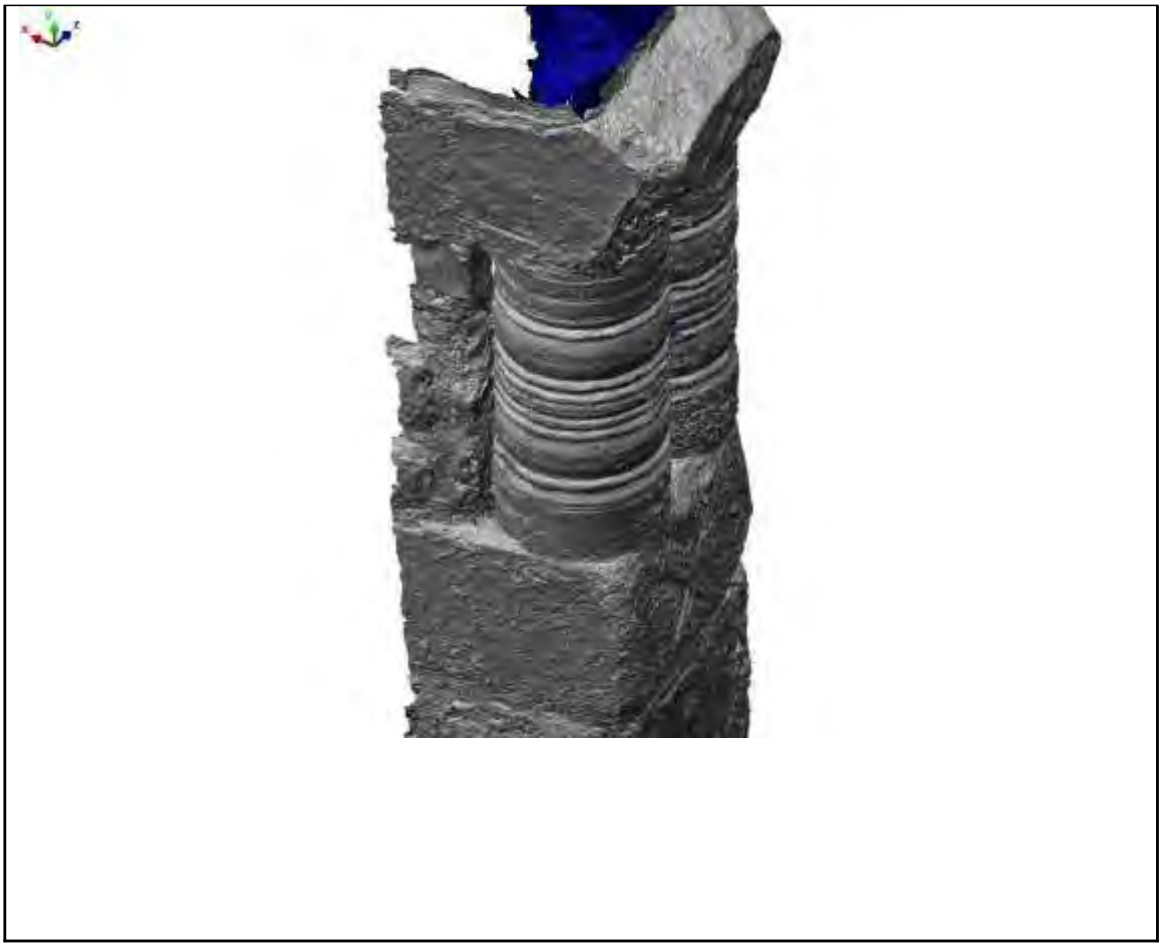












Data Storage			
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Images CDs:	Number: 1334 and 1337	Off Site	Z Drive
Metadata DVD:	Number: 1337	Off Site	Z Drive
Model file names:	Wearmouth - autoHF only-13-6 mill.STL All holes with less than 30 edges filled automatically. Wearmouth - Complete-HF-5-8 mill.STL All fill that can be filled are filled – low resolution mesh. Wearmouth - Complete-HF-7-4 mill.STL All fill that can be filled are filled – medium resolution mesh. Wearmouth - Complete-HF-9-7 mill.STL All fill that can be filled are filled – medium resolution mesh. Wearmouth - Complete-HF-14 mill.STL All fill that can be filled are filled – high resolution mesh.		
Format:	STL		
Complete data DVD:	Number: 1337	Off Site	Z Drive
Client copy sent to:	Sarah Semple Department of Archaeology Durham University South Road, Durham, DH1 3LE.		
Date:	22/09/2011		
Signed off by:	AL		

[1] *The Modelmaker X laser scanning system comprises a 3DScannersUK Ltd.[1] (now Metris) 3D laser scanning sensor mounted on a seven axis Faro Technologies Ltd. 'Gold' measuring arm. The scanner uses the principle of triangulation to record the surface as a thin stripe of laser light is scanned over the object. The length (maximum) of the stripe emitted from the sensor during scanning was 100mm. The distance between measured points along the stripe is 0.10mm. The distance between stripes is dependent on the speed at which the operator moves the sensor over the surface, and on how many times the sensor is passed over a given area. The scanning system captures 27 000 points per second.*
The accuracy of the system is approximately ±0.1mm. Actual accuracy will depend on the nature of the surface of the object and scanning conditions.
Calibration checks were carried out to check the scanner was performing within specification (see above)

[2] *The raw point data was sampled with a point spacing of 0.3mm prior to registration and alignment. The 2σ value (average error) of the alignment was 0.042mm. The two pillars were meshed, compressed and hole filled separately, but using the same*

parameters. Once mesh editing was complete they were merged and the final compression was applied. The aligned point cloud was meshed using the parameters detailed above, and the resulting polygon models comprised 47.5 + 50 million polygons. Compression gave model comprising 7.9 + 8.3 million polygons. Automatic hole filling was undertaken in PWv11 on all holes less than 30 edges in size. All other holes that were filled were filled manually. The completed models were merged and further compression gave models of 9.4million, 7.4 and 5.8 million polygons. The models provided are listed above.