Historic England

Geospatial Imaging

Church of St Edward and the Market Place, Leek, Staffordshire
Geospatial Survey of Standing Medieval Crosses

Li Sou

Discovery, Innovation and Science in the Historic Environment

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SUMMARY

The church of St Edward the Confessor lies to the north of the town centre of Leek, Staffordshire, and two Anglo-Saxon stone cross shafts currently stand in its churchyard. Additionally, a complete later medieval market cross stands in the town market place.

In response to a request from Imogen Sambrook, Heritage at Risk (HAR) Projects Officer for the West Midlands region, the Geospatial Imaging team undertook a programme of survey for these three scheduled crosses, as well as historical features on the walls of St Edward's church (figure 1), to create a record of their current physical condition. Both laser scanning and photography for structure-from-motion (SFM) photogrammetry were conducted on site, and 3D outputs, including 3D PDFs, Autodesk ReCap projects and OBJ files, were produced. From these outputs, it was possible to analyse the carved details on some of the stonework in greater detail using polynomial texture mapping (PTM), enhancing our understanding of these monuments and providing scope for further research.

CONTRIBUTORS

The geospatial survey was undertaken by Li Sou and David Andrews, of Historic England's Geospatial Imaging team. Li Sou, with the assistance of Jon Bedford, of Historic England's Imaging team, processed the laser scan point data for mesh generation, and digital imagery for structure-from-motion photogrammetry. PTM models were generated by Andy Crispe, of Historic England's Imaging team. Li Sou conducted the data analyses of the project, with additional comments from David Andrews and Jon Bedford. Unless stated otherwise, the images used in the text were produced by the author.

ACKNOWLEDGEMENTS

The author would like to thank the warden of St Edward's church, Geoff Channon, for his help in preparing the churchyard for survey and highlighting significant historical features. Thanks also to members of the Corpus of Anglo-Saxon Stone Sculpture project, who have provided much useful information on the history of the early medieval crosses.

ARCHIVE LOCATION

The report has been deposited at the Historic England Archive, The Engine House, Fire Fly Avenue, Swindon SN2 2EH.

DATE OF SURVEY

The surveys took place on the 11th and 12th April 2016.

CONTACT DETAILS

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PART 1: THE PROJECT

INTRODUCTION

From 11th-12th April 2016, three medieval crosses in the market town of Leek, Staffordshire, were surveyed through laser scanning and photography by Li Sou, CIfA Specialist Training Placement in Geospatial Investigation Techniques, and David Andrews, Geospatial Imaging Analyst at Historic England. Being scheduled monuments, a later medieval market cross and two Anglo-Saxon cross shafts had been placed on the Heritage at Risk (HAR) register due to the substantial effects of weathering that have caused their decorated surfaces and markings to deteriorate. A request was made by members of the HAR team from the West Midlands office of Historic England to conduct a programme of laser scanning and photogrammetric survey in order to comprehensively record the present condition of the crosses, to provide a record of their present state and to better understand their history before further detail is lost (figure 1). In addition, a photographic record of medieval archers' sharpening marks and a Norman grave cover incorporated into the structure of St Edward's church was made.

The project was undertaken as part of the placement holder's training programme with the Geospatial Imaging team at Historic England. A combination of SFM photogrammetry and laser scanning, using two different models of laser scanner were used, thus broadening the types of data to be processed and programmes required, in order to provide further training and experience for the placement holder. Once the data was generated, it was possible to identify inscriptions and carvings on the sculptures with great clarity, which offers new potential for historic and archaeological research. The different formats of 3D data were saved and are stored with Historic England's Geospatial Imaging team, whilst the photography has been archived in the Historic England Archive.

BACKGROUND

The remains of the two scheduled Anglo-Saxon stone cross shafts are situated 11m east (UID 1012656) and 2m south (UID 1012657) of St Edward's church, within the churchyard. Both date to the 10th century (Sidebottom 2015). Such crosses were often erected to mark preaching sites, and date from the eighth to tenth centuries AD. They are most frequently found throughout northern England, with a few examples further south (Historic England 2016a). Presently, fewer than 50 early medieval high crosses survive in England, therefore it was determined that it was necessary to record these two examples, in order to maintain a record of their present state for future research and knowledge, particularly as the close vicinity of both crosses is a factor of substantial interest.

The cross on the eastern side (UID 1012656) comprises a rounded shaft with small carved patterns on three sides, with a gradual taper to a prominent circular collar featuring interlace carving, reflecting Scandinavian tradition. Above this, the cross shaft becomes rectangular, featuring further interlace carving on each panel, leading up to the broken remains of a cross head that is believed to have been destroyed

during the Reformation (Channon 2015 *pers. comm.*). The present plinth is a modern addition, although it was documented in the early 20th century to have stood in its current position for some time (Pape 1945-6, 35).

The Anglo-Saxon cross presently situated nearer to the church (UID 1012657) was restored from pieces found lying in the churchyard and re-erected in 1885 (Pape 1946-7, 38). It had previously faced variable amounts of damage and wear, although interlaced carvings are still visible on some sides and a runic inscription is located on the lower part of the shaft (Sidebottom 2015). The original positions of both Anglo-Saxon crosses is unknown, however it is presumed that they were separately located in the landscape to serve as meeting places for worship before St Edward's church was built on this site (Cleverdon 2015, 2).

Whilst the construction date of the original church is not known, a timber church was located on the site from 1232, and was subsequently rebuilt in 1320 after the original burnt down (Sperring-Toy 2015, 3). The reuse of a post-Norman conquest grave cover as building material for the western wall attests to this (Cramp 2015 *pers. comm.*). On the exterior walls and buttresses of St Edward's church, deeply carved grooves are visible. These are speculated to have been caused by the repeated use of the walls for sharpening arrow heads by medieval archers, who practiced in the churchyard (Channon 2015, *pers. comm.*). The grooves are located on the outer northern wall of the church.

The standing market cross (UID 1012658), currently situated in the town's market place, is thought to date from the early 15th to 17th century, with a later 19th century pedestal (Historic England 2016b, Staffordshire County Council 2016). It was returned to this original location in 1986, having previously been removed to Cemetery Road in 1806 (Historic England 2016b, Historic England 2016c). Since it is also a scheduled monument, it was determined that this later cross would also benefit from 3D recording.

Figure 1: (Top left) Anglo-Saxon cross UID 1012656 with rounded shaft. (Top right) reconstructed Anglo-Saxon cross UID 1012657. The fragments at the base do not belong to the cross. (Bottom left) later medieval market cross in Leek marketplace. (Bottom right) arrow sharpening grooves and a Norman grave cover from the exterior walls of St Edward's church. Images not to scale.

PART 2: VISUALISATION TECHNIQUES

METHODOLOGY

The three scheduled medieval crosses have never been fully surveyed and analysed, although the two Anglo-Saxon crosses within St Edward's churchyard are to be included in the Staffordshire volume of the Corpus of Anglo-Saxon Stone Sculpture (CASSS) in Britain catalogue, which contains historiographical and stylistic information on the crosses (in press). As such, it was decided a programme of detailed survey was required to collect 3D information on all three crosses, in addition to two other historic features located in the exterior structure of St Edward's church.

For the standing crosses, two methods were applied: SFM photogrammetry and laser scanning. For the non-scheduled historic carved features (a Norman grave cover reused as part of the church's building material and medieval arrow sharpening marks located on one of the north-west buttresses), only photography was taken for SFM processing into 3D models.

All methods used were conducted in order to achieve the outputs requested in the casework support form provided by the HAR team, that is, to produce 3D models in the PDF format usable by the Historic Environment Record for Staffordshire, and to provide the survey data as an Autodesk ReCap project for the HAR team.

Still photography

Still photography was undertaken using a Canon EOS 5D mark II, 21.1 megapixel full frame DSLR camera, with a wide-angle (24mm) fixed prime lens fitting Historic England's metric survey criteria for digital cameras (Andrews, Bedford and Bryan 2015). The majority of the photography was taken with the camera mounted on a tripod and the aperture priority setting used. Where parts of the monuments were too high for a standard tripod, the camera was attached to a photographic mast and the shutter priority setting was applied. The camera was remotely controlled using a Camranger and its associated mobile phone app. The initial images were saved as RAW format files in maximum file size.

SFM photogrammetry processing

Colour and exposure correction of the captured RAW images took place using Adobe Camera RAW to ensure all images reflected the correct colouration of the stonework as seen by eye on site. The files were converted into TIFF format for SFM processing in Agisoft Photoscan, where scale data was input. Additionally, masking of non-relevant details within all photos was required to avoid extraneous points being generated, which can substantially increase processing time (figure 2).

It was found in processing the market cross that a registration error occurred in placing markers on the 1m scale within the photography. To overcome this problem, control points were extracted as 3D co-ordinates from the laser scans taken of the

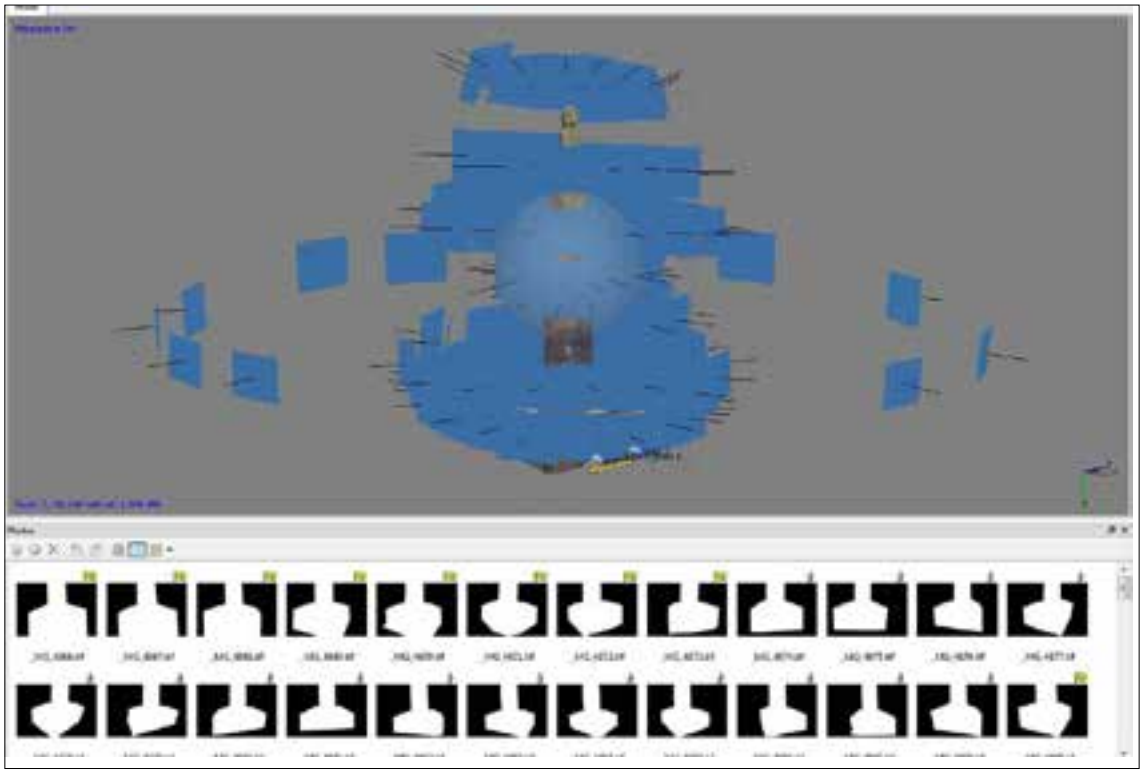

Figure 2: Screen capture of the Photoscan project. The top window displays the complete textured mesh generated from photographs. Each blue rectangle indicates a camera position. Below, the masked areas of each photograph are outlined in black, preventing extraneous scenery from being processed.

cross. It was then possible to incorporate this data into Photoscan when the relevant points were matched spatially, so the photography could be aligned correctly.

Following the generation of a high resolution mesh and texture in Photoscan, the 3D meshes of the models were decimated to reduce file size, and exported as 3D PDFs as required by the Historic England West Midlands HAR team and Staffordshire County Historic Environment Record. However, due to the low resolution limitations of this format, high resolution versions of the model meshes were additionally saved and exported as OBJ files, which can be further manipulated in other 3D processing programmes for analysis and dissemination. The TIFF imagery data has been catalogued and archived by Historic England.

Laser scanning

The two Anglo-Saxon crosses were laser scanned using a Leica P40 ScanStation, as it was possible to obtain high resolution window scans of the faces of the crosses (1mm points across the target scanned surface) after initial 360° scans were completed. The most significant element to record using the scans was the carved decoration on the crosses, particularly the runic inscription on UID 1012657, as the CASSS project team are particularly interested in attempting to translate it. The laser scanner provides metrically accurate measurements which can also be used to scale and orientate a SFM model correctly by providing 3D co-ordinate data.

Due to the market cross being over 5 metres tall, the FARO Focus 3D S120 laser scanner was used to record this monument, as it was possible to attach the scanner to an extendable tripod to reach the highest areas of the cross. This was not possible with the Leica P40 as it is too heavy to use on the extendable tripod, but may be suitable for the new Leica BLK360 given its size, weight and portability.

Laser scan processing

Data from the FARO Focus scanner was imported into FARO Scene, where point clouds were produced of each scan. It was noticed that the scans taken from the extendable tripod at a height were distorted due to high winds causing the tripod pole to sway, so it was decided that the higher scans should not be used. In total, nine separate scans were registered together, and were used to produce a point cloud of the market cross, using only local coordinates not tied to any national grid systems (figure 3). These were combined into a single point cloud project file in Autodesk ReCap that can be maintained as a metrically accurate record of the complete market cross for future reference and use in the Historic England archives.

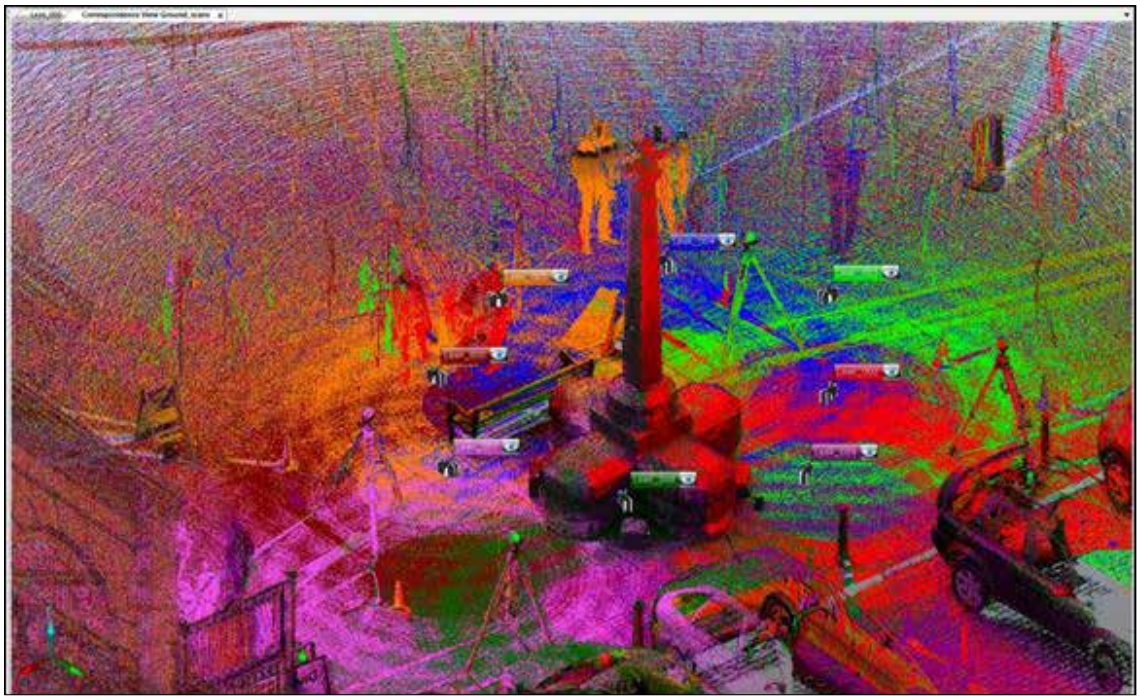

Figure 3: Screen capture of laser scan data in FARO Scene. Note how the scanner has recorded all of its surroundings, including passers-by. The different colours indicate different scans.

The scan data taken from the Leica P40 was imported into Leica Cyclone. The data had been registered using resection in individual Scan Worlds for each laser scan that took place. The high resolution window scan of the runic inscription was exported as a PTX file, which was further processed into a mesh in Geomagic Studio 2012, a 3D mesh editing programme. Firstly, the scan was cropped so only the area of the cross with details of the runes remained. As the extraction of this scan

data is intended only to reveal the runes in greater clarity, the “fill holes” function in Geomagic was used, despite the fact that such applications extrapolate the existing accurate point measurements to fill in areas without information. After this was done, a mesh was created by wrapping the points and converting it into a polygon object, which was then saved as an OBJ file.

PART 3: EVALUATION OF RESULTS

EXAMINATION OF THE CARVING DETAILS

During the course of the project, both while recording on site and viewing the resultant 3D models, it was found that there are several carved details on the stonework that are of historical interest. These include a runic inscription on one of the faces of the rectangular shafted Anglo-Saxon cross (UID 1012657), the outlines of carved decoration on a Norman grave cover, now incorporated into the exterior wall of St Edward's church, and some engravings on the top of the market cross. Runic inscriptions are a rare feature on Anglo-Saxon sculpture, and the example in Leek is at present the only known inscription on a cross shaft in the region of Derbyshire and Staffordshire (Sidebottom 2015). It was proposed that these carvings should be exported into easily viewable formats for experts in medieval sculpture and runes to view and potentially decipher.

The SFM photogrammetric meshes of the grave cover and rectangular cross, and a mesh of the runes taken from the laser scan data were exported as OBJ files and processed through virtual Polynomial Texture Mapping (PTM) (also known as Reflectance Transformation Imaging) by Andy Crispe, Graphics Officer for Historic England. PTM is able to produce virtual views of an object under various lighting directions, therefore it enables the viewing of the inscriptions under raking, oblique light conditions. The OBJ files were lit by a virtual light dome in 3D Studio Max, and images with each different light position were extracted and processed in dedicated PTM software. This produced PTM files that can be opened with freely available viewing software that allows the user to manipulate lighting positions on an object.

Examination of a runic inscription

Viewing the PTM files of the runes acquired from laser scanning and SFM photogrammetry, it was clear that the two models look substantially different. On the photogrammetric mesh, the surface appears smoother, whilst the surface of the model from laser scans appears grainier (figure 4).

From visual analysis of the PTM files alone, it is clear that the clarity of the runes varies depending on the angle of raking light from both datasets. When the light is positioned to the left side, the inscription looks more deeply incised on the laser scan model, as deeper and darker shadows are cast over its surface (figure 5). However, raking light from above the carvings defines the runes better in the photogrammetric model, as the stippled and grainy surface of the laser scan model appears more noisy, making them more difficult to discern (figure 6).

In this instance, it appears that both datasets have areas of better clarity, dependant on the positions of the virtual lighting source. It is not evident that one of the models is better overall than the other for examining the runes in such detail as the two datasets present notably different visualisations of them.

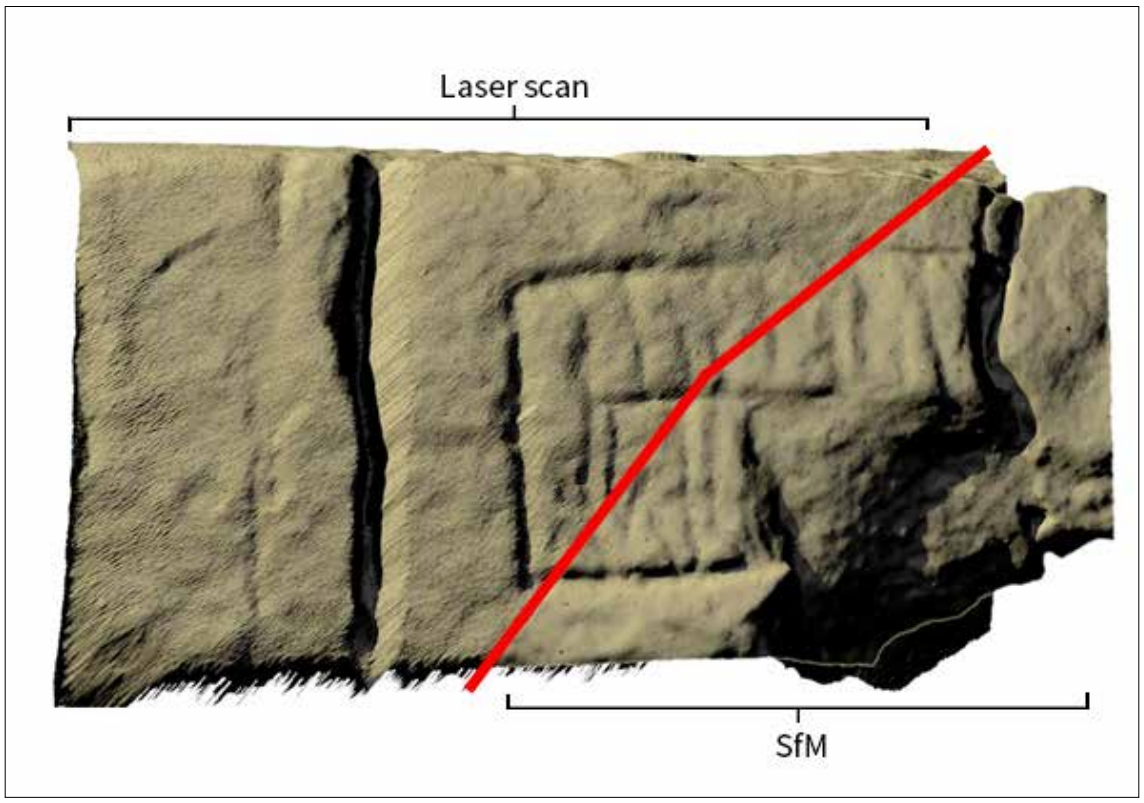

Figure 4: comparison of laser scan (left of red line) and SFM photogrammetry (right of red line) 3D models, visualising the runic inscription on one of the Anglo-Saxon crosses. Image source: Andy Crispe.

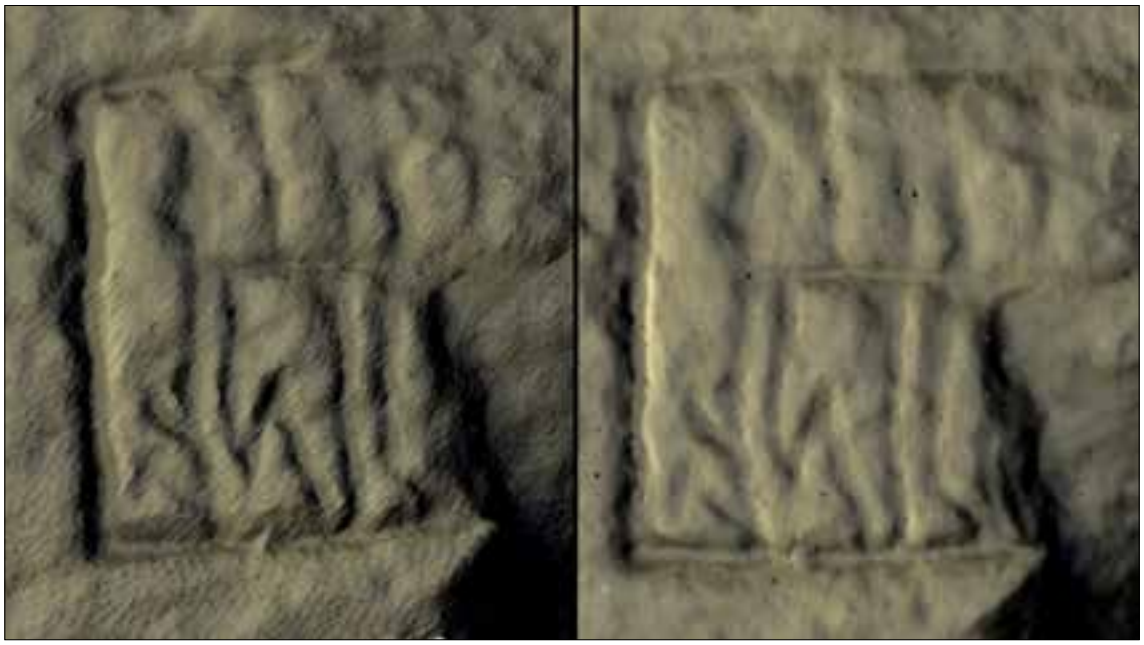

Figure 5: Virtual raking light from the left side of both PTM images. Left: PTM image from laser scan data. Right: PTM image from SFM photogrammetry. Note how the depths of the shadows are greater from the laser scan data, and the better clarity of several of the lower line of runes, although striping features across the surface. The symbol on the bottom left looks substantially different between the datasets.

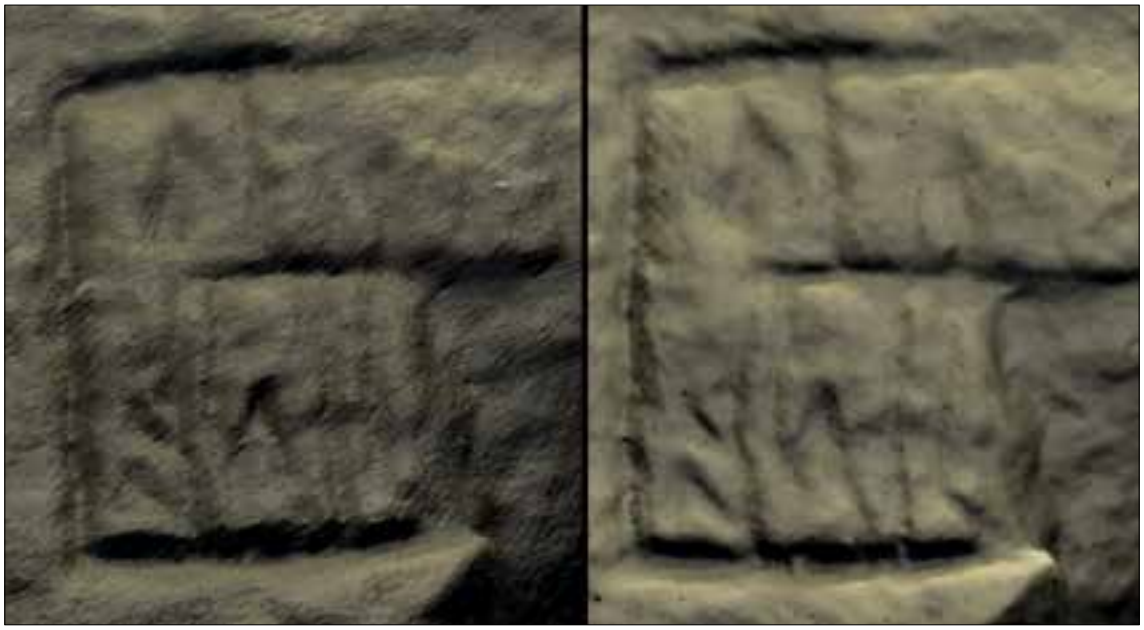

Figure 6: Virtual raking light from above both PTM images. Left: PTM image from laser scan data. Right: PTM image from SFM photogrammetry. Note how the grainy texture of the laser scan model, affected by striping, makes it difficult to see detail in the top row of runes in comparison with the SFM image.

To determine whether alternative mesh rendering software affects the presentation of the virtually lit models, the dense point cloud of the photogrammetric model was exported in PLY format and imported into Geomagic, where a new mesh was generated using this software, with its default settings. The initially generated mesh maintains the correct colouring as the original stone cross, taken from the photogrammetric data, and using Geomagic's light position tool, this aids in highlighting the shadows of the inscription. In contrast, replacing this colour data with a single tone can make it more difficult to observe the carvings, however it does present the depths of the carvings as calculated by SFM photogrammetry more clearly, without being obscured by the extra colours (figure 7).

It can therefore be suggested that the two techniques of SFM photogrammetry and laser scanning can complement each other in aiding in the identification of such inscriptions. The appearance of the mesh outputs is different in these two data sources, but it is also clear that their presentation can be strikingly varied between different software. It is clear that the visibility of carved elements is dependent on the mesh display settings used, such as matte or reflective.

Whilst the PTM model generated from laser scans appears to suggest a greater depth of carving than similarly coloured SFM meshes produced in Photoscan, it is apparent that the mesh produced in Geomagic from the photogrammetric data also provides much shaded detail, in addition to the true colour of the stone surface. It can therefore be concluded that there is not one ideal view of these runes from all of the different outputs, and this study has demonstrated that a variety of different visualisations may be required to produce a broad range of imagery, to tease out all of the details necessary to analyse the carvings.

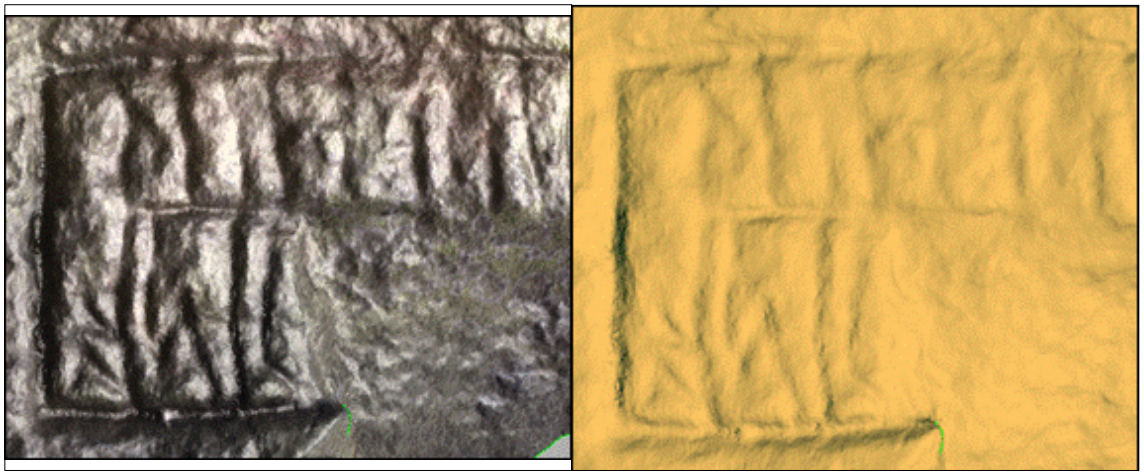

Figure 7: SFM point cloud wrapped into a mesh in Geomagic Studio. Left: using the software's default settings. Note the "shiny" texture of the initial mesh. Right: using a matte colour scheme. Geomagic has a very limited selection of colours, and this was the closest to those in PTM models.

Examination of a post-Conquest grave cover

PTM was also found to be a useful technique to help draw out further detail of carvings noticed upon generation of the 3D model of the Norman grave cover from SFM photogrammetry. PTM processing was conducted by Andy Crispe (figure 8), and this revealed previously unnoticed carved details on the stone, which was obscured by shadow while fieldwork took place.

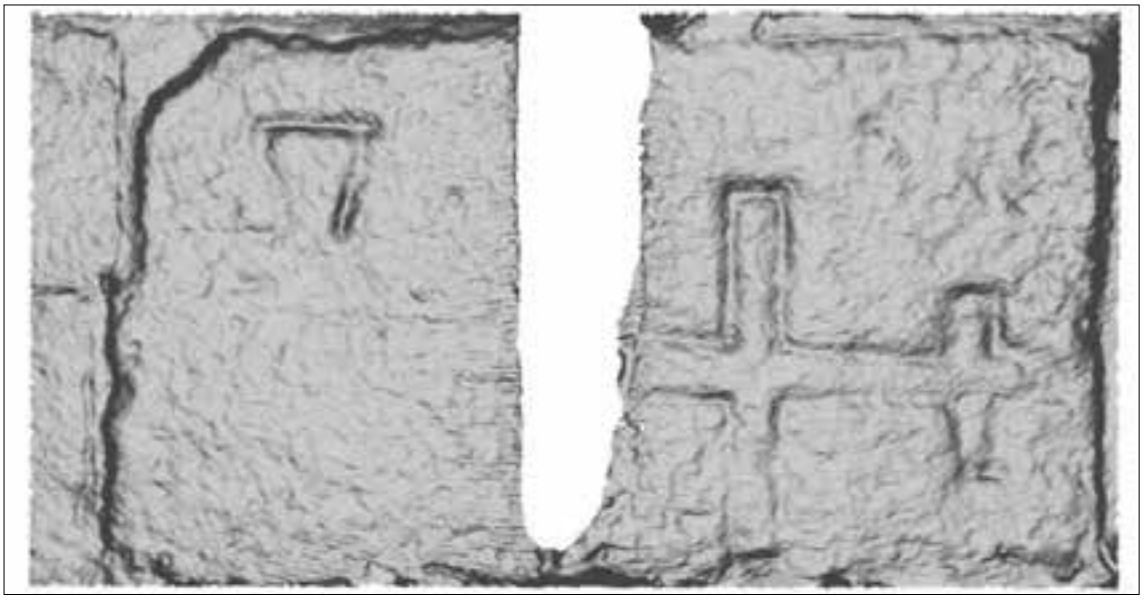

Figure 8: PTM model of the grave cover, using specular enhancement visualisation to bring out the carved details. A modern drainpipe lying over the centre of the panel has been cropped out. Image source: Andy Crispe.

Whilst the cross-shaped feature on the right side of the panel was easily distinguished, the feature to the top left of the panel was not clearly visible on the still photography taken on site. Following discussion with medieval specialists, it has been suggested that the feature on the right could possibly be a simplistic depiction of a sword, whilst the feature to the left may be a hand axe (Douglas 2016 *pers. comm.*). Alternatively, it is possible the carving depicts a stylised cross, similar to examples from across the country dating from the 11th-12th centuries, such as found in Stallingborough, Lincolnshire (figure 9).

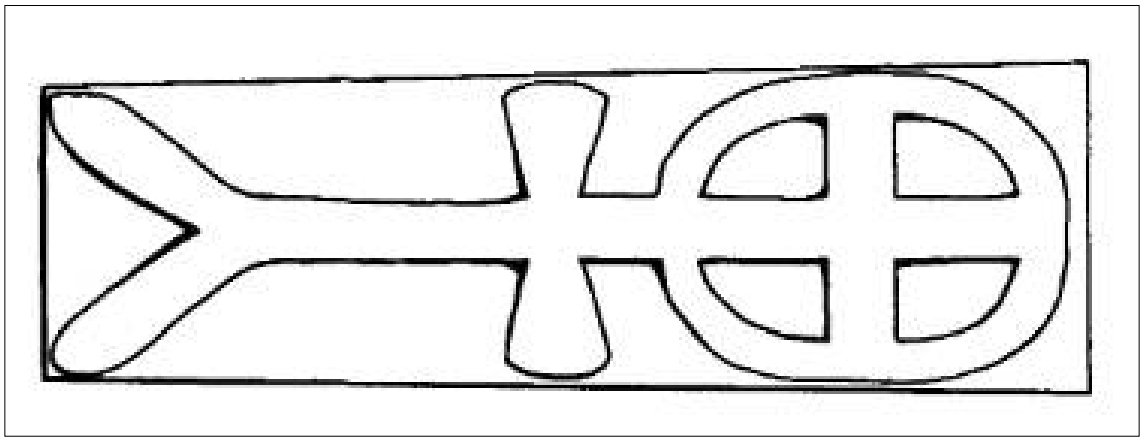

Figure 9: 12th century decorated Coffin lid from Stallingborough, Lincolnshire. Note the curved arms below the main cross-head. Image source: Butler, L.A.S. 1964. 'Minor Medieval Monumental Sculpture in the East Midlands', in The Archaeological Journal 121 (1), p.120.

The reuse of pre-existing ecclesiastical stonework in the foundation layers of a later church has been recognised, and suggested to have been practiced as a means of retaining a collective memory of the older structure for the community that used it (Douglas 2003, 136).

Whilst understanding and reconstructing the original appearance of this carving in full was not within the remit of this project, this does highlight the analytical potential of PTM models generated from SFM photogrammetry for further medieval carvings. It is a useful method for introducing a wider range of views and perspectives of these historic monuments than using still photography and illustrations alone.

3D and PTM models of the runic inscription were sent to members of the CASSS project who had previously recorded the crosses in the Leek churchyard, to determine whether the 3D data could provide any further information to complement their current knowledge of the scheduled sculptures. Members of the project found the ability to rotate the monuments useful, and better than viewing the four separate faces independently as still photographs. Similarly, Historic England HAR Project Officers regarded the 3D PDFs to be a very useful and accessible method of viewing the current condition of the stonework (Marriott; Sambrook 2016, *pers. comm.*).

Examinations of inscriptions on the market cross

While processing the digital imagery acquired of the market cross for SFM photogrammetry, it was noted in the photographs that several inscriptions feature on the cross head. Additionally, once the 3D model of this cross was generated using the imagery, carved decorations were visible on the ends of the cross arms (figures 10 and 11). Analysis of the cross head was conducted through exporting the dense point cloud from Photoscan, into Geomagic Studio as a PLY file. A mesh was then generated, using the points, and the 3D model was virtually lit to examine the carved features on its surface.

Figure 10: (Left) south-facing side of the market cross head, viewed in Geomagic with virtual lighting to highlight the engravings and carved decorations on the cross arms. (Right) the left side cross arm features an engraved cross encased in a circle, on its end. The green areas indicate gaps in the mesh, where 3D data was missing.

It is unsurprising that there is no mention of these inscriptions in current records of the monument, as the cross stands at over 5 metres tall on its current plinth, so without specialist access, it is very difficult to view the cross head in detail. The cross shaft had cracked at some time in its history and is currently reinforced by a modern metal bolt. It is recorded that it was removed from the market place and stood in a cemetery from 1806 until 1986, when it was returned to its original location (Historic England 2016c). It could be speculated that some of the engravings were made while it was moved, when the uppermost parts could be easily reached.

The motif of a wheeled cross is carved on the ends of the horizontal cross arms, the centre of both faces of the cross, and on either side of an oval collar below the cross head, suggesting these were original decorations. It is possible that two concentric circles and a star-like motif on the northern face could be original features, however, the substantial erosion on both faces makes this difficult to confirm without closer

inspection. There is little sign of any original decorations on the collar on the north-facing side.

Figure 11: (Left) north-facing side of the market cross head, in Geomagic. Note the two concentric circles on the right cross arm, and the star-like motif on the upper cross arm. (Right) an engraved cross within a circle mirrors a similar decoration on the other horizontal cross arm, potentially suggesting these decorations were carved at the same time.

On the southern face of the cross, several inscriptions are present; on the top cross arm are some ambiguous uppercase letters. The right arm features an inscription that appears to read 'CLIFFE', but the weathered condition of the cross makes it difficult to determine if any preceding letters exist. Directly below the central cross-in-circle are more Latin letters, potentially reading 'E S e'. It is possible that the oval-shaped collar below the cross head contained a date, between the two wheeled-cross decorations, but weathering has obscured this and it is not visible on the 3D model.

The disparity of the dates of the cross in different records emphasises how little is known about it, however, a more detailed closer examination of these carvings may provide further information that could contribute greatly to our understanding of the monument's history and thus aid in dating it more accurately.

LASER SCANNING COMPARED TO SFM PHOTOGRAMMETRY

Both laser scanning and SFM photogrammetry have produced point clouds of a sub-millimetre resolution. According to Historic England's metric survey specification (Andrews, Bedford and Bryan 2015), this level of detail is sufficient for presentation to a scale of 1:10, therefore the both datasets are fit for the production of detailed drawings or other presentation methods, if needed.

It was found that some of the laser scan points skimmed over edges of some recorded features, resulting in incorrectly extrapolated points in the point cloud and meshes from this data, however, as SFM was the primary method of generating 3D models in this project, this was not too large an issue, particularly as many of the incorrect points occurred around the modern bases of the monuments, rather than the medieval sculptures themselves (figure 12).

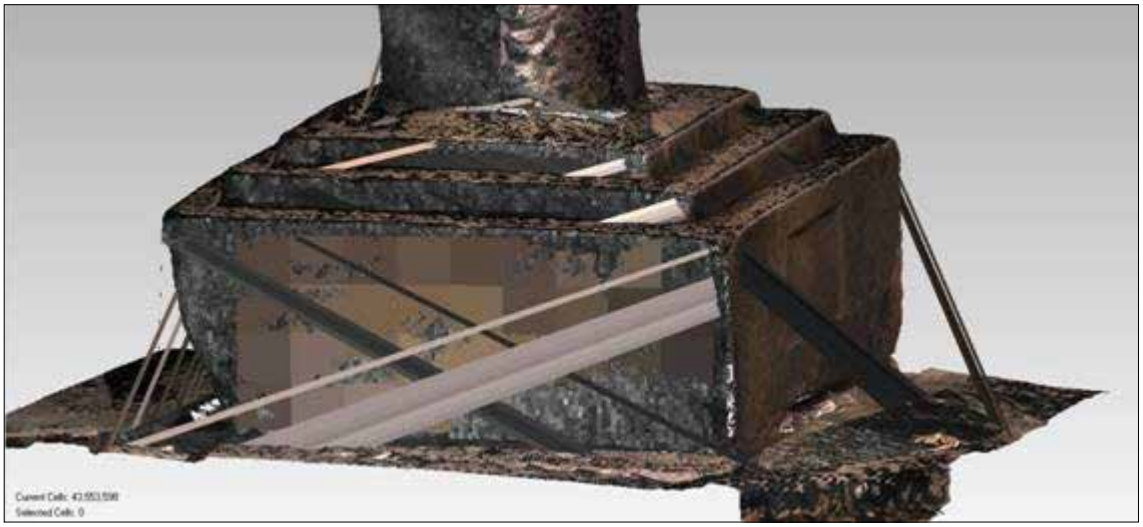

Figure 12: Detail view from the cumulative, coloured point cloud from all Leica P40 laser scans of one of the Anglo-Saxon crosses in St Edward's churchyard, in Geomagic Studio. Note how some of the points recorded of the edges of the base have become elongated stripes, due to the laser skimming across the edge of the surface and down onto the ground. In hindsight, further editing of the raw point cloud may have prevented this effect.

Whilst no such problems effected the photogrammetric processing, there was an issue in the placement of markers taken from scale bars used in shot for particular Photoscan projects. It was found that the software incorrectly identified points and warped the dense point cloud as a result, although scale bars have been used successfully in many other projects. To resolve this, unique points of detail were selected and their local co-ordinates extracted from the laser scans and imported into Photoscan. This method successfully reconfigured the dense point cloud of the market cross SFM project. This clearly demonstrates how undertaking both techniques in fieldwork is beneficial, should unexpected errors arise in post-processing the data away from site.

Unfortunately, strong winds in the market place caused distortion in the laser scans taken from the extendable tripod, which made them unusable, however adequate ground-level coverage was taken to produce a suitably dense point cloud of the market cross.

Similar conditions persisted when the photography of this cross taken from the telescopic mast, although the use of the shutter-priority setting allowed sharp images to be taken. Whilst this was highly beneficial, a compromise had to be made in using this setting rather than aperture-priority, in that the photography taken from height was slightly less sharp than that taken from ground level, although it was not out of focus. Despite this problem, the resulting 3D meshes and textures were of an even quality throughout, apart from the undersides of the cross arms (figure 13). This however, was to be expected in the SFM processing, as little of the photography was able to capture these difficult to reach areas.

Figure 13: SFM model of the market cross. Note the uneven texture of the undersides of the cross arms, and also a rather pixelated area on the right cross arm, from a lack of photos and high resolution imagery.

With the strong winds that faced the team while on site, it was clear the resolution of the images acquired was the best that could be achieved within the timeframe and cost of the project. Placing barriers around the busy pedestrianised area around the market cross, and erecting scaffolding to provide a steady base for aperture-priority photography from height would have been costly and a logistical challenge. It can therefore be concluded that the quality of the 3D meshes and textures generated was the best that the fieldwork conditions could allow.

PART 4: CONCLUSIONS

In conclusion, the project was highly successful in producing 3D records of these three scheduled monuments in Leek using SFM photogrammetry. In this instance, laser scanning was used as a complementary technique to provide supporting measured spatial data where needed, as the SFM workflow in Agisoft Photoscan enabled the generation of the necessary 3D PDFs very quickly, once the meshes were decimated accordingly.

For their requirements, a permanent record of the condition of the monuments, Staffordshire County Council HER and Historic England's West Midlands HAR Projects Officer concluded that the 3D PDFs were highly suitable and accessible. The ReCap projects will be accessible to Historic England staff as their service agreement with AutoDesk permits staff to use ReCap on company workstations.

From the initial analyses of the carved decoration recorded through the course of this project, it is clear that there is a substantial amount of further research potential for these monuments and historic features. The PTM technique has proven that such visualisations are a highly effective aid in identifying etched engravings. Whilst the 3D visualisation of the market cross has suitably achieved the requirement of presenting its overall current condition, the shallow inscriptions and decorations on the market cross head will require more detailed examination to better understand their context. It is suggested that further close-range photography and SFM photogrammetry may achieve this, but as this requires working from a height, it is not within the remit of this present project.

The project encompassed a wide range of geospatial imaging techniques, equipment and software, providing the Geospatial Imaging team's placement holder with a substantial amount of data to process and analyse, proving an ideal training platform for improving her familiarity and understanding of industry-standard workflows in this sector.

All related images (TIFF files) are archived in the Historic England archive, using the project registry number 16/107/1L.

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