YORK ARCHAEOLOGICAL TRUST
finding the future

Glaze Colour Analysis Project: First Phase Report

An *Insight* Report

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GCAProject.wordpress.com

Contents

1. INTRODUCTION

The intention behind this project was to research whether pottery sherds can be characterised by the unique colours of their glaze, without any semblance of bias from the observer. This principle can then be potentially used to determine significant differences in the glazing traditions of a single pottery manufacturing tradition, which could prove to be important in the observation of a pottery ware's homogeneity across its spatial and temporal distribution range. This research could create a useful tool to be used by experts and non-experts for use in the characterisation of archaeological ceramics.

In order to achieve these aims, two phases of this research were devised. The first involved the design, manufacture, and testing of a device that would create standardised conditions in which pottery sherd samples could be photographed and analysed. The device must also be portable, adaptable to the variable sizes and forms that excavated sherds take, and able to be potentially replicated in the future. Above all, it must be able to function for extended periods, in any exterior light level. The second phase will be to analyse the individual RGB codes for a $1cm^2$ target area of each sherd processed by the aforementioned device. This would be achieved by the use of a camera slotted into the top of the device, with the resulting photographs entered into a colour-averaging program, which would present the resulting data as RGB codes. This data will be entered into a database, for which uncharacterised sherds can then be compared to, and subsequently identified objectively. This will initially be conducted on a small number of sherds from Yorkshire, in order to ensure that the process works, before the process is formulated into a computer program to simplify and speed the process up. This program will be able to both enter new sherds into the database, and present the user with information about any pottery wares identified, in a style similar to that used by the online Roman pottery database 'Potsherd' (http://potsherd.net/atlas/potsherd).

As part of the agreement between the GCA Project and York Archaeological Trust, all plans for the light chamber produced as part of this project will be submitted with this report, as well as the RGB database used to test the light chamber in the first phase. Also as part of this agreement, an online blog detailing the project's progress has been updated throughout (https://gcaproject.wordpress.com/), and will be maintained through to the completion of the second phase.

This report will discuss the methodology, manufacturing processes, and initial results related to the first phase of this project, as well as detailing the difficulties encountered, the methods used to resolve these problems, and any future changes to the project based on the results.

2. CONSTRUCTION OF THE LIGHT CHAMBER

2.1 Design

The design of the light chamber first came in the form of a two-dimensional mock-up, formulated as a proof-of-concept before the project started (Figure 1), and was based on the criteria for the light chamber mentioned in the introduction to this report. A ceptometer (an instrument designed to measure light levels) was included in this initial design to ensure that light levels remained the same in the chamber's interior. However, after consultation with an engineer (Luke Rutter at the University of Sheffield), it was suggested that adding a voltage regulator between the batteries and LED lights in the chamber would be both more practical and cost-effective. With this in mind, the next task was to produce a three-dimensional mock-up of the chamber (Figure 2), and send this file to manufacturers who could send a price quote, as well as the length of time it would take to produce. This was achieved using a free 3D design program called Google Sketchup, which while relatively basic, is user-friendly and its designs can be converted into 3D building and printing programs used by manufacturers. At this stage, the ceptometer was removed, and flat and pyramidal "view frames" were added, which could slot into the interior of the chamber, aligned with the camera's eye-view of the sherd, in order to negate the requirement for measured scales on the base of the chamber. The concept of a sliding door was also introduced to allow easy access to the interior while keeping the view frame in place.

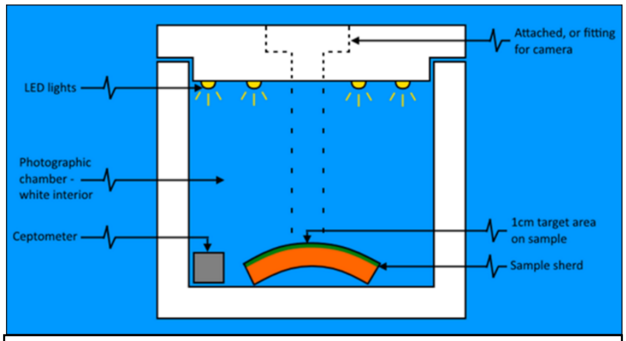

Figure 1: (Above) The Initial 2D design for the light chamber.

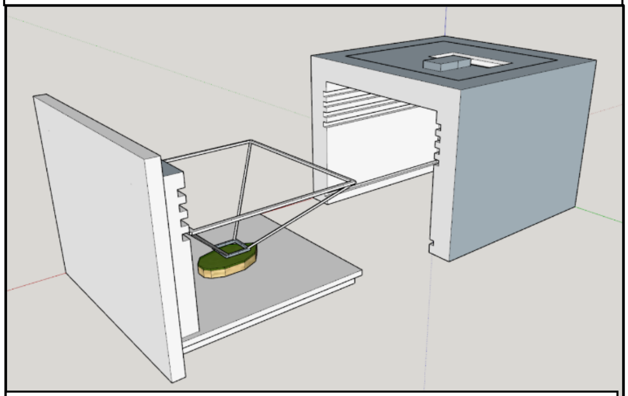

Figure 2: (Above) The first 3D design for the light chamber with alterations.

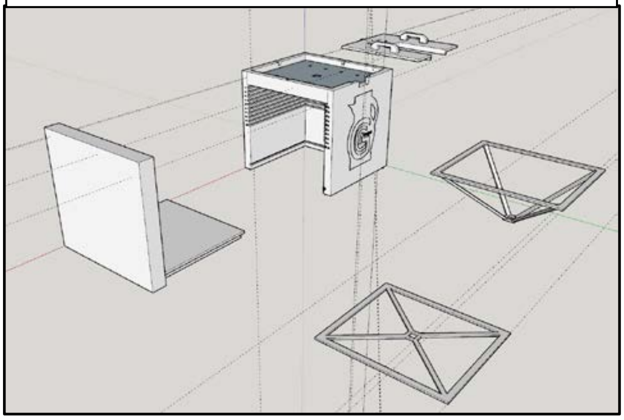

Figure 3: The final 3D design for the light chamber with further alterations.

After approaching three manufacturers, Dundee University was selected as it was the only one of the manufacturers to quote a price below the project's budget. Dundee University then requested measured designs, which were supplied shortly afterwards with a few alterations (Figure 3). These alterations included more slots for the view frames to allow for differently sized sherds to be more easily accommodated, and after further consultation with the engineer, the replacement of the small LED bulbs with 10cm white strip LED lights. The slot for the camera on the exterior was measured to fit a Samsung A5 smartphone, as it has a high quality camera and can automatically backup photographs, and the smartphone itself did not need to be purchased out of the project's budget.

These designs could then easily be read by the manufacturing programs housed at Dundee University to the exact measured specifications, discussed in section 2.3.

2.2 Materials

After reviewing the submitted designs, the staff at Dundee University suggested that the framework for the light chamber would be best manufactured from MDF (Medium-Density Fibreboard). The engineer was again consulted to discuss whether this would post a fire hazard after the addition of electronics. To reduce this risk, the engineer suggested that the electronics should be mounted to a sheet of Perspex, and sealed with a plastic outer plate. This process was deemed acceptable to the staff at Dundee University, and the light chamber was again redesigned to be constructed with more traditional carpentry fittings (Figure 4), while not compromising the structure of the initial design.

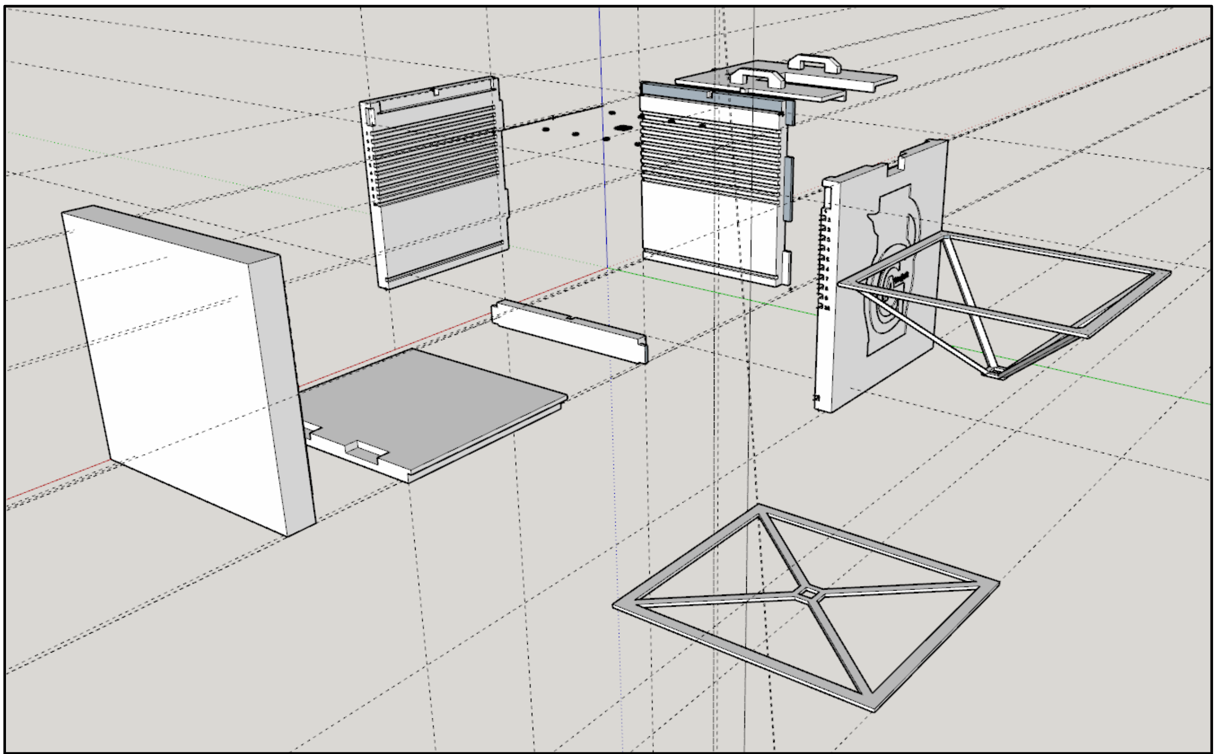

Figure 4: The final 3D design with alterations to allow for a wood-based framework design, the designs programmed into the manufacturing machines.

After manufacture was complete, the MDF accounted for approximately 90% of the overall structure of the light chamber, with laser-cut Perspex accounting for 3%, and 3D-printed plastic accounting for 7%. The sections were fitted together using industrial-strength wood adhesive, with other fittings later added, which will be discussed in section 2.5.

In terms of electronics, the power is supplied by an on-off powerpack encasing eight AA batteries, which feeds into an adjustable voltage regulator, both of which are mounted onto the exterior of the chamber. The regulator then feeds into a set of four LED light strips mounted in a square formation in the interior of the chamber, surrounding the opening for the camera, with four equally sized light diffusers encasing them to reduce glare.

2.3 Manufacturing

The MDF components for the light chamber were first cut with a rotating saw to their required sizes, and then slowly carved into their measured shapes using a rotating drill bit (Figure 5). This process presented a few problems for the project, as not only was this process slow, it was delayed significantly by Dundee University departmental closures due to a week-long heavy snowfall. As such, this process took up two more weeks than allocated for this stage of the project, causing substantial delays in RGB colour testing as a result. This process also required the MDF boards to be nailed down during the drilling process, meaning that sealant was required to plug these holes during the assembly process.

As mentioned in section 2.2, a 3mm thick sheet of white Perspex was laser cut, in order to provide a suitable platform on which to mount the electronics, as well as the flat view frame mentioned in section 2.1 (Figure 6). An outer plate housing these electronics, as well as the pyramidal view frame, were manufactured on a 3D printer (Figure 7).

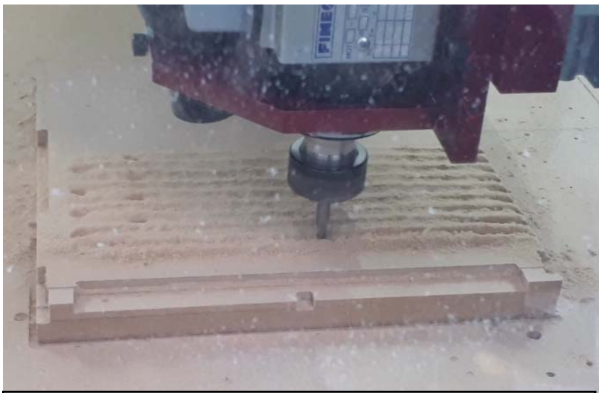

Figure 5: The process of carving the West panel with a rotating drilling machine.

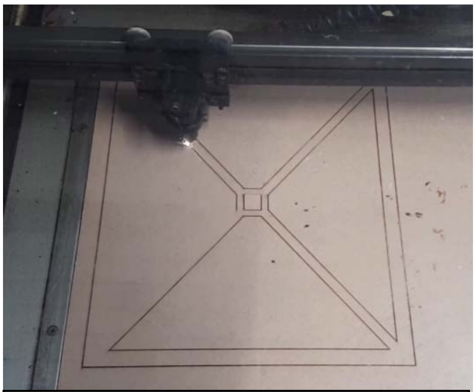

Figure 6: The process of cutting the flat view frame with a laser cutter.

Figure 7: The process of producing the pyramidal view frame with a 3D-printer.

2.4 Assembly

After the panels had been completed, some alterations were necessary to ensure that all panels fit together as designed. These alterations involved the use of manual tools rather than industrial-grade machinery, and wood adhesive was more than sufficient to fix the wood and Perspex panels together. At this stage, the engineer was brought in in person, and the required electronics were purchased and fitted into the light chamber successfully. The interior was painted white, allowing for testing of the chamber's functionality to begin.

These initial tests involved photographing a large number of sherds within a short space of time, to ensure that the light chamber would be able to help create the large database planned for in the second phase of the project. However, two problems became apparent during these initial tests, discussed below in section 2.5.

2.5 Modifications

During these tests, the sliding door one which the sherds would often become stuck in the main chamber, at best shifting the carefully placed sherd, at worst becoming unmovable. The decision was then taken to remove the bottom shelf from the door, fixing it to the main chamber. The door itself would then be modified by having its view frame grooves removed, and attaching it to the left side of the main chamber with two small brass hinges. The door would then be sealed shut with magnets placed on both the door and the main chamber. This significantly decreased the time it took to process each sherd, and ensured that the sherd didn't move around during transition.

The second problem was the view frame, as initial tests suggested that even though the LED lights were placed above the sherd sample, the view frame would cast a shadow over the target area it was designed to highlight (Figures 8 & 9). The decision was taken to remove the view frames from the process altogether, and reverting to scales on the platform on which the sherd sits. However, the grooves designed to house these view frames were not wasted, as a 3mm piece of MDF was then used as a platform to elevate sherds towards the camera, increasing the definition of the sample's photograph while retaining the scale within the shot.

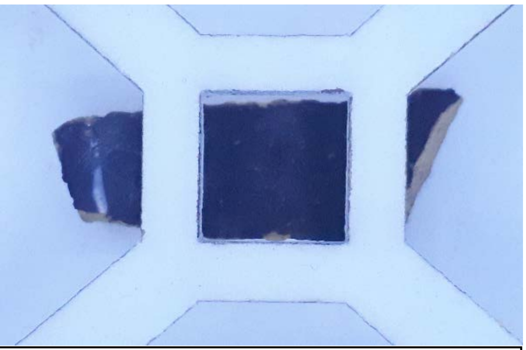

Figure 8: Sample photographed in the light chamber with a view frame.

Figure 9: Sample photographed in the light chamber without a view frame.

3. FUNCTIONALITY TESTING

3.1 Samples

The majority of the samples used to test the functionality of the light chamber were supplied by the pottery reference collection housed in York Archaeological Trust's Pottery Department. A short visit to YAT's Heslington Road warehouse was also necessary to increase the variety of glaze types analysed using the light chamber. Sherds of the type known as 'Ryedale Ware' were over-represented in this sample, in order to establish whether glazes from multiple pottery production sites differed from each other. In total, 472 sherds were analysed, and all samples used for this stage have since been returned.

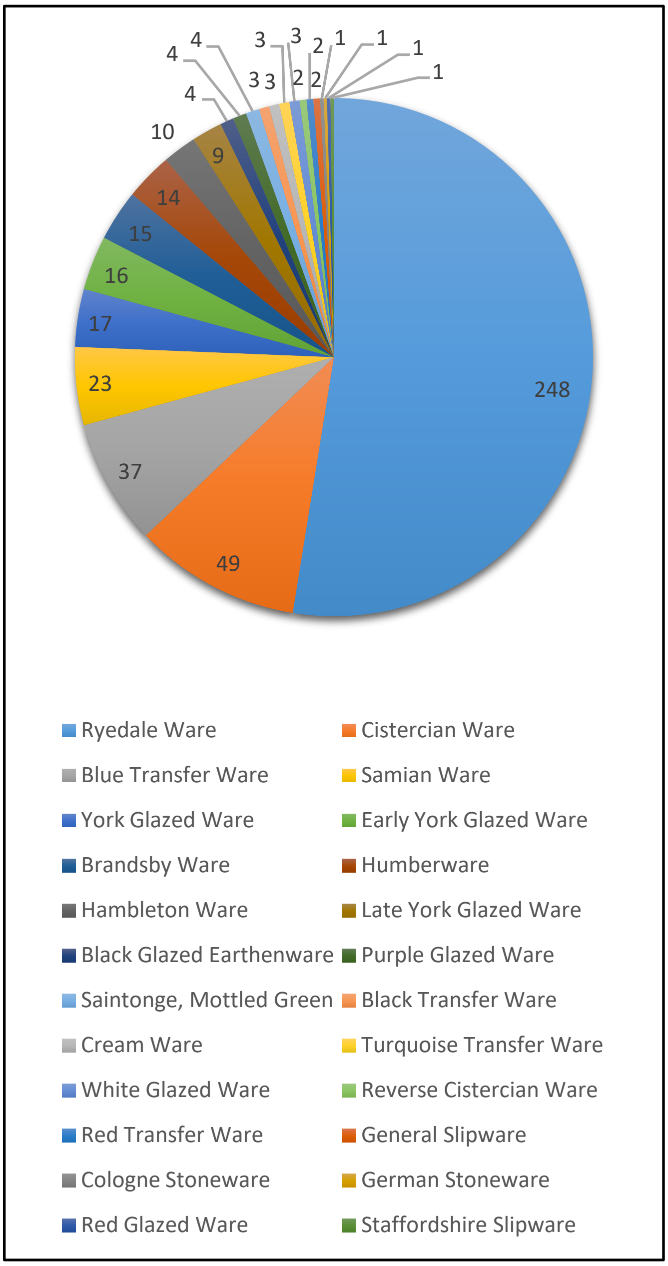

Figure 10: Chart displaying the proportions of the different pottery types used in the test sample.

3.2 Methodology

For the first phase of the project, three tests were devised to conclusively determine whether the light chamber functions as designed.

3.2.1 "Watertight" Test

This test was devised in order to ensure that no exterior light could enter the chamber and potentially affect the results. A small sherd and a large sherd of the same pottery type were photographed over 15 hours at 3 hour intervals, with the chamber placed by an open window. The RGB codes of both the sherds and the white background were then analysed to observe any significant differences based on the light levels outside.

3.2.2 Camera Test

This test was devised in order to ensure that the camera would not adjust the brightness of the image it takes based on the colour and size of the sherd. A variety of pottery wares were selected in order to attain the most representative results possible, and a smaller and larger sample were selected from each ware, as the difference in the white background exposed to the shot could force the camera to adjust its brightness. In this instance, the RGB codes of only the white background were selected in order to determine whether the camera was adjusting its brightness, as no two sherds were the same and therefore could not be compared to a degree of accuracy.

3.2.3 RGB Comparison Test

This test was devised in order to determine whether two sherds of the same type could be compared and characterised based on their RGB codes. While a large amount of data was collected for this test, only a fraction could be analysed before the end of the first phase of this project, owing to manufacturing delays for the light chamber and the amount of time it currently takes to gather RGB code data for each image. This test was conducted by obtaining the average RGB codes for a 1cm^2 area of the centre of each sherd by cropping the photograph taken in the light chamber and running the resulting image through a colour-averaging program (http://mkweb.bcgsc.ca/color-summarizer/?analyze). These RGB codes are then charted on graphs and can then be compared against both each other and new entries, with clusters of data hopefully corresponding with what ceramicists consider to be a single pottery ware.

3.3 Results

3.3.1 "Watertight" Test

The results for the watertight test were initially not encouraging. If the light chamber had functioned as designed, the lines on Figures 12 to 14 would all be perfectly horizontal. However, on closer inspection the results suggest that the readings were much more consistent during darker hours. This suggests that a small amount of sunlight had entered the chamber during daylight hours, and the deviations observed during these hours could be due to the variation in sunlight. Therefore, a solution could be to produce a black cover for the chamber in order to simulate darker exterior conditions. Once this has been produced, the test will be conducted for a second time on the same sherds, hourly this time, to observe whether this was indeed the problem, or whether a different problem has caused this variation.

Figure 11 displays the RGB codes for the white background on which the sherd sat. Its RGB code was consistently at the maximum, i.e. it was pure white. This phenomenon of higher background RGBs was also observed in the Camera test, and could present a further hurdle for the project to overcome.

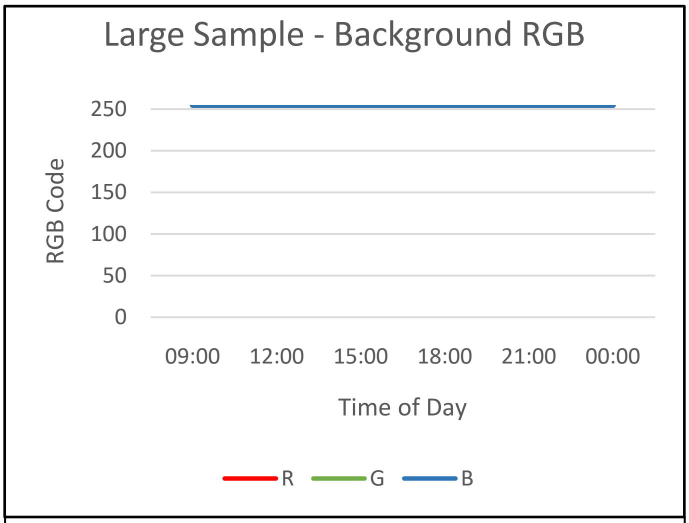

Figure 11: (Above) Graph displaying the RGB variations for the colour of the background on which the larger sample was situated, over 15 hours.

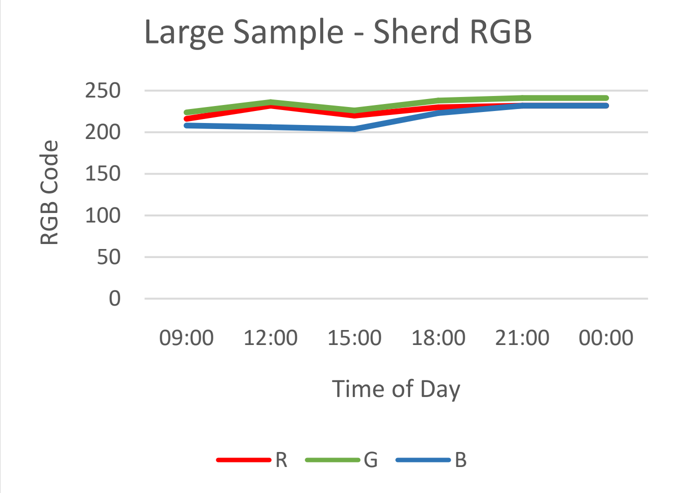

Figure 12: Graph displaying the RGB variations for the colour of the larger sample sherd, over 15 hours.

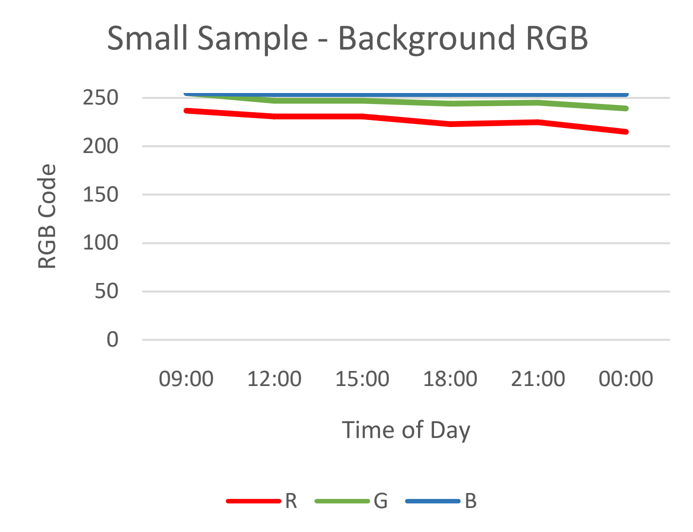

Figure 13: Graph displaying the RGB variations for the colour of the background on which the smaller sample was situated, over 15 hours.

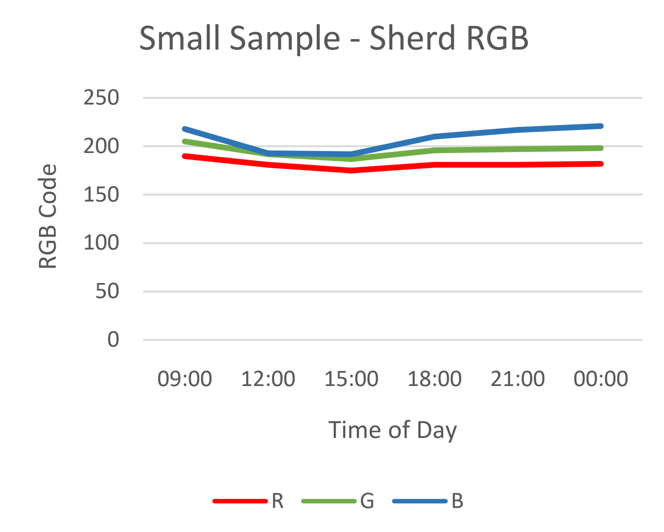

Figure 14: Graph displaying the RGB variations for the colour of the smaller sample sherd, over 15 hours.

3.3.2 Camera Test

The camera test became a concern very soon after the first few photographs were taken, as it was clear that the static white background was changing in brightness based on how large the sherd being photographed was, as well as the colour of its glaze (Figures 15 & 16). Steps are currently being taken to find the based method in which to negate this effect, including changing the colour and pattern of the background, the use of different cameras, as well as researching ways to inhibit the camera from correcting the shot.

The result of this difficulty is that the overcoming the camera test's problems has now become the project's highest priority. Therefore, the camera test has now been expanded to include processing RGB codes from the sherds and the backgrounds, using several new backgrounds displayed in Figure 17, changing where the camera is focussing in the chamber, artificially increasing and decreasing the light levels captured by the camera, and increasing the number of pottery types sampled. As a result, the number of photographs taken for this test has increased exponentially, and results in the form of graphs and charts may be delayed until the processing program is written over the next few weeks.

Figure 15: First photograph taken of sample 10 on a white background.

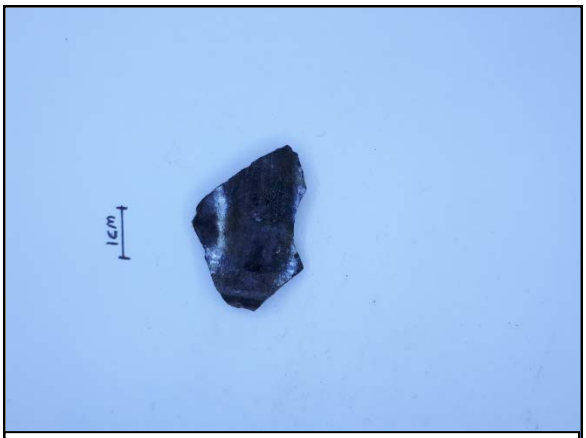

Figure 16: First photograph taken of sample 169 on a white background.

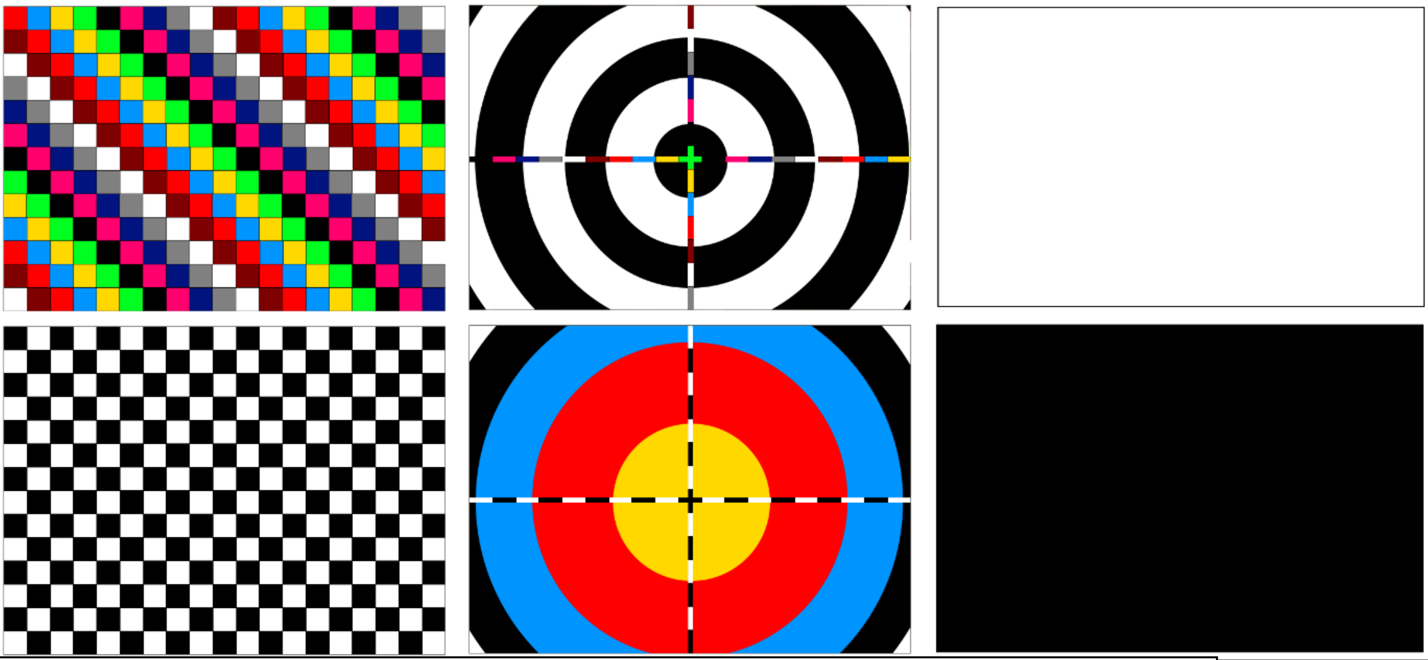

Figure 17: New sample backgrounds devised for further camera testing from the top-left clockwise: Colour Chequerboard, Black and White Rings, White, Black, Colour Rings, and Chequerboard.

3.3.3 RGB Comparison Test

With the inconsistencies in light levels discovered by the Camera Test, the RGB Comparison Test has largely been delayed until the Camera Test has been completed. However, the photographs already taken as part of this test will be compared with the photographs taken after the light chamber and camera corrections have taken place, in order to both calibrate the new results, but also to help determine which statistical models would be most appropriate to compare results, as discussed in section 3.4.

3.4 Further Planned Tests

Further tests will be conducted upon the conclusion of the Camera Test and once the new software for processing photographs has been written over the next few weeks. These tests will be largely aimed at increasing accuracy in pottery ware recognition, and three experiments have been devised for this so far: An experiment to determine whether pottery ware recognition can be improved by splitting the captured images into multiple RGB codes based on the proportion of each colour that makes up the image (which can already be achieved on the colour analysing program already used by this project); An experiment to determine whether enlarging the 1cm^2 target area will also improve pottery ware recognition; And an experiment examining whether observing the differences in RGB codes, rather than using the RGB codes themselves improves accuracy. More tests designed to improve the process will most likely materialise as the project progresses, and once the whole system can identify sherds to a high degree of accuracy against its localised database, work will begin to expand this database for new samples.

4. CONCLUSIONS

4.1 Summary

In terms of the construction of the light chamber, the project has so far proven successful. The only issue with the light chamber itself not yet corrected has been highlighted by the watertight test, which given some creativity, should be overcome quickly. In terms of ease of replication, the light chamber has also proven successful, as it was manufactured on a small budget by easily accessible materials. Once the final modifications are taken into account in the 3D files used to construct it, they could potentially be sent anywhere in the world to be manufactured quickly and cost-effectively, weather permitting. It may be testament to it then that the two major issues that the project has to overcome are the camera's auto-adjust function, and the need for a quicker method in which to process the vast amount of data it can produce in such a short space of time.

Plans to overcome both of these issues are currently being implemented, and once all further tests have been conducted, and the system proves itself to be a viable tool for sherd recognition and scrutiny, its applications could extend to several branches of the heritage sector, as discussed in section 4.2. At this point the project will be perfectly positioned to move into the next stage of development, making the system fast, user-friendly and as informative as possible aided by comprehensive and easily accessible software based on a wide database of RGB data and sherd photographs.

4.2 Potential Applications

If the above methodology can produce a successfully replicable light chamber and associated program that can quickly, cheaply, and objectively characterise glazed pottery, it could become a useful tool for archaeologists, specialists, museums, and the general public. There is also potential for it to be used as an educational aid in schools or universities. Its nature as a non-intrusive method of archaeological analysis presents the potential for it to be used in several different ways:

4.2.1 Archaeologists

- *This could be used on-site to aid in dating contexts, or reinforcing interpretation on context sheets. The same could be applied to post-excavation report writing.*

4.2.2 Specialists

- *Ceramicists could potentially reduce the size of their unknown pile, and potentially increase the accuracy and improve the background information submitted in pottery reports. Even without the associated software, it can be used to quickly produce high-quality photographs of pottery sherds for subsequent publication.*

4.2.3 Museums

- *Similar to archaeologists, this could be used to date and characterised sherds from sites excavated decades before contextualising features and finds became common practice. It could also potentially be used as a publicly available piece of equipment to support an exhibition. An internal database could also be produced to compare* *new entries with sherds held by the museum. Similarly to specialists, this can be used to quickly produce high-quality photographs of pottery sherds for subsequent publication.*

4.2.4 General Public

- *This could be used to support schemes such as the Portable Antiquities Scheme, as glazed sherds found by the public can be more quickly and accurately assessed. It could be generally used by collectors and enthusiasts as an informative or characterisation tool.*

4.2.5 Education

- *This could be used in schools as a teaching tool for history or archaeology, assuming sherds for analysis are provided ethically. It could also be used for a similar purpose in universities, as well as to assist ongoing research projects and excavations. Similar to a museum, an internal database could also be produced to compare new entries with sherds held by the university.*

This series of *Insights* has been contributed by York Archaeological Trust staff members and external specialists for Finding the Future. They aim to frame an understanding of aspects of the Trust's collection of artefacts and their archaeological context; and also to enhance staff involvement. The authors represent a broad range of experience and knowledge.

Insights are not presented as YAT publications, they have not been peer reviewed or edited to full publication standard. Rather they should be seen as statements reflecting the research, ideas, knowledge and interests of the individual authors. They are not necessarily designed to be the definitive word, may not always agree with the Trust's previous publications, and some of their content may be subject to debate or different interpretation. All within the spirit of Finding the Future.