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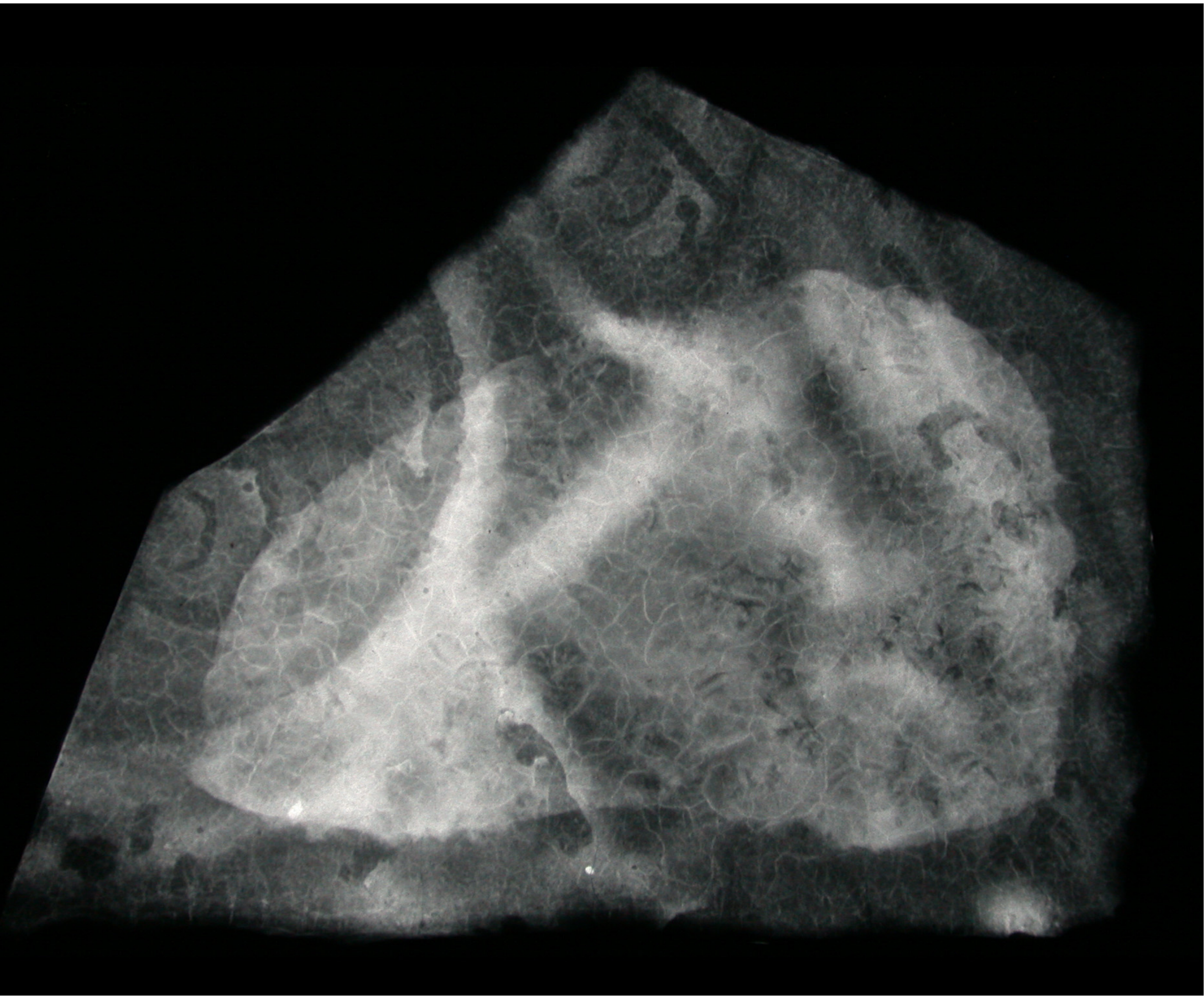
CHURCH END, CHESTERTON, WARWICKSHIRE
INVESTIGATIVE CONSERVATION OF GLASS

ARCHAEOLOGICAL CONSERVATION REPORT

Karla Graham



ARCHAEOLOGICAL SCIENCE

ENGLISH HERITAGE

Research Department Report Series 85-2011

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SUMMARY
This report covers the investigative conservation of medieval painted window glass from the site of Chesterton Manor, Warwickshire. The conservation included X-radiography to indicate and record the presence of painted decoration as well as to provide information on condition. The effectiveness of X-radiography as an investigative tool was assessed and is reported on. A selection of sherds underwent remedial conservation to stabilise the glass.

CONTRIBUTORS
Karla Graham

ACKNOWLEDGEMENTS
To Sarah Jennings for her enthusiasm for the finds and her advice and support. I would like to thank to David Adams of the Warwickshire Archaeological Research Team (WART) for access to the glass excavated by WART. My thanks also to project team members Sarah Reilly, Sarah Brown, David Dungworth and Gareth Hatton whose preliminary results are referenced in this report.

ARCHIVE LOCATION
The finds from the evaluation remain the property of the landowner who expressed a wish to have them returned once preliminary processing and quantification had been completed at Fort Cumberland. The glass was returned to him and is in the care of the Warwickshire Archaeological Research Team in their store at Chesterton.

DATE OF RESEARCH
2002-2004

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INTRODUCTION

The site of Chesterton comprises a complex of earthworks possibly related to the displaced medieval village of Church End, Chesterton, Warwickshire. The site is a Scheduled Ancient Monument: SAM no. 35105, Warwicks 106. A management issue had been brought to the attention of the Inspector of Ancient Monuments by an amateur group: the Warwickshire Archaeology Research Team (WART). The site was being disturbed by rabbit burrowing and WART had been monitoring the site and its environs for over a decade. The disturbance was evident by the large amounts of highly decorated medieval window glass being recovered from the burrows' up cast (Fig. 1). Up to 2002, WART had retrieved and stabilised disturbed finds from the bank including some 385 sherds of window glass (of which approximately 95% is decorated).

Figure 1: Example of highly decorated Chesterton window glass

The English Heritage (EH) Archaeological Projects team undertook an evaluation in November 2002. The work was in accordance with one of the teams' then strategic objectives: to assess damage to sites outside of the planning process and to carry out strategic projects to address this. The evaluation aimed to determine the extent of damage and assist in finding a solution to the SAM management problem (Reilly 2002). Specifically, it aimed to establish the state of preservation of archaeological remains in order to be able to assess the impact of the damage caused by burrowing. To date, an interim report has been produced outlining the background to the work, a description of the site and a summary of the results of the fieldwork (Reilly and Jennings 2002).

This report covers the following archaeological conservation work;

- The devising a preventive conservation strategy for the fieldwork phase to stabilise the glass through packaging and storage.
- The assessment (including X-radiography) and investigative conservation of a selection of glass determined by the finds specialist.
- The remedial conservation (consolidation) of a selection of glass for display purposes at the EH Festival of History event in 2003.

FIELDWORK: GLASS PACKAGING STRATEGY

A packaging strategy for recovering large numbers of damp painted glass is not included in the standard EH Centre for Archaeology Recording Manual so, to address this, one was designed in conjunction with the project finds specialist. The packaging strategy was designed to ensure the glass was recovered from the site safely (to maintain it in its current condition) and efficiently (time and material resources). The strategy needed not only to be suitable for recovery but also deposition with the final repository.

The packaging had to provide physical protection (including during transit) and support an appropriate environment for the glass (not promote deterioration). The strategy should keep the glass accessible whilst at the same time reducing the need for handling ie to balance the conservation needs with the requirement to undertake specialist work (assessment of the material). Lastly, it should be appropriate for a non conservator to implement through training and the provision of a guideline for onsite work.

The packaging strategy devised involved the following (*see* also Figs. 2 and 3);

- Large Stewart® boxes (polypropylene) were selected for their high surface area relative to their low depth (measuring 51cm x 31cm area by 10cm depth).
- In each Stewart box there are 3 trays of glass storage that can be lifted out individually using cotton tape handles (Fig. 2).
- Each tray comprises a lower support layer of Correx® (polypropylene) and two overlying layers ('glass layer 1 and 2') of Plastazote® (polyethylene) (Fig. 3).
- The glass is contained within recesses cut into the top Plastazote® layer.
- A layer of Plastazote® is located over the glass prior to the next tray (Fig. 3).
- Any space above the 3 trays is filled with layers of Jiffy foam to prevent movement during transit.

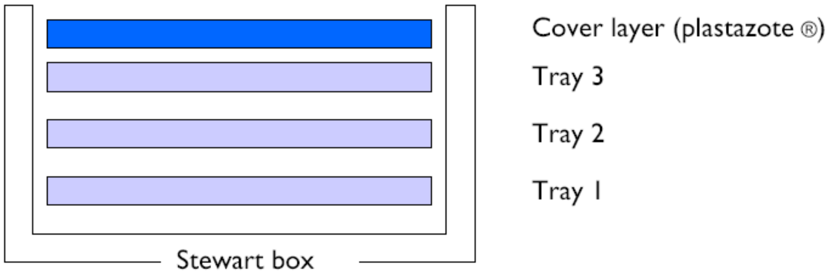


Figure 2: Glass storage box with 3

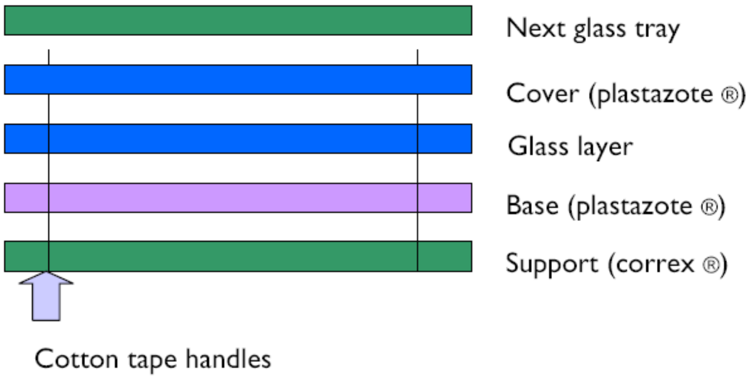


Figure 3: Exploded view of what each tray shown in Fig. 1 contains. Depending on the thickness of the glass, 1 or 2 glass layers are required.

The trays were pre-prepared prior to the excavation. As the cut-out recesses had to be tailored to fit each individual sherd of glass, this work was undertaken onsite (*see* Fig. 4)

Figure 4: Finds assistant Ellie Brook preparing each glass layer (left) and completed layer (right)

Glass cannot be stored in damp, cold storage indefinitely and must be stabilised. A study by Naomi Earl on the storage systems for waterlogged archaeological glass showed that corrosion occurs when glass is stored long term in polyethylene foam cut-outs and high relative humidity i.e. in a sealed stewart box (Earl 1999). The corrosion is a result of water condensing on the surface of the glass and concentrating leached alkali which attacks the glass.

GLASS

WART Glass

The glass recovered by WART was cleaned and treated by WART and stored in boxes containing cotton wool. It is understood (from pers comm between WART and Sarah Jennings) that the glass was treated using a solution of Johnson's® Baby Oil (Paraffinum liquidum, Isopropyl Palmitate and Partum). 'Superglue' in a thinner was used to varnish the whole surface and applied to the edges.

The WART glass was repacked into the EH packaging system by the finds assistant during fieldwork. An additional box of glass sherds was sent to Fort Cumberland by WART in May 2003. These sherds were still damp and packed either wet sandwiched in between plastazote or, submerged in Johnson's® Baby Oil. Two sherds were selected for conservation by the finds specialist and the remaining glass did not undergo conservation. The WART glass totalled 469 sherds.

Glass from the English Heritage fieldwork

On site, most of the glass was recovered with soil deposits on the surface. Voluminous surface dirt was mechanically removed in the finds hut by the finds assistant but a thin layer of soil remained which in many cases obscured the surface detail. The glass was returned to Fort Cumberland in batches during fieldwork. To reduce the likelihood of mould growth, the glass was temporarily stored in a cold room at approximately 4°C and in the dark. In total, 1440 sherds of glass were recovered from the fieldwork.

At this stage, investigative conservation was required to identify the glass with painted decoration present (for dating by the finds specialist) and to establish the condition of the glass. The condition would indicate the impact of the burial environment and rabbit activity upon the glass as well as inform the conservation treatments. X-radiography is used as a rapid screening technique for metalwork so it was decided to apply the technique to the glass sherds to also rapidly scan for decoration and condition.

X-RADIOGRAPHY

In the past, Xeroradiography of glass has been undertaken with success to clarify decoration on a select number of glass fragments (Knight 1989; Watts 1994). Xeroradiography is now a largely redundant technology due to the advances in medical imaging technologies (O'Connor and Maher 2002). A sample of the Chesterton glass was X-rayed using conventional radiography to determine if it could record both condition and decorative features. As the initial results were promising (Fig. 5), it was decided to proceed with X-raying the remaining sherds.

Figure 5: Examples of initial x-rays (sherds 51 and 54) showing both paint and condition

Kodak AA400 x-ray film was used at low kilovoltages and short exposure times (45 and 50kv, 3mA and 12 seconds). 30 x 40cm X-ray film was selected as it measured slightly smaller than the glass trays that the sherds were stored in. An X-ray could therefore be taken of the glass laid out in exactly the same arrangement as it was laid out in storage (the glass was removed from the trays). For assessment purposes, this made it easy to relate the glass in its storage unit to its X-ray image (particularly as the glass was not numbered with a small find number).

ASSESSMENT

Technology

Samples of glass were examined by Gareth Hatton and David Dungworth, EH Technology team and a short report produced (Hatton and Dungworth forthcoming). The glass was examined using a Scanning Electron Microscope and the chemical composition was determined using an energy dispersive X-ray detector. High levels of potash and low levels of soda indicated that the glass is a forest glass.

Architectural investigation

Sarah Brown, Senior English Heritage Architectural Investigator, examined the glass and accompanying X-rays and produced an interim report (Brown 2003). Brown concluded that the glass represents the uncoloured 'marginal' glass that was discarded when the valuable coloured glass and lead was salvaged for re-use. On stylistic grounds, a small group of glass dates to the late 13th century with the majority of the glass dating to the first half of the 14th century.

68 sherds were selected by Brown for further study (full assessment) and these required cleaning to remove the overlying soil. The glass was classed as a bulk find and therefore not assigned small find numbers or EH laboratory numbers. For the purpose of X-radiography, condition assessment and evaluating the conservation strategy and treatment, the selected sherds were assigned temporary numbers (1 to 68).

Condition assessment

Methodology

In damp atmospheres, potash glass (forest glass) is more liable to decay than soda glass. This is as a result of its composition: too much lime, too little silica and large quantities of potassium ions that are readily soluble (Dillon 1994; Pollard and Heron 1996). Much has been written on the condition and deterioration processes of glass (Cronyn and Davison 1996; Knight 1996; Pollard and Heron 1996). The Chesterton glass was assessed based on the condition assessment developed by Dillon (Dillon 1994). The condition was assessed from the X-radiograph (extent of surviving core and appearance of the core) and from visual examination (surface condition and overall condition categories). The condition categories are outlined in tables 1 to 4 with examples in tables 5 and 6. The results are presented in table 7 and summarised in tables 8 and 9.

Table 1: Extent of surviving core from X-ray

Category	Description
Border (B)	Area of low density (ie edge corrosion) >1mm thick around distinct glass core.
Core (C)	Core glass present in most of sample.
Core-gone (CG)	Border extends so that little or no core is present (<0.5% of sample area).

Table 2: Appearance of core from X-ray (after Dillon 1994)

Category	Description
Amorphous (Am)	Irregular 'mottled' appearance (usually associated with circular pitting).
Border-Core	Distinct area of low density (i.e. edge corrosion) >1mm thick around a distinct glass core.
Crazing (Craz)	Microcracks cover surface.
Speckled (S)	Discrete circular areas (associated with weathering plug-type pitting).
Indeterminate (I)	No visible structure (undecayed core).

Table 3: Condition Assessment (after Dillon 1994)

Category	Description
Excellent	Translucent No decay
Good	Some decay No tendency to lamination / crumble for example
Fair	Decayed Liable to lamination / crumble in future for example
Poor	Decayed Active lamination / crumbling for example

Table 4: Sub-condition of each sherd face (after Dillon 1994)

Category	Description
Smooth (S)	Even surface.
Scuffed (F)	Very shallow micropits or scratches.
Pitted (P)	Small (S) Medium (M) Large (L)
Metallic (opaque)	Smooth, shiny, opaque surface, usually brown.
Opaque / translucent (O/T)	Mixed surface.
Iridescent / 'Hydrogen glass'	
Chalky	Pieces are completely white in appearance although the paint decoration is still visible on the surface

Table 5: Example condition categories from x-ray

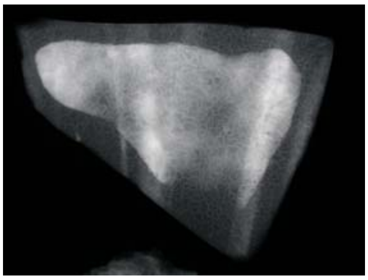
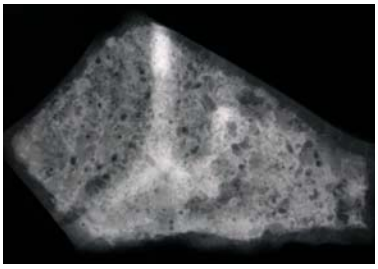
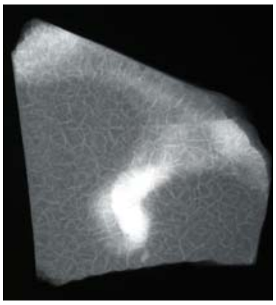
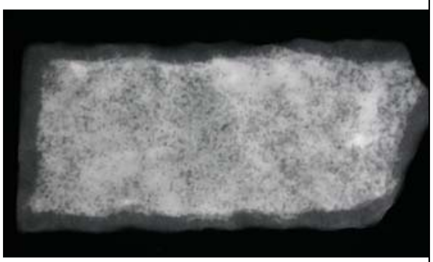
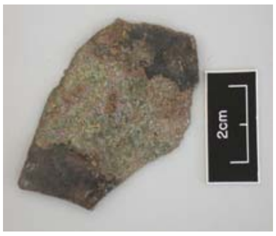
Category	Example	Description
Border-core		Distinct area of low density (i.e. edge corrosion) >1mm thick around a distinct glass core.
Amorphous		Irregular 'mottled' appearance (usually associated with circular pitting).
Crazing		Microcracks covering the surface. Fine cracking or 'crazing' may be caused by cycles of hydration and dehydration.
Speckled		Discrete circular areas (associated with weathering plug-type pitting).
Indeterminate		No visible structure (undecayed core).

Table 6 Example condition categories from visual examination

Category	Example	Description
Translucent / semi-translucent		A few pieces remain semi translucent on one side: 12, 15, 40, 56.
Metallic (opaque)		As the glass the decays, hydrated oxides of iron and manganese are precipitated out.
Iridescent 'Hydrogen glass'		The soluble components of glass (such as sodium and potassium ions) are leached out and replaced by smaller protons (hydrogen). The smaller volume of the hydrogen ions creates physical stress in the glass. The glass contracts and collapses splitting into a series of weathering layers (lamellae). These layers reflect light unequally producing the iridescent effect.When weathered glass is damp it can appear translucent, shiny and in a relatively good condition since the water sits in between the layers. In this example, the surface has laminated to expose an iridescent surface.
Corrosion / Pitted		Pitting can occur where leached alkali concentrates on the surface (for example in cracks or surface scratches) resulting in an increase in the pH and the localised breakdown of the silica network of the glass. The high pH is confined to the pit and the corrosion continues downwards. White deposits in the pit consist of hydrated silica, gypsum (calcium sulphate) or syngenite. Small circular pits and then pitting that has coalesced into larger areas of pitting. All pitting is present on the non decorated, exterior face of the glass which is a well recorded if not fully understood phenomenon (Newton 1996).
Chalky / crumbling		Pieces are completely white in appearance although the paint decoration is still visible on the surface (sherds 37, 38 and 39). This glass has literally been turned to silica gel. When the humidity changes, the weathering layers shrink and expand leading to exfoliation.

Category	Example	Description
Laminated		Loss of surface.

RESULTS

Visual examination

From visual examination, the majority of the sherds were in a fair or good condition and fairly evenly split between the two categories (Table 8). The difference between these two categories was that the fair condition sherds tended to be chalky and / or more pitted. The good condition sherds displayed pitting but this tended to comprise smaller and fewer pits.

Table 8: Summary results: condition from visual examination

Condition	Total sherds
Poor	8
Fair	25
Good	23

Surface appearance	Poor	Fair	Good
Chalky	8	16	
Pitted	6	21	15
Crumbly		1	
Delamination		1	

X-radiography

Table 9: Summary results: condition from X-ray

		Condition (from visual examination)		
Core extent	Core appearance	Poor	Fair	Good
Border (Area of low density (i.e. edge corrosion) >1mm thick around distinct glass core.)	Amorphous	1	1	3
	Crazing	1	1	4
	Amorphous & Crazing		3	1
	Speckled	1	8	2
	Speckled & Crazing	1		
	Iridescent		2	1
Core (Core glass present in most of sample.)	Amorphous		4	2
	Crazing	1	3	1
	Amorphous & Crazing		1	
	Speckled	3	1	2
	Iridescent		1	7

X-radiography was an effective tool for identifying the presence and extent of decoration although, upon the removal of soil, more decoration was apparent from visual examination. To assess just how effective X-radiography was at detecting decoration, separate tracings on Melinex were made: red for visual examination (after removal of the soil, Fig. 5) and black for X-ray (Fig. 6). The outlines were then overlaid to compare and determine approximately what percentage of the visual decoration was picked up on the X-ray (Fig. 7 and Table 10).

Table 10: Summary results of amount of decoration (from visual examination) detected on X-ray

Percentage range (%)	No. of sherds
0	16
1 to 25	18
26 to 50	12
51 to 75	4
76 to 99	4
100	1

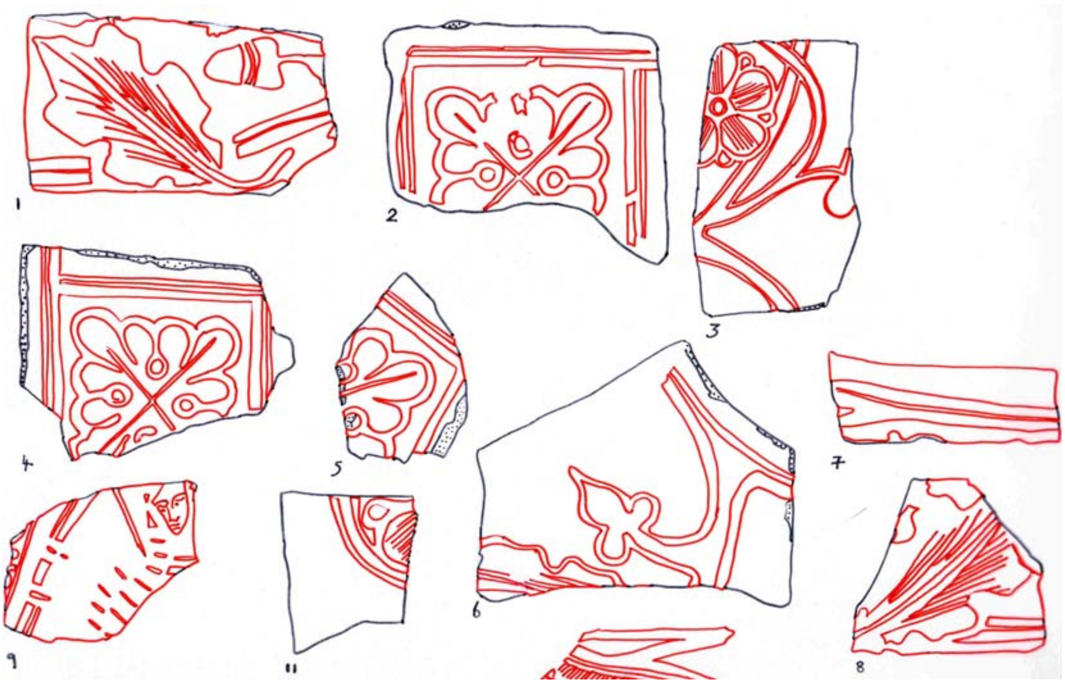


Figure 5: Decoration observed from visual examination

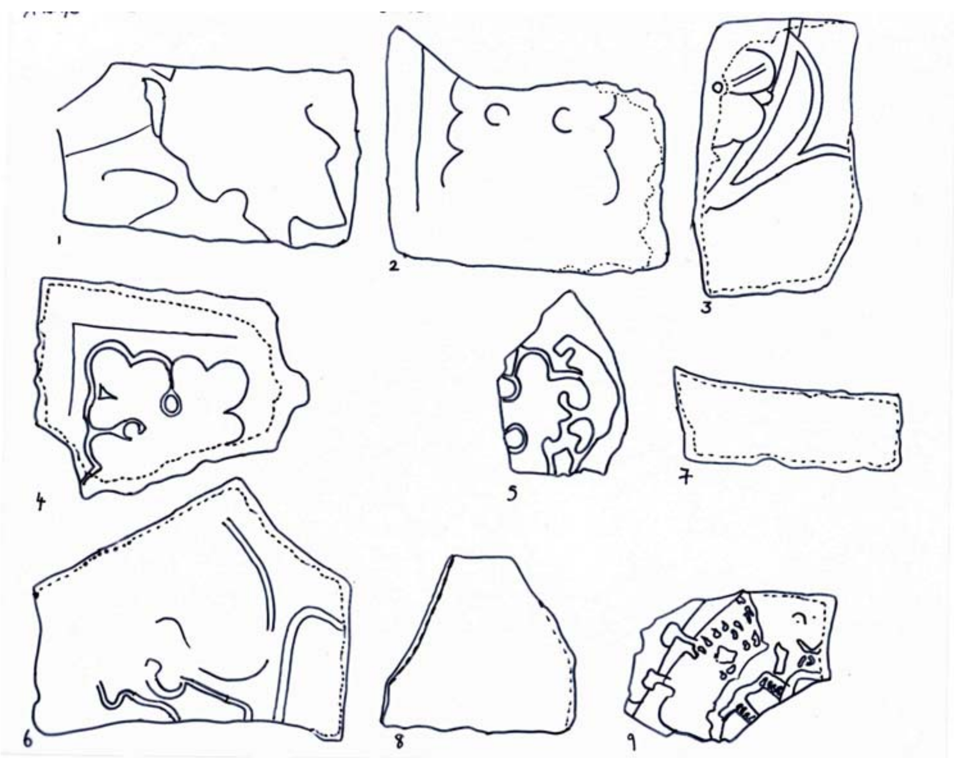


Figure 6: Decoration observed on X-radiograph

The exercise indicated that X-radiography revealed the decoration on 70% of decorated sherds tested. Where the decoration was not visible on the X-radiograph, the condition of the sherds was fairly even spread across the good, fair and poor condition categories.

Of the X-rays that revealed known decoration, X-radiography showed less than 50% of the decoration present on each sherd (*see* Table 10). The X-ray results indicate that X-radiography is not a comprehensive technique but should be one of many tools applied to investigative conservation. It is worthwhile noting that 5 X-rays showed additional decoration not visible to the naked eye.

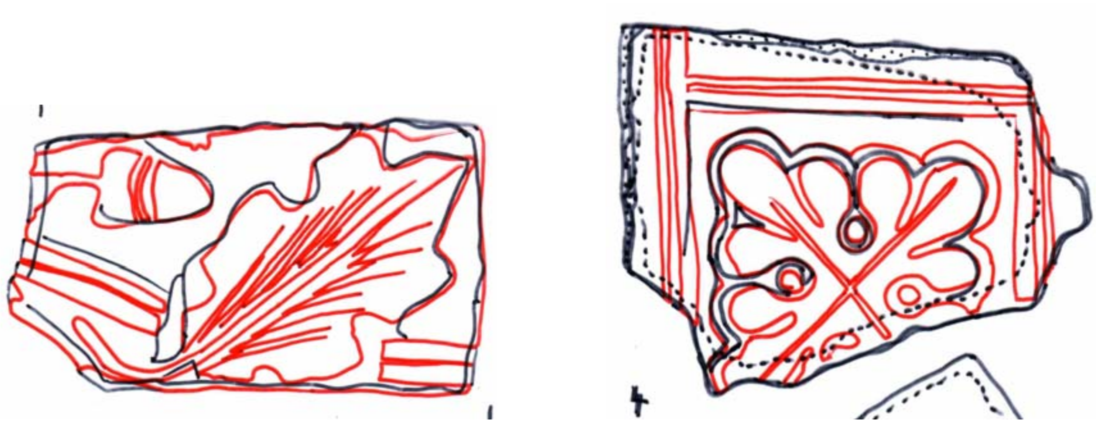


Figure 7: Example of x-ray decoration (black) overlain decoration observed by visual examination (red)

REMEDIAL CONSERVATION

25 sherds (numbered 1 to 25) were selected by the Finds Specialist for a display about the Chesterton project at the Festival of History.

Cleaning

Surface dirt was removed using cotton wool swabs wetted in a 50:50 solution of distilled water: Industrial Methylated Spirits (IMS). The fragments were covered with a piece of silicone release paper to slow down the rate of evaporation.

Consolidation

Only the sherds that remained wet required consolidation (see Appendix 1: Sherd number 2). The remainder of this subset of glass had dried out slowly either in the burial environment or post-excavation (see Appendix 1: Sherd numbers 4, 5 and 6).

Ideally, a series of test should have been carried out to test the efficiency of the different consolidation methods. The deadline for the glass to go on display meant that one method was selected from a literature review without undertaking laboratory tests (Davison and Newton 1996; Alten and de Laperouse 2000). A Polyvinyl Acetate (PVA) was selected over an acrylic colloidal dispersal since it was suggested to impart more strength to the glass (Alten and de Laperouse 2000).

The glass was stabilised using a 4% solution of Polyvinyl Acetate (PVA) (Vinamul 40224) in distilled water. The two sherds were immersed in the solution and the solution placed in a bell jar. A partial vacuum was drawn on the solution and then the bell jar was sealed and left overnight (17 hours). The sherds were taken out of the solution and the excess liquid was removed from the surface with a cotton wool swab (the surface was intact and adherent). The sherds were placed on and under silicone release paper to slow down and control the drying process. The sherds were periodically turned over until dry. Any excess PVA was removed using a scalpel under binocular magnification.

SUMMARY

The X-rays taken suggest that X-radiography is useful in the majority of cases for indicating and recording the presence of painted decoration (70% of the sample tested). This is probably dependent on the condition of the glass and the type and condition of the painted decoration. X-Radiography contributes to the effective assessment of the condition (internal corrosion) as this could be determined in each case. This exercise did however indicate that further investigative conservation is required to fully record *all* surface decoration.

The 65 sherds selected by the EH Architectural Investigator were assessed and underwent some investigative conservation (removal of soil deposits). Most of the glass had some overlying soil and the removal of this soil to clarify the surface decoration was a time consuming task. Consolidation of the glass was only undertaken (and where required) for the purpose of a display at the EH Festival of History 2003 in agreement with the find specialist and the land owner. The consolidation was successful and PVA is recommended as a treatment for other Chesterton glass sherds requiring consolidation.

The project did not continue into the full assessment and analysis stages as the landowner requested the return of the material. It was not possible to complete the conservation assessment of the whole assemblage regarding condition, investigative conservation potential and remedial conservation requirements. Whilst the whole glass assemblage had been X-rayed there was no opportunity to complete the investigation of whether the X-ray results (condition assessments and observations of decoration) correlated with the actual glass condition and volume of decoration upon the removal of overlying soil. There was also no opportunity to assess the long term success of the consolidation treatment undertaken.

The study did however show that X-radiography is an invaluable tool in the condition assessment and investigative conservation of window glass. It can provide different levels of information ranging from an indication of the presence of painted glass within an assemblage to, detailed information to guide the removal of soil deposits thus preventing the loss of fragile paint decoration.

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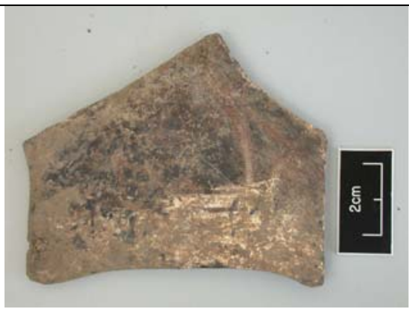
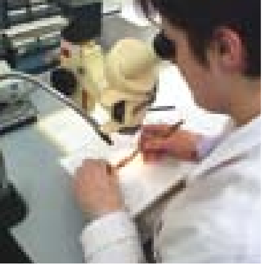
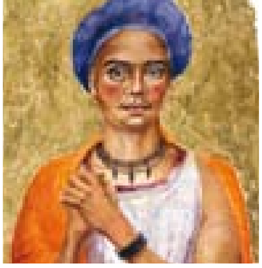
APPENDIX 1: EXAMPLES OF GLASS BEFORE AND AFTER CONSERVATION

Sherd no.	Before conservation	After conservation
2		
4		
5		
6		



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