Northeast Historical Archaeology

Volume 48 | Article 7

2019

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Cover Page Footnote

Acknowledgements The authors would like to thank the many people who assisted us in six years of research, acquisition of experiment materials, experimentation, and editing including: The George Washington Foundation, Zac Cunningham, Dr. Uldis Kaktins and Nina Kaktins, Dr. William Schindler, John Earl, George Miller , Heather Baldus, Robert Hunter, Meagan Townes, Meagan Budinger, Kerry Gonzalez, Elyse Adams, Judy Jobrak, Joe Blondino, Lauren Jones, Mack Headley, Travis Walker, Philip J. Carstairs. A special thanks go to David Muraca, Director of Archaeology and Vice President of Museum Content for The George Washington Foundation. Without his support, our project would not have been as successful.

"Take an Ounce of Suffolk Cheese": Home Repair of Eighteenth-Century Ceramics at Ferry Farm, George Washington's Boyhood Home

Mara Z. Kaktins, Melanie Marquis, Ruth Ann Armitage, and Daniel Fraser

The archaeological discovery at Ferry Farm of 18th-century glue residues on tea and table wares belonging to George Washington's mother, Mary, raised a number of questions. Although recent research in the archaeological and decorative-arts community on repaired ceramics and glasswares was helpful to some extent, it focused primarily on professional repairs; at-home mending remained a mystery. Archaeologists at Ferry Farm responded by conducting extensive experimental archaeology on historical glues, replicating period glue recipes to determine the properties of these historical adhesives. Additionally, samples of suspected glue residue were analyzed by chemists from Eastern Michigan and Lourdes universities utilizing direct analysis in real-time (DART) mass spectrometry. The resulting data have shed light on what the sociotechnic artifacts say about a woman in Mary Washington's social and economic position while highlighting an extremely common, yet archaeologically ephemeral, activity.

La découverte archéologique à Ferry Farm de résidus de colle du XVIII^{e} siècle sur des articles de thé et de table appartenant à Mary, la mère de George Washington, a soulevé un certain nombre de questions. Bien que les recherches récentes en archéologie et des arts décoratifs sur les céramiques et verreries réparées aient été utiles dans une certaine mesure, elles se sont principalement concentrées sur les réparations professionnelles. La réparation à domicile est restée un mystère. Les archéologues du site de Ferry Farm ont répondu à cette question en menant une vaste archéologie expérimentale sur des colles historiques, en reproduisant des recettes de colle d'époque pour déterminer les propriétés de ces adhésifs historiques. De plus, des échantillons de résidus de colle suspectés ont été analysés par des chimistes des universités de l'Est du Michigan et de Lourdes en utilisant une analyse directe en spectrométrie de masse en temps réel (DART). Les données qui en résultent ont mis en lumière ce que les artefacts sociotechniques disent de la position sociale et économique de Mary Washington, une femme, tout en mettant en évidence une activité extrêmement commune, mais archéologiquement éphémère.

Introduction

Ferry Farm, the reconstructed Washington family home from 1738 to 1772, is perched on a high bank of the Rappahannock River in Stafford County, Virginia, across from the Fredericksburg City Dock. There George Washington lived from ages 6 to 22. When George was 11, his father Augustine died, leaving his mother Mary, who never remarried, to raise five children on a significantly diminished income (King George County Will Book 1743). The Ferry Farm site, owned by the George Washington Foundation, has been the focus of intensive archaeological study since 2001 under the supervision of chief archaeologist David Muraca. The discovery of the footprint of George Washington's boyhood home was formally announced in 2008 (Muraca et al. 2011) (FIG. 1). Since that time, a reproduction of the Washington home and its contents has been constructed on that footprint using analysis of architectural and domestic artifacts, the talents of architectural historians, and historical documents, including inventories, newspaper accounts, and letters.

Excavations concentrated on locating the main house and its associated outbuildings have yielded an assemblage of over 775,000 artifacts. This collection includes tens of thousands of ceramic sherds from Mary Washington's many tea and table wares, including creamware and white salt-glazed stoneware vessels bearing evidence of glue residues. The dating and context of these ceramics indicates that they once belonged to Mary Washington and were used extensively throughout her time in the home.

The discovery of the glue residue began with one of Mary Washington's more elaborate tableware pieces, a creamware punchbowl exhibiting an enameled floral motif accented with cherries, unearthed in the main cellar of the house (FIG. 2). The Aquia Creek sandstone–lined Washington house cellar yielded evidence of three fill episodes. The earliest was deposited while the cellar was in use, from 1728 to ca. 1770. The second occurred at the time the Washingtons were leaving the site in 1772. That fill episode represented the abandonment of the cellar and capped the primary deposits. The last fill episode took place when the house was abandoned sometime prior to 1830. The overwhelming majority of sherds that make up the punchbowl, and subsequently identified, glue-repaired vessels were found in the second fill episode, when, presumably, the family was discarding items that were deemed not suitable to be moved to Mary's new abode. In addition, creamware sherds with similar floral motifs and a color palette identical to those seen on the punchbowl were recovered from another sealed cellar located under the house passage. This large cellar appears to have been filled fairly rapidly following abandonment, with the artifacts from the uppermost levels dating to around 1770, shortly before Mary Washington left Ferry Farm for a new home in the Town of Fredericksburg (Muraca et al. 2010).

The archaeological discovery of the glue residues on the creamware punchbowl was the result of a reanalysis of Mary Washington's creamwares by Ferry Farm's ceramics and glass specialist Mara Kaktins. Dating from ca. 1762 to the early 1770s (Towner 1957, 1978), this small punchbowl, termed a "sneaker," would have been passed around from person to person while punch was consumed directly from it (Johnson 1785). Careful examination revealed heavy use wear, showing that the bowl was utilized extensively prior to being

Figure 1. Excavated Washington house footprint with plan view overlay showing Aquia Creek sandstone lined cellar beneath central passage. (Photo by The George Washington Foundation, 2019; overlay by Laura Galke, 2019.)

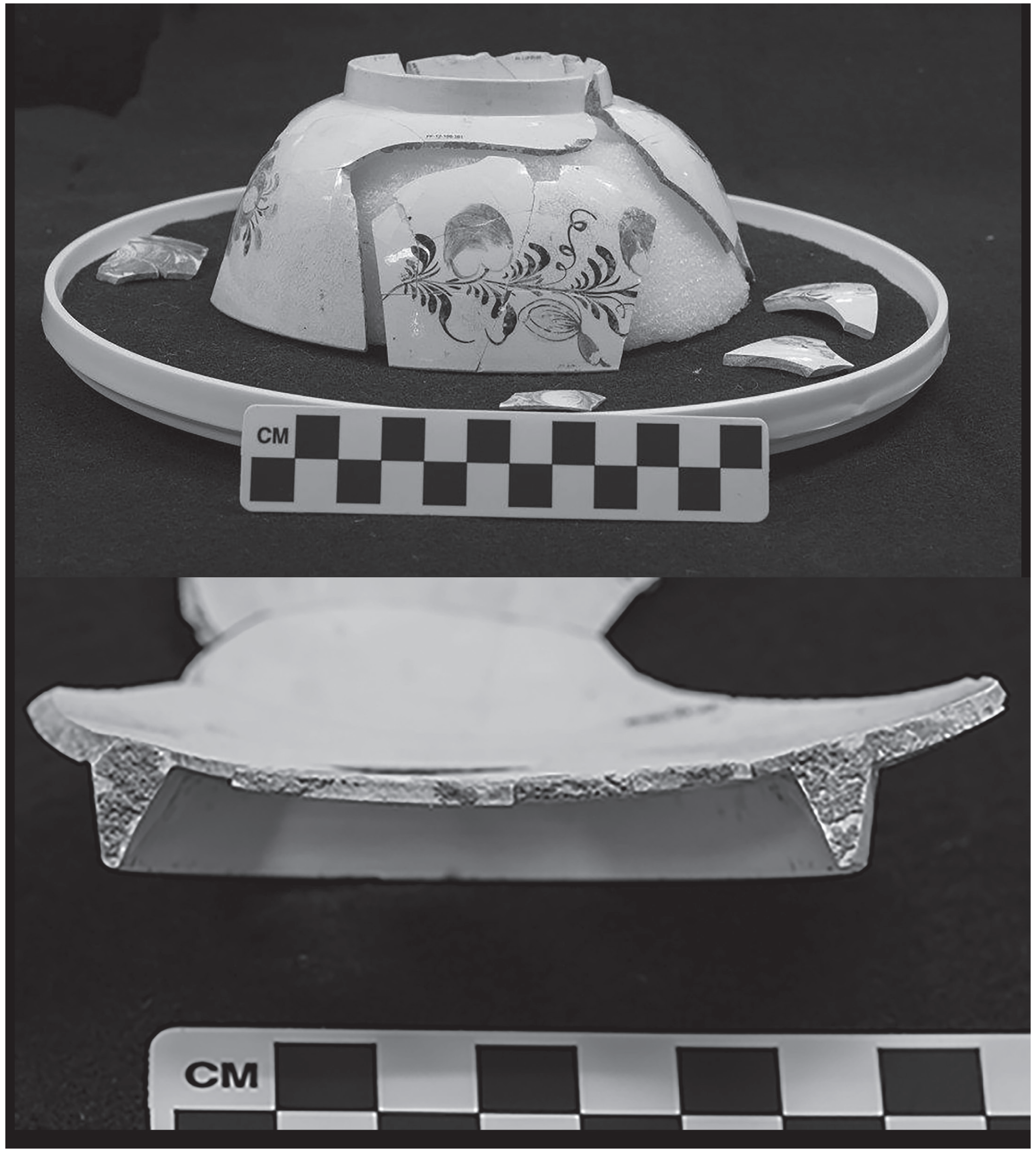

Figure 2. Mary Washington's creamware punchbowl and cross-section of base with glue residue visible; excavated from Ferry Farm. (Photo by The George Washington Foundation, 2019.)

broken into at least four different fragments, at which point it was mended with glue before a presumed second breakage episode and eventual discard. The glue residue is visible as a light brown substance adhering to the broken edges and interior of the vessel. A cross section of the bowl's interior shows glue extending across multiple adjacent sherds along the entire base of the vessel. Microscopic examination confirms that the residues are not simply post-depositional organic deposits, since they are not evidenced on other artifacts from the Ferry Farm cellar features. Scrutiny under magnification also reveals brush strokes from the application of the adhesive. Additionally, glue residues were found adhered to contiguous sherds, having survived the washing process in the lab following excavation.

Following the initial discovery, our team was encouraged to examine other tea and table wares dating from Mary Washington's occupation of Ferry Farm. To date, fragments of six distinct vessels from the Washingtons' time at Ferry Farm have been found to exhibit signs of repair using adhesives. These include a creamware platter and plate; an enameled creamware lid, likely from a teapot; a molded, white, salt-glazed stoneware plate rim; and a medium-sized, white, salt-glazed stoneware hollowware base. A sherd of porcelain with an Imari palette had also been previously identified as having glue residues adhering to it, although subsequent chemical analysis indicated that the substance was either not an adhesive or had been contaminated by the off-gassing of an artifact bag previously considered "conservation grade," but which no longer meets those criteria. The repairs reveal a philosophy toward objects and a specific activity taking place in the Washington household that was previously unknown and not documented in the historical record.

More analysis of the glue was needed, as the discovery of these residues prompted several questions: Are the same glues present on all of the sherds?; What is the composition of the glues?; Were the mended vessels functional after their repair or used only for display?; Was the mending done professionally or by a resident of the property?

A review of historical documents and ongoing dialogues with colleagues indicate that evidence of repaired vessels is not uncommon archaeologically. Published literature within the field, however, was somewhat lacking on the subject when we began research in 2012. It should be noted that there are now a number of scholars within the field who have set about researching and writing on this subject, e.g., Miller and Brown (2016) and Kuettner (2016). It would appear that evidence of mending has gone largely unrecognized, and, even where it has been seen, it has been given little attention due to insufficient information existing on the topic. Nonetheless, much advancement in the understanding of ceramic mending has taken place in the decorative-arts field as a result of mended ceramics becoming more popular as collectibles. Once shunned for their imperfections, these repaired objects now command prices almost equivalent to their unbroken counterparts and are written about in blogs, such as "Past Imperfect" (Baseman 2020).

A Brief History of Ceramics Mending

People have been mending ceramics for thousands of years. In addition to the use of adhesives for that purpose, one of the earliest noted prehistoric mending techniques involved drilling holes on either side of the break and lashing the sherds together with sinew. This method was often combined with a plant- or animal-based glue to water seal the break (Boëda et al. 1996; Charters et al. 2007; Stewart 1998). A search of 18th- and 19th-century all-purpose handbooks, cookbooks, and encyclopedias revealed a multitude of glue and cement recipes––too numerous to list here––ranging from surprisingly simple to exceedingly complicated and downright disgusting. In most of this literature it is implied that these recipes can be made in the home and are effective enough to produce viable vessels from broken fragments, even making them stronger than before they shattered (Cooley 1851). "China menders," or those who specialized in repairing ceramics, often used metal rivets or staples when making repairs. This process begins by carefully drilling shallow holes on either side of the break that angle toward each other, but do not erupt through to the other side. A thin strip of heated soft metal, such as copper, is then inserted into the holes, and the two broken sides are pulled closer together as the metal cools and contracts (Miller and Brown 2016; Warwell 1767). A skilled mender could also paint the rivets to camouflage the repair, as seen in this Chinese export-porcelain punchbowl (FIG. 3) in the George Washington Foundation's collection from Kenmore, the home of George's sister Betty and her husband Fielding Lewis. When mending this punchbowl, great attention to detail was paid in matching the famille rose palette on the staples and filling in gaps in the design, with the mender going so far as to paint tiny eyes on a staple running across a male figure's face. Archaeologically, these drill holes and rivets would be the most apparent, and likely the most common, signs of ceramic repair.

Figure 3. Chinese export porcelain punchbowl exhibiting two painted-over rivets. (Courtesy of the Kenmore Collection; Photo by The George Washington Foundation, 2019.)

Various other techniques were employed by china menders. Bands of metal could be used in lieu of rivets to stabilize a vessel or reattach a handle, as is the case with the Castleford stoneware sauceboat depicted in Figure 4. Holes were drilled through the body of the vessel, through which pins were inserted and attached to bands that anchor the broken handle. The mend is further stabilized and camouflaged with the addition of white paint. White lead paint was commonly used as a sealant mastic in the 18th century and is capable of surviving archaeologically (Kuettner 2016). However, short-wave ultraviolet-light analysis indicated the substance on the sauceboat is a later zinc paint, which fluoresces as a bright yellow-green when exposed to ultraviolet radiation. Lead paint would appear as a rusty-brown color unless suspended in linseed oil, in which case it would manifest as a bluish-white glow (Carden 1991). Zinc paint, invented in 1834 (Osmond 2015), appears to have been commonly utilized to cover up and secure mends as well. Ultraviolet analysis of paint on mended ceramics within the Kenmore collection revealed that, of six vessels thought to have been repaired with the aid of paint, zinc-based paints had been used for four of them. Among the observations made

Figure 4. Castleford stoneware sauceboat with band repair. (Personal collection of Mara Kaktins; Photo by The George Washington Foundation, 2019.)

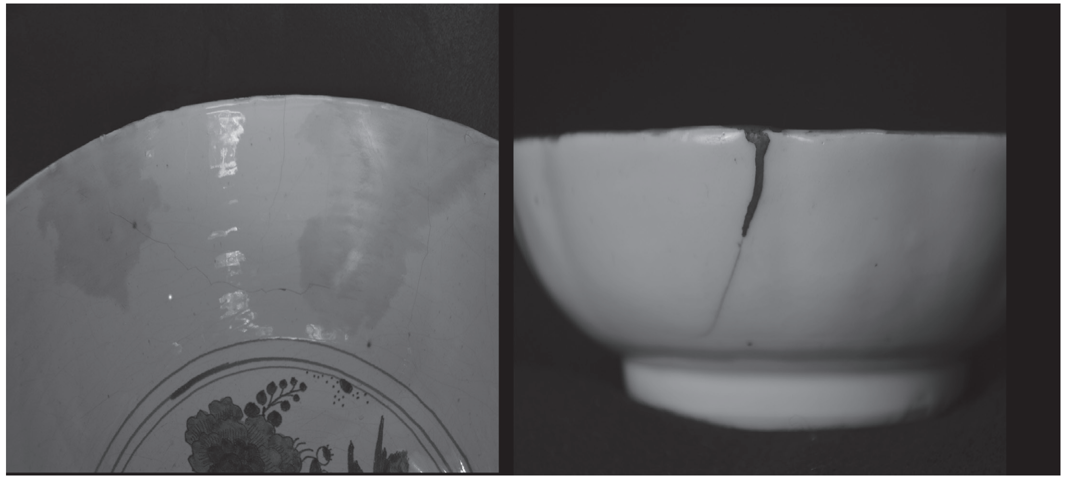

Figure 5. Vessels with repairs; *left*, Tin-glazed punch bowl with fill repairs; *right* porcelain saucer mended with Kintsugi technique. (Personal collection of Mara Kaktins; Photo by The George Washington Foundation, 2019.)

was that, unlike the lead paint, the zinc paint tended to discolor to a dingy yellow making the repairs much more noticeable after time. The utility of ultraviolet light should not be overlooked in the pursuit of archaeological residues. Long employed in the decorative-arts world, it is an inexpensive preliminary tool for recognizing anomalies not visible to the naked eye, as well as to highlight where further analysis may prove fruitful.

Bridging gaps with lacquers and fills is another way of binding pieces of broken ceramic together, as in the Japanese technique of *kintsugi*, in which the broken sherds are mended with lacquer that is then accentuated with metals, typically gold (fig. 5, *right*). The highlighted cracks consequently become quite visible and are a testament to an event in the life of the ceramic. The results are regarded as beautiful, aligning with the Japanese philosophy of *wabi-sabi*, which recognizes that a damaged object (or person) is not diminished in value or usefulness (Gettis and Bachmann 2018: 4). This is in direct opposition to mending for the purpose of hiding the defect, as Mary Washington did, rather than celebrating the use life of the damaged vessel (Hammill 2016). In some cases menders went to great lengths to disguise the breaks on ceramics. The filling of cracks in the large tin-glazed punchbowl in Figure 5 was disguised by sanding the fill material down until it was flush with the surface of the rest of the vessel. While this technique may have initially concealed the break, the removal of the top layer of glaze allowed for liquids and dirt to seep into the bowl, creating the contrast seen here.

Shattered handles, spouts, and lids could be replaced with metal substitutes by those skilled in creating them, and the handles were often wrapped in rattan, although other creative repairs abound (Baseman 2020). The missing strawberry-shaped knop of the Chinese export-porcelain tureen lid in Figure 6 has been filled with a malleable organic substance, such as wax or resin, that has since hardened and discolored to a dark brown. Another example, an enormous creamware punchbowl belonging to the Fredericksburg Masonic Lodge No. 4, has been repaired on multiple occasions over its lifetime. It exhibits professional rivets and fills with overpainting, combined with an inventive repair using a resinous substance to plug a hole in the base (fig. 6).

Although providing a necessary service, the mending trade was not always the most respectable or profitable one. Sometimes referred to as "tinkers," craftsmen plying this trade were often immigrants and/or minorities. It does appear that some menders did make a respectable living and established permanent residence in larger cities, though many china menders were itinerant workers (fig. 7). With the advent of synthetic glues and increasing access to inexpensive tablewares in

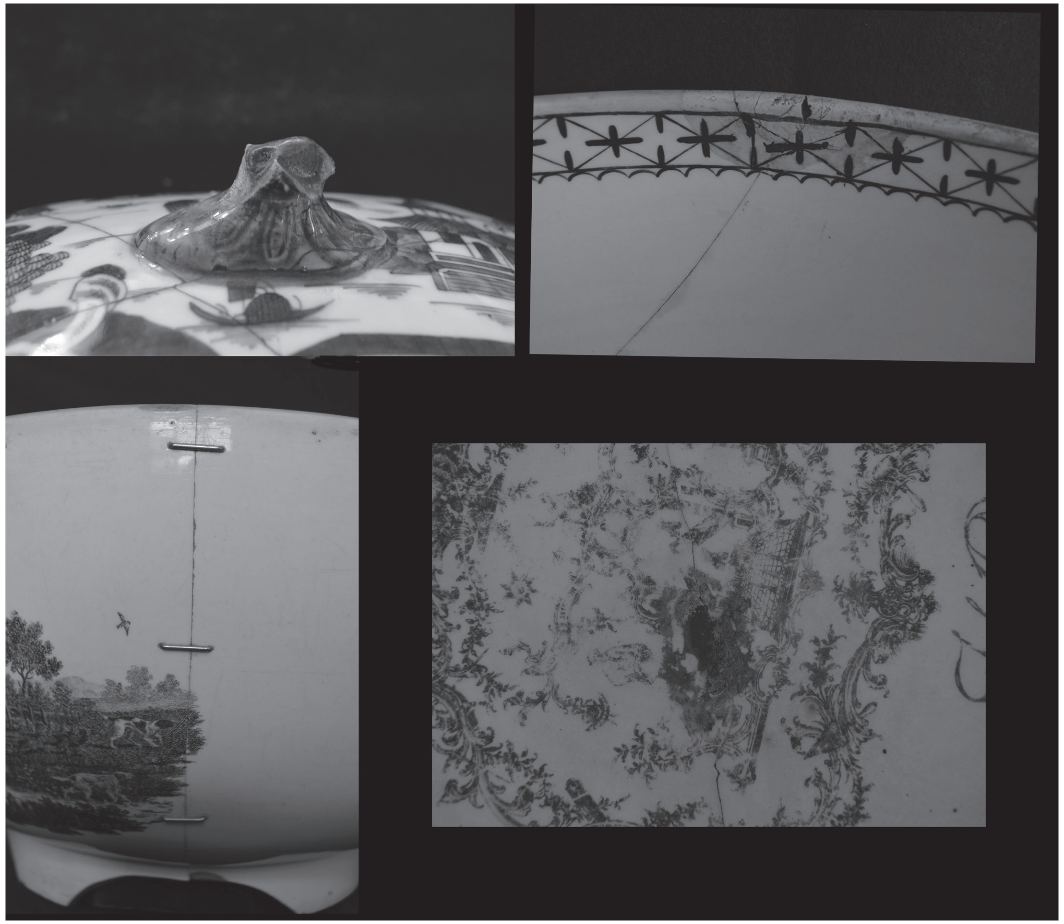

Figure 6. Clockwise from *top left*: Porcelain tureen with resinous knop insert (Courtesy of the Kenmore Collection); Masonic punchbowl with professional fill and overpaint, rivets, and inventive resin plug repair (Courtesy of the Collection of Fredericksburg Masonic Lodge #4). (Photo by The George Washington Foundation, 2019.)

the 20th century, the need for professional china menders waned (Miller and Brown 2016).

To date, no artifacts excavated at Ferry Farm show any evidence of having been professionally mended with drill holes, metal hardware, or filling, although we know that Mary would have had access to a professional mender just across the river in Fredericksburg. George Weedon, a goldsmith operating in town during the 1760s and 1770s, lists having mended "China bowls" in his account book in 1773 (Weedon 1773-1791). According to Weedon's records, this service was not inordinately expensive. Despite that, it would appear that Mary specifically chose to have her ceramics mended solely with glue.

Making the Glues

To confirm our identification of the residues as glues and to better understand the process of mending ceramics with 18th-century adhesives, we ventured into the realms of analytical chemistry and experimental archaeology. From each archaeological vessel thought to exhibit glues, a sample of residue approximately the size of a pinhead was extracted using sterile disposable steel blades. These were analyzed by chemists at Eastern

Michigan University using DART-MS. Concurrent with the chemical analysis, we began to replicate a number of 18th- and 19th-century home glue recipes in order to assess the post-mending functionality of a vessel repaired with these homemade glues. We replicated multiple iterations of three basic glue types found in the period literature: cheese, hide, and resin glues. In addition to actually producing adhesives from our historical recipes, we established a system of documenting and photographing the experiments. Details, such as ingredients and amounts used, mixing process, application methods, observations of color and appearance (under natural, fluorescent, and ultraviolet light, as in Figure 8), consistency, efficacy, and results, for each type were recorded. Additionally, samples of our experimental glues and all of the ingredients used were sent to Eastern Michigan University chemists to provide comparative data for analysis conducted on the archaeological residues. This step proved crucial in correctly identifying elements of the archaeological glues.

Figure 7. Itinerant Scottish mender (Hamilton 1922: 90).

Our first difficulty in reproducing 18th-century glues lay in obtaining all of the ingredients necessary to manufacture historical adhesive recipes. In all, we had to find sources for hide chips, various mastics and gums, beeswax, garlic, duck eggs, brandy, ox gall (bile), Suffolk cheese, and isinglass (derived from the swim bladders of fish), as well as a suitable source of lime and multiple resins and tars. Creating some recipes proved impossible, given our inability to readily secure obscure ingredients, such as ox blood and the "[w]hite slime of large snails" (Cooley 1851). Additionally, many of the recipes assumed a certain amount of preexisting knowledge that our team lacked. For example, to date, we are still uncertain of exactly what constitutes a "large snail" and how one goes about "milking" it, although we suspect it is an unpleasant experience for the snail.

The first glue reproduced was cheese glue, which involved only three simple ingredients: cheese, pickling lime, and egg whites. The recipe below is from the *Scots Magazine* (1765: 228)

> For the uniting the parts in the broken china or earthen-ware vessels, as also glass, where the joint visible is not of consequence, the following composition, which is much more easily prepared, may be substituted for the foregoing.
>
> "Take an ounce of Suffolk cheese, or any other kind devoid of fat; grate it as small as possible, and put it, with an equal weight of quicklime, into three ounces of skimmed milk. Mix them thoroughly together, and use the composition immediately."

Suffolk cheese, the original cheese called for in this recipe, is actually an extinct cheese. The cheese equivalent of hard tack, it was extremely low in moisture and eaten primarily by 18th-century sailors during long voyages. Judging by the disdainful descriptions of this cheese in historical documents, it is not hard to understand why it is no longer made (Pepys 1661). As a substitute, Romano cheese left to dry out for a few days and then grated was deemed an appropriate substitution based on its hardness or firmness in texture. The resulting glue proved unsuited to ceramic mending, having a lumpy consistency, setting too quickly to be practical, and with a very disagreeable odor. Useful cheese glue was finally created after additional research into period cheese glues, with our final product being a hybrid of a number of different recipes using less lime and substituting egg whites for milk (Cooley 1851; *Scots Magazine* 1765). The resulting final cheese glue recipe was easy to make and effective as an adhesive.

The next type of glue replicated was hide-based glue. The primary ingredient for this type of adhesive is produced by rendering pieces of animal hide. Most of our understanding of this type of glue resulted from researching furniture carpenters, who use it often (Edwards 2001; Mills 2011). The cabinetmaker's shop at Colonial Williamsburg alerted us to the *Handmaid to the Arts* (Dossie 1764), an all-purpose guide for housewives containing two hide-glue recipes we could duplicate. The first was relatively simple, containing dried animal-hide glue chips (listed as "common glue," "glue" being a ubiquitous 18th- and 19th-century term for pure hide glue, an ingredient in many composite glues), brandy, and quicklime, which resulted in easily applied and efficient glue. The recipe reads:

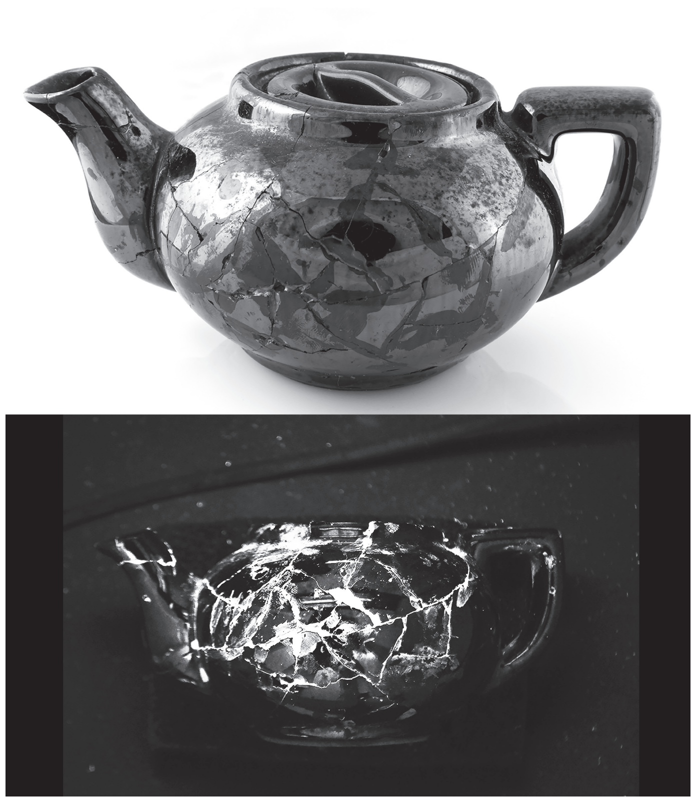

Figure 8. *Left*, thrift shop experimental teapot mended with hide glue under natural light; *right*, same pot using ultraviolet radiation. (Photo by The George Washington Foundation, 2019.)

> Take common glue in very small or thin bits, and isinglass glue; and infuse them in as much spirit of wine as will cover them, for at least twenty-four hours. Then melt the whole together; and, while they are over the fire, add as much powdered chalk as will render them an opake white. (Dossie 1764: 23-4)

The second hide glue was by far the most complicated of the four we produced. This combination of substances included hide glue (described as "good glue" below), brandy, garlic juice, ox gall (gallbladder bile), various resins, vinegar, quicklime, and isinglass.

> Take two ounces of good glue, and steep it for a night in distilled vinegar. Boil them together the next day. Beat a clove of garlic with half an ounce of ox-gall into a soft pulp, strain the juice through a linen cloth, using pressure, and add it to the glue and vinegar.
>
> Take then of sandarac [a tree resin] powdered, and turpentine, each one dram [3.8 grams, or for fluid measurements 1/8 oz., 3.7 ml, or roughly equal to 0.75 tsp.], and of sarcocol [resin from a shrub] and mastic, powdered, each half a dram; and put them into a bottle with an ounce of highly rectified spirit of wine. Stop the bottle; and let the mixture stand for three hours in a gentle heat; frequently shaking it. Mix this tincture also with the glue while hot; and stir them well together with a stick or tobacco pipe, till part of the moisture be evaporated; and then take the composition from the fire; and it will be fit for sure. When this cement is to be applied, it must be dipt in vinegar; and then melted in a proper vessel, with a gentle heat. (Dossie 1764: 29)

This hide glue proved the most effective in terms of application and efficacy, and stored well for over a year.

The last glue reproduced was resin based:

> A cement for Derbyshire spare and china &c, is composed of 7 parts of resin and 1 of wax, with a little plaster of Paris; a small quantity only should be applied to the surfaces to be united, for, as a general rule, the thinner the stratum of a cement, the more powerful its action. (Baynes 1888: 328)

While there were only three simple ingredients: beeswax, resin, and lime, manufacturing the resin from pine sap proved a somewhat flammable endeavor. Our ability to maintain controlled fire situations away from the museum and visitors at all times was critical while making and experimenting with the highly combustible materials. The resin we produced seemed unsuited to glue making, as the resulting glue had to be kept at a high temperature to work with it and proved too dark in color, and thus would have looked unsightly on Mary Washington's light-colored wares. Our experiments with resin glue helped us to understand that a better application for this particular glue might be for mending large food-storage and preparation vessels, such as redware crocks with dark glazes. However, initial results of the DART-MS residue analysis indicated that another type of resin may have been utilized: birch tar. A sample of this material thus had to be obtained for comparative purposes. This was achieved by roasting birch bark in an oven constructed for the purpose with a drip can buried beneath it to catch the resin. Five hours of continuous roasting resulted in approximately a quarter-cup of resin which, after chemical analysis was complete, proved to be incongruent with the resin detected in our archaeological glue.

The Experiments

In order to test the efficacy of our glues, we obtained, at a local thrift store, several ceramic plates and hollowware vessels to be broken and repaired with our homemade period adhesives. We selected porcelains, earthenwares, and stonewares that had pastes and glazes similar to those manufactured in the 18th century. All experimental vessels were given identification numbers to facilitate documentation. After being broken on a wooden floor composed of wide boards to replicate likely historical breakage conditions, every ware type was mended with each of the three experimental glue types. Our foremost concern was how effectively the glues repaired a vessel. Although all of the glues functioned to some extent, the resin glue proved difficult to apply, then cooled and dried quickly. We were unable to completely mend any vessels with the resin glue. The cheese glue performed as intended after we created our own recipe using multiple sources, although it set very quickly and was somewhat untidy. It was also ascertained that application of this glue using one's bare hands is not advised, as the pickling lime is caustic to skin. The hide glues, however, mended all ceramics well and were barely visible on the exteriors of the vessels.

The next phase of experimentation involved subjecting our mended vessels to typical use and discard conditions. This included tests for stress/strain resistance and strength, hot- and cold-water retention, and how well the glues withstood burial and exposure to typical Virginia temperature and humidity conditions. A group of mended vessels was placed in polyester mesh bags and buried in the back-dirt pile on our site from 21 August 2012 until 20 February 2013 to determine how post-depositional processes affected the glues. After burial, the resin glue had been altered significantly in color and texture, turning from black to a medium brown, and easily flaked from the edges, having become extremely brittle. Both cheese glues had cemented to the edges of the vessels after burial and changed from white to a mottled gray. The cheese glue was deemed to be the one most likely to survive archaeologically and most closely resembled the residues observed on Mary Washington's wares. Not unexpectedly, both hide glues completely disappeared from the sherds when inspected with the naked eye. However, placing our buried experimental sherds under short-wave ultraviolet light revealed that trace amounts of the glue remained and appeared bright blue.

Assuming that 18th-century adhesives, which are composed entirely of organic ingredients, might fail when confronted with typical Virginia weather, our team placed vessels mended with each of the glues in a structure without climate control for six months, while weather conditions were monitored. Of those, only one of our hide glues and one cheese glue appeared to be adversely affected. The first and simplest of the hide glues, used to mend a teacup in this instance, was yellowed and peeling from the surface of the cup, although the vessel itself was intact. A saucer mended with one of our cheese glues appeared to be unaltered, although it fell apart shortly after being brought into our laboratory. The strength of the glues were examined by stacking weights on flatwares mended with them. Surprisingly, all passed this test, as we ran out of space to place the weights before any of the vessels broke, some of them holding several pounds of weight. This would seem to validate the claims by many of the 18th-century recipe authors that the glues produced would be incredibly strong, perhaps making the item even stronger than it was before it broke (Cooley 1851). However, the water test proved that none of the glues could mend a vessel to the point that it was completely functional. Hollowwares repaired with each of the experimental glues were filled with cool and then hot water to test the mends. Only one vessel mended with our second, and most complicated, hide glue did not leak when filled with cold water, although it did fail the subsequent hot-water test. The pine-resin glue resisted cold water well, but became pliable in hot water, significantly weakening the mends. It should be noted that most of these glues are remarkably effective at holding vessels together when stored in climate-controlled environments. Our experiments were conducted between 2012 and 2013, and all of the ceramics successfully mended by our team (and not intentionally destroyed during testing) remain intact at the time of this writing and have become useful teaching tools for foundation education programs.

Chemical Characterization Results

In an attempt to confirm our identification of the residues as historical adhesives and to determine the composition of the potential mastics, we undertook chemical analysis of the glue residues. Given what we learned from our experiments, we believed that the composition of the glue may indicate how the repaired ceramics might have been used. For example, hide glues are readily soluble, and resin or pitch glues soften in hot water, which would render a teacup repaired with either type of glue to be suitable for display only rather than continued usage. We used two methods for the analysis: Fourier-transform infrared spectroscopy (FTIR) for nondestructive characterization, and DART-MS to confirm or exclude organic chemical compounds representative of ingredients from historical 18th-century glue recipes.

FTIR spectroscopy is a way of characterizing the electronic bonds within organic and inorganic compounds based on how they interact with light in the infrared region of the spectrum. Certain bonds or combinations thereof (called "functional groups") can be identified because they absorb specific frequencies; thus, a plot of how much light is absorbed as a function of frequency—called a spectrum—gives a kind of fingerprint of the molecules. Like fingerprints, these spectra can be compared to standard databases of samples of known composition to identify an unknown material. Mixtures of materials can make the spectra quite complicated to interpret, particularly if the material consists of different materials in varying proportions. However, it is possible to collect FTIR spectra without destroying the sample and is a good first step in characterizing materials such as these glues. DART-MS is a relatively new analytical approach for identifying organic molecules. Unlike gas chromatography–mass spectrometry, which is routinely used to characterize residues in archaeological contexts, DART-MS requires minimal to no sample preparation. The material of interest is simply held—in forceps or the closed end of a glass tube—in front of the DART ion source that heats the sample and gives the molecules that are released a charge (i.e., ionizes them). The sample is positioned between the DART source and the inlet into the mass spectrometer, where the ions produced are sorted and detected. A typical DART-MS spectrum is acquired in seconds. DART-MS is a good way to rapidly screen samples for the presence or absence of expected compounds that are characteristic of one or more of the ingredients in the glues.

The FTIR spectra showed that the primary component of the glue residues is calcium carbonate. This is consistent with the use of lime in the period recipes. Quicklime (calcium oxide) and pickling lime (calcium hydroxide, formed by the hydration of quicklime) both harden by absorbing carbon dioxide from the air to form calcium carbonate. No organic components were observed by FTIR to further clarify which specific type of glue was present. Previous mass-spectrometry studies (Fraser et al. 2016: 112) indicated that some sample preparation would be useful in determining the nature of the Ferry Farm glues. A few milligrams of each glue residue was dissolved in 6M hydrochloric acid to remove the calcium carbonate, in the hope that doing so would reveal the organic portion of the glue. The main drawback of this sample preparation method is that some compounds may break down under these conditions, making their identification difficult. Other compounds, such as abietic acid and its oxidation products, are stable when treated with acid; such compounds would be indicative of the use of a resin or pitch obtained from pine. Because pitch is produced by heating pine resin, additional compounds, such as retene, are formed (Pollard et al. 2017: 297–303). Hydroxyproline is an amino acid found primarily in the protein collagen; its presence in the glues would indicate a glue derived from skin or connective tissue, such as hide, bone, and isinglass. Beeswax is a common ingredient in 18th-century glue recipes and can be best identified with DART-MS based on the presence or absence of monoesters formed through the condensation of long-chain alcohols and fatty acids (Garnier et al. 2002). Fatty acids themselves are ubiquitous in the soil burial environment and, thus, were not considered in this study.

The overwhelming majority of the residues showed no significant evidence of organic compounds that would aid in identifying the type of glue. However, oxidation products of abietic acid and retene were observed in the glue residue from the punchbowl foot, indicating that this residue was likely from a resin-based glue or at least contained a heat-treated resinous component. In addition, several beeswax compounds (monoesters and hydroxy-monoesters of palmitic acid and fatty alcohols of 22, 26, and 28 carbon-chain lengths) were observed in this sample, even following pretreatment with acid. None of the resin or beeswax compounds were observed in the solution controls, nor were they found in the context soil provided for analysis, thereby giving us additional confidence that these compounds did originate in the glue residue itself rather than some post-depositional environmental contaminant.

The glue residue from the molded, white, salt-glazed stoneware plate sherd showed traces of retene and some abietic acid oxidation products as well, but, due to the low signal intensity, it is not clear that this truly represents the presence of resin glue. The lack of hydroxyproline cannot rule out the original presence of hide glue, however, as it may have simply decayed in the burial environment.

More experimentation utilizing beeswax as a glue ingredient may inform future results and help us understand its use in ceramic mending as well as other household uses. Moreover, pointed analysis of the "workyard" areas of the archaeological site and the small-finds collection may reveal more about the processes involved in mending and possible tools or containers associated with glue making.

Conclusion

Extensive cross-disciplinary research has demonstrated that the residues found on Mary Washington's china are indeed glues, with some form of lime being an ingredient common to all of them. It is noteworthy that these mastics survived, given the generally acidic soil environment at Ferry Farm. Chemical testing also revealed multiple types of glues with traces of beeswax and resins, indicating there were multiple breakage and repair episodes. Our experimental archaeology results suggest that Mary Washington was having her ceramics mended, not for practical purposes, but so she could continue to display them, and there is documentary evidence for this practice. A 1926 letter from mender Harry A. Eberhardt of Philadelphia asks a client whether the china was to be mended for just "cabinet use," in which case he planned on "cementing only" (Miller and Brown 2016: 155). Kuettner's work on repaired ceramics documents an individual complaining in 1757 that a large percentage of the china in his house could not be used, as it had been broken and cemented, then arranged in a way as to

Figure 9. Work yard in rear of reconstructed Washington house where activities such as glue making will be interpreted. (Photo by The George Washington Foundation, 2019.)

conceal the breaks (Kuettner 2016). The importance of appearing to own complete fashionable china was not lost on Mary Washington. As a widowed mother who successfully raised five children to adulthood on a significantly reduced income following the death of her husband, she would certainly have been well versed in frugality. Interestingly, our reproduction of period glues also indicated that, if Mary Washington was choosing to have her ceramics mended utilizing homemade glues, she probably would not have been making glues or repairing her china personally. This generally unpleasant task would most likely have fallen to an enslaved individual at Ferry Farm.

This study also highlights the importance of making concerted efforts to identify archaeological residues and the utility and ease of detecting otherwise invisible substances on artifacts through observation under ultraviolet light. Ultraviolet light can also provide initial clues to determine the composition of archaeological residues, although, ultimately, methods such as x- ray fluorescence or mass spectrometry should be employed for more accurate identification, if possible. For a more detailed discussion of archaeological residue analysis see *A Practical Approach to the Chemical Analysis of Historical Materials* (von Wandruszka and Warner 2018).

Ultimately, our research is informing our interpretation of the lives of the Washingtons at Ferry Farm. Today, visitors to the recreated Washington home are welcome to explore the house and all of its reproduced furnishings in very tactile ways, such as sitting in the chairs, investigating facsimile documents in the drawers of a desk, practicing tea rituals with reproduction ceramics, and even warming themselves by a fire lit in the hearth. Educational programming, such as the making of glues and mending of ceramics, can be opportunities for public engagement that offer glimpses, not only into the lives of the Washingtons, but into the activities of enslaved people living and working at Ferry Farm. The next phase of Ferry Farm's development will be the creation of an interpretive work yard where a "glue-making" station will be created (FIG. 9). As a result of the discovery of historical glues, our organization incorporates 18th-century cheese-glue production and mending into our educational programs. They inform the public of this little known, but likely common, practice taking place where Washington grew up; an ephemeral behavior that, in this case, is only evidenced through archaeology. Interpreting

such behaviors is critical, not only in understanding the lives of families like the Washingtons, but in revealing the minutiae of daily life in their time. Pointing out the significance of the archaeology of the mundane to the public helps our visitors identify with social norms that sometimes mirror their own.

Acknowledgments

The authors would like to thank the many people who assisted us in six years of research, acquisition of experiment materials, experimentation, and editing, including the George Washington Foundation, Zac Cunningham, Dr. Uldis Kaktins, Nina Kaktins, Dr. William Schindler, John Earl, George Miller, Heather Baldus, Robert Hunter, Meagan Townes, Meagan Budinger, Kerry González, Elyse Adams, Judy Jobrak, Joe Blondino, Lauren Jones, Mack Headley, Travis Walker, and Philip J. Carstairs. A special thanks goes to David Muraca, Director of Archaeology and Vice-President of Museum Content for the George Washington Foundation. Without his support our project would not have been as successful.

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