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Glassmaking Tests at Early Jamestown? Some New Thoughts and Data[1]

[This "footnote" will be unnumbered, and the other footnotes renumbered.]

Early prospection efforts in North America relied heavily on the use of crucibles to test suspected valuable minerals for potential exploitation. This process, which is well known for metal ores, has also been proposed for glassmaking at colonial Jamestown. Here, we revisit a recent publication suggesting that certain Hessian crucibles from the site bore evidence for these glassmaking tests, and present new data on crucible operations at the site. We argue that the evidence is more consistent with testing ores for their precious metal content than with glassmaking. Despite this, the historical evidence for glassmaking tests in this early period remains strong, and further research may well identify its material remains.

Jamestown

The foundation of Jamestown in the spring of 1607 marked the first permanent English settlement in America and was driven by the expectation of great profit promised by the new and unspoiled land of Virginia. Besides the quest for precious metals and the hope of finding a cross-continental waterway that would provide access to the riches of the East, glassmaking was a major aim of the settlers because glass was at that time imported to England in large quantities and at great expense; the possibility of starting a glassmaking industry with local raw materials offered an opportunity to boost English production. Jamestown glass production has received some attention over the last decades, starting from the information that a "tryal of glasse" was made during the initial months of activity.[2] Unfortunately, nothing else is known about this glass except that it was shipped to London, presumably to be checked. During excavations of James Fort, the initial settlement of the Jamestown colonists, a large assemblage of workshop-related artifacts was unearthed from pre-1610 contexts. For the most part, these are triangular crucibles of the Hessian type,[3] and while many of them display clear traces of metallurgical activity,[4] some were interpreted as glassmaking vessels.[5]

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1. *Acknowledgments*. We are very grateful to the Jamestown Rediscovery archaeological project for support and access to materials. This work is part of Umberto Veronesi's Ph.D. project, generously funded by the Arts and Humanities Research Council (award ref. 1738300). The analytical work was carried out at the Wolfson Archaeological Science Laboratories, Institute of Archaeology, University College London.

2. John Smith, *The General Historie of Virginia, New England and the Summer Isles; Together with the True Travels, Adventures and Observations, and a Sea Grammar*, Glasgow: J. MacLehose, and New York: Macmillan, 1907, p. 179; J. C. Harrington, *A Tryal of Glasse: The Story of Glassmaking at Jamestown*, Richmond, Virginia: Dietz Press, 1972.

3. On the importance of Hessian crucibles in the early modern period, see, for example, Marcos Martinón-Torres, Thilo Rehren, and Ian C. Freestone, "Mullite and the Mystery of Hessian Wares," *Nature*, v. 444, no. 7118, November 23, 2006, pp. 437–438, and the literature therein.

4. Marcos Martinón-Torres and Thilo Rehren, "Trials and Errors in Search of Mineral Wealth: Metallurgical Experiments in Early Colonial Jamestown," *Rittenhouse: Journal of the American Scientific Instrument Enterprise*, v. 21, no. 2, 2007, pp. 82–97; Carter Hudgins, Marcos Martinón-Torres, and Thilo Rehren, "From the Mines to the Colonies: Archaeological Evidence for the Exchange and Metallurgical Usage of English Copper in Early 17th Century Virginia and Ireland," in *Ireland and Britain in the Atlantic World*, ed. Audrey J. Horning and Nick Brannon, Irish Post-Medieval Archaeology Group Proceedings, v. 2, Dublin: Wordwell, 2009, 157-180.

5. William M. Kelso, *Jamestown: The Truth Revealed*, Charlottesville and London: University of Virginia Press, 2017, pp. 155–159.

In a recent paper, J. Victor Owen and two co-authors presented the results of their analytical study of a number of such suspected glass-related materials.[6] Besides fragments of glass cullet with a European composition that were probably brought to Virginia, they discuss three samples of glassy residues stuck to crucibles. (One additional sample of the same type had previously been published by Robert Brill.[7]) They appear dark green to black and were interpreted as remnants of glassmaking experiments using local raw materials such as beech and kelp ashes, local sand, and possibly oyster shells for lime. The rather unusual composition of the crucible residues—with elevated levels of alumina, boron, and antimony oxide, among others—is understood as indicating attempts to adapt European recipes to the new natural environment of Virginia.

This note reviews the evidence for glassmaking at early Jamestown in light of new data from the analysis of three more crucible fragments of the same type as those mentioned above.

The Crucibles

The three samples presented here are fragments of Hessian crucibles containing a black glassy residue and closely resembling the ones studied by Owen and his colleagues (Fig. 1). Macroscopically, they seem to lack unquestionable signs of metallurgical activity, such as metal droplets and the green discoloration typical of copper corrosion. The chemical composition and microstructural makeup of small cross sections were studied with a scanning electron microscope with an energy-dispersive X-ray spectrometer (SEM-EDS), yielding data compatible with those published earlier by Brill and by Owen and his co-authors.

FIG. 1.

The glassy matrices of the residues contain numerous grains of partly dissolved feldspars (Fig. 2), whose presence is responsible for the high levels of alumina as well as a significant amount of the soda and/or potash detected (Table 1). In one case (JR392A), a peculiar type of lead-bearing feldspar goes together with an enrichment of lead oxide in the glassy phase, and with the formation of small metallic droplets within the original crystals (Fig. 3). These are made of lead, with occasional minor quantities of antimony, nickel, and arsenic, as well as some sulfur, a pattern of impurities that was also found in some of the ores assayed at the site and discussed elsewhere.[8]

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[6]. J. Victor Owen, John D. Greenough, and Beverly A. Straube, "Compositional Characteristics of Jamestown "Tryal" Glass (Virginia, ca. 1608)," *Historical Archaeology*, v. 48, no. 4, 2014, pp. 76–94.

[7]. Robert H. Brill, *Chemical Analyses of Early Glasses*, v. 1, *Catalogue of Samples*, Corning: The Corning Museum of Glass, 1999, p. 192.

[8]. Umberto Veronesi, Marcos Martinon-Torres, and Thilo Rehren, "Testing the New World: Early Modern Chemistry and Mineral Prospection at Colonial Jamestown, Virginia, 1607–1610,", forthcoming.

These results are consistent with those reported by Owen and his colleagues, indicating that the same operation was being carried out in the crucibles discussed in this note.

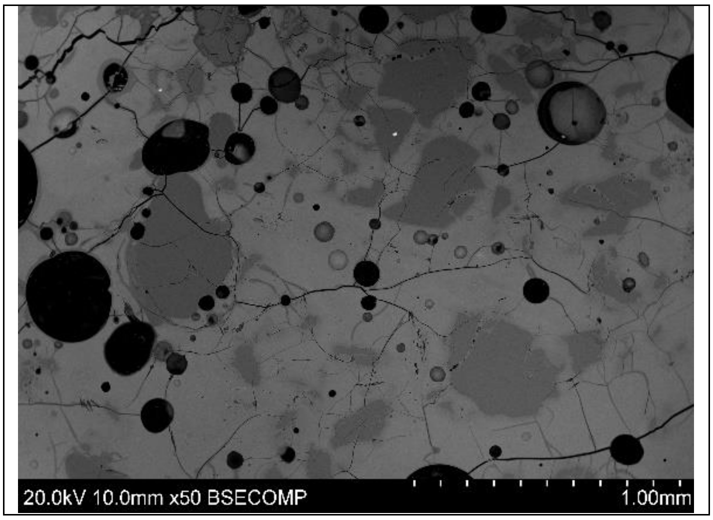

FIG. 2.

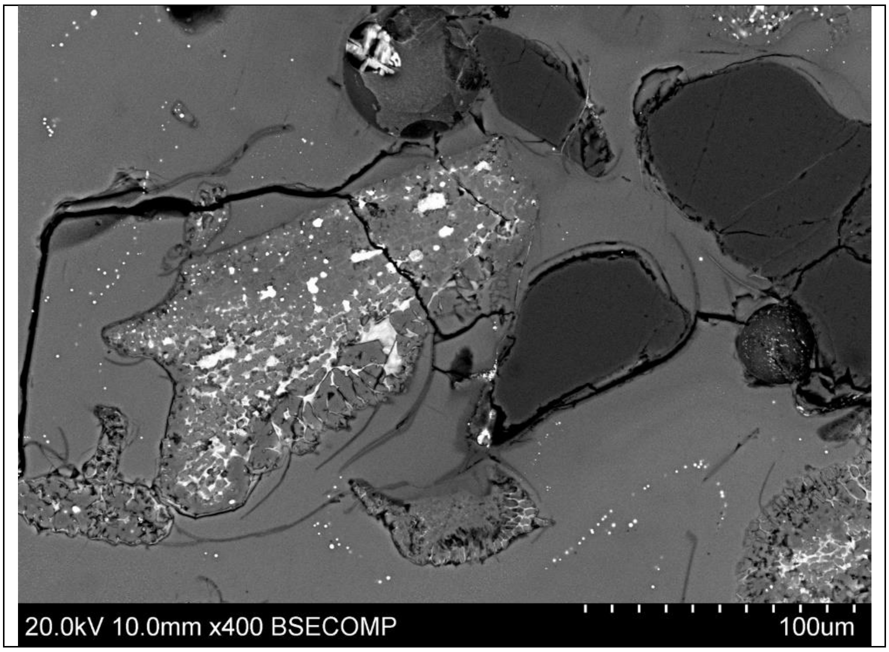

FIG. 3.

Glassmaking or Metal Testing?

We argue that trials of glassmaking would have been rooted in contemporaneous European practice, using either wood ash or the ashes of alkali-rich plants such as kelp. The former would have resulted in glass rich in calcium oxide, potash, and phosphate, while the latter would have provided a soda-rich glass.[9] By contrast, the mixed-alkali, alumina-rich but lime- and phosphate-

[9]. For typical late medieval and early modern period northern European wood-ash-based glassmaking recipes, see, for example, C[aroline] M. Jackson and J[ames] W. Smedley, "Medieval and Post-Medieval Glass Technology: Melting Characteristics of Some Glasses Melted from Vegetable Ash and Sand Mixtures," *Glass Technology*, v. 45, no. 1, February 2004, pp. 36–42; C[aroline] M. Jackson, C. A. Booth,

poor composition observed here is more consistent with the presence of feldspar as one of the main raw materials.[10] Particularly noteworthy is the absence of significant amounts of lime in the analyzed glassy material, which is in stark contrast to the most common wood-ash glass used at the time in northern Europe. The elevated iron oxide content, ranging from 1.5 to nearly 4.5 weight percent (wt %), is also not consistent with an attempted glass production. In view of the abundance of woodlands around Jamestown, and the potential availability of salt-rich plants such as kelp on and off the seashore some 30 miles away, one would assume that any glassmaking tests would conform to either of these two fundamental recipes, and not deviate toward an entirely unrelated approach.

Instead, we argue that, in the cases reported here and previously by Owen and his co-workers, the testing of suspected ore minerals involved the inclusion of feldspar in the crucibles, most likely as gangue (that is, a non-metal-bearing part of the ore to be tested),[11] or possibly added as a flux[12] to promote the formation of a slag during the test, and that these crucibles are indeed related to metallurgical testing. The connection to metallurgy is strongly indicated by the presence of lead-rich metal inclusions and a significant content of lead oxide in the glassy phase in two of the three crucibles we analyzed, and in J14 analyzed by Owen and his colleagues, and of several wt % antimony oxide in the other two crucibles they analyzed. The presence of soda and potash in all

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and J[ames] W. Smedley, "Glass by Design? Raw Materials, Recipes and Compositional Data," *Archaeometry*, v. 47, no. 4, November 2005, pp. 781–795; and Karl Hans Wedepohl and Klaus Simon, "The Chemical Composition of Medieval Wood Ash Glass from Central Europe," *Chemie der Erde – Geochemistry – Interdisciplinary Journal for Chemical Problems of the Geosciences and Geoecology*, v. 70, no. 1, March 2010, pp. 89–97. For kelp as a source of soda in early modern English glassmaking, see David Dungworth, Patrick Degryse, and Jens Schneider, "Kelp in Historic Glass: The Application of Strontium Isotope Analysis," in *Isotopes in Vitreous Materials*, ed. Patrick Degryse, Julian Henderson, and Greg Hodgins, Studies in Archaeological Sciences, v. 1, Leuven, Belgium: Leuven University Press, 2009, pp. 113–130.

[10]. Depending on the feldspar, the alkali content derived from feldspar would contribute between about 50 and 80 percent of the wt % alumina in the melt. Feldspar-based glassmaking occurred at that time in West Africa, but it is unlikely to have been known to the Jamestown craftsmen. See James W. Lankton, O. Akin Ige, and Thilo Rehren, "Early Primary Glass Production in Southern Nigeria," *Journal of African Archaeology*, v. 4, no. 1, 2006, pp. 111–138; Ian C. Freestone, "An Indigenous Technology? A Commentary on Lankton et al. 'Early Primary Glass Production in Southern Nigeria,'" *ibid*., pp. 139–141; and Abidemi Babatunde Babalola and others, "Chemical Analysis of Glass Beads from Igbo Olokun, Ile-Ife (SW Nigeria): New Light on Raw Materials, Production, and Interregional Interactions," *Journal of Archaeological Science*, v. 90, February 2018, pp. 92–105.

[11]. While the lead content of feldspar itself is commonly low, pegmatites often contain sulfides, such as galena, embedded in feldspar, and can then attract the attention of prospectors. See, for example, F. Čech, Z. Misař, and P. Povondra, "A Green Lead-Containing Orthoclase," *Tschermaks Mineralogische und Petrographische Mitteilungen*, v. 15, no. 3, September 1971, pp. 213–231, esp. p. 218. The concentration of lead prills within the residual feldspar crystals, seen in sample JR392A, demonstrates that the lead was closely intergrown with the feldspar.

[12]. Cf. G. Agricola's list of "additamenta" in his seventh book (translated by Hoover and Hoover, see below), p. 232, n. 6, as "fluxes." Feldspar certainly fits the description of some of these as "stone which easily melts": Georgius Agricola, *De re metallica*, trans. Herbert Clark Hoover and Lou Henry Hoover, London: The Mining Magazine, 1912, p. 111. However, as was kindly pointed out by an advance reader of our note, the amount of feldspar in the charge, indicated by the alumina level in the slag, would account for only less than half of the total alkali content. This is consistent with the notion that the feldspar was indeed gangue (that is, part of the ore to be tested), and that another alkali source was added as a flux. In our view, it is unlikely that this would have been seaweed ash, as proposed by Owen and his co-authors [note 5]; that ash would have contributed much higher strontium than we observed, and also more lime than alkali (see Dungworth, Degryse, and Schneider [note 8], table 5.2, for the composition of Atlantic seaweed). Instead, we propose that an evaporate alkali salt or mineral of some kind was used. A fuller discussion of this aspect is part of the ongoing doctoral research of one of the authors of this note (U.V.).

analyzed glassy slags, over and above that provided by the feldspar gangue, demonstrates the addition of an alkali-rich flux such as soda ash or saltpeter, while the presence of more than 2 wt % boron oxide in J14 may be a further indication of the inclusion of some other, as yet unidentified, mineral fluxes in that test.[13]

Supporting evidence for this assumption of a metallurgical origin of the residues in these crucibles comes from preliminary observations of the form and distribution of the glassy residues. In metallurgical crucibles, the glassy slag normally floats atop the main charge, typically a metal-rich bath that solidifies at the bottom of the vessel when the crucible is allowed to cool. In this scenario, the crucible is broken up to retrieve the metal regulus, leaving a negative impression underneath the glassy slag, and a slag layer or "fin" protruding from the inner side wall of the crucible. This is seen, for instance, in figure 1 of the publication by Owen and his co-authors for their crucible J14. In other such cases, the glassy slag is preserved only near the rim, while the lower part of the crucible is barely coated by slag because of the protection afforded by the liquid metal (Fig. 4).[14]

By contrast, in crucibles from glassmaking tests, one would expect that the only charge in the crucible was the off-white test batch, which would more or less fill the vessel, and that any glass would settle at the bottom of the vessel.[15] This is a feature frequently seen in glassworking crucibles, too, and accordingly the glassy material should not be thicker on the side walls than near or at the bottom of the crucibles. Two well-preserved crucibles from Jamestown are more likely candidates for this (Fig. 5), and we hope to investigate them in the near future.

FIG. 4.

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[13]. Borax ($Na_2B_4O_7$, with varying amounts of crystal water) has been used as a flux in metallurgy at least since the early Middle Ages: see William G. Woods, "An Introduction to Boron: History, Sources, Uses, and Chemistry," *Environmental Health Perspectives*, v. 102, supp. 7, *Health Effects of Boron*, November 1994, pp. 5–11, doi:10.2307/3431956.

[14]. This macroscopic evidence for the glassy residue floating on top of a denser phase is not always clear, as in the case of the crucible rim fragment shown in Figure 1, because it depends on the amount of slag produced and the preservation of the vessel in question.

[15]. See, for instance, Thilo Rehren and Edgar B. Pusch, "Late Bronze Age Glass Production at Qantir-Piramesses, Egypt," *Science*, v. 308, no. 5729, June 17, 2005, pp. 1756–1758, figs. 2 and 4.

FIG. 5.

Conclusion

There is no reason to doubt that a batch of experimental glass was produced at Jamestown in 1608, as the surviving documents unambiguously tell us. However, in this note, we suggest that the traces and outcomes of such activity have yet to be analyzed, and we offer new considerations and further analytical data that cast serious doubts on the previous interpretation of some crucible residues from Jamestown as remnants of glassmaking activity. Instead, the available evidence points firmly to ore-processing operations as the most probable activity conducted within the crucibles with a dark glassy slag. Other finds from Jamestown are more likely to hold the physical evidence for glassmaking trials, such as the one depicted here.

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FIGURE CAPTIONS

FIG. 1. Fragments of Hessian crucibles with black glassy residues adhering to the inner walls.

FIG. 2. Glassy residue in sample JR1957A, showing partly melted feldspar inclusions scattered across it.

FIG. 3. Detail of feldspar inclusion in sample JR392A, with numerous small lead prills (*bright*), predominantly within the original mineral grain (*gray*) in a glassy slag matrix. Residual quartz grains are dark gray.

FIG. 4. Crucible fragment with glassy slag adhering near the rim, while the body and lower part of the vessel are almost free of slag. This is typical for metallurgical operations, but not commonly seen in glassmaking or glassworking crucibles. Find JR1545C, scale in cm.

FIG. 5. A well-preserved potential glassmaking crucible with characteristic residues for a partly fused batch. Find JR81F, H. (vessel) about 15 cm.

TABLE 1

Chemical Composition of the Three Glassy Crucible Residues Analyzed*

	Na_2O	K_2O	MgO	CaO	Al_2O_3	SiO_2	FeO	P_2O_5	SO_3	Cl	TiO_2	PbO
JR1957A	9	13.3	1.7	2.6	8.1	59.3	4.4	0.1	0	0.6	0.7	0.2
JR1545C	9.7	12.4	0.7	1.3	10.8	60.4	3.1	bdl	bdl	0.6	0.9	bdl
JR392A	6	17	2.3	4.8	10.5	53.2	2.6	0.6	0.6	0.4	0.8	1.2

* Results are shown as wt % and normalized to 100%.