COMPOSITIONAL ANALYSIS OF POT SHERDS FROM AN EARLY-19TH CENTURY MILLING VILLAGE IN NORTHEAST PENNSYLVANIA

Khori Newlander
Danielle Cannon
Carly Plesic

ABSTRACT

As a non-destructive method for multi-element analysis, portable X-ray fluorescence spectrometry (pXRF) has the potential for broad archaeological application. Here, we employ pXRF for the compositional analysis of whiteware and stoneware sherds collected from Stoddartsville, a nineteenth century milling village built along the upper Lehigh River in northeast Pennsylvania. Our analysis demonstrates that we can use compositional data to distinguish between makers of macroscopically similar pottery. In turn, these data will expand our ability to source pottery from Stoddartsville, providing insight into the regional economy, the development of local ceramic industries, and consumer agency.

INTRODUCTION

The rise of American industry during the late-eighteenth and nineteenth centuries dramatically transformed the United States. Accordingly, a growing number of archaeological studies have examined the pervasive, interrelated impacts of industrialization on work and domestic life in urban and rural settings throughout the Middle Atlantic and Northeast (e.g., Coppock 2015; Davis 2015; Ford 2011; Heberling 2015; Metheny 2007, 2010, 2013; Walton 2015; Wurst 2002; Wurst and Mrozowski 2016). Except for archaeological research on coal company towns (e.g., Roller 2015; Shackel 2016, 2018; Shackel and Roller 2012; Westmont 2019), comparatively few studies have examined how industrialization resonated in small communities in eastern Pennsylvania.

Best known as the site of an early-nineteenth-century milling village, Stoddartsville provides an opportunity to document the cultural changes that accompanied an attempt to bring industry to northeast Pennsylvania. To understand the unfolding of industrialization, as well as concomitant changes in demography and social organization, we must view the process in the context of regional conditions and connections. Though socially and spatially distant from the centers of industrialization and economic development located to the east, Stoddartsville was not an island of industry unto itself. Rather, it was a node within a "networked industrial landscape" (Worth 2005) that included flows of people, technology, commodities, and ideas within and between villages and cities located throughout the Middle Atlantic and Northeast. This conception provides a useful starting point for examining the complex, multi-scalar relationships between the physical environment, societal structures, and individual experiences as they were recast by industrialization (Casella 2005; Ford 2011; Metheny 2013; Mrozowski 2005; Pauls 2006; Westmont 2019).

We are especially interested in examining how physical and cultural factors, especially accessibility to larger markets and related transportation costs, intersected to shape the extractive activities of the villagers, as well as their participation in the regional industrial economy. Indeed, the establishment of Stoddartsville as a node within a networked industrial landscape centered on Philadelphia would have changed the flow of commodities through the region. Archaeological study of Stoddartsville provides an opportunity to examine the economic consequences of industrialization at two analytical scales: (1) at the level of the village, the quantity and diversity of commodities consumed at Stoddartsville provides a measure of the participation of this community in the regional economy; and (2) at the level of the domestic unit, comparison of the quantity and diversity of artifacts recovered from different contexts at Stoddartsville may reveal variability in commodity consumption attributable to how different socioeconomic or ethnic groups experienced industrialization.

Often, archaeologists infer socioeconomic organization and regional interactions by sourcing artifacts back to their point of origin (e.g., a quarry or other place of manufacture). Tracing the movement of artifacts and raw materials across the landscape allows archaeologists to define links between different places and people. A fundamental challenge in sourcing pot sherds is that many potteries produced pottery that looks alike. Relying on maker's marks to determine the potteries represented by an assemblage at an historic site is a useful way to begin to establish regional connections and patterns of consumption; however, most pot sherds do not possess maker's marks. Absent maker's marks, visual attributes are often insufficient for determining where the pottery was manufactured. Fortunately, geochemical methods can provide chemical data for sourcing pottery (e.g., Emmitt et al. 2018; Frahm 2018; Gjesfjeld 2018; Greer and MacDonald 2020; Hunt and Speakman 2015; Owen 2001; Stoner 2016; Wilke et al. 2016).

Here, we provide a simple test of the ability to distinguish between macroscopically similar pottery attributable to different makers using compositional data. We employed portable X-ray fluorescence spectrometry (pXRF) for the compositional analysis of whiteware and stoneware collected from domestic contexts at Stoddartsville. Our analysis of these data demonstrates differences in the “recipes” used by the potteries that made some of the whiteware and stoneware consumed at Stoddartsville. These differences allow us to use compositional data to source pot sherds to potteries located within the eastern United States and across the Atlantic, thereby documenting the links Stoddartsville developed as the village grew into a short-lived center of trade and industry. At a more general level, our study demonstrates the potential for historical archaeologists to use compositional data, even in the absence of makers’ marks, to source historic artifacts and, in turn, develop insights into regional economies, the development of local industries, and consumer agency.

INDUSTRIALIZATION IN EASTERN PENNSYLVANIA: STODDARTSVILLE IN HISTORIC CONTEXT

The story of Stoddartsville is really the story of industrialization, urbanization, and economic development more generally, though told from the perspective of eastern Pennsylvania. In the early nineteenth century, the agricultural economy of the Lehigh Valley was centered on Easton, Allentown (at the time called Northampton), and Bethlehem. The upper Lehigh Valley, where Stoddartsville is located, was a wilderness punctuated by small settlements (Waltman 1983). The economic outlook and significance of the Lehigh Valley would soon change dramatically, however, as a fledgling America engaged in a “second war of independence” to establish its own industrial power and thereby secure economic independence from Europe (Knies 2001:34).

In the late eighteenth through the mid-nineteenth centuries, large commercial ventures developed along the Lehigh River to exploit the iron ore available in the lower Lehigh Valley and the anthracite coal, discovered in 1791, near the upper Lehigh Valley (Waltman 1983;

Westmont 2019). Profiting from these resources required successfully transporting them to markets in Philadelphia, and so Josiah White and Erskine Hazard set themselves the task of improving navigation of the Lehigh River, funded, in part, by John Stoddart, the founder and namesake of Stoddartsville (Hansell 1992; Sheehan et al. 1989). The efforts of White and Hazard led, either directly or indirectly, to the opening of the Lehigh Canal in 1829, the establishment of the anthracite and coal trade through the Lehigh Valley, the extraordinary growth of iron manufacturing along the Lehigh River, and the building of the Lehigh Valley Railroad (Waltman 1983). Indicative of the dramatic social and economic transformations occurring along the Lehigh River, the population of the Lehigh Valley nearly doubled during the first half of the nineteenth century, from 45,000 in 1820 to 88,400 in 1850 (Bryzski 1957).

Situated along the Great Falls of the Lehigh River, Stoddartsville provides an opportunity to document the cultural changes that accompanied an attempt to bring industry to the wilderness of northeast Pennsylvania. Stoddartsville is best known as the site of an early nineteenth century milling village built by John Stoddart (Bradsby 1893). A Philadelphia industrialist, Stoddart planned to buy grain in the Wyoming Valley, transport it via the Easton and Wilkes-Barre Turnpike to Stoddartsville, grind it at his mill, and then ship the flour to Philadelphia using the Lehigh and Delaware Rivers, thereby diverting the grain trade from Baltimore to Philadelphia (Figure 1; Sheehan et al. 1989). In support of his vision, Stoddart quickly built a grist mill, sawmill, general store, inn, workers' cabins, family mansion, and other village structures (Figure 2). Stoddart's plan failed, however, as promises by the Lehigh Navigation and Coal Company to make the Lehigh River navigable went unmet. Stoddart was forced to sell his land in the 1820s to pay his debts. Over the next few decades, the coal industry's need for cheap lumber prompted renewed growth—and an economic pivot—at Stoddartsville (Nigro 2002). Between 1835 and 1865, the village grew to 40 houses and employed approximately 200 laborers in support of the lumber trade (Bradsby 1893). The lucrative lumber trade ended after a devastating forest fire in 1875. In the early 1900s, Stoddartsville experienced another resurgence, as wealthy families from New York and Philadelphia began to summer in the Poconos. Today, Stoddartsville remains a popular summer getaway.

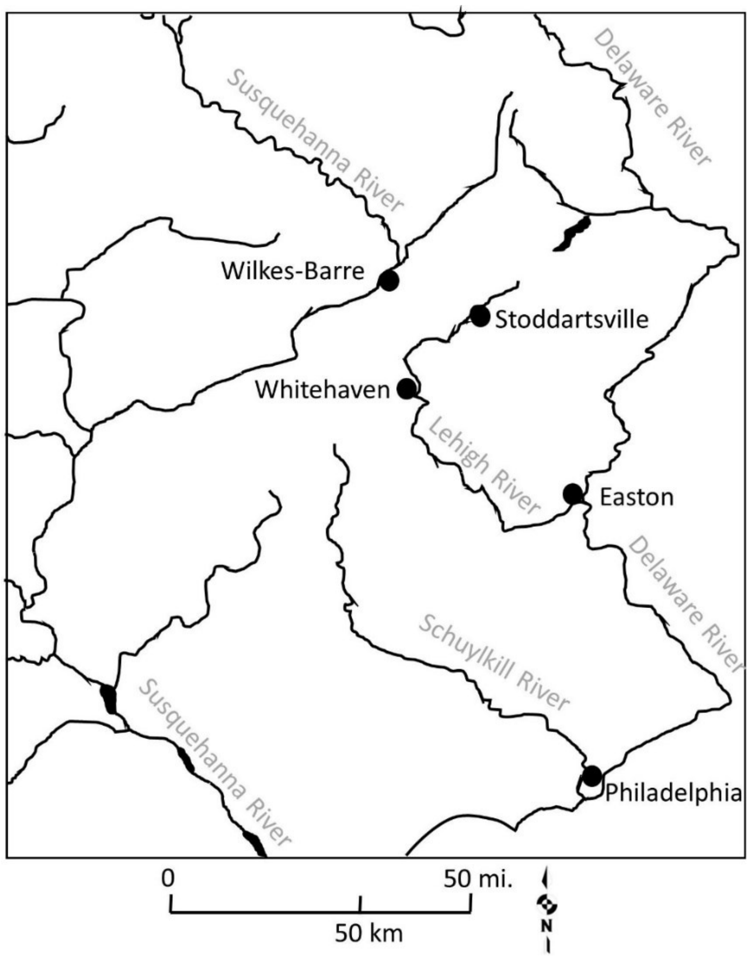


Figure 1. Map showing the location of Stoddartsville in relation to the rivers and towns that informed Stoddart's business venture in northeast Pennsylvania (redrawn from Sheehan et al. 1989).

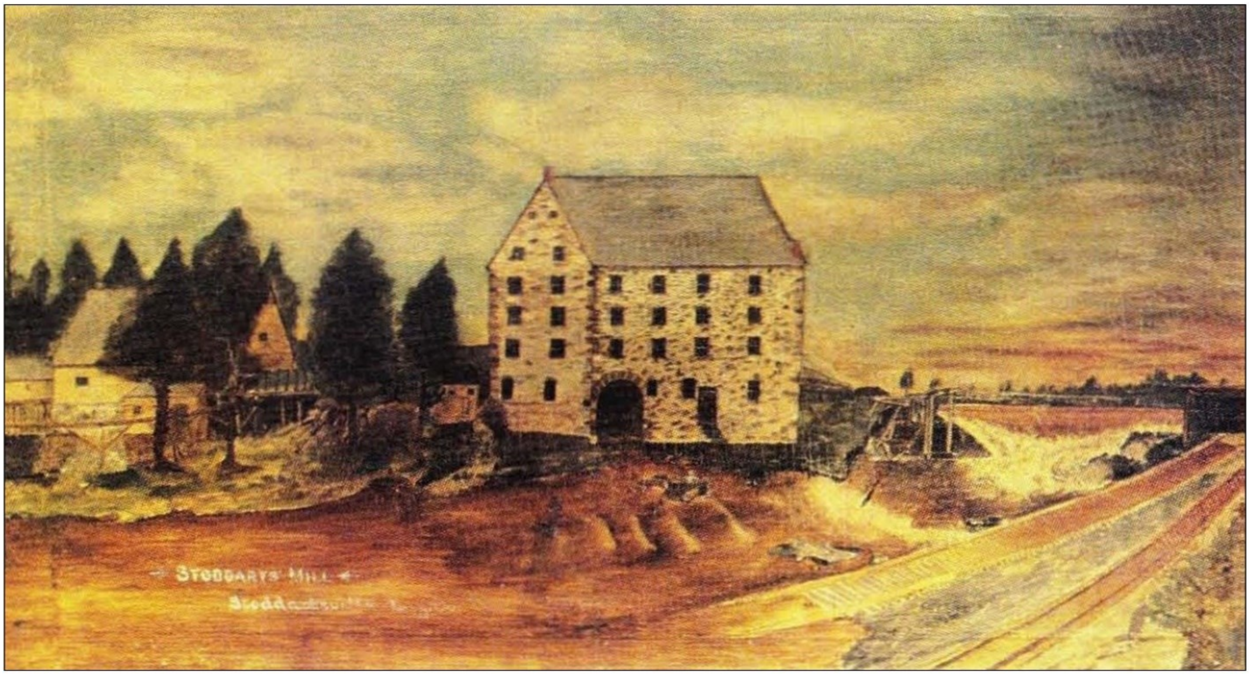


Figure 2. An anonymous oil painting (ca.1820) depicts the Easton and Wilkes-Barre Turnpike crossing the Lehigh River at Stoddartsville. The grist mill stands in the center of the painting with a shingle mill and sawmill to the left, separated by the race that provided water to power the mills. Picture provided by the Stoddartsville Preservation Society.

Stoddartsville reflects a grand American experiment: an attempt to secure economic independence from Europe through investment in industry while avoiding the social ills that plagued Europe’s industrial cities (Kasson 1979, Marx 1964, Prude 1983). The solution advocated by pro-industrialists, such as Alexander Hamilton and Trench Coxe, was to create a nonurban American industry, locating factories in rural areas to “make unimproved nature productive” and exploiting what they perceived as the “previously untapped labor” of women, children, and older members of the population (Shackel 1996:87). Archaeological research at Stoddartsville, as a manifestation of this American experiment, provides an opportunity to examine the unfolding of industrialization in small, rural communities.

PREVIOUS RESEARCH AT STODDARTSVILLE

In 1986-1987, SJS Archaeological Services (SJS) assessed the historical and archaeological resources along the upper Lehigh River in advance of improvements to the F. E.

Walter Dam that, if completed, would have placed Stoddartsville and the surrounding area under water (Sheehan et al. 1989). The historical and archaeological assessment conducted by SJS documented the location of the foundations of several early village structures, focusing on the structures built and used by John Stoddart, who founded Stoddartsville, and Lewis Stull, who is associated with the boom in the lumber trade at the village in the mid-nineteenth century (Sheehan et al. 1989). Test units excavated by SJS focused especially on the inn Stoddart built for travelers on the Easton and Wilkes-Barre Turnpike. These data are useful for obtaining a general picture of the organization and evolution of the community, but they provide only a small window onto the daily lives of its residents.

At the invitation of the current landowners and the Stoddartsville Preservation Society (SPS), Newlander recently renewed archaeological investigation at Stoddartsville. While the local residents of Stoddartsville are steeped in village history, they are often, understandably, focused on their families' particular connections to the village. Our research seeks to understand Stoddartsville from a regional, socioeconomic perspective, thereby situating the personal stories of life at the village within the larger context of a region being transformed by industrialization. To that end, Newlander has directed the Kutztown University Archaeology Field School (KUAFS) in systematic archaeological research at Stoddartsville.

Although the ruins of the mills and foundations of several early village structures remain, many informative structures are no longer visible. For example, an early-nineteenth-century map of Luzerne County documents a row of stone cottages (referred to herein simply as the workers' cabins) that housed the mill hands just across the race from the grist mill (Figure 3); however, these structures are no longer visible above ground. Additionally, only a slight depression in the ground surface betrays the location of the Stoddartsville general store. Significantly, these structures contain archaeological traces of everyday life at Stoddartsville. Accordingly, the KUAFS began its work at Stoddartsville by trying to define the footprint of the general store and workers' cabins more precisely. The KUAFS used historic maps in combination with geophysical survey to locate subsurface anomalies suggestive of buried cultural features (e.g., stone foundations, concentrations of metal artifacts). Informed by the results of the geophysical survey, the KUAFS located and excavated in the Stoddartsville general store. Additionally, the KUAFS excavated in archaeological deposits that, based on their location, are likely associated with the workers, although the footprint of their residences has been harder to define.

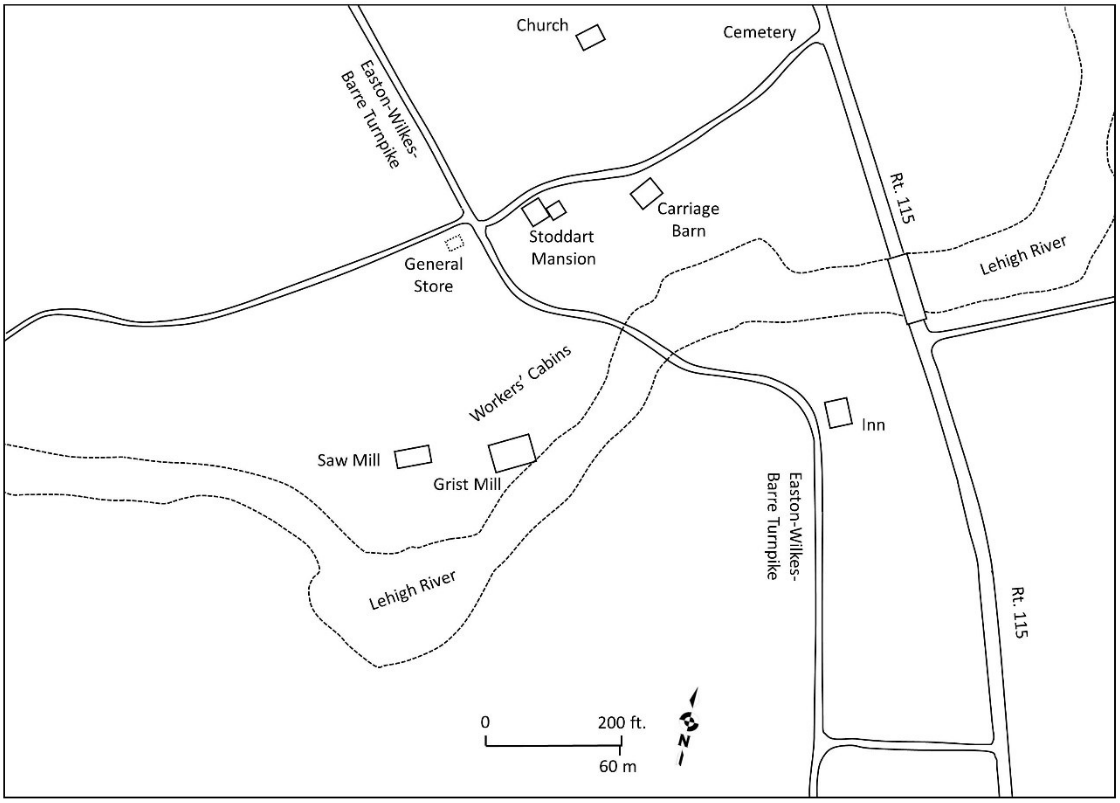


Figure 3. Map depicting the location of some of the important structures in Stoddartsville (redrawn from Sheehan et al. 1989).

The KUAFS also excavated in the ruins of the Stoddart Mansion, a two-story, Georgian-style frame house built as a residence for John Stoddart's son Isaac (Sheehan et al. 1989). Isaac was sent to oversee day-to-day operations of the village. After Stoddart's venture failed, the mansion changed ownership several times, eventually coming into the possession of Lewis Stull in 1862. The Stoddart Mansion was one of the few original village structures to survive the forest fire of 1875. Stull's children reopened the mansion, renamed The Maples, to paying summer guests starting around 1900. The Maples finally burned down in 1951 after one of Lewis Stull's daughters reportedly dropped an oil lamp. Excavation in the Stoddart Mansion is of significance because it provides a point of comparison with the general store and workers' cabins.

As is true at many historic sites, the artifact assemblage recovered from our excavations at Stoddartsville is dominated by nails, pottery, and glass. Additional classes of artifacts, no less interesting but certainly less abundant, include animal bones, buttons, clay tobacco pipes, coins, and other personal effects (e.g., keys). A primary objective of our research at Stoddartsville is to document variability in the consumption of commodities by the residents of the village, reflective of their evolving social formations and connections to other villages within the burgeoning regional economy. Due to poor transportation networks, many towns and cities inland from east coast ports, including Stoddartsville, participated in a market economy in a limited way until the 1830s (Ross 1985). By 1840, Pennsylvania contained 974 miles of canal and 954 miles of railroad lines (Pearse 1876). The expansion of transport networks and declining transport costs throughout the nineteenth century made regional markets more porous. New consumer goods were created, used, and discarded with greater frequency as the culture of capitalism and industrialization took hold during the nineteenth century (Shackel 1994). Indeed, the establishment of Stoddartsville as a node within a networked industrial landscape centered on Philadelphia would have changed the flow of commodities through the region. Yet not all communities participated in the capitalist industrial economy in the same way or with the same vigor. And not all social groups within industrializing communities enjoyed access to the same commodities.

Although Stoddart's vision for his village failed, he established connections between Stoddartsville and other production centers that, over the life of the village, reflect its changing economic focus, demographic and social composition, and regional connections. By examining variability in the artifacts recovered from the Stoddart Mansion, general store, and workers' cabins, we have begun to identify: (1) synchronic variability in patterns of commodity consumption that reflects the different social groups (e.g., classes) who lived and worked in the village; and (2) diachronic variability in patterns of commodity consumption that reflects the changing role of Stoddartsville within the evolving regional economy. We hoped to expand our understanding of the regional connections and patterns of consumption established at Stoddartsville through the provenance analysis of pot sherds recovered from the site.

SOURCING POTTERY USING COMPOSITIONAL DATA

Often, archaeologists trace the movement of artifacts and raw materials across the landscape by using visual and chemical data to source artifacts back to their point of origin (e.g., a quarry or other place of manufacture). Sourcing ceramic artifacts can be particularly challenging for several reasons, however. Because raw clay sources are often numerous throughout any landscape and can be transported and blended by various geological processes (e.g., weathering of volcanic ash, alluvial deposition), establishing a representative sample of potential raw clay sources is challenging (Arnold et al. 1991; Eerkens et al. 2002; Gjesfjeld 2018). Additionally, the compositional analysis of pottery may have lower spatial and geochemical resolution compared to other artifacts simply because raw clay sources are often larger than stone sources (Neff 2001). In the context of historical archaeology, this problem may be mitigated to some degree because the point of origin to which we are attempting to link pot sherds is a specific pottery. Even if drawing from similar raw clay sources, different potteries may be distinguished from each other by the distinct "recipes" they used to create their pastes. Of course, another basic problem plagues attempts to source pot sherds: many potteries produced pottery that looks alike. Except for those few sherds that possess makers' marks, visual attributes are often insufficient for determining where the pottery was manufactured. Fortunately, pXRF is an analytical method that can provide information on the chemical composition of a wide variety of materials, including pottery (e.g., Frahm 2018; Hunt and Speakman 2015; Wilke et al. 2016).

Here, we used pXRF to acquire compositional data for several pot sherds. Analyses were conducted using a Vanta M Series handheld XRF equipped with a rhodium anode 50 kV X-ray tube and a large area silicon drift detector (SDD). Sherds that possessed flat areas and lacked visually detectable surface modifications were selected for analysis. One spot was analyzed per sherd for a 180-second live-time count using the GeoChem 3-beam mode. We found that the Vanta pXRF spectrometer used here reproduced chemical data previously obtained on geological specimens using an Olympus Premium-series Delta pXRF spectrometer (Newlander et al. 2015).

Using similarities in design motifs and pot sherd refits, we created groups of visually similar sherds that each included a sherd with a maker's mark (Table 1). We then used chemical data acquired with pXRF to determine if visually similar pottery from different makers was chemically distinctive. Many of the same elements are present in pottery, though in varying amounts (Table 2). Because the kinds and amounts of trace elements are uniquely characteristic of individual clays and clay products, they, together, with minor elements, are the basis for most provenance analyses of pottery (Rice 1987). Not all minor or trace elements are useful for the provenance analysis of pottery, however. We ignored elements present in the sub-parts-per-million range, gases, and elements known to be volatile during the firing process (e.g., As, Sb, and Bi) or mobile during burial (e.g., P; Orton and Hughes 2013:170). We also tried to minimize redundancy in the data by not basing our pottery discrimination solely on those elements that are correlated (e.g., Ni and Cr; K, Rb, Ce, and Ba; Ca and Sr; see discussion in Rice 1987:420). With these considerations in mind, we carefully examined the variability exhibited by ~40 elements that we could quantify to determine if compositional data would allow us to differentiate visually similar pottery. We present our analysis of whiteware pastes, whiteware slips, and stoneware pastes in turn.

Table 1. Pottery included in the analysis.

Pottery	**Location**	**Date**	**N**
Blue Ridge, Southern Potteries Inc. (A)	Erwin, TN	Early-1900s	20
Enoch Wood & Sons (B)	Burslem, Staffordshire, England	Early-1800s	5
Canonsburg (C)	Near Pittsburgh, PA	Early-1900s	30
Royal Sphinx (D)	Holland, The Netherlands	Late-1800s	29
Moritz Zdekauer (E)	Bohemia, Czech Republic (Austria)	Early-1900s	8
John Wedge Wood (F)	Tunstall, Stoke-on-Trent, England	Mid-1800s	10
Evan R. Jones and Evan B. Jones (G)	Pittston, PA	Ca. 1880	15
Unknown Stoneware 1 (H)			10
Unknown Stoneware 2 (I)			5

Table 2. Typical chemical constituents of pottery (Rice 1987).

Abundance	**Elements**
Major elements (≥2%)	Si, Al, O; frequently Ca, Fe, K
Minor elements (0.1%-2%	Ca, Fe, K, Ti, Mg, Mn, Na, Cr, Ni
Trace elements (<0.1%)	Cs, Rb, V, U, Ta, Sc, Li, Au, Se, Sb, Sr, Co, and the lanthanide series

RESULTS & DISCUSSION

In North America, a wide variety of ceramic wares occur at historical archaeological sites, including common pottery (terracottas and unrefined earthenwares), refined earthenwares (white improved earthenware, vitreous China, yellowware, and redware), stoneware (utility stoneware and fine stoneware), and porcelain (Euroamerican porcelain and Chinese porcelain) (Denker and Denker 1982; Majewski and O'Brien 1987; Miller 1980; Ramsay 1947). The range of available wares was significantly reduced by the success of the English ceramic industry during the 1800s, which displaced many fine ware types, including white, salt-glazed stoneware, and tin-glazed earthenware (Miller 1980). The major ceramic type available during the nineteenth century was English white earthenware, which included creamware, pearlware, and stone China. Not surprisingly, white earthenware dominates the pottery assemblage at Stoddartsville.

Whiteware is loosely defined as any white earthenware or semi-porcelain which is opaque (Majewski and O'Brien 1987). This includes wares to imitate porcelain but lacking the translucency of the finer ware because of the type of clays used or the thickness of the piece. The production of cream-colored wares in imitation of the varieties of English pieces available during the late eighteenth and early nineteenth centuries certainly occurred in America. Examples of such American-made wares, however, are difficult to distinguish from their English counterparts. By the mid-nineteenth century, American refined earthenwares became more recognizable, partly because of their decorations, but primarily because manufacturers often marked their wares (Majewski and O'Brien 1987; Miller 1980).

We recovered several whiteware sherds while excavating at Stoddartsville, especially in the Stoddart mansion. These whiteware sherds derive from many different potteries, both in America and in Europe. The potteries included in our analysis of whiteware are listed in Table 1 and depicted in Figure 4. Using the statistical program JMP ®, we created boxplots that depict some of the compositional variability exhibited in the pastes (Fig. 5) of the whiteware produced by these potteries. Boxplots provide a picture of the variation for each element, allowing the analyst to readily identify the amount of dispersion and skewness in the data. The ends of the box are the 25th and 75th quantiles (the quartiles). The whiskers extend from the quartiles for a distance equal to 1.5 x the interquartile range (the difference between the quartiles). Points beyond the whiskers are outliers. The line across the middle of the box identifies the median sample value. If a distribution is normal, the quantiles shown in the boxplot are approximately equidistant from each other. Figure 5 also includes graphical comparisons for each pair of means using a Student's *t*-test. The diameters of each circle represent the differences between the means. An outside angle of circle intersection of less than 90° or no overlap indicates a significant difference between the concentrations obtained for different potteries.

Figure 4a. Blue Ridge pottery.

Figure 4b. Enoch Wood & Sons.

Figure 4c. Canonsburg pottery.

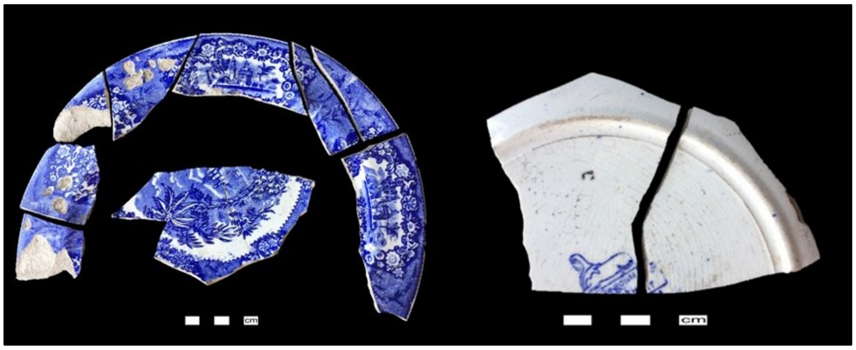


Figure 4d. Royal Sphinx Company.

Figure 4e. Zdekauer pottery.

Figure 4f. John Wedge Wood, not to be confused with Josiah Wedgwood (Boger 1971:373).

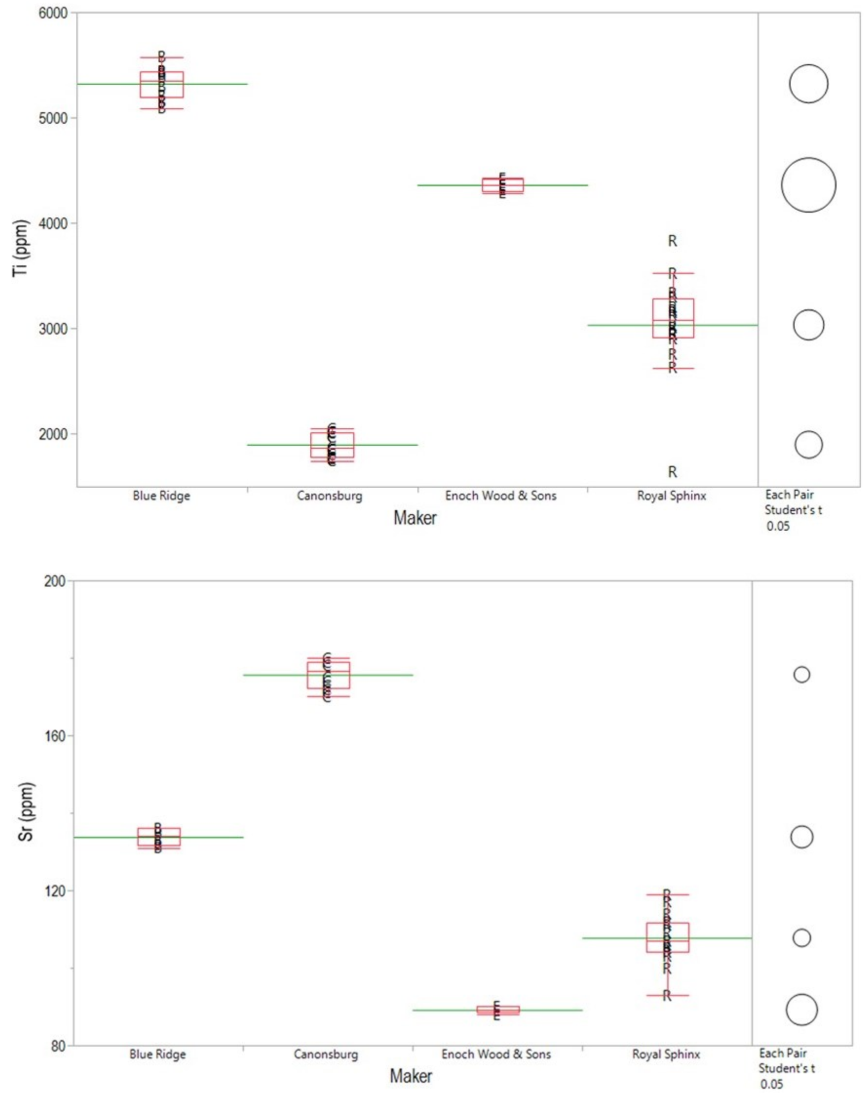


Figure 5. Boxplots comparing whiteware pastes for Ti and Sr. Mean concentrations for each maker are depicted by the long horizontal lines.

Simple univariate statistical analysis suggests compositional differences between the whiteware produced by the potteries included herein. Many archaeologists also use multivariate statistical analyses for working with compositional data. Although the assumptions of discriminant analysis are difficult to satisfy in practice (Hughes 1986:57-59), it remains a commonly used multivariate statistical technique for sourcing artifacts (e.g., Baxter 2003; Luedtke 1979:749; Orton and Hughes 2013:180). Discriminant analysis uses the values provided for known groups of objects (in this case, potteries) to identify combinations of discriminating variables (elements) that minimize separation within groups and maximize separation between groups. These allocation rules then are used to assign unknowns (pot sherds) to known groups (potteries).

Rather than include all elements in the discriminant analysis, we included a few well measured elements that exhibited variability across the potteries (Al, K, Ti, Mn, Ni, Rb, Sr, Zr). This allowed us to avoid an increase in the misclassification rate that typically accompanies the use of many variables in discriminant analysis (e.g., Dunn and Varady 1966). We used a stepwise selection procedure to choose elements that maximize the distance between each source's centroid (multivariate mean). The discriminant analysis platform in JMP® uses squared Mahalanobis distance (D^2) to maximize the distance between known groups. Variables are added to the discriminant analysis based on F-ratios (variance ratios). Although F-statistics are not easily interpreted, they do provide a general indication of how much adding a particular variable to the analysis contributes to the discrimination of known groups (Hughes 1986). Based on the F-ratios, Rb (F-ratio = 4471.84) and Sr (F-ratio = 4161.83) contribute most to the discrimination of whiteware pastes. A bivariate scatterplot confirms that much of the structure in these data is captured by these two elements (Fig. 6).

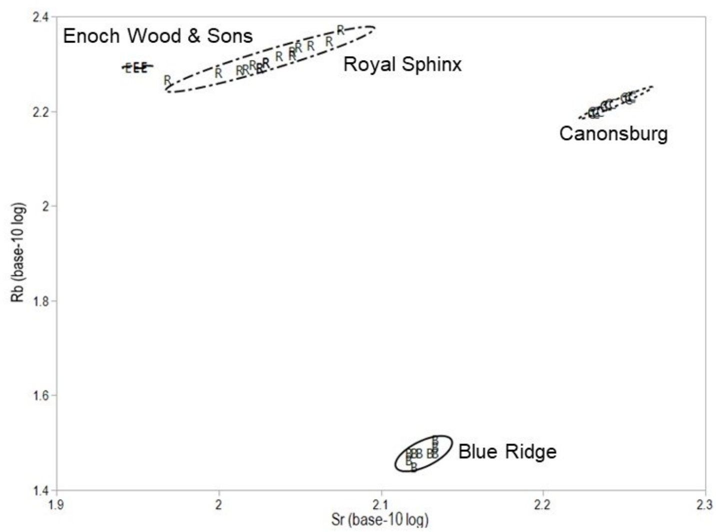


Figure 6. Bivariate scatterplot of Rb vs. Sr for whiteware pastes. The ellipses represent a 95% confidence interval.

We found that three elements (Rb, Sr, and Ti), transformed to their base-10 logarithms, were necessary to discriminate whiteware pastes with no misclassifications. As others have observed, the “percent misclassified” in discriminant analysis tends to exaggerate the accuracy of the analysis because the allocation rules used to discriminate known groups are applied to the same cases from which they were generated. The result is a statistical self-fulfilling prophecy (Hughes 1986:66). A better test of the discriminant analysis is the cross-validation method known as jackknifing (Jones 1974; Quenouille 1956). In the jackknife method, the D^2 of each value from the centroid of a group is calculated based on estimates of the mean, standard deviation, and correlation matrix that does not include the value itself. In this case, the jackknife method resulted in a misclassification of only 1 of 51 pot sherds (a correct classification rate of 98.0%). Clearly, the pastes of whiteware from different potteries can be distinguished from one another using univariate, bivariate, and multivariate statistical analyses of the compositional data acquired by pXRF.

We also acquired compositional data for slips of whiteware produced by different potteries. We recognize that the chemical analysis of slips poses different challenges than the chemical analysis of pastes (e.g., potential for surface contamination; x-rays penetrating beyond the slip to the underlying paste). Accordingly, we recognize the need for cautious optimism as we present our results. As with whiteware pastes, we found that univariate and bivariate statistical analysis demonstrated compositional differences between the potteries represented in our whiteware sample. We also used a set of well-measured elements (Ti, Mn, Fe, Co, Ni, Zn, Rb, Sr, Zr, and Nb) to conduct a discriminant analysis, following the steps described above. We found that Zr (F-ratio = 5219.83) and Zn (F-ratio = 1588.07) contribute most to the discrimination of whiteware slips. In fact, these two elements, transformed to their base-10 logarithms, are sufficient for discriminating whiteware slips with no misclassifications. The jackknife method of cross-validation resulted in no misclassifications either. Clearly, the slips of whiteware from different potteries can be distinguished from one another using univariate, bivariate, and multivariate statistical analyses of the compositional data acquired by pXRF.

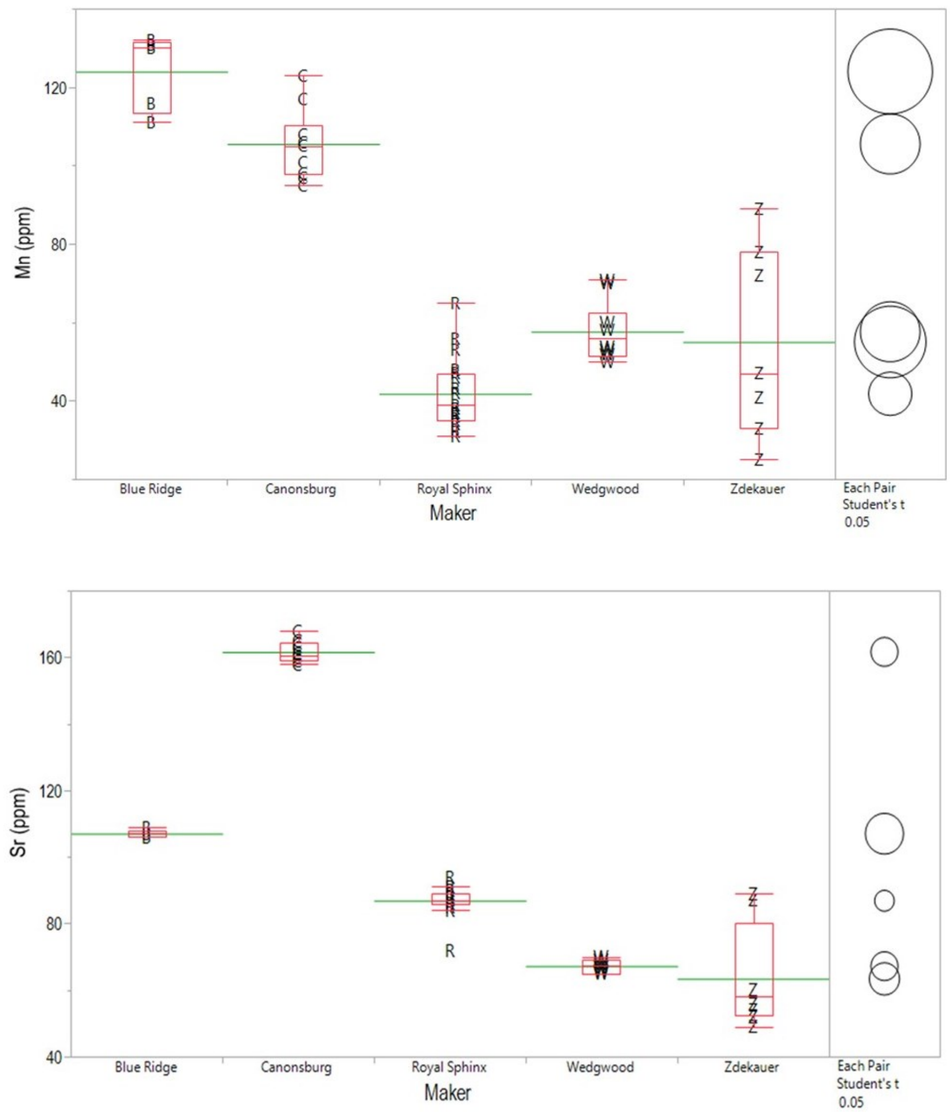


Figure 7. Boxplots comparing the slips of whiteware makers. Mean concentrations for each maker are depicted by the long horizontal lines.

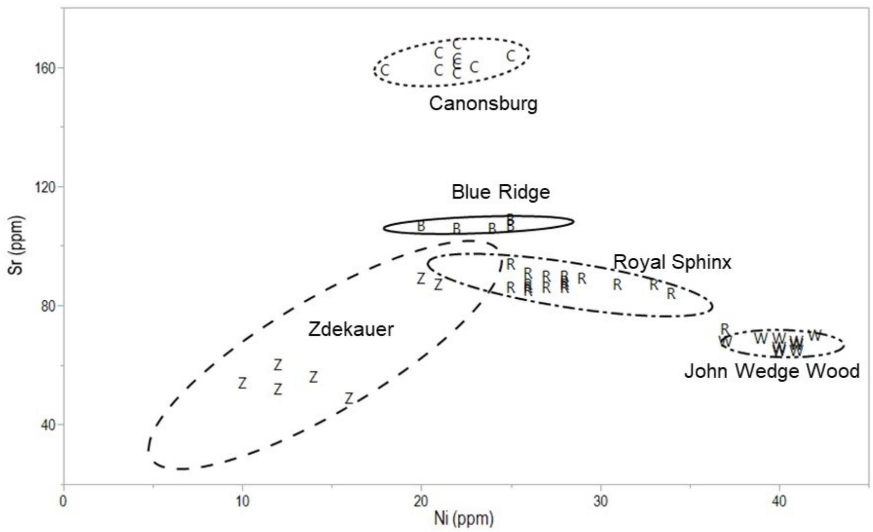
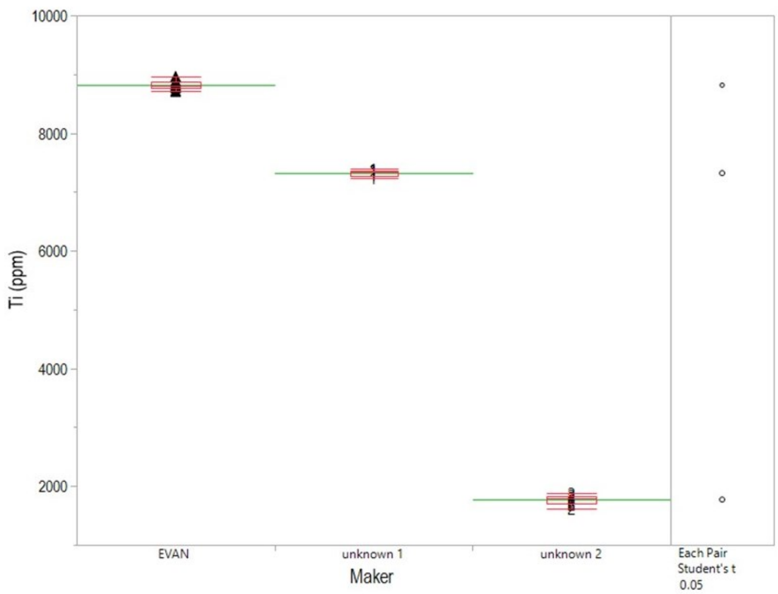


Figure 8. Bivariate scatterplot comparing the slips of whiteware makers. The ellipses represent a 95% confidence interval.

Finally, we collected compositional data for stoneware found at Stoddartsville. Stonewares are made from fine, dense clays and are fired at temperatures of about 1200-1350° C, which usually is high enough to achieve at least partial vitrification of the clay body (Rice 1987). Stonewares may be unglazed or may exhibit a lead or salt glaze. The salt glaze is a thin, glassy glaze found exclusively on stoneware fired at a high temperature. Stoneware was first produced in England and Germany in the sixteenth and seventeenth centuries, but it was not until the eighteenth century that it was developed into a fine tableware. American potters have made stoneware from the 1630s to the present and from one end of the country to the other (Ketchum 1991). Consequently, stoneware, especially gray salt-glazed stoneware, is common on historic sites throughout North America.

Stoneware was manufactured in locations across North America during the eighteenth and nineteenth centuries (Ketchum 1991). By the second half of the nineteenth century, potteries in the vicinity of Stoddartsville were making stoneware. For example, we recovered a potsherd from the workers' cabins with a maker's mark that indicates it was made ca. 1880 by Evan R. Jones and Evan B. Jones, stoneware potters in Pittston, PA, located about 20 miles northwest of Stoddartsville (Fig. 9). Interestingly, other stoneware found on site is chemically distinct from the Evan stoneware, as reflected by univariate (Fig. 10), bivariate (Fig. 11), and multivariate statistical analysis.

Figure 9. Stoneware made by Evan R. Jones and Evan B. Jones in the late-1800s in Pittston, PA.



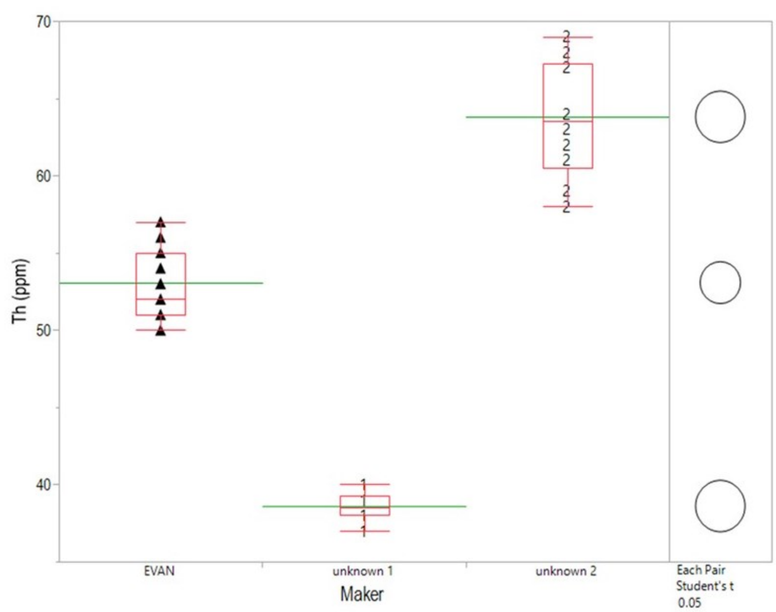


Figure 10. Boxplots comparing the pastes of stoneware makers. Mean concentrations for each maker are depicted by the long horizontal lines.

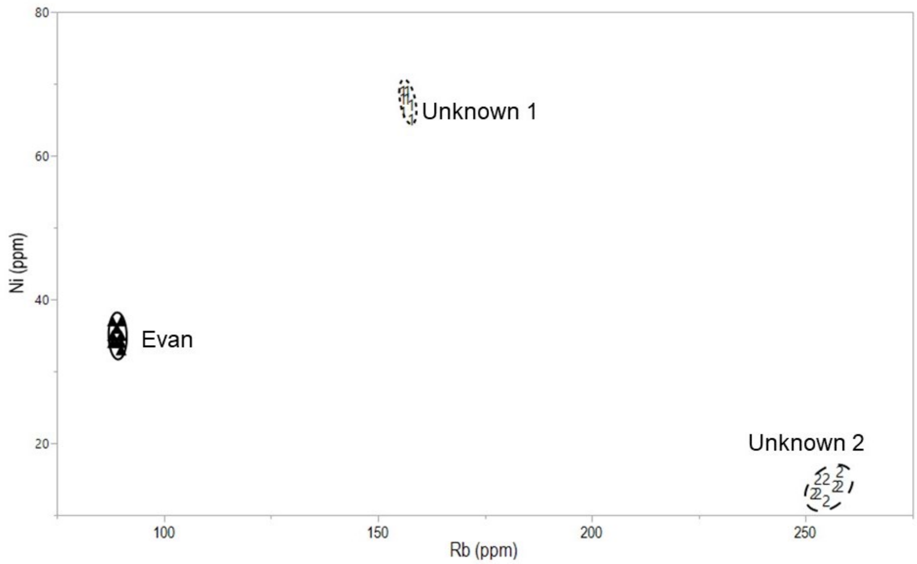


Figure 11. Bivariate scatterplots comparing the pastes of different stoneware makers. The ellipses represent a 95% confidence interval.

Though promising, we recognize our results as preliminary. For example, we recognize that discriminant analysis, by design, is susceptible to Type 2 and Type 3 errors (Hughes 1986). Type 2 errors result when an artifact is assigned to a source (a pottery) outside the study when it is from a source within the study (Luedtke 1979). Type 3 errors result when an artifact is assigned to a source within the study when it is from a source outside the study. These errors follow from a basic assumption of discriminant analysis: each unknown is a member of a known group included in the study. In other words, discriminant analysis will assign all pot sherds to a pottery in the study, even if the pot sherd derives from a pottery not included in the study. In this case, we employed discriminant analysis to explore compositional differences between potteries based on pot sherds we know are from specific potteries, mitigating the potential for Type 2 and Type 3 errors. As we expand our sample to include more potteries and as we extend our analysis to include pot sherds truly of unknown provenance, the potential for Type 2 and Type 3 errors will increase.

Still, the results of our analysis suggest that careful analysis of compositional data can facilitate the sourcing of pot sherds from historic sites. Indeed, we found that pottery produced by different potteries represented at Stoddartsville varies in abundance of several minor and trace elements for both whiteware and stoneware. We can use these compositional differences to source pot sherds that lack maker's marks, thereby expanding our understanding of the regional economy, the development of local ceramic industries, and consumer agency.

CONCLUSION

Here, we demonstrated the ability to discriminate between different whiteware and stoneware makers represented in the pottery assemblage at Stoddartsville using compositional data acquired with pXRF. The ability to chemically differentiate pottery from different makers allows us to source pot sherds that lack maker's marks. We can use these data to document the links developed between Stoddartsville and the surrounding region as the village grew into a short-lived center of trade and industry in northeast Pennsylvania. Whereas the whiteware suggests links between Stoddartsville and distant potteries, the stoneware defines local links between Stoddartsville and nearby potters. At a more general level, our study demonstrates the potential for historical archaeologists to use compositional data, even in the absence of makers' marks, to source historic artifacts, providing insight into regional economies and other aspects of sociocultural organization (e.g., Bloch 2016; Greer and MacDonald 2020; Scarlett et al. 2007).

ACKNOWLEDGMENTS

We thank our colleagues in the Departments of Anthropology & Sociology and Physical Sciences for their support. Fieldwork and analysis was supported by grants from Kutztown University, the Pennsylvania State System of Higher Education (PASSHE), and the National Science Foundation (Award #2122134). We thank the Kerrick Family and Stoddartsville Preservation Society for the opportunity to work at this site. Finally, we thank Roger Moeller for the invitation to submit this manuscript and his helpful guidance in bringing it to publication.

REFERENCES CITED

Arnold, Dean E., Hector Neff, and Ronald L. Bishop

1991 Compositional analysis and “sources” of pottery: an ethnoarchaeological approach. *American Anthropologist* 93(1):70-90.

Baxter, Michael J.

2003 *Statistics in Archaeology*. Hodder Arnold, London.

Bloch, Lindsay

2016 An elemental approach to the distribution of lead-glazed coarse earthenware in the eighteenth-century Chesapeake. *American Antiquity* 81:231-252.

Boger, Louise Ade

1971 *The Dictionary of World Pottery and Porcelain*. Charles Scribner’s Sons, New York.

Bradsby, Henry C.

1893 *History of Luzerne County, Pennsylvania: With Biographical Sketches*. S. B. Nelson, Chicago.

Bryzski, Anthony J.

1957 *The Lehigh Canal and Its Effect on the Economic Development of the Region Through Which It Passed, 1818-1873*. Doctoral dissertation, New York University, New York.

Casella, Eleanor Conlin

2005 “Social Workers”: New directions in industrial archaeology. In *Industrial Archaeology: Future Directions*, ed. by Eleanor C. Conlin and James Symonds, pp. 3-31. Springer, New York.

Coppock, Gary F.

2015 Abraham S. Valentine’s log washer and the resuscitation of the nineteenth-century iron industry of Central Pennsylvania. *IA. The Journal of the Society for Industrial Archaeology* 41:48-69.

Davis, Christine

2015 Jones and Laughlin Steel Works: 130 years of industry/25 years of archaeology. *IA. The Journal of the Society for Industrial Archaeology* 11(1):9-25.

Denker, Ellen and Bert Denker

1982 *The Warner Collector's Guide to North American Pottery and Porcelain*. The Main Street Press, New York.

Dunn, Olive Jean and Paul D. Varady

1966 Probabilities of correct classification in discriminant analysis. *Biometrics* 22:908-924.

Eerkens, Jelmer W., Hector Neff, and Michael D. Glascock

2002 Ceramic production among small-scale and mobile hunters and gatherers: A case study from the southwestern Great Basin. *Journal of Anthropological Archaeology* 21:200-229.

Emmitt, Joshua J., Andrew J. McAlister, Rebecca S. Phillips, and Simon J. Holdaway

2018 Sourcing without sources: Measuring ceramic variability with pXRF. *Journal of Archaeological Science: Reports* 17:422-432.

Ford, Ben

2011 Worker housing in the Vermont Copper Belt: Improving life and industry through paternalism and resistance. *International Journal of Historical Archaeology* 15:725-750.

Frahm, Ellery

2018 Ceramic studies using portable XRF: From experimental tempered ceramics to imports and imitations at Tell Mozan, Syria. *Journal of Archaeological Science* 90:12-38.

Gjesfjeld, Erik

2018 The compositional analysis of hunter-gatherer pottery from the Kuril Islands. *Journal of Archaeological Science: Reports* 17:1025-1034.

Greer, Matthew C. and Brandi L. MacDonald

2020 Which town did it come from? Sourcing locally-made ceramics in the Mid-Atlantic. *North American Archaeologist* 41(4):135-167.

Hansell, Norris

1992 *Josiah White: Quaker Entrepreneur*. Canal History and Technology Press, Easton, PA.

Heberling, Scott D.

2015 The archaeology of failure: An example from the Juniata Iron District of Pennsylvania. *IA. The Journal of the Society for Industrial Archaeology* 41:25-47.

Hughes, Richard E.

1986 *Diachronic Variability in Obsidian Procurement Patterns in Northeastern California and Southcentral Oregon*. University of California Publications in Anthropology 17. Berkeley.

Hunt, Alice M. W. and Robert J. Speakman

2015 Portable XRF analysis of archaeological sediments and ceramics. *Journal of Archaeological Science* 53:1-13.

Jones, Howard L.

1974 Jacknife estimation of functions of stratum means. *Biometrika* 61:343-348.

Kasson, John F.

1979 *Civilizing the Machine: Technology and Republican Values in America, 1776-1900*. Penguin Books, New York.

Ketchum Jr., William C.

1991 *American Stoneware*. Henry Holt and Company, New York.

Knies, Michael

2001 *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*. Canal History and Technology Press, Easton, PA.

Luedtke, Barbara E.

1979 The identification of sources of chert artifacts. *American Antiquity* 44:744-757.

Majewski, Teresita and Michael J. O'Brien

1987 The use and misuse of nineteenth-century English and American ceramics in archaeological analysis. *Advances in Archaeological Method and Theory* 11:97-209.

Marx, Leo

1964 *The Machine in the Garden: Technology and the Pastoral Ideal in America.* Oxford University Press, New York.

Metheny, Karen

2007 *From the Miners' Doublehouse: Archaeology and Landscape in a Pennsylvania Coal Company Town*. University of Tennessee Press, Knoxville.

2010 Engendering the corporate landscape: A view from the Miners' Doublehouse. In *Archeology and Preservation of Gendered Landscapes*, ed. by Sherene Baugher and Suzanne M. Spencer-Woods, pp. 313-340. Springer, New York.

2013 Modeling communities through food: Connecting the daily meal to the construction of place and identity. *Northeast Historical Archaeology* 42:147-183.

Miller, George L.

1980 Classification and economic scaling of 19th century ceramics. *Historical Archaeology* 14:1-40.

Mrozowski, Stephen A.

2005 Cultural identity and the consumption of industry. In *Industrial Archaeology: Future Directions*, ed. by Eleanor Conlin Casella and James Symonds, pp. 243-260. Springer, New York.

Neff, Hector

2001 Synthesizing analytical data – Spatial results from pottery provenance investigation. In *Handbook of Archaeological Sciences*, ed. by Don R. Brothwell and A. Mark Pollard, pp. 733-747. John Wiley & Sons, Hoboken.

Newlander, Khori, Nathan Goodale, George T. Jones, and David G. Bailey

2015 Empirical study of the effect of count time on the precision and accuracy of pXRF data. *Journal of Archaeological Sciences: Reports* 3:534-548.

Nigro, Augustine

2002 *Landscaping the Lehigh: The Creation of a Middle Industrial Landscape in Nineteenth-Century Pennsylvania*. Doctoral dissertation, West Virginia University, Morgantown, WV.

Orton, Clive and Michael Hughes

2013 *Pottery in Archaeology*. 2nd ed. Cambridge University Press, New York.

Owen, J. Victor

2001 Provenience of eighteenth-century British porcelain sherds from Sites 3B and 4E, Fortress of Louisbourg, Nova Scotia: Constraints from mineralogy, bulk paste, and glaze compositions. *Historical Archaeology* 35:106-119.

Pauls, Elizabeth P.

2006 The place of space: Architecture, landscape, and social life. In *Historical Archaeology*, ed. by Martin Hall and Stephen W. Silliman, pp. 65-83. Blackwell Publishing, Malden, MA.

Pearse, John B.

1876 *A Concise History of the Iron Manufacture of the American Colonies up to the Revolution, and of Pennsylvania until the Present*. Allen, Lane & Scott, Philadelphia.

Prude, Jonathan

1983 *The Coming of Industrial Order: Town and Factory Life in Rural Massachusetts, 1810-1860*. Cambridge University Press, New York.

Quenouille, M. H.

1956 Notes on bias in estimation. *Biometrika* 43:353-360.

Ramsay, John

1947 *American Potters and Pottery*. Tudor, New York.

Rice, Prudence M.

1987 *Pottery Analysis: A Sourcebook*. The University of Chicago Press, Chicago.

Roller, Michael

2015 *Migration, Modernity and Memory: The Archaeology of the Twentieth Century in a Northeast Pennsylvania Coal Company Town, 1897-2014.* Doctoral dissertation, University of Maryland, College Park.

Ross, Steven J.

1985 *Workers on the Edge: Work, Leisure, and Politics in Industrializing Cincinnati, 1788-1890*. Columbia University Press, New York.

Scarlett, Timothy James, Robert J. Speakman, and Michael D. Glascock

2007 Pottery in the Mormon economy: An historical, archaeological, and archaeometric study. *Historical Archaeology* 41(4):72-97.

Shackel, Paul A.

1994 Interdisciplinary approaches to the meanings and uses of material goods in Lower Town Harpers Ferry. *Historical Archaeology* 28(4):3-15.

1996 *Culture Change and the New Technology: An Archaeology of the Early American Industrial Era*. Plenum Press, New York.

2016 The meaning of place in the anthracite region of Northeastern Pennsylvania. *International Journal of Heritage Studies* 22:200-213.

2018 Immigration heritage in the anthracite coal region of Northeastern Pennsylvania. *Journal of Community Archaeology & Heritage* 5(2):101-113.

Shackel, Paul A. and Michael Roller

2012 The Gilded Age wasn't so gilded in the anthracite region of Pennsylvania. *International Journal of Historical Archaeology* 16:761-775.

Sheehan, Glenn W., Anne M. Jensen, and Malcolm K. Sender

1989 Archaeological and Architectural Investigations at F. E. Walter Dam and Reservoir. Report to the U.S. Army Corps of Engineers, Philadelphia District, from SJS Archaeological Services, Inc., Bridgeport, PA.

Stoner, Wesley D.

2016 The analytical nexus of ceramic paste composition studies: A comparison of NAA, LA-ICP-MS, and petrography in the prehispanic Basin of Mexico. *Journal of Archaeological Science* 76:31-47.

Waltman, Charles A.

1983 Influence of the Lehigh Canal on the industrial and urban development of the Lehigh River. *Proceedings of the Canal History and Technology Symposium* 2:87-104.

Walton, Steven A.

2015 Machinery to match the materials: Iron ore washing in Pennsylvania. *IA. The Journal of the Society for Industrial Archaeology* 41:71-92.

Westmont, V. Camille

2019 *Creating Anthracite Women: The Roles of Architecture and Material Culture in Identity Formation in Pennsylvania Anthracite Company Towns, 1854-1940*. Doctoral dissertation, University of Maryland, College Park.

Wilke, Detlef, Dagmar Rauch, and Patrick Rauch

2016 Is non-destructive provenancing of pottery possible with just a few discriminative trace elements? *STAR: Science & Technology of Archaeological Research* 2(2):141-158.

Worth, David

2005 Gas and grain: The conservation of networked industrial landscapes. In *Industrial Archaeology: Future Directions*, ed. by Eleanor Conlin Casella and James Symonds, pp. 135-154. Springer, New York.

Wurst, LouAnn

2002 "For the means of your subsistence…look under God to your own industry and frugality": Life and labor in Gerrit Smith's Peterboro. *International Journal of Historical Archaeology* 6:159-172.

Wurst, LouAnn and Stephen A. Mrozowski

2016 Capitalism in motion. *Historical Archaeology* 50(3):81-99.