2015

BEAUTIFUL FORMS AND COMPOSITIONS ARE NOT MADE BY CHANCE: EXPLORING THE EFFICACY OF PORTABLE X-RAY FLUORESCENCE TO SORT AND SOURCE ENGLISH LEAD GLAZED CERAMICS

Steven J. Sarich
Michigan Technological University

Follow this and additional works at: https://digitalcommons.mtu.edu/etds
Part of the Materials Science and Engineering Commons, and the Other History of Art, Architecture, and Archaeology Commons

BEAUTIFUL FORMS AND COMPOSITIONS ARE NOT MADE BY CHANCE: EXPLORING THE EFFICACY OF PORTABLE X-RAY FLUORESCENCE TO SORT AND SOURCE ENGLISH LEAD GLAZED CERAMICS

By

Steven J. Sarich

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Industrial Archaeology

MICHIGAN TECHNOLOGICAL UNIVERSITY

2015

This thesis has been approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE in Industrial Archaeology

Department of Social Sciences

Thesis Advisor: *Dr. Timothy J. Scarlett*

Committee Member: *Dr. Mark D. Rouleau*

Committee Member: *Dr. John D. Richards*

Department Chair: *Dr. Patrick E. Martin*

Table of Contents

List of Figures

List of Tables

Acknowledgements

I would like to extend my deepest appreciation to all those who have helped and supported me during my time at Michigan Technological University. First and foremost, my thanks goes out to my advisor, Dr. Tim Scarlett, who set me on this path and encouraged me throughout. I would also like to thank Dr. John Richards who was kind enough to lend me not only the instruments to carry out this research, but also his time and knowledge. Thanks also to Dr. Mark Rouleau for his advice and guidance and getting me to think differently about the data.

I also thank the Chipstone Foundation, especially Jon Prown who has helped me countless times and whose support has never wavered. Furthermore, this research was conducted with the aid of the Robert and Mary Buttle Scholarship awarded by the American Ceramic Society and I could not be more appreciative.

It is also necessary to mention my fellow graduate students whose good humor helped me get by and whose input was essential for making sense of a bunch of numbers. These people include: Sean Gohman, Dan Schneider, John Arnold, Mark Dice, Robert Anthony, Carol Griskavich, Dan Trepal, Eric Pomber, Adrian Blake, and Dr. Marc Henshaw.

Most importantly I would thank my family who always have my back and help me keep things in perspective. My respect and love go out to my mother, Jackie and my father, Rick.

Abstract

Advances in portable X-ray fluorescence (pXRF) technology have made it a viable option for the non-destructive exploration of the underlying chemical composition of ceramic artifacts for the purposes of classification. However, because the literature regarding the use of this instrument on historic artifacts is limited, it is necessary to begin with a broad scale exploratory assessment that might act as a jumping off point for future studies on this topic. Toward that end, this research uses a collection of British and Continental European ceramics ranging from 1650-1920, owned and curated by the Chipstone Foundation in Fox Point, WI, to explore the efficacy of using pXRF to sort and source those materials. The chemical patterns in the data are tested against the known provenance of these artifacts which has been pre-determined by ceramic experts and material culture analysts.

Of the 102 samples that have been tested, primary focus is given to items crafted in London and Staffordshire which account for the largest portion of artifacts in the dataset. Principle component analysis is used to better understand the underlying structure of the entire dataset to ultimately reduce the number of chemical variables to those that best distinguish each group. Using those particular chemical variables, a separate dataset of London and Staffordshire mean intensity readings is subjected to factor analysis which resulted in two components being identified. The calculated factor scores are incorporated into a binary logistic regression model to determine if the samples can be correctly sorted into their pre-established provenance categories. A second model that incorporates the year of production is also presented which shows an improved ability to classify those samples. These results are ultimately situated within the historic context of the pottery making industry in England which was highly influenced by the Industrial Revolution and developments in ceramic technology.

Chapter 1: Introduction to Archaeological Classification and Portable X-Ray Fluorescence

The characterization and classification of artifacts is a cornerstone of archaeological analysis that entails the detailed examination and description of an object or assemblage. Classification draws on an array of external and internal details of the artifacts. The confluence of that information leads the researcher to conclusions regarding the archaeological record and the groups of people that took part in its creation (Prown 1982). That ancillary or external information is often lacking for historical artifacts, however, or non-existent in prehistoric contexts. Throughout the history of the discipline, this has lead archaeologists to develop means of extracting relevant and valuable information purely from the artifacts themselves. Scholars developed typologies and classification schemes as systems of thought. In other words, these systems became tools for formulating questions by comparing and contrasting the characteristics of artifacts. Subsequent research then answers those questions.

Culture historians, in the early years of archaeology, developed pragmatic and regional systems for making artifact comparisons. Chronologies of cultural and technological developments and diffusion developed as a result. Early examples include Gladwin and Gladwin’s (1930) regional chronological classification of southwestern pottery or the Midwestern Taxonomic System used to find confluences of traits that characterized the past cultures in North America (McKern 1939). Later, processual archaeologists endeavored to discover the exact role of artifacts in cultural systems and in the surrounding environment. Archaeologists began to favor models of cross-cultural human behavior based on the archaeological and ethnoarchaeological record over the recreation of "unique events in all their idiosyncratic detail" (Trigger 2006, 401).

An interest in human agency in the conceptualization and production of things, however, led archaeologists to a post-processual school of thought. An artifact in an historic or prehistoric context was seen as "an active element" within the society where it was produced (Trigger 2006, 453). Post-processual archaeologists emphasize artifacts as symbols and identify traits reflective of an individual's role in society. The classification of artifacts therefore became a tool to gain insight into race, class, and gender in a given society or to reveal the minds of the makers. The artifacts themselves are not of central importance necessarily, but rather the primary focus is on the individual who is crafting them.

These elements, along with particular tenets of preceding paradigms, are being incorporated into the contemporary archaeological toolkit. The classification of artifacts in modern archaeology has taken on a more pragmatically minded processual-plus flavor. This approach views material culture from multiple theoretical perspectives to achieve a holistic understanding of past cultures and human behavior. This framework also incorporates a multitude of methods that are most productive for answering a given research question.

Any artifact research, no matter the theoretical framework for classifying artifacts, must ultimately confront the practical realities of archaeology. Archaeologists draw their conclusions from things. This necessitates developing tools for examining and organizing those material remains. For much of the history of the discipline there has been a reliance on diagnostic characteristics of artifacts that can be seen with the naked eye or through an optical microscope. Material science techniques in archaeology have gained a great deal of traction over the last few decades and are useful lines of research. Systems of classification based on the chemical fingerprint of artifacts can serve to reinforce existing systems or uncover variation that would otherwise go unnoticed.

The Benefits of Material Science and Portable X-Ray Fluorescence

Techniques in material science allow archaeologists and material culture analysts to understand artifacts at a mineralogical and elemental level. This is most useful in the absence of macroscopic diagnostic features which would typically be used for identifying and classifying artifacts. Several of these techniques, including pXRF, involve concentrating x-rays into a fine beam which interacts with the material under analysis. Given enough energy, an electron is dislodged from an M, L, or K electron orbital. To maintain neutrality, a higher shell electron drops into the gap. The binding energy of electrons increases the further they are from the nucleus. The difference in energy as a higher shell electron drops into a lower shell, determined by the distances between the M, L, and K shells, leads to the emission of radiation in the form of photons which are detected by the instrument (Figure 1.1) (Piorek 1997; Rice 1987). As the atomic structure of each element is different, the energy emitted will be characteristic of that element and result in M, L, and K spectral peaks. The instrument and software also calculates counts, or net intensities of an elemental which act as a measure of the amount of that element in the artifact. This information factors into a patterned "fingerprint" that can be linked with artifacts or raw material of similar composition.

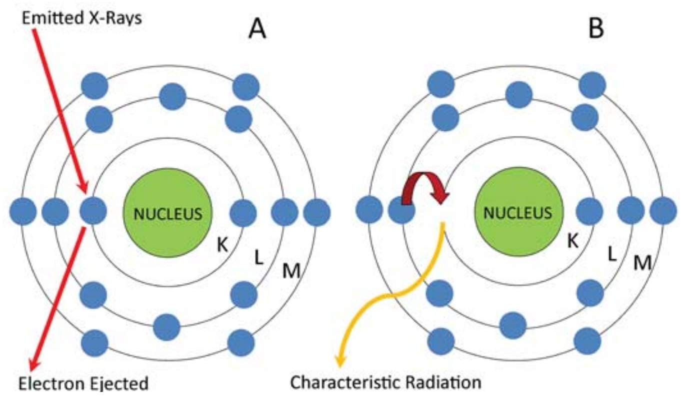

Figure 1.1 Basic diagram of X-ray fluorescence. A) Emitted X-rays eject an inner shell electron. B) A higher shell electron fills the gap to maintain electrical neutrality which causes the emission of characteristic radiation.

This approach to artifact analysis operates under the assumption that objects or groups of objects made by people can be distinguished based on their elemental fingerprint. This distinction is based on alternative approaches to the production of items even though the same basic end may be achieved. In other words, one potter may produce a similarly shaped vessel or another, however each may be utilizing different raw materials for both fabric and glaze as well as using varying amounts of those raw materials in their recipes. This divergence in approaches to production is shown to manifest itself in differing chemical signatures allowing archaeologists to sort and "source" objects to particular individuals, pottery shops, or ceramic producing regions (Forster and Grave 2013; Hou et al. 2004**)**. The development of these types of technologies for analyzing materials marks a sizeable expansion of the archaeologist's toolkit for understanding the archaeological record.

An array of features characterize field portable X-ray fluorescence (pXRF), shown in Figure 1.2, that are highly attractive to material culture analysts and archaeologists. As the name suggests, the device can be transported to a location such as

Figure 1.2 Basic instrument setup with complete software package, vacuum pump, and instrument stand.

a museum or into the field to perform *in situ*, non-destructive artifact characterization. In cases of delicate, highly valuable, or non-transportable items this is of great benefit as they do not have to be handled or moved apart from positioning the object for analysis or transitioning from one reading location to another. The pXRF instrument is also capable of performing an analysis non-destructively by reading the surface characteristics of objects, however, homogenized or powdered samples can be used as well to randomize the distribution of constituents. Furthermore, this technology has evolved in recent years to achieve greater accuracy and detect a wider array of constituent elements relative to its earlier incarnations while still maintaining its portability (Potts 2008). Given these features coupled with its lower operating costs and short reading times relative to most bench instruments it is worthwhile to assess its ability to chemically classify artifacts. Through the use of a curated collection of intact British and Continental European ceramics, attributed to manufacture dates from approximately 1650 to 1915, this study tests the efficacy of the pXRF instrument for archaeological analysis. This is meant to be a proof-of-concept study that will demonstrate the use of pXRF and factor analysis to sort ceramic artifacts by provenance using the chemical signature of the surrounding tin-opacified lead-oxide glaze of each artifact.

A Brief Overview of Glaze Constituents

Many British ceramics from the seventeenth to the nineteenth century feature earthenware fabrics fired at a lower temperature with a relatively high degree of porosity. The permeable fabric necessitates the application of a non-permeable glaze in order to hold liquid and for aesthetic effect. There are several types of ceramic glazes, but the artifacts at the heart of this study were coated with a lead based tin-opacified glaze. Lead oxide acts as a flux to lower the melting point of the clay to encourage the formation of a smooth glassy surface. Aluminum and silicon are also fundamental constituents which help to stabilize the surface. That is to say keep the glassy surface from running or cracking and help the glaze adhere to the fabric surface (Rice 1987).

Potters from the Netherlands introduced tin-glazing to England in the middle of the sixteenth century (Black 2001). It is a variation on the primarily lead based glazes which have a long history in pottery production. This became a popular glazing strategy as the tin, when fired, interacts with the other glaze constituents to form tiny air bubbles in the glaze which scatter light and thus create a glossy, white surface that imitated fine imported porcelain finishes. The basic combination of lead, aluminum, and silicon along with tin was applied to the vessels and fired in a glost kiln. Colorants would subsequently be dusted or painted depending on the desired outcome. Common colorants include cobalt, iron, copper, nickel, or manganese. Table 1.1 lists common stabilizers, fluxes, opacifiers, and colorants. The use of colorants as well as the underlying, fundamental lead or tin-glazed coating was subject to experimentation over the years in Britain and

Continental Europe to achieve an aesthetically pleasing and white product. An extensive number of these artifacts can be found among the collections at the Chipstone Foundation.

Table 1.1 List of common stabilizers, fluxes, opacifiers, and colorants.

Stabilizers	**Fluxes**	**Opacifiers**	**Colorants**
Silicon	Lead	Tin	Copper
Aluminium	Calcium	Titanium	Cobalt
	Potassium		Manganese
	Sodium		Iron
	Magnesium		Nickel
	Zinc		

The Benefits and Limitations of the Chipstone Ceramic Collection

In the middle of the twentieth century, Stanley and Polly Stone started collecting seventeenth and eighteenth century British and European ceramics. In the 1980s the Chipstone Foundation was formed to manage this collection and educate people about the importance of these items. Approximately 505 ceramic objects are curated by the Chipstone Foundation. The artifacts chosen for this analysis have known provenance information assessed by experts in the field of historic British and Continental European ceramics (Hume 2001, Martin 1999). This information is catalogued in an online database managed by the University of Wisconsin-Madison, a permanent record of which resides at the Chipstone headquarters. The valuable nature of artifacts held in this collection make pXRF ideal for extracting elemental data without damaging any of the items. The volume of objects curated by the foundation allows for the examination of a substantial number of samples in a single location without significantly disturbing artifacts or transporting them great distances. The Archaeological Research Laboratory at the University of Wisconsin-Milwaukee very kindly agreed to lend the instrument for the purposes of carrying out this study.

This study is meant to demonstrate the viability of using the pXRF instrument, i.e. act as a proof-of-concept study, to sort ceramic artifacts based on their respective chemical signatures. This study comes with certain limitations however. Because the initial collector, Stanley Stone, was interested in a certain subset of ceramic artifacts, it is open to question whether they are truly representative of the population of tin-opacified and lead glazed wares made in these ceramic producing regions. Additional concerns include differential preservation of ceramic vessel types. Furthermore, this study itself focused on a particular subset of the collection. Nevertheless, the research strategy employed here was deemed acceptable as a useful starting point to gain some insight into the effectiveness of the instrument to characterize these artifacts.

Document Structure

The five subsequent chapters of this thesis build on one another and culminate in a synthesized assessment that situates this work among the archaeological systematics and ceramic classification literature. Chapter 2 entails a retrospective review of systematics and classification over the course of the archaeological discipline. This is meant to provide some context on those topics as well as emphasize the absolute importance of artifact, and more specifically, ceramic classification in the archaeological realm. This is also meant to highlight the need for a constant re-examination of the toolkit available to the archaeological researcher for organizing and describing material culture as it is the foundation for all subsequent research into the archaeological record. This chapter will also feature a discussion of the use of material science techniques, with a focus on portable X-ray fluorescence, in contemporary archaeology. However, theoretical concepts regarding pragmatism in classification and having an understanding of the mind of the maker are essential in sorting artifacts effectively regardless of the technique for so doing.

Having established the usefulness of pXRF for material culture analysis, Chapter 3 introduces the methodological elements of the study of the Chipstone collection. This includes a review of the instrument specifications, the samples and the sample size, the process of data collection, and the data analysis procedure and protocols set down by the University of Wisconsin-Milwaukee Archaeological Research Lab. Chapter 4 will detail the results of that data analysis including the trends shown in the principle component analysis, the subsequent ANOVA and post-hoc tests linking the clusters of data to their provenance designations., and the focused factor analysis and regression models for the Staffordshire and London artifacts. With these results in hand, Chapter 5 explores the implications of the findings and situates them within the literature on glaze raw materials and chemical analysis. Finally in Chapter 6, a reflexive examination of the gleaned results leads to new questions manifested as a results of the experiments and features closing remarks on the benefits of arcaeometric analysis.

Chapter 2: The Disciplinary Evolution of Systematics and Classification

Approaches to artifact classification have taken on many iterations over the years as new paradigms and frameworks are introduced into the archaeological discipline. In all these instances the classification of artifacts was meant to better understand the movements, behaviors, and habits of people and the changing nature of the culture or cultures engaged in the production of particular items by viewing the often subtle variations in form or decoration of artifacts. Classification helps to make sense out of the vast amounts of materials in the world. Once sorted, archaeologists can start to ask questions about the past. Despite this common goal, the means by which these phenomena are understood has been open to much debate, largely between processually minded archaeologists with defined types which become the primary units of analysis (Dunnell 1971; 1986), cognitive scholars who see the mind of the maker among variations in artifacts (Renfrew 2005) and post-processual thinkers who view the changing meanings of artifacts over time and utilize more relativistic vernacular labels or folk taxonomic systems to better understand the emic values imbued in objects (Shanks 1998).

In recent years, these debates have subsided to a certain extent, having been reconciled in the minds of many scholars who see value in pragmatically driven research designs to classify and interpret artifacts in the archaeological record (Read 2009). Not only are interpretive frameworks being developed to unpack the meanings surrounding particular formal or stylistic choices, but there appears be a resurgence in the application of natural science techniques to the study of artifacts influenced in large part by advancements in technology. Material science and archaeometric techniques have been introduced into the realm of systematics and artifact classification that bring into the fold an alternate means of differentiating cultural items through the use of chemical data (Kingery 1996; Orton and Hughes 2013). This does not eliminate the need for macroscopic diagnostic information of, in the case of the research presented here, whole or partial ceramic artifacts. The chemical classifications are meant to supplement those other systems or provide contrast to them.

Archaeologists organize artifacts in an iterative process. New technology or alternate thinking forces necessary reconceptualization of relationships among objects. New groupings of objects, or awareness of new traits, alters archaeologist's understanding of the people that made or used them. It is worthwhile to chart the trajectory of intellectual thought related to this topic to assess the established toolkit available to the contemporary archaeologist. This continual reconceptualization of artifact classification gave rise to this pragmatic paradigm that utilizes macroscopic as well as elemental information. It is useful to keep this context in mind when determining where the research presented here might fit within the larger realm of systematics and classification.

This discussion is organized by paradigmatic shifts in the archaeological discipline which influenced not only the organization of objects, but also the types of questions archaeologist's asked of the archaeological record. This discussion necessarily begins within the realm of culture-historical archaeology, a period which laid the foundation for typological debates subsequently brought about by the processual and post-processual turn in archaeology. The many complexities archaeologist's uncovered as a result of those debates went a long way toward influencing the current state of archaeology. In a sense, the discipline has returned to the central tenet of the anthropological field as a holistic pursuit which brings to bear systematic, interpretive, and material science approaches to the study of past human behavior.

Culture-Historical Archaeology and the Development of Classificatory Systems

The central goal of the culture-historical paradigm has been to "trace historical relations through time and space. Such historical findings are the necessary prerequisites for evolutionary generalizations about the process of change" (Trigger 2006, 313). Concepts like acculturation, assimilation based on the degree of contact, and the organization of cultures across space and over time were developed based on the similarities and differences of styles and forms. However, the application of these ideas was largely focused on prehistoric and contact period contexts with less regard for historic sites. For example, Quimby and Spoehr (1951) looked at the regular changes in form of native-made objects over time among museum collections during the contact period in North America to see the steady assimilation of Western ideas into the material culture of Native groups. The tenets of culture-historical archaeology are reflected also in *Culture and Acculturation of the Delware Indians* by William Newcomb (1956) which narrowed the scope to changes among a particular group of Native Americans. These authors traced steady cultural changes based on the materials being produced. In other words, it was thought that one culture would transition into another form based on the degree of contact, though with a certain disregard for the complexities of these changes. For example, an article by Jörgen Meldgaard (1960) featured a straightforward and simple model that showed a temporally broad and steady progression, based on tool materials and house forms, from Late Archaic groups in the Eastern Arctic to Early Woodland who then became the Dorset people. Over time, however, scholars began to recognize the complexities inherent in the archaeological record and this led to both cladistic and reticulation models to trace evolving artifact features and therefore demonstrate cultural transitions over time (O'Brien et al. 2012; Tëmkin and Eldredge 2007). At its core, the cladistic model argues that a single population over time begins to branch out to produce multiple new populations, languages, cultural values, etc. This allows archaeologists to trace representative artifacts in the archaeological record back to a common ancestral culture (Tehrani and Collard 2002). On the other hand the reticulation model puts forth the idea that multiple groups or populations are responsible for the rise of multiple modern populations, languages and cultural values and can be seen as a more convoluted "braided stream" (Moore 1994; O'Brien et al. 2002). These later years of culture-historical archaeology set the stage for a more systematic approach to the study of artifacts; one that would more accurately depict the observed changes in the archaeological record taking place over time.

As a result of these disciplinary developments, archaeologists created classification systems for an array of artifact classes including ceramics. One early example is Gladwin and Gladwin's (1930; 1931; 1933) classificatory system of pottery of the southwest that was "based on relative degrees of trait similarities, its dendritic pattern involved geographical considerations and it was implicitly chronological; roots formed before stems and stems before branches" (Trigger 2006, 284). Will C. McKern (1939) created an alternate system called the Midwestern Taxonomic Method. This system divided units of occupation into components then foci which, in turn, were further subdivided. At the time of their inception, these systems separated cultures into a rough chronological framework or situated them in approximate geographic space. Ford's (1962) seriation method required careful observations of stratigraphy and detailed artifact descriptions, and this led scholars to a continual re-examination of classification systems.

Issues surrounding classification erupted with the Ford-Spaulding debate. Albert Spaulding (1953) argued that types were discovered and thus real to makers. Classification should, therefore, fit the cultural context. James Ford (1954), on the other hand, saw types as being constructed by the archaeologist as a practical solution to the sometimes chaotic nature of culture change. Charles Ewen (2003, 70) noted that Ford and Spaulding's approaches "were designed to answer different questions…One could argue that Ford was promoting paleoethnology…while Spaulding championed paleoethnography." Because of these discussions culture-historical archaeologists were able to give a firm description and history to particular groups or past cultures.

A number of classificatory systems in historical archaeology were also devised, applied, and refined. These include the type-variety system (Dunnell 1971; Gifford 1960; Sabloff and Smith 1969), the SHA typological systems that establish date of manufacture based on technology history (Lindsey 2015), and more focused systems addressing a particular region such as the Potomac Typological System (Beaudry et al. 1983). Furthermore, industrial archaeology still maintains a firm foothold in the regional nuts-and-bolts approach to classification. Becher and Becher (2004) developed a typology of industrial structures based on formal changes over time. Bayley and Rehren (2007) offer a classification of crucibles based largely on differences in function.

In the realm of ceramics, the type-variety system was developed and is a popular way of describing an assemblage of pottery. It is designed to deconstruct ceramic artifacts into ware, type, variety, and group and analyze the interrelationship between these variables to establish ceramic complexes and chronologies (Sabloff and Smith 1969). The type-variety system has been criticized for being too rigid in its definition of types which often times have a great deal of overlap. Hammond (1972, 452) noted that,

> This loss of effectiveness may perhaps be partly resolved by treating the Ceramic Group as a polythetic set of attributes…within which the possession of any one attribute is neither sufficient nor necessary for membership. Thus neither a common vessel form, nor the color, nor even the presence of slip, nor the absence, presence, or variety of ornament matter provided that the specimen possesses a certain number of the defined attributes which encapsulate the group.

This debate speaks to the core concern of archaeologists at this time which centered on making sense of the material world. Classification in the culture-historical realm is focused largely on description and identifying certain patterns. New intellectual developments in anthropology and archaeology would challenge the straightforward narratives presented by the culture-historian, approaches that acknowledged a number of other cultural and ecological factors that influenced the nature of the archaeological record as well as the form and function of artifacts.

A Systematic Approach to Artifact Classification

Moving forward to the middle decades of the 20th century, culture-historical archaeology dominated the study of material culture and the archaeological record. However an alternate approach was taking shape in the form of the processualist paradigm (Binford 1989). Scientific practice was incorporated into archaeological research and patterns in the archaeological record were being studied using computers and multivariate statistics. This technological and methodological change mirrors the current evolution in contemporary archaeological practice influenced by material science studies.

This paradigm is discussed in several articles by Binford (see Binford 1983; Binford and Quincy 1972), but his 1962 article "Archaeology as Anthropology" is notable for a number of reasons, one of which is his deconstruction of material culture into the technomic, socio-technic, and ideotechnic. According to Binford (1962, 217) "change in the total cultural system must be viewed in an adaptive context both social and environmental, not whimsically viewed as the result of 'influences,' 'stimuli,' or even 'migrations' between and among geographically defined units." The cultural system is revealed through the study of the three classes of material culture stated above. This new framework resulted in a more systematic and process oriented approach to culture change and the study of the archaeological record. This developing framework was explored, again, by Binford (1965) who advocated for the use of particular artifacts, ceramics among them, to reveal the workings of given subsystems of a culture and basing classification on formal, decorative and primary and secondary functional elements.

Robert Dunnell's (1971; 1986) work exemplified these intellectual trends and outlined a strategy for utilizing artifact types as the basic unit of analysis. This approach also used etic classifications that would be universal to the assemblage of items made by individuals in a given culture. In the words of Dunnell (1971):

> If several objects hold features in common, and those features are of human origin, there is but a single plausible account. Intentionally or unintentionally, consciously or unconsciously, the objects were made to look alike by people who can be treated as possessing similar ideas about them and who have the same categories of features and ways of

> articulating the features into whole artifacts. In short, the objects can be treated as expressions of the same mental template (132).

In this sense, the individual is exchanged for culturally guided groups and focus is placed on common classes of traits rather than particular details of a given artifact (Read 2009). The concept of commonalities between material objects is central to the approach of this research. The sorting of artifacts chemically operates under the assumption that particular groups of potters utilized like glaze recipes that are independent of those developed in another pottery producing region. However, questions regarding the exact nature and cause of those shared features are addressed in greater detail by cognitive and post-processual scholars who seek to understand the mind of the maker and the evolution of the sequence of operations to achieve a desired outcome in the creation of objects.

Cognitive and Post-Processual Approaches to Artifact Types

Cognitive approaches to the archaeological record were influenced by developments in the broader discipline of cognitive anthropology and related fields. The paradigm endeavored to utilize material culture to better understand the mental processes at work as people crafted objects which would subsequently make their way into the archaeological record (Abramiuk 2012; Renfrew 1993, 1998). Cognitive archaeology borrows many of the theoretical underpinnings of cognitive anthropology and psychology. A goal of cognitive archaeology is to craft networks of typologies often based on the vernacular terminology of makers and craftspeople to see how ideas regarding the production of objects might develop and be transferred. In other words, the idea is to "develop a secure methodology by which we [cognitive archaeologists] can hope to learn how the minds of the ancient communities in question worked and the manner in which that working shaped their actions" (Renfrew 2005,41).

Often cognitive interpretations take on a dialectical flavor with back and forth interaction between the mental conceptualization of the maker and real world practice. The strengths and limitations of the material strongly influences the form as the final outcome is re-conceptualized as skill and technology develops (Bleed 2001; Keller and Keller 1996; Schlanger 1996). In this sense, individual action plays a role in the construction of forms and styles, all of which are factored into the organization of the artifacts. James Deetz (1977) saw these slight style differences as variations on a theme, however, and returned to the concept of shared ideas of material culture. Deetz considered artifacts as "reflections of the mental templates of the makers" though this normative framework has been criticized as too formulaic (Neuwirth et al. 2002, 113). Certain concepts, though, overlap with the central dictates of the post-processual paradigm in archaeology which, at its core, attempts to account for human agency and individuals as major influencing factor in the variation found in the archaeological record (Johnson 2010, 108).

As noted above, throughout the 1960s and 70s the archaeological discipline was rich with processual concepts including Binford's (1965; Binford 1968) middle range theory and framing culture as consisting of multiple interacting systems all of which factor into the interpretation of the archaeological record. In the 1980s and 1990s, however, a paradigm shift took place (Kuhn 1962) primarily led by archaeologists influenced by the postmodern turn in the social sciences (Hodder 1982; 1985), who raised a number of questions regarding processual thought in archaeology. The idea of cultures as systems was considered particularly problematic, or as Matthew Johnson (2010, 102) stated, "in particular, they pointed to the need to address cognitive factors, the difficulties of positivist epistemology, and the problems with developing middle-range theory…" Ian Hodder, for example, was a processualist, and believed that processes in modern cultures could be associated with the processes of the past as reflected in the archaeological record (Hodder and Orton 1976; Johnson 2010, 102). Over the course of his research in Africa, however, he came to several conclusions that led him to believe that processual concepts were no longer adequate in explaining patterns in the archaeological record and past human behavior (Johnson 2010, 103). Hodder (1991) explained that:

> From a hermeneutic point of view, the failure of the processual archaeology of the 1970s and early 1980s was that it too often took a cavalier, externally based approach where the data were simply examples for the testing of universal schemes, with too little attention paid to context and to understanding the data in their own terms. The possibility that radically different processes might be encountered was thus difficult to entertain. From the point of view of critique, the failure of processual archaeology was its blindness to its own ideologies (12).

Post-processualism began to focus, to a much greater extent, on the context of material culture and considers the social factors embedded within a past culture.

Processual thinkers argued that the archaeological record is a reflection of systems operating within a society, and can give insight into the interaction between these systems that were part of a particular culture. Lewis Binford (1983, 25) stated, "the archaeological record is a static contemporary phenomenon. It is structured matter motionless and noninteractive in terms of the properties of historical interest to the archaeologists" (Binford 1983, 25). Material remains offer a snapshot of the systems functioning with one another and any changes that may be perceived are extrasomatic in nature (Binford 1962). In contrast, one of the emphases of post-processualism is that cognitive processes as well as a number of other non-behavioral factors influence material culture, and objects are imbued with certain meanings and, over time, these meanings change. Where processualism narrows the focus to certain extrasomatic means of adaptation, a number of distinct frameworks within the post-processualist paradigm attempt to understand the beliefs and symbols that may give insight into the social structure or interaction between groups and individuals. Ultimately, the physical objects found in the archaeological record embody the beliefs and values of people. This adds a level of complexity to the organization of objects which may fill a particular cultural or societal role among one group of individuals, but not another.

The debates in historical archaeology have largely centered on topics well within the post-processual realm that typically involve research into race, class, gender, symbolic interpretation, and power relations (Shackel and Little 1992). However, in recent years there appears to be a reemergence of interest in the creation of typological systems facilitated in large part by a desire for flexibility in design and the utilization of alternate methods and technology which offer an alternate perspective on the organization of artifacts (See Fluzin et al. 2012; Smith et al. 2014).

On the topic of classifying artifacts, Michael Shanks and Ian Hodder (2007) explain that,

> Classification operates under a 'rule of the same.' Taxa are characterized by relative *homogeneity*. This is a legitimate strategy for coping with the immense empirical variety and particularity that archaeologists have to deal with. However, we should be clear that classification does not give the *general* picture; it gives the *average*. It is not a general picture because there is no provision in classification for assessing the norm, the taxa…, not the variation within a class, nor the variability of variability.

> Classification is less interested in coping with particularity…Why are the members of a class of pots all in fact slightly different? (150).

This assertion is worthwhile to keep in mind when approaching the topic of classifying artifacts and does indeed factor into the broad epistemological framework of the research presented here. Particularities, to a degree, are not the end goal for the study of chemical data in the case of this exploratory examination of historic ceramic glazes. Rather the trends that manifest themselves are of central importance as they will inevitably lead to more focused questioning and a readjustment of the current lens of inquiry. Determining the reason for commonalities and divergence in glaze chemistry requires further research into the societal, economic, technological, and cognitive factors at play during the time these historic ceramic materials were being produced.

Potentials of Material Science and Archaeometry

Because particular constituent materials were chosen for a given end, material science techniques investigate the structure of assemblages. Formal, stylistic, spatial, chemical as well as other forms of evidence can be used to understand the association, context, and meaning of objects. Various techniques have been developed to analyze the constituent elements of an artifact to source those materials or understand the microstructure and begin to understand the processes involved in its creation (Henderson 2000; Rice 1987). A researcher can also undertake a detailed phase analysis to understand the properties and interactions of the material and thereby enter the mind of the maker who was forming educated decisions based on their ever-developing principled knowledge. However, in the words of Kingery (1996, 196), "there is always tacit knowledge embodied in artifacts, and it is not easy to interpret the function and use of a complex construction without culture-specific knowledge or specific instruction." This means that the approach to the study of material culture always entails a confluence of evidence drawn from both the artifact itself in the form of chemical data as well as anthropological and historical information.

Nevertheless, there is an ever growing body of archaeological projects and scholarly literature using material science technology and techniques to characterize or "fingerprint" artifacts from the archaeological record including ceramic artifacts and assemblages (Maggetti 2012; Maggetti et al. 2014; Papadopoulou et al. 2007). Though the literature on historic fabric and glaze analysis is not as extensive as that involving prehistoric artifacts, several studies using French faience, i.e. French tin-glazed earthenware, have been undertaken. Work by Marino Maggetti, for example, contains a great deal of contextual and chemical information regarding French samples collected from several pottery shops. Maggetti analyzed these faience sherds to develop chemical reference groups which researchers can use to determine the provenance of archaeological samples by comparing the chemical signature of the artifact in question to the reference group (Maggetti 2012; Maggetti et al. 2014). In an effort to distinguish between pottery workshops, Maggetti, Rosen and Serneels (2014 utilized both X-ray fluorescence and X-ray diffractometric techniques to the study of French faience samples of sherds. While these techniques have certain advantages in terms of their abilities to provide high quality chemical and mineralogical information, both are destructive techniques that require that lab staff mill the samples to a fine powder.

Other archaeometrists have established non-destructive alternatives that do not require damage to artifacts and offer other useful features. Recent literature addressed issues of reliability as it relates to portable instruments like pXRF analyzers. These articles emphasize the need for quality standards to check the instrument is operating consistently, performing multiple runs at appropriate reading locations on the artifact, and taking precautions to reduce attenuation, i.e., loss of x-ray intensity by absorption, during analysis (Craig et al. 2007; Shackley 2010; Speakman et al. 2011; Speakman 2012). This research was mindful of these necessary standards, and analytical practice followed the protocols established by the University of Wisconsin-Milwaukee Archaeological Research Lab.

Archaeologists are now utilizing field portable X-ray fluorescence instruments heavily in prehistoric contexts and in analysis driven by research designs from Art History. Hand-held pXRF analyzers provide data to sort and source materials beyond their macroscopic diagnostic characteristics at a level of accuracy that is adequate for the purposes of the archaeologist who is interested in the averaged patterns, as Shanks and Hodder (2007) would state, that are present in the data (Liritzis and Zacharias 2011; Shugar and Mass 2012). Researchers have used pXRF devices on a wide range of ceramic artifacts including Neolithic Grecian pottery (Papadopoulou et al. 2007), glazed stonewares from north-east Asia (Mitchell et al. 2012), cuneiform tablets from the Near East (Goren et al. 2011), and pre-colonial pottery from Sao Luis, Brazil (Ikeoka et al. 2011). Each of these studies has achieved some level of success for "sourcing" artifacts, at least at the regional level, usually in conjunction with neutron activation or mass spectroscopic techniques used for comparative purposes. Nicola Forster and Peter Graves (2013) undertook a pilot study of lead glazed Byzantine vessels from Cyprus and noted that some of the compositional groups matched well with particular pottery manufacturers, though this was not the case for all groups. Nevertheless, these results encouraged the authors to pursue a larger characterization study of Cypriot ceramics (2013, 485). These studies have shown field portable XRF has a great deal of potential for non-destructive, in-situ analysis of ceramic materials, though the literature is sparse with regards to the application of this technique to the study of historic artifacts in general and ceramics in particular. The research presented here is intended to add to the literature on classification and pXRF with a focus on historic rather than prehistoric materials.

Chapter 3: Methods for Assigning Provenance Using Glaze Constituents

This proof-of-concept study uses portable X-Ray fluorescence (pXRF) to source historic ceramic materials through the use of a body of data with known production location information. This case study focuses on lead-glazed and tin-opacified wares housed in the Chipstone Foundation collection of British and European ceramics. As stated earlier, the premise is to gain elemental net intensity data both non-destructively and *in situ*. In other words, the entirety of the pXRF instrument readings are performed at the facility where all the samples are currently curated with little sample preparation. This is meant to demonstrate to the archaeological community that useful, reliable, and meaningful information can be obtained quickly, cost effectively, and without affecting the integrity of these valuable cultural resources.

Speakman and Shackley (2013) have recently commented on pXRF studies that they characterize as examples of "silo science" due to the use of uncalibrated data. Speakman and Shackley argue that the result is not good science as these studies lack reproducibility and inter-laboratory comparability. Because my study relies upon uncalibrated net intensity values, it might be argued that the result is an example of this genre. Certainly, my results would be more broadly comparable if my data represented calibrated values for analyzed elements. However, the instrument available to me lacked that capability, as the appropriate calibrations had not been loaded at the time I collected and analyzed the data. Consequently, this work must be seen as a preliminary "proof of concept" study valid only at the level of the Chipstone collection. However, if one assumes: 1) that the analyzed sample is representative of Staffordshire and London wares in general and; 2) that the net intensity values are a reasonable proxy for the elemental concentrations in the samples, results suggest a statistically valid separation between London and Staffordshire wares based on the variation in tin content. While this result cannot be generalized to other collections (i.e, recorded net intensity values cannot be used to suggest the real range of difference because a different instrument will likely return different net intensity values), other researchers can attempt to replicate my basic finding that tin concentrations vary significantly. This variation is further supported by observed shifts in production, distribution, and social vogues during the time the pottery in the Chipstone sample was produced and used. Thus, the results presented here should have analytical utility beyond the Chipstone collection and the present study.

Toward that end, I analyzed the readings using R Statistical Software to establish the chemical fingerprint of the samples and used factor analysis to link those signatures to the known provenance designations. Clusters, on the one hand, need to be identified among the intensity readings which act as an indirect measure of the variation in glaze production strategies utilized by the various production centers. I can then compare the extracted factors and samples designated as coming from the Staffordshire region and London region, two major pottery manufacturing areas with the former located in the north of England and the latter in the South (shown in Figure 3.1). The geographical separation, the development of independent pottery manufacturing techniques, and the tin glazed industry's waning in London should produce distinguishable chemical signatures. In SPSS, I used factor analysis to study a reduced dataset of only London and

Figure 3.1 Map showing major pottery manufacturing sites in the 17th and 18th centuries.

Staffordshire materials with averaged net intensities of stabilizers and fluxes to determine differences in glaze production strategies. Two binary logistic regression models, utilizing the factor scores, determined the probability of samples being correctly assigned to either Staffordshire or London. Other researchers can test this model in future studies using similar lead and tin-glazed ceramic artifacts held by Chipstone and other facilities.

An Initial Exploration of the Chipstone Data

Prior to determining the relationship between the Staffordshire and London materials this research aims to utilize the entire dataset of analyzed samples from Britain and Continental Europe. Analysis of the complete dataset seemed a natural starting point for getting a sense of the data and the interaction between chemical variables before refining the approach. Though the number of Continental European artifacts is small and cannot be included in the factor analysis and regression models, their inclusion in the principle component analysis and analysis of variance is useful. Principle component scores coupled with ANOVA and Tukey post-hoc tests for determining potential differences between groups provided some sense of the divergence in compositions between the artifacts. I posit that English ceramics, broadly speaking, are not the same compositionally as Continental European ceramic artifacts in the Chipstone dataset. The major influencing variables that help to capture the greatest trends in the data were retained while removing redundant or unnecessary variables to further distinguish the English and Continental European artifacts from one another.

With this broad geographical understanding that English ceramics are unique from those in Europe, the question then turns to whether the two major sets of artifacts from Staffordshire and London have unique compositional characteristics determined through factor analysis and logistic regression. This allowed for an appraisal of the level of geographical focus that can be achieved with the instrument starting with a broad assessment of all the data and moving toward a narrower regional assessment.

A reduced dataset with all representative samples, but using only data of elements uses as glaze stabilizers and fluxes, was examined using PCA and ANOVA. I was able to determine the appropriateness of using those fundamental glaze constituents for the final regression model that focuses on distinguishing London and Staffordshire made materials. The reason for retaining the stabilizers and flux components in the second principle component analysis and subsequent factor analysis of the London and Staffordshire materials is based on the assumption that the glaze manufacturing process became more standardized over time. The fundamental constituents of the lead based glazes were retained, but variability in decorative colorants will be present even in a single pottery shop (Hale 2008; Owen and Sutherland 1901). I offer further discussion of this topic in the subsequent chapters.

A Note Regarding the Relationship between Glaze Chemistry Readings

Glaze is a vitreous, non-permeable coating in which elements are not represented randomly. Particular elements will correlate because of the nature of glaze production. Silicon and aluminum, for example, are fundamental constituents of the glaze composition which act as stabilizers to keep the glaze from running or from cracking. Lead and tin also likely correlate as an increase in the percent of lead will require a decrease in tin or vice versa depending on the level of opacity or translucence that the potter would like to achieve. Despite these correlations between elements, other forms of analysis are required to make a determination if particular production factors have an effect on the classification of artifacts into one category or another. It is highly useful, nevertheless, to analyze the chemical variables using principle component analysis to understand the exact underlying structure of the chemical data which can be taken into consideration when determining which variables to include in the regression models.

The Instrument and Instrument Specifications

The University of Wisconsin-Milwaukee Archaeological Research Lab (ARL) loaned the pXRF instrument for the purposes of this experiment. ARL's instrument is a Bruker AXS Tracer IIIv +with a Si pin detector, and an X-ray tube featuring a Rh target. As such, the analysis followed the UW-Milwaukee pXRF protocols. I chose not to use a filter in order to gain a wide spectrum of chemical information, and after consultation with UW-Milwaukee ARL staff and consultants at Bruker Corporation, determined that the instrument should be set at 15 KeV and 25 µA. Depending on the amount of lead, a 15 KeV beam under vacuum could penetrate up to 5 mm, so this protocol was meant to minimize depth of penetration. Readings were taken under vacuum and without a beam filter to reduce the amount of atmospheric attenuation and a voltage regulator was put in place to maintain a steady power output allowing the instrument to operate consistently. The voltage regulator stopped functioning midway through the experiment, so power levels were checked regularly to ensure that fluctuations were not occurring.

Three flat or approximately flat areas were chosen on each vessel to accommodate the collimated 3x4mm X-ray beam. Furthermore, plain white areas or low colorant areas were targeted. All vessel locations were scanned for three continuous runs at 180 seconds per run totaling nine minute scans for each location (180s x 3 = 540s). The scan time for a single sample, therefore, was 1,620 seconds or 27 minutes yielding 9 cases of net intensity readings to gain a representative overview of the glaze surface. Before and after each analysis session a kaolinite clay standard (Kaolin KGa-2) was used to be certain that the instrument was running consistently. Precise chemical compositional data for this standard has been published in the *Data Handbook for Clay Materials and Other Non-metallic Minerals* (Van Olphen and Fripiat 1979) and is shown below in Table 3.1.

Table 3.1 Characteristics of the kaolin clay standard used to check consistent instrument performance.

Kaolin Kga-2, (high-defect)	
Origin:	Probably lower tertiary (stratigraphic sequence uncertain)
	County of Warren, State of Georgia, USA
Location:	33o19' N-82o28' W approximately, topographic map Bowdens Pond, Georgia
	N 3315-W 8222.5/7.5, Collected from face of Purvis pit, October 4, 1972.
Chemical Composition(%):	SiO2: 43.9, Al2O3: 38.5, TiO2: 2.08, Fe2O3: 0.98, FeO: 0.15, MnO: n.d.,
	MgO: 0.03, CaO: n.d., Na2O: <0.005, K2O: 0.065, P2O5: 0.045, S: 0.02,
	Loss on heating: -550oC: 12.6; 550-1000oC: 1.17, F:0.02.
Cation Exchange Capacity:	3.3 meq/100g
Surface Area:	N2 area: 23.50 +/- 0.06 m2/g
Thermal Analysis:	DTA: endotherm at 625oC, exotherm at 1005oC, TG: dehydroxylationweight loss
	13.14% (theory 14%) indicating less than 7% impurities.
Infrared Spectroscopy:	Typical spectrum for less crystallized kaolinite, however the mineral
	is not extremely disordered since the band at 3669 cm-1is still present in the spectrum.
Structure:	(Catr Ktr)[Al3.66 Fe(III).07 Mntr Mgtr Ti.16][Si4.00]O10(OH)8, Octahedral charge: .16,
	Tetrahedral charge: 0.00, Interlayer charge: .16, Unbalanced charge: .15, Extra Si: .04

The Chipstone Ceramic Samples

The Chipstone Foundation owns and curates all the objects used in this study. The foundation began in the 1980s with an endowment from the Stone family dedicated to maintaining the large ceramic, furniture, and print collections accumulated by Stanley and Polly Stone or purchased during the years since they created their foundation. The Chipstone Foundation now owns and curates approximately 505 ceramic objects. The ceramic materials are primarily seventeenth, eighteenth, and nineteenth century English lead and tin-opacified wares with comparable earthenware fabrics. Through the eighteenth and nineteenth centuries a transition to cream-colored wares and whiter improved earthenwares occurred, and these types are dominant in the Chipstone collection. Of the many vessels in the collection, I analyzed 102 (N=102) using the Bruker pXRF instrument. Table 3.2 lists the Chipstone vessel types and the number of each analyzed. For more detail regarding individual vessels and vessel images see Appendix A and B.

Table 3.2 Chipstone vessels types and the number analyzed using the pXRF instrument.

Chipstone Vessel Types											
Chargers	Plates	Bottle/Jugs	Cups/Tankards	Pots/Teapots	Jars	Bowls	Figurines	Wall Pockets	Fruit Stands	Handwarmers	Total
21	17	9	14	18	8	4	6	2	2	1	102

The analyzed samples can be subdivided into English and Continental European made artifacts with 32 (n=32) attributed to London based potteries, 41 (n=41) produced in Staffordshire, and 7 (n=7) from Bristol. Experts attributed objects to Kent (n=2), Essex (n=1), Liverpool (n=1), the general Midlands area (n=2), Stoke-on-Trent (n=4), Derbyshire (n=1), England generally (n=2), and Glasgow (n=1). Ceramicists have also identified samples from European pottery shops including the Netherlands (n=4), France (n=2), Italy (n=2), Portugal (n=1), and Czechoslovakia (n=1). One vessel has been traced to Massachusetts (n=1) and one is unknown (n=1).

Net Intensity Readings and Initial R Preparation

Once analyzed, I imported the resulting spectra into the Bruker Artax software to begin the Bayesian deconvolution process which helps to identify the most probable compositional components of the historic glazes and their associated net intensities. The Artax software can only analyze 100 spectra at one time resulting in several project files that were combined in Microsoft Excel. I created a new characterization method using the software by identifying components in a random selection of spectra to craft a preset list of elements. This was an iterative process that entailed selecting a spectrum, identifying the elements, and testing the updated method on a subsequent spectrum to determine if additional elements should be included. The final method was used to analyze all the remaining spectra in each project set. Net intensities were extracted for 18 elements including: Al, Co, Cr, Cu, Fe, Ga, K, Mn, Ni, Pb L, Pb M, Rh, Rh L, Si, Sn, Sn L, Ti, Zn. A majority of identified elements and their associated net intensities come from K shell readings unless otherwise labeled. The instrument detected only the L and M shell spectral peaks for lead as greater power levels are needed to detect K shell lead readings. This analysis uses the lead L shell counts as a measure of lead in the artifacts. Because of the Rh target, this element will always appear in the list of identifiable components and therefore subsequent analyses did not use either the K shell or. A qualitative scan of the data also lead to the removal of certain other elements from the analysis including Cr, K, Pb M, and Sn K because they appeared at negligible levels or presented as 0 or negative values which are essentially noise in the spectrum requiring correction. This left a total of 12 remaining major glaze elements that were used in the initial principle component analysis and tests of significance.

I removed particular artifacts in the dataset due to the ambiguity of their assigned provenance designations and low sample sizes. Those items included the England (general) materials and the samples from Liverpool, Essex, Kent, Derbyshire, the Midlands, Massachusetts, Czechoslovakia, and the unknown sample. The sample from Glasgow was retained due to the suggested relationship between London and Glasgow pottery shops which entailed the occasional movement of potters between those two locations. The dataset now featured 90 samples. Subsequent to this qualitative culling, a letter designation was assigned to the remaining British and Continental European samples (presented in Table 3.2), included in a new field in the R prepared dataset. A unique artifact identifier was assigned to each item that consisted of the artifact

Table 3.3 List of provenance designations and number of samples.

Provenance	R Designation	# of Samples
London	L	32
Staffordshire	S	41
Bristol	B	7
Glasgow	G	1
Italy	I	2
France (Rouen)	FR	1
France (Nevers)	FN	1
Portugal	P	1
Netherlands	N	4

designation, the reading number, and the reading location. After converting the spreadsheet to a .txt file, I uploaded the data into the R Statistical Software.

Removing Anomalous Readings with R

The Mahalanobis distance metric was applied in order to remove extreme or anomalous chemical readings from the dataset. According to Hulit (2012:32) "the Mahalanobis distance is a robust metric designed to measure the distance of each reading from the center of all the readings for the artifact. It differs from Euclidean distance metrics in that it takes into account the nature of chemical data to tend towards elliptical shapes when projected in two dimensions." In this case, I analyzed the three measurements that comprise a single case (i.e. a single reading location) to check for consistency among those measurements. The software removed cases from the dataset that deviated greatly from other measurements leaving readings that represent the net intensities of the glaze components across the surface of the ceramic object. As a result of the Mahalanobis distance metric analysis, the software identified and removed 63 readings in this initial broad analysis. Furthermore, a software function identified any cases that included net intensity values less than or equal to zero and removed those as well. As a result 750 readings remained after applying the distance metric and 721 after removing zero or negative net intensities for all 102 samples. Having culled any outliers from the dataset, the remaining cases were ready to be examined using principle component analysis.

R Statistical Software Analysis

I used principle component analysis (PCA) to analyze relationships among elements to see if they are indicative of variations in the glaze production process or some other latent variable(s) linked to particular sites of manufacture. PCA allows a researcher to see correlations among multiple variables and identify compositional differences between artifacts based on its position in multidimensional space. A principle component is essentially a line that fits the greatest spread among data points in a cloud. The line is a representation of variation among two or more variables. Within the R software, I applied the GrayILRv2 function contained within the Hulit Source for clustering and compositional analysis (Hulit 2012). As a result, the function produced a biplot "which aims to represent both the observations and variables of a matrix of multivariate data on the same plot" (Hulit 2012, 48). Rather than thinking in so many dimensions, the plot provides a more intuitive two dimensional representation. The number of dimensions is equivalent to the number of elemental variables and with each component more of the variation in the data is explained, i.e. particular trends in the data are being captured. The first principle component explains the highest percentage of variation. The elements (i.e. variables) in the first principle component with high loading values have the greatest influence on the distribution of the data. Subsequent principle components capture the remaining variation characterized by alternative sets of variables that influence the respective components. The amount of variation captured by each component is represented visually in the form of a screeplot. Focus is given to those components up to the point of a horizontal leveling as these components represent a majority of the variation among the artifacts.

Furthermore, the correlation between elements is representative of a latent variable that cannot be measured directly. Ultimately, those elemental variables with the highest loading values, i.e. those elements with the highest level of interaction and explanatory power, can be looked at in greater detail while ignoring others in an effort to reduce the dimensionality of the overall dataset. Archaeometric convention states that explaining 50-60% of the variation is adequate and follows UW-Milwaukee ARL standards.

Chapter 4: Results of Dimension Reduction and the Development of a Glaze Chemistry Regression Model

The following section provides the results of the statistical analysis of the Chipstone ceramic data and presents two logistic regression models used to predict the provenance of London and Staffordshire materials. Prior to principle component analysis the Mahalanobis distance metric function removed anomalous readings from the dataset. After running the distance metric function, 750 readings remained for subsequent culling. Another function in the Hulit (2012) package that identified zero or negative intensity readings removed them from the dataset. Upon running this package 721 cases remained for use in the principle component analysis that included all remaining readings and utilized all of the relevant, identified elements. I created a subset of net intensity measures and the GrayILRv2 command, developed by Dr. J. Patrick Gray (Hulit 2012), provided the loading values, individual reading scores or standing on each component, and the percent of variation explained by each component. It also automatically generated a biplot and a screeplot for the data.

The screeplot in Figure 4.1 shows four principle components that account for a majority of the variance, however the first three components are adequate per ARL standards. Analyzing the percent of variation explained by each of the four components, I determined that Component 1 accounts for ~29%. Each additional component explains an increasing amount of variation with all four major principle components accounting for a cumulative sum of 70% of the variation (Table 4.1). In studying the PCA biplot, the data appears to

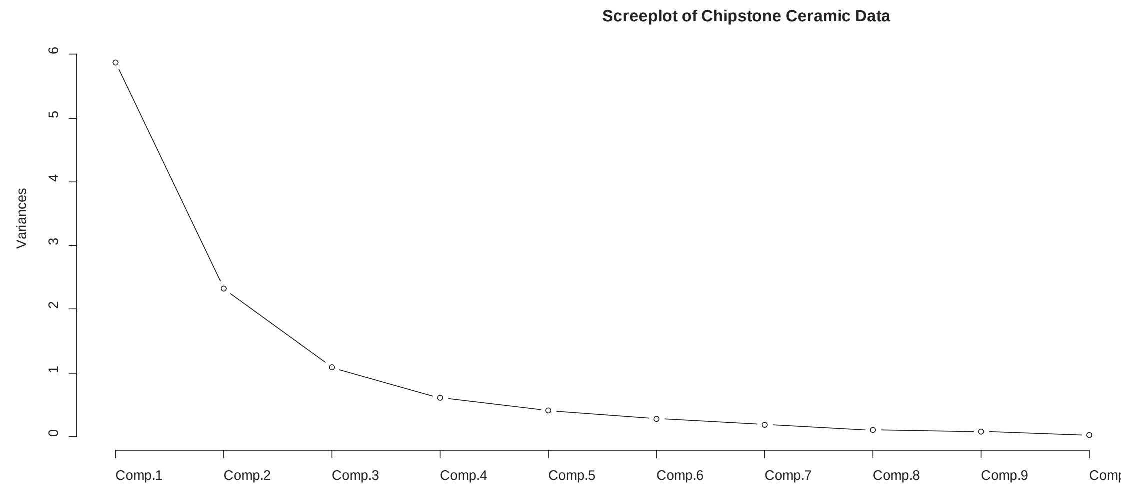

Figure 4.1 Screeplot of entire Chipstone dataset. This plot indicates four major principle components.

Table 4.1 Percentage of the variation for each principle component and the associated cumulative sum for the entire Chipstone dataset.

Percent Variation of Chipstone Ceramic Data										
Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8	Comp.9	Comp.10	Comp.11
29.429362	18.514763	12.673716	9.466257	7.761725	6.438849	5.317259	3.905716	3.467725	1.994504	1.030124
Cumulative Sum of Percent Variation Chipstone Ceramic Data										
Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8	Comp.9	Comp.10	Comp.11
29.42936	47.94412	60.61784	70.0841	77.84582	84.28467	89.60193	93.50765	96.97537	98.96988	100.00000

be elliptical in shape with several possible clusters being apparent (Figure 4.2). The loading values indicate the explanatory weight of particular variables on the distribution of the data. This information factors into the decision to retain certain variables or remove them to reduce dimensionality when conducting subsequent tests. The analysis focused on the loadings of the four major components identified which are listed in Table 4.2 with notable values highlighted. Viewing the loading measures, overall the higher values are often associated with fundamental glaze constituents, i.e. stabilizers such as aluminum and silicon, along with fluxes such as lead, particularly in the first principle component. It is possible then to say that the principle components with these variables

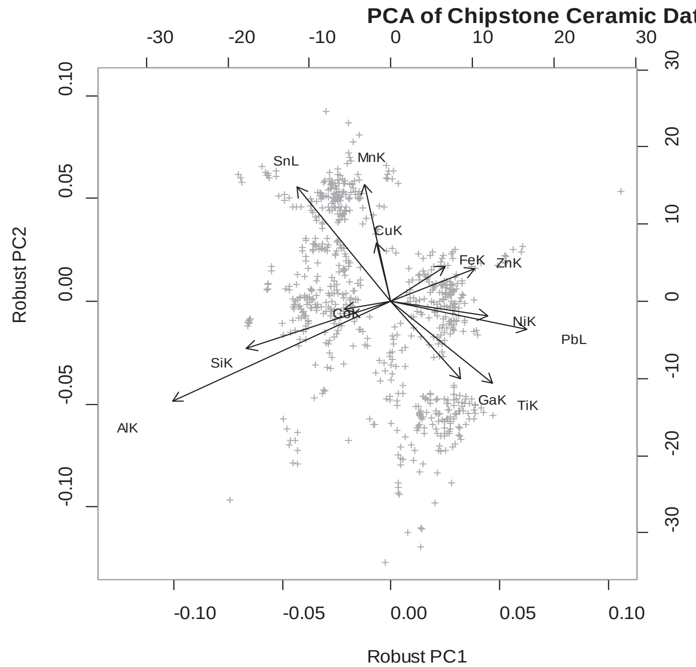

Figure 4.2 PCA biplot showing multiple clustering indicating possible compositional differences.

Table 4.2 PCA loadings for the entire Chipstone dataset with high loading values indicated.

PCA Loadings for All Data				
	Comp. 1	Comp. 2	Comp. 3	Comp. 4
Al	**-0.59803652**	**-0.41256175**	-0.16168662	0.03282603
Co	-0.12710500	-0.03273245	-0.12366019	**-0.30431481**
Cu	-0.03810563	0.24323265	0.16036956	**-0.47004273**
Fe	0.14959512	0.14602156	-0.29178832	-0.20848093
Ga	0.19149149	**-0.32045661**	0.18731731	0.29321967
Mn	-0.07252857	**0.48397013**	-0.19274925	**0.69077076**
Ni	0.26524659	-0.06133849	**0.42470556**	-0.12335846
Pb	**0.37243646**	-0.11802426	*0.22688753*	0.11601712
Si	**-0.39461537**	-0.19603727	*0.08444303*	0.05249406
Sn	*-0.25612610*	**0.47226534**	**0.40762361**	-0.02214774
Ti	*0.27781315*	**-0.33805390**	-0.12613309	0.12187723
Zn	*0.22993438*	0.13371504	**-0.59532913**	-0.17886021

captured the greatest amount of variation in the data. In other words, the opposition of aluminum and silicon to lead represents the greatest trend in the data.

Furthermore, aluminum and tin oppose one another in the second principle component and a correlation between tin and manganese as well as titanium and gallium. Nickel and tin cluster in the third principle component and are in opposition to zinc.

Cobalt and copper cluster in the fourth component and oppose manganese. Based on these results it is difficult to conceptualize the groupings of variables apart from the loading scores on PC1 which does not feature any colorants. However, Components 2 and 3 show tin as positively correlated with particular colorants which may be some indication of a conscious decision by the pottery to create a colored opaque glaze for purely artistic reasons or to better cover the coarse earthenware fabric. This is discussed further below.

To determine if the compositions of categorical groups differ significantly from one another it is necessary to run an ANOVA test with a 95% confidence interval (α=.05) on all four components. Each of the four ANOVA tests show statistically significant results (PC1: p=1.24e-13; df=8; PC2: p=<2e-16, df=8; PC3: p=<2e-16, df=8; PC4: p=<2e-16, df=8). The p-values and associated ANOVA information is shown in Table 4.3. Because the analysis concluded that at least one significant grouping is present in

Table 4.3 ANOVA results of the entire Chipstone dataset.

ANOVA Results for Chipstone Ceramic Data					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ANOVA PC1	8	196.1	24.51	10.26	1.24e-13 ***
Residuals	712	1701.3	2.39		
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ANOVA PC2	8	267.8	33.47	15.82	<2e-16 ***
Residuals	712	1506.3	2.12		
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ANOVA PC3	8	273	34.12	12.62	<2e-16 ***
Residuals	712	1925	2.70		
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ANOVA PC4	8	356.5	44.56	26.36	<2e-16 ***
Residuals	712	1203.7	1.69		

each principle component, I applied a Tukey post-hoc test to determine significant differences between each of the individual provenance categories. Those pairings with significant values less than α=.05 have been consolidated in Table 4.4. It is particularly

Table 4.4 Tukey post-hoc results for the entire Chipstone dataset with provenance designation key.

Tukey Post-Hoc PC1					Tukey Post-Hoc PC2				
	diff	lwr	upr	p adj		diff	lwr	upr	p adj
S-FN	1.97278817	0.349066692	3.5965096	0.0053047	B-P	1.813355570	0.188139755	3.4385710	0.0159683
L-FN	2.29141596	0.658573747	3.9242582	0.0004912	L-P	2.362470770	0.826051102	3.8988900	0.0000728
B-FN	2.67201166	0.944800641	4.3992227	0.0000633	G-P	3.347923208	0.823702120	5.8721440	0.0013575
N-FN	3.21698113	1.365786405	5.0681759	0.0000031	L-N	1.569992631	0.651561442	2.4884240	0.0000050
FR-FN	3.28490610	0.947887320	5.6219249	0.0004763	G-N	2.555445069	0.352124268	4.7587660	0.0099232
P-FN	3.77551338	1.508272133	6.0427546	0.0000102	B-S	0.657435048	0.005971059	1.3088990	0.0459528
I-FN	4.03914575	2.056500795	6.0217907	0.0000000	L-S	1.206550248	0.827519537	1.5855810	0.0000000
I-G	2.71470229	0.267860620	5.1615440	0.0170599	G-S	2.192002687	0.153677152	4.2303280	0.0242134
B-S	0.69922349	0.006874961	1.3915720	0.0456283					
N-S	1.24419296	0.283458612	2.2049273	0.0020167					
P-S	1.80272521	0.179003729	3.4264467	0.0169227					
I-S	2.06635758	0.871799255	3.2609159	0.0000036					
I-L	1.74772979	0.540803185	2.9546564	0.0002650					
I-B	1.36713409	0.035309751	2.6989584	0.0390558					
Tukey Post-Hoc PC3					Tukey Post-Hoc PC4				
	diff	lwr	upr	p adj		diff	lwr	upr	p adj
S-P	2.28969478	0.56247461	4.016915	0.0013691	S-FR	2.294095600	0.847502700	3.740688500	0.000035200
S-FN	1.74412789	0.01690773	3.471348	0.0456880	S-FN	2.069370600	0.703600900	3.435140300	0.000101400
S-N	1.45793225	0.43595911	2.479905	0.0003573	S-B	1.652746800	1.070387900	2.235105700	0.000000000
S-L	1.19401469	0.76552051	1.622509	0.0000000	S-I	1.512758300	0.507972900	2.517543700	0.000116600
S-B	0.82512383	0.08864386	1.561604	0.0152104	S-P	1.437015000	0.071245300	2.802784700	0.030499400
					S-L	1.259264200	0.920439800	1.598088600	0.000000000
					S-N	1.156932800	0.348825100	1.965040600	0.000333100

S=Staffordshire	L=London	B=Bristol	G=Glasgow	I=Italy	FR=France (Rouen)	FN=France(Nevers)	P=Portugal	N=Netherlands

noteworthy that compositional differences exist between British artifacts and several Continental European artifacts across all four principle components. Furthermore, in the case of the second, third, and fourth principle components there are significant differences between Staffordshire and London materials based on the associated chemical variables for those components.

These components feature several colorants and in the case of Component 2 gallium and tin load highly. The p-value=.0000 in the Tukey post-hoc test indicates there are some compositional differences between artifacts involving these variables which appear to be negatively correlated. It is curious that Staffordshire and London materials do not differ significantly in the first principle component, yet Bristol and Staffordshire materials do. Because the first component is characterized by fundamental glaze elements it is of interest to see how retaining those variables and removing particular colorant variables effects the loadings and subsequent ANOVA results. Furthermore, the presumed variability in the application of color to each item during production makes it worthwhile to investigate those constituents that are necessary to achieve a glaze that will behave appropriately when fired and therefore be more consistent throughout the production of successive items.

Reducing the Dataset to Fundamental Glaze Constituents

Because of the assumed high degree of variability in the application of colorants, which are subject to the whims of the artist and the desires of the mass market, I reran the principle component analysis with a reduced number of variables based on the higher measures for stabilizing and fluxing agents particularly in the first principle component. For this subsequent analysis aluminum, copper, gallium, lead, silicon, tin, and zinc were retained as variables. I chose to retain copper, despite being a colorant, for its fluxing effect. Once again, the analysis identified four components as accounting for a majority of the variance as shown in the screeplot (Figure 4.3). The screeplot shows that these first

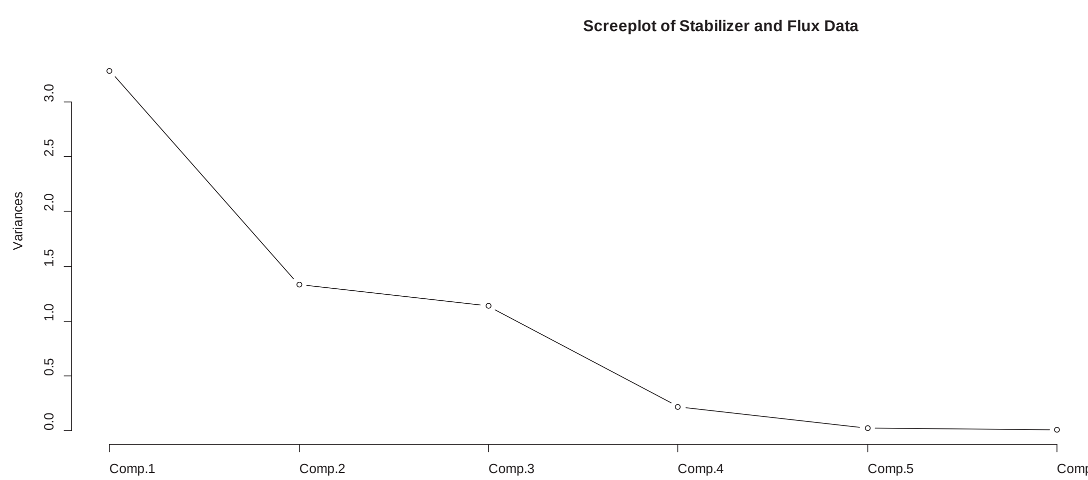

Figure 4.3 Screeplot of Chipstone stabilizer and flux dataset.

four principle components capture ~95% of the variation , summarized in Table 4.5.

Table 4.5 Percentage of the variation for each principle component and the associated cumulative sum for the reduced chipstone dataset.

Percent Variation of Stabilizer and Flux Data					
Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6
38.334161	24.404741	22.567737	9.815842	3.156235	1.721285
Cumulative Sum of Percent Variation Stabilizer and Flux Data					
Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6
38.33416	62.7389	85.30664	95.12248	98.27871	100.00000

Furthermore, the first two PCS account for ~63% of the variation. Looking forward to the factor analysis, it is possible to see some overlap in how certain variables load, notably gallium in the second PC and second Factor component. The biplot shows two larger clusters, however, surrounded by smaller groupings (Figure 4.4). This is potentially

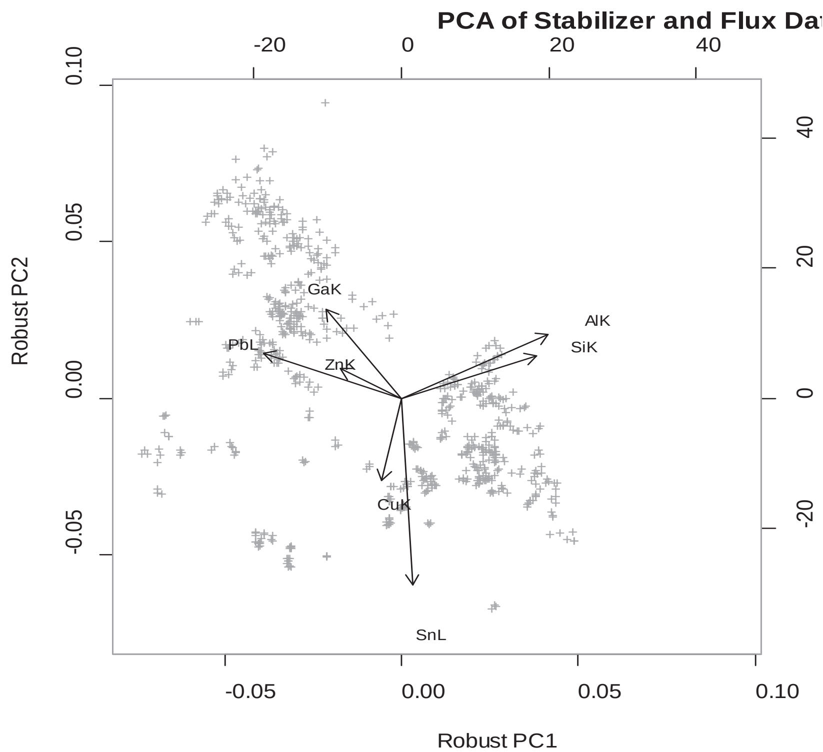

Figure 4.4 PCA biplot of the reduced dataset showing two clusters.

explained by the much larger number of Staffordshire and London samples also hinted at by the unusual shape of the screeplot that plateaus after components 1 and 2 and descends between components 3 and 4.

Loading measures for this reduced dataset are presented in Table 4.6 which show

Table 4.6 PCA loadings for the stabilizer and flux Chipstone data with major loading values indicated.

PCA Loadings for Stabilizers and Fluxes				
	Comp.1	Comp.2	Comp.3	Comp.4
AlK	**0.55974571**	0.26484550	-0.04283422	-0.19295304
CuK	-0.07348023	**-0.34137870**	**-0.35836980**	**-0.73550883**
GaK	-0.28498131	**0.36710920**	**0.33793103**	-0.08806853
PbL	**-0.52695423**	0.18568500	**0.32637015**	-0.03844671
SiK	**0.51571173**	0.17644760	0.16014641	0.21628085
SnL	0.04349591	**-0.77352390**	**0.30500527**	**0.33544776**
ZnK	-0.23353758	0.12081530	**-0.72824884**	**0.50324850**

higher values and a positive correlation of aluminum and silicon and opposition to lead in Component 1. Copper and gallium are negatively correlated in Component 2 with a high value for tin as well. Gallium, lead, and tin correlate in Component 3, though oppose copper. There is also a high value for zinc. Component 4 features a high loading value for copper and slight clustering of tin and zinc. To determine whether this reduction helps to explain the compositional differences, I used ANOVA once more to determine compositional differences among the four principle components. All four components returned significant values indicating at least one significantly different provenance grouping based on this set of variables (PC1: p=1.73e-11, df=8; PC2: <2e-16, df=8; PC3: p=<2e-16, df=8; PC4: p=9.1e-14, df=8) detailed in Table 4.7. The Tukey post-hoc test

Table 4.7 ANOVA results for the Chipstone stabilizer and flux data.

ANOVA Results for Stabilizer and Flux Data					
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
ANOVA PC1	8	120.8	15.099	8.788	1.73e-11 ***
Residuals	6695	1194.2	1.718		
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
ANOVA PC2	8	210.8	26.344	12.56	<2e-16 ***
Residuals	695	1457.6	2.097		
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
ANOVA PC3	8	361.5	45.19	194.8	<2e-16 ***
Residuals	695	161.2	0.23		
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
ANOVA PC4	8	94.2	11.779	10.36	9.1e-14 ***
Residuals	695	789.9	1.137		

showed that the number of pairings which present as being significantly different increase in the case of the second, third, and fourth principle components. Significant pairings increase from eight to 14 for Component 2, five to 13 for Component 3, and seven to eight for Component 4. The number of pairings drops from 14 to 12 for Component 1. The p-value for the Staffordshire and London pairing in Principle Component 1, which together represent the greatest number of artifacts analyzed, drops from p=.2530 to p=.0731. While this is not statistically significant based on the assigned confidence interval, however it is an improvement. Table 4.8 shows these results.

Table 4.8 Tukey post-hoc results for the Chipstone stabilizer and flux data with provenance designation key

Tukey Post-Hoc PC1					Tukey Post-Hoc PC2				
	diff	lwr	upr	p adj		diff	lwr	upr	p adj
L-P	1.53405493	0.150526231	2.9175836	0.0171851	S-G	1.74151261	0.21867571	3.2643495	0.0118574
S-P	1.86185921	0.483489979	3.2402284	0.0009907	I-G	2.04783330	0.12259049	3.9730761	0.0272292
G-P	2.07923229	0.156526712	4.0019379	0.0227888	N-G	2.67099607	0.87569789	4.4662942	0.0001512
FN-P	2.81201647	0.662366284	4.9616667	0.0017129	P-G	4.40658258	2.28235713	6.5308080	0.0000000
S-FR	1.62348528	0.245116050	3.0018545	0.0081216	N-FN	2.21372093	0.12777295	4.2996689	0.0278909
FN-FR	2.57364254	0.423992355	4.7232927	0.0065158	P-FN	3.94930744	1.57435119	6.3242637	0.0000106
L-I	1.15850726	0.038681647	2.2783329	0.0361804	S-L	0.69757914	0.31926150	1.0758968	0.0000005
S-I	1.48631153	0.372866671	2.5997564	0.0012176	N-L	1.62706260	0.60374077	2.6503844	0.0000332
FN-I	2.43646879	0.446279443	4.4266581	0.0047631	P-L	3.36264911	1.83411197	4.8911862	0.0000000
L-N	1.01654783	0.090305941	1.9427897	0.0193282	N-B	1.23163445	0.08911369	2.3741552	0.0235898
S-N	1.34435210	0.425834768	2.2628694	0.0002134	P-B	2.96722096	1.35644726	4.5779947	0.0000005
FN-N	2.29450936	0.406449967	4.1825688	0.0052899	P-S	2.66506997	1.14223308	4.1879069	0.0000026
					P-I	2.35874928	0.43350648	4.2839921	0.0047113
					P-FR	2.30324044	0.17901499	4.4274659	0.0221354
Tukey Post-Hoc PC3					Tukey Post-Hoc PC4				
	diff	lwr	upr	p adj		diff	lwr	upr	p adj
FN-S	0.84992117	0.232414080	1.4674283	0.0007069	S-I	1.08352579	0.17794459	1.9891070	0.0065712
P-S	1.02653397	0.520048006	1.5330199	0.0000000	N-I	1.52355894	0.37900022	2.6681177	0.0012777
N-S	1.08595130	0.748439319	1.4234633	0.0000000	G-I	1.54515919	0.12787687	2.9624415	0.0208296
G-S	1.32026803	0.813782067	1.8267540	0.0000000	N-P	1.33938117	0.01775859	2.6610038	0.0441655
B-S	1.34232461	1.131634869	1.5530143	0.0000000	S-B	0.75706517	0.29072780	1.2234025	0.0000198
L-S	1.47692630	1.351100238	1.6027524	0.0000000	N-B	1.19709833	0.35602287	2.0381738	0.0003746
I-S	1.54275162	1.133612919	1.9518903	0.0000000	S-L	0.59399604	0.31549460	0.8724975	0.0000000
FR-S	1.82822128	1.321735317	2.3347072	0.0000000	N-L	1.03402919	0.28070295	1.7873554	0.0007431
L-FN	0.62700513	0.007942081	1.2460682	0.0444162					
FR-FN	0.97830011	0.188404615	1.7681956	0.0040230					
FR-P	0.80168731	0.095183305	1.5081913	0.0130513					
L-N	0.39097500	0.050624601	0.7313254	0.0112112					
FR-N	0.74226997	0.145165107	1.3393748	0.0038084					

S=Staffordshire	L=London	B=Bristol	G=Glasgow	I=Italy	FR=France (Rouen)	FN=France(Nevers)	P=Portugal	N=Netherlands

Based on the outcome of this second analysis it appears that the removal of particular colorants improves the ability to detect differences between groups of both

British and Continental European made artifacts. Furthermore, the analysis showed potential compositional distinctions between those materials made in Britain which had highly significant values, particularly in those components with higher lead, tin, gallium, zinc, and copper loadings. With this knowledge in mind regarding the relationships between fundamental glaze constituents, the focus turns to the Staffordshire and London materials in particular to determine those glaze constituents that best factor into each group and if those artifacts can be sorted into their respective provenance categories.

Factor Analysis of Staffordshire and London Mean Net Intensity Readings

Due to the results of the principle component analysis of the overall dataset, I determined that the analysis should be re-focused to emphasize fundamental glaze elements of the Staffordshire and London made materials. Toward that end, I placed those measures into a separate dataset and averaged the multiple readings for each pot to achieve a single representative reading of each glaze constituent variable. Furthermore, I removed copper from the analysis so as to have a dataset that included only those variables which constituted the fundamental aspects of the glaze, i.e. stabilizing and fluxing agents. Within SPSS, I conducted a factor analysis to see if these observed variables hint at some broader unobserved variables such as different glaze production strategies. Variables now correlate positively or negatively with the factor, i.e. the latent variable. The factor analysis utilized the Anderson-Rubin method "in which the least squares formula is adjusted to produce factor scores that are not only uncorrelated with other factors, but also uncorrelated with each other." (DiStefano et al. 2009, 5). This aids in the elimination of multicollinearity which is understandable given that there are necessary elements in the glaze chemistry to achieve a given end. (DiStefano et al. 2009).

As a result, the factor analysis extracted two components that cumulatively account for ~71% of the variance. Table 4.9 details these values and Table 4.10 shows

Table 4.9 Factor loading values for the Staffordshire and London data.

Factor Loadings		
	Comp. 1	Comp. 2
Alkavg	0.892	
GaKavg		0.893
PbLavg	-0.852	0.348
SiKavg	0.974	
SnLavg	0.516	-0.397
ZnKavg		-0.617

Table 4.10 Factor analysis results of the Staffordshire and London mean intensities.

Factor Analysis of Staffordshire and London Mean Net Intensities						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% Variance	Cumulative %
1	2.78	46.375	46.375	2.782	46.375	46.375
2	1.5	25.022	71.396	1.501	25.022	71.396
3	0.97	16.151	87.547			
4	0.54	8.976	96.524			
5	1.64	2.732	99.255			
6	0.05	0.745	100.000			

the associated factor loadings. Of particular note is the positive correlation between Factor 1 and tin. This is to say that as the Factor 1 score of an artifact increases, i.e. an artifacts standing on a factor goes up, the amount of tin will also increase. Furthermore, aluminum, lead and silicon have a strong association with the first factor.

Gallium is a major characteristic of Factor 2 and positively correlates with that factor. Gallium has a very high loading value and is a distinctive characteristic of Factor 2. A positive correlation also exists between Factor 2 and lead. Furthermore, Factor 2 is negatively correlated with tin. Those artifact glazes that have a high Factor 2 score will have greater intensities of gallium and lead though feature much less tin in their compositions resulting in a clear finish rather than an opaque one.

Developing a Model for Predicting Staffordshire or London Provenance

In light of this information regarding the notable variables for Factor 1 and Factor 2, it is now possible to use the factor scores to develop a binary logistic regression model that utilizes the London and Staffordshire provenance designations as the dependent variable. Not taking into consideration any other information, the regression analysis assumed the model would correctly predict the provenance by chance alone 56.2% of the time. When including the factor scores in the model the chi-square test (α=.05) of the null hypothesis shows p value=.000 indicating that the model can make some distinction between Staffordshire and London materials as a result of the inclusion of the factor scores in the analysis. However, when looking at the Cox & Snell R Square value it is low showing that only 23.2% of the variability of the data is being explained. In this instance, the model correctly categorized 79.5% of the samples overall with 75% of the London materials correctly predicted to be from London and 82.9% of Staffordshire samples correctly predicted to come from Staffordshire (Table 4.11).

Table 4.11 Logistic regression Model 1 showing the number of correctly predicted samples using factor scores.

	Classification		
	London	Staffordshire	% Correct
London	24	8	75
Staffordshire	7	34	82.9
Overall			79.5

Only the Factor 2 scores of the chemical variables that constitute the second factor contribute to the predictive ability of the model, as seen in Table 4.12.

In an effort to improve upon this model, I re-ran the logistic regression analysis with the variables in the previous model as well as the addition of the estimated year of production. In this case the Cox & Snell R Square value improves significantly which

Table 4.12 Details of significant variables that contribute to the predictive ability of Model 1.

Variables in the Equation						
	B	S.E.	Wald	df	Sig.	Exp(B)
Factor 1	-0.148	0.263	0.316	1	0.574	0.863
Factor 2	1.322	0.381	12.033	1	0.001	3.751
Constant	0.295	0.271	1.189	1	0.276	1.344

now indicates that 50.1% of the variability in the data is now being explained. The overall percentage of correctly predicted samples also increases to 87.7% with 84.4% of London samples correctly attributed to London and 90.2% of Staffordshire materials correctly predicted as coming from Staffordshire (Table 4.13). Factors 1 and 2 as well the

Table 4.13 Logistic regression Model 2 showing the number of correctly predicted samples using factor scores and year of production.

Classification			
	London	Staffordshire	% Correct
London	27	5	84.4
Staffordshire	4	37	90.2
Overall			87.7

estimated year of production are significant and therefore are contributors to the ability of the model to make an accurate prediction of provenance. Table 4.14 details this

Table 4.14 Details of significant variables that contribute to the predictive ability of Model 2. All variables are significant contributors.

Variables in the Equation						
	B	S.E.	Wald	df	Sig.	Exp(B)
Factor 1	-1.755	8.717	8.717	1	0.003	0.173
Factor 2	0.807	3.665	3.665	1	0.056	2.242
Est. Year	0.043	0.011	15.035	1	0.000	1.044
Constant	-74.219	19.234	14.889	1	0.000	0.000

information. The results of this exploratory analysis into making provenance attributions based on the constituent chemical fingerprints of these ceramics can now be considered in the light of historical trends in the British pottery industry to gain a better understanding of why particular glaze constituents aid in distinguishing between groups.

Chapter 5: The Evolution of the Pottery Industry in the Eighteenth and Nineteenth Centuries

It is of interest to examine the historical context of ceramic production and consumption in England to gain a deeper understanding of the results of this study. As a corollary to this, further consideration should be paid to the reasons behind the improved results when I removed the lead and tin-opacified glaze colorants from the principle component analysis, ANOVA, Tukey post-hoc tests, and the regression models. Because of the notable difference between pottery groups, particularly the distinction between Staffordshire and London artifacts, it is useful to consider industrial pottery practice in England during the eighteenth and nineteenth centuries. During this time, changes wrought by the Industrial Revolution led to alterations in pottery fabric and glazes and led to the large scale commodification of decorative ceramics.

Changing ceramic markets necessitated a higher degree of production resulting in a pervasiveness of ceramic objects during the eighteenth and nineteenth centuries. These changes go a long way toward explaining many of the observed patterns and differences in the data. Standardization of glaze processes led to regional commonalities, but technological change in pottery and glaze production resulted in national distinctions. From a disciplinary perspective these results strengthen the justification for a refined archaeological toolkit and utilizing chemical analysis to aid in sorting through these materials, in particular taking advantage of the beneficial features of the portable X-ray fluorescence instrument.

English Ceramic Economy in the Eighteenth and Nineteenth Centuries

The eighteenth century marked a period of industrialization and expansion of population and wealth in England. Entrepreneurs began investing in the development of technologies to facilitate the extraction of raw materials and the creation of finished products of greater variety in order to satisfy a growing national and global market place. Very early in this period, the production of pottery was one industry among many that was influenced by these forces, though maintained a fascination with exotic goods and stylistic elements. In the early decades of the 1700s, many pottery manufacturers tried developing imitations of Chinese, Japanese, and Mediterranean designs that often featured fine porcelain fabrics and delicate aesthetic qualities that caught the eye of many consumers (Hume 2001). However, organizations attempting to encourage domestic developments in the sciences and arts such as the Royal Society of Arts, founded in 1754, advocated for a movement away from the imitation and importation of these Eastern and Mediterranean ceramic traditions toward innovative English-made styles (Berg 2002).

London based potteries at Southwark and Lambeth were producing tin-glazed wares that attempted to approximate the appearance of overseas porcelain and later production expanded to a large degree particularly in Liverpool (Ostermann 2006). Not only were these potters conducting experiments on ceramic technologies and processes of manufacture, but new styles were emerging as well. Rosemary Troy Krill (2010, 135) noted that "some obvious evidences of development include sgraffito-decorated earthenware, influenced by an ethnic tradition; various white-bodied tea and dinner wares, affected by cross-cultural influences and social practices; and the diversity of transfer-printed wares, stimulated by the desire to expand ceramic markets." Because of the advancements made by these individuals, a flowering of styles and forms flooded into the marketplace to meet the demands and tastes of a rising middle and upper class.

Pottery production during this period of English ceramic reflects shifts in societal and consumer aesthetics and cultural and cross-cultural influences that resulted in the production of new artifact forms. In tandem with new domestic scientific and technological developments, by the late 1700s "the number of forms had been extended to include a variety of objects for the home such as rectangular flower-holders, pen-and-ink stands, puzzle jugs, and a full complement of tea-drinking items…" (Cooper 2000, 155). A number of factors converged in the 1700s in England that altered the ways in which people were able to purchase goods and maintain and present themselves within society. Agricultural difficulties, population shifts, and the development of factories and mass production all served to alter the landscape of Britain (Mokyr 1985). A growing urban middle class was on the rise bolstered by a strengthened entrepreneurial spirit and characterized by a strong desire to express themselves to other members of their socioeconomic rank by purchasing decorative additions to display in their homes and on their dress (Berg 2007). Bermingham and Brewer (2013, 13) explained that "of the character models available to the late eighteenth century it was the ideal of the 'bohemian' or 'romantic' that most predisposed its types to consume. The romantic creed of self-expression, Campbell believes, aligned easily with consumption's promise of hedonistic self-gratification" (citing Campbell 1987).

While the ceramic market, and the market for other luxury goods fluctuated throughout the first decades of the 1700s, by the end of the eighteenth century the marketplace had evolved to meet the tastes and demands of the middle class consumer, whose home was “rich in material goods which signified much about the social and cultural values of its occupiers…” (Richards 1999, 71). According to Dean et al. (2004) among households in Kent the percentage of those that owned plates increased from 14% in the early 1600s to 85% by the early eighteenth century, and in Cornwall this number went from 4% to 85%. The authors note similar increases among many other ceramic consumer goods in those same areas indicating changing tastes and greater affordability (Dean et al. 2004).

The eighteenth and nineteenth centuries marked an evolution of the consumer who was now able to obtain desirable goods for display as well as engage in leisure activities that gave individuals the opportunity to demonstrate their social rank through such a display (Bermingham and Brewer 2013). These sorts of engagements were certainly a product of the time which was characterized by shifting social, cultural, and economic circumstances. This new population of consumers exhibited a growing degree of extravagance and excess reflected in conspicuous consumptive behavior. Such behavior may have been an expression of identity, or to distinguish oneself among a growing population of similarly well-to-do people. During this time elements of Georgian high style had an important influence on the goods being sought, and with each passing decade the means were being put in place to meet the whims of the buyers.

Standardization and Rethinking the Ceramic Production Process

In order to meet the demands of a rising mass market, the English ceramic industry experimented with new forms of factory organization. Writing in the nineteenth century, Simon Shaw (1900[1829]) noted that by the middle of the eighteenth century the organization of workers in Staffordshire pottery factories changed significantly and was one factor that facilitated increased production. According to Shaw:

> The increase of workmen, the subdivision of labour in every process; and the dexterity and quickness consequent on separate persons confining themselves solely to one branch of the Art, with the time saved in the change of implements and articles, instead of retarding, greatly promoted the manufacture, by increasing its excellence and elegance (166).

Given this reorganization that separated workers into particular activity areas of the overall manufacturing process, it is assumed that those engaged in the glazing process would follow the dictates of the master. This individual would have extensive knowledge regarding the necessary proportions of glaze constituents most appropriate to achieve a desired appearance, and this knowledge would be passed down to their apprentice(s).

Apart from the re-organization of workers to increase productivity, it is also the case that the production process itself, i.e., the operational sequence of making ceramic items, was becoming increasingly standardized. Jessica Hale (2008) offers a condensed list of seven production tasks that are described by Malcom Graham (2000, 13[1908]), a Staffordshire Vicar who published a photo-essay of nineteenth century earthenware production. Hale's list includes clay preparation, shaping, biscuit firing, application of glaze, glost firing, application of decoration, and a final firing. The glazing process can be further subdivided, as described by Owen (1901), beginning with the dipping of wares into a glaze bath, a subsequent inspection by the ware-cleaner, and a firing in the glost oven. During each firing, saggers were used to protect the wares in both early wood-fired kilns and subsequent larger coal-fired bottle kilns (Burton 1902). The application of colorants by blowing, painting, or dusting happened subsequent to the glost firing. After the addition of color and decoration the wares were placed in the kilns for the final firing.

Despite this newly specialized workforce that engaged in the glazing process, these craftsmen were becoming increasingly disconnected from the actual experimentation with and production of the glaze. This task was increasingly being taken over by chemists or other materials specialists. Goodfellow and Booth, for example, developed an improved fluid glaze and John Greatbatch is credited with the development of so-called China Glaze for Wedgwood that further refined Goodfellow and Booth's method (Miller 1987; Shaw 1900[1829]). Looking back over the course of the nineteenth century up to the time of publication of *A Potter's Book*, Bernard Leach (1976, 134) made note of the changes that resulted from this evolution of the English pottery craft and states "industrialization of pot making has involved such a heightened degree of standardization of material that it is now no longer the universal practice for potters to know their glaze materials and to make their own glazes." With such contextual information in mind it is now possible to make linkages between English pottery making history and the information derived from the pXRF chemical analysis.

Situating Glaze Chemistry in its Historical Context

Affordable material substitutes for porcelain were in growing demand by English consumers during the late eighteenth century. However, these ceramics featured a coarse earthenware fabric which necessitated the heavy use of tin glazing in order to produce a porcelain-like finish. Black (2001, 8) notes "it is impossible…to estimate how much tin-glazed earthenware was produced in the seventeenth and eighteenth centuries, but Peter Francis…estimates 44 million pieces between 1723 and 1781 from factories outside London alone (citing Francis 2000). The desire of consumers for improvements to fabric and glaze alike did not fall on deaf ears, however. Josiah Wedgwood, for example, was beginning to utilize a growing body of scientific knowledge on the production of pottery. Glenn Adamson (2007) noted a paradigm shift in the eighteenth century from secretive alchemy to modern science in several realms, including pottery production, which was to the benefit of industrialists and entrepreneurs. Scientific experimentation allowed better precision and control over the constituent elements of the clay, the firing temperature and atmosphere, and the glaze. Eventually, this would result in a product to rival expensive, imported porcelains (Musson and Robinson 1969). As the nature and behavior of materials related to pottery production became public knowledge, it was possible to refine manufacturing techniques and apply that knowledge to industrial production (Adamson 2007).

With the development of cream-colored ware in the mid-1700s, the English, and in particular the Staffordshire ceramic industry saw a massive expansion and by the later decades of the eighteenth century "Josiah Wedgwood…achieved undisputed preeminence, and became the greatest agent in the world-wide distribution of the cream-coloured earthenware of North Staffordshire" (Miller 1980; Wedgwood 1913, 85). Originally using Dorsetshire ball clay with a mixture of other local clay, the Wedgwood recipe was altered with the discovery of kaolin deposits in Cornwall. The use of kaolin clays improved the fabric even more and allowed production of a much refined ware (Wedgwood 1913, 84). This development shook the British ceramic industry at this time as "the introduction and success of industrially manufactured cream-coloured wares in the second half of the eighteenth century led to a decline in the popularity of tin-glazed ware, and by around 1800 production of it had virtually ceased" (Bagdade and Bagdade 2004; Cooper 2000, 155).

Taking this into consideration, it is possible to look at the elements that best characterize the respective factors extracted through the factor analysis. Of greatest interest are the loading values of tin on Factors 1 and 2 of the Staffordshire and London stabilizers and fluxes. The fact that tin does not characterize Factors 2 to such a high degree relative to the tin value in Factor 1 seems to reflect the historic developments of glaze production in that region. Furthermore, tin is negatively correlated with Factor 2, but positively correlated with lead indicating that London and Staffordshire can be distinguished based on separate glaze production processes. Tin, as an opacifier, was no longer needed to produce a lustrous porcelain-like appearance in Staffordshire-made wares as they transitioned from the rougher local clays to the finer kaolinite material. However, Factor 1 is noteworthy for its greater loading value for tin and the associated higher intensity measures and factor scores for the London artifacts. As pointed out above, tin-glaze production was initiated among London based pottery shops and continued for many decades afterward before production experiences a sharp decline. Thus, the difference in tin is one of the most distinguishing characteristics of ceramic objects made in Staffordshire or London. Given the use of Cornwall kaolinite deposits by Staffordshire factories, it is also worthwhile to consider the presence of gallium in the second factor of the factor analysis which is linked to the Staffordshire glaze production strategy. Gallium is relatively uncommon; however, it is found in greater concentrations in association with aluminosilicate minerals, including those that constitute kaolinite, and is found during the extraction of alumina and zinc (Gray et al. 2000). Gray et al. (2000) states that:

> The early stages of weathering of primary host rocks is characterized by leaching of alkalis, alkali-earths and silicon, consequently, gallium and aluminum may remained linked in secondary minerals, typically kaolinite and gibbsite, retaining in part the originally affinity in the lateritic cover (339).

While gallium may not be an intentional component of the glaze recipe, its presence hints at the change in raw materials used by Wedgwood and the Staffordshire potters, namely the use of kaolin clays. Coupled with the overall intensities of the other highly loaded elements these materials can be sorted into their respective places of manufacture.

Chapter 6: Future Research Using pXRF to Study Glaze Chemistry

As a result of this analysis a number of intriguing questions remain to be considered, in particular, future testing of the exploratory model that has been presented here. The principle component analysis focused the study to the major glaze constituents. Subsequent tests indicated compositional differences that encouraged further exploration. The factor analysis refined my understanding of the glaze chemistry which allowed for the characterization of the factors as London and Staffordshire glaze production strategies. Though the first of the two logistic regression models assigned the artifacts to the correct provenance or production area to a fair degree, the inclusion of the year of production allowed the model to achieve a greater level of statistical significance and improved the pseudo-R^2 values. Such results encourage the use of the pXRF as one tool for gaining a deeper understanding of the Chipstone collection as well as other ceramic assemblages. While this analysis could be reproduced, it would only be useful for drawing further conclusions about this collection, however, alterations to the research design and further testing is worthwhile.

To refine the model for predicting provenance it would be beneficial to use the pXRF instrument to scan not only more of the British artifacts in the Chipstone collection, but also branch out to other repositories of historic British and Continental European ceramics to see if a greater number of readings of materials will support the conclusions drawn from this initial model. It is necessary to determine a research strategy that eliminates the sampling bias issue inherent in this study (Speakman and Shackley 2013). One possible solution is to use collections of sherds and wasters in a blind study and subsequently compare groups to known provenance information. In addition, Hunt and Speakman (2015) discuss the issues of measuring low Z elements and propose certain protocols for the analysis of ceramics and sediments as raw materials.

A new research design would begin by calibrating the existing dataset and the analysis would be re-run using parts per million values. Sherds in Chipstone's collection would be analyzed using pXRF and destructive analytical techniques to derive detailed compositional fingerprints of the glaze. A filter might be developed, in collaboration with Bruker, to target the specific constituents of lead glazes. Furthermore, a comparative study could be conducted using the ELIO Bruker analyzer that produces an XRF map of complex design surfaces. Should this line of research prove fruitful, the analysis could expand to sherds or whole vessels that do not yet have provenance information associated with them. This would further support the portable X-Ray Fluorescence instrument as a useful tool, both in the field and the lab, for sorting historic archaeological ceramics.

Apart from refining the model, developing greater knowledge about the raw materials used for the production of glaze and how those constituents interact with one another as well as confirming the link between raw material source and the pottery shop would be a productive avenue for research. On the one hand, it would reveal the nature of the kaolinite clay deposits that Staffordshire potters used in the late eighteenth century and determine if gallium and specific isotopes of other elements are present both in the those clay sources and in the glaze being made from those sources. It is an opportunity to assess the depositional effects on glaze chemistry by comparing the raw material chemistry to the fired artifacts. This may stretch beyond the abilities of the pXRF instrument, though it would be interesting to utilize it as one tool among many for that research.

Such research would begin to fill in the entire commodity chain from raw materials to production and ultimately distribution into the mass market. This would give some insight into the spread of goods at every stage facilitated by the influences of the Industrial Revolution and the rise of consumerism. Tracing these goods chemically and archaeologically leads to multiple avenues to assess consumer choice as well as have knowledge of production. Archaeologists could reopen the issue of modeling consumer behavior discussed by Henry (1991), Klein (1991), Spencer-Wood (1987), and Wurst (1999). Furthermore, making basic national attributions to ceramic assemblages at archaeological sites based on the chemical fingerprinting of artifacts would be worthwhile given the strictures of mercantilism in the seventeenth and eighteenth centuries. Mercantilism lead to the expansion of trade routes, but restrictions on trade itself. Many European nations, including Britain, expanded their reach by establishing colonies and footholds across the world (Ormrod 2003). Materials were extracted and produced, but trade with foreign nations restricted (Ormrod 2003). Undertaking chemical analysis at a British colonial site and finding goods produced by a foreign nation may reveal occurrences of smuggling or deviations from established foreign relation policies. Such as research strategy could be expanded to other contexts including Roman and Mayan sites to reveal the exchange of goods, illicit or otherwise.

Furthermore, having that understanding of the raw and finished materials would help in potentially recreating the glaze recipes. This would entail not only an understanding of those raw sources, but also a careful chemical analysis of the glaze. A detailed reading of the historical record is also necessary that would provide insights into the specific ratios of constituents. This would likely involve a battery of tests and the use of a calibrated pXRF instrument as well as other techniques for gaining quantitative percentages of elements in the glaze.

Having an understanding of the glaze, coupled with the knowledge gained from the study of each stage of production, leads to interesting questions regarding technology transfer and the sharing of knowledge of practice. These transferences can be attained in a variety of ways including the traditional master and apprentice relationship. It might also be accomplished through industrial espionage or the movement of skilled workers to an alternate ceramic producing factory or region. Materials based research also provides an opportunity to assess the loss of diversity in glaze production strategies and recipes as that knowledge is concentrated into a smaller group of skilled glaze chemists and material scientists.

Concluding Remarks on Glaze Analysis using Portable X-Ray Fluorescence

This exploratory foray into determining provenance based on the chemical compositions of British and Continental European lead and tin-opacified glazes is very much reliant on an understanding of the technical and methodological material science techniques, and in particular the nature of portable X-Ray fluorescence. This is coupled with a firm grounding in the historical literature that contextualizes the presence or absence of certain glaze elements. In this particular case, the trajectory of English made ceramics and the influence of industrialization on that process offer powerful insights into the patterns this study produced as a result of the principle component analysis, the subsequent factor analysis and the final logistic regression models.

The archaeologist or material culture analyst has an opportunity to utilize pXRF and other analytical tools to gain a better understanding of materials through the study of their underlying distinctions and similarities. These studies may provide new knowledge regarding the producers and the users of items manufactured from the materials studied. It should be stated outright that the portable X-Ray Fluorescence instrument cannot be considered a magic wand that will instantly generate conclusions regarding the archaeological record. A study such as this one must draw on a multitude of tools in the archeaological toolkit to achieve a holistic understanding of the material under study. Furthermore, generating that understanding is an iterative process whereby new information leads to a reexamination of the dataset, and seemingly anomalous results may force the researcher to alter the framework through which they view events in history.

Coupled with this, the importance of collaboration, drawing on the specialized knowledge of other researchers in various fields, and linking that knowledge together to craft an effect research design should be emphasized when approaching a study such as this one. This research is, on the one hand, situated well within the discipline of archaeology, but it also draws heavily on the material science of ceramics. There are elements of the industrial historical past and a solid understanding of the disciplinary history of archaeology regarding systematics and artifact classification. This study is ultimately operating from a processual-plus or historical-processual worldview. That is to say, that to understand the distinguishing and overlapping characteristics of these ceramics, which leads to effective classification schemes, it is necessary to utilize multiple perspectives and methods, explore the practices of the people who made them, and have broader cultural and societal knowledge. This deeper understanding, in other words, "will be found only through the cumulative, painstaking, data-rich, multi-scalar studies of proximate causation" (Pauketat 2001, 87). As this study shows, people, technology, and society have an effect on glaze chemistry and ceramic production. Portable X-ray fluorescence offers a window into that broader story and can deepen our knowledge of archaeological materials and their chemistry. It is a tool for revealing the similarities or differences among an assemblage of ceramics. This information can factor into the formation of classification systems that will be useful in future archaeological research. Archaeometric approaches to material culture studies, broadly speaking, are one beneficial avenue of ceramic classification research as well offer the opportunity to bridge the divide between the natural and social sciences.

References

Abramiuk, Marc A. 2012. *The Foundations of Cognitive Archaeology*. Cambridge: MIT Press.

Adamson, Glenn. 2007 "The American Arcanum: Porcelain and the Alchemical Tradition." *Ceramics in America* 10: 94-119.

Bagdade, Susan D., and Allen D. Bagdade. 2004. *Warman's English & Continental Pottery & Porcelain: Identification and Price Guide*. Iola: KP Books.

Bayley, Justine and Thilo Rehren. 2007. “Towards a Functional and Typological Classification of Crucibles.” In *Metals and Mines: Studies in Archaeometallurgy*: 46-55.

Beaudry, Mary C., Janet Long, Henry M. Miller, Fraser D. Neiman, and Garry Wheeler Stone. 1983. "A Vessel Typology for Early Chesapeake Ceramics: The Potomac Typological System." *Historical Archaeology*: 18-43.

Becher, Bernd and Hilla Becher. 2004. *Basic Forms of Industrial Buildings*. Gothenburg: Hasselbad Center.

Berg, Maxine. 2002. "From imitation to invention: creating commodities in eighteenth-century Britain." *The Economic History Review* no. 55 (1):1-30.

Berg, Maxine. *Luxury and Pleasure in Eighteenth-Century Britain*. Oxford University Press 2007.

Bermingham, Ann, and John Brewer. 1995. *The Consumption of Culture, 1600-1800: Image, Object, Text*. New York: Routledge.

Binford, Lewis R. 1962. "Archaeology as Anthropology." *American Antiquity*: 217-225.

Binford, Lewis R. 1965. "Archaeological Systematics and the Study of Culture Process." *American Antiquity*: 203-210.

Binford, Lewis R. 1968. "Some Comments on Historical Versus Processual Archaeology." *Southwestern Journal of Anthropology*: 267-275.

Binford, Lewis R. 1983. *In Pursuit of the Past*. London: Thames and Hudson.

Binford, Lewis R. 1989. "The ‘New Archaeology’, Then and Now." in *Archaeological Thought in America*: 50-62.

Binford, Lewis R., and George Irving Quimby. 1972. *An Archaeological Perspective*. New York: Seminar Press.

Black, John. 2001. *British Tin-glazed Earthenware*. Buckinghamshire: Shire Publications.

Bleed, Peter. 2001. "Trees or Chains, Links or Branches: Conceptual Alternatives for Consideration of Stone Tool Production and Other Sequential Activities." *Journal of Archaeological Method and Theory* no. 8 (1):101-127.

Bruker Elemental. 2008. Bruker AXS Handheld S1 Tracer Portable XRF Analyzer User Manual. Kennewick: Bruker Elemental.

Burton, William. 1902. *A History and Description of English Porcelain*. London: Cassell and Son, Ltd.

Cooper, Emmanuel. 2000. *Ten Thousand Years of Pottery*. Philadelphia: University of Pennsylvania Press.

Craig, Nathan, Robert J. Speakman, Rachel S. Popelka-Filcoff, Michael D. Glascock, J. David Robertson, M. Steven Shackley, and Mark S. Aldenderfer. 2007. "Comparison of XRF and PXRF for Analysis of Archaeological Obsidian from Southern Peru." *Journal of Archaeological Science* no. 34 (12):2012-2024.

Dean, Darron, Andrew Hann Nfa, Mark Overton, and Jane Whittle. 2004. *Production and Consumption in English Households 1600-1750*. New York: Routledge.

Deetz, J. 1977. *In Small Things Forgotten: The Archaeology of Everyday Life in Early America*. New York: Doubleday.

DiStefano, Christine, Min Zhu, and Diana Mindrila. 2009. "Understanding and Using Factor Scores: Considerations for the Applied Researcher." *Practical Assessment, Research & Evaluation* no. 14 (20).

Dunnell, Robert C. 1971. "Sabloff and Smith's" The Importance of Both Analytic and Taxonomic Classification in the Type-Variety System"." *American Antiquity*: 115-118.

Dunnell, Robert C. 1986. "Methodological issues in Americanist Artifact Classification." *Advances in Archaeological Method and Theory*: 149-207.

Ewen, Charles R. 2003. *Artifacts*. Walnut Creek: Altamira.

Fluzin, Philippe, Marion Berranger, Sylvain Bauvais, Gaspard Pagès, and Philippe Dillmann. 2012. "An Archaeological and Archaeometrical Approach of Ferrous Semi-Product: A Diachronic Qualitative Typology (VIIth c. BC.-IInd c. AD)." *Acta Mineraria et Metallurgica, Studi in Onore di Marco Tizzoni*:195-204.

Ford, James A. 1954. "The Type Concept Revisited. *American Anthropologist* 56(1): 42-54.

Forster, Nicola, and Peter Grave. 2013. "Effects of Elevated Levels of Lead in Ceramics on Provenancing Studies Using Non-destructive PXRF: a Case Study in Byzantine Cypriot Glazed Ceramics." *X-Ray Spectrometry* no. 42 (6):480-486.

Gifford, James C. 1960. "The Type-variety Method of Ceramic Classification as an Indicator of Cultural Phenomena." *American Antiquity*:341-347.

Gladwin, W., and H. S. Gladwin. 1930. *Some Southwestern Pottery Types, Series I*: Medallion Papers.

Gladwin, W., and H. S. Gladwin. 1931. *Some Southwestern Pottery Types, Series II*: Medallion Papers.

Gladwin, W., and H. S. Gladwin. 1933. *Some Southwestern Pottery Types, Series III*: Medallion Papers.

Goren, Yuval, Hans Mommsen, and Jörg Klinger. 2011. "Non-destructive Provenance Study of Cuneiform Tablets Using Portable X-ray Fluorescence (pXRF)." *Journal of Archaeological Science* no. 38 (3):684-696.

Graham, Malcolm. 1908. *Cup and Saucer Land*. Stoke-on-Trent: Staffordshire and Stoke on Trent Archive Service.

Gray, Floyd, Deborah A. Kramer, and James D. Bliss. 2000. "Gallium and Gallium Compounds." In *Kirk-Othmer Encyclopedia of Chemical Technology*. New York: John Wiley & Sons, Inc.

Hale, Jessica A. 2008. *Secrets of the North Staffordshire Ceramic Recipes: Identifying Chemical Cariation and Uniformity Using an Archaeometric Approach*, Language, Culture, and Society, Oregon State University.

Hammond, Norman. 1972. "A Minor Criticism of the Type-Variety System of Ceramic Analysis." *American Antiquity* no. 37 (3):450-452.

Henderson, J. 2000. *The Science and Archaeology of Materials: An Investigation of Inorganic Materials*. New York: Routledge.

Hodder, Ian. 1982. *Symbols in Action: Ethnoarchaeological Studies of Material Culture*. Cambridge: Cambridge University Press.

Hodder, Ian. 1985. "Postprocessual archaeology." *Advances in Archaeological Method and Theory*:1-26.

Hodder, Ian, and Clive Orton. 1976. *Spatial Analysis in Archaeology*. Cambridge: Cambridge University Press.

Hou, Xiandeng, Yihua He, and Bradley T Jones. 2004. "Recent Advances in Portable X-Ray Fluorescence Spectrometry." *Applied Spectroscopy Reviews* no. 39 (1):1-25.

Hume, Ivor Noël. 2001. *If These Pots Could Talk: Collecting 2000 Years of British Household Pottery*. Milwaukee: Chipstone Foundation.

Hunt, A. M., and R.J. Speakman. 2015. Portable XRF Analysis of Archaeological Sediments and Ceramics. *Journal of Archaeological Science*, *53*, 626-638.

Ikeoka, R. A., C. R. Appoloni, P. S. Parreira, F. Lopes, and A. M. Bandeira. 2012. "PXRF and Multivariate Statistics Analysis of Pre-Colonial Pottery from Northeast of Brazil." *X-Ray Spectrometry* no. 41 (1):12-15.

Johnson, Matthew. 2010. *Archaeological Theory: An Introduction*. New York: John Wiley & Sons.

Keller, Charles M., and Janet Dixon Keller. 1996. *Cognition and Tool Use: The Blacksmith at Work*. Cambridge: Cambridge University Press.

Kingery, D. 1996. "Materials Science and Material Culture." In *Learning from Things: Method and Theory of Material Culture Studies*, edited by D. Kingery, 181-204. Washington, D.C.: Smithsonian Institution Press.

Krill, Rosemary Troy. 2010. *Early American Decorative Arts, 1620-1860: A Handbook for Interpreters*. Walnut Creek: AltaMira Press

Kuhn, Thomas S. 1962. "The Structure of Scientific Revolutions."

Leach, B. 1976. *A Potter's Book*. London: Faber & Faber.

Lindsey, W. Historic Glass Bottle Identification & Information Website. In *Society for Historical Archaeology*.

Liritzis, Ioannis, and Nikolaos Zacharias. 2011. "Portable XRF of Archaeological Artifacts: Current Research, Potentials and Limitations." In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M. Steven Shackley, 109-142. New York: Springer.

Maggetti, M. 2012. "Technology and Provenancing of French faience." *Seminarios de la Sociedad Espanola de Mineralogia* no. 9:41-64.

Maggetti, M., J. Rosen, and V. Serneels. 2014. "The Origin of 18th–19th Century Tin-Glazed Pottery from Lorraine, France." *Archaeometry*.

McKern, William C. 1939. "The Midwestern Taxonomic Method as an Aid to Archaeological Culture Study." *American Antiquity* no. 4 (4):301-313.

Meldgaard, Jørgen. 1960. "Origin and Evolution of Eskimo Cultures in the Eastern Arctic." *Canadian geographical journal*: 64-75.

Miller, George L. 1980. "Classification and Economic Scaling of 19th Century Ceramics." *Historical Archaeology*:1-40.
Miller, George L. 1987. "Origins of Josiah Wedgwood's 'Pearlware'." *Northeast Historical Archaeology* no. 16 (1):83-88.
Mitchell, Darren, Peter Grave, Michael Maccheroni, and Evgenia Gelman. 2012. "Geochemical Characterisation of North Asian Glazed Stonewares: A Comparative Analysis of NAA, ICP-OES and Non-Destructive pXRF." *Journal of Archaeological Science* no. 39 (9):2921-2933.
Mokyr, Joel. 1985. *The Economics of the Industrial Revolution*. Totowa: Rowman & Allanheld.
Moore, John H. 1994. "Putting Anthropology Back Together Again: The Ethnogenetic Critique of Cladistic Theory." *American Anthropologist* no. 96 (4):925-948.
Musson, A. E., and Eric Robinson. 1969. *Science and Technology in the Industrial Revolution*. Toronto: University of Toronto Press.
Neuwirth, Jessica L., Matthew Palus, and Mark P. Leone. 2002. "Cognitive Archaeology." In *The Encyclopedia of Historical Archaeology*: 112-114.
Newcomb, William Wilmon. 1956. *The Culture and Acculturation of the Delaware Indians*. Ann Arbor: University of Michigan.
O'Brien, Michael J., Briggs Buchanan, Mark Collard, and Matthew T. Boulanger. 2012. "Cultural Cladistics and the Early Prehistory of North America." In *Evolutionary Biology: Mechanisms and Trends*, 23-42. Berlin: Springer.
O'Brien, Michael J., Rlee Lyman, Youssef Saab, Elias Saab, John Darwent, and Daniel S. Glover. 2002. "Two Issues in Archaeological Phylogenetics: Taxon Construction and Outgroup Selection." *Journal of Theoretical Biology* no. 215 (2):133-150.
Ormrod, David. 2003. *The Rise of Commercial Empires: England and the Netherlands in the Age of Mercantilism, 1650-1770*. Cambridge: Cambridge University Press.
Orton, Clive, Michael Hughes, and Mike Hughes. 2013. *Pottery in Archaeology*. Cambridge: Cambridge University Press.
Ostermann, M. 2006. *The Ceramic Narrative*. London: A. & C. Black.
Owen, Harold. 1901. *The Staffordshire Potter*. G. Richards.
Papadopoulou, D., A. Sakalis, N. Merousis, and N. C. Tsirliganis. 2007. "Study of Decorated Archeological Ceramics by Micro X-ray Fluorescence Spectroscopy." *Proceedings of the 10th International Symposium on Radiation Physics ISRP 10* no. 580 (1):743-746.
Pauketat, T.R. 2001. Practice and History in Archaeology: An Emerging Paradigm. *Anthropological Theory*, no. 1(1):73-98.
Piorek, Stanislaw. 1997. "Field-portable X-ray Fluorescence Spectrometry: Past, Present, and Future." *Field Analytical Chemistry & Technology* no. 1 (6):317-329.
Potts, P. J., and Margaret West. *Portable X-ray Fluorescence Spectrometry Capabilities for In-situ Analysis*. RSC Pub. 2008.
Prown, Jules David. 1982. "Mind in Matter: An Introduction to Material Culture Theory and Method." *Winterthur Portfolio*:1-19.
Quimby, George I., and Alexander Spoehr. 1951. "Acculturation and Material Culture." *Fieldiana. Anthropology* no. 36 (6):107-147.

Read, Dwight W. 2009. *Artifact Classification: A Conceptual and Methodological Approach*. Walnut Creek: Left Coast Press.
Renfrew, A. C. 1998. *Cognition and Material Culture: The Archaeology of Symbolic Storage*. Cambridge: McDonald Institute for Archaeological Research.
Renfrew, A. C. 2005. "Cognitive Archaeology." In *Archaeology: The Key Concepts*, edited by A. C. Renfrew and P. Bahn, 41-5. London: Routledge.
Renfrew, Colin. 1993. "Cognitive Archaeology: Some Thoughts on the Archaeology of Thought." *Cambridge Archaeological Journal* no. 3 (2):248-50.
Rice, P. M. 1987. *Pottery Analysis: A Sourcebook*. Chicago: University of Chicago Press.
Richards, Sarah. 1999. *Eighteenth-century Ceramics: Products for a Civilised Society*. Manchester: Manchester University Press.
Sabloff, Jeremy A., and Robert E. Smith. 1969. "The Importance of Both Analytic and Taxonomic Classification in the Type-variety System." *American Antiquity*:278-285.
Schlanger, Nathan. 1996. "Understanding Levallois: Lithic Technology and Cognitive Archaeology." *Cambridge Archaeological Journal* no. 6 (02):231-254.
Shackel, Paul A., and Barbara J. Little. 1992. "Post-processual Approaches to Meanings and Uses of Material Culture in Historical Archaeology." *Historical Archaeology*: 5-11.
Shackley, M. Steven. 2010. "Is There Reliability and Validity in Portable X-ray Fluorescence Spectrometry (PXRF)." *The SAA Archaeological Record* no. 10 (5):17-20.
Shanks, Michael. 1998. "The Life of an Artifact in an Interpretive Archaeology." *Fennoscandia Archaeologica* no. 15:15-42.
Shanks, Michael, and Ian Hodder. 2007. "Processual, Postprocessual and Interpretive Archaeologies." In *Museums in the Material World*, edited by Simon J. Knell. New York: Routledge.
Shaw, Simeon. 1900 [1829]. *History of the Staffordshire Potteries; and the Rise and Progress of the Manufacture of Pottery and Porcelain; with References to Genuine Specimens, and Notices of Eminent Potters*. London: Scott, Greenwood, & Son.
Shugar, A. N., and J. L. Mass. 2012. *Handheld XRF for Art and Archaeology*. Leuven: Leuven University Press.
Smith, Neil G., Avshalom Karasik, Tejaswini Narayanan, Eric S. Olson, Uzy Smilansky, and Thomas E. Levy. 2014. "The Pottery Informatics Query Database: A New Method for Mathematic and Quantitative Analyses of Large Regional Ceramic Datasets." *Journal of Archaeological Method and Theory* no. 21 (1):212-250.
Spaulding, Albert C. 1953. "Statistical Techniques for the Discovery of Artifact Types." *American Antiquity* 18(4): 305-313.
Speakman, Robert J. 2012. "Evaluation of Bruker's Tracer Family Factory Obsidian Calibration for Handheld Portable XRF Studies of Obsidian." *Report prepared for Bruker AXS, Kennewick, WA. Available on-line: http://www. bruker-axs. com/fileadmin/user_upload/PDFse/handhelds/Bruker_Obsidian_Report. pdf.*
Speakman, Robert J., Nicole C. Little, Darrell Creel, Myles R. Miller, and Javier G. Iñañez. 2011. "Sourcing Ceramics with Portable XRF Spectrometers? A

Comparison with INAA using Mimbres Pottery from the American Southwest." *Journal of Archaeological Science* no. 38 (12):3483-3496.
Speakman, Robert. J. and M.S. Shackley. 2013. Silo Science and Portable XRF in Archaeology: A Response to Frahm. *Journal of Archaeological Science* no. 40(2), 1435-1443.
Spencer-Wood, Suzanne M. 1987. *Consumer Choice in Historical Archaeology*. New York: Plenum Press.
Tehrani, Jamshid, and Mark Collard. 2002. "Investigating Cultural Evolution through Biological Phylogenetic Analyses of Turkmen Textiles." *Journal of Anthropological Archaeology* no. 21 (4):443-463.
Tëmkin, Ilya, and Niles Eldredge. 2007. "Phylogenetics and Material Cultural Evolution." *Current Anthropology* no. 48 (1):146-154.
Trigger, Bruce G. 2006. *A History of Archaeological Thought*. Cambridge: Cambridge University Press.
Wedgwood, Josiah C. 1913. *Staffordshire Pottery and its History*. London: S. Low, Marston & Co. Ltd.
Wurst, LouAnn and Randall H. McGuire. 1999 "Immaculate Consumption: A Critique of the "Shop Till You Drop" School of Human Behavior. *International Journal of Historical Archaeology* no. 3(3):191-199.

Appendix A: Chipstone Sample Log

The Chipstone sample log with details for each artifact used in the analysis.

Chipstone Sample Log						
UWM Protocols						
15KeV/25µA	Full glaze area					
180 sec runs	3 areas/3 runs					
No filter	Kaolin Kga-2 Std					
Vacuum						
Volt regulator						
Sample #	*Identifier*	*Origin*	*Est. Date*	*Item Type*	*Glaze Type*	*Scanned Areas*
STD1	Kaolinite_Start_#	USGS				Sample Case
CS1	1993.3	London	1628-1650	Charger	White tin-glaze	Flat inner base
CS2	1991.13	London	1680-1710	Porringer	White tin-glaze	Flat inner base
CS3	1997.24	London	1650	Charger	Blue lead-glaze	Flat inner base
CS4	1990.6	London	1690-1720	Charger	Blue tin-glaze	Flat inner base
CS5	2011.7	Bristol	1700-1720	Charger	Blue tin-glaze	Flat inner base
STD2	Kaolinite_End_#	USGS				Sample Case
STD3	Kaolinite_Start2_#	USGS				Sample Case
CS6	2013.1	Portuguese	1670	Charger	Blue tin-glaze	Flat inner base
CS7	2000.58	England	1600	Charger	Blue tin-glaze	Flat inner base
CS8	2006.7	Italy	1620-1640	Charger	Tin-glaze	Flat inner base
CS9	1995.7	London	1660-1680	Hand warmer	White tin-glaze	Flat surface of books
CS10	1962.16(1)	London	1670-1685	Charger	Blue tin-glaze	Flat inner base
STD4	Kaolinite_End2_#	USGS				Sample Case
STD5	Kaolinite_Start3_#	USGS				Sample Case
CS11	1962.16(2)	London	1670-1685	Charger	Blue lead glaze	Flat base
CS12	1993.15	London	1628	Bottle	White tin-glaze	Body
CS13	1992.20	London	1650-1670	Posset pot	White tin-glaze	2 body/ 1 Lid
CS14	1992.21	London	1680	Posset pot	White tin-glaze	1 handle lid/2 body
CS15	2013.2	London	1660	Charger	Green lead-glaze	Front edge
CS16	1995.16	London	1681	Charger	Blue tin-glaze	Flat of area edge
CS17	1965.10	Staffordshire	1695	Owl jug	Lead-glaze	2 top head/ 1 body
CS18	2005.13	Massachusetts	1780-1820	Storage jar	Tin-glaze	1 Top lid/2 body
CS19	1969.11	Liverpool	1750-1770	Punch bowl	White tin-glaze	2 base/ 1 body
STD6	Kaolinite_End3_#	USGS				Sample Case
STD7	Kaolinite_Start4_#	USGS				Sample Case
CS20	1988.24	England	1670-1710	Charger	Lead glaze	Edge on front
CS21	1990.12	Staffordshire	1680-1720	Charger	Lead glaze	Flat inner base
CS22	1993.23	Staffordshire	1677	Charger	Lead glaze	Flat inner base
CS23	1993.16	Staffordshire	1715	Charger	Lead glaze	Flat edge on front
CS24	1998.3	Midlands?	1720-1740	Dish	Lead glaze	Flat inner base
CS25	1990.17	Kent	1722-1727	Tyg	Lead glaze	Rim
CS26	1970.4	Staffordshire	1670-1690	Charger	Lead glaze	Flat edge front
CS27	1989.12	Staffordshire	1650-1680	Charger	Lead glaze	Edge on front
CS28	1999.4	Staffordshire	1690	Charger	Lead glaze	Flat inner base
STD8	Kaolinite_End4_#	USGS				Sample Case
STD9	Kaolinite_Start5_#	USGS				Sample Case
CS29	1991.8	Staffordshire	1730	Charger	Lead glaze	Flat inner base
CS30	1967.13	Staffordshire	1695	Cup	Lead glaze	Body
CS31	1993.6	Staffordshire?	1733	Puzzle jug	Lead glaze	Body
CS32	1984.3	Midlands?	1731	Cup with cover	Lead glaze	Body
CS33	1994.3	Staffordshire	1710	Cup	Lead glaze	Body
STD10	Kaolinite_End5_#	USGS				Sample Case

The Chipstone sample log with details for each artifact used in the analysis continued.

Chipstone Sample Log (Continued)						
STD11	Kaolinite_Start6_#	USGS				Sample Case
CS34	1963.15	Kent	1649	Tyg	Lead glaze	Body
STD12	Kaolinite_End6_#	USGS				Sample Case
STD13	Kaolinite_Start7_#	USGS				Sample Case
CS35	2009.10	Netherlands	1690-1710	Plate	Tin-glazed	Inner base
CS36	1965.11	Netherlands	1700-1799	Jar	Delftware	Body
CS37	1996.125	Netherlands?		Plate	Delftware	Flat inner base
CS38	1952.18	Unknown		Barber's Bowl		2 inner base/1 base
CS39	1964.10	Italy	1600	Plate	Majolica	2 inner base/1 front
CS40	1966.8	London	1725	Punch bowl	Blue tin-glaze	2 body/1 base
CS41	1960.6	France (Rouen)	1700	Bleeding bowl	Faience	Body
CS42	2000.44	Staffordshire	1700-1725	Fuddling cups	Lead-glaze	Body
CS43	2001.71	Bristol	1710-1730	Plate	Delftware	Flat inner base
CS44	2001.74	Bristol	1710-1730	Plate	Delftware	Flat inner base
CS45	2001.69	Bristol	1750	Plate	Delftware	Flat inner base
STD 14	Kaolinite_End7_#	USGS				Sample Case
STD15	Kaolinite_Start8_#	USGS				Sample Case
CS46	2009.9	Bristol	1760-1775	Plate	Delftware	2 inner base/1 base
CS47	2001.63	Staffordshire	1775-1785	Plate	Lead glaze	2 inner base/1 base
CS48	2000.32	Staffordshire	1775-1785	Plate	Lead glaze	2 inner base/1 base
CS49	2001.1	Staffordshire	1780-1790	Compote	Lead glaze	Flat inner base
CS50	2000.38	Staffordshire	1780	Loving Cup	Lead glaze	Body
CS51	2000.36	Staffordshire	1810	Tankard	Lead glaze	Outer base
STD16	Kaolinite_End8_#	USGS				Sample Case
STD17	Kaolinite_Start9_#	USGS				Sample Case
CS52	2000.33	Derbyshire	1774-1780	Plate	Lead glaze	2 inner base/1 base
CS53	2003.35	Carlton China	1915	Ship Figurine	Lead glaze	Body
CS54	2003.38	Carlton China	1914-1915	WWI Figurine	Lead glaze	Flat Back
CS55	2003.36	Shelley China	1917	Camel Figurine	Lead glaze	Body
CS56	2003.40	Victoria China	1918	Tank Figurine	Lead glaze	Body
CS57	2003.37	Grafton China	1914-1918	WWI Figurine	Lead glaze	Body
CS58	2000.48	Staffordshire	1800	Jug	Lead glaze	Body
CS59	2006.15	Staffordshire	1800-1840	Mini Pitcher	Lead glaze	Body
CS60	2003.39	Arcadian China	1914-1918	WWI Figurine	Lead glaze	Body
STD18	Kaolinite_End9_#	USGS				Sample Case
STD19	Kaolinite_Start10_#	USGS				Sample Case
CS61	2006.16	Staffordshire	1800-1830	Mini Pitcher	Lead glaze	Body
CS62	2000.49	Staffordshire	1755-1775	Teapot	Lead glaze	Body
CS63	1990.18	Staffordshire	1760	Teapot	Lead glaze	Body
CS64	1978.6	Staffordshire	1745-1765	Teapot	Lead glaze	Body
CS65	2012.17	Staffordshire	1782-1785	Loving Cup	Lead glaze	Body
CS66	2012.16	Staffordshire	1782-1785	Teapot	Lead glaze	Body
CS67	2000.14	Staffordshire	1755	Tea Bowl/Saucer	Lead glaze	Bottom of Saucer
CS68	2012.15	Staffordshire	1782-1785	Portrait Mug	Lead glaze	Body
STD20	Kaolinite_End10_#	USGS				Sample Case
STD21	Kaolinite_Start11_#	USGS				Sample Case
CS69	2000.52	Staffordshire	1755	Teapot	Salt glaze	Body
CS70	1966.23	Nevers, France	1700s	Jardiniere	Salt glaze	Body
CS71	1983.6	Staffordshire	1760	Coffeepot	Salt glaze	Body
CS72	2005.1	Staffordshire	1755-1760	Teapot	Salt glaze	Body
CS73	1992.16	London	1680	Jardiniere	Tin-glaze	Body
CS74	1968.2	London?	1705	Charger	White tin-glaze	Flat inner base
CS75	2001.25	Essex	1893	Charger	Lead glaze	Flat inner base
CS76	1968.8	London	1702-1714	Charger	Tin-glaze	Flat inner base
CS77	1967.15	London	1695	Charger	Tin-glaze	Flat inner base
STD22	Kaolinite_End11_#	USGS				Sample Case

The Chipstone sample log with details for each artifact used in the analysis continued.

Chipstone Sample Log (Continued)						
STD23	Kaolinite_Start12_#	USGS				Sample Case
CS78	1963.28	Netherlands	1670-1700	Charger	White tin-glaze	Flat inner base
CS79	1961.13	Bristol	1727-1740	Charger	Blue tin-glaze	Flat inner base
CS80	1997.1(1)	London	1760	Sauce Boat	Tin-glaze	Body
CS81	1997.1(2)	London	1760	Sauce Boat	Tin-glaze	Body
CS82	2000.55	Staffordshire	1760	Sauce Boat	Tin-glaze	Body
CS83	2002.21	London	1740	Plate	Tin-glaze	Flat inner base
CS84	1964.31	London	1670-1700	Apothecary Jar	Tin-glaze	Body
CS85	1964.30	London	1670-1700	Apothecary Jar	Tin-glaze	Body
CS86	1967.18	London	1670-1700	Apothecary Jar	Tin-glaze	Body
CS87	1992.18	London	1700	Plate	Tin-glaze	Flat inner base
CS88	1964.29	London	1675-1700	Lozenge Jar	Tin-glaze	Body
STD24	Kaolinite_End12_#	USGS				Sample Case
STD25	Kaolinite_Start13_#	USGS				Sample Case
CS89	1989.10(1)	Staffordshire	1760	Fruit Basket/Stand	Green lead glaze	Flat inner base stand
CS90	1989.10(2)	Staffordshire	1760	Fruit Basket/Stand	Green lead glaze	Flat inner base stand
CS91	2008.1	Staffordshire	1770	Plate	Green lead glaze	Flat inner base
CS92	2001.51	Staffordshire	1790-1810	Dish	Green lead glaze	Flat base
CS93	1989.4(2)	London	1760	Wall Pockets	Delftware	Flat base
CS94	1989.4(1)	London	1760	Wall Pockets	Delftware	Flat base
STD26	Kaolinite_End13_#	USGS				Sample Case
STD27	Kaolinite_Start14_#	USGS				Sample Case
CS95	1995.4	Staffordshire	1775	Tumbler	Lead glaze	Body
CS96	1972.7	London	1669	Armorial Cup	Delft	Body
CS97	1991.7	London	1775-1785	Tankard	Delft	Body
CS98	1964.41	London	1765	Plate	Blue tin-glaze	Flat inner base
CS99	1999.16	Glasgow	1760	Plate	Tin-glaze	Flat inner base
CS100	1975.10	Bristol	1753	Armorial Cup	Blue delft	Body
CS101	1969.20	London	1676	Plate	Delft	Flat inner base
CS102	2000.66	London	1761	Plate	Delft	Flat inner base
STD28	Kaolinite_End14_#	USGS				Sample Case

Appendix B: Selected Photos of Chipstone Samples

Available images of artifacts used in the analysis taken from the Chipstone Foundation archives. See Appendix D for permission letter.

 CS1	 CS2
 CS3	 CS4
 CS9	 CS10

Images of analyzed Chipstone artifacts continued.

 CS12	 CS13
 CS14	 CS16
 CS17	 CS19

Image of analyzed Chipstone artifacts continued.

CS20

CS21

CS22

CS23

CS24

CS25

CS26

CS27

Images of analyzed Chipstone artifacts continued.


CS34


CS39


CS40


CS41


CS63

CS64


CS71


CS74

Images of analyzed Chipstone artifacts continued.

 CS76	 CS77
 CS80	 CS84
 CS85	 CS86

Images of analyzed Chipstone artifacts continued.

CS87

CS95

CS96

CS97

CS98

CS100

CS101

Appendix C: Raw Net Intensity Data for Chipstone Materials

Raw net intensity data for the artifacts used in the statistical analysis.

uniqueID	desig	readloc	readnum	AlK	CoK	CuK	FeK	GaK	MnK	NiK	PbL	SiK	SnL	TiK	ZnK	site	estyear
CS1.1.1	CS1	1	1	1822	10807	1181	36518	5221	345	3698	384402	12204	5132	817	93	L	1640
CS1.1.2	CS1	1	2	2355	6107	1210	20286	2866	19	2930	250931	4976	2198	681	655	L	1640
CS1.1.3	CS1	1	3	2036	5297	1789	26742	4729	298	2723	346082	10325	5032	667	313	L	1640
CS1.2.1	CS1	2	1	1865	14515	1369	41140	5498	265	4869	407512	11616	5448	631	202	L	1640
CS1.2.2	CS1	2	2	1707	17568	1533	43885	5345	332	6213	418941	8236	5061	865	424	L	1640
CS1.2.3	CS1	2	3	1542	19251	1254	44520	5234	322	6572	424291	6943	4989	639	271	L	1640
CS1.3.1	CS1	3	1	1754	13747	1423	42784	5612	444	4309	416780	9858	5723	589	568	L	1640
CS1.3.2	CS1	3	2	1759	13156	1505	42075	5291	806	4388	418137	9092	6067	608	0	L	1640
CS1.3.3	CS1	3	3	1939	12913	1556	41772	5808	651	4229	418258	10182	6026	709	114	L	1640
CS2.1.1	CS2	1	1	1985	534	5073	19536	3946	703	1949	303047	9093	15217	662	109	L	1690
CS2.1.2	CS2	1	2	2267	534	5185	19861	4195	699	2416	306558	9038	15501	376	246	L	1690
CS2.1.3	CS2	1	3	2142	360	5178	19403	4199	764	2026	307072	8747	15101	269	301	L	1690
CS2.2.1	CS2	2	1	2113	382	5218	20329	4201	892	1846	313777	8519	15664	190	320	L	1690
CS2.2.2	CS2	2	2	2147	411	5496	20685	4186	720	1832	319290	8353	15603	391	313	L	1690
CS2.2.3	CS2	2	3	2193	431	5416	20272	4078	533	2092	319541	8446	15503	594	367	L	1690
CS2.3.1	CS2	3	1	2144	680	4747	17997	3495	675	2172	276014	8156	12746	557	241	L	1690
CS2.3.2	CS2	3	2	2165	375	4798	18086	3369	469	1864	278619	8349	12782	440	547	L	1690
CS2.3.3	CS2	3	3	2241	465	4688	18094	3399	456	2005	280465	8239	12750	453	174	L	1690
CS3.1.1	CS3	1	1	1800	729	4131	17348	6058	16810	1782	412699	8636	3146	685	592	L	1650
CS3.1.2	CS3	1	2	1725	1259	3463	19250	5924	23612	1593	407360	8623	3646	703	731	L	1650
CS3.1.3	CS3	1	3	1800	1075	3848	17579	6107	19509	1909	409114	10683	3020	728	895	L	1650
CS3.2.1	CS3	2	1	1786	3344	3492	19541	5552	37618	2255	391987	11731	3224	856	1196	L	1650
CS3.2.2	CS3	2	2	1722	7262	3496	24181	5370	45169	3765	390733	11106	2862	1133	940	L	1650
CS3.2.3	CS3	2	3	1778	4259	3753	21405	5317	37660	2754	390385	11113	3233	969	1006	L	1650
CS3.3.1	CS3	3	1	1647	3793	4721	20661	5825	3561	2850	419962	7968	3441	537	510	L	1650
CS3.3.2	CS3	3	2	1741	5100	4765	22080	5719	3568	3180	420233	7631	3514	800	557	L	1650
CS3.3.3	CS3	3	3	1680	8128	4420	22842	5344	3673	4282	426887	7056	3359	680	681	L	1650
CS4.1.1	CS4	1	1	2206	1668	30807	27101	2148	1272	2041	265034	7129	7362	623	12236	L	1700
CS4.1.2	CS4	1	2	2280	1697	30877	27075	2284	1524	2350	267753	7249	7194	642	12378	L	1700
CS4.1.3	CS4	1	3	2199	1715	30603	27393	2272	1035	2579	269322	7195	7129	628	12755	L	1700
CS4.2.1	CS4	2	1	2097	1711	49425	32768	2288	1091	2387	309284	8268	8032	840	17978	L	1700
CS4.2.2	CS4	2	2	2068	1914	49917	32940	2640	1173	2170	310008	8242	8061	572	17893	L	1700
CS4.2.3	CS4	2	3	1966	1921	49805	33073	2781	1386	2196	312685	8156	7967	660	17682	L	1700
CS4.3.1	CS4	3	1	1771	1823	56181	34208	2425	1301	2586	327721	8098	8011	555	24377	L	1700
CS4.3.2	CS4	3	2	2102	1590	55371	34142	2576	1032	2385	330124	7979	7839	511	24693	L	1700
CS4.3.3	CS4	3	3	1864	1713	54905	34805	2540	1040	2210	331107	8092	7657	568	24730	L	1700
CS5.1.1	CS5	1	1	1868	733	4010	25237	6138	9474	1541	408035	10823	2538	1634	687	B	1710
CS5.1.2	CS5	1	2	1788	712	4660	24953	6055	9614	1788	411935	10260	2546	1535	850	B	1710
CS5.1.3	CS5	1	3	1932	482	4019	24940	6077	9261	1604	413602	10386	2527	1625	769	B	1710

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS5.2.1	CS5	2	1	1936	12943	2338	27246	4987	672	7823	388170	8542	2866	1628	2969	B	1710
CS5.2.2	CS5	2	2	1874	12627	2289	27455	5034	567	7585	391472	8753	2647	1445	3092	B	1710
CS5.2.3	CS5	2	3	1757	12977	2441	27502	5010	255	8045	393509	8900	2698	1309	2726	B	1710
CS5.3.1	CS5	3	1	1895	893	4095	30352	6122	406	1361	405094	10018	3355	1268	680	B	1710
CS5.3.2	CS5	3	2	1828	1025	4483	30364	5807	554	1744	407925	10328	3475	1518	882	B	1710
CS5.3.3	CS5	3	3	1850	883	4232	30004	6386	659	1604	408278	10301	3384	1197	715	B	1710
CS6.1.1	CS6	1	1	1481	22320	590	35754	4963	2583	6287	375211	1019	1418	1119	254	P	1670
CS6.1.2	CS6	1	2	1706	24139	991	38462	5789	2690	6686	410517	1075	1511	1227	365	P	1670
CS6.1.3	CS6	1	3	1630	24315	715	38735	5431	2866	7278	409727	1111	1483	1257	466	P	1670
CS6.2.1	CS6	2	1	1775	16526	809	32212	5118	2128	4545	393301	644	1956	5481	489	P	1670
CS6.2.2	CS6	2	2	1666	16369	658	32422	5523	2048	5048	392681	538	2036	5194	443	P	1670
CS6.2.3	CS6	2	3	1779	16638	690	32310	5034	1924	5174	394625	581	2047	5265	226	P	1670
CS6.3.1	CS6	3	1	1886	1838	1529	19698	4446	22525	2245	336555	501	1213	6573	434	P	1670
CS6.3.2	CS6	3	2	1977	2136	986	20567	4488	22349	2403	340075	512	1224	6744	241	P	1670
CS6.3.3	CS6	3	3	1894	1967	1286	20321	4529	22827	2470	341185	480	1202	6707	405	P	1670
CS8.1.1	CS8	1	1	2052	631	52933	34213	5071	2247	1531	361581	9226	2909	1647	342	I	1630
CS8.1.2	CS8	1	2	2051	572	54059	33658	5005	2289	1428	367622	9664	2924	1958	292	I	1630
CS8.1.3	CS8	1	3	2066	503	53985	34416	4792	2036	1504	368035	9912	2973	1636	232	I	1630
CS8.2.1	CS8	2	1	1983	701	75530	35897	5287	1283	1095	380806	10391	2967	1008	645	I	1630
CS8.2.2	CS8	2	2	1871	646	75144	36562	5587	1312	959	381630	10254	3032	1084	472	I	1630
CS8.2.3	CS8	2	3	2055	691	76360	36318	4880	1040	1172	382239	10404	3188	1002	0	I	1630
CS8.3.1	CS8	3	1	2357	645	3680	27855	5603	589	1632	383356	14936	3804	1552	486	I	1630
CS8.3.2	CS8	3	2	2327	761	3711	27928	5823	492	1397	384606	14971	3960	1570	505	I	1630
CS8.3.3	CS8	3	3	2431	507	3811	27852	5374	455	1417	386918	14868	3893	1427	187	I	1630
CS9.1.1	CS9	1	1	1709	569	3658	25070	5167	554	1091	383973	6157	14983	697	271	L	1670
CS9.1.2	CS9	1	2	1741	637	4009	24615	5221	532	1475	385741	6376	15083	489	206	L	1670
CS9.1.3	CS9	1	3	1830	769	4090	24870	5311	598	1552	386868	6079	14905	676	155	L	1670
CS9.2.1	CS9	2	1	1930	476	3398	24764	5010	521	1715	372494	8265	15521	569	147	L	1670
CS9.2.2	CS9	2	2	1865	570	3110	25011	4812	335	1455	372799	8308	15641	450	321	L	1670
CS9.2.3	CS9	2	3	1958	1034	3425	25301	4964	676	1409	372970	8493	15578	464	258	L	1670
CS9.3.1	CS9	3	1	1860	1258	3448	25039	4944	982	1419	377588	9075	16409	382	412	L	1670
CS9.3.2	CS9	3	2	1895	1457	3237	25299	5175	862	1784	378892	9036	16134	468	273	L	1670
CS9.3.3	CS9	3	3	1852	1760	3659	25353	5320	1025	1625	380511	9019	16335	518	433	L	1670
CS10.1.1	CS10	1	1	1964	882	46679	24146	4604	433	1123	362252	10569	12128	169	299	L	1670
CS10.1.2	CS10	1	2	1891	1025	46078	24092	4772	450	1614	363383	10748	12302	577	301	L	1670
CS10.1.3	CS10	1	3	1848	992	45939	23691	4889	495	1618	364401	10464	12449	429	334	L	1670
CS10.2.1	CS10	2	1	1762	392	152414	25762	3721	475	957	317538	6466	14500	401	1025	L	1670
CS10.2.2	CS10	2	2	1750	514	152239	25590	3962	501	1133	320329	6391	14414	333	998	L	1670
CS10.2.3	CS10	2	3	1773	679	152501	26052	3829	469	1293	320209	6437	14465	346	749	L	1670
CS10.3.1	CS10	3	1	1956	593	6639	20979	4332	706	1820	332680	7929	11628	474	117	L	1670

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS10.3.2	CS10	3	2	1916	942	6508	21593	4461	663	2099	335440	7929	11728	440	276	L	1670
CS10.3.3	CS10	3	3	1949	368	6605	20925	4256	286	1927	335509	7755	11672	493	159	L	1670
CS11.1.1	CS11	1	1	1309	1009	4842	31958	6374	190	1892	438620	5967	4932	722	300	L	1670
CS11.1.2	CS11	1	2	1471	1055	4702	32319	6623	715	1513	439177	6174	4644	601	496	L	1670
CS11.1.3	CS11	1	3	1304	874	4617	32192	6324	610	1430	440993	6006	4869	610	286	L	1670
CS11.2.1	CS11	2	1	1427	795	5269	29256	6637	308	1510	438090	7296	5573	571	11	L	1670
CS11.2.2	CS11	2	2	1362	1187	5198	29434	6497	299	1544	441011	7308	5498	467	0	L	1670
CS11.2.3	CS11	2	3	1481	819	5628	29775	6893	369	1654	440615	7616	5328	444	293	L	1670
CS11.3.1	CS11	3	1	1389	716	5057	29452	6407	137	1557	422981	7756	4532	475	444	L	1670
CS11.3.2	CS11	3	2	1403	621	5561	29788	6122	274	1673	424414	7769	4441	334	454	L	1670
CS11.3.3	CS11	3	3	1468	666	4768	29468	6243	110	1476	426411	7599	4511	600	393	L	1670
CS12.1.1	CS12	1	1	1664	19154	1251	44964	5062	394	9678	393602	16909	9553	471	249	L	1628
CS12.1.2	CS12	1	2	1829	19174	1014	45280	5009	328	9961	393987	16689	9710	383	59	L	1628
CS12.1.3	CS12	1	3	1866	19398	1132	44923	4927	260	9813	395093	17057	9601	495	114	L	1628
CS12.2.1	CS12	2	1	2232	8862	1482	33249	5135	407	4911	382474	19666	12121	442	98	L	1628
CS12.2.2	CS12	2	2	2267	8719	1293	33414	5464	216	4793	383773	19947	12135	538	351	L	1628
CS12.2.3	CS12	2	3	2263	8571	1238	33129	5224	222	4510	383981	19901	11923	699	162	L	1628
CS12.3.1	CS12	3	1	1585	21031	1021	36523	4625	666	10811	393733	7428	10135	523	103	L	1628
CS12.3.2	CS12	3	2	1519	21010	1135	36849	4801	403	10840	397274	7356	9967	429	75	L	1628
CS12.3.3	CS12	3	3	1574	21206	930	36463	4916	294	10350	396290	7531	10298	435	335	L	1628
CS13.1.1	CS13	1	1	1781	604	2644	23558	5317	613	1378	384985	7552	18334	341	454	L	1660
CS13.1.2	CS13	1	2	1560	701	2837	23312	5147	547	1400	386921	7231	18223	347	341	L	1660
CS13.1.3	CS13	1	3	1772	539	2194	22885	5204	336	1342	388298	7287	18197	484	326	L	1660
CS13.2.1	CS13	2	1	1530	735	2340	23217	5649	266	1140	380709	9423	16562	396	205	L	1660
CS13.2.2	CS13	2	2	1673	643	2334	23379	5234	577	1011	384837	9722	16488	328	232	L	1660
CS13.2.3	CS13	2	3	1611	801	2240	22900	5446	501	1300	383737	9579	16810	289	428	L	1660
CS13.3.1	CS13	3	1	1745	481	2402	23817	5141	519	1605	363527	11056	15382	471	392	L	1660
CS13.3.2	CS13	3	2	1834	802	2577	23825	5428	529	1658	368090	11277	15477	630	173	L	1660
CS13.3.3	CS13	3	3	1677	718	2601	23668	5115	242	1615	368646	11031	15428	437	235	L	1660
CS14.1.1	CS14	1	1	1856	18498	1711	40755	4692	24702	18691	369684	15677	9638	471	269	L	1680
CS14.1.2	CS14	1	2	1854	18948	1937	40864	4909	25157	18490	371876	15528	9807	567	344	L	1680
CS14.1.3	CS14	1	3	1953	18931	1997	40765	4551	24541	18710	372043	15476	9375	477	428	L	1680
CS14.2.1	CS14	2	1	1951	861	3258	25174	5076	1328	1413	382946	13057	9823	645	2673	L	1680
CS14.2.2	CS14	2	2	1987	1039	3695	25004	5137	1712	1649	386845	13139	9987	802	2821	L	1680
CS14.2.3	CS14	2	3	1775	919	3162	24901	5268	1862	1535	385786	12967	9894	671	2728	L	1680
CS14.3.1	CS14	3	1	1642	884	35684	26776	5076	354	1387	392769	6482	8397	459	690	L	1680
CS14.3.2	CS14	3	2	1609	620	35361	26579	5017	404	1461	394321	6596	8711	444	609	L	1680
CS14.3.3	CS14	3	3	1671	552	35392	26399	5333	529	1286	395792	6355	8780	498	587	L	1680
CS15.1.1	CS15	1	1	1686	1353	84035	29389	4687	519	1168	395745	8459	3339	760	2663	L	1660
CS15.1.2	CS15	1	2	1568	1967	83272	29874	4698	541	1334	398638	8240	3518	707	2828	L	1660

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS15.1.3	CS15	1	3	1717	1446	83076	29546	4686	366	1055	399255	8400	3278	635	2742	L	1660
CS15.2.1	CS15	2	1	1577	2036	69712	27517	4937	437	1440	403049	6524	3374	714	2315	L	1660
CS15.2.2	CS15	2	2	1540	1811	69098	27554	5089	711	1389	405352	6646	3503	736	2021	L	1660
CS15.2.3	CS15	2	3	1473	1912	68879	27445	4861	669	1399	406276	6698	3514	550	1933	L	1660
CS15.3.1	CS15	3	1	1538	6325	8238	28437	6377	657	2955	431124	7476	2709	729	373	L	1660
CS15.3.2	CS15	3	2	1541	6495	8279	28097	5758	401	2986	434984	7549	2725	732	407	L	1660
CS15.3.3	CS15	3	3	1408	6478	8443	28407	6079	720	2949	433767	7422	2656	700	457	L	1660
CS16.1.1	CS16	1	1	1533	15561	13444	40316	4026	2728	5408	384052	9843	7499	470	3333	L	1681
CS16.1.2	CS16	1	2	1793	15985	12952	40944	4299	2272	5409	388423	9682	7515	422	3491	L	1681
CS16.1.3	CS16	1	3	1572	15392	12997	40583	4105	2001	4905	388229	9775	7686	625	3703	L	1681
CS16.2.1	CS16	2	1	1483	40869	6170	62473	3321	4113	13352	377136	8041	3744	620	3957	L	1681
CS16.2.2	CS16	2	2	1615	39974	5899	62275	3425	4301	12822	378834	8097	3431	355	3761	L	1681
CS16.2.3	CS16	2	3	1590	39727	5973	61500	3771	3774	13527	377940	8254	3339	776	3416	L	1681
CS16.3.1	CS16	3	1	1644	28115	10156	51885	4069	3629	8712	394573	9956	5402	691	4100	L	1681
CS16.3.2	CS16	3	2	1640	27845	10283	52169	3675	3339	8729	395703	9889	5322	452	3254	L	1681
CS16.3.3	CS16	3	3	1658	27731	9697	52200	3801	3724	8642	396437	9831	5507	632	3425	L	1681
CS17.1.1	CS17	1	1	2267	1179	1434	34184	6884	538	1560	432979	7552	283	5815	467	S	1695
CS17.1.2	CS17	1	2	1936	811	1274	34177	6798	239	1428	434878	7670	316	5478	749	S	1695
CS17.1.3	CS17	1	3	2140	853	1291	33682	6860	361	1685	434356	7462	365	5744	441	S	1695
CS17.2.1	CS17	2	1	1910	809	1621	32188	6828	61	1328	448921	5382	66	4234	869	S	1695
CS17.2.2	CS17	2	2	1854	781	1642	31730	7249	154	1284	452044	5132	182	4161	650	S	1695
CS17.2.3	CS17	2	3	2160	720	1165	32001	6672	1	1523	453966	5231	67	4221	779	S	1695
CS17.3.1	CS17	3	1	1645	1019	1480	46106	6899	295	1538	445881	4750	91	3718	1106	S	1695
CS17.3.2	CS17	3	2	1806	975	1297	46451	6591	501	1482	452062	4778	84	3640	1055	S	1695
CS17.3.3	CS17	3	3	1962	1141	1343	46428	6769	305	1283	452872	4784	148	3523	1008	S	1695
CS21.1.1	CS21	1	1	1882	540	1336	22537	6498	360	1719	452190	5112	316	3890	2330	S	1690
CS21.1.2	CS21	1	2	1736	655	1717	22773	6646	368	1614	456811	5038	246	3569	2640	S	1690
CS21.1.3	CS21	1	3	1761	416	1366	22389	6908	90	1481	458651	4906	190	3608	2554	S	1690
CS21.2.1	CS21	2	1	2075	676	1568	31414	6254	707	1692	418593	5528	403	4477	2978	S	1690
CS21.2.2	CS21	2	2	1956	690	1321	30990	6060	821	1301	420883	5806	492	4265	2661	S	1690
CS21.2.3	CS21	2	3	1962	816	1023	31469	6124	569	1430	421790	5918	400	4315	2735	S	1690
CS21.3.1	CS21	3	1	1905	558	1446	27050	6595	323	1468	452284	5176	342	4018	2796	S	1690
CS21.3.2	CS21	3	2	1806	814	1980	27198	6794	564	1745	454938	5283	334	4225	2811	S	1690
CS21.3.3	CS21	3	3	1732	678	1489	27228	6727	234	1584	456442	5397	421	4147	2251	S	1690
CS22.1.1	CS22	1	1	2148	617	2006	28236	6837	167	1324	458149	7513	299	5550	676	S	1677
CS22.1.2	CS22	1	2	2137	978	1931	27563	7022	408	1510	459297	7531	224	5496	640	S	1677
CS22.1.3	CS22	1	3	2095	643	2092	27721	7335	369	1337	460387	7581	235	5212	915	S	1677
CS22.2.1	CS22	2	1	2094	644	1826	26360	7018	180	1429	446347	5810	242	4471	647	S	1677
CS22.2.2	CS22	2	2	2075	690	1559	26207	6982	377	1703	449730	5677	341	4577	751	S	1677
CS22.2.3	CS22	2	3	1933	687	1332	25974	6883	158	1366	449373	5480	201	4498	389	S	1677

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS22.3.1	CS22	3	1	1924	598	1962	28972	6760	629	1379	434157	5607	255	4748	896	S	1677
CS22.3.2	CS22	3	2	1909	762	1751	29528	6944	444	1477	435906	5347	224	4768	860	S	1677
CS22.3.3	CS22	3	3	1989	960	2047	29212	6594	359	1778	437400	5560	244	4700	1341	S	1677
CS23.1.1	CS23	1	1	2369	1190	1508	55660	6430	514	1223	429574	8378	340	5043	1677	S	1715
CS23.1.2	CS23	1	2	2294	1011	1790	54537	6421	224	1089	430742	8464	356	5015	1855	S	1715
CS23.1.3	CS23	1	3	2384	1098	1465	54384	6609	182	1396	431703	8245	293	5347	1846	S	1715
CS23.2.1	CS23	2	1	2388	868	1502	34901	6458	212	1477	434582	8582	329	5500	1070	S	1715
CS23.2.2	CS23	2	2	2499	884	1819	34401	6747	415	1386	436185	8646	272	5263	964	S	1715
CS23.2.3	CS23	2	3	2519	848	1657	34717	6588	132	1374	436960	8653	410	5102	926	S	1715
CS23.3.1	CS23	3	1	2333	1036	1541	50242	5852	564	1201	389695	8024	322	8110	1697	S	1715
CS23.3.2	CS23	3	2	2296	1194	1600	50044	5807	560	1383	390847	8271	369	7764	1328	S	1715
CS23.3.3	CS23	3	3	2250	1057	1978	49588	5779	286	1472	393131	8226	395	7716	1719	S	1715
CS26.1.1	CS26	1	1	2046	1213	1951	59796	6543	454	1328	414252	5270	412	3826	1512	S	1680
CS26.1.2	CS26	1	2	2086	898	1699	59133	6521	148	1132	418239	5195	386	3876	1658	S	1680
CS26.1.3	CS26	1	3	2011	821	1700	58925	6706	238	1079	420235	5072	287	3954	1310	S	1680
CS26.2.1	CS26	2	1	2146	1170	1704	71247	6185	317	1198	429230	6438	222	4165	1669	S	1680
CS26.2.2	CS26	2	2	2165	1187	1697	70925	6689	252	1095	431622	6399	360	3978	2001	S	1680
CS26.2.3	CS26	2	3	2149	1120	1763	66582	6325	574	980	433490	6181	261	3972	2134	S	1680
CS26.3.1	CS26	3	1	2091	1364	1652	72966	5985	681	1206	413685	5782	314	4072	2019	S	1680
CS26.3.2	CS26	3	2	2046	1460	1893	72769	6085	629	923	416958	5688	312	4076	1613	S	1680
CS26.3.3	CS26	3	3	2053	1667	1458	73276	6136	406	1091	416424	5776	349	4107	2021	S	1680
CS27.1.1	CS27	1	1	1674	980	1594	50559	6191	355	1321	439904	4472	233	3198	7701	S	1665
CS27.1.2	CS27	1	2	1775	1059	1762	50227	6600	361	944	441284	4622	146	3254	7677	S	1665
CS27.1.3	CS27	1	3	1738	943	1512	50984	6248	470	1101	443357	4500	156	3349	7010	S	1665
CS27.2.1	CS27	2	1	1937	777	1250	38748	6553	388	1428	448992	5470	189	3373	9809	S	1665
CS27.2.2	CS27	2	2	1691	965	1848	41911	6472	385	1027	452645	4158	154	3443	9833	S	1665
CS27.2.3	CS27	2	3	1628	752	1359	42160	6340	433	1521	454042	3991	213	3340	9579	S	1665
CS27.3.1	CS27	3	1	1782	1079	1459	48902	5939	1524	1234	430500	4271	300	2819	8055	S	1665
CS27.3.2	CS27	3	2	1846	942	1384	48953	5869	1398	1296	434138	4213	241	2834	8233	S	1665
CS27.3.3	CS27	3	3	1800	992	1669	49022	6105	1536	1172	434133	4384	151	2816	8631	S	1665
CS28.1.1	CS28	1	1	2171	636	1957	27324	6322	417	1331	411862	4885	223	4905	7841	S	1690
CS28.1.2	CS28	1	2	2134	490	1780	27866	6056	557	1704	413093	4646	250	4879	7895	S	1690
CS28.1.3	CS28	1	3	1941	580	1738	27904	6108	855	1597	414738	4716	304	5176	7609	S	1690
CS28.2.1	CS28	2	1	2114	479	1841	22282	6870	572	1554	454286	4976	196	3786	5266	S	1690
CS28.2.2	CS28	2	2	1828	614	2133	22395	6224	225	1495	458099	5063	210	3657	5401	S	1690
CS28.2.3	CS28	2	3	1889	597	1998	22167	6747	556	1547	457048	4949	194	3805	5476	S	1690
CS28.3.1	CS28	3	1	2000	678	2151	25375	6433	378	1564	416020	5045	255	4792	5873	S	1690
CS28.3.2	CS28	3	2	1903	701	2111	25212	6044	299	1389	418461	5022	272	4344	5496	S	1690
CS28.3.3	CS28	3	3	2169	724	2265	25145	6456	572	1702	420737	5163	216	4492	5686	S	1690
CS29.1.1	CS29	1	1	1700	854	3068	37313	6139	201	1458	434464	5531	138	5773	11200	S	1730

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS29.1.2	CS29	1	2	1618	807	3116	37572	6133	546	1232	436201	4960	166	5682	10503	S	1730
CS29.1.3	CS29	1	3	1536	933	2971	37484	6425	613	1250	436101	4803	250	5988	10597	S	1730
CS29.2.1	CS29	2	1	1382	1043	2927	51997	6430	217	1051	458060	4079	290	6442	5888	S	1730
CS29.2.2	CS29	2	2	1287	916	2827	51755	6792	205	1106	457904	4067	275	6501	6290	S	1730
CS29.2.3	CS29	2	3	1260	1014	3054	51674	6524	97	1353	460424	4103	195	6232	5858	S	1730
CS29.3.1	CS29	3	1	1311	766	3122	35561	6925	449	1406	444053	4884	242	5065	8387	S	1730
CS29.3.2	CS29	3	2	1467	736	2710	35243	6637	129	1074	444126	4998	271	5338	8384	S	1730
CS29.3.3	CS29	3	3	1581	543	3180	35377	6296	586	1498	446558	5260	256	5200	8190	S	1730
CS30.1.1	CS30	1	1	1430	707	1572	58583	6116	590	940	438672	3982	278	6193	27624	S	1695
CS30.1.2	CS30	1	2	1333	917	1923	57543	5770	589	1079	441791	3999	170	6090	27245	S	1695
CS30.1.3	CS30	1	3	1284	829	1777	57933	6424	732	943	442588	4157	160	5750	27953	S	1695
CS30.2.1	CS30	2	1	1361	778	1696	30533	6026	786	1173	445065	4362	500	6587	33757	S	1695
CS30.2.2	CS30	2	2	1297	578	1976	29965	5990	864	1123	448211	4298	427	6527	34517	S	1695
CS30.2.3	CS30	2	3	1251	296	1637	30350	5893	883	1279	449552	4243	388	6763	34856	S	1695
CS30.3.1	CS30	3	1	1229	556	910	37750	6038	1273	1316	437829	4466	765	9060	20571	S	1695
CS30.3.2	CS30	3	2	1336	661	1362	37684	6351	1209	1321	439237	4634	582	8531	21320	S	1695
CS30.3.3	CS30	3	3	1405	485	1328	38064	6407	1258	1323	438461	4572	602	8770	20822	S	1695
CS31.1.1	CS31	1	1	1284	1083	1559	55489	7155	507	1192	460621	4928	231	5441	797	S	1733
CS31.1.2	CS31	1	2	1273	1110	1887	55615	6956	493	988	462358	4824	335	5134	1018	S	1733
CS31.1.3	CS31	1	3	1370	1089	1556	55436	6930	358	908	463027	4839	275	5114	1120	S	1733
CS31.2.1	CS31	2	1	1362	772	2045	37416	7223	841	1253	467804	4080	236	5565	1374	S	1733
CS31.2.2	CS31	2	2	1296	663	1722	37676	7065	942	1381	466909	3798	260	5800	905	S	1733
CS31.2.3	CS31	2	3	1381	762	1946	37697	7500	878	1212	468490	3755	290	5724	746	S	1733
CS31.3.1	CS31	3	1	1199	1143	1514	66071	7158	305	1010	456475	3779	405	5747	1455	S	1733
CS31.3.2	CS31	3	2	1403	1092	1705	65575	6944	506	1036	460117	3921	278	5831	1240	S	1733
CS31.3.3	CS31	3	3	1239	1042	1652	65135	7537	559	910	459096	3734	380	5894	1732	S	1733
CS33.1.1	CS33	1	1	1366	950	2132	50064	7111	1003	1176	461796	4307	363	5615	1258	S	1710
CS33.1.2	CS33	1	2	1208	856	1800	49241	7250	1069	1067	463431	4148	272	5533	1261	S	1710
CS33.1.3	CS33	1	3	1307	1095	1557	49011	7128	1070	1084	465079	4059	253	5570	1068	S	1710
CS33.2.1	CS33	2	1	1342	697	1935	33874	6808	818	1248	462356	3508	355	6257	1854	S	1710
CS33.2.2	CS33	2	2	1302	510	1586	33311	7253	566	1239	462208	3363	359	6187	1495	S	1710
CS33.2.3	CS33	2	3	1247	565	2136	33261	6862	754	1368	462541	3370	329	6247	1629	S	1710
CS33.3.1	CS33	3	1	1187	685	1697	36387	7036	967	1249	468205	3688	380	6316	2492	S	1710
CS33.3.2	CS33	3	2	1291	661	1267	35700	6771	556	1123	468242	3713	430	6311	1830	S	1710
CS33.3.3	CS33	3	3	1255	750	1472	36330	7458	721	1191	470458	3765	224	6259	2254	S	1710
CS35.1.1	CS35	1	1	1364	18218	2565	34450	5354	774	11308	374978	8566	11971	434	109	N	1700
CS35.1.2	CS35	1	2	1291	17821	3075	34585	5308	752	11616	378840	8559	11891	489	504	N	1700
CS35.1.3	CS35	1	3	1318	18436	2644	34620	5395	939	11284	380320	8491	11931	399	127	N	1700
CS35.2.1	CS35	2	1	1404	794	3691	19712	5067	643	1270	370778	9291	15593	180	650	N	1700
CS35.2.2	CS35	2	2	1462	639	3618	20215	4857	962	1206	371926	9318	15675	268	564	N	1700

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS35.2.3	CS35	2	3	1441	827	4053	20268	5073	1061	1307	371715	9215	15649	471	781	N	1700
CS35.3.1	CS35	3	1	1478	1813	2603	34408	4538	1450	1920	357844	7919	13840	629	597	N	1700
CS35.3.2	CS35	3	2	1588	1793	2632	34563	5043	1011	1786	358364	7933	13604	529	925	N	1700
CS35.3.3	CS35	3	3	1511	1762	3027	34886	4780	955	2118	359055	8052	13658	600	1067	N	1700
CS36.1.1	CS36	1	1	1464	11433	2851	22994	6143	2101	7958	428344	7105	3663	652	605	N	1750
CS36.1.2	CS36	1	2	1259	11096	2798	23371	6092	2199	7965	428898	7054	3633	785	480	N	1750
CS36.1.3	CS36	1	3	1281	11105	3135	23234	6127	2349	7951	429065	7182	3794	805	550	N	1750
CS36.2.1	CS36	2	1	1389	701	3597	14342	5748	508	1811	407376	8573	10888	114	893	N	1750
CS36.2.2	CS36	2	2	1481	831	3565	14372	5858	547	1496	408992	8569	10868	177	1208	N	1750
CS36.2.3	CS36	2	3	1536	850	4139	14396	5589	420	1778	408661	8536	10856	476	1369	N	1750
CS36.3.1	CS36	3	1	1423	929	3312	13587	5420	472	2349	412788	8256	9582	697	576	N	1750
CS36.3.2	CS36	3	2	1483	984	3675	13474	6057	538	2195	413388	8610	9606	447	946	N	1750
CS36.3.3	CS36	3	3	1442	916	3893	13378	5878	481	2275	415806	8519	9879	340	1055	N	1750
CS37.1.1	CS37	1	1	1176	4763	547	55106	5613	327	748	400725	5655	2639	602	51002	N	1750
CS37.1.2	CS37	1	2	1179	4387	815	55131	5340	314	757	404772	5472	2481	653	51736	N	1750
CS37.1.3	CS37	1	3	1281	4589	342	55512	5611	529	636	403490	5487	2611	408	51904	N	1750
CS37.2.1	CS37	2	1	1220	6871	513	73367	5423	85	1413	398036	5281	2357	220	49048	N	1750
CS37.2.2	CS37	2	2	1248	6932	393	72354	5545	69	1370	400155	5299	2238	514	48891	N	1750
CS37.2.3	CS37	2	3	1100	6935	360	73077	5426	181	1647	401297	5113	2144	301	48999	N	1750
CS37.3.1	CS37	3	1	1188	9835	459	49723	5655	171	1325	405786	5932	3720	322	31877	N	1750
CS37.3.2	CS37	3	2	1382	9778	715	48923	5754	184	1368	408857	6051	3871	163	31482	N	1750
CS37.3.3	CS37	3	3	1218	9704	316	49338	5852	281	1103	409811	6052	3917	352	31718	N	1750
CS39.1.1	CS39	1	1	1606	507	2588	20935	5407	322	1437	394441	7760	11474	226	516	I	1600
CS39.1.2	CS39	1	2	1646	508	2728	20672	6187	675	1489	395040	8121	11339	327	523	I	1600
CS39.1.3	CS39	1	3	1400	515	2200	20222	6034	510	1312	396231	7925	11175	277	488	I	1600
CS39.2.1	CS39	2	1	1319	529	2390	21083	6234	315	1132	405311	7585	12132	418	363	I	1600
CS39.2.2	CS39	2	2	1375	316	2640	21190	6243	429	1276	408943	7790	12311	324	455	I	1600
CS39.2.3	CS39	2	3	1315	587	2500	21012	6132	602	1060	408481	7834	12225	354	247	I	1600
CS39.3.1	CS39	3	1	1340	670	2138	22099	5991	413	880	403411	7798	12173	459	531	I	1600
CS39.3.2	CS39	3	2	1408	769	2822	22298	5973	233	1294	406133	7698	12218	299	693	I	1600
CS39.3.3	CS39	3	3	1310	731	2441	21723	5981	411	1136	407425	7847	12176	542	612	I	1600
CS40.1.1	CS40	1	1	1595	943	9459	23402	5344	726	1086	388627	9279	9098	1626	666	L	1725
CS40.1.2	CS40	1	2	1664	477	9394	23566	5556	515	1175	389252	9058	9216	1663	847	L	1725
CS40.1.3	CS40	1	3	1546	618	9700	23289	5694	809	1590	390887	9005	9071	1807	620	L	1725
CS40.2.1	CS40	2	1	1613	459	8003	22818	5819	820	1589	403276	10644	7413	1930	609	L	1725
CS40.2.2	CS40	2	2	1661	785	7574	23084	5799	724	1350	404963	10672	7669	1685	494	L	1725
CS40.2.3	CS40	2	3	1798	568	7311	22572	5355	745	1193	405574	10505	7810	1912	441	L	1725
CS40.3.1	CS40	3	1	1725	552	7878	24588	6002	475	1481	410510	10381	6322	1900	890	L	1725
CS40.3.2	CS40	3	2	1457	674	7839	24735	5950	898	1287	411466	10332	6384	1852	522	L	1725
CS40.3.3	CS40	3	3	1572	499	8055	23977	6058	717	1523	412706	10263	6525	1831	581	L	1725

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS41.1.1	CS41	1	1	1569	10008	6857	11024	5912	2894	1276	405467	9074	15947	207	1249	FR	1700
CS41.1.2	CS41	1	2	1653	9891	7105	10802	5939	2862	1394	409455	8940	16217	83	943	FR	1700
CS41.1.3	CS41	1	3	1411	10004	6817	10508	5808	3069	1304	409404	9088	16136	180	1222	FR	1700
CS41.2.1	CS41	2	1	1629	1309	7132	10485	5414	121	1272	405390	8758	18133	22	902	FR	1700
CS41.2.2	CS41	2	2	1494	915	7030	10317	5432	313	1064	407999	8818	18523	82	836	FR	1700
CS41.2.3	CS41	2	3	1634	823	7103	9997	5641	41	1032	408925	8596	18443	154	722	FR	1700
CS41.3.1	CS41	3	1	1633	1196	8163	10250	5500	43	1062	408526	8440	18377	125	665	FR	1700
CS41.3.2	CS41	3	2	1580	930	8264	10297	5510	102	1108	411158	8194	18299	88	459	FR	1700
CS41.3.3	CS41	3	3	1604	784	8233	10581	5450	103	937	412503	8287	18529	0	604	FR	1700
CS42.1.1	CS42	1	1	1494	334	2211	54436	5542	125887	623	391137	6641	538	5049	3578	S	1710
CS42.1.2	CS42	1	2	1405	603	2449	55141	5654	125738	965	391509	6719	565	4824	3972	S	1710
CS42.1.3	CS42	1	3	1422	574	2496	54020	5503	125819	895	393154	6535	464	4912	3991	S	1710
CS42.2.1	CS42	2	1	1355	523	2184	52172	5338	129969	673	386487	6993	465	4900	3099	S	1710
CS42.2.2	CS42	2	2	1351	269	2029	51788	5517	129902	680	388259	6943	329	4690	3064	S	1710
CS42.2.3	CS42	2	3	1458	509	2602	52353	5450	130118	879	388436	6817	383	4648	2819	S	1710
CS42.3.1	CS42	3	1	1376	237	2285	48996	5384	130109	624	390657	6961	458	5486	3708	S	1710
CS42.3.2	CS42	3	2	1577	3	1885	49076	5381	130028	654	391417	7134	438	5080	3640	S	1710
CS42.3.3	CS42	3	3	1524	789	2298	48974	5370	130114	994	390714	6924	474	5280	4026	S	1710
CS43.1.1	CS43	1	1	1672	11999	3687	32615	5169	882	11521	387716	11058	5076	1400	632	B	1720
CS43.1.2	CS43	1	2	1814	11710	3772	32502	5273	1361	11321	393942	11206	4958	1720	390	B	1720
CS43.1.3	CS43	1	3	1645	11709	3786	32971	5035	746	11162	392762	11253	4912	1558	759	B	1720
CS43.2.1	CS43	2	1	1723	657	5058	25745	5333	784	1978	393264	11157	4893	1781	1096	B	1720
CS43.2.2	CS43	2	2	1876	758	4847	25296	5753	839	1752	393183	11019	4525	1669	763	B	1720
CS43.2.3	CS43	2	3	1802	632	4622	25397	5961	704	1799	394841	11011	4640	1769	829	B	1720
CS43.3.1	CS43	3	1	1695	870	5139	25641	5451	730	1766	379593	11088	6665	1441	1198	B	1720
CS43.3.2	CS43	3	2	1666	575	5046	25506	5473	837	1396	381614	11239	6772	1521	1062	B	1720
CS43.3.3	CS43	3	3	1689	855	5117	25239	5674	646	1766	381897	11319	6766	1640	1303	B	1720
CS44.1.1	CS44	1	1	1653	1325	4359	30947	6238	702	1653	421202	9020	3803	2077	1049	B	1720
CS44.1.2	CS44	1	2	1664	1127	4266	31335	5733	676	1513	422167	9343	3708	1865	1145	B	1720
CS44.1.3	CS44	1	3	1665	1242	4620	31636	6061	365	1739	422821	9035	3671	2081	935	B	1720
CS44.2.1	CS44	2	1	1597	1061	4648	29522	5768	599	1547	401463	9260	7420	1744	1425	B	1720
CS44.2.2	CS44	2	2	1691	1365	4211	29813	5803	412	1456	402406	9580	7299	1739	1269	B	1720
CS44.2.3	CS44	2	3	1647	1240	4676	29604	5783	734	1806	402968	9252	7263	1551	910	B	1720
CS44.3.1	CS44	3	1	1577	972	4473	31121	6208	570	1893	403225	10551	4688	1560	1207	B	1720
CS44.3.2	CS44	3	2	1634	1072	4456	31052	6037	825	1724	405900	10729	4815	1803	1434	B	1720
CS44.3.3	CS44	3	3	1687	1023	4298	30604	5990	543	1969	406494	10737	4826	1807	1463	B	1720
CS45.1.1	CS45	1	1	1559	390	5553	23278	4579	819	1702	337678	9494	22452	827	835	B	1750
CS45.1.2	CS45	1	2	1744	500	5827	22981	4263	809	1446	338851	9685	22347	890	1060	B	1750
CS45.1.3	CS45	1	3	1648	405	6062	23300	4582	661	1562	338440	9631	22805	973	1173	B	1750
CS45.2.1	CS45	2	1	1862	692	5834	23407	4517	889	1420	340666	9919	22629	992	1074	B	1750

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS45.2.2	CS45	2	2	1694	485	5674	23321	4306	967	1601	342341	9826	22985	931	855	B	1750
CS45.2.3	CS45	2	3	1872	519	5735	23072	5024	731	1599	343150	9668	22473	874	1233	B	1750
CS45.3.1	CS45	3	1	1511	410	5651	23336	4484	928	1612	340017	10009	22898	1110	1179	B	1750
CS45.3.2	CS45	3	2	1824	520	5478	23709	4536	534	1545	340459	10192	22973	888	1182	B	1750
CS45.3.3	CS45	3	3	1725	427	5461	23446	4582	900	1641	341416	10266	23019	1290	986	B	1750
CS46.1.1	CS46	1	1	17629	2175	4194	22342	6444	1074	1686	288967	64954	28651	58	535	B	1770
CS46.1.2	CS46	1	2	17994	2045	4210	22432	6144	809	2060	290103	64655	28261	143	681	B	1770
CS46.1.3	CS46	1	3	17809	2174	4043	22325	6466	945	2104	289560	64685	29146	430	196	B	1770
CS46.2.1	CS46	2	1	17912	2139	4144	22156	6233	1128	1751	291587	65000	28789	235	414	B	1770
CS46.2.2	CS46	2	2	18193	1912	4055	22105	6351	1176	2018	291589	64536	28586	345	416	B	1770
CS46.2.3	CS46	2	3	17977	2041	4261	22497	6327	1052	1774	292456	65103	28555	357	477	B	1770
CS46.3.1	CS46	3	1	23113	2312	3934	22941	6491	991	1739	289290	66257	26431	251	461	B	1770
CS46.3.2	CS46	3	2	23303	2453	3708	22775	6513	976	1598	290898	65899	26411	253	432	B	1770
CS46.3.3	CS46	3	3	23219	2218	3622	22110	6589	766	1676	290961	65763	26405	0	509	B	1770
CS47.1.1	CS47	1	1	25781	664	1793	13148	9233	450	1195	359970	55970	666	3828	240	S	1770
CS47.1.2	CS47	1	2	25667	734	2092	13071	9564	263	1365	360414	55967	615	3670	429	S	1770
CS47.1.3	CS47	1	3	25475	1100	1847	13454	9211	320	1006	360854	55994	694	3697	-1	S	1770
CS47.2.1	CS47	2	1	29905	600	1489	15012	9442	263	982	348259	60108	796	3767	264	S	1770
CS47.2.2	CS47	2	2	29961	1040	1566	14590	9392	408	1130	349769	60309	737	3731	-1	S	1770
CS47.2.3	CS47	2	3	29453	794	1497	14774	9581	232	922	350814	60358	680	3788	243	S	1770
CS47.3.1	CS47	3	1	26080	724	1741	13451	9181	320	773	359697	54216	410	3408	141	S	1770
CS47.3.2	CS47	3	2	25887	765	2012	13780	9290	19	833	360822	53715	561	3450	263	S	1770
CS47.3.3	CS47	3	3	25813	711	2094	13819	9213	161	1049	362002	54475	599	3446	228	S	1770
CS48.1.1	CS48	1	1	17977	389	2551	9658	9310	138	911	367931	45111	154	3405	290	S	1770
CS48.1.2	CS48	1	2	18245	681	2242	9679	9131	242	811	368132	45596	160	3429	76	S	1770
CS48.1.3	CS48	1	3	18430	408	2505	9485	9450	285	1032	368489	44897	163	3507	353	S	1770
CS48.2.1	CS48	2	1	19504	740	2439	10479	9620	290	992	365526	46756	210	3519	381	S	1770
CS48.2.2	CS48	2	2	19203	406	2214	10280	9235	155	869	367751	46713	147	3309	321	S	1770
CS48.2.3	CS48	2	3	18613	725	2217	10725	9273	343	1120	366585	46129	136	3457	587	S	1770
CS48.3.1	CS48	3	1	19992	721	2612	10055	9224	1	1105	364365	45389	129	3489	540	S	1770
CS48.3.2	CS48	3	2	19920	635	2354	10105	9210	82	1091	365218	45005	62	3487	383	S	1770
CS48.3.3	CS48	3	3	20080	518	2432	9991	9086	175	956	364835	45130	38	3334	401	S	1770
CS49.1.1	CS49	1	1	28738	1147	2103	6688	9253	378	1159	355881	65722	1867	1387	345	S	1785
CS49.1.2	CS49	1	2	28836	1203	1955	6714	9033	532	1615	358168	65683	1898	1183	448	S	1785
CS49.1.3	CS49	1	3	28429	1158	2245	6758	9218	478	1462	359515	65176	1804	1258	418	S	1785
CS49.2.1	CS49	2	1	29609	1268	2234	6811	9386	577	1522	356734	67575	1870	1201	559	S	1785
CS49.2.2	CS49	2	2	29713	1203	2115	6798	8926	450	1292	357972	67242	1628	1037	305	S	1785
CS49.2.3	CS49	2	3	29227	1081	2016	6701	9233	698	1426	359395	66756	1921	1337	441	S	1785
CS49.3.1	CS49	3	1	25607	1289	2187	6794	9192	654	1552	359801	67541	1634	922	538	S	1785
CS49.3.2	CS49	3	2	25278	1344	2296	7149	8828	483	1426	361450	66822	1875	992	389	S	1785

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS49.3.3	CS49	3	3	25379	1422	2403	6614	9004	542	1422	361629	66319	1916	1180	447	S	1785
CS50.1.1	CS50	1	1	24274	2303	1362	13628	9496	538	952	360769	51097	1128	2640	247	S	1780
CS50.1.2	CS50	1	2	23933	2036	1919	13598	9736	305	1291	361352	50818	1159	2597	546	S	1780
CS50.1.3	CS50	1	3	23646	1945	1735	13906	9476	338	1363	361276	50931	1047	2849	322	S	1780
CS50.2.1	CS50	2	1	23493	1733	1604	13578	8983	303	950	362291	50382	1052	2778	374	S	1780
CS50.2.2	CS50	2	2	23236	1947	1571	13369	9164	379	1116	363810	49689	1114	2577	223	S	1780
CS50.2.3	CS50	2	3	23334	1904	1838	13491	9281	318	1109	363634	49479	1140	2781	431	S	1780
CS50.3.1	CS50	3	1	24990	2014	1375	14323	9296	668	1060	356581	53292	1495	2666	278	S	1780
CS50.3.2	CS50	3	2	24495	1970	1631	14482	9371	326	1021	358850	53380	1512	2758	486	S	1780
CS50.3.3	CS50	3	3	25366	2137	1674	14727	9369	222	1152	357443	53011	1495	2668	155	S	1780
CS51.1.1	CS51	1	1	17724	1874	1191	6111	9102	103	1366	364333	43242	2215	2204	113	S	1810
CS51.1.2	CS51	1	2	17602	2142	1218	6118	9103	268	1460	364859	42960	2148	2040	-4	S	1810
CS51.1.3	CS51	1	3	17461	2267	1158	6422	9306	206	1546	364913	42769	2105	2102	201	S	1810
CS51.2.1	CS51	2	1	14383	1723	1242	5882	9164	277	1509	375471	39987	2324	2037	464	S	1810
CS51.2.2	CS51	2	2	14228	1942	1289	6225	9304	428	1572	374749	39744	2151	1911	182	S	1810
CS51.2.3	CS51	2	3	13788	2076	1284	5888	9243	1	1640	375884	40500	2151	2122	257	S	1810
CS51.3.1	CS51	3	1	15971	2103	1566	5772	9248	116	1541	365513	40714	1896	2305	175	S	1810
CS51.3.2	CS51	3	2	16735	2081	1506	5933	9300	1	1439	365041	40976	2086	2294	240	S	1810
CS51.3.3	CS51	3	3	16176	2256	1296	5717	9175	255	1469	365444	40778	2172	2414	157	S	1810
CS53.1.1	CS53	1	1	98548	2192	2381	24635	6322	1513	470	212656	122753	14854	579	987	S	1915
CS53.1.2	CS53	1	2	98240	2105	2344	24628	6438	1434	486	213160	123248	14534	535	687	S	1915
CS53.1.3	CS53	1	3	98672	2268	2283	25267	6339	1548	605	213076	122032	14893	682	680	S	1915
CS53.2.1	CS53	2	1	105566	2573	2372	26123	5747	1881	751	198221	123028	15148	490	905	S	1915
CS53.2.2	CS53	2	2	104349	1967	2558	25730	6107	1341	579	200532	123676	14535	600	829	S	1915
CS53.2.3	CS53	2	3	104757	2140	1977	25920	5898	1436	376	200138	123169	14639	347	877	S	1915
CS53.3.1	CS53	3	1	92298	1630	2373	22584	6942	1163	394	238551	116576	14780	488	434	S	1915
CS53.3.2	CS53	3	2	92020	2039	3036	22816	6921	1035	865	238587	116938	14851	660	1160	S	1915
CS53.3.3	CS53	3	3	92334	1875	2572	22949	6654	1163	538	240226	116493	14641	365	744	S	1915
CS54.1.1	CS54	1	1	50747	1016	1828	15254	7489	662	1004	277169	90038	19673	319	210	S	1915
CS54.1.2	CS54	1	2	50596	1014	1762	15284	7729	836	913	277484	90480	19972	374	381	S	1915
CS54.1.3	CS54	1	3	50708	887	1665	15531	7489	959	931	278930	89486	19521	264	260	S	1915
CS54.2.1	CS54	2	1	48580	1155	2113	15260	7803	910	935	283151	88177	20224	426	636	S	1915
CS54.2.2	CS54	2	2	49928	1061	1766	15258	7884	929	736	283289	88029	20557	474	358	S	1915
CS54.2.3	CS54	2	3	49138	924	1703	15033	7667	1194	760	284952	87165	20325	619	182	S	1915
CS54.3.1	CS54	3	1	50981	1285	2088	15719	7743	1211	926	275697	91077	20009	510	667	S	1915
CS54.3.2	CS54	3	2	50552	1046	1824	15854	7569	1091	638	277572	90638	20015	582	395	S	1915
CS54.3.3	CS54	3	3	50821	993	2112	15965	7523	1287	763	277372	90646	20152	318	429	S	1915
CS55.1.1	CS55	1	1	94663	3127	2121	31537	4264	2128	555	106398	134410	14527	993	2039	S	1917
CS55.1.2	CS55	1	2	95434	2979	2069	31735	3930	1831	864	107607	133440	14388	986	2033	S	1917
CS55.1.3	CS55	1	3	95915	3048	2107	32282	3690	1967	844	107009	134018	14522	928	1927	S	1917

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS55.2.1	CS55	2	1	69082	1980	2397	23506	6838	1292	704	221565	110348	10335	857	893	S	1917
CS55.2.2	CS55	2	2	69691	1675	2151	23444	6533	1357	641	223938	109982	10279	808	1176	S	1917
CS55.2.3	CS55	2	3	69795	2210	2197	23884	6477	1531	703	222654	110256	10113	602	1002	S	1917
CS55.3.1	CS55	3	1	70095	1172	2194	18377	7533	751	622	254034	109547	7252	557	1012	S	1917
CS55.3.2	CS55	3	2	70258	1008	2209	17891	7457	775	723	256258	109116	7044	777	660	S	1917
CS55.3.3	CS55	3	3	69628	1431	1970	17937	7356	871	574	256020	109258	7394	747	803	S	1917
CS57.1.1	CS57	1	1	54169	573	2582	11378	8717	567	762	307802	87660	4394	560	1093	S	1916
CS57.1.2	CS57	1	2	53561	717	3083	11197	8842	640	936	309389	87757	4721	584	1466	S	1916
CS57.1.3	CS57	1	3	53652	847	2806	11631	8704	893	896	309457	88292	4689	550	1013	S	1916
CS57.2.1	CS57	2	1	18275	78294	1805	23102	7629	13268	5546	286910	52257	2851	140	14145	S	1916
CS57.2.2	CS57	2	2	22190	75483	1667	23493	7767	13540	5094	289652	58545	2814	266	9155	S	1916
CS57.2.3	CS57	2	3	22199	75379	1557	23652	7332	13152	5113	290833	58523	2583	577	8999	S	1916
CS57.3.1	CS57	3	1	16293	51195	2045	15453	8518	9636	3621	322856	45569	2501	1179	3891	S	1916
CS57.3.2	CS57	3	2	16779	49281	1953	14657	8224	9197	3599	324078	46004	2127	1132	2818	S	1916
CS57.3.3	CS57	3	3	16494	49599	1804	15011	8142	9426	3574	324801	45390	2054	1240	2307	S	1916
CS58.1.1	CS58	1	1	20387	1057	2235	5282	9529	618	1455	358643	46024	620	2245	157	S	1800
CS58.1.2	CS58	1	2	20006	1238	2273	5337	9791	511	1474	359330	45954	639	2191	172	S	1800
CS58.1.3	CS58	1	3	19672	1066	2415	5117	9585	183	1552	360549	45797	821	2215	238	S	1800
CS58.2.1	CS58	2	1	19613	1108	2526	5439	8963	496	1154	360556	46418	637	2127	0	S	1800
CS58.2.2	CS58	2	2	19439	1279	2610	5206	9418	405	1752	361106	46427	612	2273	287	S	1800
CS58.2.3	CS58	2	3	19417	1177	2621	5400	9469	321	1599	361112	46547	581	2372	235	S	1800
CS58.3.1	CS58	3	1	20405	888	2320	5774	9322	339	1235	357859	46495	696	2156	342	S	1800
CS58.3.2	CS58	3	2	20194	1085	2051	6158	8981	320	1441	358538	46680	627	2277	295	S	1800
CS58.3.3	CS58	3	3	19984	960	2262	6012	9351	278	1121	359925	46644	611	2319	177	S	1800
CS59.1.1	CS59	1	1	17395	1946	951	27199	9207	205	799	366458	37848	204	3293	403	S	1820
CS59.1.2	CS59	1	2	17586	1586	882	27380	8910	3	746	366708	38099	138	3494	527	S	1820
CS59.1.3	CS59	1	3	17429	1610	1032	27294	9095	101	629	367578	37599	318	3396	611	S	1820
CS59.2.1	CS59	2	1	17986	1830	1432	27813	9235	46	697	361342	37329	128	3471	706	S	1820
CS59.2.2	CS59	2	2	18082	1563	1024	27017	9076	172	628	362013	37290	192	3732	253	S	1820
CS59.2.3	CS59	2	3	17850	1884	1068	27405	9216	177	865	362728	37258	153	3677	565	S	1820
CS59.3.1	CS59	3	1	18824	2288	1326	33087	9182	374	831	360220	38554	346	4046	513	S	1820
CS59.3.2	CS59	3	2	18554	2340	899	32730	9250	499	822	360783	38330	309	4194	400	S	1820
CS59.3.3	CS59	3	3	18541	2020	1040	32846	9304	250	572	361024	38439	371	4053	340	S	1820
CS60.1.1	CS60	1	1	51529	708	1318	13998	8213	814	834	289460	90144	10837	348	1397	S	1916
CS60.1.2	CS60	1	2	51368	1030	1533	14073	8354	880	1019	290530	89793	10782	344	1322	S	1916
CS60.1.3	CS60	1	3	52041	1299	1336	14696	8055	755	1163	289927	90345	10816	387	1199	S	1916
CS60.2.1	CS60	2	1	60973	1238	1834	15901	7896	974	809	254871	92283	14525	347	2018	S	1916
CS60.2.2	CS60	2	2	60720	1122	1625	16224	7667	1123	586	255550	92033	14660	422	1876	S	1916
CS60.2.3	CS60	2	3	60813	1210	1528	16048	7586	1216	722	255214	92075	14387	451	1661	S	1916
CS60.3.1	CS60	3	1	60607	1201	1397	16333	7724	944	804	253546	91793	14489	420	2102	S	1916

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS60.3.2	CS60	3	2	59568	1185	1648	16366	7971	918	882	256599	92705	14334	464	2073	S	1916
CS60.3.3	CS60	3	3	60287	1175	1737	16118	7940	1236	908	255955	91614	14399	316	2101	S	1916
CS61.1.1	CS61	1	1	19500	6593	1289	96258	8445	1329	580	337422	46695	91	3585	1053	S	1815
CS61.1.2	CS61	1	2	19232	6260	1202	95443	8222	1	317	338897	46826	145	3623	1316	S	1815
CS61.1.3	CS61	1	3	18834	6466	1317	95346	8191	800	417	339749	46644	114	3385	1226	S	1815
CS61.2.1	CS61	2	1	21507	7222	1390	100363	8514	824	200	328156	47104	124	3591	1172	S	1815
CS61.2.2	CS61	2	2	21411	7002	1102	100279	8230	1713	263	327964	46821	62	3586	1291	S	1815
CS61.2.3	CS61	2	3	21897	7145	1253	99643	8312	1581	235	327839	47067	49	3453	1406	S	1815
CS61.3.1	CS61	3	1	21110	6595	1378	93421	8628	1924	319	332971	46818	171	3307	1597	S	1815
CS61.3.2	CS61	3	2	21547	6111	1280	93429	8678	1518	76	332348	46720	32	3724	1155	S	1815
CS61.3.3	CS61	3	3	20946	6639	1185	93191	8705	1692	381	332554	46968	36	3524	1007	S	1815
CS62.1.1	CS62	1	1	6441	2714	25900	72106	5746	117442	381	315809	21750	2487	4050	2174	S	1760
CS62.1.2	CS62	1	2	6570	2740	26385	72635	5717	116429	257	317581	21898	2405	3660	2447	S	1760
CS62.1.3	CS62	1	3	6339	2213	26379	71343	5805	115908	132	316911	21927	2378	3972	2418	S	1760
CS62.2.1	CS62	2	1	7231	2725	15150	73354	5936	120176	331	315435	24039	2020	4033	1625	S	1760
CS62.2.2	CS62	2	2	7237	2672	14509	72688	5913	118785	1	317262	23885	1775	4026	1468	S	1760
CS62.2.3	CS62	2	3	7109	2623	14832	72881	6264	119349	237	315498	24075	1844	3943	1810	S	1760
CS62.3.1	CS62	3	1	3627	2061	152227	64838	3405	98654	109	284000	14959	1529	3186	12774	S	1760
CS62.3.2	CS62	3	2	3734	1838	152341	64906	3044	97481	155	284015	15185	1304	2850	12411	S	1760
CS62.3.3	CS62	3	3	3828	2103	150916	64313	3226	97118	329	283991	14890	1309	3027	12160	S	1760
CS63.1.1	CS63	1	1	15677	4325	2586	69097	8373	19536	447	339979	39146	204	4645	1293	S	1760
CS63.1.2	CS63	1	2	15411	4348	2807	67974	8062	19098	666	340832	39179	219	4979	1148	S	1760
CS63.1.3	CS63	1	3	15435	4411	2510	68701	8120	18938	484	343187	38603	52	4512	917	S	1760
CS63.2.1	CS63	2	1	15874	4300	2116	70345	8232	20341	342	338101	38185	287	5156	1122	S	1760
CS63.2.2	CS63	2	2	15797	4238	2084	70080	8064	20247	260	337886	37814	310	4616	1050	S	1760
CS63.2.3	CS63	2	3	15482	4534	2174	70842	8364	21133	379	339156	37605	289	4572	1349	S	1760
CS63.3.1	CS63	3	1	17604	4669	2005	77261	7921	24414	443	333188	41532	451	5007	1448	S	1760
CS63.3.2	CS63	3	2	17335	4715	1964	76923	7746	23989	330	333393	41605	459	4899	1429	S	1760
CS63.3.3	CS63	3	3	17270	4948	2082	77179	7784	24316	390	334071	41583	432	4855	1482	S	1760
CS64.1.1	CS64	1	1	18616	6167	3725	121917	6137	103088	406	287348	43613	1116	6066	1681	S	1755
CS64.1.2	CS64	1	2	18354	6067	3641	120773	6122	102846	443	287997	43741	1037	6247	1701	S	1755
CS64.1.3	CS64	1	3	18540	6236	3487	120896	6319	102416	324	288633	43784	935	5991	1692	S	1755
CS64.2.1	CS64	2	1	18903	6043	3582	119479	6423	102169	410	286811	44739	1078	5894	1491	S	1755
CS64.2.2	CS64	2	2	19112	6177	3481	119501	6629	102127	160	287918	44464	986	6018	1795	S	1755
CS64.2.3	CS64	2	3	18848	6106	3554	119062	6133	101622	108	288000	44555	1111	5834	1768	S	1755
CS64.3.1	CS64	3	1	18029	5830	3800	122914	6370	104097	294	289666	45631	922	5994	2033	S	1755
CS64.3.2	CS64	3	2	18017	6235	3493	122350	5957	103565	308	290635	45255	693	5800	1701	S	1755
CS64.3.3	CS64	3	3	18225	6446	3345	122850	6254	104071	468	290076	45599	685	6134	1737	S	1755
CS65.1.1	CS65	1	1	19557	5627	1736	84167	8034	1292	347	344760	47920	251	4095	839	S	1785
CS65.1.2	CS65	1	2	19226	5295	2050	84374	8437	1304	349	345413	47592	276	4277	1115	S	1785

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS65.1.3	CS65	1	3	19177	5322	1924	84662	8127	1294	270	346046	47423	273	4199	1016	S	1785
CS65.2.1	CS65	2	1	22074	5706	1784	82664	8536	1521	409	338836	48272	307	4315	976	S	1785
CS65.2.2	CS65	2	2	22076	5675	2035	82052	8586	1552	224	339085	47610	394	4169	972	S	1785
CS65.2.3	CS65	2	3	22102	5760	1973	82152	8262	1728	317	338854	47807	216	4181	1067	S	1785
CS65.3.1	CS65	3	1	22707	6235	1868	91407	8112	1923	324	335225	48282	357	4623	1394	S	1785
CS65.3.2	CS65	3	2	22496	6123	1710	90439	7934	1747	309	335277	48121	301	4613	996	S	1785
CS65.3.3	CS65	3	3	22401	6101	1864	90344	8212	1960	278	335512	48329	504	4516	1117	S	1785
CS66.1.1	CS66	1	1	17298	9298	2270	125269	7785	14544	108	313553	41022	1535	4122	2135	S	1785
CS66.1.2	CS66	1	2	17258	9520	2560	125216	7632	14460	233	313342	41542	1463	4145	2134	S	1785
CS66.1.3	CS66	1	3	17893	9439	2538	125122	8062	14557	239	314267	41538	1502	4104	2418	S	1785
CS66.2.1	CS66	2	1	16537	8783	2480	118079	7385	14205	346	320794	40567	1839	3757	1878	S	1785
CS66.2.2	CS66	2	2	16388	8711	2446	118035	7825	14064	255	320541	40087	1679	3916	1452	S	1785
CS66.2.3	CS66	2	3	16990	8765	2376	118251	7637	14117	238	320530	40070	1770	3957	1891	S	1785
CS66.3.1	CS66	3	1	17726	10212	2281	130850	7175	17338	454	306481	42381	1777	4271	1846	S	1785
CS66.3.2	CS66	3	2	17591	10030	2411	130224	7340	17100	336	307297	42322	1863	4015	1810	S	1785
CS66.3.3	CS66	3	3	17905	10072	2128	131325	7521	16738	256	306906	42459	1947	3999	2083	S	1785
CS67.1.1	CS67	1	1	14814	4465	6016	91745	6637	98213	89	297250	37173	1315	5172	1450	S	1755
CS67.1.2	CS67	1	2	15062	4824	5985	91608	6384	98190	239	298122	37430	1339	4722	1013	S	1755
CS67.1.3	CS67	1	3	14864	4739	5977	91275	6575	97736	553	298481	37314	1361	4803	1367	S	1755
CS67.2.1	CS67	2	1	14904	4438	5781	87264	6257	94345	339	300401	37303	1616	4752	1120	S	1755
CS67.2.2	CS67	2	2	14905	4198	6263	87027	6595	94073	289	301701	37389	1546	4678	1488	S	1755
CS67.2.3	CS67	2	3	14268	4410	6174	86376	6494	93883	526	302525	37241	1807	4909	1376	S	1755
CS67.3.1	CS67	3	1	15156	4837	6288	91296	6366	97822	806	297016	36552	1487	5026	1105	S	1755
CS67.3.2	CS67	3	2	15169	4402	6151	91515	6446	97435	512	297648	36738	1468	4938	1393	S	1755
CS67.3.3	CS67	3	3	15005	4516	6162	91054	6179	97808	293	297872	36595	1270	4886	1231	S	1755
CS68.1.1	CS68	1	1	33614	4870	1443	21935	9364	551	2278	323394	67550	2530	3766	194	S	1785
CS68.1.2	CS68	1	2	33736	5124	1433	21774	8888	206	2160	324641	67305	2381	3463	198	S	1785
CS68.1.3	CS68	1	3	33549	5123	1724	22339	9095	484	1965	325463	67388	2435	3538	207	S	1785
CS68.2.1	CS68	2	1	27455	4350	1500	19420	9270	282	1896	349523	59059	1339	3500	233	S	1785
CS68.2.2	CS68	2	2	27550	3783	1635	19009	8998	191	1690	350437	58732	1377	3554	263	S	1785
CS68.2.3	CS68	2	3	27851	3894	1511	19059	9214	539	1816	351272	58885	1357	3647	378	S	1785
CS68.3.1	CS68	3	1	31146	4878	1544	22186	8718	613	2031	326737	69576	2561	3445	322	S	1785
CS68.3.2	CS68	3	2	31220	4751	1787	22006	8755	581	2029	327383	68868	2891	3674	425	S	1785
CS68.3.3	CS68	3	3	31579	5028	1810	22375	8654	271	2168	328675	69092	2750	3596	435	S	1785
CS69.1.1	CS69	1	1	62241	68709	1572	75416	5072	3651	23466	229296	119033	4866	18659	4543	S	1755
CS69.1.2	CS69	1	2	62231	69261	2015	75372	5010	3733	23203	230612	118483	5092	18779	4782	S	1755
CS69.1.3	CS69	1	3	62265	69337	1747	75250	5077	4369	23246	229872	119013	5182	19045	4665	S	1755
CS69.2.1	CS69	2	1	62783	71002	1990	71546	5210	3900	23695	239879	115993	4876	16416	3988	S	1755
CS69.2.2	CS69	2	2	63022	70834	1641	71755	5325	3722	23601	240586	115709	4656	16468	3769	S	1755
CS69.2.3	CS69	2	3	63028	70416	1938	71690	5284	4248	23525	240619	114825	4839	16480	3888	S	1755

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS69.3.1	CS69	3	1	63604	67810	2073	76323	5287	4322	22984	237974	117961	4718	17066	4570	S	1755
CS69.3.2	CS69	3	2	64680	67712	1906	75646	5328	4408	22533	237208	117062	4542	17038	4535	S	1755
CS69.3.3	CS69	3	3	64807	67831	1609	75490	5198	3957	22729	237193	117358	4723	16942	4387	S	1755
CS70.1.1	CS70	1	1	23818	39857	2935	46415	6652	1097	15018	328081	69794	7672	194	1647	FN	1750
CS70.1.2	CS70	1	2	24448	38609	3148	46313	6771	1298	14780	328364	68817	7864	630	1581	FN	1750
CS70.1.3	CS70	1	3	24358	39080	3391	45966	6980	1432	14907	328626	68629	7890	566	1900	FN	1750
CS70.2.1	CS70	2	1	23029	38937	3226	45814	6597	1326	14875	330986	70097	7745	501	1702	FN	1750
CS70.2.2	CS70	2	2	22502	38949	3264	46167	6459	1300	14753	330661	69832	7742	742	1612	FN	1750
CS70.2.3	CS70	2	3	22822	38917	3256	46310	7026	1237	14963	331781	69420	7887	367	1253	FN	1750
CS70.3.1	CS70	3	1	26172	45079	3236	52146	5874	1993	16581	315403	76523	10636	455	1544	FN	1750
CS70.3.2	CS70	3	2	26636	45089	3638	52198	5877	1432	17071	316781	75974	10632	356	1313	FN	1750
CS70.3.3	CS70	3	3	26364	44522	3356	51853	6076	1787	16644	317562	76368	10216	446	1648	FN	1750
CS71.1.1	CS71	1	1	1062	47629	994	119425	2339	5613	14445	247087	1045	451	89795	5176	S	1760
CS71.1.2	CS71	1	2	1184	47676	634	119476	2683	5726	14589	248767	1098	407	89295	5817	S	1760
CS71.1.3	CS71	1	3	1109	48160	800	119169	2291	5458	14676	248783	1003	401	89637	5585	S	1760
CS71.2.1	CS71	2	1	1193	70154	478	159080	2456	9442	20674	238016	943	1067	10078	5067	S	1760
CS71.2.2	CS71	2	2	1271	70393	746	158932	2286	8991	21078	240368	789	1202	10290	5294	S	1760
CS71.2.3	CS71	2	3	1152	70944	516	158570	2383	9279	20791	240064	765	1272	9904	4954	S	1760
CS71.3.1	CS71	3	1	682	72926	442	172445	2511	9784	21207	260932	2084	1859	9348	5078	S	1760
CS71.3.2	CS71	3	2	762	72459	493	172330	2572	10229	20749	262416	2106	1923	9507	4643	S	1760
CS71.3.3	CS71	3	3	804	72895	43	172240	2725	9757	20605	263348	2187	1742	9305	4699	S	1760
CS72.1.1	CS72	1	1	1902	89400	567	201220	1317	8863	40224	240637	4945	2565	8509	9279	S	1760
CS72.1.2	CS72	1	2	2053	88903	305	201815	1568	9546	40602	241044	5109	2690	8524	10018	S	1760
CS72.1.3	CS72	1	3	1822	88243	361	202180	1399	8905	40274	242017	5077	2732	8306	10219	S	1760
CS72.2.1	CS72	2	1	56269	104836	5065	271615	2510	24423	30488	113120	118746	9093	7816	15720	S	1760
CS72.2.2	CS72	2	2	56524	105404	5352	271653	2445	24805	30390	113708	118706	9038	7716	15940	S	1760
CS72.2.3	CS72	2	3	56637	105679	4752	271152	2383	25454	30523	113363	118925	9062	7729	15542	S	1760
CS72.3.1	CS72	3	1	5827	98038	1450	154978	3143	4097	42315	290458	52726	1656	6640	7777	S	1760
CS72.3.2	CS72	3	2	5942	97531	1545	155235	3524	3574	42710	290861	51818	1825	6561	7667	S	1760
CS72.3.3	CS72	3	3	5802	98404	1594	155462	3582	4204	42817	291816	51802	1734	6528	8318	S	1760
CS73.1.1	CS73	1	1	31689	53406	3188	51997	5891	1512	14299	276398	84145	12847	110	1136	L	1680
CS73.1.2	CS73	1	2	32180	53068	2902	52192	5767	1552	14809	276384	84349	12539	195	848	L	1680
CS73.1.3	CS73	1	3	32829	53546	2839	51949	6310	1204	14398	275773	83953	12084	321	868	L	1680
CS73.2.1	CS73	2	1	31811	55574	3262	53045	5838	986	15307	284827	84852	10195	289	913	L	1680
CS73.2.2	CS73	2	2	31760	55875	3318	53440	5730	1076	15613	284620	83398	10433	185	1033	L	1680
CS73.2.3	CS73	2	3	31173	55875	3286	53180	5960	1096	15609	285053	83785	10204	310	927	L	1680
CS73.3.1	CS73	3	1	31815	32086	2672	30358	5994	649	9000	282121	86554	18167	346	817	L	1680
CS73.3.2	CS73	3	2	32364	31761	2706	30255	5945	749	9232	282724	86504	18144	154	544	L	1680
CS73.3.3	CS73	3	3	31754	31843	2758	30702	6025	732	9511	283453	86531	18164	204	702	L	1680
CS74.1.1	CS74	1	1	21998	4906	2625	33380	5921	1114	2654	273550	78747	26531	86	761	L	1705

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS74.1.2	CS74	1	2	22383	5174	2932	32902	6014	1172	2205	275203	78342	26591	142	698	L	1705
CS74.1.3	CS74	1	3	22044	5010	2850	33361	5766	1110	2217	276717	79284	26805	158	780	L	1705
CS74.2.1	CS74	2	1	19671	8480	3039	41113	5747	1152	5271	269225	78057	26945	170	757	L	1705
CS74.2.2	CS74	2	2	20056	8479	2781	40952	5645	1023	5021	270258	77429	26822	285	921	L	1705
CS74.2.3	CS74	2	3	19896	8346	2914	40807	5731	1122	4732	271133	77900	26522	249	885	L	1705
CS74.3.1	CS74	3	1	20294	13740	2381	43413	5681	906	8606	273620	76827	24483	270	457	L	1705
CS74.3.2	CS74	3	2	19851	13615	2683	43437	5629	1028	9173	273599	76349	25229	531	703	L	1705
CS74.3.3	CS74	3	3	20633	13552	2943	43377	5786	771	9366	274933	76789	25058	114	665	L	1705
CS76.1.1	CS76	1	1	19160	9558	2210	26351	6680	1004	6498	309905	64301	24345	101	697	L	1708
CS76.1.2	CS76	1	2	18945	9585	2296	26616	6731	730	6635	313504	63756	24506	65	508	L	1708
CS76.1.3	CS76	1	3	18761	9194	2475	26299	6782	864	6532	313046	63259	24596	22	1006	L	1708
CS76.2.1	CS76	2	1	16476	21271	2307	42700	6311	1297	12966	313887	60591	21441	281	518	L	1708
CS76.2.2	CS76	2	2	16450	21254	2406	42630	6324	1209	13586	316011	60528	21479	92	439	L	1708
CS76.2.3	CS76	2	3	16685	20676	2502	43034	6387	1627	13403	315346	60061	21709	31	483	L	1708
CS76.3.1	CS76	3	1	16431	1429	2597	21612	6636	1629	655	310062	63291	28279	136	721	L	1708
CS76.3.2	CS76	3	2	16178	1141	2521	21043	6574	1352	517	311456	62989	28199	181	720	L	1708
CS76.3.3	CS76	3	3	16806	1466	2506	21111	6443	1446	852	310804	63349	28330	62	700	L	1708
CS77.1.1	CS77	1	1	5938	2455	2213	47615	5941	4030	667	324909	39558	21218	1175	602	L	1695
CS77.1.2	CS77	1	2	6061	2740	2719	47859	5688	3919	723	326755	39460	21345	1350	887	L	1695
CS77.1.3	CS77	1	3	5999	2508	2300	47459	5803	4014	618	326299	39507	21218	1102	747	L	1695
CS77.2.1	CS77	2	1	8581	6638	2117	40050	6466	7674	1624	329912	47625	21952	273	417	L	1695
CS77.2.2	CS77	2	2	8241	6418	2197	40574	6344	7838	2027	332188	47320	22149	564	431	L	1695
CS77.2.3	CS77	2	3	8450	6782	2151	40810	6341	7654	1846	331483	46820	22484	815	471	L	1695
CS77.3.1	CS77	3	1	8952	1151	2390	25296	6545	1711	797	334168	51069	23556	304	293	L	1695
CS77.3.2	CS77	3	2	8998	1747	2384	24893	6627	1770	891	335560	51718	23441	221	611	L	1695
CS77.3.3	CS77	3	3	8890	1257	2256	25142	6575	1932	1085	336229	51348	23429	204	426	L	1695
CS78.1.1	CS78	1	1	15553	23930	12670	53829	4733	1276	15595	297821	63661	20549	423	5910	N	1685
CS78.1.2	CS78	1	2	15659	23681	13221	53670	4913	1553	15417	299512	63843	20657	188	5596	N	1685
CS78.1.3	CS78	1	3	15552	23581	12475	53612	4763	1416	14839	299431	63679	20492	3	5701	N	1685
CS78.2.1	CS78	2	1	18331	18398	36794	76649	4080	16298	9489	266232	66215	15060	650	46149	N	1685
CS78.2.2	CS78	2	2	18368	18104	37324	75735	4172	15828	9244	267173	66357	15051	418	46204	N	1685
CS78.2.3	CS78	2	3	18200	18120	36954	75122	4154	15789	9281	267958	66435	14973	369	46589	N	1685
CS78.3.1	CS78	3	1	18915	27834	2933	51789	6525	985	19755	313849	66567	13662	485	973	N	1685
CS78.3.2	CS78	3	2	19173	27682	2684	51819	6357	898	19923	315110	65682	13301	268	1073	N	1685
CS78.3.3	CS78	3	3	18998	27647	2387	51651	6471	841	19735	314625	65390	13289	268	806	N	1685
CS79.1.1	CS79	1	1	19468	8289	8447	30843	6839	3960	7685	331883	62133	9283	1578	904	B	1735
CS79.1.2	CS79	1	2	19073	8763	8310	31537	6755	3843	7490	331540	62392	9119	1780	1129	B	1735
CS79.1.3	CS79	1	3	19407	8750	8244	31381	7023	4045	7551	332602	62146	9455	1936	948	B	1735
CS79.2.1	CS79	2	1	21038	1832	9358	27141	6877	1046	1411	329692	65169	10762	1916	1472	B	1735
CS79.2.2	CS79	2	2	21315	1767	9298	26423	7258	1181	1347	329842	65071	10528	1612	1352	B	1735

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS79.2.3	CS79	2	3	21267	1741	9443	27075	7144	1080	1152	329788	65022	10463	1571	1466	B	1735
CS79.3.1	CS79	3	1	17064	7701	8191	37824	6277	3556	7062	314710	62806	17067	1089	1017	B	1735
CS79.3.2	CS79	3	2	17213	7814	7891	37840	6330	3541	6910	315239	62295	16921	870	1140	B	1735
CS79.3.3	CS79	3	3	17015	8027	7942	38024	6340	3470	6755	316983	63110	16614	941	1074	B	1735
CS80.1.1	CS80	1	1	12494	66664	9984	75351	5102	1149	66216	300007	55283	5815	972	1946	L	1760
CS80.1.2	CS80	1	2	12618	66661	9661	75108	4804	1594	65812	301902	55132	5922	973	2053	L	1760
CS80.1.3	CS80	1	3	12522	66030	9976	74786	4945	1390	64838	302604	54747	5901	1008	2165	L	1760
CS80.2.1	CS80	2	1	32569	4649	11116	38592	6250	758	2582	302289	87396	14801	561	5231	L	1760
CS80.2.2	CS80	2	2	32921	4865	10968	38740	6240	1224	2550	303142	86944	14896	455	5615	L	1760
CS80.2.3	CS80	2	3	33028	4755	10496	38690	6245	829	2365	302964	87044	14683	537	5152	L	1760
CS80.3.1	CS80	3	1	10675	22615	10163	45583	5622	912	18248	327547	44909	10894	824	3582	L	1760
CS80.3.2	CS80	3	2	10611	21583	10843	45486	5567	834	18703	330655	44508	10969	930	3494	L	1760
CS80.3.3	CS80	3	3	10481	22275	10151	45727	5784	1181	18179	328562	44256	11050	939	3358	L	1760
CS81.1.1	CS81	1	1	16263	41197	10080	66471	5281	1070	37087	315970	59232	6488	1115	2829	L	1760
CS81.1.2	CS81	1	2	16770	41392	10098	66815	5518	1391	37174	315164	58629	6211	1001	3301	L	1760
CS81.1.3	CS81	1	3	16469	40673	10147	66645	5509	1621	37436	316932	58418	6383	973	3192	L	1760
CS81.2.1	CS81	2	1	19980	3368	13338	36617	6305	1150	1792	312927	62055	16823	589	6067	L	1760
CS81.2.2	CS81	2	2	19822	3499	13140	36485	6274	1168	1699	314280	61768	16960	823	5751	L	1760
CS81.2.3	CS81	2	3	19928	3249	13546	36790	6342	955	1857	314548	62185	16631	677	6137	L	1760
CS81.3.1	CS81	3	1	16628	24497	11795	47804	5487	1274	20472	311546	58804	12578	690	3832	L	1760
CS81.3.2	CS81	3	2	16876	24207	12024	47341	5683	1031	20471	312610	58911	12334	691	4629	L	1760
CS81.3.3	CS81	3	3	16351	24324	11828	47699	5639	1193	20616	312338	58328	12224	949	4005	L	1760
CS82.1.1	CS82	1	1	14272	323	1439	8954	8683	458	1005	380568	49134	12065	1233	545	S	1760
CS82.1.2	CS82	1	2	14138	568	1429	9158	7865	559	1252	381624	49521	12319	1097	371	S	1760
CS82.1.3	CS82	1	3	14383	445	1022	9154	8133	554	1260	381201	48903	12061	1129	235	S	1760
CS82.2.1	CS82	2	1	12768	2874	1561	10219	8088	625	2840	382309	49928	10410	1043	313	S	1760
CS82.2.2	CS82	2	2	12658	3086	1417	10205	8141	737	2913	383172	49575	10248	928	109	S	1760
CS82.2.3	CS82	2	3	12573	3301	1791	10505	8244	685	3319	384766	49431	10252	1114	470	S	1760
CS83.1.1	CS83	1	1	15919	7426	5592	34971	5776	1084	5559	306386	65527	19495	730	1682	L	1740
CS83.1.2	CS83	1	2	16217	7346	5350	34910	6082	1022	5585	306372	65979	19625	767	1666	L	1740
CS83.1.3	CS83	1	3	15950	7106	5861	34803	6097	1211	5379	307251	65779	20050	716	1708	L	1740
CS83.2.1	CS83	2	1	16096	1781	5801	26916	6087	1257	1203	287675	65651	31256	548	1833	L	1740
CS83.2.2	CS83	2	2	15954	1744	5467	26664	5649	1228	1217	289596	65962	31028	222	1619	L	1740
CS83.2.3	CS83	2	3	16009	1683	5393	26792	5991	1321	939	289170	65359	31001	401	1707	L	1740
CS83.3.1	CS83	3	1	17807	1732	5657	26840	5925	942	984	288283	65338	31289	668	1720	L	1740
CS83.3.2	CS83	3	2	17997	1981	5522	26725	5983	1402	1124	289763	65474	31152	332	1868	L	1740
CS83.3.3	CS83	3	3	17807	1934	5593	26874	5937	1070	1264	289014	65626	31361	469	1679	L	1740
CS84.1.1	CS84	1	1	22912	2020	1946	28976	7075	640	863	312620	72650	25058	204	-1	L	1685
CS84.1.2	CS84	1	2	22849	1945	1609	29261	6900	1051	584	313583	72226	24735	70	383	L	1685
CS84.1.3	CS84	1	3	22799	2164	1800	29081	6895	978	795	312493	72642	24591	235	446	L	1685

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS84.2.1	CS84	2	1	19202	1922	2063	29419	6994	1428	724	314013	70662	25176	148	531	L	1685
CS84.2.2	CS84	2	2	19528	1791	2336	29819	6945	1477	574	315040	70530	25185	155	518	L	1685
CS84.2.3	CS84	2	3	19376	2126	2058	29831	7028	1351	530	314596	70364	25446	180	384	L	1685
CS84.3.1	CS84	3	1	20386	1788	2219	28580	6772	1264	619	318186	69565	24934	189	744	L	1685
CS84.3.2	CS84	3	2	20307	2093	2191	28519	6823	1063	934	319680	69234	24755	233	689	L	1685
CS84.3.3	CS84	3	3	20683	2072	2002	28794	7046	1052	659	318930	69286	24551	133	443	L	1685
CS85.1.1	CS85	1	1	22642	2029	2568	28448	6651	928	675	300145	74438	27180	166	338	L	1685
CS85.1.2	CS85	1	2	22500	2165	2913	28053	6531	1075	843	301887	74066	26885	362	505	L	1685
CS85.1.3	CS85	1	3	22782	1816	3022	28322	6448	643	474	301935	73938	26819	138	389	L	1685
CS85.2.1	CS85	2	1	23471	2355	3194	28677	6535	891	865	298094	74474	26813	310	442	L	1685
CS85.2.2	CS85	2	2	23553	2298	3084	28928	6510	1033	750	300838	74454	26605	193	361	L	1685
CS85.2.3	CS85	2	3	23133	1885	3159	28662	6566	820	542	299807	75246	26658	192	417	L	1685
CS85.3.1	CS85	3	1	20654	1678	2779	27929	6546	846	457	303010	72400	28418	188	486	L	1685
CS85.3.2	CS85	3	2	20920	2142	2818	28217	6530	1063	743	304022	72150	28587	75	460	L	1685
CS85.3.3	CS85	3	3	21320	1886	3062	27793	6551	1134	820	302861	72109	28737	57	787	L	1685
CS86.1.1	CS86	1	1	20598	1527	2246	22428	6518	1564	889	304019	69289	27108	26	309	L	1685
CS86.1.2	CS86	1	2	20607	1506	2145	22357	6874	1362	494	305168	68255	26715	159	354	L	1685
CS86.1.3	CS86	1	3	20679	1226	2167	22021	6811	1164	687	305567	68818	26885	8	343	L	1685
CS86.2.1	CS86	2	1	20333	1477	2235	21540	6913	1378	678	303369	69740	25893	136	189	L	1685
CS86.2.2	CS86	2	2	20184	1429	2330	21645	6737	1430	599	304916	69381	26394	188	669	L	1685
CS86.2.3	CS86	2	3	20344	1210	2376	21597	6655	1299	815	304572	69642	25769	2	667	L	1685
CS86.3.1	CS86	3	1	19195	1382	2386	22935	6429	1400	627	307116	69353	26453	1	255	L	1685
CS86.3.2	CS86	3	2	19584	1389	2416	22410	6527	1449	626	307534	69862	26041	154	387	L	1685
CS86.3.3	CS86	3	3	19299	1157	2141	22912	6789	1257	471	307294	68860	26101	277	189	L	1685
CS87.1.1	CS87	1	1	17684	1643	10464	23825	5703	1087	605	294875	64903	30606	16	3158	L	1700
CS87.1.2	CS87	1	2	17500	1968	10636	23610	5857	887	872	296282	64801	30448	144	3268	L	1700
CS87.1.3	CS87	1	3	17202	2028	10520	23651	5724	549	828	296208	64884	30737	-27	3108	L	1700
CS87.2.1	CS87	2	1	17566	1773	10441	23802	5626	740	757	295379	65725	30392	64	3192	L	1700
CS87.2.2	CS87	2	2	17401	1537	10784	23796	5848	979	670	296239	65416	30225	107	3440	L	1700
CS87.2.3	CS87	2	3	17277	1887	10443	23364	5687	1077	843	296007	65825	29953	26	2731	L	1700
CS87.3.1	CS87	3	1	17793	1803	11235	24079	5888	767	746	296422	65507	30728	-17	3271	L	1700
CS87.3.2	CS87	3	2	17575	2066	11427	23904	5625	1157	768	298208	65870	30692	0	3265	L	1700
CS87.3.3	CS87	3	3	17352	2033	11384	23365	5723	1039	999	296574	65188	30389	214	3162	L	1700
CS88.1.1	CS88	1	1	22660	1823	2189	29982	6725	2180	713	303770	71489	23411	90	493	L	1685
CS88.1.2	CS88	1	2	22956	2319	2034	29321	6947	1694	771	305739	70835	23226	342	581	L	1685
CS88.1.3	CS88	1	3	22832	1923	2208	29427	6900	2047	685	304655	70248	23181	93	558	L	1685
CS88.2.1	CS88	2	1	21209	1790	2319	29615	6658	1675	581	307826	69190	23867	256	349	L	1685
CS88.2.2	CS88	2	2	21694	2165	2147	29627	7095	1803	646	308354	69064	23772	363	432	L	1685
CS88.2.3	CS88	2	3	21540	1796	2145	29277	6876	2028	795	306868	69369	23826	242	514	L	1685
CS88.3.1	CS88	3	1	21090	2024	2193	29518	6815	1931	592	307865	69091	24357	270	707	L	1685

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS88.3.2	CS88	3	2	21260	1981	2246	29815	7019	1718	626	309135	68941	24308	203	501	L	1685
CS88.3.3	CS88	3	3	21435	2095	2206	29576	7063	2073	736	307918	68744	24395	381	575	L	1685
CS89.1.1	CS89	1	1	8689	795	179701	10279	5518	157	496	321616	30635	472	3131	5018	S	1760
CS89.1.2	CS89	1	2	8995	647	178210	10077	5681	168	165	322206	30621	513	3230	5115	S	1760
CS89.1.3	CS89	1	3	8742	637	178533	10072	5742	347	263	320859	30377	392	3209	5232	S	1760
CS89.2.1	CS89	2	1	8522	973	175403	10342	5652	1	381	320851	29265	508	3190	5413	S	1760
CS89.2.2	CS89	2	2	8233	843	175190	10284	5527	280	362	322292	29384	468	3259	4956	S	1760
CS89.2.3	CS89	2	3	8958	803	175143	10308	5785	83	613	321321	29809	558	3096	5380	S	1760
CS89.3.1	CS89	3	1	8765	734	163372	10618	5650	204	540	326186	29753	718	3178	4621	S	1760
CS89.3.2	CS89	3	2	8861	879	163691	10553	5649	105	344	326720	30029	746	2936	5167	S	1760
CS89.3.3	CS89	3	3	8651	870	163080	11081	5685	90	410	327025	29946	619	3228	4604	S	1760
CS90.1.1	CS90	1	1	8630	587	180714	8531	5838	1	345	318668	30285	68	2712	4633	S	1760
CS90.1.2	CS90	1	2	8588	597	179790	8506	5793	234	247	319250	30441	79	2729	4506	S	1760
CS90.1.3	CS90	1	3	8448	481	179935	8429	5622	151	463	318778	30196	125	2661	4656	S	1760
CS90.2.1	CS90	2	1	9799	664	178661	8026	5880	1	444	322204	34313	64	2568	4566	S	1760
CS90.2.2	CS90	2	2	9448	469	178397	8007	5906	42	203	321298	33450	36	2438	4334	S	1760
CS90.2.3	CS90	2	3	9554	582	177705	8007	5828	79	402	321848	33773	65	2489	4557	S	1760
CS90.3.1	CS90	3	1	7816	548	183675	8231	5618	1	260	318787	28334	113	2930	4712	S	1760
CS90.3.2	CS90	3	2	7927	664	185242	8584	5745	97	352	318629	29105	141	2723	4773	S	1760
CS90.3.3	CS90	3	3	7732	661	184565	8248	5679	255	318	319487	28594	81	2974	4559	S	1760
CS91.1.1	CS91	1	1	12220	1045	172732	10904	5921	194	531	324247	43194	435	2087	4513	S	1770
CS91.1.2	CS91	1	2	12363	760	172921	10575	5972	272	265	325856	43419	326	2410	4629	S	1770
CS91.1.3	CS91	1	3	12433	837	172254	10850	6183	1	629	326334	43316	437	2201	4570	S	1770
CS91.2.1	CS91	2	1	11618	1133	166443	10812	6113	227	693	332752	44179	450	2093	4100	S	1770
CS91.2.2	CS91	2	2	11526	735	166218	10497	6178	161	503	334156	44385	422	2205	3798	S	1770
CS91.2.3	CS91	2	3	11399	699	166333	10793	6112	30	597	333066	43831	516	1892	4266	S	1770
CS91.3.1	CS91	3	1	13076	620	177238	10227	5786	159	320	325778	45732	304	2159	4586	S	1770
CS91.3.2	CS91	3	2	12920	768	177416	9986	5775	60	290	328094	45612	379	1848	4859	S	1770
CS91.3.3	CS91	3	3	12820	664	177783	9962	5993	68	490	326767	45513	347	2076	4502	S	1770
CS92.1.1	CS92	1	1	12093	1302	142619	7814	6447	384	619	336110	38454	421	2095	3726	S	1800
CS92.1.2	CS92	1	2	12325	1458	143067	7973	6262	365	546	336960	38133	353	2133	3584	S	1800
CS92.1.3	CS92	1	3	11998	1725	142397	7963	6402	352	807	335995	38687	379	1993	3803	S	1800
CS92.2.1	CS92	2	1	11969	1590	139632	7922	6194	191	685	339340	38741	447	1895	3531	S	1800
CS92.2.2	CS92	2	2	11850	1632	138809	8111	6217	492	612	339902	38451	418	2034	3676	S	1800
CS92.2.3	CS92	2	3	11980	1105	139074	7988	6091	91	503	339200	38435	445	2140	3886	S	1800
CS92.3.1	CS92	3	1	16176	1575	138419	7815	6307	238	737	332385	46389	476	1884	3970	S	1800
CS92.3.2	CS92	3	2	16312	1165	137727	7624	6399	214	318	334135	45488	364	1482	4422	S	1800
CS92.3.3	CS92	3	3	15779	1354	137434	7727	6324	171	505	333990	45846	272	1493	3924	S	1800
CS93.1.1	CS93	1	1	15855	1654	6275	18492	6673	895	1191	306961	61178	29108	-34	1185	L	1760
CS93.1.2	CS93	1	2	15692	1623	6409	18769	6316	955	1189	308753	60118	28624	0	1340	L	1760

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS93.1.3	CS93	1	3	15411	1427	6434	18795	6339	785	821	309057	60873	28979	3	1281	L	1760
CS93.2.1	CS93	2	1	15270	1656	6074	18716	6243	840	1083	308439	60834	29249	-55	1323	L	1760
CS93.2.2	CS93	2	2	15154	1471	5702	18582	6359	653	809	308907	60307	29374	151	1069	L	1760
CS93.2.3	CS93	2	3	15133	1313	6205	18706	6190	922	770	309212	60245	29076	72	1228	L	1760
CS93.3.1	CS93	3	1	14592	1801	6811	18947	5786	883	1027	307488	60704	28629	2	1194	L	1760
CS93.3.2	CS93	3	2	14694	1620	6861	18407	6603	973	960	309465	60473	28028	209	1407	L	1760
CS93.3.3	CS93	3	3	14572	1405	6817	18638	6273	1065	1100	308791	60252	27988	-6	1201	L	1760
CS94.1.1	CS94	1	1	14852	1409	6422	18024	6321	1070	993	309216	57845	28697	-32	1355	L	1760
CS94.1.2	CS94	1	2	14890	1763	6444	17710	6405	1034	947	310050	57360	28499	71	1382	L	1760
CS94.1.3	CS94	1	3	14639	1712	5761	17981	6291	950	729	311579	57794	28304	84	797	L	1760
CS94.2.1	CS94	2	1	13822	1698	6229	17713	6417	1225	1135	311003	56776	29123	11	1283	L	1760
CS94.2.2	CS94	2	2	13612	1600	6153	17907	6404	1062	935	311765	57306	28565	-33	1289	L	1760
CS94.2.3	CS94	2	3	13659	1439	6114	17531	6439	750	896	310090	56659	29005	-27	1043	L	1760
CS94.3.1	CS94	3	1	12546	1388	6249	17640	6194	974	938	311601	55934	28405	-34	847	L	1760
CS94.3.2	CS94	3	2	12399	1341	6604	17733	6535	900	1029	312671	56439	28454	41	1154	L	1760
CS94.3.3	CS94	3	3	12863	1540	6351	17874	6389	1071	1096	312457	56270	28434	76	1216	L	1760
CS95.1.1	CS95	1	1	1780	532	2275	9922	8466	1	1450	495086	2817	143	1595	220	S	1775
CS95.1.2	CS95	1	2	1688	343	1921	9737	8410	1	1373	498150	2619	202	1622	274	S	1775
CS95.1.3	CS95	1	3	1848	491	2606	9443	8518	59	1315	498565	2644	135	1265	332	S	1775
CS95.2.1	CS95	2	1	1745	502	2135	9589	8304	256	1533	501642	1964	48	1441	0	S	1775
CS95.2.2	CS95	2	2	1748	548	2206	9432	7977	119	1554	503122	1911	166	1400	414	S	1775
CS95.2.3	CS95	2	3	1743	345	2328	9414	8257	1	1367	502818	1911	196	1459	284	S	1775
CS95.3.1	CS95	3	1	1745	533	1696	9213	7780	18	1358	489937	1787	87	25264	124	S	1775
CS95.3.2	CS95	3	2	1678	383	2044	9569	7740	38	1310	491715	1763	97	24786	199	S	1775
CS95.3.3	CS95	3	3	1763	399	1940	9762	7703	2	1472	491758	1750	129	25200	122	S	1775
CS96.1.1	CS96	1	1	16794	1112	1773	18839	6976	766	687	308532	61316	28907	25	308	L	1669
CS96.1.2	CS96	1	2	16286	918	1750	18730	6655	995	862	309950	61614	28986	0	233	L	1669
CS96.1.3	CS96	1	3	16423	1257	1946	19077	6928	1218	700	310864	61440	28763	1	369	L	1669
CS96.2.1	CS96	2	1	17230	1641	1762	19621	6887	1486	922	310686	61511	27377	86	325	L	1669
CS96.2.2	CS96	2	2	16989	1170	2078	19196	6980	1054	745	311104	60808	27762	-20	334	L	1669
CS96.2.3	CS96	2	3	17441	1152	1620	18751	6792	1058	964	310898	60848	27231	25	389	L	1669
CS96.3.1	CS96	3	1	14972	1105	2054	18853	6703	981	834	311164	61097	29481	100	518	L	1669
CS96.3.2	CS96	3	2	15271	1339	2254	18848	6687	921	982	311619	60730	29723	-32	550	L	1669
CS96.3.3	CS96	3	3	15258	1385	2195	18909	6674	853	1062	312710	60932	29607	40	726	L	1669
CS97.1.1	CS97	1	1	1609	25690	12320	48549	4304	1708	18671	425640	5810	5377	1493	3743	L	1780
CS97.1.2	CS97	1	2	1579	25916	12319	48541	4651	1422	18885	426411	5636	5150	1461	4096	L	1780
CS97.1.3	CS97	1	3	1770	26176	12590	47858	4584	1347	18813	426850	5738	5217	1566	4201	L	1780
CS97.2.1	CS97	2	1	4434	15600	12919	38087	5855	1526	10816	402213	31251	4289	1503	3895	L	1780
CS97.2.2	CS97	2	2	4337	15138	12850	38197	6348	1142	10859	403208	30819	4345	1330	3969	L	1780
CS97.2.3	CS97	2	3	4501	15469	13309	38030	5956	1157	10825	403457	31007	4330	1491	4155	L	1780

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS97.3.1	CS97	3	1	18577	14982	12455	36005	6571	1327	9366	343815	59877	4659	1555	3776	L	1780
CS97.3.2	CS97	3	2	18455	14560	12490	35487	6376	1271	9570	345668	59822	4652	1643	4179	L	1780
CS97.3.3	CS97	3	3	18230	14665	12748	36085	6386	1416	9657	344494	59498	4462	1584	4123	L	1780
CS98.1.1	CS98	1	1	21137	2575	15581	34941	5509	3923	913	299851	69620	22449	523	6705	L	1765
CS98.1.2	CS98	1	2	21306	2423	15078	35363	5508	4342	608	300767	69397	22353	432	6415	L	1765
CS98.1.3	CS98	1	3	21419	2523	15361	34860	5693	4203	601	302786	69644	22378	424	6544	L	1765
CS98.2.1	CS98	2	1	20306	2413	15018	34274	5770	4382	521	300196	69742	22172	550	6792	L	1765
CS98.2.2	CS98	2	2	20450	2450	15251	34522	5734	4391	406	300606	69415	21864	222	6441	L	1765
CS98.2.3	CS98	2	3	20208	2322	15113	34131	5758	4303	595	301848	69384	21850	496	6561	L	1765
CS98.3.1	CS98	3	1	21486	2590	15726	35158	5633	4189	693	300237	69284	22322	305	6605	L	1765
CS98.3.2	CS98	3	2	21202	2799	16457	35004	5577	4440	590	300453	68907	22087	287	6763	L	1765
CS98.3.3	CS98	3	3	21163	2649	16269	35102	5790	4426	633	301151	68703	21897	307	6878	L	1765
CS99.1.1	CS99	1	1	15516	1384	8156	21078	6219	661	706	306567	64525	24537	111	4029	G	1760
CS99.1.2	CS99	1	2	15862	1467	7998	20949	6140	817	909	307972	63869	24892	37	3930	G	1760
CS99.1.3	CS99	1	3	15953	1659	7535	21284	6142	744	1087	308364	64391	24772	139	3220	G	1760
CS99.2.1	CS99	2	1	16318	1559	8675	21271	6093	899	898	307730	64617	25013	-28	3873	G	1760
CS99.2.2	CS99	2	2	16245	1632	9279	21016	6116	652	1094	308855	64940	25271	-45	4208	G	1760
CS99.2.3	CS99	2	3	16290	1614	8317	21001	6233	961	752	309186	64483	25232	-24	3764	G	1760
CS99.3.1	CS99	3	1	16938	1778	7990	21021	6215	559	1056	305326	64660	24384	66	4209	G	1760
CS99.3.2	CS99	3	2	16917	1525	8166	21581	6101	563	933	307859	64531	24458	78	3756	G	1760
CS99.3.3	CS99	3	3	17386	1745	8168	21718	6169	581	1015	306652	65085	24482	-26	4075	G	1760
CS100.1.1	CS100	1	1	19582	31784	2609	52875	6280	1125	32674	292893	65535	14478	755	166	B	1753
CS100.1.2	CS100	1	2	19380	31601	3182	52628	6108	1345	32596	294148	65593	14301	869	443	B	1753
CS100.1.3	CS100	1	3	19219	31802	2684	52643	6299	1438	32529	293820	65490	14251	641	446	B	1753
CS100.2.1	CS100	2	1	17301	44447	3148	61306	6432	1367	51753	300301	60784	9488	947	459	B	1753
CS100.2.2	CS100	2	2	17372	44493	3755	62192	5964	1346	52591	300091	60228	9437	903	389	B	1753
CS100.2.3	CS100	2	3	17346	44600	3336	61934	5967	1249	52349	301201	60665	9611	1247	209	B	1753
CS100.3.1	CS100	3	1	18296	27972	2790	49709	6000	973	29046	293835	65511	14756	902	383	B	1753
CS100.3.2	CS100	3	2	17942	28419	3232	49837	6468	1443	29978	295157	64241	14559	931	481	B	1753
CS100.3.3	CS100	3	3	18220	28165	3106	50068	6110	1074	30093	295527	64701	14482	728	462	B	1753
CS101.1.1	CS101	1	1	1099	830	2748	31302	5265	1021	858	389913	6779	19187	655	9157	L	1676
CS101.1.2	CS101	1	2	1193	1123	3076	32107	5477	900	870	392144	6810	19065	790	9256	L	1676
CS101.1.3	CS101	1	3	1255	1210	2884	31908	5535	805	906	392437	6947	19261	811	8979	L	1676
CS101.2.1	CS101	2	1	2286	990	8004	29563	5730	1300	824	356616	24511	19001	774	6362	L	1676
CS101.2.2	CS101	2	2	2286	1112	7769	29177	5438	1017	866	359134	24783	19124	678	6548	L	1676
CS101.2.3	CS101	2	3	2470	976	7477	29446	5461	986	682	360320	24515	19094	715	5829	L	1676
CS101.3.1	CS101	3	1	1049	1092	2939	31038	5475	815	726	390210	5562	18706	1657	1813	L	1676
CS101.3.2	CS101	3	2	934	971	2811	30972	5700	923	875	393503	5472	18220	1535	2168	L	1676
CS101.3.3	CS101	3	3	1148	794	2872	30988	5869	1063	894	394226	5627	18213	1398	1933	L	1676
CS102.1.1	CS102	1	1	1980	1077	8224	38607	4791	1204	662	362821	10716	26313	909	3022	L	1761

Raw net intensity data for the artifacts used in the statistical analysis continued.

CS102.1.2	CS102	1	2	2013	1247	8654	38145	5560	1364	1283	365035	10650	26207	661	3140	L	1761
CS102.1.3	CS102	1	3	2130	987	8312	38560	4962	1070	915	366295	10735	26127	796	3077	L	1761
CS102.2.1	CS102	2	1	1856	884	8420	28075	4951	1232	1131	377956	6015	25462	593	3265	L	1761
CS102.2.2	CS102	2	2	1883	1073	8558	27689	4748	1572	1121	380063	5981	25402	725	2764	L	1761
CS102.2.3	CS102	2	3	1970	948	8343	27900	4826	1185	1047	378906	5991	25858	535	2957	L	1761
CS102.3.1	CS102	3	1	1802	1106	8232	27333	4590	1397	1386	383700	2659	22450	496	3093	L	1761
CS102.3.2	CS102	3	2	1957	760	8073	27294	4830	975	1411	384595	2823	22512	819	3107	L	1761
CS102.3.3	CS102	3	3	1967	1047	8161	27125	5014	1152	1317	385112	2974	22796	747	3056	L	1761

Appendix D: Permissions

Permission letter to reprint images in Appendix B.

Academic Office Building
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931

April 13, 2015

Jon Prown
Chipstone Foundation
7820 N Club Cir
Milwaukee, WI 53217

Dear Jon Prown:

I am completing a Master's thesis at Michigan Technological University entitled " BEAUTIFUL FORMS AND COMPOSITIONS ARE NOT MADE BY CHANCE: EXPLORING THE EFFICACY OF PORTABLE X-RAY FLUORESCENCE TO SORT AND SOURCE ENGLISH LEAD GLAZED CERAMICS." I would like your permission to reprint in my thesis images of ceramics held by the Chipstone Foundation in the section titled "Appendix B" of the document. These images depict the samples analyzed during my research.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages, and to the prospective publication of my dissertation by ProQuest through its ProQuest® Dissertation Publishing business. ProQuest may produce and sell copies of my dissertation on demand and may make my dissertation available for free internet download at my request. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that the Chipstone Foundation owns the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return to me the physical letter via mail and a scanned digital copy via email. Thank you very much.

Sincerely,

[redacted]

Steven J. Sarich

PERMISSION GRANTED FOR THE
USE REQUESTED ABOVE:

[redacted]

Jon Prown

Date: 4/14/15